







# Augmented Reality Cultural Route at the Xeros River Valley, Larnaca, Cyprus

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**Abstract.** Landscape studies have evolved into a significant branch of historical archaeological research, by placing emphasis on the ecological, economic, political and cultural values of pre-modern settled and sacred landscapes. The aim of our work is to support the systematic exploration of landscape archaeology in the Xeros River valley in Cyprus, through time, from prehistory to today, through the design and development of an Augmented Reality (AR) application. The AR application supports the exploration of pre-modern monuments and archaeological sites in the Xeros River valley, serving as a guided tour for visitors of the area. By employing image recognition and utilizing a location-based practice, the application provides the users with an immersive and educational experience. Initial reactions by experts in landscape studies indicate the potential of the application in enabling the narration and visualization of the historicity of the landscape and the fate of religious and other monuments of the past 1500 years.

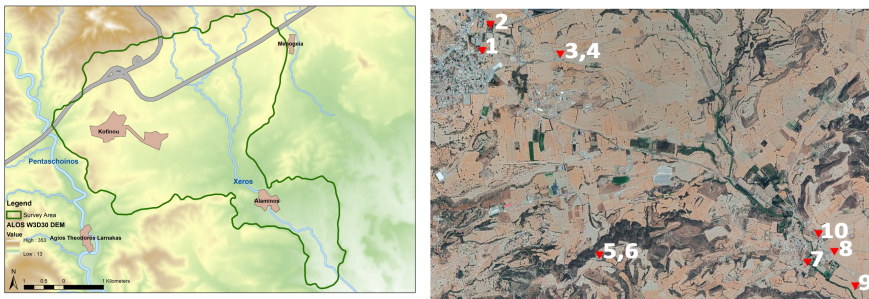
**Keywords:** Augmented reality · Landscape studies · Xeros valley

## 1 Introduction

The aim of our work is to support the systematic exploration of landscape archaeology, the formation and evolution of settled and sacred places in the Xeros River valley in Cyprus through time, from prehistory to today. As part of a systematic study in this area [6], a range of informed methods and interdisciplinary approaches to Cypriot landscapes and society, including archaeological surface

survey, geophysical prospection, geoarchaeology, digital Humanities and Anthropology, are employed in order to explore relevant research questions.

The Xeros River valley is located at a major junction of the Nicosia-Limassol-Larnaca motorways. The study of the archaeological material from several sites in the Xeros valley confirms continuous human habitation and land use in the area from prehistory to the present. Abandoned Turkish-Cypriot settlements, Christian and Muslim religious monuments in Kophinou and Alaminos, the Turkish-Cypriot (T/C) cemetery of Kophinou, the medieval tower and the Ottoman watermill of Alaminos, stone bridges of the British colonial period, abandoned beehives and other exceptional examples of traditional culture on the island comprise landmarks of this collective memory in the landscape of the valley today. At the same time, the presence and coexistence of these monuments in the Xeros valley in the 21st century reflect timeless and current phenomena: prosperity and symbiosis, displacement, immigration and human suffering, creation of national and religious identities, destruction of sacred sites, and abandonment (Fig. 1).



**Fig. 1.** The Xeros valley area (left) and the cultural route of the AR Application (right)

In this paper we focus our attention on the design and implementation of an Augmented Reality (AR) application that supports the exploration of pre-modern monuments and archaeological sites in the Xeros River valley, serving as a guided tour for visitors of the area. By employing image recognition and utilizing a location-based practice, the application provides an immersive and educational experience. The development of the contents of the application was based on historical research and on interviews and oral history accounts of community members from the villages of the Xeros river valley. The interpretive text of the application was written having in mind its possible users: international tourists, domestic tourists (Greek-Cypriots and Turkish-Cypriots) and locals. The purpose of the mobile tour application is to narrate the historicity of the landscape and the fate of religious and other monuments of the past 1500 years. The suggested route involves the following landmarks: (1) the T/C quarter of Kophinou, (2) the T/C cemetery of Kophinou, (3) the church of Panagia Kophinou and (4) the Byzantine village of Kophinou, (5) the church of Panagia Astatkhiotissa and (6) the Medieval rural settlement of Astatkion, (7) the church of Agios Mamas

in Alaminos, (8) the tower of Alaminos, (9) the watermill of Alaminos, (10) the T/C quarter of Alaminos (mosque and school).

Through this guided tour, visitors and current inhabitants of the Xeros valley have the opportunity to get in touch with the historical memory of the region and gain, in an indirect and novel way, an experiential contact with the monuments (religious and secular) and their surroundings. The operation of the application utilizes target images placed at the Points of Interest (POI) along the cultural route. The application encourages visitors to visit those POIs and scan the target images using their smartphones. Once a target is recognised, the users are able to see historical information about the corresponding monument while in particular cases (Panagia Kophinou and Astatkiotissa), they can observe a recreation of part of the settlement through their smartphone's camera feed. A score is maintained while the user visits each monument. The objective is to motivate the users to complete the route by visiting all the monuments/landmarks and experiencing an enhanced AR exhibition while getting information about the historical and archaeological context of each site.

## 2 Literature Review

While a Virtual Reality system relies entirely on computer-generated factors, AR does not allow the user to lose the sense of presence in the real world while supplementing some part of reality with virtual content [5]. AR has been used extensively to support the visualisation of cultural heritage sites and exhibits, aiming to bridge the gap between digital recreation, educational information and scientific research. The *Archeoguide* project uses specialised hardware and complicated system architecture to allow the viewers to experience the ancient Greek architecture and ancient Olympic sports events on site [8]. Zoellner *et al.* [9] proposed an AR application in which the original Reichstag building in Berlin is reconstructed while information in the form of photographs from different times are overlaid on the real scene. This application also includes an indoor, museum application focused around a satellite image of Berlin on which a 3D model of the Berlin Wall and the urban development are displayed. The *Roman Reborn* project also superimposes 3D models of Roman monuments on a large floor map in a museum installation [10]. *Dead Men's Eyes* is another AR project where a smartphone and an Arduino microcontroller are used to bring to life sights, sounds and smells at the exact place that they happened. In an outdoor AR experience, Sheffield's medieval castle is virtually restored in the Castlegate area in Sheffield city centre, where it used to stand. A large virtual object (castle) is overlaid on the mobile phone's camera view while a range of sensor data is used to tackle a variety of practical challenges that arise when employing an AR application outdoors [4].

Limitations such as constrained space in the case of large artefacts, storage of artefacts in distant sites and damaged/missing parts of archaeological artefacts can be overcome with the use of AR. Gherardini *et al.* [2] achieved the enhancement of the fruition of artefacts and significantly advanced their visualisation by suggesting an AR application accessible from a mobile device and

capable to be used in both inside and outside museum environments. This approach included the photogrammetric reconstruction of two Roman funerary lion sculptures located in Modena, Italy and their integration into an AR application.

The greatest challenge in making AR work outdoors lies in the registration problem [1]: aligning correctly the virtual with the real. Outdoor environments pose difficulties in determining the user's position and orientation while insufficient display contrast due to uncontrolled lighting conditions that hardens the registration and affects the user's experience.

### 3 Design of the AR Application

#### 3.1 Aims, Specifications, Requirements

Many AR systems have been developed to support the visitors' experiences in archaeological sites and have managed to enhance user engagement. The focus of the vast majority of these applications has been the reconstruction and the process of superimposing 3D models on their corresponding real-world structures [7]. In this paper, we propose an AR application that utilises location awareness for the engagement of the users in a treasure hunt-like experience and for the registration of virtual objects in the real-world environment.

The application superimposes 3D information spheres on specific target images which are located in particular geographical locations along the path. The information spheres act as information 'hotspots' and once they are found, scanned and tapped on, they display additional information in the form of text, images, 360 viewers and 3D virtual models placed in the surrounding areas of particular locations. The application does not only allow the users to passively observe the monuments with superimposed information, but it also encourages explorations in the area by keeping a score of the targets the user has found.

Figure 2 gives an overview of the system operation. The application is developed using Unity game engine and AR Foundation. The image recognition facility that AR Foundation incorporates allows the recognition of target images which are placed at specific locations near the monuments. The device's sensors are also used for the support of the visitors' exploration and the registration of the virtual 3D models in the real-world environment.

#### 3.2 Asset Collection

Except from text information that is included at each point of interest, the application is enriched with 360 panoramas images and 3D models that are placed at the surrounding landscape. 3D models used include a reconstruction of an early Byzantine basilica - built in the late 6th or early 7th century AD and on the ruins of which, the standing domed church of Panagia Kophinou was constructed later - and a 3D model of an early medieval longhouse which was created to match the typical medieval and post-medieval house-type in Cyprus and elsewhere (see Fig. 3). The 3D model of the longhouse was used for creating visualisations of settlements at nearby fields, where surface archaeological evidence suggests the location of habitation sites.

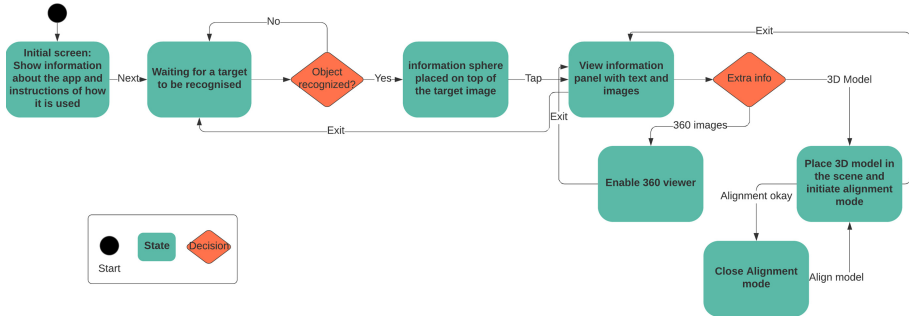


Fig. 2. State diagram - General flow of the system

### 3.3 Gamification

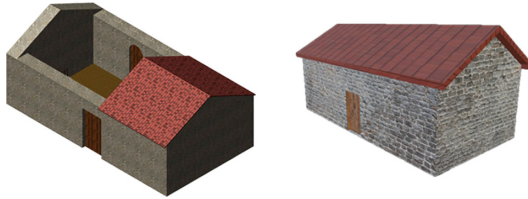
The adaptation and usage of the game technology outside of the game industry is known as gamification. Digital and serious games are attracting more and more academic attention and the value of gamification focused on heritage sites and applications is significantly increased due to the new possibilities that it encapsulates regarding user engagement and interaction with cultural heritage information. The proposed AR application is designed to embed the element of gamification by incorporating a treasure hunt game, which involves collecting virtual points by visiting particular monuments and sites and scanning specific target images that are placed there.

### 3.4 Placing the Virtual Model in the AR Scene

In the case of the Kophinou and Astathkiotissa churches, the user is able to visualise the medieval settlements that used to exist in the surrounding fields. Based on directions from archaeologists, multiple 3D models of the medieval longhouse were combined to create a settlement, and this was placed in the surrounding area in AR and with the use of the device’s geographical location. The placement of the virtual settlements was a challenging task because the virtual models needed to be placed without the use of a marker/target image. Instead, the placement was achieved by accessing the device’s location and transforming the GPS coordinates into the Unity world space. To convert between cartesian coordinate systems, scaling and rotation transforms are required. For the conversion of latitude, the difference between the required position of the 3D model and the user’s location is multiplied by a constant (111,132). For longitude, assuming that the earth is roughly spherical, the arc length of a degree of longitude changes with the latitude, approaching zero at the poles [3]. The equation below captures this:

$$111319.9 * \text{Math.Cos}(\text{latitude} * (\pi/180)) \tag{1}$$

In this way, the 3D model is spawned based on the user's location and calculating the offset in longitude and latitude that we want the virtual object to be placed. Due to the fact that the earth is not a perfect sphere and the inaccuracy of the smartphone's GPS sensor, a manual user alignment is also utilised so that the user can further correct the registration error by using a dedicated graphical interface for fine tuning the rotation, translation and scaling the 3D model.

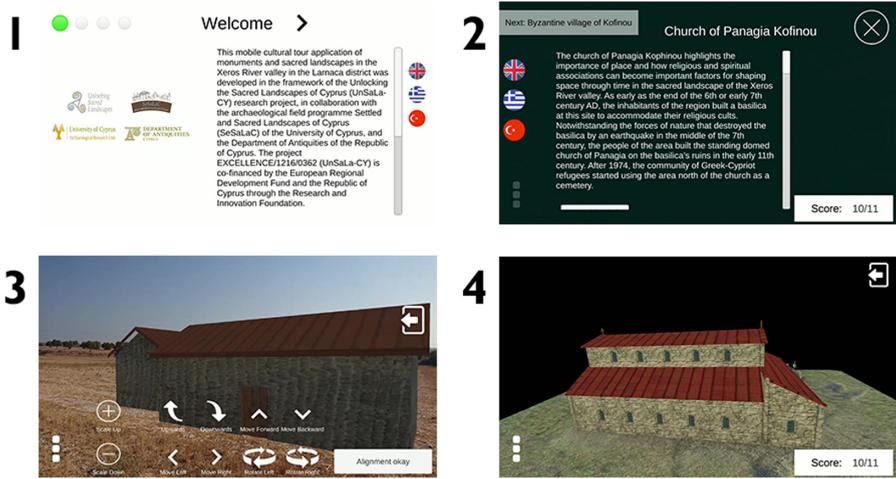


**Fig. 3.** Example of a medieval longhouse and the resulting 3D model created in Blender

### 3.5 System Operation and Evaluation

Fig. 4 shows typical screenshots from the system operation. A video of the results is given at <https://tinyurl.com/yyrgd6mj>. Limitations of the system are tightly related to the difficulties of making AR work outdoors such as uncontrolled environment conditions, insufficient lighting contrast, difficulties in determining the user's position and orientation and occlusion detection. As part of future work these limitation will be addressed.

Nevertheless, it is important to note that this is the first time in Cyprus that archaeological data for the existence of lost settlements, in combination with evidence for the use of sacred monuments from the early Byzantine period to today, is translated into an AR cultural route. It is also the first time that an archaeological surface-survey project employs AR to offer back to local societies and foreign visitors a user-friendly tool for the exploration of the region's past and historical significance, in three languages, i.e. Greek, English and Turkish. The initial idea and the ultimate aim of collecting and interpreting archaeological data, followed by the creation of the AR cultural route, is to explore and acknowledge the historicity and 'centrality' of the Xeros valley through the ages. The AR route will eventually encourage locals and visitors to explore this neglected rural landscape, by appreciating the 'negativity' of the valley's collective memory, imprinted in its abandoned sites and buildings.



**Fig. 4.** The overall system in action. (1): The initial screen of the application. This welcomes the user and displays information about the application, the project and the route, (2): The panel with text and images that is displayed once a user finds and scans a target image. (3): Placement and alignment of the 3D model of the medieval settlement at the surroundings of Panagia Kophinou. (4): Viewing the reconstruction of the early Byzantine basilica

## 4 Conclusions

This paper presented an AR application in which the users are immersed in a treasure hunt-like game while participating in an innovative experience in terms of the act of visiting an archaeological site/monument. A location-based approach in combination with a manual user alignment allowed an adequate registration of the virtual model in the real-world environment. AR software opens up new possibilities for the enhancement of archaeological sites. We have presented an approach in which local communities and visitors have the opportunity to experience an interesting cultural route through time and through the preserved monuments and the discovered archaeological sites in the area, from the early Byzantine period to date.

As part of the future work further communication strategies will be considered following the completion of a research component of the “Unlocking Sacred Landscapes” project on the experience of the monuments by local and national visitors, as these will provide the basis for a more personal dialogue between the monuments, the audiences and the local communities. In addition we plan to stage a comprehensive user survey with multiple participants in order to evaluate the functionality, user experience and educational impact of the application. We also plan to enhance the realism of the 3D model that is placed in the surroundings by performing adaptive color normalization and by estimating the position of the sun and creating virtual shadows.

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