# Using Virtual Reality in Promoting Cultural Heritage

**Topoleanu Adrian**
Ovidius University of Constanta
124 Mamaia Bd., 900527, Constanta
adriantopoleanu@yahoo.com

**Popovici Dorin-Mircea**
Ovidius University of Constanta
124 Mamaia Bd., 900527, Constanta
dmpopovici@univ-ovidius.ro

**ABSTRACT**

This paper details the creation and implementation of a virtual reality (VR) museum aimed at promoting cultural values and heritage, specifically focusing on the Dobrogea region in the southeast of Romania. Based on Unreal Engine 5 [38] and VR technologies, Dobrogea Virtual Reality Museum offers an interesting, interactive learning experience that departs from traditional museum visits. The region, divided into Tulcea and Constanța counties, is an underappreciated hub of art and culture. The VR museum addresses a significant issue faced by local museums: lack of public interest and the need to adapt to digital advancements. By providing an immersive, accessible platform, the application aims to revitalize these cultural institutions. Users can explore photorealistic representations of real artifacts, captured using photogrammetry techniques, enhancing visual fidelity. Informative text displays taken directly from museum staff complement the experience, making learning a more engaging experience. Additionally, the VR museum allows users to interact with and manipulate cultural objects, creating a personal and memorable encounter.

**Author Keywords**

Virtual Reality (VR); Culture; Heritage; Virtual Museum; Interaction; User Interaction; Education;

**ACM Classification Keywords**

Human-centered computing:
Human computer interaction (HCI); Interaction design; Visualization; Cultural Heritage accessibility;

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## INTRODUCTION

Museums have long served as cultural sanctuaries, preserving heritage, art, and history for generations [11]. However, as society becomes more digital, there's a growing gap between the content offered by museums and modern audience expectations. Traditional museum visits are often limited by factors like artefact location, tourist accessibility, time and weather constraints. Museums constantly compete with online media to attract the interest of younger generations increasingly immersed in the digital realm. The core issue is how museums can adapt to the digital era while preserving the essence of art and culture. This question forms the foundation of this research, which aims to explore the intersection of art, culture, and technology through virtual reality (VR).

The significance of this issue extends beyond museum walls. Cultural heritage preservation is crucial in a world threatened by natural disasters and cultural erosion. VR can serve as a digital ark, safeguarding artifacts and heritage in a secure and accessible format [19]. It enables innovative educational methods, making learning engaging and memorable, and caters to diverse learning styles, ensuring knowledge is not just disseminated but also understood and retained. VR democratizes access to art and culture, eliminating geographical barriers [25]. For instance, a student in a remote village can explore the Louvre or the Acropolis, fostering global unity and cultural understanding. Empowering creativity through VR allows artists and curators to experiment with new forms of expression, pushing the boundaries of what defines art in the digital age. Aspects of acceptance, experience, and expectation of VR with the underlying values are not well understood but are important for the sustainability of the communication of cultural heritage as a bequest to future generations [13].

Globally, many initiatives have embraced Virtual Reality (VR) for cultural heritage preservation and promotion. Institutions like the British Museum, Louvre, and Smithsonian [26, 36] offer virtual tours and immersive experiences, allowing visitors to explore exhibits and artifacts in a digital environment. These virtual tours often include interactive features such as 360-degree views and detailed information overlays, which enhance the educational experience and make cultural heritage more accessible to a global audience.

Projects such as the Digital Museum of Digital Art (DiMoDA), the Virtual Museum of the Archaeological Museum of Thessaloniki, and Art Graphique & Patrimoine (AGP) [7] showcase VR's potential in creating captivating digital exhibitions. DiMoDA, for example, presents digital artworks in an entirely virtual space, allowing for innovative exhibition designs that challenge the boundaries of traditional art presentation. Similarly, the Virtual Museum of the Archaeological Museum of Thessaloniki offers users the chance to explore ancient artifacts in a reconstructed virtual environment, providing a unique educational experience. Art Graphique & Patrimoine (AGP) utilizes VR to create detailed 3D models of cultural monuments, enabling virtual preservation and making these sites accessible to users worldwide. These initiatives demonstrate the versatility of VR in enhancing cultural heritage experiences, offering both preservation and innovative ways to engage with history and art.

## TECHNOLOGIES USED FOR CREATING VIRTUAL MUSEUMS

Lighting, photogrammetry, sound, ambiance, interactivity, and user experience (UX) are considered as essential technologies for creating an immersive and interactive virtual museum experience.

Virtual reality, as technology support for such a museum experience, has grown significantly in recent years, never ceasing to slowly move on with the development in research, far from the spotlights, patiently waiting for hardware to improve in power and decrease in price to support its features [17]. The arrival of Head Mounted Displays (HMD) on the market for end-users has positioned these technologies as a new channel to promote new simulated or contextualized experiences [9]. High-resolution VR headsets from companies like Oculus and HTC create increasingly realistic and immersive virtual environments [21].

Lighting is crucial in virtual environments as it significantly affects visual realism and user immersion. Key aspects include real-time lighting, which changes dynamically based on user interactions or virtual environment settings, and pre-calculated lighting, providing high-quality static lighting for elements that do not require dynamic changes. Various light types, such as directional lights, point lights, and spotlights, replicate the lighting conditions found in physical museums. Global illumination simulates light reflection from surfaces, providing a natural and realistic lighting scenario, while proper use of shadows and reflections adds depth and realism to the virtual space [24].

Photogrammetry creates highly detailed three- dimensional (3D) models from images, essential for accurately representing artifacts in a virtual museum [15]. High-resolution photos ensure detailed 3D models, while high-quality textures enhance realism. Seamless integration of photogrammetric models into the virtual environment maintains performance and visual quality [27].

Advanced scanning technologies, including photogrammetry and 3D laser scanning, allow producing precise digital replicas of cultural artifacts (see Figure 1) that will be available to the community for free interaction, study, exploration, and discovery [15].

Sound design is critical for an immersive virtual museum experience, enhancing atmosphere and providing essential contextual information. Ambient sounds create a sense of place, such as crowd murmurs or nature sounds, depending on the exhibit.

**Figure 1. 3D scanned artifacts.**

Directional sounds guide user attention, while interactive sounds respond to user actions, like footsteps or artifact manipulation. Narrations and audio commentaries provide additional descriptions and information, enriching the user experience .

Interactivity and UX elements are crucial for engaging visitors in a virtual museum, ensuring intuitive navigation and interaction within the virtual space. This includes designing an intuitive interface for easy navigation and interaction with exhibits. Interactive elements like manipulable objects, informative pop-ups, and interactive displays enhance user engagement.

Programming languages and tools play a crucial role in developing virtual museums, enabling the creation of interactive, visually engaging, and functional virtual museum experiences. Scripting and programming languages are integral to the development process, enabling the creation of interactive elements, automations, and game mechanics in the virtual museum. Important languages used in Unreal Engine 5 (UE5) and virtual museum development include C++, Blueprints (Visual Scripting), and Python [12].

3D modeling software is essential for creating detailed models of artifacts and exhibits in a virtual museum. These tools work alongside photogrammetry data to produce high-quality 3D assets. Key 3D modeling tools include Blender [10], Autodesk Maya [6], ZBrush [40], and Agisoft Metashape [3]. Creating a virtual museum with VR capabilities requires specialized tools and technologies to ensure an immersive and interactive experience. Key VR tools include Oculus SDK [31], SteamVR [33], OpenXR [30], and VR Interaction Frameworks like Virtual Reality Toolkit (VRTK) [39].

The Dobrogea Virtual Museum aligns with these technological trends, utilizing state-of-the-art equipment and methods to ensure high-fidelity virtual representations.

## PROPOSED SOLUTION AND IMPLEMENTATION

The proposed solution detailed in this paper is the development of a virtual museum for the Dobrogea region. Being a lesser-known part of Romania, Dobrogea offers a vast and interesting history that deserves attention. Creating a museum that can be explored in virtual reality allows museums in the area to have the promotion they deserve. In collaboration with the National History and Archeology Museum of Constanța [14], the Institute for Eco-Museum Research "Gavrilă Simion" Tulcea [37] and the National History Museum of Romania from Bucharest, the virtual museum houses around 80 3D scanned artefacts from Tulcea and Constanța [1, 2].

The Dobrogea Virtual Museum project employs Unreal Engine 5 for its development, chosen for its advanced capabilities in rendering high-fidelity graphics and constructing realistic environments. Unreal Engine 5's features [32], such as dynamic global illumination and advanced physical simulations, contribute to creating an immersive and authentic virtual experience that aligns with the project's goals of enriching user engagement and preserving cultural heritage [20].

HTC Vive Pro [18] is the selected VR equipment, known for its precise motion tracking, room-scale immersive experiences, and ergonomic controls. This hardware choice enhances user interaction within the virtual environment, ensuring an unique, intuitive, gesture-based experience. The HTC Vive Pro's technological power and ergonomic design facilitate a seamless and immersive exploration of the virtual museum [8].

Interactive features are integrated throughout the virtual museum, transforming users from passive observers to active participants. Users can interact with 3D artifacts, triggering additional contextual information and creating a personalized learning experience. These features add depth to the virtual museum, fostering a deeper understanding of Dobrogea's cultural heritage.

The computer used for building, rendering and running the application is equipped with the following technical specifications:

- Processor: 4$^{th}$ generation I7 4790K 4.0 GHz.
- Graphics Processing Unit (GPU): GIGABYTE R9 390X G1 Gaming Edition, 8 GB VRAM.
- Random-Access Memory (RAM): 16 GB, 3200 MHz.
- Motherboard: ASRock Fatal1ty Z97 Killer
- Power Supply (PSU): Thermaltake 650W
- Operating System (OS): Windows 10 Professional

This configuration shows that even older generation computers can still reliably run and build Virtual Reality applications, showcasing the availability of VR for a large portion of consumers.

## APPLICATION PRESENTATION

The artistic design of the Dobrogea Virtual Museum is intentionally spacious, creating a pleasant and relaxed environment that encourages users to explore exhibits at their own pace (see Figure 1). The wide, open areas prevent feelings of confinement, which can be a concern in VR environments. This open design allows users to move freely and comfortably, enhancing their overall experience.


**Figure 2. Museum's layout.**

**Figure 3. Overall look of the museum.**

A sense of symmetry in the museum's open space adds structural balance and maintains a professional appearance without disrupting visual harmony. This design choice helps guide the user's gaze naturally through the space, focusing their attention on the artifacts without distraction from an uneven or chaotic environment, aiding in intuitive navigation.

In the starting area, users can quickly identify two paths to take, either left or right (see Figure 3). While this design might initially split the user's attention, it ensures that they always feel in control and have open possibilities, fostering curiosity, exploration, and excitement. There are three main focal points: statues in the center that function like a "roundabout," guiding users

to all points of the museum, including the four adjacent gallery rooms separated from the main exhibition.

The adjacent rooms offer a minimalist approach, maintaining viewer focus on the artifacts. Clean lines, neutral colors, and simple textures keep attention centered on the exhibits, reducing visual clutter and making the space feel open. This minimalist aesthetic aligns with modern museum design trends, emphasizing clarity and ease of navigation. Each of the four galleries is categorized, each focusing on a distinct type of artifact.

**Figure 4. Exhibition room example.**

The vases and amphorae from Tulcea (see Figure 4), showcased in one exhibition room, highlight historical relics and the craftsmanship of ancient potters in the region [34]. By placing these artifacts in a dedicated space, users can appreciate the unique ceramic styles of Tulcea. Another adjacent room features busts and head statues from Constanța, offering insights into the region's sculptural art and cultural expressions. The third room displays sculptural representations of notable figures and deities from Constanța, further highlighting the region's rich cultural heritage. The final exhibition presents antiquities from Tulcea, providing a glimpse into ancient daily life and artistic sensibilities.

Many significant artifacts from both counties invite users to interact, observe from all sides, compare, or even move them, marking a departure from the traditional museum approach of "look but don't touch" and opening the path to interactive learning.

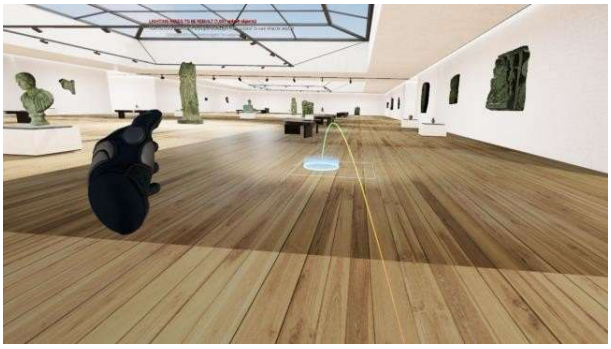
### Visualization/Head Mounted Display (HMD)

The user's perception of the museum is crucial in this project. Choosing virtual reality technology was natural, as a simple 3D project in Unreal Engine would not do justice to the artifacts or the user experience [29]. In VR, realities can be simulated, are open to user movement and real-time interaction with the contained objects [32]. Consequently, the HTC Vive Pro was selected to connect the user with the environment. Integrating this headset with Unreal Engine requires the OpenXR plugin and a dedicated VR hub like SteamVR for testing and running VR applications, as HTC products cannot run directly from the engine without these plugins.

After setting up the VR peripherals (including base stations with sensors and two controllers), users can enter the environment. In VR games, the need for a character model is replaced by the user's own body, with the headset acting as the head and viewpoint. This is achieved in the engine through the VRPawn blueprint, which sets height and adds a collision capsule to track the user's position in the visual environment. The view is provided by a camera module positioned at the top of the collision capsule, ensuring normal height and perception in the game. The HMD module is added in front of the camera to synchronize visual input and movement with the headset. VR.PixelDensity is used to adjust sampling for HMD resolution. Users can perform a snap turn using the touchpad on the left controller, allowing quick rotation without physically turning their heads. This feature is especially useful when the HMD is out of the base stations' range. Users can remain forward-facing in reality while turning in the virtual environment.

### Controls/Hands/Interaction

In VR, controllers represent the user's hands, enabling a wide range of actions (see Figure 5.b).



a.

b.

**Figure 5. Navigation to an artifact(a), Interaction with an artifact (b).**

The project uses realistic hand models and predefined animations for grabbing and pointing. The VR system tracks the position and orientation of the controllers in real time, ensuring the virtual hands match the user's movements.

A blueprint handles input from the controllers, allowing users to grab objects. Thanks to these technologies the user has the opportunity to experience without the need to come into contact with the real objects [4]. When the grab button is pressed, a sphere is created around the controller to detect the nearest object, which is then attached to the hand. This system is implemented for all small, manipulable artifacts. The blueprint also ensures there are no conflicts between the left and right hands. When the user releases the object, the blueprint releases it immediately.

### Movement/Teleportation

Due to VR system limitations, users cannot physically walk through the virtual museum. Instead, teleportation is used, allowing users to move to a chosen location within the virtual space (see Figure 5.a). This method minimizes motion sickness and provides simple, clear controls. Users press and hold a button on the right controller to select a teleportation point, indicated by a colored line and circle [11].

Teleportation is implemented in the VRPawn blueprint, starting with an input action node for the teleport button. Four functions ensure a smooth teleportation experience: Start Teleport Trace, Teleport Trace, End Teleport Trace, and Try Teleport. These manage initiating the trace, performing the trace, ending the trace, and teleporting the user to the valid location.

### Types of items and information display

In the Dobrogea Virtual Museum, user interaction goes beyond just viewing and interacting with artifacts. The project aims to make history and culture more accessible and engaging while ensuring that users leave with a deeper understanding of the objects they encounter [24]. One of the primary goals is to educate users about the cultural landmarks of Dobrogea. To achieve this, a floating text widget is used to present accurate information, provided by experts from the physical museums, as well as information from official websites.

The information snippets are kept short and concise to give users a clear idea of the artifacts without overwhelming them or causing eye strain. This approach allows users to choose whether to read the information panels, promoting learning without forcing it upon them . The design ensures that even if users prefer to explore and interact with objects rather than read about them, they have the option to do so.

In the virtual museum, information is displayed around artifacts in three distinct ways to enhance user experience (see Figure 6). For static objects, text appears in a widget when users approach, ensuring that the information is only visible when relevant and disappears when the user moves away, keeping the view clean. For larger, immovable artifacts like statues, information is displayed on all sides to provide a comprehensive view, with multiple widgets placed around these objects to avoid clutter.


**Figure 6. Descriptive texts for artifacts.**

Interactive objects, which users can manipulate, follow a similar information display method but with added functionality that hides text when the object is grabbed, allowing for an unobstructed interactive experience [23].

This design approach ensures that users can explore and learn about Dobrogea's cultural heritage in a way that is both engaging and informative. The combination of visual interaction and educational content provides a richer, more immersive museum experience [22].

## USER EXPERIENCE (UX)

The user experience in the Dobrogea Virtual Museum is meticulously designed to ensure a captivating, immersive, and educational journey, focusing on user interaction, human-machine dynamics, ergonomics, feedback, and ease of use. User interaction is crucial, transforming traditional visitors from passive observers into active participants. The virtual environment offers meaningful and engaging interactions with artifacts, enhancing understanding and appreciation. Virtual reality transcends physical limitations, providing an interactive experience that traditional museums cannot match [5].

Ergonomics and ease of use are fundamental to the museum's design. The HTC Vive Pro headset and controllers are selected for their comfort and ergonomic features, ensuring users can explore the museum for long periods without discomfort. The headset has adjustable straps for a secure fit, and the controllers are designed for intuitive use, with buttons strategically positioned for ease. The setup, including base station positioning, supports extensive user movement, enhancing the overall immersive experience [28]. Although the initial setup may seem daunting, the application is pre-configured by museum professionals, allowing users to enjoy VR without needing expensive equipment or technical expertise. Once set up, navigation and interaction within the virtual environment are simplified, ensuring users can focus on the content and experience.

**Figure 7. User interacting with an artifact**

Human-machine interaction in the Dobrogea Virtual Museum is organic and intuitive. The HTC Vive Pro headset, with high-resolution displays, a 90 Hz refresh rate, and precise motion tracking, creates an immersive environment. The controllers act as extensions of the user's hands, enabling gestures and actions that mimic real-world interactions. This seamless integration between human input and machine response is essential for adapting cultural institutions to the modern, digitalized world [16].

User feedback is vital in continuously improving the virtual experience, as it helps adapt the application to the audience's real needs. Analyzing how users manipulate objects and navigate the virtual space provides valuable insights for optimizing the museum experience. Effective user feedback not only enhances the experience but also contributes to the continuous refinement and development of the museum, making visits enjoyable, educational, and tailored to the audience's real needs [5].

The museum offers freedom of movement and interaction with 80 cultural artifacts from the Dobrogea region, categorized by region or subject location within the museum. Users can closely examine artifacts without protective barriers, providing a unique experience compared to traditional museums. The virtual environment delivers clear, concise information about each artifact, triggered by user proximity, enhancing cultural learning. Interacting with artifacts allows users to engage actively with the cultural landscape of Dobrogea, fostering a deeper investment in the experience. The intuitive teleportation system and simple, immersive menu design further enhance the user experience, ensuring that navigation and access to functionalities do not disrupt the immersion.

## CONCLUSION

In conclusion, our paper proves once again that VR technology has the potential to renew interest in history and museums among a broad audience that might be distanced from these interests. Thus, by creating the Dobrogea Museum in VR, significant emphasis was placed on human-computer interactions and the ability to captivate and engage users in direct learning [35].

The application actively demonstrates the importance of integrating VR technologies as a means of promoting Romanian culture and the specific culture of the Dobrogea region. Transferring users into a virtual environment that simulates interaction on a more personal level supports the idea of visual and interactive education. Users are encouraged to immerse themselves and feel as if they are handling pieces of history with their own hands [41]. Elements such as lighting, photogrammetry, and design played a crucial role in maintaining a faithful representation of a museum, including a main hall and four additional galleries containing approximately 80 displayed artifacts. The inclusion of detailed textual information, provided by reliable sources, ensures that users receive concise and clear educational content about each artifact, making the learning process both enjoyable and informative.

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