Enter the Hindenburg: Experiencing Cultural Heritage by Social Interaction in Hybrid Space

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Abstract. The *Enter the Hindenburg* virtual reality (VR) experience is an immersive installation designed to enhance visitor engagement with cultural heritage through interactive and social elements. Through the reconstruction of the iconic airship Hindenburg, visitors can explore historical narratives in a multi-sensory and embodied way. A key aspect of the experience is its emphasis on social interaction, achieved through cooperative tasks and rich avatar expressions that foster a sense of presence, trust and engagement. In addition, the hybrid presence of a museum guide—who remains in the physical space while interacting with visitors in VR—ensures accessibility while maintaining the authenticity of a human-led narrative. This project is an example on how to integrate immersive technology into museum exhibitions can create dynamic, participatory and socially enriched encounters with cultural heritage and provide experiential learning.

Keywords: Virtual Reality · Cultural heritage · Social interaction.

1 Introduction

The Hindenburg, destroyed on landing at Lakehurst, USA on May 6, 1937, was one of the largest airships ever built (245m long and 41.2m in diameter) and remains a significant artefact of aviation history [30, 8]. Its dimensions make it almost impossible to be physically reconstructed, exhibited, or being directly experienced. These characteristics are shared by many other elements of cultural heritage, which prevents them from being on display [28]. Technologies such as immersive virtual reality (VR) have emerged as powerful tools to fill this gap, capable of recreating objects or environments with a high degree of multi-sensory realism [1]. By creating a virtual version of the LZ 129 Hindenburg airship in an immersive VR environment, we provide an example of how to bridge the gap between past and present for today's audiences. In addition to a realistic recreation of the airship, its virtual exploration is enhanced by an interactive and social experience: Visitors can explore the interior of the Hindenburg through a virtual tour led by a real museum guide, represented in virtual space by a realistic avatar capable of non-verbal communication such as facial movements and gestures. In addition, users can control the airship's navigation with a physical steering wheel and operate its systems collaboratively with other visitors. This interactive experience conveys not only historical facts, but also the lived context and ambience of the past—an aspect of heritage that is difficult to capture through traditional media. Unlike previous projects that focused on passive exploration, this initiative advances (social) interactivity, historical fidelity, and user engagement through improved graphical fidelity, refined usability, and deeper narrative immersion. While AI has played an increasing role in VR heritage projects, this approach prioritizes manual curation, expert-driven reconstructions, and real-time adaptive experiences grounded in empirical research. By emphasizing historical detail, enhanced user guidance, social interaction, and multi-sensory integration, this project sets a new standard for immersive cultural heritage experiences, surpassing traditional VR applications.

2 Background and Related Work

Virtual heritage experiences should be designed to enhance knowledge dissemination and public engagement. As Science7 [25] highlights, integrating digital platforms, interactive devices, and multimedia installations plays a crucial role in interpreting cultural heritage. Empirical studies indicate a strong public interest in VR-based museum experiences. Around 77% of heritage enthusiasts favor virtual access to otherwise inaccessible historical sites and collections [3]. VR is transformative in cultural heritage, improving accessibility, engagement, and historical learning [5, 23, 1]. Museums have also recognized that visitors often learn through shared observations and storytelling during exhibits [3]. Research on mixed reality in cultural heritage emphasizes user engagement models, educational integration, and the role of immersive technologies in preservation and accessibility [32]. AI-driven storytelling enhances engagement through natural language processing, enabling interactive narratives, gamified experiences, and character-driven storytelling [13]. However, VR social interactions, while reflecting real-world norms, differ in appearance and behavior, affecting trust and communication [10]. A key challenge remains the isolation of users in VR, especially in semi-public environments where detachment from the surroundings and loved ones can lead to social disconnection [9]. This isolation may hinder broader acceptance of VR in semi-public spaces. This isolation may hinder the broader acceptance of VR in semi-public spaces. In addition, immersive VR experiences often include virtual humans, either as avatars or as AI-driven embodied agents. Users are expected to engage socially with these virtual characters, and research shows that people do respond socially to them [16]. However, these interactions are not always consistent across different contexts. Despite VR's increasing presence in museums, studies suggest that static reconstructions still dominate over dynamic, user-driven exploration, even though visual and auditory elements significantly shape historical perception [14]. Many museum visitors find interactive, social elements in immersive VR unfamiliar and unintuitive, leading to hesitation in trying them. To address this, onboarding and offboarding concepts from semi-public displays [2] have been adapted for immersive VR [12].

Table 1 presents selected applications that focus on immersive (social) VR in the context of cultural heritage. Each application has been reviewed based on the following criteria: **Embodied Agent**, describing the implementation of virtual agents, such as non-playable characters (NPCs) or virtual guides; **Physical Proxies**, indicating whether physical objects are integrated in combination with immersive virtual reality (iVR) elements; **Audience Funnel**, which considers how the design supports audience engagement and gradual involvement; **User × Agent Interaction**, highlighting the types of social interactions between users and virtual agents; and **User × User Interaction**, which examines the nature of social interactions among users within the virtual environment.

Year	Embodied Agent	Phys. Proxies	Aud. Funnel	User × Agent Interaction	User × User Interaction	Source
2025	Yes	Partial	Partial	Yes	Yes	[6]
2024	Yes	No	No	Yes	No	[17]
2023	Yes	No	No	One-way	No	[18]
2023	No	Yes	Partial	Minimal	No	[29]
2022	Yes	Yes	Yes.	No	Yes	[22]
2021	Yes	Yes	Yes	Partial	No	[27]
2019	No	Yes	Yes	No	Yes	[12]
2018	Yes	n.d.	n.d.	n.d.	n.d.	[24]
2013	Yes	n.d.	No	Text and Speech	Voice only	[15]

Table 1: Overview of immersive (social) VR applications in cultural heritage. N.d. = not defined.

The analysis reveals that the level of interaction with these agents varies, from minimal or one-way interactions to more active, collaborative engagements. While some applications integrate physical proxies and support audience onboarding, such elements remain inconsistently applied across the field. Notably, user-to-user interaction is often absent, pointing to an underexplored potential in the social dimension of virtual heritage environments.

3 Staging, Presentation and Guidance

As VR technology—often combined with agents or avatars—becomes more integrated into museum exhibitions [19], it is crucial to carefully design the entire user experience, from onboarding to offboarding. Brignull and Rogers [2] describes this process as an audience funnel for displays in semi-public spaces, which has been adapted for VR exhibitions by Wölfel et al. [31, 26, 12].

1. **Negative experiences from earlier HMD usage**: Older devices, such as Cardboard HMDs, lacked high refresh rates and precise tracking, often causing motion sickness.

2. **Leap into the unknown**: Some individuals hesitate to engage with HMDs due to unfamiliarity or concerns about disorientation. Presenting the virtual content already before the immersive VR experience can lower the fear by providing a hint on what to expect and allowing to accommodate before the experience.

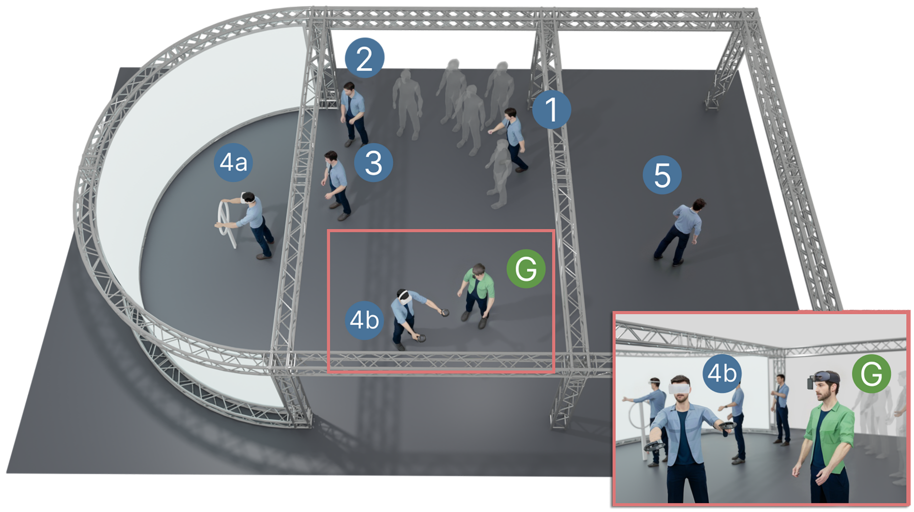

Fig. 1: The Hindenburg VR Audience Funnel. 1: Passer-By, 2: Spectator, 3: Explicitly Interacting User, 4a: HMD User - Flight, 4b: HMD User - Tour, 5: Offboarding and Follow-Up Action, G: Guide

An adapted version of the audience funnel is presented in Fig. 1 with modifications between stages 3 to 5, as no implicit interaction was implemented in this installation. Furthermore, the role previously defined as someone who interacted alongside or assisted the HMD user (stage 7) has been reconceptualized into that of an official guide ("G" highlighted in green in Fig. 1), emphasizing active support as well as knowledge transfer during the immersive experience. A newly introduced intermediate stage emphasizes the transition from flying (stage 4a) to exploring (stage 4b) the Hindenburg while staying in immersive VR. The individual steps are described in more detail next:

- **Onboarding (Stages 1-3):** Before entering the VR environment, visitors are introduced to the experience using a 180° widescreen canvas in the physical exhibition space (see Fig. 2c and Fig. 2d for details). This onboarding process shows the historic hangar in which the Hindenburg was built and prepares the user for the switch to VR. The onboarding phase corresponds to users one to three from Section 3. The duration of onboarding is dynamic and takes as long as it takes for the previous employee to arrive in the engine room.

- **VR Experience (Stage 4):** As soon as the user puts on the head-mounted display and touches the steering wheel, the VR experience begins.
  - **Flight (Stage 4a):** Once aboard the Hindenburg, visitors find themselves in the airship cockpit. During the simulated flight over Lake Constance, which is streamed in real-time using satellite data from Cesium[3], users receive optional detailed information about the airship, while they can steer the Hindenburg using a physical steering wheel (see Fig. 2d), whose rotation is tracked with a Vive Tracker and substituted to VR. The flight will also be broadcast on the 180° screen for potential spectators. As shown in Fig. 1, while user 4a acts as the pilot in the cockpit, user 4b controls altitude and speed from the engine room. Communication between the two roles supports coordinated interaction. This interaction makes a significant difference to engagement and enhances the experience [20]. The control setup is adapted for simplicity and no replicate of the original mechanisms of the Hindenburg, yet follows its baseline concept.
  - **Dining Room (Stage 4b):** As part of the flight sequence, visitors enter the Hindenburg's dining room. The room offers historical information in a passive learning format while displaying the surrounding virtual landscape. The environment replicates the interior design of the original airship.
  - **Navigation and Communication (Stage 4a and 4b):** The second visitor, located in the engine room, is responsible for managing the airship's acceleration and deceleration. Communication with the pilot enables synchronized navigation. Informative elements embedded in the scene convey the functional principles of propulsion and altitude control. This role is simplified for usability but maintains instructional value.
- **Offboarding and Follow-Up Action (Stage 5):** After the VR experience ends, visitors are guided through an offboarding phase that transitions them back into the real-world museum environment. This process allows for reflection and discussion, concluding the experience in a structured and accessible manner (see Section 3 for more details on the audience funnel), and might trigger follow-up actions such as posting about the installation in social media.

Our adaptations ensure a seamless transition of passersby and spectators into becoming HMD users by providing an external visualization of the VR experience. This is achieved through a 10×2m, 180° projection wall, which displays the in-VR perspective from a third-person view as well as an onboarding procedure, allowing for cognitive accommodation before using the headset. By offering this early-stage exposure, we lower the psychological barrier associated with stepping into an unfamiliar virtual environment, enabling visitors to make an informed

[3] https://cesium.com/

decision about their engagement. Furthermore, by integrating physical objects, such as a steering wheel, into the VR experience, we establish a rest-frame, which plays a crucial role in spatial orientation and sensory grounding. The presence of a tangible reference point helps mitigate sensory dissonance, reducing the risk of motion sickness and enhancing proprioceptive feedback. Additionally, the steering wheel serves as an intuitive interaction interface, leveraging existing motor skills and muscle memory, thus reducing cognitive load and increasing immersion. This multi-sensory integration also facilitates a stronger sense of agency, allowing users to feel more connected to the virtual environment while maintaining a stable point of reference in physical space. By combining third-person visual previews with haptic and proprioceptive anchors, we create a gradual onboarding process that enhances user comfort, minimizes cybersickness, and fosters a more intuitive and immersive VR experience, particularly in semi-public spaces where immediate user adaptation is essential.

4 Social Interaction

Incorporating social interactions into cultural heritage VR experiences allows visitors to better connect with the environment, the guide, and each other. It fosters a greater sense of presence and immersion for visitors. It encourages deeper engagement by making the experience feel more personal and relevant, improves memory retention by linking actions to social contexts, and supports experiential learning. In addition, social interaction can motivate participation because shared experiences often feel more meaningful and enjoyable.

4.1 Guiding Avatar

The guiding avatar, which has no influence on preserved presence [4], in the VR experience serves as a virtual embodiment of the museum guide, enhancing the visitor's social presence and engagement. Created from a refined 3D scan of the guide, the avatar acts as a knowledgeable companion, providing historical context, explaining visual elements, and sharing stories about the Hindenburg and Zeppelin heritage. His consistent presence in each scene ensures a cohesive narrative, provides intuitive guidance, and fosters a deeper emotional connection so that visitors feel accompanied throughout the experience, enhancing immersion and reducing the sense of isolation within the virtual space. For the avatar to be effective, it must appear lifelike to avoid the discomfort associated with the uncanny valley—a phenomenon where an almost human-like figure causes discomfort [11]—and must resemble the actual museum guide to provide familiarity.

4.2 Hybrid Presence

A deliberate design choice was made to keep the real-world guide outside the virtual environment, preventing motion sickness and fatigue from prolonged VR use [7]. Instead, the guide interacts with both VR and non-VR visitors using 2D screens that display the VR experience, allowing seamless engagement across both realms. This hybrid approach enhances accessibility and inclusivity. The guide can support VR visitors while simultaneously engaging with non-VR visitors, e.g. during a group tour, broadening the exhibit's impact.

To preserve the visual appearance of the museum guide, we digitally recreated him one-to-one for the VR experience as described in [21] add back in after accepted. The actual guide remains outside the virtual world to ease the onboarding process and to avoid the physical strain that would result from working all day in VR. This allows for interactions with people in both the real and virtual worlds. Using an iPhone with *FaceID* capability (iPhone X onwards) and Unreal Engine's LiveLink, facial expressions and lip movements are streamed into the VR experience in real time, providing 52 Apple ARKit blend shape values. To avoid holding the iPhone, a custom helmet (see Fig. 2b) was designed to position the device directly in front of the user's face. A Vive tracker was mounted on the helmet to transmit head position and orientation. In addition, two Vive controllers are used to animate the avatar's arms using inverse kinematics and to control the experience (e.g., changing scenes). As a result, the guide's gestures and facial expressions are accurately mirrored by the avatar, allowing for intuitive non-verbal communication, such as pointing out significant elements in the VR environment.

4.3 Joint Interaction and Cooperation in VR

In our application, visitors immersed in VR could step into the historical roles of workers and pilots. This approach allows them to gain a deeper understanding of concrete historical practices and challenges, bringing the cultural experience closer to them. Active participation in these roles transforms passive observation into immersive exploration, resulting in memorable and meaningful experiences. The experience integrates multiple interaction points with the virtual guide. Two key sequences are designed to foster engagement and deepen understanding of the historical context:

- **Zeppelin steering:** In this stage, users act as pilots, steering the Zeppelin using a real-world wheel (for yaw) and joystick buttons (for climb and descent), reflecting the airship's original rudder and elevator controls.
- **Board communication:** The engines and thus the Hindenburg's airspeed were controlled manually from the engine room, based on commands by telephone from the wheelhouse. Two visitors, as pilot and engine operator, interact verbally while steering. This fosters collaboration and shared problem-solving.

Throughout these stages, the guide's avatar facilitates social interaction, ensuring visitors receive guidance and support. The design encourages authentic collaboration, reinforcing a shared sense of presence.

Using realistic tracking technologies and a hybrid presence ensures visitors feel connected and engaged. The guide's ability to interact across virtual and physical spaces enriches the social dynamics and reinforces the cultural narrative. Ultimately, this approach fosters a shared sense of presence, ensuring the experience is both educational and memorable.

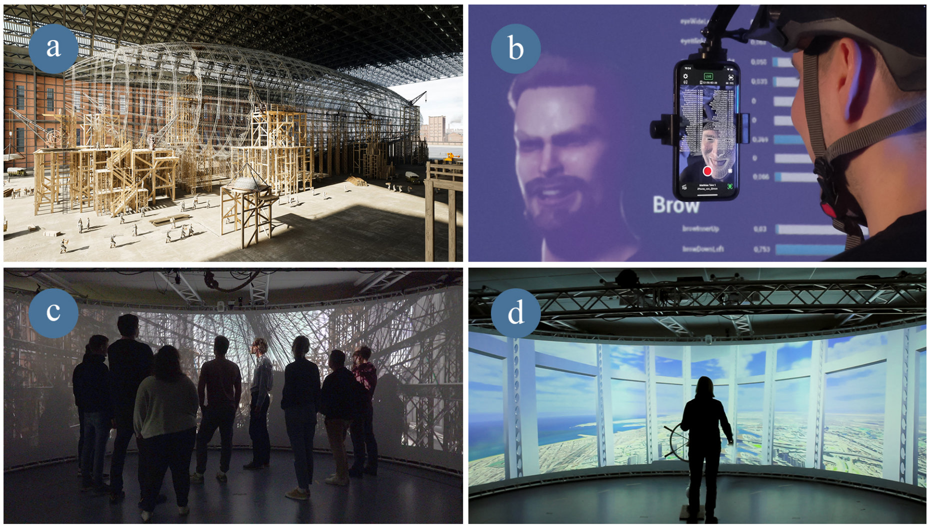

Fig. 2: a) Hindenburg Skeleton b) Guide wears helmet with iPhone c) Onboarding for the VR experience. (Image courtesy of Jan Holthaus - Used with permission) d) Visitor controls Hindenburg in VR with real-time view for bystanders

5 Implementation Details

We created the content for the VR experience using Blender 4.3 and Unreal Engine 5, enabling high-fidelity visuals and real-time lighting through Nanite[4] and Lumen[5] technologies.

- **Hindenburg:** Using detailed construction sketches from the Zeppelin Museum Friedrichshafen[6], we modeled the aluminum skeleton in Blender (see Fig. 2a), making minor simplifications such as triangular instead of square struts or by using transparent textures instead of holes in the 3D model, which reduces the number of polygons from 4.8 million to 3.1 million.
- **Hangar:** While the actual hangar stood in a large, open area, we decided to place some industrial buildings in the background to block the view of the

[4] https://dev.epicgames.com/documentation/unreal-engine/nanite-virtualized-geometry-in-unreal-engine
[5] https://dev.epicgames.com/documentation/unreal-engine/lumen-technical-details-in-unreal-engine
[6] https://www.zeppelin-museum.de/en

horizon and prevent rendering problems such as shadow distance. The proportions, construction, and materials were taken one-to-one from the actual model. Throughout the entire experience, the Hindenburg is shown from the outside without the outer skin to give a more impressive visual impression. Due to fear of heights, we have equipped some of the positions with railings to ensure a comfortable experience for all visitors.

6 Discussion

The Hindenburg VR experience successfully demonstrates how immersive technologies can bridge the gap between past and present, providing visitors with an interactive, social and historically rich environment. The introduction of social interaction and cooperative tasks provides an opportunity to deepen engagement, but also presents usability challenges. One notable social challenge is that individuals are often reluctant to engage with new tasks or technologies if they feel observed by others [9]. This issue is particularly relevant in VR, where viewers can observe the HMD user, but the user typically cannot see them [9]. To mitigate this, we implement a gradual onboarding process and encourage social interaction among multiple visitors within the virtual environment. In addition, the 180° display engages the audience in the narrative. Future versions of the project will also include a self-embodiment of the visitor to increase presence, but also to facilitate interaction with the objects. The hybrid presence of the museum guide, remaining in the physical space while interacting with virtual visitors, is a novel approach that could improve user engagement while maintaining accessibility for less tech-savvy visitors. However, the multitasking of managing experiences in VR and non-VR simultaneously can still be exhausting for the tour guide. To address this challenge, the guide's interactions in VR could be partially replaced by an AI agent, and the guide would only become active when needed.

7 Conclusion and Future Work

In conclusion, by introducing the concept of hybrid social avatars, this project has made significant progress in enhancing VR experiences in cultural heritage contexts. With this approach, we aim to enable trained experts to seamlessly engage with museum visitors within the virtual reality environment, requiring minimal additional training for the guides. The presence of a knowledgeable guide in VR not only enhances the perceived authenticity of the experience, but also has the potential to improve visitor engagement and learning outcomes by facilitating contextualized, real-time interactions. In addition to direct interaction with the guide, HMD users will also have the opportunity for social engagement by collaboratively controlling and operating the airship. The 180° screen provides a gradual onboarding process that aligns with audience funnel theory, reducing visitors' apprehension about new technologies and unfamiliar interactions common to HMD use in museums. The current setup opens up several areas for further exploration. Specifically, we plan to extend the user experience by incorporating two additional interactive stages: first, visitors will operate a physical controller to steer a crane and virtually assist in the construction of the Hindenburg. Second, visitors will have the opportunity to paint and personalize the outer shell of the airship, leaving their unique mark on the exhibit and fostering a stronger emotional and personal connection to history. Finally, there are distinct advantages to exhibiting such experiences in museums, which provide physical and social contexts that enhance virtual interactions and enrich visitors' understanding and appreciation of historical narratives in ways that purely digital or remote exhibitions cannot replicate.

References

1. Alabau, A., Fabra, L., Martí-Testón, A., Muñoz, A., Solanes, J.E., Gracia, L.: Enriching user-visitor experiences in digital museology: Combining social and virtual interaction within a metaverse environment. Applied Sciences **14**(9), 3769 (Apr 2024)
2. Brignull, H., Rogers, Y.: Enticing people to interact with large public displays in public spaces. In: Proceedings of INTERACT. vol. 3, pp. 17–24 (2003)
3. Bruce, F., Pittock, M., Liu, H.: Museums in the metaverse: Audiences and impact report (2024)
4. Butz, M., Hepperle, D., Wölfel, M.: Influence of Visual Appearance of Agents on Presence, Attractiveness, and Agency in Virtual Reality, p. 44–60. Springer International Publishing (2022)
5. Chong, H.T., Lim, C.K., Rafi, A., Tan, K.L., Mokhtar, M.: Comprehensive systematic review on virtual reality for cultural heritage practices: coherent taxonomy and motivations **28**(3), 711–726
6. Chrysanthakopoulou, A., Chrysikopoulos, T., Arvanitis, G., Moustakas, K.: Reimagining historical exploration: Multi-user mixed reality systems for cultural heritage sites. Applied Sciences **15**(5), 2854 (2025)
7. Dennison, M.S., Wisti, A.Z., D'Zmura, M.: Use of physiological signals to predict cybersickness. Displays **44**, 42–52 (2016), contains Special Issue Articles – Proceedings of the 4th Symposium on Liquid Crystal Photonics (SLCP 2015)
8. Dick, H., Robinson, D.: The golden age of the great passenger airships: Graf Zeppelin and Hindenburg. Smithsonian Institution (1992)
9. Eghbali, P., Väänänen, K., Jokela, T.: Social acceptability of virtual reality in public spaces: experiential factors and design recommendations. In: Proceedings of the 18th International Conference on Mobile and Ubiquitous Multimedia. p. 1–11. MUM 2019, ACM (Nov 2019)
10. Han, E., Bailenson, J.N.: Social interaction in vr (05 2024)
11. Hepperle, D., Purps, C.F., Deuchler, J., Wölfel, M.: Aspects of visual avatar appearance: self-representation, display type, and uncanny valley. The Visual Computer **38**(4), 1227–1244 (2022)
12. Hepperle, D., Siess, A., Wölfel, M.: Staging Virtual Reality Exhibits for Bystander Involvement in Semi-public Spaces, p. 261–272. Springer International Publishing (2020)
13. Hettmann, W., Wölfel, M., Butz, M., Torner, K., Finken, J.: Engaging museum visitors with ai-generated narration and gameplay. In: Brooks, A.L. (ed.) ArtsIT, Interactivity and Game Creation. Springer Nature Switzerland, Cham (2023)

14. Izaguirre, J.I., Ferrari, A.A., Acuto, F.A.: Exploring cultural heritage and archaeological research from a vr-based approach. Digital Applications in Archaeology and Cultural Heritage **32**, e00318 (2024)
15. Kennedy, S., Fawcett, R., Miller, A., Dow, L., Sweetman, R., Field, A., Campbell, A., Oliver, I., McCaffery, J., Allison, C.: Exploring canons & cathedrals with open virtual worlds: The recreation of st andrews cathedral, st andrews day, 1318. In: 2013 Digital Heritage International Congress. p. 273–280. IEEE (2013)
16. Kyrlitsias, C., Michael-Grigoriou, D.: Social interaction with agents and avatars in immersive virtual environments: A survey. Frontiers in Virtual Reality **2** (2022)
17. López García, I., Schott, E., Gohsen, M., Bernhard, V., Stein, B., Fröhlich, B.: Speaking with objects: Conversational agents' embodiment in virtual museums. In: Proceedings of IEEE International Symposium on Mixed and Augmented Reality (ISMAR). pp. 279–288 (2024)
18. Lucifora, C., Schembri, M., Poggi, F., Grasso, G.M., Gangemi, A.: Virtual reality supports perspective taking in cultural heritage interpretation. Computers in Human Behavior **148** (2023)
19. Machidon, O.M., Duguleana, M., Carrozzino, M.: Virtual humans in cultural heritage ict applications: A review. Journal of Cultural Heritage **33** (Sep 2018)
20. Pallud, J.: Impact of interactive technologies on stimulating learning experiences in a museum. Information and Management **54**(4), 465–478 (Jun 2017)
21. Purps, C.F., Janzer, S., Wölfel, M.: Reconstructing Facial Expressions of HMD Users for Avatars in VR, p. 61–76. Springer International Publishing (2022)
22. Reimat, I., Mei, Y., Alexiou, E., Jansen, J., Li, J., Subramanyam, S., Viola, I., Oomen, J., Cesar, P.: Mediascape xr: A cultural heritage experience in social vr. In: Proc. ACM Multimedia (MM 22) (2022)
23. Rizvic, S., Boskovic, D., Mijatovic, B.: Advanced interactive digital storytelling in digital heritage applications. Digital Applications in Archaeology and Cultural Heritage **33**, e00334 (Jun 2024)
24. Schofield, G., Beale, G., Beale, N., Fell, M., Hadley, D., Hook, J., Murphy, D., Richards, J., Thresh, L.: Viking vr: Designing a virtual reality experience for a museum. In: Proceedings of the 2018 Designing Interactive Systems Conference. DIS18, ACM (Jun 2018)
25. Science7 Academies: Cultural heritage – science for the future (2024), accessed: 2025-03-20
26. Siess, A., Hepperle, D., Wölfel, M., Johansson, M.: Worldmaking: Designing for Audience Participation, Immersion and Interaction in Virtual and Real Spaces, p. 58–68. Springer International Publishing (2019)
27. Testón, A.M., Muñoz, A.: Digital avatars as storytellers to produce natural and humanized museum visits with extended reality. In: MW21: MW 2021 (2021)
28. UNESCO Institute for Statistics: Cultural heritage (2009), accessed: 2025-03-18
29. Vishwanath, G., Diaz-Kommonen, L., Svinhufvud, L.: Citizen curation of digital cultural heritage through the co-design of a virtual reality museum. In: INTETAIN 2023 (Demo track). p. 1–4 (ext. abstract) (2023)
30. Waibel, B.: Das Zeppelin-Luftschiff LZ 129 Hindenburg. Sutton Verlag GmbH (2012)
31. Wölfel, M., Hepperle, D., Siess, A., Deuchler, J.: Staging location-based virtual reality to improve immersive experiences. EAI Endorsed Transactions on Creative Technologies **6**(21), 163221 (Feb 2020)
32. Zhang, J., Wan Yahaya, W.A.J., Sanmugam, M.: The impact of immersive technologies on cultural heritage: A bibliometric study of vr, ar, and mr applications. Sustainability **16**(15) (2024)