

A Multisource Reality-Virtuality Approach for E-Culture and Civic Engagement in the Marche Region

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Abstract—Digital technologies can enhance cultural and landscape heritage in inner areas by connecting distributed assets, local communities, and public-facing applications. The main challenge is transforming heterogeneous data, acquired from different sources, scales, and devices, into coherent content reusable across multiple visualization systems and public spaces. This paper presents MSXR, a multi-source reality-virtuality approach developed by the Università Politecnica delle Marche with the Unione Montana Marca di Camerino (UMMC) within the SNAI “Alto Maceratese” framework. The project involved 17 municipalities, each selecting one cultural and one landscape asset, and collected approximately 0.75 TB of multi-modal data through drone imagery, 360° capture, terrestrial laser scanning, high-resolution photography, and video. These data were processed and adapted into immersive rooms, XR experiences, and interactive totems for e-culture, e-tourism, and civic engagement. Deployments in Pieve Torina and Visso demonstrate how multi-source heritage data can support scalable smart-community applications, while highlighting practical constraints related to heterogeneous spaces and display configurations.

Index Terms—Cultural Heritage, Digital Humanities, Extended Reality, 3D Digitization, E-Tourism

I. INTRODUCTION

Digital documentation and reuse of cultural and landscape heritage are strategic for smart communities, supporting preservation, education, e-tourism, e-culture, and civic engagement. This is particularly relevant for the inner areas of Central Italy, where valuable but dispersed heritage is affected by demographic decline, infrastructural fragility, limited accessibility, and, in the Marche Apennines, the consequences of the 2016 seismic sequence [1], [2]. In these contexts, digital heritage becomes a primary channel for cultural access and territorial promotion: 3D digitization, VR, AR, 360° media, immersive rooms, and interactive totems can make distributed assets accessible even when physical visitation is constrained [2]. However, real-world projects must go beyond isolated 3D models or single-technology demonstrations, requiring the integration of heterogeneous visual and spatial data into coherent ICT applications across devices, public spaces, and interaction modalities [3].

This paper presents MSXR, a multi-source reality-virtuality approach developed within the SNAI “Alto Maceratese” framework by the Università Politecnica delle Marche in collaboration with the Unione Montana Marca di Camerino

(UMMC). The project involved 17 municipalities, each selecting one cultural and one landscape asset, and aimed to transform heterogeneous heritage data into coordinated public-facing applications for e-culture, e-tourism, civic engagement, and territorial valorization. Multi-source data acquired through drone imagery, 360° capture, terrestrial laser scanning, high-resolution photography, and video were processed and adapted for immersive rooms, AR experiences, VR applications, and interactive totems. MSXR focuses on the practical integration of common municipality-selected content across heterogeneous visualization channels and public spaces. This enables a distributed model of cultural communication in which small municipalities can participate in a shared digital infrastructure while preserving the specificity of their local heritage assets. The main contributions of this work are: (i) a real-world smart-community case study involving 17 municipalities and both cultural and landscape heritage assets; (ii) a multi-source acquisition and processing strategy combining drone imagery, 360° capture, laser scanning, high-resolution photography, and video; (iii) the adaptation of common heritage contents across multiple public-facing channels, including immersive rooms, AR, VR, and interactive totems; (iv) an applied model for supporting e-culture, e-tourism, civic engagement, and territorial valorization in inner areas.

II. MSXR: DESIGN AND IMPLEMENTATION

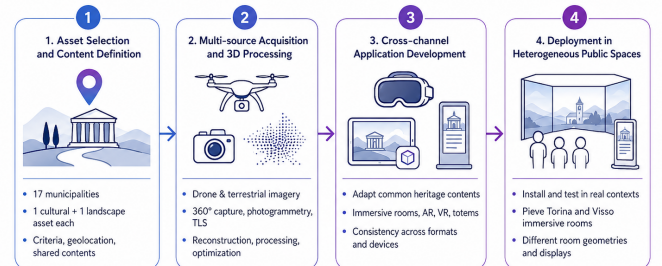


Fig. 1: Overview of the MSXR workflow.

MSXR addresses the valorization of distributed cultural and landscape heritage in the Alto Maceratese area through the multi-source and multi-channel process illustrated in Fig. 1. The goal is not only to digitize heritage assets, but to acquire

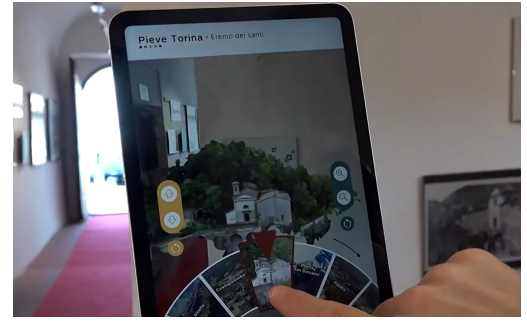


Fig. 2: Two deployed MSXR experiences: the acquired and curated heritage data are projected into public-facing immersive environments, including combining room-scale projection (left) and AR-based interaction (right) to support cultural communication and territorial valorization.

heterogeneous data and adapt common municipality-selected contents to different ICT applications for smart communities, e-culture, e-tourism, and civic engagement.

- **Phase 1 - Asset Selection and Content Definition:** each of the 17 municipalities selected two assets, one cultural and one landscape-related. This phase included the definition of inclusion criteria, site geolocalization, and the identification of the descriptive contents to be reused across the different applications.
- **Phase 2 - Multi-source Acquisition and 3D Processing:** the selected assets were acquired through heterogeneous techniques, including drone and terrestrial imagery, 360° capture, photogrammetry, terrestrial laser scanning, high-resolution photography, and video acquisition. The collected data were then processed, reconstructed, and optimized according to the requirements of the target visualization systems.
- **Phase 3 - Cross-channel Application Development:** the acquired and processed content was adapted into a coherent set of public-facing applications, including immersive rooms, AR experiences, VR applications, and interactive totems. This phase addressed the challenge of preserving content consistency while adapting to different interaction modalities, display formats, and hardware constraints.
- **Phase 4 - Deployment in Heterogeneous Public Spaces:** the applications were installed and tested in different public contexts, including the immersive rooms in Pieve Torina and Visso, together with XR and totem-based solutions. This phase highlighted practical constraints related to room geometry, screen configurations, architectural discontinuities, and the reuse of the same contents across different public installations.

The implementation of MSXR relied on a large-scale acquisition campaign across the involved municipalities, producing approximately 0.75 TB of multi-modal data, including drone and terrestrial 360° images, standard drone imagery, 4K videos, terrestrial laser scanner point clouds, and high-resolution photographs. This heterogeneous strategy enabled the documentation of assets with different scales and characteristics, from landscapes and architectural elements to selected

cultural objects and sites. The resulting data were processed into reusable digital heritage assets, including 3D models, point clouds, 360° media, photographs, and video documentation. These resources were then processed and optimized for interactive interfaces. The final outputs include immersive applications supporting different levels of fruition, from VR exploration and AR visualization to room-scale multimedia experiences. Fig. 2 shows two examples of the public-facing results: an immersive room installation at the “Museo della Nostra Terra” and an AR application allowing users to explore digitized heritage assets through a tablet-based interface ¹.

III. DISCUSSION AND CONCLUSION

MSXR shows how immersive technologies can support heritage valorization through a territorially grounded workflow connecting asset selection, multi-source 3D digitization, immersive application development, and public access. Developed within the SNAI “Alto Maceratese” context, the project produced approximately 0.75 TB of multi-modal data and translated it into VR, AR, and immersive-room installations. Preliminary observations at the deployment sites suggest that these experiences can improve access to distributed cultural and landscape assets, while highlighting the importance of narrative clarity, simple interaction, spatial adaptation, and technological sustainability. Future work will include systematic user evaluation and adaptive or AI-assisted storytelling tools.

REFERENCES

- [1] E. Balloni, D. Ceka, R. Pierdicca, M. Paolanti, A. Mancini, and P. Zingaretti, “Comparative assessment of neural rendering methods for the 3d reconstruction of complex heritage sites in the inner areas of the marche region-italy,” *Digital Applications in Archaeology and Cultural Heritage*, vol. 35, p. e00371, 2024.
- [2] B. Rodriguez-Garcia, H. Guillen-Sanz, D. Checa, and A. Bustillo, “A systematic review of virtual 3d reconstructions of cultural heritage in immersive virtual reality,” *Multimedia Tools and Applications*, vol. 83, no. 42, pp. 89 743–89 793, 2024.
- [3] P. Saithong and J. Yoddee, “Immersive digitalization of cultural heritage: a validated virtual reality museum platform using integrated 3d and 360-degree technologies,” *Frontiers in Virtual Reality*, vol. 7, p. 1767312, 2026.

¹ Authors would like to Michele Sasso and Tommaso Pantaloni at Ubisive srl for the development and optimization of apps.