Beyond Creating Collections: A Scoping Review of 3D Heritage Storytelling

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Abstract

This paper aims to demonstrate how virtual reality (VR), augmented reality (AR), and 3D archaeological reconstructions have been employed to immerse viewers into historical places with the inclusion or exclusion of digital narratives in the heritage and tourism sectors. Countless galleries, libraries, archives, and museums have included digitally re-created objects and re-imagined scenes in situ through theatrical sets and live historical re-enactments to help visitors see and contextualise objects from history. What if these techniques were applied to 3D virtual narrative experiences? This scoping review focuses primarily on selected studies that create 3D models for archaeology, VR, and AR that utilise 3D models, and virtual heritage 'edutainment' experiences published within the last five years (i.e., 2018-2023). It gives an overview of the current methods and technologies used to create 3D heritage productions for scientific studies, heritage preservation and tourism, and educational applications. Ultimately, this paper discusses possibilities for future work on how extended reality and 3D models could be included in narrative experiences based on gaps in the existing research.

Keywords

3D archaeology, 3D heritage, cultural heritage, digital storytelling, virtual reality, augmented reality, gamification, edutainment

1. Introduction

Digital Humanities scholars alike have made huge strides in digitising and creating digital-born archives and objects. More recently, many scholars are creating a variety of 3D objects for scientific purposes or as case studies of specific historic sites. Many 3D objects are interactive on a web interface, which are labelled and dated, and allow the user to rotate the image and view it at different angles. However, beyond that minute or two of interaction, there is often (but not always) little contextual narrative or further applied use of the created digital objects for outreach initiatives or public engagement. These 3D cultural heritage models are now a critical component in cultural heritage conservation, and are being also employed in other use cases, such as in education, tourism, virtual and augmented reality experiences (Nishanbaev 2020, 1).

In recent years, digitised archives have been increasingly used to create digital narrative experiences for the public in a variety of applications. Major European projects have contributed to the development of digital archives that include 3D models, such as Europeana (2020), Time Machine Europe (2024), and iHERITAGE (2024). Examining the life cycle of DH and arts projects, digitised 3D cultural models are becoming more accessible and can thus be further utilised to develop innovative 3D digital narrative experiences for virtual heritage tourism. For example, scholars across disciplines have been experimenting with digital storytelling and gamification of cultural heritage. Countless galleries, libraries, archives, and museums (GLAMs) have included digitally re-created objects and re-imagined scenes in situ through theatrical sets and live historical re-enactments to help visitors see and

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contextualise the objects in history. What if this could be re-created in guided virtual narrative experiences using 3D models?

This short conference paper provides an overview of separate, yet interdependent, areas for future digital developments in the context of GLAMs and the heritage and tourism sectors, which have and can further benefit from developing extended reality (XR) narratives with 3D archaeological reconstructions. This scoping review follows the lifecycle of how 3D models, developed for archaeological studies, can be digitally archived in (open access) databases, linked with other 'big data', and/or further applied to creative arts projects that use XR environments to transform seemingly empty objects and spaces into narrative virtual worlds for public audiences. The focus is primarily on studies that employ 3D modelling for archaeology, virtual reality (VR) and augmented reality (AR) applications for cultural heritage, and 3D 'edutainment' experiences published within the last five years (i.e., 2018-2023). It provides an overview of the current methods and technologies used to create 3D heritage productions for scientific studies, heritage preservation, tourism, and educational applications.

2. Background on using 3D Models in Archaeology

Archaeological sites present many unique challenges for reconstructing history. They are often severely eroded into ruins, there is often a lack of written historical records about the site's occupation, and present-day researchers may have difficulty reimagining the cultures of thousands of years ago. History is often crafted from incomplete evidence, and this can challenge its authoritative basis (Poole 2018). While scholars cannot piece together the past with archaeological evidence alone, digital narrative arguably allows for the expansion of 3D objects into imagined communities, places, and lifestyles that the public could engage with through immersive virtual experiences.

Photogrammetry is a technique used by archaeologists to create 3D objects, and is divided into object-based, ground-based and aerial. Object-based photogrammetry involves producing models from as small as sub-centimetre artifacts to large movable objects, such as stones, ceramics, and human or animal bones (Magnani et al. 2020, 740). Ground-based photogrammetry produces models of immovable objects and features documented at ground level, which is useful for preserving images of sediment characteristics throughout the excavation process and preserving threatened or degraded buildings or places (Magnani et al. 2020, 744). Aerial-based permits the analysis of site that are typically inaccessible to pedestrian surveying, such as rock art panels, however, mapping ground surfaces is difficult with significant ground vegetation and there can be legal limitations with aerial photography due to the accessibility of drones (Magnani et al. 2020, 749). Object-based photogrammetry has assisted archaeologists in developing digital objects that can be used to accurately replicate measured objects, assist with visualising and reading degraded artifact surfaces, and documenting underwater heritage (Magnani et al. 2020, 741-745). In one case study, Robinson et al. (2019) used ground- and aerial-based photogrammetry with LiDAR data to make hypotheses about the destroyed architecture of Neolithic temples in Malta.

In many cases of 3D archaeology, the models are created using photogrammetry and other digital techniques for the purposes of scientifically measuring accuracy for further analysis or to reconstruct different ruins back into a virtual whole. However, as Shishido et al. (2017) summarise, there have been increased technological advancements in developing new 3D experiences and 3D models have been applied to printing, television, audio, modelling, and gaming. For example, 3D printing of 3D models using photogrammetry can be and have been used in museums (Balletti and Ballarin 2019). Balletti and Ballarin's (2019) research showed a high level of precision in the 3D models, albeit not metrically flawless, to an untrained eye and where the general concept is prioritised, are more than sufficient for purposes of public displays. Looking beyond more specific case study approaches, Rahaman et al. (2019, 2) provided a methodology for producing 3D digital assets from photographs to be deployed within an extended reality environment with interactivity to support cultural heritage visualisation and learning. However, this Rahaman et al. (2019) similarly focus on the technologies used to produce 3D images and the technologies available for creating extended reality (XR – an umbrella term

encompassing virtual, augmented, and missed reality) experiences rather than on how to develop a narrative experience aimed at a public audience.

While the technologies and techniques archaeologists use to record objects and ground-based artefacts tend to be the focus of published literature in these domains, the digital 3D models also contain narrative potential for reconstructing the public's understanding of the past. Creating 3D models of real-world heritage objects using 3D modelling software or photogrammetry can be expensive and requires a high-level of expertise, however, there are free and open-source software available for non-experts to create and share 3D objects in a restricted budget (Rahaman and Champion, 2019). As Magnani et al. (2020, 752-753) also confirm, the cost and process of photogrammetry has become more democratised to enable the creation of more complex 3D datasets and the resulting 3D models can be integrated with VR platforms, web viewers, and game engines to increase accessibility. These positive developments in accessibility of 3D datasets leads to larger digital infrastructures to enable their reuse in other creative media arts projects like XR narrative experiences.

2. Integrating linked data in interactive infrastructures for 3D heritage

Digital Humanities scholars have developed many digitised archives, databases, and other digital infrastructures to house heritage content in a variety of formats. Existing large-scale infrastructures for digitised cultural heritage data include Wisski, Arches, ResearchSpace, and Omeka S (Nishanbaev et al. 2021, 2). Europeana's cloud infrastructure also contains heritage data including 3D archaeology collections, and more recently, CulturalERICA provides an interface to retrieve data from Europeana using REST API (Bertocci et al. 2023, 2). CulturalERICA focuses on using conversational agents (i.e., natural language interactions) to provide structured answers to users' queries (Bertocci et al. 2023), which thus functions more like a personalised search engine rather than providing a directed narrative arc to the linked data contained in the semantic web. In many cases, members of the public or other users who are less familiar with the database may not have enough contextual information to know which keywords, topics, or questions to ask the conversational agent. Another example of digital infrastructure, Cloudy Culture, uses cloud services to store cultural heritage data in the National of Library of Scotland and Scotland's national galleries, which contain digitised maps, books, articles, and images (Bertocci et al. 2023). The focus of Cloudy Culture is similarly providing the public with access to scientifically created 3D models, but these lack a cohesive narrative so that general users can understand the wider socio-cultural context of the archaeologically preserved artifacts. The Smart Architecture for Cultural Heritage in Emilia Romanga (SACHER) project involved developing a cloud-based, open-source platform for managing 3D models of cultural heritage and a search engine to retrieve data from heterogeneous sources (Bertocci et al. 2023, 2). However, Bertocci et al. (2023) focus on creating linked data for "tourists" or "general users" to explore without constraints or following a guided path which similarly leaves the user with limited contextual narrative context for the 3D models in a VR environment. Nishanbaev et al. (2021) note that integrating Web Geographic Information Systems (GIS) with 3D web-based visualisations and linked open data can allow for new ways for users to explore digital cultural heritage, which would have location as an added context.

Going beyond linking different data and infrastructures, Kiourt et al. (2016) demonstrated how "DynaMus" – a web-based virtual museum – connects to repositories, such as Europeana and Google, to create virtual exhibitions that can be customised based on the user' creativity via modern game engine technologies. The system provides "a first-person virtual world navigation and content manipulation experiences" and can include educational activities in VR technology (Kiourt et al. 2016, 990). However, from the examples given with the paper, it is unclear how much historical and narrativised content is provided to the user. The authors noted that they will be investigating options for integrating virtual agents to serve as exhibition guides, coupled with artificial intelligence (AI) to support user-defined guided tours (Kiourt et al. 2016, 990). In other words, they may develop avatars to act as guides or search-engine like results related to the cultural heritage collections or exhibits. To date, an under-researched area is what users think of tour-guide style avatars in the cultural heritage virtual spaces as few user studies on this have been found in the published literature. Avatars are very common in gaming environments, and perhaps users who have played or frequently play fictional video games may enjoy

avatars. However, it is unclear if less technologically experienced users enjoy interacting with these avatars or if they would prefer the agency to experience historical virtual environments through an unmediated first-person perspective. As Champion (2021, 175) notes, avatars' relationship to the virtual story world or gaming environment are often "merely cosmetic" and they do not involve genuine role-playing and learning. These questions regarding virtual museums, the use of avatars, and guided tours leads into the research domain of XR.

3. Using 3D models in Extended Reality Environments

Popular technologies used for archaeological research purposes as well as for creating public engagement experiences include virtual, augmented, and mixed reality, 3D visualisations, and geographic information systems (GIS). Virtual reality (VR), augmented reality (AR), and mixed reality (MR) are often discussed together and sometimes mistakenly used interchangeably albeit each having their own affordances, limitations, software, and hardware involved. VR immerses the user in a simulated world without the possibility of seeing the real environment, AR augments the virtual world with live scenes from the physical world, and MR blends the virtual and physical environment in different ways (Bekele et al. 2018). Bekele et al.'s (2018) survey showed that these applications have been used in various cultural heritage cases including for exhibition enhancement (21%), reconstruction (13%), virtual museums (6%), education (1.5%), and exploration (1.5%).

Through a series of six case study examples, Bezzi et al. (2018, S57) note how 3D web technologies are commonly being used in commercial archaeology, which include for purposes of tourism improvement, real time field-work management, scientific communication, and preserving cultural heritage. For example, the tourist application, in Unity Game engine for Punta Linke in Italy, did include some short descriptions of the "hotspots" being explored and a website created for the historical border for the Treaty of Rovereto of 1753 in Veneto, Italy included a "simple timeline" of related chronological events (Bezzi et al., 2018). Despite the different applications of 3D archaeology, none of these six case studies involved the development of an overarching educational narrative to accompany the 3D models, but instead the focus was on creating an interactive 3D simulated environment. In a wider survey of the literature (i.e., 132 papers), Skublewska-Paszkowska et al. (2022) found that 3D technologies are being used primarily for 3D scanning, 3D modelling, VR and AR to virtually present tangible heritage including monuments and ancient artefacts, and to capture and preserve intangible heritage ranging from craftmanship, folk dances, storytelling, and game-based education. Scholarship focused on storytelling and gamification represented only 13% of the papers sampled, while tangible and intangible culture were found to be the focus largely in architectural, settlement, museum, and software studies (Skublewska-Paszkowska et al. 2022). Skublewska-Paszkowska et al.'s (2022, 18) results showed, most published papers from 2005-2020 primarily focus on presentation, virtual exposition, and datasets rather than on web applications, AR applications, museum, mobile apps, or games. In sum, presenting the 3D models commonly takes precedence over offering a more developed narrative experience in XR media.

Going beyond mere presentation, each XR medium has its affordances and limitations as a technology and within the context of its application. When it comes to using different options for extended reality in the heritage sector, choices need to be made on whether objects or scenarios should be presented in one media or another to communicate the information and have the desired impact on the targeted audience (e.g., academics; museum visitors of all ages; cultural heritage tourists). When it comes to applying heritage in VR or AR environments, a key difference is in the physical requirements to experience the digital content. In the case of AR, the user needs to be physically present in situ and VR's potential has been recognised in the tourism industry to provide a "sensation of interacting with the place visited" (Barrado-Timón and Hidalgo-Giralt 2019, 2). While VR, on the other hand, is more commonly recognised as a useful application for the safeguarding and conservation of heritage (Barrado-Timón and Hidalgo-Giralt 2019, 2). Many scholars have recognised a shift from informative cultural heritage products towards an experience of cultural heritage, which involves creating more immersive content that enhances the tourist experience (Barrado-Timón and Hidalgo-Giralt 2019, 3). As Champion (2021, 176-177) argues, "if they are to be more than static models, archaeological simulations must be simulations of the past through present remains, contemporary scholastic

imagination, and evidence-based hypotheses." Therefore, a focus on constructing well-researched narrative(s) with expertise from archaeologists and/or historians to support the visualised 3D models is important to provide meaning to an XR experience beyond visual interactivity.

Other observed trends in the published literature to date include creating XR applications that include 3D reconstructions of churches/cathedrals (Soto-Martin et al. 2020; Allal-Chérif 2022; Mah et al. 2019), castles (Leach et al. 2018; Dyulicheva et al. 2022; De Paolis et al. 2022), and urban heritage (Barrado-Timón and Hidalgo-Giralt 2019; Banfi 2021). Using 3D models in a variety of XR applications is a step forwards to help disseminate research findings and to begin reaching wider public audiences. Many case studies that use 3D models in XR media tend to focus more on the technologies, accuracy, and clarity of the visualised objects that are usually presented in a 360-degree interactive interface. Taking these reconstructions a step further towards narrativization, other scholars have implemented 3D heritage into educational XR experiences that also aim to entertain members of the public.

4. 3D Heritage in VR Gamification and Edutainment

Scholars have operationalised 3D models in a variety of different 'edutainment' applications. Edutainment is a portmanteau of education and entertainment and is commonly used to describe a variety of XR experiences that can include storytelling and gamification. Gamification involves using game elements in non-game contexts (Deterding et al. 2021), such as health, education, and digitised cultural heritage. In the tourism sector, Poux et al. (2020, 4) summarise that VR's has been investigated in six primary areas including: education, accessibility, marketing, planning and management, heritage preservation, and entertainment. Overall, they found that VR has had a positive effect on essential learning and entertainment, but further research is required on user interaction needs to further engage and enhance the learning experience (Poux et al. 2020, 4).

Many examples of VR applications appear in Italian museums (Bozelli, et al. 2019, 3-4), and many examples of gamification for 3D cultural heritage have been developed based on settings in Greece. For example, Roumana et al. (2022) developed a cultural heritage 3D puzzle in a VR environment for students using Unity and high-resolution 3D models (developed using photogrammetry) of an ancient Greek temple and statue. However, the game did not perform very well from a user experience perspective and re-constructing a 3D puzzle object after correctly answering historical questions is an example of gamification interactions, rather than focusing on a more wholistic narratively guided experience. In another gamified web-based and VR-based experience, the history and tradition of jumping off the Old Bridge in Mostar, Bosnia and Herzegovina, was created (Selmanović et al. 2020). There were five stories (delivered as voice over narration with 360-degree videos) that included: (1) an introduction, (2) overview of the bridge's history, (3) architecture, (4) destruction and reconstruction and (5) narratives about the bridge diving history and competitions based on an interview with a famous diver (Selmanović et al. 2020, 13:6). The information was followed by a quiz to assess how much users learned and if they answered 60% correctly, they could proceed to a simulation of the virtual bridge dive (Selmanović et al. 2020, 13:6). As seen in these few selected examples, edutainment-focused VR experiences often employ a quiz as an educational yet gamified approach to ensuring the user paid attention to the narrative and as an attempt to increase their retention by reviewing the information presented in another format. A common result of users' success in such quizzes, is the ability to "unlock" an additional VR scene or experience.

Another identified gap in the literature, reviewed thus far, is in user testing with cultural heritage tourists. As previous research shows (Basaraba 2022), the reported demographics of cultural heritage tourists include the age range of approximately 30-55 years old and they tend to hold one or more post-secondary degrees. However, many user testing studies have been done with students under 30 years of age, many of whom come from computer science or gaming backgrounds. For example, Selmanović et al. (2020, 13:13) surveyed participants aged 20-34 years old, 69% of which were either teachers or

students. If the aim is to develop future VR experiences for cultural heritage with narrativized content aimed at cultural heritage tourists, future user studies should focus more on the target demographics.

Looking at other case studies that provide more narrative-focus in their content development, two examples are highlighted here. Firstly, a case study by Hajirasouli et al. (2021) involved creating a VR experience that focused on four fixed frames and sceneries of Kandovan (an ancient cone-shaped settlement in Iran). The frames showed what Kandovan looked like and in advance of the VR viewing, an accompanying narrative was delivered separately in a poster that detailed the changes in the settlement from its original state until its current form (Hajirasouli et al. 2021, 148). The user testing results showed that the VR experience allowed viewers to get a better understanding of how the settlement changed over time including recent unauthorised constructions, and that the VR added a sense of place that resulted in an increased level of empathy towards the respective community (Hajirasouli et al. 2021, 149). This project demonstrates the how a multimedia approach (i.e., a poster, 360-degree video exhibition, and the VR presentation using Oculus Rift S) can be used to create a digital heritage experience that communicates the historical significance of infrastructural changes over time with an accompanying temporal narrative rather than only visual 3D reconstructions accompanied by brief descriptions.

Secondly, the ArkaeVision project (Bozelli et al. 2019) involved developing a web portal, VR application and AR application for the Hera II Temple of Paestum and the Swimmer Tomb—both archaeological ruins located in Italy from a formerly ancient Greek city. The web portal was used to introduce the project before users engaged with the VR application which focused on the 3D model of the environment and monument to explore inside, and the AR application which had further information about the reality that surrounds it by adding virtual data overtop the real artefact (Bozelli et al. 2019, 5). This suite of digital experiences was aimed at a public audience (including tourists), that involved on-site gaming, edutainment, online supports and activities for virtual representations of monuments, works of art and objects, and associated stories (Bozelli et al. 2019). These narrative-oriented multimedia digital experiences demonstrate different methods for how 3D models can be further applied into different products for public education and entertainment. There are future possibilities to continue creating VR and AR experiences for GLAM visitors and cultural heritage tourists since previous studies have shown their edutainment value.

5. Workflow Challenges for Creating 3D Extended Reality Heritage Narratives

The narrativization of 3D archaeology and cultural heritage is not without a myriad of challenges. As Lombardo and Damiano (2012, 18) explain, one challenge is that the primary goal is often to inform visitors about the history of the site and as a result, the storytelling is subordinated to the guided visit. Existing databases, such as the Europeana archaeology database (2023), currently contain mostly objects housed in museums and the pottery and weapon remnants do not tell many stories. Furthermore, there is the challenge of copyright and creation of digital narratives that require web hosting and sustainable digital platforms/archives that do not become unsupported (e.g., Adobe Flash being discontinued had an impact on many narrative productions). While the Internet is a primary medium for the dissemination and for long-term archiving of 3D cultural heritage models, the development of more free and open-source content management systems or databases is needed (Nishanbaev 2020, 1) before these artefacts can be further narrativized into imagined archaeological pasts.

The convergence between software studies in cultural heritage applications, scientific 3D objects, creative arts practitioners, and GLAMs also presents other challenges. Some noted challenges with using AR and VR for communicating heritage content include: the subversion of sociospatial relationships whereby there is a disconnect between the social and geo-location of the heritage and the virtual space within which it is represented; and the potential simplification or trivialisation of complex heritage material to achieve a more playful or gamified experience (Barrado-Timón and Hidalgo-Giralt 2019, 16-17). In other words, XR technologies can focus on moving viewers into an “emotional past” within the viewers’ own time (as per Hartog, 2015) rather than on the nostalgic link to the historical past (Barrado-Timón and Hidalgo-Giralt 2019, 18), which results in a less impactful educational engagement. When it comes to 3D modelling, it has been used to replicate, with accuracy, objects,

artefacts and monuments, and the resulting 3D models can be transferred into VR and AR environments to deliver tourism experiences (Little et al. 2018). However, 3D models themselves they may offer a limited immersive experience, while immersive media such as VR and AR experiences, in turn offer little accuracy (Little et al. 2018, 4). Therefore, further studies into the 3D data captured for presentation and integration into VR are needed (Little et al. 2018, 4).

Another well-known challenge with created VR experience is motion sickness felt by users. A few studies showed that using "teleportation" can help reduce motion sickness, by replacing one view with another in a frame rather than having the user appear to be moving/travelling through the virtual space from one location to another (e.g., Little et al. 2018; Bozzelli et al. 2019; Walmsley and Kersten 2020). A series of other common challenges with developing VR or AR heritage tourism experiences include: the costs of development and related technological hardware, the ability for individual users to adopt the new technologies when it comes to digital literacies or preferences for non-technologically mediated experiences, and the energy consumption of these technologies or the threat of them becoming outdated or obsolete (Allal-Chérif 2022, 8). Finally, unlike digitised archives, which may have a few different file types and associated metadata to store and organise the data, increased challenges also arise with preserving the varying digital formats of XR productions. For example, the British Library has developed a digital archive for interactive digital narratives (Clark et al. 2020). If more XR narrative experiences are developed, it also presents more born-digital archiving challenges.

6. Potential Contributions of 3D Heritage Narratives Going Forward

As for the potential impact on the field, new media reconstructions (e.g., 3D re-creations, animations, extended reality) will help protect and digitally preserve archaeological and other heritage sites from damage due to mass tourism and environmental erosion. Virtual tourism experiences could substitute in-person travel (as necessary due to environmental impacts or world events such as COVID-19 lockdowns) by allowing people to see and virtually interact with the built heritage up close. Bec et al. (2021) propose the concept of "Second Chance Tourism", where they argue that virtual and mixed reality offer opportunities for people to experience tourism sites that are at risk of natural or climate-based deterioration, destruction, or over-tourism. Bec et al. (2021, 2) argue that Second Chance Tourism gives destinations a "second life" so visitors can experience them in a variety of different media either onsite or off-site through digital experiences. GLAMs and DH labs could also hold interactive workshops or installations of these narrativized 3D objects for the longevity of the objects and to reach wider audiences with scholarly outputs through more accessible media.

Based on user testing with different devices in different settings, Petrelli (2019, 10) recommends VR for heritage that is ruined or lost, 3D reconstructions in AR for comparing present day and past appearances, and that most of the work in immersive experiences should be dedicated to creating high-quality visual reconstructions rather than in adding characters or additional features, such as a quiz. Petrelli (2019, 10) further notes that the visual reconstruction should be paired with a well-crafted and accurate story that fits the heritage, and that VR or AR should be designed with minimal interactions to leave users to enjoy the real setting. These recommendations could be helpful for the development of future extended reality narratives that use 3D archaeological models.

Lastly, in terms of ongoing technological developments, Mattys et al. (2021) proposed a concept of "Animated Spatial Time Machine" in their example where they created a 4D web environment along with XR applications as part of their "3D city game Ghent" project, which focused on reconstructing disappeared environments. The three dimensions in reference to 3D are understood to be height, width and length, while Mattys et al. (2021, 2) note that time is often seen as the 4th dimension, and spatial resolution is the 5th dimension. Similarly, the 5Dculture project (2024), currently running from 2023-2024, aims to enrich European's portal of digital collections with more 3D assets to "foster their reuse in education, tourism and creative and cultural sectors." Therefore, these 4D and 5D foci will also need to be researched and considered in the workflow for creating future XR narrative experiences aimed at members of the public and/or tourists.

7. Conclusion

Thus far, digital humanities scholars have begun creating 3D cultural heritage collections as data and some of these have been incorporated into different XR experiences. There are evidently challenges in the reproducibility and repurposing of 3D models as data or digital artifacts for re-use or original creation for XR projects. It is argued that these projects become challenging if scientific and arts-based (e.g., public dissemination) goals are treated equally. Approaches to long-term sustainability and the longevity of digital humanities and arts projects, including digital preservation are needed in future research studies on using 3D models in XR narrative experiences. Ongoing and future research on this project will investigate the identified gaps in existing user studies and further examine how to incorporate new media technologies from both scientific and creative perspectives.

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