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Beyond Street Signs: Ethical and Situated Cultural Storytelling using AI and Extended Reality

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Abstract

Honorific street names that commemorate historical figures, events, or cultural symbols constitute a frequently overlooked, yet symbolically important layer of urban heritage. Beyond their practical function in navigation and spatial organization, they also encode ideological narratives into public space that shape collective memory and identity. However, traditional cultural heritage (CH) tools do not engage with their contested meanings, particularly in politically divided urban landscapes. In this paper, we explore how the integration of extended reality (XR) and artificial intelligence (AI) can bring place names to life by turning them into interactive and personalized stories. Focusing on the center of Nicosia, Cyprus (a politically divided urban landscape), we present an intelligent tourist guide that combines mobile XR, conversational AI, and lifelike avatars to deliver personalized and multilingual narratives at the sites of honorific street names. We conclude by discussing the ethical challenges of algorithmic memory mediation in contested urban spaces and argue that such systems, when designed responsibly, can foster critical engagement, pluralistic representation, and new forms of civic pedagogy within the domain of CH.

CCS Concepts

• ***Applied computing*** → ***Interactive learning environments; Digital libraries and archives; Media arts;*** • ***Human-centered computing*** → ***Mixed / augmented reality;***

1. Introduction

Honorific street names commemorate historical figures, events, or cultural symbols and hence they constitute a rich, yet overlooked layer of urban heritage. While they serve practical purposes such as navigation and spatial organization, they also have a powerful symbolic role by embedding ideological values and shaping collective memory. As mechanisms through which political and cultural authorities inscribe historical narratives into public space, street names often reflect dominant perceptions of the past and contribute to the construction of national identity [BCB*21]. Despite their cultural significance, they often remain unnoticed, with their meaning being overlooked and their historical connections and connotations forgotten. This latent symbolic potential invites new modes of engagement, especially through emerging technologies that can reanimate the historical layers of the urban fabric.

Extended reality (XR), including virtual reality (VR), augmented reality (AR) and mixed reality (MR), offers powerful tools for transforming overlooked cultural heritage (CH) into meaningful educational content. Several systematic reviews and case studies report the effectiveness of XR in education and heritage [GV24, KTK24, DLMM24, ZWYS24, SE24]. By enabling immersive and multisensory experiences, XR not only revitalizes neglected heritage elements but also enriches learning environments. In doing so, it expands the notion of educational resources by bringing forgotten or underappreciated dimensions of urban history into active pedagogical use. Yet their broader adoption has been limited by technical complexity and the need for specialized skills.

The XR4ED (Extended Reality for Education) project [Pro25c, LMP*24,LMS24] responds to these challenges by providing a low-threshold platform that enables educators and creators to develop and deploy XR-based educational content with ease. With features such as embodied VR avatars, intelligent AR agents, and a collaborative asset-sharing marketplace, XR4ED supports social interaction, collaboration, and embodiment, key dimensions of effective learning and engagement. Building on these capabilities, the integration of XR into urban landscape offers new ways to reactivate symbolic spaces (e.g., honorific streets) to harness the experiential affordances of immersive media to render memory, identity and entangled histories more accessible and engaging.

Focusing on the historic center of Nicosia, the capital of Cyprus, this paper explores how XR and AI technologies can reactivate the symbolic dimension of urban toponymy by transforming honorific streets into sites of location-based storytelling. This ongoing development brings together two complementary components: an In-

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telligent Tourist Guide and the "Honorific Streets" interface[†]. The aim is to deepen visitor engagement with the city's multilayered heritage through immersive and context-sensitive interaction. The subsequent sections are structured as follows: Section 2 introduces honorific toponymy as an intangible layer of urban CH and reviews the current state of the art in mobile XR and AI application for tourist guidance. Section 3, outlines the XR4ED's technological framework by detailing its modular system architecture and the narrative capabilities enabled by intelligent AR avatars, multimodal interaction, and collaborative learning features. Section 4 situates the study within Nicosia's historical and geopolitical context. Section 5 describes the methodology for deploying an AI- and XR-powered Intelligent Tourist Guide to generate dynamic, site-specific narratives. Section 6, examines the ethical implications of algorithmic mediation in a contested urban memoryscape. Section 7 explores the potential of AI-driven XR Tourist Guides for urban tourism, education, and CH. Section 8 outlines key limitations and proposes directions for future research, while Section 9 concludes the paper by summarizing the main contributions and implications.

2. Background and Related Work

2.1. Honorific Streets and Place Naming

Street names, though seemingly mundane components of urban infrastructure, are deeply entangled with power, memory, and identity [Aza96]. Their apparent neutrality obscures their role as emblematic *lieux de mémoire*, sites where collective memory is inscribed and perpetuated. Beyond assisting with spatial orientation and urban administration, street names function as symbolic instruments of authority because they encode dominant ideologies into everyday space and legitimize hegemonic narratives through ostensibly banal acts of naming [Aza96, Aza09, RR08]. This symbolic function has intensified since the emergence of the modern state in the 18^{th} and 19^{th} centuries, when street naming became instrumental in shaping national identities and promoting invented traditions [Ca92]. More broadly, naming streets and places serves as a powerful form of territorialization and identity construction. Cohen and Kliot [Ca92] observed how place-naming functions as a strategy for states to selectively commemorate historical events and cultivate national consciousness. Similarly, Azaryahu [Aza96] described street naming as an instrument of administrative control, while Guyot et al. [GS07] emphasized its role in shaping place identity through territorial inscription.

Historical cases vividly illustrate these dynamics. In apartheid-era South Africa, colonial authorities fused European and Afrikaans names to erase indigenous identities, while post-apartheid renaming efforts sought to redress these symbolic erasures and promote a new national identity [GS07, AK02]. In the United States, streets named after Martin Luther King Jr. were often relegated to minor roads, reinforcing racialized geographies and traditional boundaries [MA14, RRAA10]; recent initiatives have attempted to challenge this marginalization through more prominent commemorative acts. In Spain, Oto-Peralias [OP17] analyzed the religiosity reflected in street names, finding correlations with broader cultural and economic patterns. The commemorative process of street-naming often privileges elite professions, male figures, and national heroes. At the same time, it systematically marginalizes other social groups and historical narratives [OP17]. A 2021 study analyzing 4,932 honorific street names across Paris, Vienna, London, and New York revealed persistent systemic hierarchies, including gender imbalance and the valorization of globally prestigious roles [BCB*21]. These findings were then used to develop "cultural maps" that allow users to discover distinct patterns in the ways street-naming practices in cities are gender-biased, celebrate various professions, and embrace foreign cultures [BCA*20]. Therefore, honorific street-naming operates simultaneously as a medium of symbolic recognition and as a site of exclusion, inviting acts of revision, resistance, and renegotiation. Urban landscapes become living archives of collective values and contested memories, where acts of (re)naming shape not only spatial organization but also the evolving cultural consciousness. While honorific streets encode historical and ideological narratives into the urban fabric, their latent commemorative potential often remains unnoticed. Emerging mobile technologies, particularly the convergence of XR and AI, offer new possibilities for activating these overlooked layers of urban memory by transforming static "street markers" into dynamic and situated experiences.

2.2. Mobile XR + AI Tourist Guides

The integration of XR and AI has transformed the landscape of CH mediation and urban exploration. Mobile XR has emerged as a flexible platform for location-based storytelling that enables situated and context-sensitive interactions within the urban environment [BCL15, BBG*22, LPVJ*22]. Concurrently, advances in natural language processing, conversational agents, and adaptive recommendation systems have expanded the role of AI in personalizing and curating visitor experiences in real time [HSC*24, WGC*24, FWT*24]. These developments have converged in a new generation of intelligent tourist guides, which combine geo-spatial awareness with multi-modal interfaces to present historically grounded narratives, multimedia content, and even reconstructed past events *in situ*. Unlike static signage or traditional guidebooks, mobile XR and AI systems enable users to engage with urban heritage through immersive, embodied, and dialogic modes of interaction. This shift facilitates not only access to curated knowledge, but also opens space for emotional resonance, critical reflection, and participatory engagement [VKPK21, FWT*24, Rus21].

Several recent projects exemplify the expanding potential of Mobile XR and AI in CH mediation [VKPK21]. MuNDAR (Multilingual and Multimodal Narratives for Augmented Reality) combines gamification, generative AI, and AR to create immersive, personalized user journeys in CH contexts [MM25]. VAARHeT (Voice-Activated Augmented Reality Heritage Tours) project leverages XR and AI to create personalized and interactive tours accessible through the visitors' own smart devices. It supports more and inclusive experiences that meet audience expectations [Pro25b]. The EUreka3D-XR framework operating via an online toolbox that includes resources and digital tools, allows users to transform content into XR experiences [Pro25a]. However, critical challenges persist. A key concern lies in the epistemological frameworks that

[†] https://ex.cyens.org.cy/urbanstories/

inform content generation. Many systems, lacking meaningful updates to their narrative structures and datasets, continue to privilege dominant historical perspectives. This perpetuates the marginalization of underrepresented voices and occludes alternative memory discourses [PH25]. The risk is further amplified when AI-driven applications act as authoritative mediators of public history. These systems often lack transparency regarding their sources or narrative bias. In addition, pressing ethical questions arise concerning data governance, provenance, and algorithmic accountability [TPFG24, PTP*23]. This is particularly urgent when such technologies are deployed in culturally sensitive or historically complex contexts that should be treated with cultural sensitivity and historical nuance [HSC*24, TPFG24]. In response, scholars and practitioners increasingly advocate for reflexive design methodologies that prioritize epistemic plurality, participatory authorship, and the ethical stewardship of digital heritage infrastructures [PTP*23, PH25].

While recent advancements in mobile XR and AI have broadened the modalities through which CH can be mediated, particularly via geolocated storytelling and adaptive interfaces [CCL*18, VKPK21], their application to the toponymic dimensions of the urban landscapes remains underexplored. Honorific street names, as persistent spatial inscriptions of ideological narratives and selective memory, constitute a compelling yet overlooked domain for experimental engagement. Embedding these commemorative markers within intelligent, location-aware storytelling frameworks offers an opportunity to interrogate dominant historical narratives and surface marginalized or contested pasts [Tzo18, RPK*19]. Such interventions hold the potential not only to extend the spatial and narrative reach of XR and AI beyond conventional heritage sites, but also to serve as critical platforms for addressing ethical challenges in digital CH mediation. These include algorithmic bias and the uncritical perpetuation of dominant historical narratives [PTP*23, TPFG24]. Accordingly, mobile XR and AI Tourist Guides may be re-conceptualized as tools for civic pedagogy and ethically engaged CH practices, designed to promote inclusive, reflexive, and socially responsive modes of engagement with the past.

3. XR4ED (Extended Reality for Education) Project

XR4ED consists of a comprehensive platform that enables the creation, deployment, and sharing of immersive learning experiences without requiring programming or 3D modeling expertise [LMP*24, LMS24]. Central to the project is the development of an inclusive and user-centric ecosystem that promotes collaboration, pedagogical innovation, and ethical technology use across Europe's educational landscape.

3.1. System Architecture

The XR4ED platform is built upon a robust microservices-based architecture designed for scalability, modularity, and ease of integration [LMP*24, LMS24]. Each microservice addresses a specific function within the system such as user authentication, data management, licensing, file handling, and product cataloging. These services communicate via RESTful APIs or asynchronous messaging protocols, and most are backed by PostgreSQL databases following a schema-per-service model to ensure data separation and scalability. The platform's XR Marketplace facilitates the publication and retrieval of XR assets (e.g., 3D models, interactive scenarios, avatars, and pedagogical tools). It also supports role-based access control and ensures a dynamic exchange of educational solutions. The platform's DevOps environment streamlines content development, testing, and deployment by integrating multiple third-party services. Built in PHP and hosted on cloud infrastructure, it supports secure and scalable application management. GitHub integration offers simplified on-boarding and collaborative development. The system is compatible with XR standards such as OpenXR and WebXR, facilitating cross-platform accessibility.

3.2. Intelligent AR Avatar Interaction

With the aim to enhance AR-based learning, one of XR4ED's key innovations is the integration of intelligent AR avatars that function as virtual assistants and guides within educational contexts. These avatars are designed to support multi-modal interaction that enable learners to engage with them through speech, gaze, and gesture. The communication interaction is facilitated through Azure Cognitive Services for speech-to-text and text-to-speech functionality, while natural language understanding is powered by a ChatGPT-based model that enables real-time responses to learner queries. The AR avatars can be superimposed into physical environments using SLAM algorithms or QR code tracking, offering contextually relevant support within both formal and informal learning spaces. Visual and behavioral realism is achieved through an animation pipeline that includes gaze control, facial expressions, and lip-syncing based on viseme constraints. The avatars are capable of presenting diverse multimedia formats (e.g., images, videos, PowerPoint slides, and spatial annotations), which can be retrieved from the XR4ED platform or provided by instructors. Preliminary evaluations demonstrate strong learner engagement and a clear potential of avatar-mediated AR experiences to extend educational practices beyond traditional classroom environments [LMP*24, LMS24].

3.3. Collaborative AR

The collaborative mode of the app is designed on a host-client architecture. In this configuration, one device operates as the host, functioning simultaneously as both server and client, while additional ones connect to it as clients. Networking between them is managed through Unity Networking for GameObjects that provides a stable framework for real-time collaboration. To initiate a collaborative session, a device must become the "host", acting as a server on the local network. The host accomplishes this by scanning a QR code associated with an AR scene from the XR4ED Marketplace (Orders section). Alternatively, users can load a demonstration session by selecting the "Demo" button on the QR scanner interface. Once hosting is established, the application generates a new QR code containing the session's URL and the host's IP address, allowing other devices to join by scanning this code. Upon joining, client devices download the AR scene content and establish a network connection with the host, enabling synchronized interaction. The host device retains control over the presentation flow (including the management of multimedia elements) to ensure that all participants remain coordinated throughout the session. Participants can select

their preferred language, allowing interaction with the AI avatar in the chosen language. Personalization is further enhanced by the decentralized handling of speech services: each device independently accesses speech recognition and synthesis functionalities that support swift language customization. User queries are first processed by the host, which communicates with the ChatGPT API to generate responses. These responses are then distributed to the client devices, where they can be translated into the participant's chosen language and vocalized using Azure speech synthesis API.

3.4. Educational Integration and Design Considerations

The XR4ED platform is conceived not merely as a technological framework but as a pedagogically informed educational ecosystem guided by user-centered research. XR4ED supports diverse teaching modalities (e.g., classroom-based, distance, and hybrid education), and ensures that content creation remains accessible to users without technical background. The platform is built upon the premise that XR tools must be inclusive, adaptable, and usable by a diverse range of educators and learners. Thus, it allows tailoring experiences through a variety of tools such as adaptive pacing mechanisms, instructor-led lesson sequencing, and the integration of multi-modal content, including 3D visualizations, spatial audio, interactive activities, and contextual annotations. These features empower learners to engage with complex spatial relationships, abstract concepts, and otherwise inaccessible phenomena in an experiential, immersive manner. Avatar diversity is another feature relevant to the platform's commitment to accessibility and personalization. Educators can select avatars suited to the lesson context: minimalist for focus-intensive subjects, or expressive, gesture-rich ones for disciplines such as medicine, design, or engineering. Pilot studies indicated the importance of personalization, particularly in avatar-mediated communication and dynamic content delivery in fostering engagement and enhancing learning outcomes [LMP*24, LMS24].

4. Honorific Streets of Nicosia

Nicosia, historically known as Ledra, was one of the ancient city-kingdoms of Cyprus and has been continuously inhabited since antiquity. Initially less prominent than coastal cities such as Salamis or Paphos, its importance grew during the Byzantine era, particularly in the 7th century CE, when repeated Arab raids on the coasts drove populations inland. Known by then as Lefkosia, the city evolved into an administrative and political center, a role that would deeply influence its later development as the symbolic heart of national identity struggles in Cyprus [Hil10, Mic12]. During the early decades of the British rule of Cyprus (1878–1898), urban priorities in Nicosia centered on restoring law and order in a city with poor infrastructure and sanitation. The formal naming of streets was not considered a priority. Instead, streets were commonly identified through their proximity to prominent landmarks such as bazaars, fountains, and places of worship [The24]. Nevertheless, the implementation of local governance reforms facilitated increased participation of Greek-Cypriots in administrative affairs (Figure 1).

The practice of street-naming became a symbolic tool through

Figure 1: *Detail from the first scientific map of Cyprus, based on the island's first full triangulated survey commissioned in 1878 by British governor Garnet Wolseley and prepared by H. H. Kitchener (published in London in 1885). At the time, the streets of Nicosia lacked official names as clearly observed in the map. Kitchener's map (left) is overlaid on a contemporary satellite image (right) of the center of Nicosia. Source: Research Project "Economy, Environment, and Landscape in the Cypriot Longue Durée" (2019–2022). © Harokopio University and Sylvia Ioannou Foundation. https://kitchener.hua.gr/en/*

which Greek-Cypriots sought to assert a continuous Hellenic identity, replacing what they perceived as Ottoman "relics" with references to Greek history, mythology, and national heroes, aiming to reaffirm cultural ties to Greece and promote the movement ("Enosis") for unification with Greece [The24]. Turkish-Cypriots, in turn, viewed these efforts as deliberate attempts at marginalization and responded with political resistance. Thus, the renaming of streets became an early manifestation of the island's deepening ethnic and political divisions [Pol96, The24].

The situation intensified during the 1950s and 1960s as intercommunal tensions escalated. Following the first division of Nicosia in the late 1950s, and particularly after the constitutional crisis of 1963, the city was effectively split along ethnic lines [Pol73, Pol96]. Each side engaged in large-scale renaming efforts: Greek-Cypriots purged Turkish names in the south, while Turkish-Cypriots erased Greek names in the north. In both cases, street-naming served not only to commemorate historical figures and events but also to legitimize claims to urban territory and assert distinct national identities [The24]. By the time of the Turkish invasion in 1974 and the separation of Cyprus, the use of street-names had matured into a deliberate tool of cultural and ethnic demarcation [The24]. Today, the urban landscape of Nicosia remains a visual and symbolic record of these competing historical narratives. Street-names on either side of the Green Line continue to reflect the ongoing division of memory, identity, and space, transforming the city into a palimpsest of contested sovereignties and unresolved conflict.

5. Honorific Streets as Dynamic Narratives via XR and AI

The Intelligent Tourist Guide integrates XR, AI, and animation technologies to activate honorific street names within the historic center of Nicosia. Situated within the Venetian Walls that surround the old city, an area rich in commemorative street naming practices [The24], the Guide can dynamically activate these toponymic markers for location-based storytelling that foster participatory engagements with the city's layered historical narratives. Through XR meditation, those dimensions are brought into focus by transforming urban space into an active site of inquiry and critical reflection. Leveraging the Intelligent Guide's real-time geo-location tracking and context-aware dialogue system powered by the OpenAI ChatGPT API, users approaching an honorific street are automatically prompted with personalized narratives explaining the historical, cultural, or political significance behind each name. Through the use of lifelike avatars, developed with Character Creator 4 and animated using Ready Player Me assets, these narratives are delivered with natural gestures, facial expressions, and multilingual speech synthesis via Azure Cognitive Services, offering a highly relatable and accessible mode of interaction.

The dialogic mode enables avatars to present multiple perspectives on honorific street names, ranging from conventional historical accounts to critical interpretations on evolving commemorative practices. As such, it supports interpretive engagement and encourages reflective learning. In addition, the Guide's panoramic image display system enhances spatial immersion by situating users within the historical or architectural context of specific locations, since it enables the visualization of monuments and archaeological sites, associated with particular street names and their honorees. Users can thereby engage with the toponymic narrative both verbally and visually (Figure 2a and 2b). Beyond individualized interactions, the Intelligent Tourist Guide can become a collaborative space within the multi-user XR environment. Groups of users may collectively explore the layered meanings of specific street names, contribute their own interpretations, or participate in location-based narrative quests, promoting shared learning experiences and reinforcing the platform's social and participatory dimensions. This collective engagement is critical for reanimating honorific streets not as static memorials but as living, dialogic spaces where contested histories and diverse memories can be explored reflexively. By activating honorific street names as dynamic and narrative anchors within the historic urban fabric of Nicosia, the Intelligent Tourist Guide extends its educational mission beyond static monument interpretation, to foster critically informed and dialogical engagement with an underexplored historical layer of the city. It thus exemplifies how emerging media can transform neglected layers of urban history into active sites of engagement, enriching both educational practices and public understanding of the ideological landscapes that shape contemporary cities.

6. Ethical Considerations

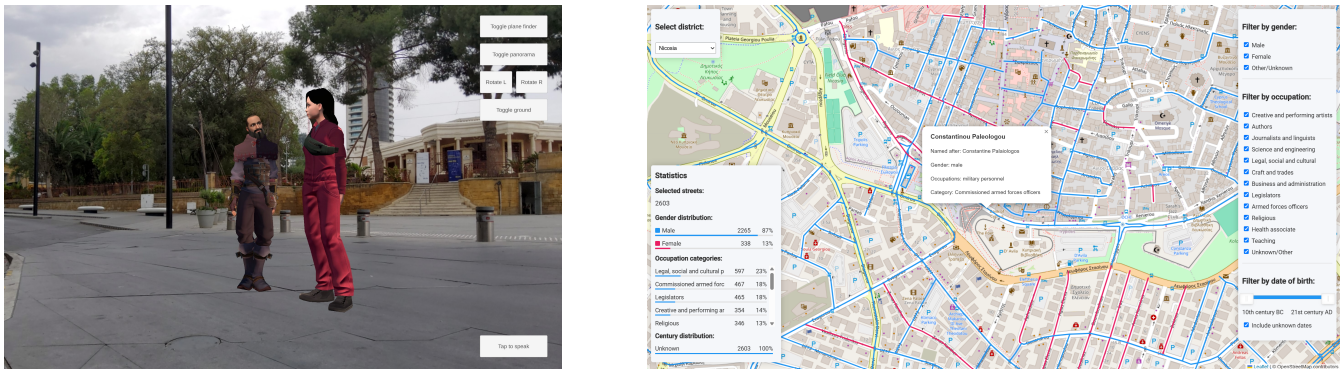
The integration of AI into CH settings offers unprecedented opportunities for innovation, preservation, and engagement. However, it also raises complex ethical challenges that have not yet been fully addressed or systematically theorized within the sector [TPFG24]. These challenges include algorithmic bias, lack of transparency, issues of cultural ownership and informed consent [CBQ*24], and the risk of commodifying cultural assets. Although overarching frameworks such as the UNESCO "Recommendation on the Ethics of Artificial Intelligence" [UNE21] and the European Commission's "Ethical Guidelines for Trustworthy AI" [CDGfCNTewsdsi19] provide valuable general principles, there is still a lack of sector-specific ethical guidelines adapted to the unique needs and roles of CH [MMdL*24, PTP*23, TPFG24]. The deployment of the Intelligent XR Tourist Guide to interpret honorific street names raises ethical concerns. Algorithmic interpretations risk reinforcing dominant narratives and marginalizing minority perspectives, and oversimplifying the contested character of urban toponymy. As AI systems increasingly mediate the interpretation and generation of cultural content, it is essential to prioritize ethical reflection and adopt inclusive and context-sensitive approaches to their design and implementation in CH settings.

6.1. Bias and Representation

AI systems rely on large training datasets, which often lack diversity or reproduce historical imbalances. In CH contexts, this can result in models privileging dominant or institutionalized narratives while excluding or misrepresenting marginalized ones [PTP*23, TPFG24, MMdL*24]. In the case of Nicosia's honorific streets, such bias are particularly sensitive, given the city's multilayered history shaped by Greek Orthodox and Turkish Muslim communities, Ottoman and British colonial legacies, and the ongoing political division of the island [The24]. If the Intelligent Tourist Guides draw on training data that overemphasizes a single historical narrative, whether colonial, nationalistic, or otherwise, it risks marginalizing alternative perspectives and reinforcing selective memory practices [GK20, MT23]. In the context of Nicosia, this could lead to honorific street names being framed in ways that privilege dominant group interpretations while overlooking the histories of minority communities, such as the Armenian and Maronite communities of the island, as well as the experiences of displaced populations. To mitigate bias and promote historical pluralism, pre-curated prompts grounded in archival and scholarly sources should be incorporated. At the same time, working collaboratively with CH professionals ensures factual grounding and interpretive breadth. ChatGPT outputs are guided by this curated input and manually reviewed to ensure historical accuracy, avoid exclusionary or reductive narratives, and support inclusive engagement. Building on this foundation, the range of prompts is expanded, integrating sources from underrepresented communities, and exploring automated validation and community-based review mechanisms to enhance accuracy, transparency, and pluralism at scale.

6.2. Inaccurate Narrative Construction

The development of reliable and trustworthy AI models depends on the availability of high-quality and diverse datasets. In the field of CH, however, such datasets are often fragmented, inconsistently annotated and difficult to standardize [MMdL*24,FG24]. These challenges are particularly acute in the case of honorific street names of Nicosia, where data and relevant archival sources are rarely available in digital format. Moreover, the relevant sources are written,



(a) **(b)**

Figure 2: *(a) The two Intelligent XR Tourist Guides standing at the junction of Eleftherias (Liberty) Square and Konstantinou Palaiologou Street. In the background, the former Nicosia Municipality Hall built on the Davilla Bastion of the Venetian Walls. (b) The "Honorific Streets" platform presenting historical context about the street's namesake, the last Byzantine emperor Konstantinos Palaiologos, who perished in 1453 during the final defense of Constantinople against the Ottomans. The street was formerly named "Alemdar", in honor of the flag-bearer who planted the first Ottoman flag on the Walls of Nicosia on 9 September 1570, when the city fell. Also located on the same street is the Bayraktar Mosque, erected by the Ottomans to honor him. The successive renaming of the street, alongside the presence of this Ottoman monument, exemplifies the layered nature of urban memory and the politicization of Nicosia's public space.*

apart from English, in languages that are less commonly represented in global digital resources, i.e., in Greek, Turkish, Armenian, Cypriot Arabic (Maronite), posing additional difficulties for annotation and standardization. As a result, the richness of data that AI systems can access and learn from is significantly limited and may thus present an overly narrow or distorted view of history [FG24]. The lack of comprehensive data sources is a significant challenge. Relying on incomplete or outdated data, it may present these historical narratives as definitive, when in fact they may be incomplete or biased. Without proper disclosure, users might mistakenly perceive AI-generated historical reconstructions as accurate historical accounts, and ignore the dynamic and evolving nature of historical interpretation [MMdL*24, FG24]. It is therefore essential to ensure that training data and archival resources are not only complete and inclusive but also properly contextualized. This would allow users to critically engage with the information provided, while understanding the limitations and bias inherent in the AI system's interpretation. Furthermore, this calls for the involvement of CH experts who can ensure the accuracy and diversity of the data, especially in cases where certain histories or perspectives might be underrepresented or misrepresented in available archives.

6.3. Ownership and Consent

Intelligent digital representations of CH raise complex legal and ethical questions including ownership, cultural sovereignty, and consent. A longstanding concern is that many CH assets were acquired or interpreted during periods of colonial domination, or remain subject to unresolved disputes. The use of AI to digitize, manipulate, or reinterpret these assets without meaningful involvement of source communities risks perpetuating extractive practices under a technological guise [PH25]. This issue extends beyond tangible artifacts to encompass intangible heritage, where AI systems may replicate storytelling styles specific to minority and ethnic groups, reinterpret local histories, or adapt traditional knowledge without proper consent or benefit-sharing; this infringes upon community intellectual property rights [PH25].

These ethical challenges become particularly acute in the case of Intelligent Tourist Guides employing AI to present urban toponymy in historically layered cities such as Nicosia. Honorific street names are not neutral designations; they constitute dense markers of collective memory, identity, and political power, reflecting contested narratives among Greek Cypriot, Turkish Cypriot, Armenian, Maronite, and other communities. In a context deeply shaped by colonial histories, political conflict, and displacement, the ways in which AI systems contextualize through narratives the city's street names carry considerable cultural and ethical weight. Without inclusive and participatory design practices, there is a significant risk that Intelligent Tourist Guides will reproduce dominant historical narratives, further marginalizing or misrepresenting minority histories and perspectives. Moreover, if AI-generated narratives reinterpret street names without consultation and consent from affected communities, they risk reinforcing historical erasures and presenting selective or contested accounts as authoritative. The re-imagining or reinterpretation of these honorifics without transparency concerning the involvement of source communities risks perpetuating new forms of cultural appropriation, in which collective memories are extracted, reshaped, and commodified without proper acknowledgment or benefit to the communities from which they originate. To mitigate these risks, the development of AI systems for CH interpretation must prioritize active engagement with local stakeholders, ensuring that historical representations remain pluralistic, critically contextualized, and sensitive to the complex realities of memory, ownership, and representation.

6.4. Transparency, Accountability, and Explainability

AI systems used in CH contexts are often developed by technology providers with limited input from heritage professionals [DRP20]. This creates a significant knowledge gap, where museum staff, historians, or archaeologists may not fully understand how algorithmic decisions are made. As a result, curatorial choices, classifications, or historical interpretations produced by AI can go unquestioned, even when they touch on sensitive or contested topics. These issues are particularly pressing in the case of AI-powered XR Tourist Guides for honorific street names. Given the deep entanglement of urban toponymy with collective memory, political conflict, and postcolonial identities, the way AI systems frame and contextualize these names carries considerable cultural and ethical weight. Without transparent, explainable processes, there is a real danger that such systems will reproduce dominant historical narratives and further marginalize minority perspectives.

To mitigate these risks, AI systems must prioritize explainability from the outset [DRP20]. Users should be able to trace the rationale behind AI-generated content, including the sources and selection criteria. This is especially critical when dealing with politically sensitive topics or symbolic urban spaces. For example, if an AI system generates a particular account of a disputed honorific street name, it must clearly disclose the basis for its interpretation and, where appropriate, present alternative viewpoints. Furthermore, XR AI Tourist Guides should be subject to regular ethical audits to evaluate cultural sensitivity, data fairness, inclusivity, and long-term impacts. These evaluations should assess whether the systems enhance cultural understanding or risk eroding cultural integrity through selective or biased representations. To support accountability, heritage institutions should favor AI models that allow for human oversight, clear documentation, public transparency reports, and participatory design processes. Community feedback mechanisms must also be integrated to empower users to question, challenge, and, where necessary, correct AI-generated content.

6.5. Education and Digital Literacy

It should also not be overlooked that to responsibly integrate AI in CH, professionals must be technically proficient to understand the ethical implications of its application. AI systems, if not managed carefully, risk oversimplifying complex cultural narratives and misrepresenting historical data [MMdL*24]. Therefore, it is essential that heritage professionals gain both technical skills and ethical awareness to navigate these challenges effectively. Education that combines digital literacy with ethical reasoning is thus crucial, while bringing together collaboratively technologists and humanists can bridge the gap [MFRR*21]. This will ensure that curators, developers, and policy makers can not only use AI tools but also critically assess their potential cultural risks. But digital literacy is also essential for the public. Users engaging with AI-powered heritage content should understand the limitations and lack of transparency of these systems. Clear explanations of how AI works and how content is generated will empower users to critically engage with AI outputs and question any potential misrepresentations. Ultimately, integrating ethical awareness into education will ensure that AI systems in CH contribute to greater cultural understanding rather than undermining it.

6.6. Systemic Risks

Beyond the epistemic and representational issues, the use of foundation models such as ChatGPT introduces broader ethical concerns. First, these systems carry significant environmental costs due to the energy-intensive nature of training and inference at scale [BGMMS21, SGM20]. Second, their training processes often rely on unlicensed data that raises concerns about intellectual property rights and consent [CTW*21]. While these issues are external to our immediate design, they shape the ethical landscape in which our system operates. Acknowledging these systemic concerns, we advocate for increased transparency, support for open-access AI infrastructure, and future development of CH-specific models trained on ethically sourced and community-governed data.

7. Discussion

The convergence of AI and XR in tourism offers new avenues for urban exploration, informal learning, and heritage preservation. We then discuss the potential of AI-driven XR Tourist Guides in relation to urban symbolic heritage, with a specific focus on honorific toponymy and their situated meanings in historically layered cities such as Nicosia.

7.1. Enhancing Urban Tourism via Contextualized Narratives

AI-powered guides transform conventional tourism into an adaptive and narrative-driven experience. Rather than standardized tours, these systems respond to user preferences and location-specific data, creating tailored journeys through the city [SSD24]. In the context of Nicosia, where historical layers are materially and symbolically inscribed in the urban fabric, such technology can illuminate overlooked or politically contested elements (e.g., a renamed street or an unmarked commemorative plaque) by situating them within broader historical and social narratives. The capacity of AI to redistribute tourist attention across the urban landscape holds additional practical benefits. By directing visitors to under-visited sites of cultural significance, AI-enabled systems can help mitigate overcrowding at popular destinations while revitalizing underdeveloped zones. This not only enhances visitor engagement but also supports more sustainable tourism practices that align with heritage conservation goals [OGMMVMFM22, SSD24]. Moreover, such systems operate independently of traditional tour structures and can be accessed spontaneously, allowing for on-demand experiences that extend visitors' interaction with the city across different times of day and contexts. In increasingly competitive urban tourism markets, this fusion of personalization and immersion represents a valuable asset for cities seeking to differentiate themselves through deeper cultural storytelling.

7.2. Educational Impact and Situated Learning

A key strength of AI-augmented XR guides lies in their educational affordances. As previously discussed, honorific street names constitute an overlooked layer of urban heritage. When reanimated through AI narratives, these names become gateways to urban memory by turning the city into a distributed pedagogical environment. By integrating visual, auditory, and interactive elements, XR

applications facilitate multisensory learning experiences that are particularly resonant for diverse audiences, including younger visitors [LMP*24,LMS24]. Beyond factual recall, these systems foster situated learning by embedding information within geographic and socio-historical contexts. Rather than simply identifying commemorative street names, they contextualize the deeds, and contested legacies behind them, encouraging critical reflection on the symbolic construction of urban space and the dynamic nature of collective memory. This pedagogical function aligns with broader goals in heritage interpretation, particularly the shift from didactic to dialogic modes of engagement. AI-guided storytelling can serve as a bridge between expert curation and public participation, offering layered narratives that challenge singular historical viewpoints while remaining accessible and engaging.

7.3. Cultural Preservation

AI- and XR-mediated Tourist Guides with particular focus on honorific street-naming offer a powerful means of preserving and revalorizing urban symbolic heritage. As semiotic markers, street names encode communal values and historical memory, yet their significance is often obscured by routine familiarity or deliberate erasure. By narrating the histories behind these toponyms, AI systems act as instruments of cultural reanimation through which neglected, contested, or marginalized figures are reintroduced into public consciousness. In politically contested settings such as Nicosia, where place-naming is deeply entangled with identity, sovereignty, and memory politics, such technologies enable the coexistence of multiple narrative layers (e.g., official, minoritary, or even counter-hegemonic). This pluralization fosters a more inclusive and dialogic form of heritage representation that challenges the dominance of singular commemorative regimes. Importantly, these systems are adaptable: their content can evolve alongside shifting socio-political landscapes, functioning as living archives of cultural change. In doing so, they sustain heritage relevance across generations and reinforce urban identity through accessible, multivocal storytelling. However, as outlined in the Limitations Section, their efficacy depends on critically navigating issues of technological dependence, algorithmic bias, and stakeholder exclusion. Without participatory design and ethical oversight, there is a risk of alienating users or distorting heritage narratives, underscoring the need for inclusive, context-sensitive implementation.

8. Limitations and Future Directions

Our work has three limitations that call for future research efforts. The first limitation is about the scope of the case study. While the paper considered ethical considerations, it does so from a particular point rooted in the historically layered and politically contested context of Cyprus, which is admittedly a distinct setting within the European space. This contextual grounding may restrict the broader applicability of AI and XR technologies into CH to regions characterized by different socio-political dynamics, cultural frameworks, and historical trajectories.

The second limitation concerns the broader implications of technological mediation in engaging with intangible dimensions of urban heritage. While XR offers new potential for reactivating overlooked heritage, its increasing reliance on screen-based interfaces risks attenuating the embodied and multisensory nature of heritage encounters [DRP20]. Such technological mediation may introduce interpretive bias and alter users' engagement with space and memory. A related concern is the growing dependency on complex digital infrastructures (e.g., sensor networks, Internet of Things (IoT) devices, and AI services), which not only demand substantial investment and ongoing maintenance but also reconfigure the modes through which CH is experienced and interpreted [OGMMVMFM22]. Over-reliance on technological systems risks transforming heritage encounters into mediated experiences that may diminish the sensorial and spatial qualities critical to processes of memory formation and meaning-making [Bur22]. Future research should explore how to balance immersive innovation with the preservation of sensory immediacy and affective connection.

Finally, although we articulated the theoretical potential of XR and AI in our case study in Nicosia, we did not provide evaluation metrics, empirical data, or analytical frameworks to assess their actual effectiveness. While existing literature and case studies indicate that XR can enhance engagement with CH [SGD*21,NSK23], the applicability of these findings to the domain of urban toponymy remains insufficiently explored. In the absence of user studies, the capacity of the proposed interventions to promote meaningful engagement with urban memory and identity cannot be conclusively determined. Future research should prioritize empirical validation to substantiate the role of XR and AI in revitalizing the neglected symbolic layers of urban toponymy, particularly within complex and contested heritage environments such as Nicosia.

9. Conclusion

We explored the potential of integrating XR and AI technologies in the development of Intelligent Tourist Guides to reactivate the symbolic dimensions of honorific street names within Nicosia's historic urban landscape. By presenting these toponyms as dynamic memorials to significant historical figures, our work highlights their potential for location-based storytelling that supports interpretive engagement with urban heritage. The use of intelligent AR avatars, collaborative XR environments, and context-aware interactions shows promise for enriching educational and promoting critical reflection on the ideological narratives embedded in the urban fabric. However, such technologies require careful attention to ethical issues, including narrative bias, authorship, informed consent, transparency, and algorithmic accountability. Addressing these concerns requires a design ethos grounded in responsibility and inclusivity to ensure equitable engagement with the past.

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