



# Augmented Reality Continuum: Categorising On-Site Digital Heritage Experiences

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**Abstract.** Heritage digitalization has garnered considerable attention in academic research, yet a discernible gap exists in comprehensive studies exploring large-scale commercial Augmented Reality (AR) projects. This research seeks to distil key insights and build a preliminary framework to look at both academic and commercial on-site AR heritage experiences to better understand the pragmatic implementations witnessed in the latest AR-driven heritage apps. The paper navigates the use of immersive technologies at heritage sites and uses the AR Continuum to categorize various types of in-situ AR heritage experiences. The goal is to understand the current trends and look for new research directions that will be able to support the rapidly evolving commercialisation of digital heritage.

**Keywords:** Digital Heritage · Augmented Reality (AR) · Heritage Site · Extended Reality

## 1 Introduction

Heritage digitalisation has become a focal point in academic research, attracting attention from scholars and enthusiasts alike due to its ability to support conservation and research and enhance heritage visitor experiences. Many authors delve into the application of technologies like Augmented Reality (AR); however, most often, this research is focused on small-scale projects and interprets the design, user experience, and technological aspects of the project [1–4]. Meanwhile, only a handful explore large-scale commercial cases within the broader industry [1, 5, 6], creating a noticeable gap that prompts scholarly exploration.

This paper aims to address this void by building a preliminary framework to analyse both commercial and academic digital experiences and the factors that influence them. Through aligning experiences produced both academically and commercially with established academic discourse, we seek to unravel the intricacies surrounding immersive heritage experiences. Approaching these ventures through an academic lens, we aim to dissect technological intricacies and pose a pivotal question: How can academia meaningfully engage with and contribute to the unfolding landscape of large-scale commercial AR projects in the domain of digital heritage?

## 2 The Use of Immersive Technologies at Heritage Sites

Initially, heritage digitalization focused on 2D and 3D digital reconstructions of places, primarily targeting conservation and educational efforts [7]. As technology has evolved and access to personal devices like smartphones has become mainstream, an increasing number of projects target the heritage visitor experience. Today, immersive technologies are widely used to create digitally-enhanced or entirely virtual experiences in a variety of heritage contexts [8].

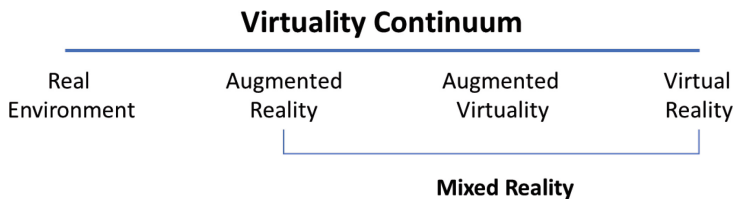
The most common types of experiences are created in Virtual Reality (VR), AR, and Mixed Reality (MR) [9], often referred to under the umbrella term Extended Reality or XR [10]. Digitalization proves invaluable for managing and preserving cultural heritage, with immersive technologies serving various purposes such as improving visitor experiences, education, reconstruction, exploration, conservation, preservation, and bringing historical events to life [1, 9].

This paper will specifically focus on the use of AR at heritage sites due to its ability to blend reality with virtuality. If VR can be used to generate a digital realm replicating a real-world environment, AR, in Azuma’s original definition, serves as a platform for integrating supplementary information into the actual surroundings in real-time and in 3D [11]. Today, using AR arguably enhances the user’s perception of the world by superimposing a wider range of computer-generated elements—such as graphics, sounds, and occasionally tactile feedback—onto the original environment, thereby enriching the overall user experience [1].

## 3 The Virtuality Continuum and New Definitions

The reality-virtuality continuum (Fig. 1) is a conceptual framework illustrating the spectrum of experiences from the physical to the virtual and was initially proposed by Paul Milgram and Fumio Kishino [12]. At one end of the continuum lies the real world, representing the tangible environment we perceive. Progressing along the continuum, AR exemplifies the midpoint, enhancing our real-world experience with digital overlays. Further along the continuum, VR fully replaces the physical world.

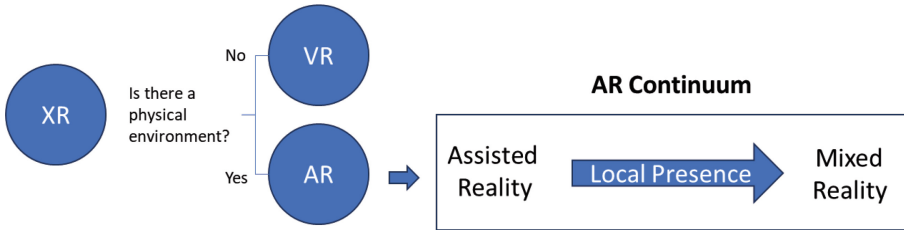
Milgram and Kishino’s work primarily focused on visual displays and the integration of digital elements into the users’ perception of the real world. The continuum helps to conceptualise and categorise technologies that mediate between the physical and virtual realms. However, the original continuum has limitations, particularly in its consideration of only visual aspects and the exclusion of other sensory modalities.



**Fig. 1.** Milgram and Kishino’s Reality-Virtuality Continuum (adapted by authors)

### 3.1 An Updated XR Framework

Rauschnabel and colleagues propose an XR framework that aims to refine and extend Milgram and Kishino's continuum [10]. They introduce the concept of XR as an umbrella term. Their framework addresses the limitations of the original model by providing distinct classifications for AR and VR, acknowledging the need for differentiation.



**Fig. 2.** Rauschnabel et al.'s XR framework and AR continuum (adapted by authors)

In Rauschnabel et al.'s framework, the AR Continuum is introduced for AR, ranging from Assisted Reality to Mixed Reality (Fig. 2). This continuum considers the level of local presence perceived by the user; in other words, the extent to which the user perceives that the content in AR is part of the real environment around them. While this framework does not specifically address digital heritage, it is well-suited to understanding the various types of AR experiences available at heritage sites and is therefore used as the basis of experience categorisation in this paper.

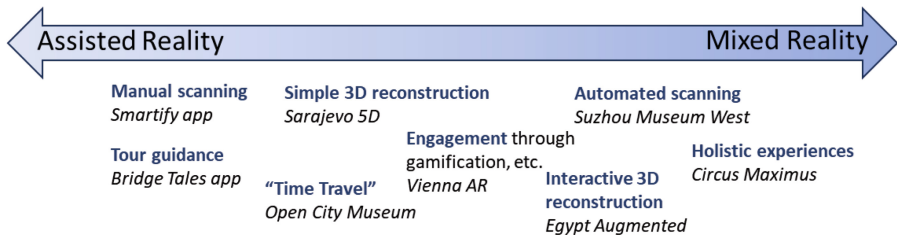
## 4 Methodology

This study employs a methodological framework integrating extensive literature review, ChatGPT exploration, and targeted Google searches to investigate the AR continuum. The literature review analysed academic sources to understand AR's historical evolution and theoretical underpinnings. ChatGPT was used to identify commercial AR cases globally; from the generated shortlist, targeted Google searches were conducted to gather information from existing studies with empirical evidence, industry reports, and case studies. Representative case studies were then selected based on their relevance to the continuum concept.

The information from the literature review, collected data, insights from ChatGPT interactions, and findings from case studies were analysed to discern patterns and trends in AR experiences. The study synthesises this information to construct a coherent narrative about the dynamic nature of AR interactions and their implications. Through critical discussions, the study explores theoretical implications, practical considerations, and future directions for AR research and innovation.

## 5 Categorizing In-Situ Immersive Heritage Experiences on the AR Continuum

The central objective of this paper is to categorise in-situ immersive heritage experiences on the AR continuum. This endeavour examines a spectrum of experiences, drawing inspiration from both academia and the latest industry applications. Figure 3 uses several case studies to exemplify where different typologies of experiences may fall on a comprehensive framework that encapsulates the diversity of in-situ immersive heritage experiences and sheds light on their evolution within the dynamic AR landscape.



**Fig. 3.** Classifying digital heritage experiences along the AR continuum (prepared by authors)

The most common AR applications are used by museums in both indoor and outdoor settings. These can usually be classified as assisted AR where visitors download an app on their mobile phone and scan QR codes or specific items to receive more information about a given heritage object. For example, the Smartify App<sup>1</sup> uses AR to provide additional information about objects in dozens of partner museums, including the National Portrait Gallery Smithsonian and The National Gallery in London [13].

More recently, indoor and outdoor museums have begun to use AR smart glasses (ARSG) to create more immersion, looking to build experiences that are closer to mixed reality on the AR continuum. For example, the Suzhou Museum West<sup>2</sup> uses this approach for two of its exhibitions. Visitors rent ARSGs and scan artifacts either automatically or via a voice prompt [14]. One study looked at the use of ARSG at the Hecht Museum in Haifa, Israel, where visitors could use ARSG in the open-air museum to see a variety of lost heritage and artifacts [3]. Litvak and Kuflik compared the use of ARSGs and smartphone, finding that the former offered easier navigation, but the latter was easier for users to adopt.

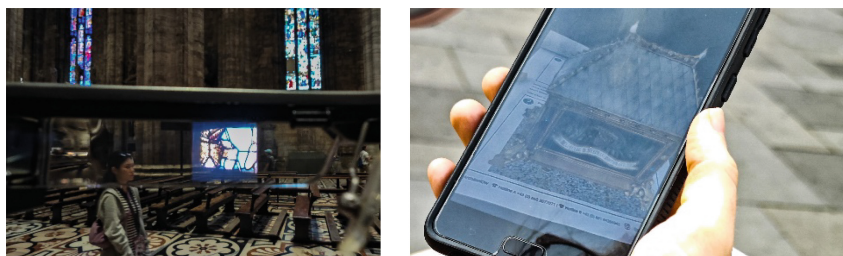
More immersive and engaging AR applications are also becoming increasingly available as technology evolves. A recently launched project by the Louvre and Snap—Egypt Augmented<sup>3</sup>—reveals the shapes, materials, colours, and decorations of selected works on view. The AR resurrects intricate drawings in 3D that have disappeared over time, leaving only bare stone [15]. Such experiences integrate the digital with the physical, moving them further along the AR continuum towards Mixed Reality.

<sup>1</sup> <https://www.smartify.org>.

<sup>2</sup> <https://www.douyin.com/shipin/7264765748411697209>.

<sup>3</sup> <https://newsroom.snap.com/egypt-augmented>.

When it comes to outdoor heritage sites or urban settings, many apps offer visitors the chance to view a reconstruction of either destroyed or lost heritage. For example, Sarajevo 5D is an AR app that digitally reconstructs six destroyed cultural monuments in the centre of Sarajevo [16]. Meanwhile, the Open City Museum offers an AR app featuring various sites in Athens. It layers signifiers from past eras (like people, vegetation, vehicles) on top of the current state of the site, taking the visitor through different periods in the site's history [17] (Fig. 4).



**Fig. 4.** Heritage site AR experiences (left to right): a) Milan Duomo AR Glasses, b) Vienna scavenger hunt (photos by author)

In addition to superimposing images on static sites, many AR apps today offer visitors tour guidance, integrating aspects of intangible heritage in the digital narrative. One of the most common types of such applications is a tour guide app like the Bridge Tales App<sup>4</sup> by Calvium; the app provides visitors with information, navigation, and historic visualisations [21]. Others, like the Glastonbury Abbey AR<sup>5</sup> app, are examples of integrating storytelling and gamification techniques to increase visitor engagement. Visitors use their smartphones to go on a “quest” and learn about the Abbey through superimposed 3D images and digital artifacts [18]. Visitors to Vienna can also experience heritage AR in an urban setting, following a mobile AR tour scavenger hunt “The Past Is Now”<sup>6</sup> across historic locations throughout the city [19].

Similarly, heritage sites also use ARSG to augment visitor engagement, moving them along the AR continuum towards mixed reality. In Rome, for example, visitors to the Circus Maximus can enjoy a 40-min “Circo Maximo Experience”<sup>7</sup> that showcases three models of the Circus in different historic periods. The user wears a headset as an audio guide and uses an AR head-mounted display (HMD) to overlap visualizations over existing site ruins [20]. The experience integrates certain aspects of intangible cultural heritage as well, showcasing scenes from the site's past.

<sup>4</sup> <https://calvium.com/projects/bridge-tales/>.

<sup>5</sup> <https://www.glastonburyabbey.com/glastonbury-stories-app.php>.

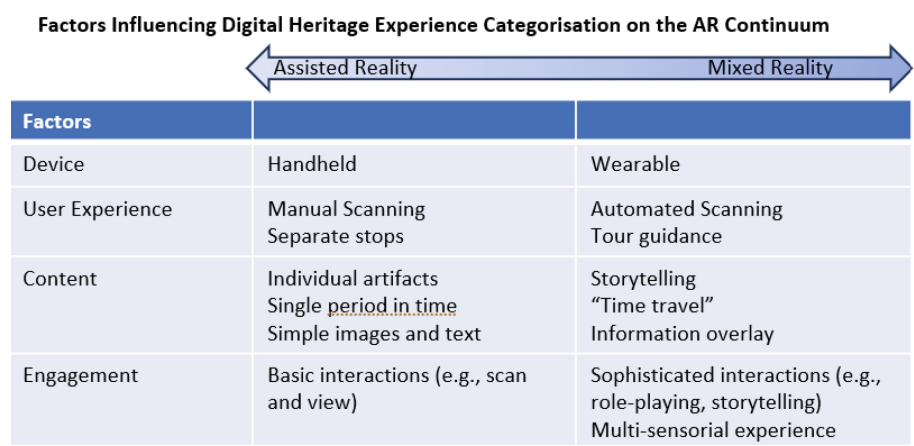
<sup>6</sup> <https://www.archaeo-now.com/english/ar-tour/>.

<sup>7</sup> <https://www.inglobetechnologies.com/circo-maximo-experience-cultural-heritage-mixed-reality/>.

6 Discussion, Limitations, and Future Research Directions

Without empirical user studies for each and every one of the existing immersive heritage experiences, it is impossible to determine the level of immersion that the user feels—this is one of the most significant limitations of this research at its current stage. However, it is still possible to hypothesise where the experience falls on the AR continuum based on various factors that make up the experience (Fig. 6). Secondly, the current research offers an excellent underpinning for future research, namely understanding the user’s perception of an experience and placing it on the AR continuum from the user’s and not a theoretical perspective.

Another important limitation is the difficulty in finding all digital heritage experiences that exist. This research primarily relied on Google searches, ChatGPT, previous academic literature, and authors’ knowledge of certain experiences. However, many other commercial and academic examples exist; due to language barriers, lack of publications, and low search engine optimisation, it can be difficult to locate them. As such, this paper aims to create a preliminary framework to look at both academic and commercial on-site AR heritage experiences. Next, it would be interesting to understand the regional, technological, contextual, and design differences that may affect the actual interpretation of such experiences by their users.



**Fig. 6.** Factors that may influence the categorization of AR heritage experiences on the AR continuum (prepared by authors)

In Fig. 6, we begin to outline the factors—device type, user experience [22, 23], content [9, 24], and engagement [25]—that influence how immersive an on-site AR heritage experience may be from a user’s perspective. These are not standalone items but represent a range of factors that are experienced in combination with one another. Each or all of them represent yet another promising research direction for academics in this field, looking at how the technology, design (user experience and content), and types of interaction may influence AR immersion.

Finally, commercial experiences represent a unique set of challenges and opportunities. While many, like the Glastonbury Abbey App, already involve academia from their inception, others are entirely led by various private and public organisations. As such, it can be difficult for academia to engage with the existing stakeholders and form part of the ideation, design, and implementation processes involved. That said, these experiences tend to reach wider audiences and enjoy significant funding, making them a treasure-trove for large-scale research that could be more generalisable. As such, it will be interesting to see how academia can become more integrated in commercial AR heritage experiences and influence their development in the future.

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