Immersive Virtual Reality Design for the Architectural Heritage of Rovigo, Italy: Digital Preservation and Interactive Exploration Based on Embodied Interaction

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Abstract

This study presents an innovative virtual reality (VR) framework for the digital preservation and interactive exploration of Rovigo's architectural heritage in Italy, focusing on its medieval city walls and their transformation over centuries. By integrating multi-source data fusion (aerial photogrammetry, laser scanning, and close-range photogrammetry), the framework achieves high-precision 3D reconstruction, capturing intricate details at millimeter-level accuracy. The immersive VR experience employs embodied interaction technologies—including gesture recognition (Leap Motion), full-body tracking (HTC Vive), and voice commands—to enable users to engage with historical narratives through hands-on activities such as simulating medieval construction techniques, participating in 19th-century demolition debates, and uncovering hidden traces in residential buildings.The framework combines linear and non-linear storytelling to balance educational rigor with user autonomy, fostering deeper connections to cultural heritage. Key contributions include: (1) a scalable methodology for heritage digitization, demonstrated through Rovigo's case; and (2) the novel integration of embodied interaction with dynamic narrative design, enhancing engagement and critical reflection on preservation challenges. Preliminary results highlight the potential of VR to bridge the gap between historical documentation and public participation.Limitations, such as data occlusion complexities and scalability for larger sites, are discussed, alongside future directions involving mixed reality (MR), augmented reality (AR), and AI-generated content (AIGC) for personalized storytelling. This research advances digital heritage practices by transforming static monuments into interactive, emotionally resonant experiences while setting a precedent for global applications.

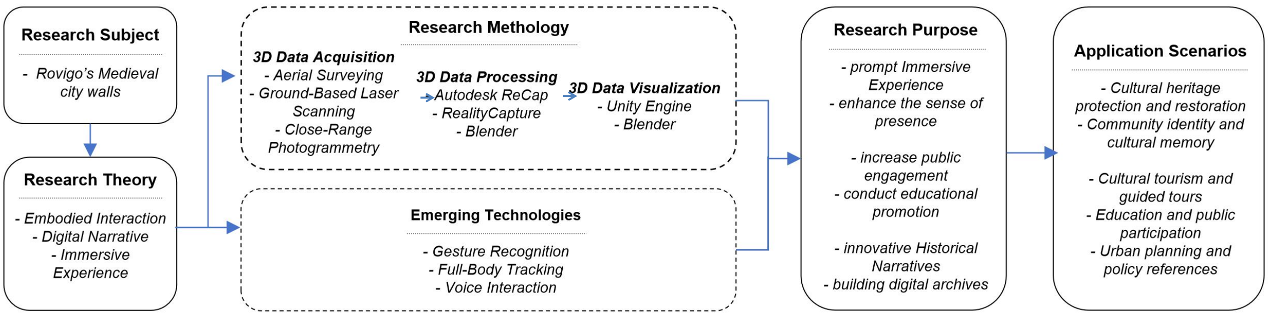

Figure 1. System architecture diagram.

1. Introduction

1.1 Research Background

Nestled in the Veneto region of Italy, Rovigo stands as a testament to the architectural and cultural evolution from the Middle Ages to the Renaissance. Its heritage, including the iconic city walls, churches, and squares, encapsulates centuries of historical narratives and artistic achievements. These structures not only reflect the socio-political dynamics of their time but also serve as tangible links to the past, offering insights into medieval construction techniques, urban planning, and community life. However, despite their historical significance, Rovigo's architectural treasures face pressing challenges. Physical degradation due to weathering, pollution, and urban development threatens their structural integrity, while a lack of public engagement exacerbates the risk of cultural amnesia.

Traditional preservation methods, such as archival documentation and static museum displays, have long been the cornerstone of heritage conservation. While these approaches are invaluable for record-keeping, they often fall short in engaging modern audiences. Static exhibits, for instance, fail to convey the dynamic historical contexts or the sensory richness of these spaces, limiting their educational impact. Moreover, the passive nature of such methods struggles to resonate with younger generations, who increasingly seek interactive and immersive experiences.

In response to these limitations, virtual reality (VR) technology has emerged as a transformative tool for cultural heritage preservation and education. VR's immersive capabilities allow users to step into historically accurate reconstructions, while its interactive features enable hands-on exploration and learning. Recent studies (Bekele et al., 2018; Xing et al., 2024; Fu et al., 2020) highlight VR's potential to bridge the gap between preservation and public engagement, offering scalable solutions for heritage sites worldwide. For Rovigo, this

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technology presents an opportunity to revitalize interest in its architectural legacy while ensuring its digital preservation for future generations.

1.2 Research Content

This study pioneers a VR-based digital preservation framework tailored to Rovigo's architectural heritage, with a focus on embodied interaction. By integrating multi-source data acquisition, digital narrative design, and cutting-edge interaction technologies, the framework enables users to explore architectural details, participate in historical reconstructions, and interact with virtual objects in real time. The project is grounded in addressing three critical challenges:

Data Integrity: Achieving high-fidelity 3D models of Rovigo's heritage requires overcoming the complexities of capturing intricate architectural details. The study employs a synergistic approach combining aerial surveying, laser scanning, and photogrammetry to ensure millimeter-level accuracy. For instance, drone-based oblique photogrammetry captures the macro-scale geometry of the city walls, while ground-based laser scanning resolves fine textures and decorative elements.

Narrative Immersion: To balance educational rigor with user engagement, the framework incorporates both linear and non-linear storytelling techniques. Linear narratives guide users through key historical events, such as the construction of the city walls, while non-linear paths allow for exploratory learning, such as uncovering hidden inscriptions or oral histories from local residents. This dual approach caters to diverse learning preferences, fostering deeper connections with the heritage.

Natural Interaction: The framework leverages embodied interaction technologies, including gesture recognition (Leap Motion), full-body tracking (HTC Vive Tracker), and voice commands, to create intuitive and immersive experiences. For example, users can simulate medieval construction techniques by stacking virtual stones or engage in historical debates through voice-activated dialogues. These interactions lower the learning curve and enhance emotional engagement, making history tangible and relatable.

1.3 Main Contributions

This study advances the field of digital heritage preservation through two key innovations:

Multi-Source Data Fusion and High-Precision 3D Reconstruction: By integrating drone aerial surveying, ground-based laser scanning, and close-range photogrammetry, the project achieves a high level of detail in virtual reconstructions. For example, the Leica RTC360 laser scanner captures textures at a resolution of 3 mm @ 10 m, enabling the digital replication of even the most delicate reliefs and murals.

Innovative Integration of Embodied Interaction and Narrative Design: The framework introduces a novel combination of gesture-based interactions, full-body tracking, and dynamic storytelling to create immersive educational experiences. Time-driven interactive scenes, such as the "Wall Construction Simulation" and the "Industrial Revolution Debate," blend linear historical narratives with user-driven exploration. This design not only enhances engagement but also fosters critical thinking about heritage conservation dilemmas, such as the tension between preservation and urban development.

Beyond its technical and narrative innovations, the framework serves as a scalable model for global cultural heritage projects. By demonstrating the practical application of embodied interaction in VR, it lays the groundwork for future research in mixed reality (MR) and augmented reality (AR) for heritage dissemination. The project's outcomes are illustrated in Figure 1, showcasing the system architecture that underpins these advancements.

The remainder of this paper delves into the historical context of Rovigo's architectural heritage (Section 2), the methodology for data acquisition and interaction design (Section 3), and the implications for future research (Section 4). Each section builds on the foundational concepts introduced here, providing a comprehensive exploration of the project's contributions to digital heritage preservation.

2. Immersive Virtual Reality Design Based on the Architectural Heritage of Rovigo

2.1 The Historical and Cultural Context of Rovigo: City Walls as "Living Historical Layers"

The medieval city walls of Rovigo stand as a testament to the dynamic interplay between urban functionality, technological progress, and societal evolution. Originally constructed as defensive structures, these walls have undergone a remarkable transformation, reflecting the shifting priorities and values of the communities that inhabited the region. This metamorphosis is not merely architectural but also cultural, encapsulating centuries of human interaction with historical heritage. The process can be dissected into three distinct yet interconnected phases, each marked by unique socio-political and economic influences.

- Pragmatism-Driven Adaptation: From Defense to Domesticity (10th–17th Century)

Following the decline of military threats in the late medieval period, the walls lost their primary defensive purpose. Residents, driven by necessity, repurposed the structures to meet their daily needs. Stone blocks from the walls were reused to build homes, while towers were converted into storage spaces or even dwellings. This phase highlights the resourcefulness of the local population, who viewed the walls not as relics but as practical assets. Historical records from the 15th century describe how families integrated sections of the walls into their homes, creating hybrid structures that blended medieval fortifications with Renaissance aesthetics. This adaptive reuse preserved the walls in a functional capacity, ensuring their survival even as their original purpose faded.

- Urbanization and Heritage Conflict: The Industrial Era (18th–19th Century)

The Industrial Revolution brought unprecedented changes to Rovigo, as it did to much of Europe. The walls, now seen as obstacles to progress, faced widespread demolition. The rise of railways and industrial infrastructure demanded open spaces, and the walls were dismantled to accommodate these developments. However, this period also saw the emergence of early preservation efforts. Local historians and architects documented the walls extensively, recognizing their cultural significance even as they were being torn down. Fragments of the walls were preserved in situ or relocated to museums, serving as tangible reminders of the city's medieval past. The debate over the walls during this era mirrored broader societal tensions between modernization and cultural preservation, a theme that remains relevant today.

- Layered Urban Landscape: Preservation and Renewal (20th–21st Century)

In the 20th century, Rovigo's walls gained recognition as cultural heritage, leading to concerted preservation efforts. The remaining sections were stabilized and integrated into the urban fabric, often serving as backdrops for public spaces or cultural events. Today, the walls exist as a palimpsest of history, with medieval stonework juxtaposed against Baroque facades and modern architecture. This layered landscape offers a unique opportunity for immersive storytelling, allowing visitors to traverse centuries of history in a single glance. The walls are no longer mere structures; they are narratives in stone, embodying the city's evolving identity.

2.2 Immersive Narrative Experience Based on Embodied Interaction Technology

This study focuses on the historical evolution of the medieval city walls of Rovigo, Italy, tracing their transformation from military fortifications to modern residential buildings. By designing multiple immersive, time-driven interactive scenes that juxtapose past and present, and incorporating embodied interaction technology, the project aims to recreate historical scenarios and enhance user engagement (see Figure 2).

Figure 2. Recreate historical scenarios and enhance user engagement using immersive narrative design

2.2.1 Interactive Scene Case 1: Wall Construction Simulation (10th–12th Century)

- Historical Context and Educational Framework

The earliest iterations of Rovigo's walls emerged in the 10th century as rudimentary wooden palisades, designed to shield the city from Magyar invasions. By the 12th century, under the patronage of the Este family, these defenses were upgraded to stone, incorporating advanced techniques such as lime mortar bonding and ashlar masonry. This scene immerses users in the labor-intensive process of wall construction, offering insights into medieval engineering and the socio-political motivations behind these monumental projects.

- Interaction Design and Technical Implementation

Users assume the role of a medieval stonemason, employing Leap Motion/VR controller to manipulate virtual stones and assemble scaffolding. The physics engine simulates the challenges of balancing uneven stones, requiring users to experiment with different arrangements to achieve stability (see Figure 3). This hands-on approach not only educates users about historical techniques but also fosters an appreciation for the skill and effort required to build these enduring structures.

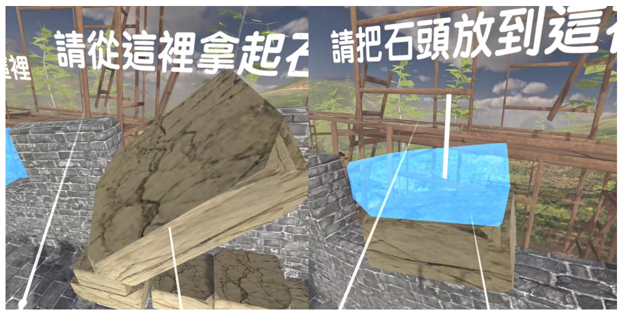

Figure 3. Simulating the process of building a fence through VR interaction

- Educational Outcomes

By engaging with the construction process, users gain a nuanced understanding of:

-- The strategic importance of Rovigo as a buffer between rival city-states such as Venice and Ferrara.

-- The communal effort behind wall-building, reflecting the collective responsibility of medieval societies.

2.2.2 Interactive Scene Case 2: The Wall Demolition Debate During the Industrial Revolution (18th–19th Century)

- Historical Context and Narrative Design:

The 19th century ushered in a wave of modernization that threatened Rovigo's medieval legacy. This scene recreates a pivotal town hall debate, where users must weigh the economic benefits of railway expansion against the cultural value of the walls. Archival records, including speeches by local officials and petitions from preservationists, inform the dialogue branches, ensuring historical accuracy.

- Interaction mechanism:

Users can interact with virtual NPCs (non player characters) based on historical figures, such as pro industrial mayors and fence protectionist priests (see Figure 4). Through some Q&A options, the system will record users' choices and track their preferences.

Figure 4. Interact with the non-player characters in VR

- Advanced Design:

We will introduce speech recognition technology to allow users to express their positions, and the system will dynamically adjust the outcome of the debate based on their arguments. For example, citing the role and function of city walls in flood prevention may make NPC tend to preserve them.

- Reflective Learning： The scene culminates in a visualization of the chosen outcome:

-- Preservation: The walls remain intact, but the city’s economic growth stagnates, prompting discussions about sustainable development.

-- Demolition: The railway accelerates commerce, but the loss of heritage sparks public remorse, mirroring real-world consequences observed in cities like Milan.

This duality encourages users to reflect on contemporary heritage debates, drawing parallels to modern urban planning challenges.

2.2.3 Interactive Scene Case 3: Exploring Historical Traces in Residential Buildings (20th–21st Century)

- Interaction Design: While exploring the streets, users discover hidden inscriptions or fragments of medieval wall paintings, unlocking related historical archives (e.g., a 14th-century craftsman's signature). Additionally, users can interact with narratives from current community members, such as oral histories about living near or within the medieval walls, capturing the site's relevance as "living heritage" (Wijesuriya, 2018).

- Historical Context: This scene emphasizes the layered nature of architecture and the continuity of historical memory. By the mid-20th century, Italy began to value its medieval heritage, and the remaining wall sections were designated as protected sites, prohibiting further demolition or modification. Residential buildings attached to the walls were gradually vacated due to structural aging, and some sections were restored as standalone historical relics. A few towers converted into residences (e.g., Torre Mozza) were redesigned as cultural spaces or boutique accommodations, preserving historical traces while introducing new functions. The integration of community narratives highlights how the walls have shaped local identity and daily life, bridging the past and present.

- Technical Implementation: Hidden artifacts are generated based on historical and cultural contexts, requiring users to collect and interpret related historical information. Community narratives are incorporated through audio recordings, video interviews, or text-based stories, accessible via interactive hotspots.(see Figure 5&6.) This narrative framework not only brings Rovigo's history to life but also sets a precedent for using embodied interaction in cultural heritage education and preservation.

Figure 5. Users can collect hidden artifacts in the virtual scene

Figure 6. Introduction of the Architectural Heritage of Rovigo in the virtual scene

- Educational Outcomes
This narrative framework not only brings Rovigo's history to life but also sets a precedent for using embodied interaction in cultural heritage education and preservation.

-- Enhanced Historical Awareness: Users gain a deeper understanding of Rovigo’s medieval heritage by uncovering

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hidden inscriptions, wall fragments, and historical archives, fostering an appreciation for layered architectural history.

-- Critical Engagement with Preservation: By interacting with narratives about demolition, restoration, and adaptive reuse, users reflect on the challenges and ethics of heritage conservation.

-- Community-Centered Learning: Oral histories and contemporary narratives highlight the walls' role in shaping local identity, connecting users to the lived experiences of past and present residents.

3. Methodology

3.1 Data Acquisition and 3D Reconstruction

The preservation and digital representation of Rovigo's architectural heritage require a meticulous approach to data acquisition and 3D reconstruction. To ensure the highest fidelity in capturing the intricate details of historical structures, a multi-source fusion strategy was employed, combining aerial surveying, ground-based laser scanning, and close-range photogrammetry. Each method was selected for its unique strengths in addressing specific challenges posed by the varied scales and complexities of the heritage sites.

- Aerial Surveying: Drones equipped with high-resolution oblique photogrammetry systems were deployed to generate comprehensive city-scale 3D point clouds. The drones, specifically the DJI Phantom 4 RTK, were flown at an altitude of 50 meters, capturing overlapping images with an 80% front and 60% side overlap ratio. This configuration ensured a point cloud accuracy of ±2 cm, which is critical for maintaining the geometric integrity of large-scale structures like city walls and squares. The photogrammetric data was processed using Pix4Dmapper, which aligned the images and generated dense point clouds, meshes, and textured models. Special attention was paid to areas with significant historical value, such as the medieval gates and towers, where additional flights were conducted to capture finer details.

- Ground-Based Laser Scanning: For capturing the detailed textures and geometries of individual buildings, the Leica RTC360 laser scanner was utilized. This device offers a resolution of 3/6/12mm at a distance of 10 meters, with an accuracy of 1.9 mm at the same range. The scanner was positioned at multiple strategic locations around each structure to ensure full coverage, with particular emphasis on ornate facades, arches, and other architectural elements that define Rovigo's historical character. Each scan was registered using Leica Cyclone REGISTER 360, which aligned the point clouds through target-based and cloud-to-cloud registration methods. The resulting high-resolution data provided a millimeter-level representation of the buildings, essential for accurate virtual reconstructions.

- Close-Range Photogrammetry: To supplement the laser scanning data, especially for decorative elements like reliefs, murals, and inscriptions, close-range photogrammetry was performed using DSLR cameras (Canon EOS 5D Mark IV with 24-70mm lenses). Over 500 high-resolution images were taken for each significant decorative feature, with lighting conditions carefully controlled to minimize shadows and highlights. The images were processed in Agisoft Metashape, which generated detailed 3D models of the decorative elements, capturing even the subtlest carvings and paint strokes. These models were then integrated with the larger point clouds to create a seamless digital representation of the heritage sites.

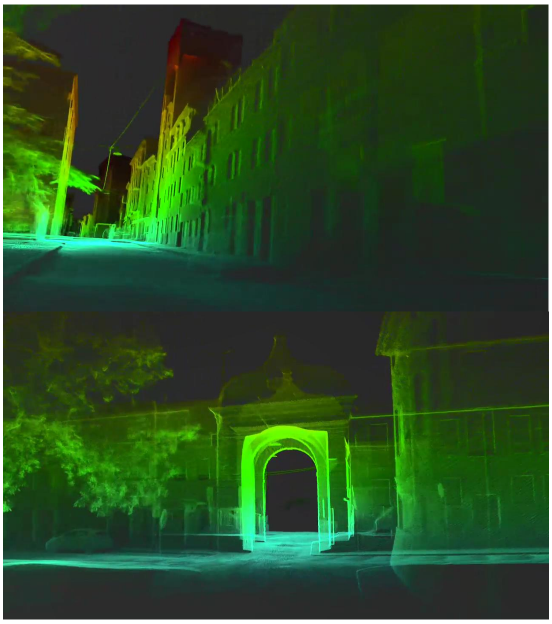

Figure 7. Processing of 3D data by 3D reconstruction software

- Data Processing and Alignment: The collected data from all three sources was processed and aligned using Autodesk ReCap and RealityCapture (see Figure 7). ReCap was used for initial point cloud cleaning and alignment, removing outliers and merging datasets from different sources. RealityCapture was then employed for mesh generation and texture mapping, leveraging its advanced algorithms to handle the large datasets efficiently. The software's ability to process millions of points while preserving detail was instrumental in creating accurate and visually appealing models.

- Topology Optimization and Material Mapping: The aligned data was imported into Blender for further refinement. Topology optimization was performed to reduce polygon counts without sacrificing detail, ensuring the models were suitable for real-time rendering in Unity. Material mapping was meticulously applied, using high-resolution textures derived from the photogrammetric data to recreate the authentic appearance of stone, wood, and other materials. Special shaders were developed to simulate weathering effects, such as moss growth and erosion, adding to the realism of the virtual environment.

- Interactive Virtual Scene Construction: The finalized models were exported to Unity Engine to construct interactive virtual scenes (see Figure 4). Unity's real-time rendering capabilities allowed for the creation of dynamic lighting and shadow effects, enhancing the immersive quality of the experience. The scenes were optimized for VR platforms, ensuring smooth performance even with high-detail models. Colliders and interactive elements were added to enable user interactions, such as touching, moving, and examining virtual objects.

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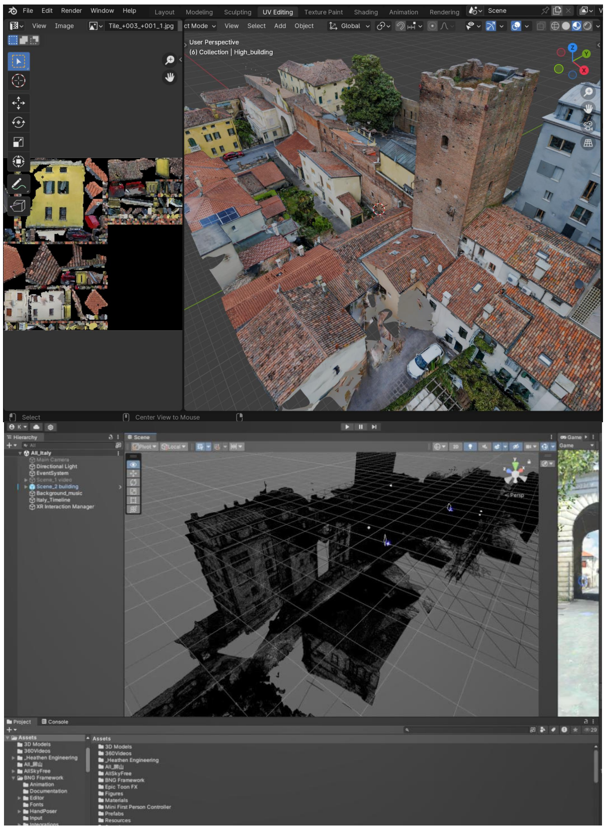

Figure 4. Design of Virtual Reality Interactions Based on Architectural Heritage in Blender & Unity Engine.

3.2 Implementation of Embodied Interaction Technology

3.2.1 Gesture Recognition

The Leap Motion controller was integrated into the VR system to enable natural and intuitive hand-based interactions. The device captures hand movements with sub-millimeter precision, mapping them to a virtual hand model in real-time. This allows users to perform actions such as grabbing, rotating, and manipulating objects with a high degree of realism.

- Use Case: In the "Wall Construction Simulation" scene, users can simulate the process of moving stones and constructing walls using virtual hands. The interaction design mimics medieval construction techniques, such as placing stones with lime mortar and operating wooden scaffolding. Physics-based simulations were implemented using Unity's PhysX engine, ensuring that the stones behave realistically when stacked or moved.

- Educational Value: Through gesture-based interaction, users gain hands-on experience with historical building techniques. They learn about the labor-intensive processes behind wall construction, the materials used, and the technological ingenuity of medieval builders. This immersive approach fosters a deeper appreciation for the craftsmanship and effort that went into creating these enduring structures.

3.2.2 Full-Body Tracking

HTC Vive Trackers were employed to synchronize users' full-body movements with their virtual avatars. Three trackers were attached to the user's waist and feet, providing real-time data on their position, orientation, and posture. This setup enables a 1:1 mapping of the user's physical movements to the virtual environment, significantly enhancing spatial presence.

- Use Case: In the "Archaeologist Exploration" scene, users embody a virtual archaeologist tasked with uncovering historical artifacts embedded in the city walls. Their movements, such as walking, crouching, and turning, are mirrored by the avatar, creating a seamless immersive experience. The scene includes interactive hotspots where users can "dig" for artifacts, with haptic feedback provided through the controllers to simulate the resistance of soil and stone.

- Educational Value: Full-body tracking allows users to physically engage with the defensive functions of medieval walls. By assuming the role of a sentry or explorer, they gain insights into the strategic importance of these structures and the daily lives of those who inhabited them. This embodied learning experience makes historical concepts tangible and memorable.

3.2.3 Voice Interaction

In the future, Our system will further incorporate the Google Speech-to-Text API to enable voice-based interactions. Users can issue commands or engage in dialogues with virtual NPCs (non-player characters) using natural language. The API's robust speech recognition capabilities ensure high accuracy even in noisy environments.

- Use Case: In the "Wall Demolition Debate" scene, users participate in a 19th-century civic discussion about the fate of the city walls. They can voice their opinions, such as advocating for preservation or supporting demolition for railway construction. The system dynamically responds to their input, altering the course of the debate and subsequent narrative outcomes.

- Educational Value: Voice interaction fosters critical thinking and empathy by placing users in historical debates. They confront the same dilemmas faced by past communities, weighing cultural preservation against urban development. This reflective exercise encourages users to draw parallels to contemporary heritage conservation challenges.

By combining these embodied interaction technologies, the VR framework not only enhances user engagement but also deepens the educational impact of cultural heritage preservation. Each interaction modality was carefully designed to align with the historical context, ensuring a cohesive and meaningful experience.

4. Discussion & Limitation

4.1 Discussion

The proposed immersive VR framework for the architectural heritage of Rovigo demonstrates significant potential in addressing the challenges of digital preservation and interactive exploration. By integrating multi-source data fusion, high-precision 3D reconstruction, and embodied interaction technologies, the framework not only preserves the physical details of the heritage but also revitalizes its historical and cultural narratives. The use of gesture recognition, full-body tracking, and voice interaction has proven effective in lowering the learning curve and enhancing user engagement, as evidenced by the interactive scenes designed for wall construction, demolition debates, and historical trace exploration.

One of the key strengths of this framework is its ability to balance educational goals with user autonomy. The linear and non-linear narrative paths allow users to explore historical contexts at their own pace while ensuring that critical cultural information is conveyed. For instance, the wall construction simulation (10th–12th century) not only teaches users about medieval building techniques but also fosters an appreciation for the labor and ingenuity of historical craftsmen. Similarly, the industrial-era demolition debate (18th–19th century) encourages users to reflect on the ongoing tension between heritage preservation and urban development, a theme that remains relevant today.

The framework also highlights the importance of community involvement in heritage preservation. By incorporating oral histories and narratives from current residents, the project bridges the gap between past and present, emphasizing the concept of "living heritage." This approach aligns with contemporary conservation strategies that prioritize the social and cultural dimensions of heritage sites (Wijesuriya, 2018). Furthermore, the technical implementation, such as the use of Leap Motion and HTC Vive Trackers, showcases how advanced technologies can be harnessed to create immersive and educational experiences without compromising historical accuracy.

4.2 Limitations

Despite its achievements, the study has several limitations that warrant consideration. First, the accuracy of 3D reconstruction heavily depends on the quality of the input data. While aerial surveying, laser scanning, and photogrammetry provide high-resolution models, challenges such as occlusions, lighting conditions, and complex architectural details can introduce errors. For example, intricate decorative elements like reliefs and murals may require additional manual refinement to achieve millimeter-level precision. Future work could explore the integration of AI-based correction tools to streamline this process.

Second, the scalability of the framework remains untested for larger or more complex heritage sites. Rovigo's architectural heritage, while rich, is relatively compact compared to sprawling historical cities like Rome or Venice. Adapting the framework to larger sites may necessitate advancements in data processing and rendering capabilities to maintain performance and user experience. Additionally, the computational demands of real-time embodied interaction could pose challenges for widespread deployment, particularly in resource-limited settings.

Third, the evaluation of user engagement and learning outcomes is preliminary. While the interactive scenes are designed to enhance immersion and education, empirical studies with diverse user groups (e.g., students, tourists, local residents) are needed to quantify their effectiveness. Metrics such as knowledge retention, emotional engagement, and usability feedback would provide valuable insights for refining the framework. Future research could incorporate longitudinal studies to assess the long-term impact of VR-based heritage education.

Lastly, the current framework focuses primarily on visual and auditory stimuli, neglecting other sensory modalities such as haptic feedback. Incorporating tactile interactions, such as the feel of virtual stone or the weight of construction tools, could further enhance immersion and realism. However, this would require additional hardware and software integration, potentially increasing the complexity and cost of the system.

5. Conclusion and Prospect

This study demonstrates the significant potential of virtual reality (VR) as a transformative tool for the digital preservation and interactive engagement of architectural heritage, as exemplified by Rovigo’s medieval city walls. By leveraging multi-source data fusion and high-precision 3D reconstruction, the framework achieves an unprecedented level of detail, enabling both accurate documentation and immersive public exploration. The integration of embodied interaction technologies—such as gesture recognition, full-body tracking, and voice commands—fosters active participation, allowing users to experience historical narratives through hands-on activities and dynamic storytelling.

The framework’s dual emphasis on linear and non-linear narratives ensures a balance between educational depth and user autonomy, encouraging critical reflection on heritage preservation challenges. Key contributions include a scalable digitization methodology and the innovative fusion of embodied interaction with adaptive storytelling, setting a benchmark for future digital heritage projects.

While challenges such as data occlusion and scalability for larger sites remain, the study outlines promising future directions, including mixed reality (MR), augmented reality (AR), and AI-generated content (AIGC) for personalized experiences. Ultimately, this research advances the field by transforming static monuments into emotionally resonant, interactive platforms, bridging the gap between historical scholarship and public engagement while offering a replicable model for global heritage preservation efforts.

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