Immersive Journeys in Smart Cities: Synergy of AR/VR, Gamification, and Civic Engagement for E-Tourism*

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I. Introduction and Objective

Urban cultural heritage faces mounting pressures from over-tourism, environmental degradation, and the digital divide. Conventional methods of heritage communication—such as physical signage, static media, or isolated exhibitions—often lack the interactivity and inclusiveness needed to engage diverse, tech-savvy audiences. Simultaneously, cities are striving to become smarter, more sustainable, and more participatory, creating an opportunity to reimagine heritage experiences through digital transformation.

This work introduces a modular digital platform, a civic-oriented, immersive digital infrastructure for urban environments. By integrating augmented and virtual reality (AR/VR), digital twins, artificial intelligence, and participatory tools, the platform enhances the way users explore and interact with cultural heritage while contributing to real-time urban sustainability goals.

The core challenge addressed in this research is the design of a digitally inclusive and scalable infrastructure that supports immersive and participatory heritage engagement, ensures accessibility across different user groups, and contributes actionable insights for cultural planning and sustainable tourism. Rather than isolating technology from civic context, the platform harmonizes immersive storytelling, open data, and user-driven interaction to foster engagement, inclusivity, and cultural resilience.

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Research Objectives

The key objectives of this study are as follows:

- To develop an immersive digital platform using AR/VR and digital twin technologies to enhance user engagement with cultural heritage.
- To integrate AI-driven personalization and gamified content that promotes inclusive, educational, and interactive tourism experiences.
- To enable civic participation through participatory sensing and open data tools that inform sustainable urban planning and cultural preservation.

II. Methodology

The methodology for developing this digital heritage platform is based on a socio-technical systems approach that combines human-centered design, modular architecture, and sustainable digital innovation. The aim is to bridge technological advancement with cultural accessibility, creating an inclusive, adaptable platform meaningful to both local communities and global users.

The platform is conceived as a multi-layered system reflecting the complexity of cultural heritage. Instead of prescribing a fixed technology stack, the approach emphasizes flexibility and

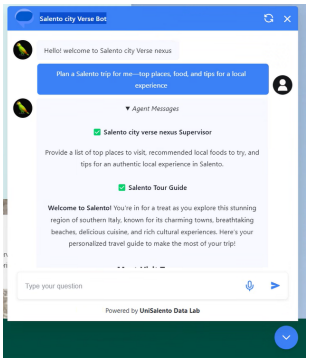

Fig. 1. Example of chatbot usage for civic engagement

Fig. 2. Timeline game

Fig. 3. Piazza Sant'Oronzo Digital Twin in Unreal Engine

interoperability, allowing diverse stakeholders—public institutions, researchers, tourists, and civic volunteers—to engage with the system using tools suited to their context.

Key principles include:

- **Modularity**: Layers and components can be independently developed, extended, or replaced without disrupting the whole.
- **Scalability and openness**: Designed to scale across regions and use cases, leveraging open standards and web technologies for broad access.
- **Ethical and inclusive design**: Providing low-tech alternatives and participatory features to reduce barriers and amplify diverse voices.

The platform's three functional layers—Immersive Engagement, Gamification, and Civic Engagement—work together to support educational, experiential, and participatory cultural interactions. Figure 4 illustrates the high-level logical architecture, abstracted from specific tools. A lightweight proof-of-concept prototype, hosted on GitHub Pages and built with standard web technologies, demonstrates the feasibility of delivering immersive and participatory experiences with minimal infrastructure, supporting scalability and sustainability.

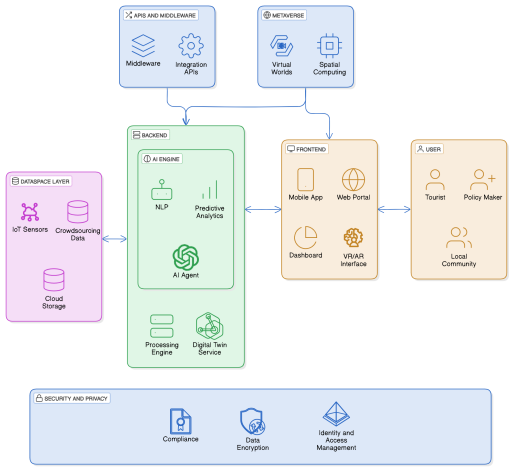

Fig. 4. Proposed Solution: tools and services

A. *Immersive Engagement Layer*

At the core of the platform lies the Immersive Engagement Layer, which leverages digital twins and real-time 3D rendering to transform how users interact with cultural spaces. Drawing on photogrammetry and LiDAR scans, high-resolution virtual reconstructions of heritage sites are created using engines like Unreal Engine and Cesium, such as the ezample in Figure 3. These are integrated with AI-powered storytelling agents that guide users through the experience, offering adaptive narratives and interactive dialogues.

B. *Gamification Layer*

The Gamification Layer complements the immersive experiences by embedding playful and educational components throughout the platform. It includes a set of mini-games such as a historical timeline challenge, as shown in FIgure 2, an image-based monument guessing activity, and a narrative-driven escape room. These are integrated with an interactive map that offers personalized cultural itineraries and contextual information.

A multi-agent conversational system enhances interactivity, allowing users to receive game hints, historical facts, and real-time feedback during gameplay. All game mechanics are designed to promote exploration and learning, with a strong alignment to the Sustainable Development Goals (SDGs), particularly those related to education, innovation, and responsible tourism.

C. *Civic Engagement Layer*

The Civic Engagement Layer introduces participatory tools that invite users to become co-creators of cultural and urban knowledge. One of the main features is mobile crowd sensing (MCS), through which tourists and citizens can collect urban data—such as noise levels—using their smartphones. This data is then visualized on real-time maps to inform urban resilience and planning strategies.

Additionally, the platform enables the crowdsourcing of oral histories, photographs, and cultural narratives. The layer is designed with extensibility in mind, allowing integration with smart city frameworks such as FIWARE for enhanced context-awareness and governance.