

Transfer Knowledge of Tangible and Intangible Heritage: Enhancing Made in Italy through eXtended Reality (XR) Technologies

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Transfer knowledge of tangible and intangible heritage: Enhancing Made in Italy through eXtended Reality (XR) technologies

Enrico Pupi

Abstract

The research is part of the MICS – Made in Italy Circular and Sustainable partnership, within the context of Spoke 2, specifically referencing project 2.06 Emotional. The project aims to enhance the understanding of Made in Italy through an immersive storytelling approach, conveying its values through Extended Reality (XR) experiences. XR technologies open new frontiers in the interpretation, representation, and digital communication of Made in Italy, which is understood as a synergy between tangible and intangible components. The study explores how these technologies and digital representation tools can preserve heritage and disseminate knowledge, blending the real and the virtual.

Parole chiave

eXtended reality (XR), Made in Italy, Digital Representation Technologies, Tangible and Intangible Heritage, Sustainability

1. Made in Italy in the digital era: Challenges and opportunities of the transition

‘Made in Italy’ represents a fundamental pillar of Italian cultural identity, symbolising excellence in the fusion of design and manufacturing (BERTOLI & RESCINITI, 2012). This heritage embodies aesthetic and qualitative values and profound sectoral expertise, leading to the worldwide recognition of Italian excellence in numerous productive fields (DELLAPIANA, 2022).

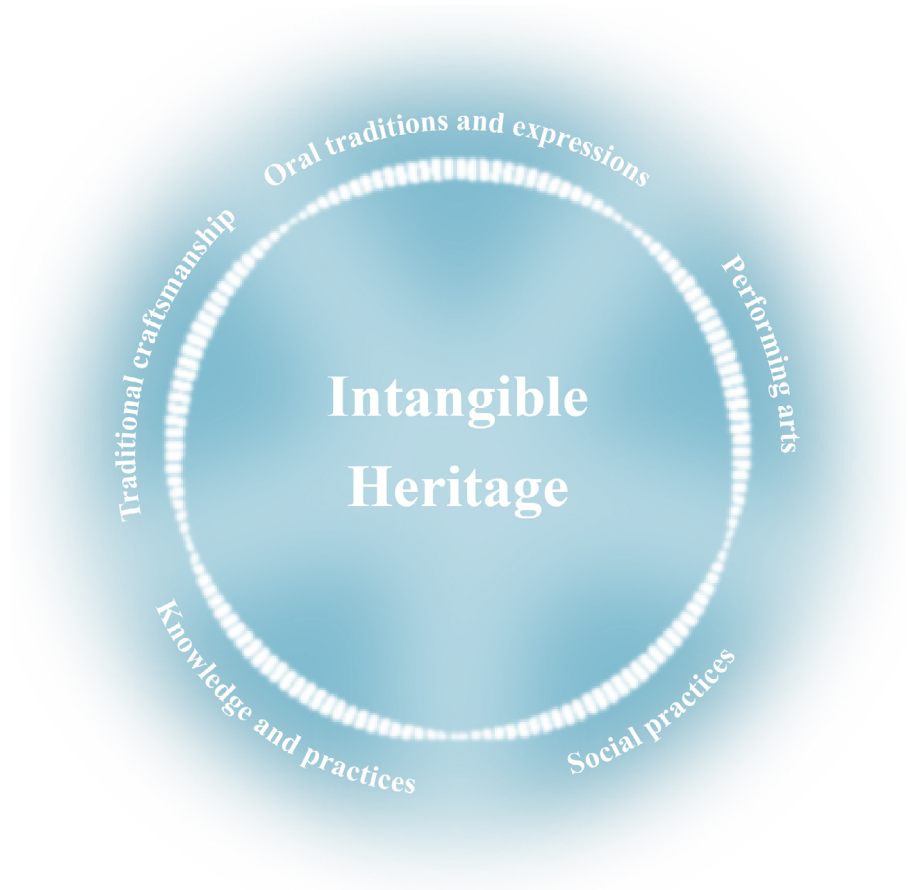
In the current era of digital transition, this rich Intangible Heritage faces a significant challenge: the mere digitalisation of artefacts risks failing to fully capture the complexity and richness of Made in Italy, which extends far beyond the physical object, encompassing five intangible domains as defined by UNESCO 2003 Convention for the Safeguarding of the Intangible Cultural Heritage (fig. 1) (BETTIOL, 2015).

Concurrently, a need emerges to effectively communicate new values, such as those related to sustainability, which often prove complex and challenging for the average consumer to comprehend (DE CHIARA, 2016). This communicative challenge intertwines with the necessity to preserve and transmit the values of Made in Italy in an increasingly digitally pervaded context.

Extended Reality (XR) technologies, comprising Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), offer the possibility of creating immersive, multimedia, and multisensory experiences, opening new frontiers in communication and heritage valorisation (FLAVIÁN et al., 2019).

Adopting these technologies represents an ambitious challenge for Italian companies: the partial lack of technological knowledge regarding available tools and their optimal utilisation poses a concrete risk of losing competitiveness.

In this context, project 2.06 Emotional – Experience Made in Italy: Immersive Storytelling Design for Contemporary Values and Sustainability, part of Spoke 2 of the Extended Partnership MICS – Made in Italy Circular and Sustainable¹, which involves Universities, Research Centres, and Businesses funded by the MUR – Mini-



¹/ Intangible Heritage Domains to be considered in digitisation, as defined by the UNESCO 2003 Convention for Safeguarding Intangible Cultural Heritage.

stry of University and Research – thanks to European Union financing the NextGenerationEU program (PNRR²), is situated. The project aims to explore the potential of XR technologies in designing immersive narratives, with the intent of effectively communicating the material and immaterial values of the Made in Italy heritage, with particular attention to aspects of sustainability.

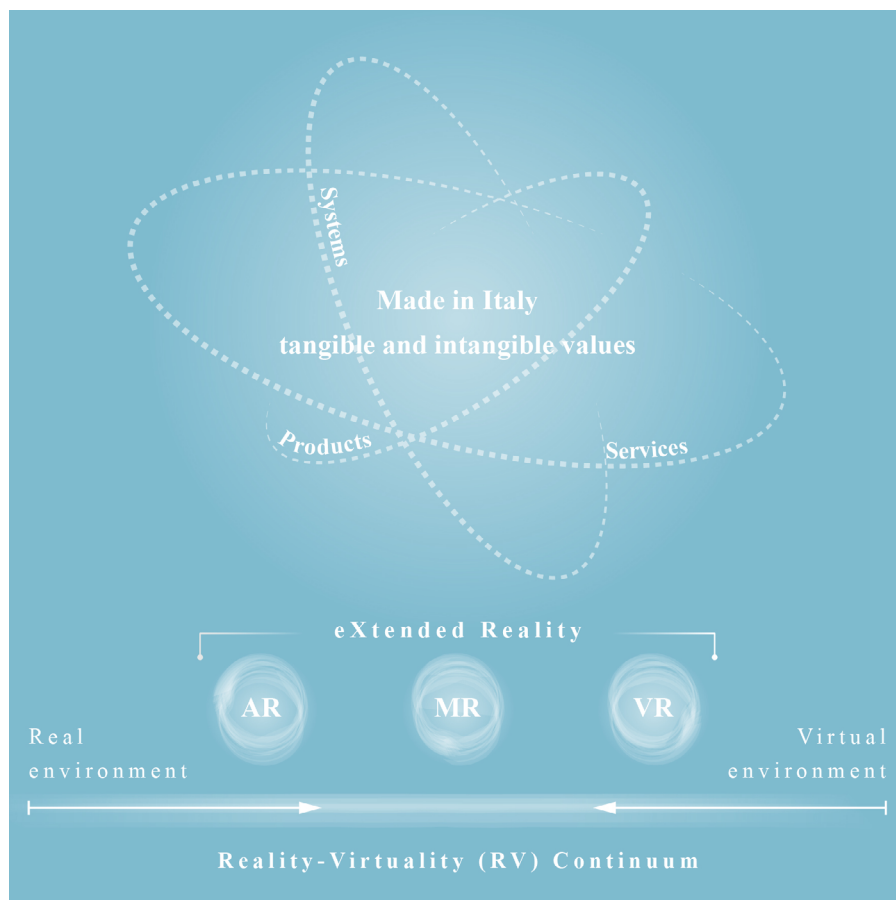
The present study is positioned at the intersection of technology, design, and culture, identifying new frontiers in the modelling, interpretation, and digital communication of Made in Italy through the lens of representation disciplines. The latter is considered in its synergistic relationship between the tangible component, linked to the materiality of objects, and the intangible one, about the immaterial sphere of products, services, and systems (fig. 2) (BEROLA & TEUNISSEN, 2018).

2. Project Emotional within the framework of European and Italian initiatives for digital innovation in cultural heritage

The Emotional project is situated within a broad framework of European and Italian initiatives to promote digital innovation and the valorisation of cultural heritage. This context provides fertile ground for developing innovative solutions like those analysed herein.

Firstly, Emotional aims to comply with the recommendations from the UNESCO 2003 Convention for Safeguarding the Intangible Cultural Heritage³. The convention's primary objective is to protect a distinct category of intangible heritage, encompassing the practices, representations, expressions, knowledge, and skills that communities, groups, and, in some cases, individuals recognise as integral components of their cultural heritage. This approach acknowledges the dynamic nature of cultural traditions and emphasises the importance of preserving living expressions of human creativity and ingenuity.

At the European level, the Digital Decade⁴ establishes ambitious objectives for the



2/ The diagram represents the functional scheme of the project: at the top are the tangible and intangible values being analysed in terms of products, services, and systems; at the bottom, the selected contents are enhanced through the concept of Reality-Virtuality Continuum (MILGRAM & KISHINO, 1994) based on the use of XR technologies.

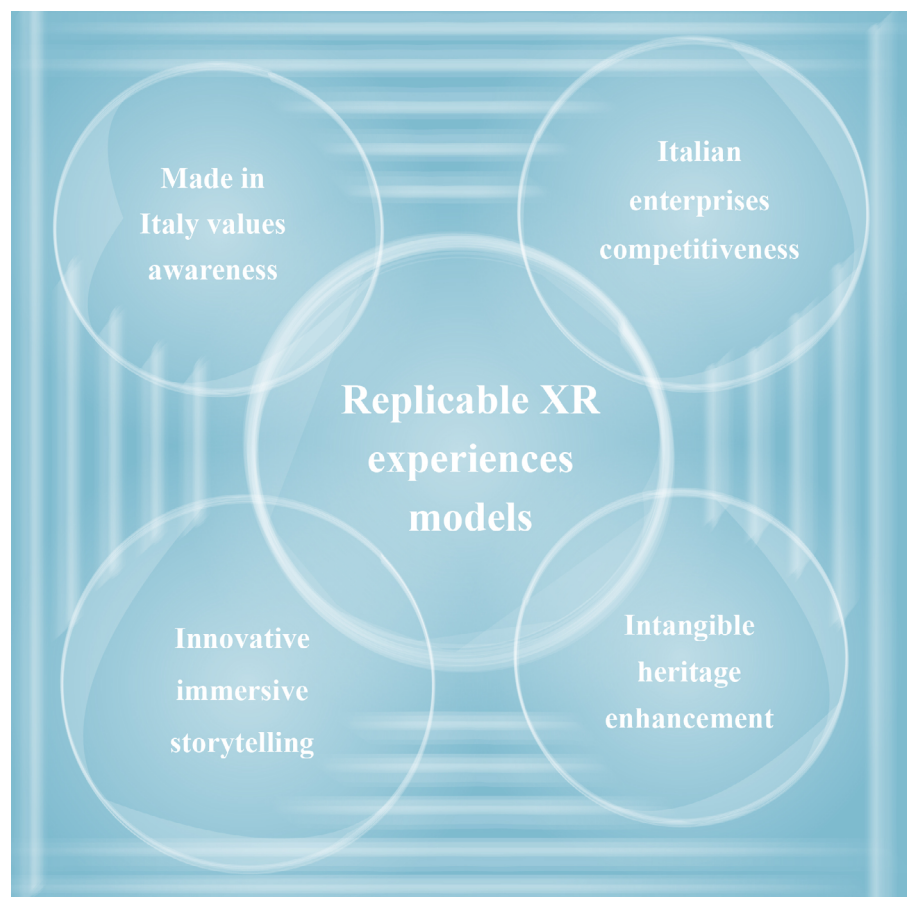
EU's digital transformation by 2030. In this context, Emotional aligns to develop advanced digital technologies and promote digital competencies, contributing to creating immersive experiences that enhance cultural heritage.

The European Union's AR/VR Industrial Coalition⁵ initiative recognises the transformative potential of AR and VR technologies across various sectors. The study presented here, through its focus on utilising XR technologies for narrating Made in Italy, positions itself as an innovative project in this context, exploring the applications of these technologies in the cultural heritage sector.

Given the nature of the project, this contribution cannot disregard the fundamental outcomes of the European project VIGIE 2020/654⁶, a study on quality in 3D digitalisation of tangible cultural heritage, which encompasses mapping parameters, formats, standards, benchmarks, methodologies, and guidelines. The primary objective of VIGIE 2020/654 is to produce a framework enabling professionals, institutions, 3D digitalisation service providers, and researchers in the field of 3D digitalisation technologies for cultural heritage to define and produce high-quality data within specific 3D digitalisation projects.

Concerning digital cultural heritage, the Europeana⁷ platform has paved the way for systematic digitalisation and online accessibility of European cultural heritage. Emotional aligns with these objectives, proposing innovative methods to render the heritage of Italian Made in Italy accessible and engaging through XR technologies (CAPURRO et al., 2023).

In the Italian context, the National Plan for Digitalisation of Cultural Heritage (PND)⁸ underscores the importance of digitalisation as a tool for cultural heritage preservation and fruition. The result of a process of sharing and comparison with various cultural institutions, the PND constitutes the vision aimed at promoting and organising the digital transformation process in the quinquennium 2022-2026, addressing primarily museums, archives, libraries, central institutes, and state cultural



3/ Conceptual diagram illustrating the Emotional project's interrelated aims in the framework of European and Italian initiatives for digital innovation in Cultural Heritage. This visual representation emphasises the multifaceted approach of Emotional in leveraging XR technologies to preserve, enhance, and promote Italian Cultural Heritage.

sites that possess, protect, manage, and enhance cultural assets. Emotional fits into this framework, proposing cutting-edge solutions for the immersive fruition of tangible and intangible heritage.

Whilst some initiatives focus exclusively on the digitalisation process, Emotional explores how XR technologies can not only preserve but also enrich and render the Made in Italy experience more engaging, distinguishing itself through its innovative approach and potential, aimed at (fig. 3):

- Creating innovative paradigms of digital storytelling for cultural heritage, with particular attention to aspects related to sustainability.
- Develop new methodologies for communicating and enhancing the intangible heritage.
- Providing a replicable model in the utilisation of immersive XR technologies for the valorisation of cultural heritage.
- Contributing to the competitiveness of Italian enterprises in the global digital landscape.
- Promote greater awareness and appreciation of Made in Italy values internationally.

Emotional responds with efficacy to current European and Italian policies and initiatives and has the potential to expand their applicative domains, opening new frontiers at the intersection of technology, culture, and industry (CÁRDENAS-ROBLEDO et al., 2022).

3. Potentialities and applications of Mixed Reality (MR) for the valorisation of Made in Italy

The evolution of XR technologies has opened new frontiers for valorising and communicating cultural heritage, with relevance for Made in Italy. Whilst VR and AR demonstrate both potentialities and partial limitations in many fields of application (D'ASCENZI et al., 2023), MR emerges as a compromise capable of mitigating the constraints and issues that characterise other types of experiences.

To understand the MR context within the broader spectrum of XR technologies, it is essential to consider the Reality-Virtuality Continuum. This conceptual framework presents a continuous scale ranging from the completely real environment to the entirely virtual environment. Along this continuum, MR occupies the space between these two extremes, encompassing both Augmented Reality (AR) and Augmented Virtuality (AV) (MILGRAM & KISHINO, 1994). Recent re-examinations of this continuum have further emphasised its relevance in categorising and understanding the various forms of XR experiences, highlighting the fluid nature of transitions between real and virtual in modern applications (SKARBEZ et al., 2021). This framework provides a valuable context for assessing the potential applications of different XR technologies in the Made in Italy sector, helping to identify the most suitable approaches for various contexts and objectives.

VR offers deeply immersive experiences but is associated with significant challenges, particularly motion sickness, which can detract from the user experience and limit its effectiveness in prolonged or sensitive settings (WEECH et al., 2019). While AR is less intrusive and can positively impact user behaviour (SCHMIDT et al., 2022), it faces limitations in terms of interaction and depth of immersion, making it less effective for fully engaging users in complex storytelling (BILLINGHURST et al., 2015).

MR offers a middle ground, balancing immersive interaction with real-world elements while overcoming some of the limitations present in both AR and VR (DALL'OSSO et al., 2022). Indeed, it can significantly reduce motion sickness problems compared to VR while maintaining a high engagement level (SPEICHER et al., 2019). This can make it particularly suitable for applications in the Made in Italy sector, where interaction with physical products and the real environment is highly relevant.

In retail, MR offers considerable opportunities, enriching experiences and allowing consumers to interact with virtual products in a real environment (FLAVIÁN et al., 2019). This approach proves particularly promising for Made in Italy, specifically for the fashion and design sector, where the quality of materials and artisanal craftsmanship are highly distinctive elements.

Interactive experiences can blend real artefacts with digital content (BEKELE et al., 2018); this technique can effectively narrate the history and evolution of Italian companies, offering users an immersive experience of the Made in Italy heritage.

Using digital platforms such as Unity to develop MR experiences, combined with head-mounted displays (HMD) like Meta Quest 3, opens interesting and innovative scenarios. Indeed, these tools allow for creating highly realistic and interactive MR experiences, overcoming previous technical limitations (ÇÖLTEKIN et al., 2020).

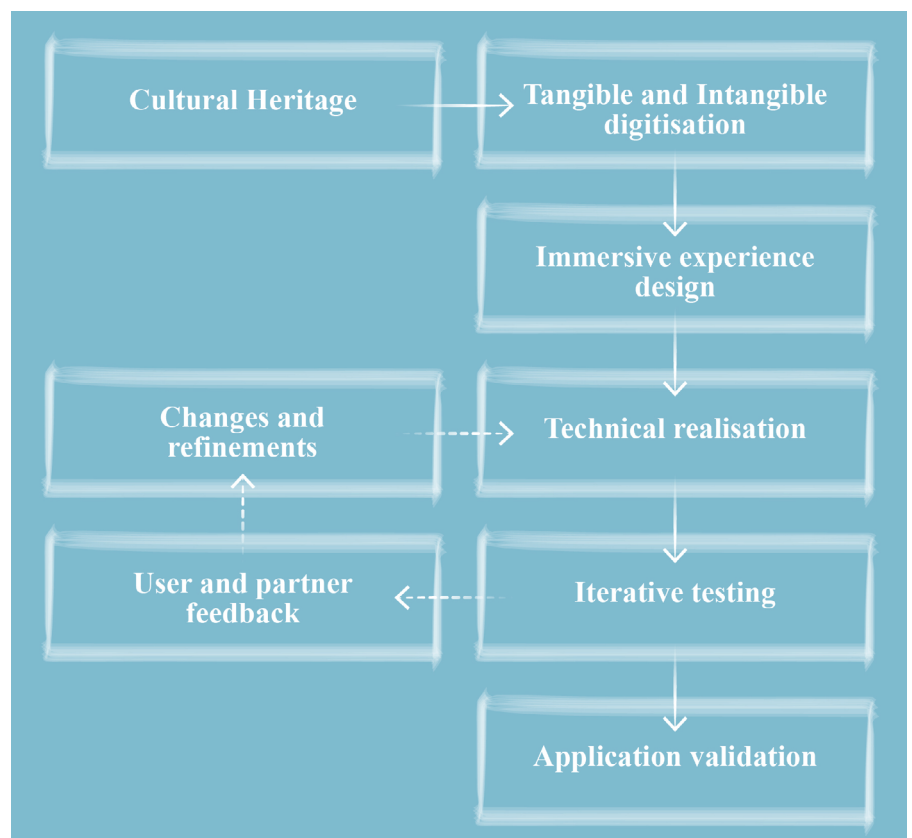
However, the effective implementation of MR requires a strategic approach, as it is fundamentally important to understand the specific affordances of each XR technology to integrate them effectively into products, services, and systems (PITT, 2020). For Made in Italy companies, this would mean investing in specialised technical skills to develop MR applications that best enhance their products and history.

MR emerges as an up-and-coming technological solution for communicating the values of Made in Italy, offering an optimal balance between immersive experience, interaction possibilities, and accessibility of use. The ability to blend virtual elements with the real environment makes it ideal for communicating the excellence and craftsmanship of Made in Italy, opening new possibilities in the valorisation and promotion of Italian tangible and intangible cultural heritage.

4. Objectives of the experimentation and new frontiers of immersive narration

Primarily, the project aims to enhance knowledge and awareness of the tangible and intangible values of Made in Italy, preserving and promoting the excellence of Italian heritage. The project aims to explore new frontiers in the communication of Made in Italy products, services, and systems, with particular attention to aspects related to sustainability (DE CHIARA, 2016). Finally, Emotional intends to stimulate innovation in the Italian manufacturing sector, fostering the adoption of advanced technologies for brand and product narration (BETTIOL, 2015).

The project outlines several concrete objectives, notably developing immersive



4/ Flowchart diagram illustrating the iterative process of developing and validating immersive experiences for Cultural Heritage preservation and promotion within the Emotional project. The workflow emphasises the project's systematic methodology in creating dynamic XR applications for Made in Italy storytelling, highlighting the importance of user feedback and iterative development in achieving optimal results.

storytelling experiences leveraging XR technologies. These experiences will be designed to communicate the unique cultural and material values of Made in Italy, with a specific focus on sustainability and contemporary relevance.

The experimentation presented here concerns the creation, via Unity, of an MR application for Oculus Quest 3, which allows the exploration of new modes of presenting heritage linked to Made in Italy (BEKELE et al., 2018).

Concurrently, complementary solutions are being developed by project partners: immersive experiences in VR (VANGI et al., 2024) through the modelling of fully interactive digital environments and virtual tours via the recording of 360° videos to offer a plurality of possible solutions (FLAVIÁN et al., 2019).

The project, ultimately, intends to elaborate guidelines and methodologies for effectively utilising XR technologies in the context of Made in Italy, providing companies with a set of capacity-building toolkits to improve their communication and competitiveness (PANTANO et al., 2017).

From this perspective, the scientific validation of the efficacy of these new narrative strategies is of fundamental importance. It will be done through tests and analyses involving partner companies and end users (fig. 4).

5. Methodology and development process: from prototyping to implementation of Mixed Reality (MR) applications

The development of MR-based applications enables the creation of highly engaging experiences that seamlessly merge real-world and digital elements. This blending provides innovative ways to explore and appreciate the multifaceted nature of Made in Italy, both in terms of tangible and intangible heritage.

The versatile tracking and anchoring techniques allow for the adaptation of applications to various product categories and exhibition contexts, maximising communicative impact and user engagement (BEROLA & TEUNISSEN, 2018). Among the different types of MR experiences that can be realised, the following are currently under study:

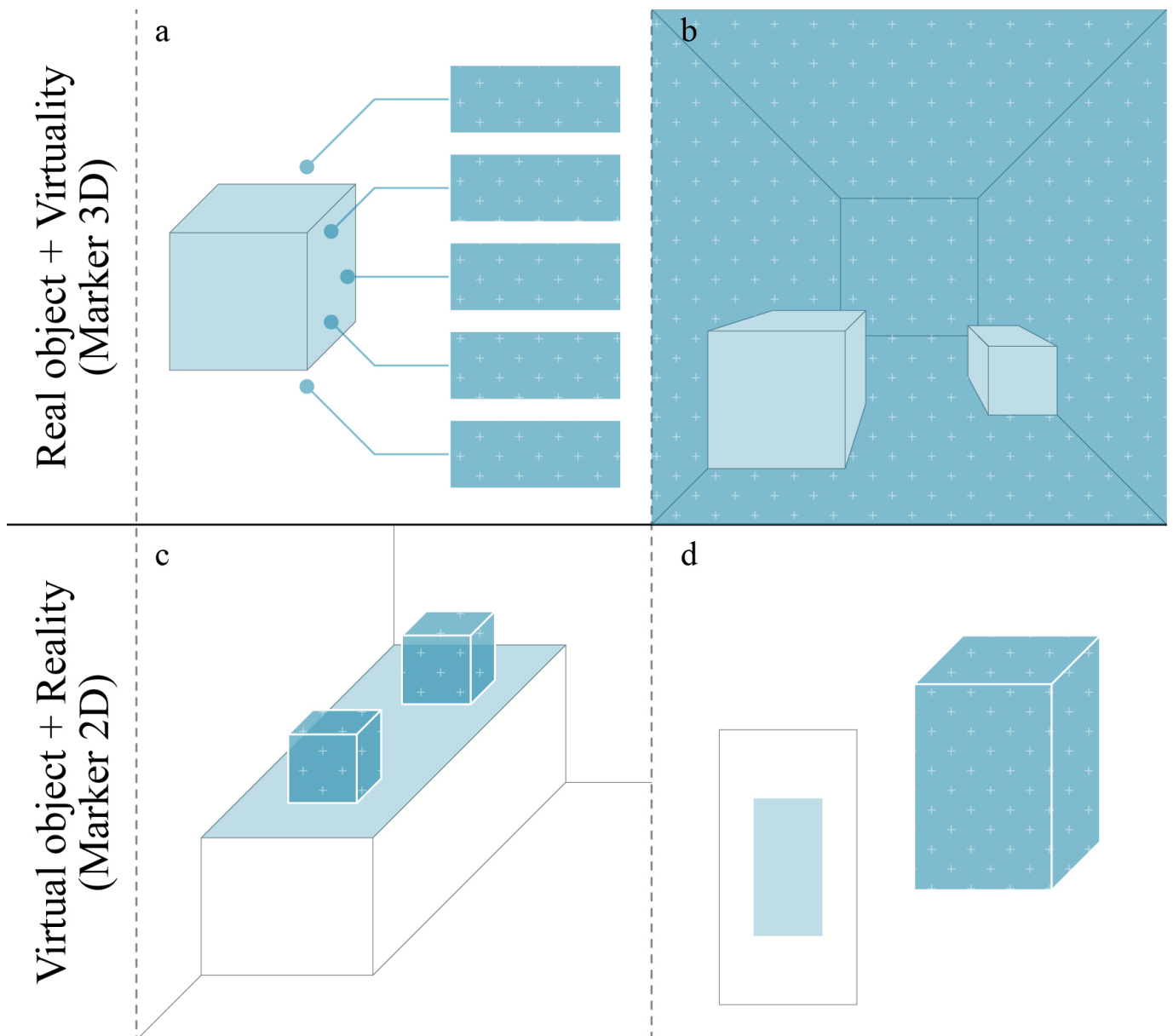
- Applications that utilise anchoring on real three-dimensional objects, using physical objects as reference points to overlay digital information. For example, an artisanal product can serve as a trigger to visualise details about the production process, materials used, or brand history (fig. 5a).
- Experiences that integrate digital representations of real objects into a virtual environment, such as creating virtual showrooms where physical Made in Italy products are presented in customisable virtual contexts (fig. 5b).
- Development of mixed environments with planar anchors, i.e., using real surfaces (floors, walls, tables) as a basis for positioning virtual objects. For instance, a virtual production line could be visualised on a real table, allowing users to explore the manufacturing process on a reduced scale (fig. 5c).
- Image- or logo-based tracking can be used as triggers for AR experiences, such as developing an application for interactive catalogues or packaging, which, when framed, display 3D models of products or multimedia content about their creation (fig. 5d).
- The technical prototyping phase follows several essential steps, extensively using Unity as the primary development platform⁹. Unity's flexibility allows for the creation of versatile MR applications adaptable to various products and devices, optimising user engagement across different use cases. The development approach allows applications to be adapted to various platforms and devices, each with its ecosystem of tools:
 - Meta Quest 3 - Meta OpenXR Unity package and Interaction Toolkit.
 - Apple Vision Pro - Apple visionOS XR Plug-in.
 - Android devices - Google ARCore XR Plug-in.
 - iOS devices - Apple ARKit XR Plug-in.
 - Microsoft HoloLens 2 - OpenXR Plug-in.

In this case, the development process for the MR application utilises the Meta Quest 3 headset, focusing on creating immersive experiences that integrate real and virtual elements, enhancing Made in Italy through various modes of interaction and visualisation.

From a methodological perspective of the workflow, the macro steps necessary for creating the application can be summarised as follows:

5/ Schematic representation of different Mixed Reality (MR) approaches for enhancing Made in Italy experiences. a) Real object + Virtuality (Marker 3D): a real object with multiple connection points overlaying digital information onto physical products. b) Real object + Virtuality (Marker 3D): real objects in a fully virtual environment, creating a customisable showroom. c) Virtual object + Reality (Marker 2D): virtual 3D objects using real planes for mixed environment experiences. d) Virtual object + Reality (Marker 2D): a 2D marker triggering the display of a 3D virtual object

- The configuration of the development environment involves installing the most recent version of Unity Editor compatible with Meta Quest 3 (Unity 2022.3.35f1) through the Unity Hub platform, ensuring to include the Android Build Support module (OpenJDK: Android SDK and NDK Tools). Subsequently, Unity's Package Manager integrates the Meta OpenXR Unity package (version 1.11.0) and the Interaction Toolkit (version 2.5.4).
- In the settings, it is necessary to configure the project for MR, modify the build parameters for Android and optimise the parameters for Meta Quest 3, which must be set to developer mode. It is also necessary to activate OpenXR as an XR plugin, configuring the specific settings for Meta Quest in the XR preferences.
- At this point, creating and developing the MR scene is possible, incorporating



both virtual and real elements. The prefabs and components provided by the Interaction Toolkit can be used to manage user interactions, such as hand and controller tracking.

- To implement the application logic, it may be necessary to write scripts in C# to manage the dynamics of interactions with virtual objects and the fusion between real and virtual elements. At this stage, it is possible to implement specific functionalities for narrating Made in Italy, such as displaying contextual information about products or simulating production processes.
- Given the mobile nature of the Meta Quest 3 wearable device, optimising the application's performance is necessary to ensure smooth operation. This includes efficient memory management, graphics optimisation, and reduction of mesh complexity to maintain a stable frame rate.
- The application validation can be conducted by performing thorough iterative tests using Unity's emulator and directly on the Meta Quest 3 device. Iterations in the design and functionalities of the experience can be refined each time, also based on any third-party feedback, paying particular attention to user experience and effectiveness in communicating Made in Italy values.
- After the validation phase, the application will be compiled for Android and uploaded to the Meta Quest 3 for final testing and fruition.
- This methodical approach to prototyping allows for the development of various highly engaging MR applications, capable of effectively blending the real world with digital elements to enhance and communicate the values of Made in Italy.

6. Preliminary results and prospects: Mixed Reality (MR) as a bridge between tradition and innovation in Made in Italy

The experimentation with the MR application for the valorisation of Made in Italy produces promising preliminary results, highlighting the potential of this technology in the sector (fig. 6). Tests on physical objects enriched with digital content demonstrate the capacity to significantly increase user engagement and render the Made in Italy values more comprehensible. The addition of digital elements enables effective communication of the history, production processes, and intangible values associated with products, services, and systems, enriching the typical sensory experience of Made in Italy with a further stratification of informational and perceptual layers. The most innovative aspect of this research lies in its attempt to bridge the gap between the physical world of Made in Italy products and the rich universe of knowledge, traditions, and processes that characterise them. MR emerges as a solution of great interest, capable of offering a multisensory experience that enriches product perception without sacrificing contact with its materiality.

Such applications can increase appreciation for excellent Italian craftsmanship, and interactions with objects through MR applications suggest that the technology has great potential to serve as a bridge between the perception of tangible and intangible heritage. Communicating sustainability values is particularly effective through the interactive visualisation of sustainable production processes that increase user awareness. The ability to visualise and interact with these elements in an immersive manner could impact consumer perception and positively influence purchasing choices.

However, the research also highlights technical challenges, such as the fluid integration between real and virtual elements and performance optimisation on mobile devices (CARDOSO et al., 2024).

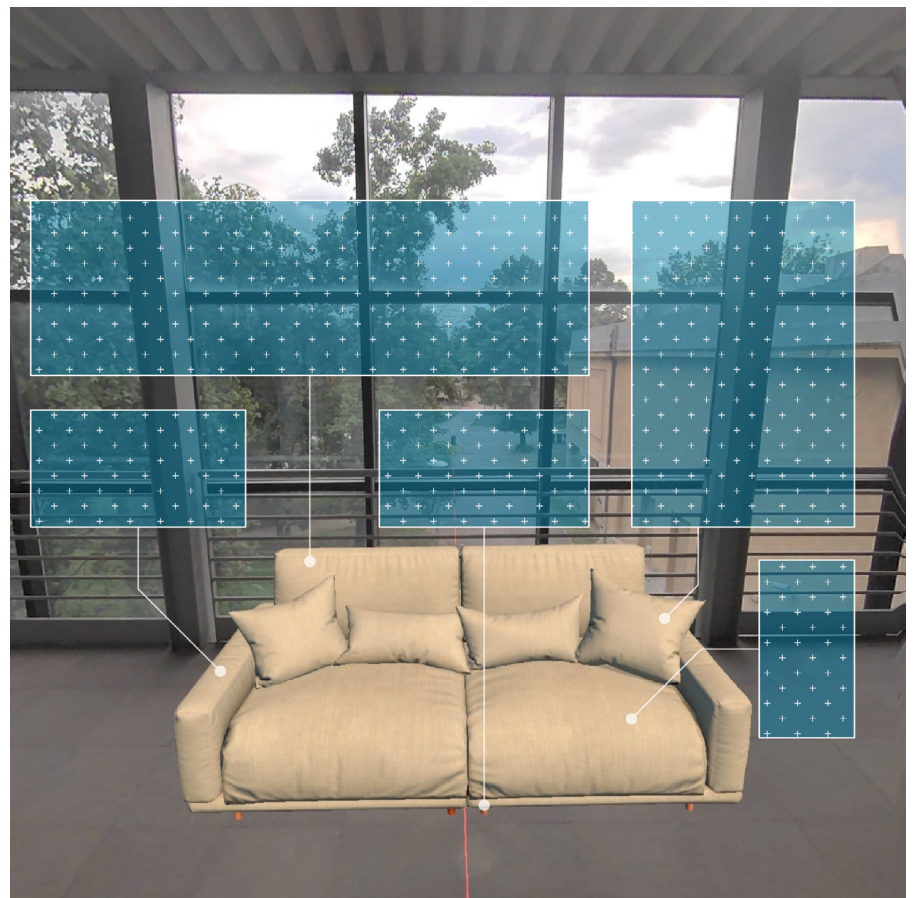
Despite these limitations, the potentialities of MR for Made in Italy are considerable, especially considering the technological development of head-mounted displays (HMD) and the evolution towards increasingly lighter, more compact, practical, and manageable devices. This trend could facilitate the large-scale adoption of technological devices, making the MR experience more accessible and user-friendly (RESE et al., 2022).

This research opens promising scenarios for innovation, positioning MR as a pivotal tool for preserving, communicating, and enhancing Italian cultural heritage in the digital era. As we move towards a future where the barriers between physical and digital become increasingly blurred, MR configures itself as a highly performant tool between tradition and innovation, offering engaging and informative experiences that can truly enrich the perception and appreciation of Made in Italy values in national and supranational markets (BERTOLA & TEUNISSEN, 2018).

Prospects for this research include:

- MR ecosystems for Made in Italy through creating XR-based platforms, where products, production processes, and cultural heritage merge into a single immersive experience. These ecosystems could unprecedentedly allow consumers to experience Made in Italy, from virtual exploration of historical production spaces to interactive participation in design and production processes.
- Immersive co-creation and AI-driven customisation through implementing AI-enhanced co-design platforms, demodulating the made-to-measure concept, and offering adaptive and highly customisable product experiences.
- Transmedia storytelling and immersive training by developing innovative narrative modalities that combine XR experiences and interactive storytelling, including preserving and transmitting traditional artisanal techniques.
- Phygital retail experiences and visualised sustainability through hybrid commercial spaces that blend physical and digital elements, incorporating engaging visualisations of products' environmental and social impact to promote conscious consumption.

It is necessary to emphasise that the results presented here are to be considered preliminary, and the experimentation is still ongoing; the design of immersive experiences is under development, intending to perfect the integration between narration, interactivity, and informative content (GARCIA & ANDUJAR, 2023). Although the research is at an intermediate stage, the results thus far support the thesis that MR can



6/ The image depicts a blend of physical and virtual elements captured through the Meta Quest 3 headset during the experimentation phase, highlighting MR's capacity to engage users and effectively communicate the multifaceted aspects of Made in Italy products, services, and systems.

offer new and effective modalities for preserving, communicating, and enhancing the Made in Italy material and immaterial heritage.

7. Acknowledgement Note

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Note

1. See <https://www.mics.tech/>
2. See <https://www.italiadomani.gov.it/content/sogei-ng/it/it/home.html>
3. See <https://ich.unesco.org/en/what-is-intangible-heritage-00003>
4. See <https://digital-strategy.ec.europa.eu/it/policies/europes-digital-decade>
5. See <https://digital-strategy.ec.europa.eu/it/policies/virtual-and-augmented-reality-coalition>
6. See <https://digital-strategy.ec.europa.eu/en/library/study-quality-3d-digitisation-tangible-cultural-heritage>
7. See <https://pro.europeana.eu/>
8. See <https://digitallibrary.cultura.gov.it/il-piano/>
9. Although this study focuses on the utilisation of Unity for the development of MR-based applications, it is essential to emphasise that there exist other platforms (Unreal Engine, OpenSceneGraph, CryEngine) and frameworks (ARCore, ARKit, Vuforia) that enable the creation of MR experiences. The choice of tools depends on various factors, including the project's specific requirements, the development team's skill set, and the target devices.

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