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Pergamon As It Once Was: A Virtual Journey into Ancient City and an Immersive Experience with AI Integration

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Abstract

This paper introduces an integrated digital reconstruction of the ancient city of Pergamon, combining Virtual Reality (VR), Artificial Intelligence (AI), and photorealistic 3D modeling to establish a historically informed and immersive virtual environment. Beginning with the production of precise architectural plans using AutoCAD®, the project develops detailed three-dimensional models of major Hellenistic and Roman-era structures—such as the Temple of Athena, the Altar of Zeus, and the Pergamon Theatre—through 3ds Max® and Blender®, followed by their spatial deployment in Unreal Engine®, incorporating terrain data, realistic lighting, and authentic textures. To elevate user engagement, historically accurate avatars were created using Character Creator® and animated with iClone®, while AI capabilities were integrated via Unreal Engine® and Convai® to allow real-time, context-sensitive interaction with users. These AI-driven characters function as narrative agents, guiding visitors through the virtual city and delivering interpretive content tied to specific landmarks. The resulting platform not only reconstructs architectural forms but also revives elements of social life and public space, offering an experiential mode of engagement with ancient urbanism. By uniting archaeological data, digital media, and conversational AI, this study exemplifies how emerging technologies can expand both the pedagogical and experiential dimensions of cultural heritage interpretation.

1. Introduction

Located in western Anatolia, about seventy miles north of Izmir, the ancient city of Pergamon (modern-day Bergama, Turkey) stands as a testament to classical civilization (Figure 1). Perched on the slopes of the Acropolis Mountain, Pergamon flourished during the Hellenistic period as a center of power, culture, and intellectual life (Smith, 2015). Its rise accelerated after Alexander the Great's defeat of the Persians in 334 BCE, leading to its establishment as the capital of the Attalid Kingdom (Miller, 2017).

Under Attalid rule, Pergamon became a cultural beacon, noted for its architectural achievements and scholarly influence (Thompson, 2012). Monumental buildings such as the Altar of Zeus, the Temple of Athena, and the Pergamon Theatre demonstrated the city's wealth and ambition (Hill, 2020). Its library (Casson, 2001), rivaling Alexandria's, further solidified its role as a major intellectual hub. In 133 BCE, following the death of Attalus III, Pergamon was bequeathed to the Roman Empire (Marshall, 2019) and continued to thrive as a provincial capital and cultural center.

However, its fortunes declined during the later Roman Empire. Granted the status of neokorate under Emperor Caracalla in the early third century, Pergamon soon faced economic hardship, an earthquake in 262 CE, and a devastating Gothic raid (Foss, 1977). These events marked the end of its prominence.

Today, the ruins of Pergamon are scattered across the Acropolis and surrounding landscape (Figure 2), offering a powerful glimpse into its illustrious past. Despite centuries of decline, its legacy endures through its architecture, artworks, and contributions to ancient science and philosophy. As a designated UNESCO World Heritage Site (UNESCO, 2021), Pergamon invites us to reimagine its former glory. What must it have felt like to navigate the vibrant streets of Pergamon at its zenith—to stand before its towering temples, to sit among thousands in its steeply tiered theatre, and to partake in the intellectual vigor that once defined the city's cultural identity?

Figure 1. Geographical Location of Pergamon

For centuries, historians and archaeologists have sought to answer this question, using artistic depictions, architectural drawings, and physical models to reconstruct the ancient city. However, despite their efforts, none of these methods could fully convey the majesty and complexity of Pergamon in its prime. The limitations of traditional approaches left much to be imagined, and the true experience of the city remained out of reach.

However, with the advent of modern digital technologies, the possibility of bringing Pergamon back to life in a more immersive and interactive way has become a reality (Marshall, 2020). Using advanced tools such as 3D modeling, Virtual Reality (VR), and Artificial Intelligence (AI), it is now possible to digitally reconstruct the ancient city with remarkable accuracy and richness.

By combining historical research with cutting-edge technology, we can not only explore the city's architecture and landmarks but also interact with the very people who once lived there. This virtual experience allows users to step into the past, experiencing Pergamon as it once was, walking its streets, visiting its temples, and engaging with its citizens.

In this paper, we aim to explore the potential of these advanced digital tools to recreate Pergamon, offering a new way to engage with and understand its cultural and historical significance. By integrating VR, AI, and interactive storytelling, we can provide a more engaging and informative experience for users, bringing them closer to the rich heritage of one of the ancient world's most remarkable cities. This approach not only offers a novel method for historical education but also serves as a model for how digital technologies can be used to preserve and experience cultural heritage in new and innovative ways.

2. Digital Reconstruction of Ancient Pergamon

2.1 Ancient City

While the ancient city of Pergamon has long occupied a central position in archaeological and historical studies, its digital reconstruction remains limited when compared to other major ancient urban centers. Prominent initiatives such as *Reviving Palmyra in Multiple Dimensions* (Silver, Fangi, & Denker, 2018) and *Reviving Ancient Rome* (Fleury & Madeleine, 2012) have established reference points for virtual heritage by leveraging high-resolution 3D modeling and immersive VR technologies to recreate complex architectural environments. These projects exemplify how virtual reconstructions can function not only as visual archives but also as platforms for public engagement, scholarly inquiry, and narrative interpretation.

Despite its historical significance, Pergamon has not received similar attention in terms of interactive digital reconstruction. Existing virtual heritage efforts for other cities have demonstrated the potential of digital tools to communicate cultural memory, yet Pergamon's digitally mediated presence remains largely underdeveloped. This project addresses that gap by focusing on the reconstruction of the city's architectural and socio-cultural topography during its peak in the Hellenistic and Roman periods. Through a multidisciplinary approach that synthesizes visual computing, heritage studies, and interactive media, the project aims to expand the representational and pedagogical scope of virtual heritage beyond traditional visualization.

What distinguishes this study from earlier digital reconstructions is its incorporation of AI-powered avatars, designed to simulate historically contextualized human interaction. These intelligent agents facilitate dynamic engagement by offering users real-time dialogue, interpretive guidance, and localized storytelling, transforming the reconstructed city from a passive exhibit into an interactive socio-spatial environment. The core research question underpinning this work is: How can AI-enhanced character interaction within immersive virtual heritage environments foster greater user engagement and promote deeper historical understanding of ancient urban life? By shifting the emphasis from static representation to dialogic experience, the project contributes to evolving paradigms in virtual heritage and expands the interpretive affordances of immersive digital reconstruction.

Figure 2. The Ruins of Ancient Pergamon.

2.2 Methodology

The methodological framework employed for the digital reconstruction of Pergamon, illustrated in Figure 3, is grounded in a multi-phase workflow that integrates archaeological documentation with advanced digital modeling techniques. The initial stage involves the generation of accurate 2D architectural schematics using AutoCAD®, based on historical excavation records and architectural publications, notably the works of Humann (1954), Wiegand (1910), and Humann et al. (1888). These schematics serve as the foundational geometry for subsequent digital modeling, ensuring that the spatial and structural characteristics of key monuments are preserved with architectural fidelity.

Following the drafting phase, the reconstruction process transitions into three-dimensional modeling using 3ds Max® and Blender®, where the 2D plans are transformed into high-resolution 3D representations of significant Hellenistic and Roman structures. This phase emphasizes volumetric accuracy, stylistic detailing, and proportional consistency derived from archaeological sources. Once modeling is completed, the digital assets are imported into Unreal Engine®, which serves as the primary platform for environmental assembly and interaction design. Here, the individual architectural models are situated within a geospatially coherent terrain, developed using topographical data to reflect the actual physical contours of ancient Pergamon. The engine facilitates not only the spatial organization of structures but also the integration of lighting systems, materials, and scene-level logic required for immersive user navigation and interaction.

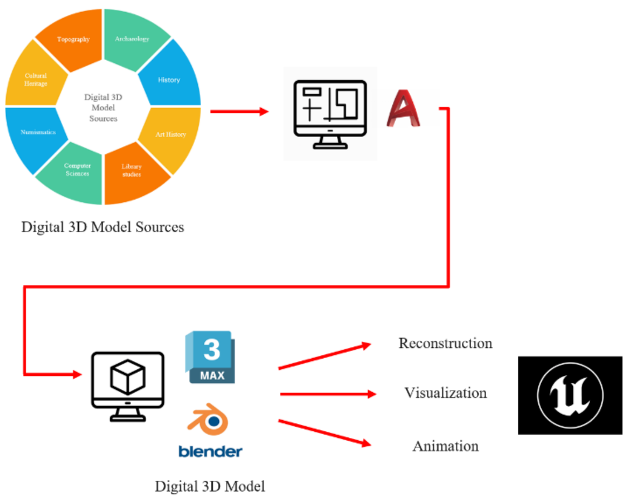


Figure 3. Methodological Workflow for the Virtual Reconstruction of Pergamon.

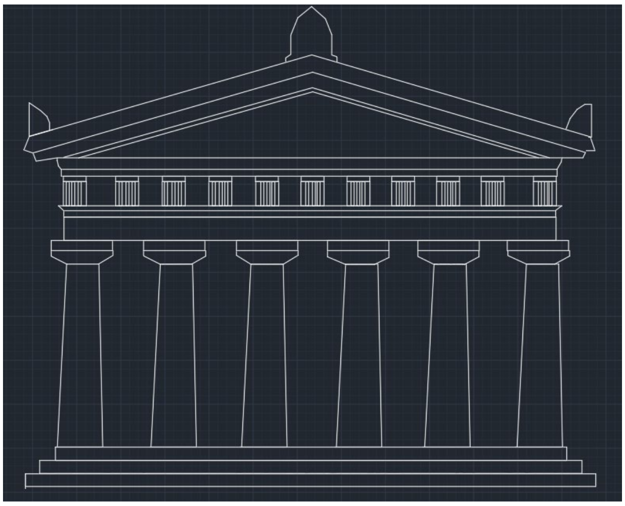


Figure 5. AutoCAD® 2D Drawings of the Façade of Athena Temple.

Figure 6. 3D model of the Doric Column of Athena Temple.

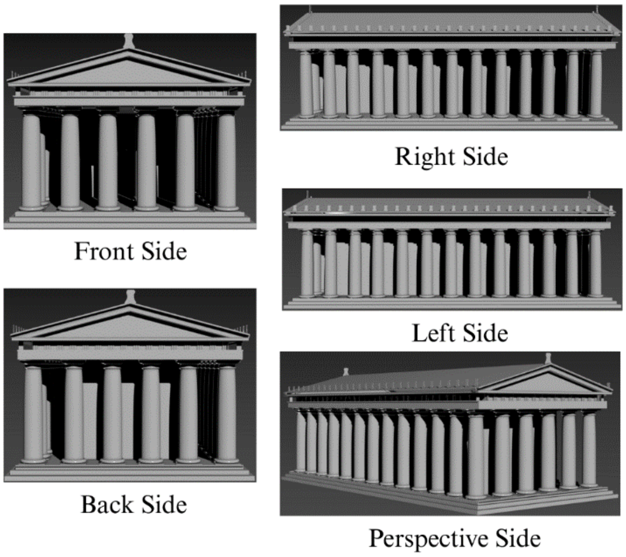


Figure 7. 3D model of Athena Temple.

2.3 3D Reconstruction of the Landmark Buildings

In this section, we present high-fidelity 3D reconstructions of four principal architectural monuments of Pergamon—namely the Athena Temple, the Zeus Altar, the Trajan Temple, and the Pergamon Theatre—each of which embodies critical advances in Hellenistic and early Roman design. The following subsections provide a detailed account of the reconstruction methodology applied to each structure, beginning with the Athena Temple, the oldest edifice on the Acropolis, and proceeding through successive stylistic and structural developments in Pergamon's urban landscape.

2.3.1 Temple of Athena: The Temple of Athena, originally constructed in the late 4th century BCE, underwent major modifications in the 3rd century BCE following Pergamon's victory over the Galatians. Dedicated to Athena Nikephoros, this triumph spurred an ambitious architectural program that significantly expanded the sanctuary. Wiegand's detailed drawings of the temple and its temenos (Figure 4) served as key references in the digital reconstruction.

Following the workflow outlined in Section 2.2, 2D schematics of the temple were produced in AutoCAD® (Figure 5) as a basis for 3D modeling. The Doric columns defining the façade were modeled as cylindrical forms, with fluting applied through subtractive operations to capture the order's characteristic rhythm and proportions.

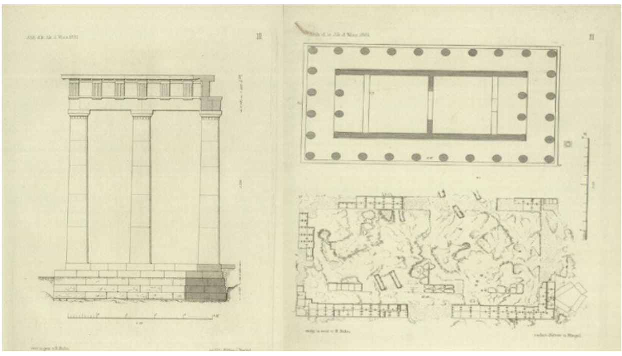


Figure 4. Reference Drawings of Athena Temple.

To replicate the traditional fluting of the Doric columns, additional cylindrical geometries were added to the base and capital. The lower components were constructed using box primitives, modified at the vertex level to ensure proportional accuracy and stylistic consistency with Doric conventions (Figure 6). The completed 3D model of the Temple of Athena is shown in Figure 7.

2.3.2 Temple of Trajan: Located on the highest level of the acropolis, north of the Athena sanctuary, the Temple of Trajan (the Trajaneum) was constructed atop a large terrace supported by a retaining wall above the theatre. Erected during the Roman Imperial period, the temple follows the Corinthian order and is dedicated to both Zeus and Emperor Trajan. Unlike the Temple of Athena, which employed local trachyte and limestone, the Trajaneum was built entirely of white marble, a material that—together with its elevated placement—provided commanding views over the surrounding landscape.

The temple's terrace rests on a massive retaining wall with a vaulted substructure, exemplifying an advanced use of structural engineering in Pergamene architecture. This technique, attributed to Hellenistic builders, was also employed in the Pergamene dedication at Delphi, illustrating the city's broader influence on the development and dissemination of vaulted construction methods.

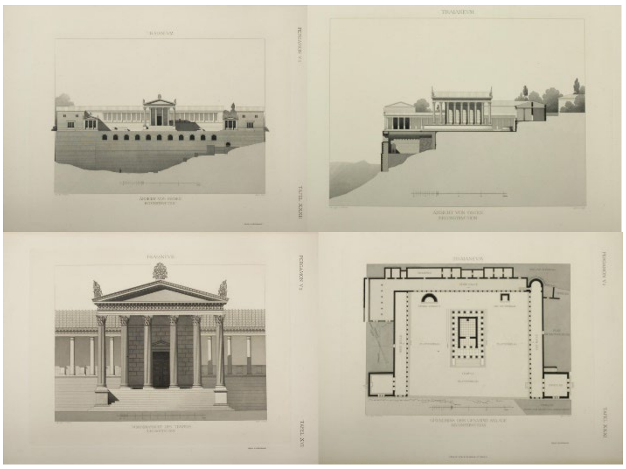
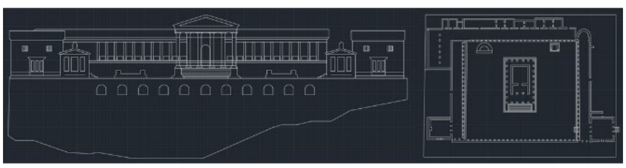


Figure 8. Reference Drawings of Trajan Temple.

Using Wiegand's architectural documentation as reference (Figure 8), 2D drawings were produced in AutoCAD® (Figure 9), forming the basis for the 3D reconstruction in 3ds Max®. Due to the complexity of the Corinthian order, the columns required a more intricate modeling process to accurately capture their ornamental detail (Figure 10). The final 3D model of the Temple of Trajan is presented in Figure 11.



Front Side Top Side

Figure 9. 2D Drawings of Trajan Temple.

Figure 10. 3D model of the Corinthian Column of Trajan Temple.

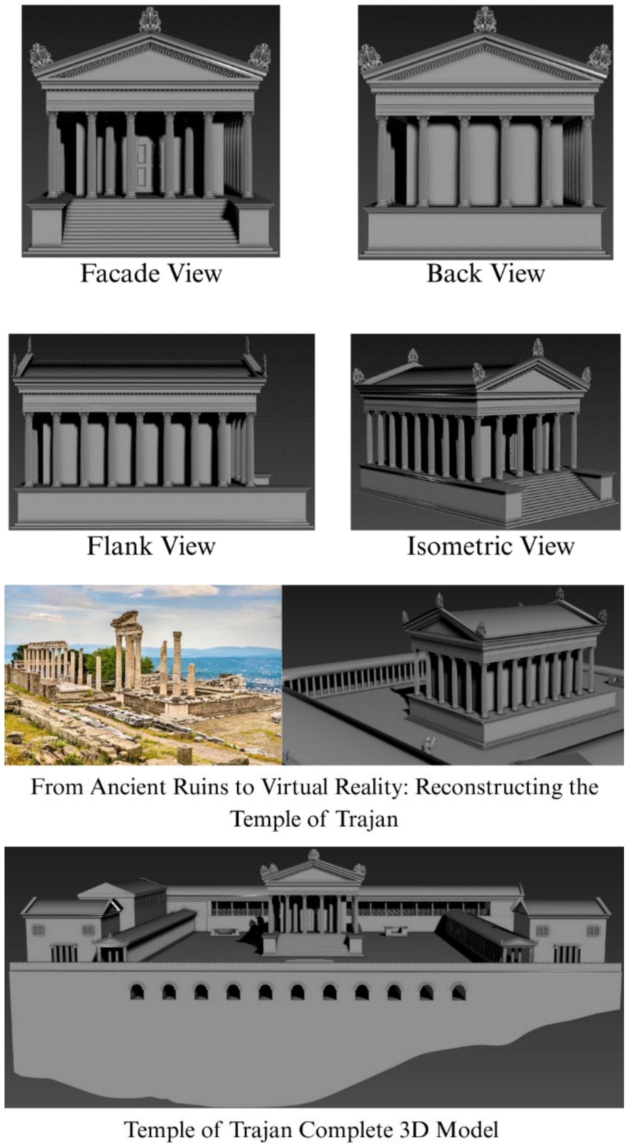


Figure 11. 3D Model of Trajan Temple

2.3.3 Altar of Zeus: Located on the highest level of the acropolis, north of the Athena sanctuary, the Temple of Trajan (the Trajaneum) was constructed atop a large terrace supported by a retaining wall above the theatre. Erected during the Roman Imperial period, the temple follows the Corinthian order and is dedicated to both Zeus and Emperor Trajan. Unlike the Temple of Athena, which employed local trachyte and limestone, the Trajaneum was built entirely of white marble, a material that—together with its elevated placement—provided commanding views over the surrounding landscape.

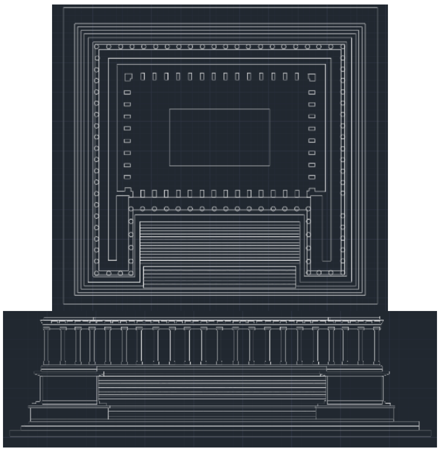


Figure 12. AutoCAD 2D Drawings of the Top and Front Views of the Altar.

Figure 13. 3D Model of the Ionic Column of Zeus Altar.

The architectural vocabulary of ancient Pergamon was shaped by the coexistence and strategic deployment of the three classical Greek orders—Doric, Ionic, and Corinthian—each embodying distinct symbolic and aesthetic functions within the city's urban fabric. The Temple of Athena, with its sturdy proportions and fluted Doric columns, conveyed strength and restraint, underscoring the temple's association with civic order and martial victory. In contrast, the Altar of Zeus employed the more graceful and ornamented Ionic order, reflecting a visual language of celebration and cultural refinement central to Pergamene identity during its artistic zenith. The Temple of Trajan introduced the Corinthian order—marked by elaborate acanthus motifs and vertical grandeur—as a symbol of imperial sophistication and Roman authority. Rather than serving purely decorative purposes, these stylistic choices reveal Pergamon's ambition to articulate power, piety, and political identity through architectural form. In this way, the city's built environment became a spatial narrative that merged Hellenistic ideals with emergent Roman influence, signaling both continuity and transformation in the aesthetics of empire.

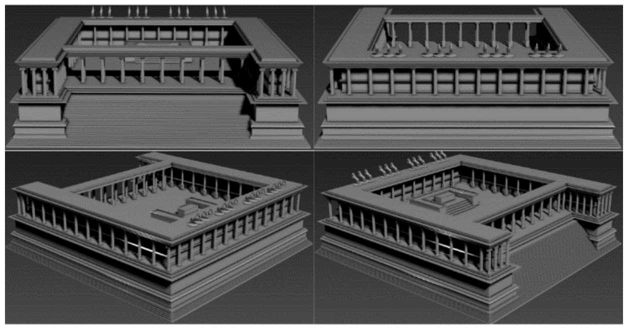


Figure 14. 3D Model of Zeus Altar

2.3.4 Pergamon Theatre: Pergamon's theatre, constructed during the Hellenistic period, functioned as a major cultural and religious center within the ancient city. This monumental marble structure, with an estimated capacity of 10,000 spectators, exhibited distinctive architectural features and played a central role in civic life.

The stage area, where performances were held, was supported by backstage structures including dressing rooms and storage chambers. The seating, arranged in a semi-circular formation along the natural slope of the hillside, ensured optimal sightlines and acoustics—features typical of Hellenistic theatre design. The venue likely accommodated a diverse array of activities, such as dramatic performances, musical events, religious rites, and civic assemblies, reinforcing its role as a central cultural institution in ancient Pergamon.

Today, the theatre endures as a remarkable testament to Pergamon's architectural ingenuity and urban planning. A detailed 3D reconstruction of the structure is presented in Figure 15.

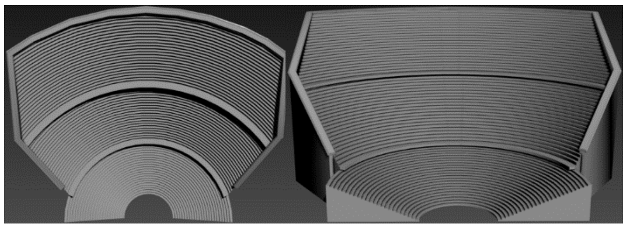


Figure 15. 3D Model of Pergamon Theatre

2.3.5 3D Model of the Ancient City: Following the reconstruction of Pergamon's four principal monuments—Trajan's Temple, the Theatre, the Altar of Zeus, and the Temple of Athena—additional architectural structures across the city were modeled to complete the urban landscape. This phase of the project drew extensively on a range of historical and archaeological sources to ensure contextual accuracy and coherence.

The modeling techniques employed for the secondary structures mirrored those used for the city's primary monuments. To ensure compatibility with the Unreal Engine environment, UVW mapping was applied to all models during the modeling phase. Upon completion, the assets were imported into Unreal Engine for integration into the broader virtual landscape. Figure 16 presents both the 2D architectural layout and the corresponding 3D model of the ancient city.

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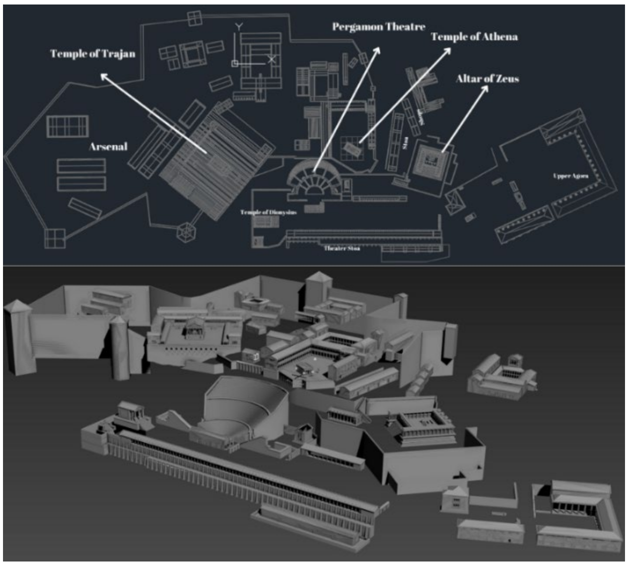

Figure 16. 2D Drawing and 3D Model of the ancient city

2.3.6 Virtual Pergamon: The final phase of the reconstruction was conducted in Unreal Engine®, aiming to produce an immersive and historically accurate virtual environment of ancient Pergamon. The terrain was generated using geospatially derived heightmaps, particularly the Skydark® dataset, to mirror the city's topography with visual and functional accuracy. Previously modeled structures were then integrated into this landscape, establishing the spatial framework for the virtual scene.

To enhance environmental realism, dynamic lighting was implemented using the Ultra Dynamic Sky plugin, allowing for nuanced atmospheric effects such as solar shifts, cloud cover, and diurnal cycles. Integration with Unreal Engine®'s lighting system ensured visual coherence across changing light conditions, contributing to historical ambiance and spatial immersion.

Material textures, sourced via Quixel Bridge®, were carefully adjusted to match the characteristic surfaces of ancient Pergamon—namely marble, limestone, and stonework. These materials were refined using the engine's material editor, with attention to chromatic tone and surface relief to ensure architectural authenticity.

By combining accurate terrain modeling, dynamic lighting, and historically grounded textures, the virtual environment achieves a high degree of immersive fidelity. This approach not only offers a compelling visualization of Pergamon's built heritage but also establishes a flexible framework for applications in education, digital preservation, and cultural storytelling (Figure 17).

Figure 17. Virtual Pergamon

3. The Creation of Historical Characters Through AI Driven Digital Workflows

To elevate the experiential depth and contextual authenticity of the virtual reconstruction, the integration of animated and interactable historical avatars was pursued as a critical design component. Moving beyond static spatial representation, the incorporation of AI-driven non-player characters (NPCs) enabled the simulation of sociocultural dynamics reflective of daily life in Roman-period Pergamon. These digital agents were not merely decorative elements but were methodically conceptualized and implemented to introduce spatial agency, narrative continuity, and embodied historical presence within the reconstructed urban landscape.

The development of historically resonant digital characters involved a multi-stage workflow beginning with the use of Character Creator® to generate anatomically and stylistically accurate Roman citizens. Period-appropriate garments and accessories were applied to ensure visual coherence with Roman sartorial norms. To enhance behavioral realism, iClone® was employed to integrate animations encompassing locomotion, speech gestures, and nuanced facial expressions. Additionally, specialized gladiator avatars were designed to represent militaristic or performative roles within the virtual cityscape, complete with historically grounded equipment such as swords, shields, and helmets (Figure 18).

Figure 18. Digitally generated Roman citizens created in Character Creator® with historically informed attire.

Subsequently, the finalized character models were integrated into the Unreal Engine® environment, where they were endowed with artificial intelligence capabilities through behavior trees and event-driven logic systems. This enabled dynamic, context-aware interactions within the reconstructed urban landscape. The overall workflow for character integration and AI implementation is outlined in Figure 19.

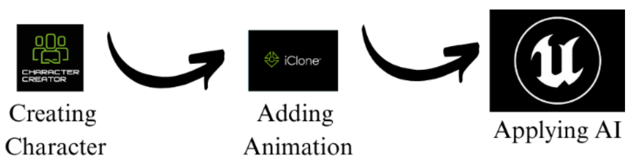

Figure 19. Workflow Diagram Illustrating the Character Integration and AI-Driven Behavior Process.

To enrich the immersive quality of the virtual Pergamon environment, historically-informed Roman characters were integrated using AI-supported workflows. These digital agents, created in Character Creator® and animated via iClone®, were imported into Unreal Engine® to simulate the social dynamics of the Roman period. Each character was assigned a unique behavioral profile in Unreal Engine®, determining variables such as walking speed, path awareness, and animation style. Predefined spline paths—curved motion routes—guided the characters through the environment to ensure realistic and culturally coherent movement patterns. Static agents performing idle animations (e.g., sitting, praying) were also added to increase visual density in public spaces. Trigger zones activated contextual conversational sequences, simulating everyday dialogue in agoras, courtyards, or temples.

This approach was employed to convey not only the physical layout of the city but also the lived experience of its inhabitants. By populating the virtual space with culturally contextualized agents, the project aims to transform a passive spatial model into an active historical narrative, fostering deeper user engagement and historical interpretation. This AI-driven character integration thus bridges architectural reconstruction with social storytelling, enhancing both engagement and interpretive depth (Figures 20-24).

Figure 20. AI-Driven Avatars in the Scene –Temple of Athena

Figure 21. AI-Driven Avatars in the Scene –Temple of Trajan.

Figure 22. AI-Driven Avatars in the Scene –Altar of Zeus.

Figure 23. AI-Driven Avatars in the Scene –Altar of Zeus.

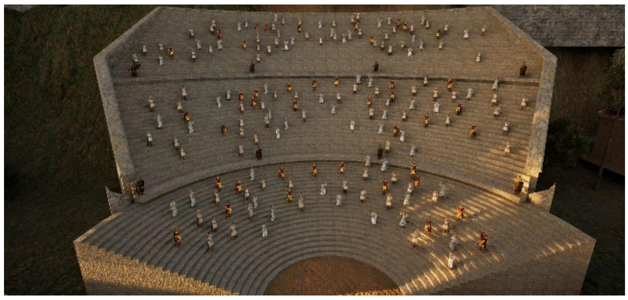

Figure 24. AI-Driven Avatars in the Scene –Pergamon Theatre.

4. The Creation of Historical Characters Through AI Driven Digital Workflows

To deepen the interpretive capacity and pedagogical potential of the virtual reconstruction, AI-based conversational agents were incorporated using the Convai® platform (Nørtoft, 2024), a system designed for real-time, natural language interaction. This integration enables Roman characters to respond contextually to user input, facilitating historically framed, dynamic dialogue sequences. Rather than delivering static informational content, characters actively engage users in conversations shaped by their proximity and interaction within the virtual environment.
Each character is linked to the Convai® API via speech triggers implemented in Unreal Engine®, allowing for location-sensitive activation of dialogue routines. When approached, the character initiates a responsive exchange featuring real-time speech synthesis, synchronized lip movement, and facial animation. These elements collectively enhance immersion and contribute to a more nuanced understanding of the social and cultural environment of ancient Pergamon.

To further support behavioral realism, animation layers were refined in iClone® (Ryu & Hur, 2014), incorporating idle postures, gesture coordination, and movement cues during dialogue. This results in interactive agents capable of expressing speech through multimodal cues, situating them as both narrators and actors within the reconstructed urban narrative (Figure 25).

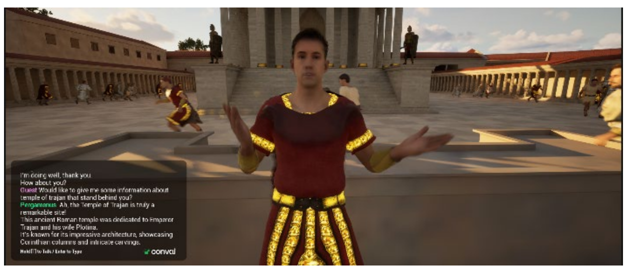

Figure 25. An AI-Driven Roman Avatar Providing Historical Information in Front of the Temple of Trajan.

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5. VR Implementation

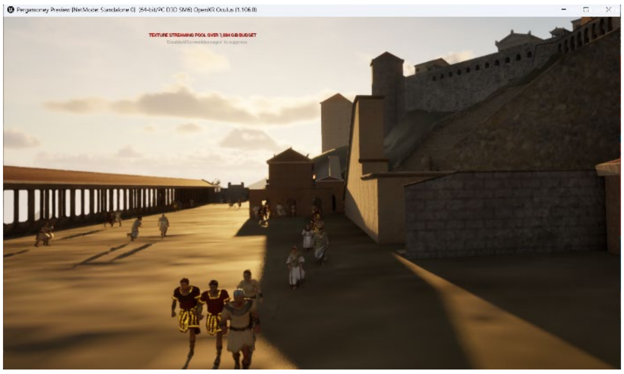

Figure 26. Virtual reconstruction of ancient Pergamon was integrated with Oculus Meta Quest 2 for an immersive experience.

To further enhance immersion and user interaction, the virtual reconstruction of ancient Pergamon was integrated with Oculus Meta Quest 2 (Figure 26). This setup enabled real-time, room-scale exploration of the environment in virtual reality. Users could navigate the city from a first-person perspective, interact with AI-driven avatars, and experience the architectural and cultural richness of Pergamon in a highly intuitive and engaging manner. While formal user evaluations have not yet been conducted, future work will involve individual VR sessions in which participants complete structured feedback forms assessing realism, usability, and engagement. The study will also investigate how effectively users retain historical information after the experience, providing insight into the VR model's educational potential.

6. Conclusion

This study presents a digital reconstruction of ancient Pergamon, integrating historical research with 3D modeling and immersive technologies. Architectural landmarks such as the Temple of Trajan, Altar of Zeus, Temple of Athena, and the theater were reconstructed with attention to stylistic and material fidelity. These structures were then situated within a geospatially accurate virtual landscape, enhanced with dynamic lighting and physically-based textures to evoke historical ambiance.

To animate the city's social dimension, AI-supported Roman characters were developed using Character Creator® and integrated into Unreal Engine® with behaviors, animations, and conversational abilities. These agents added a narrative and experiential layer to the spatial model, bridging architecture and human presence.

Finally, the virtual environment was adapted for VR deployment, enabling users to explore Pergamon in an embodied, interactive manner. Although user studies are planned for future work, this project demonstrates how immersive reconstructions can support education, storytelling, and cultural preservation by offering not only visual fidelity but also contextual and interpretive depth.

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