Geometric Documentation and Virtual Tour to Enhance the Pikionis’ Cobbled Path on Filopappos Hill

Argyri Vienna[1], Andreas Georgopoulos[1], Sevasti Tapinaki[1], Margarita Skamantzari[1]

[1] Lab of Photogrammetry, School of Rural, Surveying & Geoinformatics Engineering, National Technical University of Athens, Athens, Greece – irovien@gmail.com, drag@central.ntua.gr, sevi@survey.ntua.gr, mskamantz@central.ntua.gr

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Abstract

This project focuses on the documentation, protection, and enhancement of cultural heritage through the use of contemporary technologies, combining geometric documentation techniques with immersive virtual experiences. The case study concerns a significant architectural and landscape work by Dimitris Pikionis (1887–1968): the cobbled path on the Hill of the Muses (Filopappos), located west of the Acropolis in Athens. This pathway, both a modern monument and an archaeological site, holds exceptional architectural and historical value. It links the western ridge of the hill with the plateau leading to the Propylaea, offering distinctive views of the Acropolis from the west. Designed in situ, it incorporates fragments and marble inlays from demolished neoclassical buildings of Athens, reflecting a deliberate synthesis of history, material reuse, and landscape architecture. The innovation of this project lies in the integrated and holistic approach, employing photogrammetry, archival research, and historical analysis to document and interpret a segment of the pathway. The resulting digital models serve as the basis for an interactive virtual tour, communicating spatial, architectural, and cultural information to a wide audience. This methodology demonstrates how digital tools can support historical interpretation, long-term preservation, and meaningful public engagement with culturally significant heritage sites, offering novel ways to experience and understand layered urban landscapes.

1. Introduction

Cultural heritage is a fundamental pillar of identity, memory, and historical continuity. Monuments, historic buildings, archaeological sites, and traditional practices are invaluable testimonies to humanity’s cultural evolution. In a world increasingly challenged by social, economic, and environmental pressures, the preservation and promotion of cultural heritage are more critical than ever. Numerous international charters and conventions have been adopted to support this mission, while technological innovation now plays a central role in making heritage more sustainable and accessible to the public.

In recent decades, the intersection of cultural heritage and technology has opened new possibilities for documentation, visualization, interpretation, and education. Modern tools from the fields of geomatics and information technology allow for accurate geometric documentation and immersive digital experiences. As Böhler et al. (2001) observed, these technologies have expanded the potential for representation and communication of heritage in ways unimaginable in the past. The concept of virtual heritage (Stone, 1999) reflects this shift: the use of interactive, computer-based tools to digitally record, preserve, and reconstruct culturally significant sites and artifacts, offering engaging educational experiences across temporal and spatial boundaries.

Geometric documentation is among the most crucial applications of digital technology in the cultural heritage sector. It provides the technical basis for recording, conserving, and studying heritage assets through precise spatial data acquisition. Using methods such as terrestrial laser scanning (TLS), photogrammetry, structure-from-motion (SfM), and UAV-based imaging, specialists can capture accurate and detailed information about the shape, location, and dimensions of sites and monuments (Remondino and El-Hakim, 2006). The application of these technologies enables the generation of a wide array of outputs—including 2D representations, orthophotos, 3D textured models, point clouds, and sectional views—serving both technical analyses and broader public engagement. When integrated into interdisciplinary workflows, geometric documentation contributes to sustainable conservation efforts, enriches interpretative approaches, and facilitates collaboration among professionals from various heritage-related fields.

In recent years, digital applications for virtual tours of museums and cultural heritage sites have proliferated. Increasingly, cultural institutions are adopting technologies such as 360° panoramic imagery, 3D modeling, and virtual or augmented reality (VR/AR) to improve accessibility and engagement. Platforms like Google Arts & Culture (https://artsandculture.google.com/), the Louvre Virtual Tours (www.louvre.fr), and 360Cities (www.360cities.net/) offer users immersive experiences of cultural spaces worldwide. The continued expansion of these initiatives underscores the transformative potential of digital technologies in cultural heritage management and education.

Within this broader context, the present study focuses on a distinctive example of modern heritage located in Athens, Greece. The stone-paved path designed by Dimitris Pikionis (1887–1968) on the Hill of the Muses (Filopappos) exemplifies the fusion of modern architectural thinking with archaeological and historical sensitivity. The research combines geometric documentation techniques with archival investigation and historical interpretation, culminating in the creation of a 3D model and an interactive virtual tour. This approach highlights how 3D documentation and virtual tools can function both as preservation mechanisms and communication strategies—particularly for modern heritage assets embedded in complex historical contexts.

2. The project

2.1 The Western Hills of Athens: Historical and Cultural Significance

To the west of the Acropolis lie three prominent hills: the Hill of the Muses (Filopappos), the Pnyx, and the Hill of the Nymphs, each playing a pivotal role in ancient Athenian history (Figure 1). These hills are rich in mythology, including the legendary victory of Theseus over the Amazons. The Pnyx holds particular historical importance as the meeting place of the Athenian Ecclesia from the 6th to the 4th century BCE, where critical decisions shaping the city's future were made. Over the centuries, various interventions altered the character of these hills, disrupting their continuity as a natural, historical landscape and archaeological site. During the Early Christian period and up to the Ottoman era, the hills remained largely uninhabited. Notably, the area southeast of the Filopappos Monument served as a Christian cemetery. In the early 20th century, excavations in 1910 and the 1930s highlighted the archaeological significance of the Pnyx. In the 1950s, architect Dimitris Pikionis undertook landscape interventions on the hills, creating walking paths paved with stone that echoed ancient routes, along with viewing platforms and rest areas. The area was further enhanced through the Unification of the Archaeological Sites of Athens program (1997–2004), which continues under the supervision of the relevant Ephorate of Antiquities.

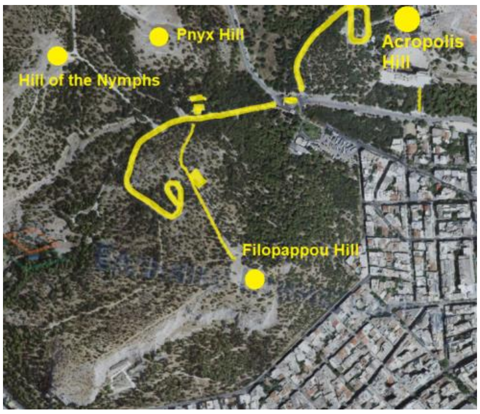

Figure 1. Western Hills of Athens and Pikionis' architectural formations (Background image from the Greek Cadastre)

Filopappos Hill—also known as the Hill of the Muses or Seggio Hill—is situated southwest of the Acropolis. It forms part of a broader area connected to the Hills of the Observatory and the Pnyx. Tradition holds that the hill was initially named after the poet Musaeus, who lived, taught, and was buried there. During the Roman era, it was renamed Filopappos in honor of Gaius Julius Antiochus Epiphanes Filopappos, a prince of Commagene and benefactor of Athens. Born around 70 CE, Filopappos was the grandson of Commagene's last king and brought considerable wealth to Athens, earning citizenship and various honors. The hill encompasses a substantial area, with the stone-paved path designed by Pikionis leading to several significant monuments, culminating at the Filopappos Monument. One of Pikionis's initial projects was the restoration of the Church of Saint Demetrios Loumbardiaris, built during the Byzantine period near the ancient Dipylon Gate, on the site of a roadside shrine dedicated to heroes Ajax and Heracles. Southeast of the church lies a notable structure known as the "Prison of Socrates", believed to have served either as Socrates' prison or as ancient baths, though this remains unconfirmed. During World War II, the building was used to conceal antiquities from the Acropolis and the National Archaeological Museum. Significant archaeological findings on the hill include the Dipylon Gate, one of the most important surviving monuments in the area; the Diateichisma, a 4th-century BCE fortification wall; and the "Kimonian Tombs," initially linked to the Olympian Kimon but later attributed to another individual. The ancient Koile Road, known for its commercial activity, was one of the busiest routes in ancient Athens, providing a secure passage for transporting goods between Athens and Piraeus, protected along its length by the Long Walls. South of the Koile Road is the Heptathronon, or the Square of the Seven Thrones (Figure 2).

Filopappos Hill remains a significant landmark in Athens, preserving the city's connection to its historical and architectural heritage, while also serving as a popular destination for both residents and visitors (Hellenic Ministry of Culture and Sports -, http://odysseus.culture.gr/h/3/gh352.jsp?obj_id=12521, 2025).

Figure 2. Monuments on Filopappos Hill
(Background image from the Greek Cadastre)

2.2 Dimitris Pikionis' Landscape Intervention on the Hill of the Muses

Dimitris Pikionis (1887–1968) was a pioneering Greek architect, artist, and intellectual whose work bridged modernism with the cultural heritage of Greece. Trained in both civil engineering and fine arts, Pikionis developed a deeply personal architectural language rooted in craftsmanship, organic composition, and philosophical reflection. A central figure in postwar Greek architectural discourse, he taught at the National Technical University of Athens and collaborated with some of the leading thinkers and artists of his time. His most celebrated work is the landscape design around the Acropolis and the Hill of the Muses in Athens, executed between 1954 and 1958 (Pikionis, 2001).

As part of the redevelopment of the southwestern approach to the Acropolis, Pikionis undertook a landmark intervention on the Hill of the Muses. The project sought to reveal the historical and natural character of the site through a synthesis of architecture, topography, and memory. Spanning approximately 600,000 square meters, the intervention included a network of stone-paved paths leading from the western saddle of

Filopappos Hill to the plateau near the Propylaea, a viewing terrace oriented toward the Acropolis, and the restoration of the chapel of Saint Demetrios Loumbardiaris (Figure 1).

Pikionis' design methodology was fundamentally site-specific. Instead of relying on rigid preliminary plans, the composition evolved in situ through intuitive engagement with the terrain, natural light, and spatial rhythms. The paths follow the topography organically, gradually revealing framed views of the Sacred Rock, the Areopagus hill, and the Athenian basin. Points of rest and contemplation—such as the terrace and the chapel—serve as rhythmic pauses in the unfolding architectural promenade (Papageorgiou, 2001). A defining feature of the intervention is its material palette. Embedded in the paving are marble fragments salvaged from demolished neoclassical buildings in Athens and Piraeus—cornices, consoles, doorframes, and slabs—thus preserving elements of the city’s architectural memory and offering an early example of creative reuse (Figure 3 & 4). Concrete is employed not only structurally but also sculpturally, particularly on the western edge of the site, where it forms curvilinear, tactile surfaces evocative of geological or botanical formations. The intervention engages sensitively with the archaeological fabric of the site. Traces such as ancient house foundations, rock-cut cisterns, and inscriptions—most notably the engraved word *FAOS (light)* - are preserved and integrated into the design, reinforcing the site's stratified historical character. In this way, architecture does not impose itself on the landscape but emerges from it, functioning as an interpretative layer upon the Attic ground (Papageorgiou, 2001).

Pikionis’ intervention on the Hill of the Muses remains a singular example of landscape architecture in postwar Greece. It constitutes a "modern promenade" of timeless quality, where architecture becomes a medium of embodied dialogue with the city’s history, inviting the visitor to reflect on the interconnections between nature, memory, and cultural identity.

Figure 3. Marble fragments salvaged from demolished neoclassical buildings used as benches

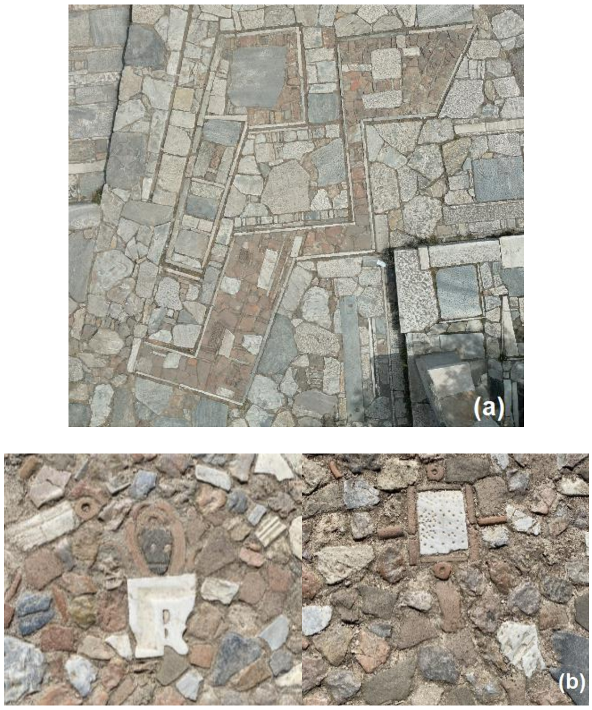

Figure 4. Clay frangments making unique formations in the terrace (a) and on the cobbled pathway (b)

3. Geometric Documentation

3.1 Data acquisition

According to Georgopoulos (2017), the geometric documentation of cultural heritage involves the acquisition, processing, and presentation of data necessary to determine the position and actual form of monuments in three-dimensional space at a specific moment in time. This process is essential for understanding the current state of monuments and planning their preservation.

The study area was defined along the northern section of the paved path, extending from the broad plateau with panoramic views of Athens and Piraeus to the viewing terrace overlooking the monuments of the Acropolis (Figure 5).

Figure 5. Orthophoto map of the study area (Background image from the Greek Cadastre)

For the photogrammetric documentation of the area, both aerial and terrestrial images were acquired. Aerial imagery was captured using unmanned aerial vehicles (UAVs), while terrestrial photography focused on detailed views of the viewing terrace. The documentation process began with the placement of ground control points (GCPs), strategically distributed to ensure visibility in as many images as possible. These points were geodetically measured using a total station to ensure spatial accuracy and avoid deformations from the GNSS measurements.

A total of five UAV flights were conducted using two different drone platforms. The objective was to achieve complete aerial coverage of the site, with particular emphasis on the paved path and the viewing terrace. Flight altitudes ranged from 5 to 40 meters, with an image overlap of 80% along the flight path and 60% across it. The resulting ground sampling distance (GSD) ranged from 0.7 mm to 4 mm, depending on flight altitude and terrain. To minimize occlusions and ensure detailed surface representation, the UAV camera was tilted at an angle of approximately 35° during the pavement survey. In total, approximately 1,100 images were acquired.

In addition, a GoPro and a Ricoh Theta S (360°) cameras were employed to capture supplementary photographs and video footage. The video was recorded while walking steadily around the site in a circular path to document its perimeter. The 360° camera was positioned at regular intervals of approximately 5 meters, resulting in 30 panoramic images. These datasets enhance both the visual interpretation and spatial understanding of the site, while also serving as auxiliary references during the processing and integration of the photogrammetric data.

3.2 Data processing

The photogrammetric processing of the dataset was carried out using Agisoft Metashape, a software application specialized in generating 3D spatial data from digital imagery. The workflow is based on two core computational techniques: Structure from Motion (SfM) and Multi-View Stereo (MVS).

The first stage involved image alignment to estimate camera positions and orientations, resulting in a sparse point cloud (Figure 6). A total of three separate projects were created to ensure that all images captured in the field could be processed without compromising resolution or accuracy, thereby achieving the best possible result. Ground Control Points (GCPs) were manually marked with sub-pixel accuracy (approximately 1 pixel) to assist in image orientation and georeferencing. Their coordinates, measured with a total station, were used to restore the absolute orientation of the model in terms of position, scale, and rotation. Alignment errors ranged from 4 to 20 mm, which was deemed acceptable for the intended application—an interactive virtual tour.

A dense point cloud was subsequently generated using high-quality settings to ensure detailed geometric reconstruction (Figure 7 & 8). Depth maps were computed for each image, and outlier points due to image noise or blur were filtered using the software’s “aggressive depth filtering” mode, which proved effective for this study area with limited fine-scale features (Agisoft Metashape Manual, www.agisoft.com).

The dense point cloud served as the basis for mesh generation. An arbitrary surface type was chosen to accurately capture both natural and architectural elements. The mesh was produced with a high face count to preserve geometric detail. Additional settings included interpolation to close holes and vertex color calculation based on the original images (Figure 9).

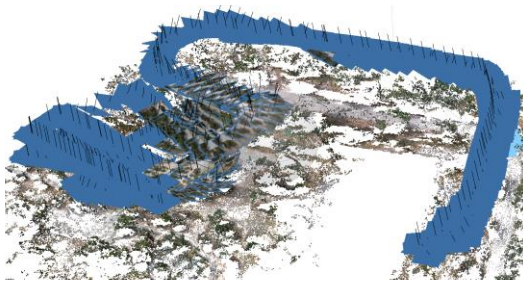

Figure 6. Generated sparse point cloud of study area

Figure 7. Generated dense point cloud of study area

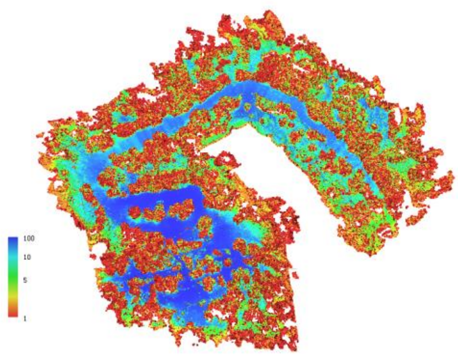

Figure 8. Point cloud confidence (errors detected only on vegetation and trees)

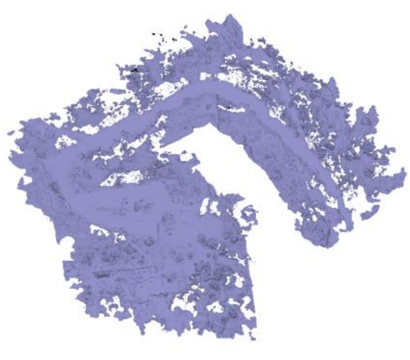

Figure 9. Generated mesh of study area

Post-processing involved both automated and manual corrections. Artifacts such as floating or overlapping triangles were removed, and missing areas were repaired using Geomagic Wrap. The mesh was continuously cross-checked with original photographs to maintain visual fidelity. Specific interventions were performed on the paved path (correcting triangles, filling gaps), and on localized areas with overlapping surfaces due to residual noise. Vegetation was removed where it obstructed surface geometry. The terrace required minimal editing—mainly the elimination of mesh artifacts caused by dense vegetation and the refinement of its rear side.

The final step involved texturing the model to achieve photorealistic rendering (Figure 11 & 12). A texture size of 4096×4096 pixels was selected for optimal quality, and six texture maps were generated to accommodate model complexity. A diffuse texture type was used to preserve color information. Texture blending was performed in two steps: low-frequency blending across overlapping images to remove seams, followed by high-frequency detail extraction from an optimal image using the Mosaic method. Additional options were enabled to fill texture gaps and filter out dynamic elements (e.g., moving vegetation) that could affect surface clarity (Agisoft Metashape Manual). These practices align with established photogrammetric principles for high-resolution cultural heritage documentation, as outlined by Remondino (2003). The resulting textured models formed the basis for the immersive virtual tour, providing a highly detailed, spatially accurate, and visually compelling representation of the site.

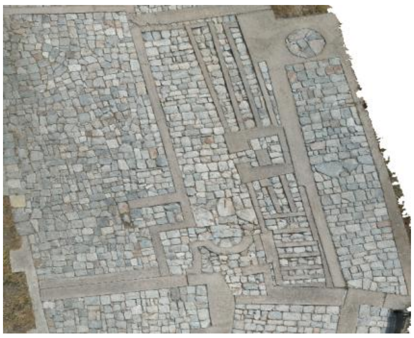

Figure 11. Textured model of the cobble stone pathway

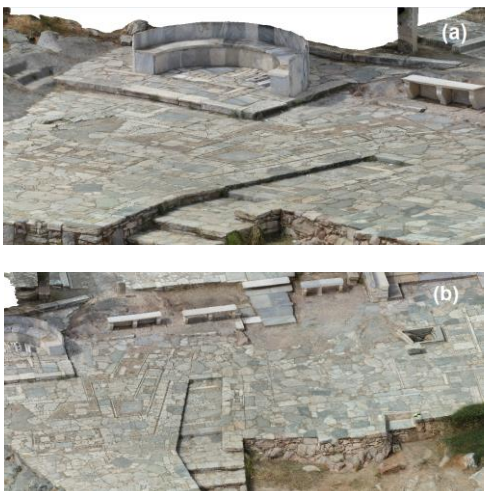

Figure 12. Textured 3D model (a) & (b)

4. Virtual Tour

The virtual tour was developed using the Unity game engine, a widely adopted cross-platform development environment primarily designed for the creation of 2D and 3D games, simulations, and immersive experiences in virtual and augmented reality. Developed by Unity Technologies, the software offers powerful real-time rendering capabilities, integrated physics engines, and modular scripting support through the C# programming language (Unity Technologies, 2023, https://docs.unity3d.com/). Unity’s flexibility and scalability make it an ideal platform for digital heritage applications. It supports immersive and educational content tailored to the exploration and interpretation of cultural landscapes, fostering public engagement through interactive media (Anderson et al., 2010; Bekele et al., 2018).

The development process began with the import of the 3D site models (in .obj format) into a new Unity project. Interactive elements were then introduced in the form of Points of Interest (Info Points), strategically placed throughout the digital reconstruction. These were visually marked in blue to draw the user's attention and embedded with toggleable pop-up panels. In total, 15 Info Points were created, each offering insights into the stone-paved path and the broader historical context of Filopappos Hill.

To guide user navigation within a predefined section of the site, invisible boundary colliders were implemented, restricting movement to the main path. A first-person controller was configured to represent the virtual visitor, featuring first-person movement and rotation controls. Lighting conditions were optimized to emulate the clarity of the Athenian sky, enhancing the visual realism of the environment. To reflect the site's natural setting, selected trees and shrubs were added in their approximate real-world locations (Figure 13). Furthermore, a 360° panoramic image of Athens — captured from the circular section of the designed pathway —was used as the application’s background, further anchoring the experience in a realistic context (Figure 14).

Figure 13. Virtual tour of the circular segment of the stone-paved pathway

A minimap interface was integrated into the lower-left corner of the screen. This feature relies on a top-down camera that tracks the avatar’s position and highlights their movement across the virtual space. The minimap assists users in locating Info Points and identifying spatial boundaries or obstacles in real time. All interactive functionalities—both for Info Points and user navigation—were scripted using C# within the Unity engine. A screenshot of this implementation, developed as part of the author's master diploma thesis entitled "Geometric documentation and virtual tour to enhance a section of the cobblestoned pathway designed by architect D. Pikionis on Philopappos Hill", is shown in Figure 15 (Vienna, 2024).

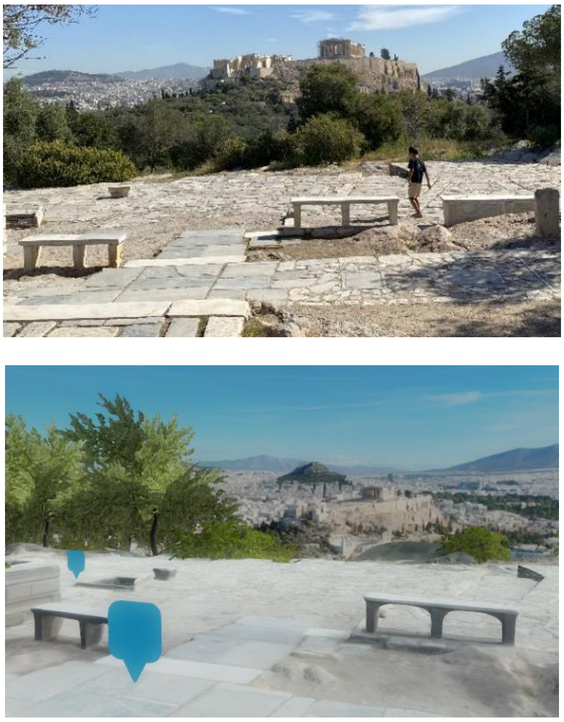

Figure 14. Terrace in real life and in virtual tour application.

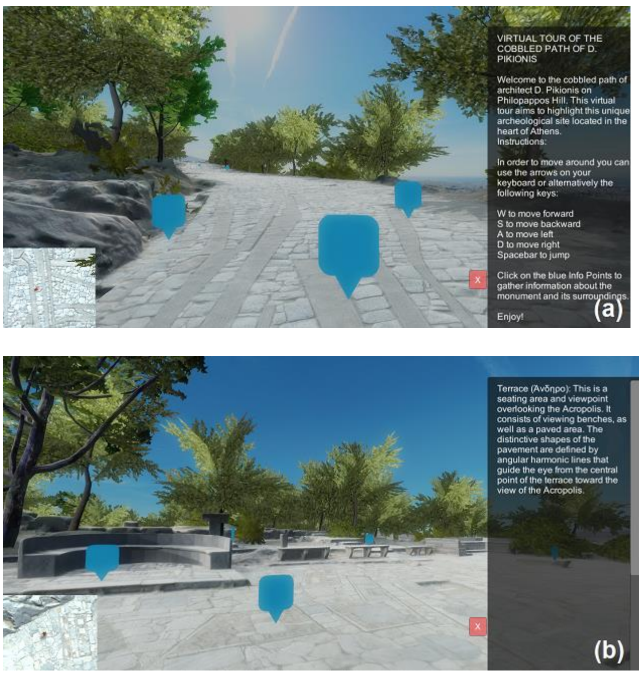

Figure 15**.** Pop-up information panels and mini map placement in the virtual tour application (a) & (b).

5. Conclusions

The landscape intervention of Dimitris Pikionis on the Hill of the Muses stands as a landmark of modern Greek architectural heritage, embodying a unique synthesis of modernist thought and vernacular tradition. His work does not simply constitute a physical route through the historic landscape; rather, it forms an architectural narrative that engages in a profound dialogue with the topography, history, and collective memory of Athens. The integration of ancient remnants, traditional craftsmanship, and natural elements reflects a design philosophy deeply rooted in the idea of continuity and cultural identity.

Given the artistic and historical significance of this site, its accurate geometric documentation emerges as a crucial tool for both preservation and scholarly interpretation. Through advanced photogrammetric methods—combining aerial and terrestrial imagery—an extremely detailed digital reconstruction was achieved, ensuring that the architectural nuances of the pathway, materials, and terrain are preserved for future study and reference.

Moreover, the development of an interactive virtual tour using the Unity game engine provides an innovative means of engaging with the monument. Through 3D models, information points, and user-guided navigation, the application enhances accessibility, promotes awareness, and invites exploration beyond the physical constraints of the site. This is particularly valuable for educational, touristic, and research purposes.

As digital technologies continue to evolve rapidly, their integration into cultural heritage workflows becomes increasingly essential. Tools such as virtual and augmented reality, immersive visualizations, and high-resolution spatial documentation open new horizons for the interpretation and communication of heritage values. In this context, the case of Pikionis' intervention exemplifies how digital media can reinforce the visibility, understanding, and long-term protection of complex and sensitive cultural landscapes.

This multidimensional approach—merging rigorous documentation with immersive digital tools—not only safeguards the legacy of Pikionis' work but also highlights the transformative potential of new technologies in preserving, interpreting, and disseminating architectural heritage. By providing high-fidelity spatial data and intuitive interaction, it offers a valuable resource for researchers, conservation professionals, and cultural institutions alike.

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