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Development of a virtual reality application for the Old Harran School

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Abstract

The objective of this project that is described in this paper was to introduce the little-known Harran School of the medieval Islamic period located in Southeast Türkiye to a broader audience using virtual reality technologies. 3D models of the medieval Inner Castle in the Harran archaeological site and one of its saloons were created using photogrammetric methods. In this main saloon, 3D models of artifacts found during excavation works on this site that were used in medieval and earlies times were placed in a museum-like style. Additional objects, illumination and paintings of great Islamic scholars were appended to create a more realistic setting in the saloon. All these 3D models were transferred to the game engine Unity to generate a virtual environment, in which the visitor can immerse. Currently, this virtual museum can be experienced by PC-based head-mounted devices. While different implementations of virtual museums are already available in Türkiye with this project, a museum deploying virtual reality technology has been realized for the first time.

1. Introduction

After the closure of the philosophy schools of Alexandria many philosophers emigrated to Carrhae in Upper Mesopotamia (today, Harran, Türkiye) and there, created the “Harran School”. According to some researchers this was the beginning of the golden age of Islam starting in 717 CE with the foundation of the first Islamic university [1]. Jabir Kura, Al-Battani, Jabir Bin-Bayan and Ibn Teymime must be named as the most influential scientists of this school. Al-Battani has been regarded as the greatest astronomer of the medieval Islamic period [2]. His importance is underlined by the fact that he inspired Copernicus in his works that becomes evident from his frequently given references to Al-Battani [3]. The end of the golden age of Islam is usually associated with the Mongol invasions in the Middle East and the Siege of Baghdad in 1258. Again, philosophers and scientists had to flee, and this time found a new residence in Spain and Sicily [4], which eventually contributed to the birth of Renaissance [5].

Anatolia as part of the fertile crescent hosted many civilizations starting with prehistoric times (most famous is Göbeklitepe that is located in the same province a Harran) until the present, houses a big treasure of artifacts and traces from high cultures like Sumer and Hittite, which are considered as an important part of the cultural heritage of Türkiye.

Until recently, preserving, protecting, storing, and exhibiting of cultural heritage was generally assigned to museums. However, during the last decades the rapid development of information technology especially in the fields of digital photography, laser scanning, computer animation and virtual reality has paved the way for displaying cultural in a virtual way. Therefore, these processes of archaeological documentation have been named digital modelling or digital documentation. Resulting from the multidisciplinary use of these technologies societies have been enabled to create a common cultural heritage. Ultimately, based on these technological evolution "cultural heritage products" of museums that form an essential part of the world’s cultural assets can now presented to ordinary users all around the world in an enhanced visual structure. With other words, museums have become universal exhibition saloons that can be regarded as a virtual environment [6].

Due to the fact that the real world exists of three dimensions visualization with the help of computers must be done in a three-dimensional way if it wants to be realistic. Naturally, such a visualization attracts much more attention as it becomes closer to reality. Using 3D modelling program that support the interaction in an intuitive way creation of 3D models has become much easier today. These programs include options for viewing the objects of interest from different angels by rotating them around different axis and creating animations of their movements [7].

Doğan & Yakar [8] stated that Geographic Information Systems (GIS) and photogrammetry have become commonly used scientific methods for the documentation of cultural heritages. They collected data of 46 historical monuments located in Silifke/Mersin and transferred them to a database. Some of those objects were reconstructed as 3D models using photogrammetric techniques.

Şasi & Yakar [9] carried out a 3D photogrammetric modelling of Hasbey Dar'ülhuffaz at the Karamanids site in Meram District /Konya. Thy took photographs of the cultural asset with a Nikon D90 camera and captured aerial photographs with a DJI Phantom 4 unmanned aerial vehicle. All data were processed with Agisoft PhotoScan and Netcad software, and a 3D model of the artifact was created.

In 2012, Yıldırım made research on how much the Topkapı Palace Museum currently takes profit of information technologies by taking in consideration virtual applications applied in many of the world's well-known museums. Based on the findings of this research recommendations on the potential future usage of the museums' assets by deploying the state-of-the-art technologies were written [10]. Ünlü [11] carried out a study, in which he described showcases for presenting Turkish museums on web pages that are planned to be hosted by the Ministry of Culture and Tourism. The results of this study found entrance into the homepage that currently consists of a collection of 47 virtual museums.

The "HafenCity University Hamburg" cooperated with the "Museum Alt-Segeberger Bürgerhaus" in developing a Virtual Reality (VR) application that brought to life again the Early Modern Age Early Modern Age of this city in the framework of a virtual museum. This application focused on showing how a house representative for a small town in a North Germany setting changed over time and eventually, becoming a museum. Several digital terrain models and 3D models of the city were created using laser scanning and photogrammetry techniques. After adding information on the city's history and further details of this building this virtual museum could be explored interactively by wearing a 'Head-Mounted-Display' (HMD) of HTC VIVE [12].

According to Yakar & Yılmaz [13] the usage of digital terrestrial photogrammetry offers many advantages for the documentation and preservation of cultural heritage as a result of their practical experience they gained at the Horozlu Han in Konya. With their work it could be demonstrated how restitution and restoration plans and preparation of relief plans can help to transfer cultural heritage to the coming generations. Uysal et al. [14] emphasize the importance of studies for humanity that deal with the protection of cultural and historical heritage and its transfer to coming generations. This could be realized by deploying different methods to produce three-dimensional models that aim at protecting and promoting archaeological artifacts. In their work it was shown how Unmanned Aerial Vehicles (UAVs) can be used as an efficient carrier of cameras for photogrammetric surveys at archaeological sites.

Buhur et al. [15] created a spatial virtual environment of Istanbul's historical peninsula for touristic purposes The study consisted of three main stages: During the first phase air-borne Light Detection and Ranging (LIDAR) data were acquired and separated into building, ground and vegetation classes by classifying them with the help of macros. In the second stage, modeling was done using building and ground classes. During the last stage, attribute and address-location information were added to the model giving users the opportunity to get information about the location and structures while navigating in the model.

According to Günen et al. [16] photogrammetry is used as a method now to transfer the physical characteristics of artefacts, objects figures, and spaces from the real world to virtual reality in a fast and cost-effective way. Using photogrammetry, the processing of data acquired optically from the real world can be deployed for creating objects, tools, spaces and even characters on a gaming screen. Models having geometry and covering textures can be produced at a level of detail that is sufficient for the polygonal requirements of a playing environment.

Uslu & Uysal [17] created a 3D model of the Demeter sculpture hosted by the Kütahya Archaeology Museum. For modelling this important antique artefact, they used terrestrial photogrammetric methods. Checkpoints marked on the artefact were measured with a Focus 6 Reflectorless TotalStation and images were taken with a Nikon Coolpix P510 camera. The data was processed with PhotoModeler software, and a 3D model of the Demeter sculpture was created. They concluded that photogrammetric techniques for documentation of cultural heritage provide great advantages in terms of accuracy, speed, cost and product variety.

Kalbani & Rahman [18] investigated issues and challenges arising from the usage of 3D city models for monitoring of flood risks in Oman based on the "City Geography Markup Language" (CityGML) standard. The aim of the study was to reduce time and effort of decision-makers by using a 3D city model to deal with flood risk management.

While being in charge with leading excavation projects at the archaeological site of Harran, Önal et al. [19] could find evidence that ancient Harran played a major role in the region during the Middle Ages. Among others, a traditional bathroom (Çarşı Hamam) located to the east of Harran's Great Mosque (Ulu Mosque) that was unearthed in 2018 and 2019. This hammam that remained largely preserved consisted of rooms with warm water and in some cases with hot water and changing rooms. As part of this work, a detailed restitution plan of the mentioned hammam was created. As these plans already exist in a suitable digital format, they could be used to make animations displaying the original architecture in detail. At the same site, to the east of Harran's Great Mosque a bazar that included many artifacts could be excavated. These artifacts consisted of different sorts of glass, pottery and metal objects, which were made available in a digital format for the Department of Geomatics Engineering for further processing to produce three-dimensional objects. Within the Inner Castle of medieval Harran, the bathrooms that were unearthed gave evidence that this castle did not only military purposes rather being used as a palace at the same time. A digital documentation of this bath, which has remained in a very good condition, could be easily used to create an animation about the everyday life in the ancient Harran City.

In "Mythology and History of Harran" [20] the history, religious diversity and social structure within the city of Harran has been described in detail. The information contained in this book forms the scientific basis for any museum be it a traditional one or be it in a virtual form to deliver essential information on the different exhibited objects and putting them into the right context for the visitor of the museum.

Building a new museum in the traditional, physical way is a big effort that requires an abundance of resources – not limited to financial ones solely. Walhimer [21] who has been in charge with establishing many museums computed the costs for the construction of the buildings related to such a museum that include the whole furniture and interior architecture and cover a space of about 1000 m^2 to be at least 2,5 million USD. On top of it, operating costs of almost 360 000 USD per year would have to be added as well.

A commonly used definition of a virtual museum is as follows: "a digital entity that draws on the characteristics of a museum, in order to complement, enhance, or augment the museum experience through personalization, interactivity and richness of content." [22]. The beginning of virtual museums [23] is marked by the first release of an application for a virtual museum tour distributed on CD-ROMs by the company Apple in 1992. These first implementations of a virtual museum applied the broader concept of virtual reality at a very basic level. They did not reach the level of a more advanced form in which the user gets totally emersed in another reality as far as visual and auditory senses are concerned.

Based on these findings, it will be shown how the ancient knowledge of Harran was translated into Arabic and enriched with its own scientific contributions, how it served as a scientific center, and as a result, how knowledge was transferred to Europe and its contribution to the emergence of the Renaissance will be investigated, The findings of the research studies on the importance of the Harran School for the oriental and western world of all relevant working groups will be presented to the academic world and the public by using new technologies such as virtual reality.

If the above-mentioned financial numbers are considered that for the erection of a traditional, physical implementation of a museum are considered it became obvious that a budget with these dimensions could only be set aside in the far future. Therefore, the idea came up to set a start with the implementation of a virtual form of the envisaged Harran Museum. Such an implementation could trigger events, which ultimately could enable the physical implementation of a museum. Consequently, a project with the title "First Step for the Establishment of a Harran School Museum" with the following purposes was initiated:

1. Recording the current status of the archaeological site of Harran using a high-resolution digital camera and photogrammetry methods,
2. Detailed reconstruction of Haran's medieval city in the form of a 3D model,
3. Data collection and their interpretation for the objects to be included in the Harran School Museum, and
4. Exhibition of components product during steps 1,2 and 3 within a virtual museum to be consumed by visitors using virtual reality devices.

Because of budget constraints works for the second component had to be postponed until additional funding would be available. In this paper, the realization of the fourth purpose will be treated in more detail.

2. Method

This project was implemented within three distinct phases (Figure 1):

1) Data Collection and Preparation Phase, in which geomatics engineers, archaeologists and historians worked in their respective field of expertise.

2) Virtual Reconstruction, realized by geomatics engineers.

3) Building of a Virtual Museum carried out mainly by computer engineers.

2.1. Recording of the current status of the archaeological site of Harran

The Structure from Motion (SfM) method can be used to produce 3D models of image data obtained from different platforms such as terrestrial or aerial. Although the SfM approach has been developed by computer vision scientist especially, to be used as an automatic feature-matching algorithm, it applies the same basic principles that are valid in photogrammetry. In their article "'Structure-from-Motion' photogrammetry: A low-cost, effective tool for geoscience applications" Westoby et al. [24] give a comprehensive description of this relatively new methodology. Photogrammetry can be defined as the technique that makes usage of multiple overlapping photographs for deriving measurements that can be used among others to generate 3D models of complex environments of single objects. SfM determines the geometrical parameters automatically without the necessity to establish a pre-defined number of known ground control points. In this research, SfM has been deployed within photogrammetry to produce realistically textured and scaled models of buildings of parts of an archaeological site and some artefacts excavated from it. It must be mentioned that the image quality decides the quality of the textured 3d model and in addition, that he availability of images taken from all sides determines the completeness of the 3D model (Figure 2).

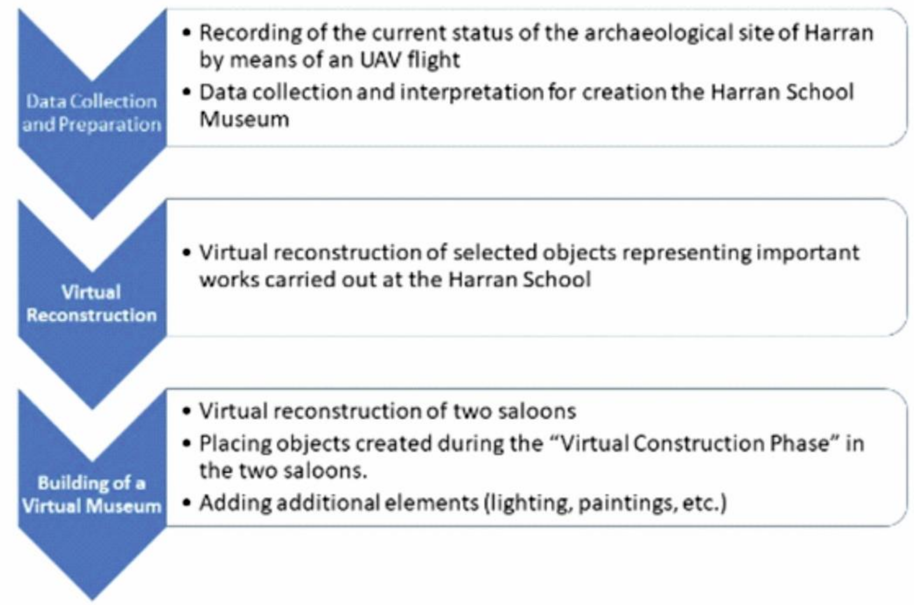

Figure 1. Workflow of the project.

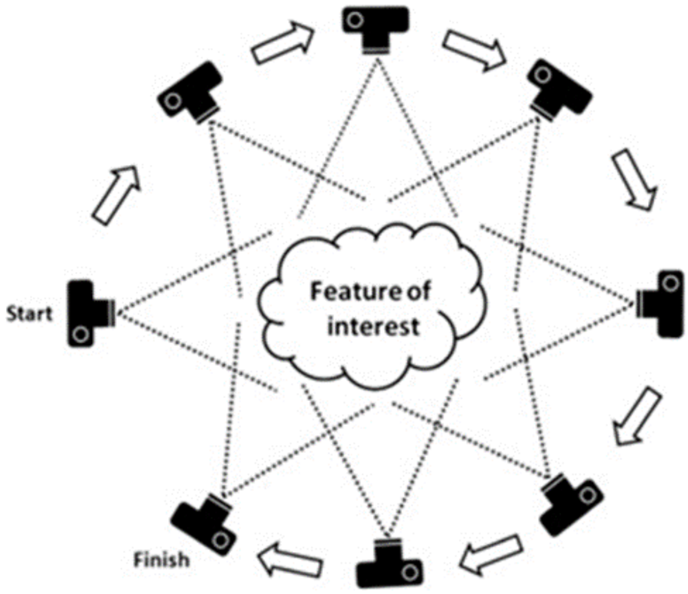

Figure 2. Terrestrial imagery capturing a feature of interest for SfM processing [24].

During the first step, images of the entire Harran Inner Castle were acquired using an Unmanned Aerial Vehicle (UAV), in this case a "Dji Enterprise Phantom 4 RTK" Quadro copter that comes with an integrated 1 inch, 20-megapixel "CMOS" sensor (Figure 3). After a flight plan had been established (Figure 4) the UAV executed the flight mission autonomously. These photographs served as a n input for constructing a 3D model with the help of Agisoft software.

During the second step, from a selected set of objects, which had been excavated at the archaeological site of Harran 3D models were created. In total, 9 models have been finished until now. Most of them originate from the Middle Ages but, some data back even to the middle and late stone age period.

Figure 3. DJI Enterprise Phantom 4 RTK.

Figure 4. Flight plan for the "DJI Enterprise Phantom 4 RTK".

2.2. Data collection and interpretation for creation the Harran School Museum

The search for documents that were directly or indirectly related to the medieval Harran School was conducted in several libraries and archives in the United Kingdom, Türkiye and Iraq. The focus of this step laid in collecting documents from the archives of the "Turkish Historical Society" in Ankara and the Süleymaniye Library located in Istanbul. These collected documents went through a rigorous screening process to determine whether a) they possessed enough significance to be considered for the Harran School Museum and b) whether they were suitable to be used in the setting of a virtual museum. Emphasis was laid on the studies of those scientists that had a proven influence on later scientific developments of the western world especially during the modern epoque. Due to time constraints and travel and visit restrictions during the pandemic the translation only of some selected documents, mostly from Arabic into Turkish could be completed. Notes on studies of relevance for inclusion in the virtual museum have been taken.

2.3. Virtual Reconstruction

Virtual reconstructing falls under the field of digital archaeology, which can be defined as "*the application of information technology and digital media to archaeology*" [25]. Although in a narrower sense works described under "Recording of the current state of the Harran archaeological site" could be considered as Virtual Reconstruction we treat them differently because the applied methodology exhibits important differences. In total 12 models have been finished until now.

In order to explain the works carried out we use a two-beak retort (Figure 5). Considered the father of chemistry in the Islamic and western world Jabir b. Hayyan (who lived in the 8th century) is accepted as the scientist who founded the chemistry laboratory in the modern sense. He conducted many experiments in the laboratory he founded. This retort had been designed with a double discharge pipe to increase efficiency and speed in distillation.

Figure 5. Two-beak retort from Jabir b. Hayyan's laboratory [26].

The three-dimensional modelling and animation software Blender was used to create the model of the retort. Cylinders were selected from the ready-made meshes offered in Blender and their dimensions were adjusted according to the retort. Then, this cylinder was shaped by changing the size and location of its faces in Edit Mod. Afterwards, a sphere was added to form the hollow cavity part of the retort at the bottom. The empty part of the retort was selected and removed from the circle with the "Extrude Faces" command. The extracted figure was separated from the sphere and then the sphere was deleted. After filling the gaps in this cut part with the "Extrude Region" tool, it was added to the prepared cylinder. In a final step, the upper part of the retort was covered with glass material and the lower part was colored according to the original image (Figure 6).

Figure 6. Virtual reconstruction of two-beak retort shown in Figure 3.

2.4. Building of a virtual museum

During this step, the purpose was to generate an application of a virtual museum, which could be consumed by means of an Android application and a desktop based one and to be viewed by an HMD for virtual reality (Figure 7). The virtual museum consisted of two separate salons that accommodated all the archaeological artifacts and in addition other related objects. The creation of these saloons was accomplished in the following way:

- The most appropriate room having a sufficient size in the Inner Castle had to be identified.
- During the second step, more than 240 photographs with a handheld high-resolution camera were taken.
- During a last step, using photogrammetric methods described above a 3D model with a precision to reveal the details of the ancient brickwork was processed.

Due to time constraints, a separate 3D model of a second room could not be constructed. Instead, a copy of the first room generated, to which an artificial passage was created.

Figure 7. The Head Mounted Device (HMD) (HTC Vive).

- Placing the exhibition room at the right location within the Inner Castle,
- Duplicating of the 3D model created for the first saloon and placing it parallel to the first room,
- Linking the original room and the duplicated with a passage having a look that is consistent with the architecture of these rooms,
- Adding artificial light sources appropriate for a museum,
- Creating bases for all the objects in the exhibition saloons, and
- Attaching portraits of four important scientists of the Harran School (Câbir bin Hayyân, El-Battani, Farabi, Sabit bin Kurra as displayed in the entrance hall of Harran University's central library) at the rear walls of the saloons.

In addition, when using the MOVE tool of UNITY, the visitor of this virtual museum will have the opportunity to move freely around within the two saloons. However, to be able to do so, the HMD he is using must be equipped with controllers. In our case, we used the HTC Vive HMD with hand controllers.

3. Results

Within this study, two major goals have been achieved:

1) Using different techniques spatial and non-spatial information of the Islamic period related to the Harran School has been collected, compiled and processed. This included the exterior and interior setting of buildings and objects excavated at the archaeological site of Harran and written sources from libraries.

2) Exhibition saloons within a virtual museum that served as a container for displaying objects created in task 1 have been generated.

When the VR application is initialized on a desktop computer, the user has the impression to fly from space to the present-day city of Harran, then to approach the archaeological site and finally to land in the Inner Castle of Harran. Figure 8 shows a 3D model of the castle's state in the year 2018. Only minor modifications due to ongoing restoration works have occurred since then.

Figure 8. 3D model of the Inner Castle of Harran showing the present-day state.

After that, he will find himself at the front side of the first of the two exhibition halls as can be seen in Figure 9. This is the starting point from where with the help of controllers of the VR system the rooms and the displayed objects can be explored in more detail.

Figure 9. One of the two exhibition saloons of the virtual museum.

Now, he can walk around in two saloons of the virtual museum located within the Inner castle. The walls of the virtual museum have been processed to have a structure that resembles the present-day appearance to deliver a sentiment of authenticity. Here, the user can inspect the exhibits which currently, contains two different kinds of selected objects, in a closer way. First, 3D models created by photogrammetric methods of objects that have been found at the archaeological site of Harran like pottery as shown in Figure 10. Second, 3D models of those tools that could been virtually reconstructed from drawings and pictures found in the related original documents of some of the most important scientist living during this epoque.

Figure 10. 3D model of a terracotta jar used during medieval times for measuring purposes (Islamic period, inventory no. HR.1.77).

Without the provision of information in the form of text, additional pictures and graphics, audio and video clips for the exhibited objects and putting them in their historical content a museum would not reach its purposes and the visitor's expectations could not be satisfied. This general requirement applies to virtual museums as well. Here the latter one can prove its superiority over the classical museums because virtually, no limits exists when it comes to linking other media to a special object.

For this project, the application has been programmed in a way that it is enough to come within a certain proximity of an exhibited object with the HMD someone is wearing. Then, additional information in form of a short text summary will be displayed in red color within the HMD (Figure 11).

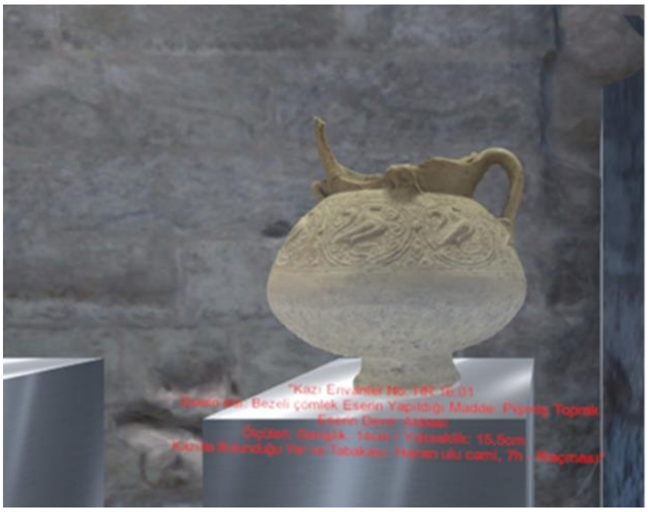

Figure 11. Explanatory text for an exhibited object in the virtual museum.

Currently, Harran School's virtual museum can only be experienced using a PC-connected HMD for virtual reality. However, it is planned to add a version for Android that would offer this application to potentially billions of people having a smartphone that can be connected to an HMD.

4. Discussion

With the goal of promoting the Harran School by spreading knowledge about it to interested people in the entire world, a virtual museum based on virtual reality technology has been built in Türkiye for the first time. Other so-called "Virtual Museums" in Türkiye offer only tours in panoramic view. However, they cannot be viewed with HMDs and therefore do not provide the real feeling of virtuality in the sense of VR [27]. In contrast, the virtual museum described in this paper will be accessible by a PC-connected HMD using channels like YouTube or even a very simple HMD that can be connected to mobile phones running on Android. When such a virtual museum is published on the Internet contrary to a physically implemented one it has the big advantage that virtually anyone in the world who ones a smartphone can be a potential visitor. Although he still must own an HMD, prices for such an Android based device start already at 10 USD. Works for publishing on the Internet are still going on.

The assumption that every owner of a smart phone having an HMD at its disposal would use such an app does not stand up to closer examination. When searching for an Android app and typing "virtual museum" at Google Play 248 results were returned. Most of these results are virtual tours in and around some well-known museums and some lesser-known ones while only a few virtual reality applications are offered. And when a more detailed analysis is conducted it becomes clear that only 13 of them exceed a download rate of more than 5000. Among them, the app of the "Louvre Museum Buddy" displaying the Mona Lisa as a logo is the most prominent one. It can be doubted that Harran School could be able to compete with the most famous painting of the world and therefore, additional effort will be required to attract mobile phone users to this planned app.

One might argue that if someone has visited a virtual museum using virtual reality glasses the incentive to visit a real archaeological site or a physical implementation of a museum related to such a site would no longer exist. Given the current state of technology with its limited image resolution of VR applications especially on mobile phones it can be doubted that virtuality would be preferred to reality. More likely is that a first virtual visit will whet the appetite to see the real physical implementation of a future museum at Harran after the required funding will have been found.

Another issue that needs further attention is the drawback that the content of the virtual museum is very limited. Currently, only thirteen objects and four paintings related to the Harran School are at display, something that cannot considered to be enough for attracting many visitors. This missing content was caused by some shortcomings of this project. The most important one is the fact that original documents or even secondary literature related to the Harran School are mostly written in Arabic and therefore, a translation into Turkish and English language is indispensable. According to our experience, many scientific terms that have been used during this epoque are no longer used in modern Arabic. Because of this, sound translations could only be guaranteed through the involvement of Arabic speakers who have a thorough knowledge in the related field of science, which in case of the Harran School covers the fields of mathematics, astronomy and medicine. This can only be achieved by means of adequate funding, something that was not available until now.

A more technical detail that we should mention is the relatively low resolution of the outer walls of Harran's Inner Castle that results in a blurred appearance of the current 3D model. This low resolution originates from the flight height of about 80 m of the UAV, which makes the products of this flight not very suitable for usage in an VR environment. Although this scene of the application lasts only a few seconds, still an enhancement will only be possible after a new flight at a longer altitude will have been realized.

Currently, only text information is available to deliver information on the exhibited objects. In future version, it is planned to add other forms of media that can deliver additional information. For example, in order to understand the implications of some of the most important discoveries at that time in the fields of mathematics and astronomy the option to watch videos on these subjects could be a big advantage.

5. Conclusion

Within the framework of this completed project, the first steps for building a virtual museum of the predecessor of the modern Harran University, the medieval Harran School, have been implemented. This virtual museum includes 3D models of its location, i.e., the Inner Castle within Harran's archaeological site, objects that have been unearthed there, the interior of the museum and display of objects and documents in two museum saloons. These components have been integrated within a virtual reality environment, which can be consumed by visitors wearing a PC connected HMD. Works for developing an Android App and adding more objects for display in the exhibition saloons is continuing. However, adding a greater number of objects that is required for creating the feeling of visiting a real museum can only be achieved with additional funding. Especially, the generation of 3D models of original scientific instruments and translation works of historical scientific documents written in medieval Arabic language into Turkish and English requires very specialized expertise. Such further enhancements are essential to attract enough users to this VR application. And only then, the ultimate goal of our efforts to attract more visitors to the real Harran can be reached.

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Author contributions

Fred Ernst: Conceptualization, Methodology **Songül Akdağ:** Data Integration, Application Development **Nizar Polat:** Data Acquisition, Photogrammetric Processing **Dursun Akaslan:** Conceptualization, Methodology **Mehmet Önal:** Field Study **Abdullah Ekinci:** Collection and Interpretation of Literature

Conflicts of interest

The authors declare no conflicts of interest.

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