

Multi-Level Interactions in Metaverse Museums: From Digital Avatars to Immersive Cultural Narratives^{*}

Liliana Cecere^{1,†}, Simone Pierre Dembele^{2,†}, Muhammad Khan^{1,†}, Angelo Lorusso^{1,*,†}, Domenico Santaniello^{1,†} and Carmine Valentino^{3,†}

¹University of Salerno, Fisciano (SA) 84084, Italy

²University OF Tartu, Ülikooli 18, 50090 Tartu, Estonia

³University of the West of England, Bristol, UK

Abstract

The metaverse is emerging as a novel domain for digital interaction, transforming accessibility and the cultural experience. Virtual museums transcend the physical constraints of conventional museums, providing immersive and dynamic experiences. This research seeks to analyse the benefits and problems presented by the metaverse by investigating spatial iterations and the influence of access devices on the user experience within museums. Virtual environments may emulate or transform actual settings, eliminating geographical constraints and leveraging digital capabilities to provide unique experiences, including animated artwork and interactive narratives. The devices employed substantially affect the experience: PCs, equipped with VR headsets and sophisticated peripherals, provide immersion and accuracy; smartphones, constrained by their small displays, excel in accessibility; tablets compromise portability and performance, yet are inferior to PCs regarding precision. The quality of internet connectivity is essential; mobile connections may induce delay, undermining fluidity and collaborative activities. User engagement varies from passive exploration to active cooperation, including artefact reconstruction. Advanced technologies facilitate intricate interactions, whereas portable devices promote simpler, more intuitive tasks. Moreover, social interactions inside the metaverse rely on non-verbal cues and interface ergonomics, underscoring the necessity of creating inclusive and flexible digital settings. In conclusion, the metaverse presents a distinctive chance to democratise cultural access, transcending traditional borders and fostering global interaction. Tailoring design and infrastructure may enhance accessibility and significance for everyone.

Keywords

Metaverse, Cultural Heritage, Human Computer Interaction

1. Introduction

In recent years, the metaverse has emerged as a fascinating digital horizon and a transformative platform for culture. New multimodal technologies are turning actual settings into virtual ones. Cultural heritage (CH) uses XR technologies to attract visitors and encourage repeat visits, making heritage content more engaging, immersive, and meaningful[1]. Digital museum spaces overcome the physical limitations of traditional museums and introduce dynamic, immersive, and interactive experiences. They also serve as a powerful medium for the narration and preservation of CH, enabling a richer and more detailed understanding of past civilisations and cultural narratives[2].

User interaction in virtual museums is vital to optimise the cultural, educational, and social effects of digital experiences. Indeed, it is the key to turning virtual museums into interactive, learning, and innovative hubs. Museums can encourage passive exploration or active engagement in collaborative activities like artefact reconstruction or instructional games. The type of museum, its geometry and spatial organisation, and the device used affect the nature of these interactions: smartphones favour intuitive and straightforward interactions, PCs allow for more complex activities due to superior computational capabilities and systems, and tablets facilitate moderately complex interactions[3, 4]. The metaverse offers 3D avatars that match the user's features, unlike previous digital worlds that

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^{*}Corresponding author.

[†]These authors contributed equally.



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recognised users by ID and username[5].

Standard avatars are no longer enough in the metaverse; therefore, the metahuman is born. DT, our metahuman, allows us to reside in virtual realms and experience our motions and expressions in real time. Due to machine learning algorithms, these synthetic people may mirror our moods, sentiments, and personalities. Modern technology allows users to customise their metaverse interlocutors, which has been demonstrated to increase satisfaction and engagement, self-esteem, and spontaneous assistance. Social and communication dynamics are becoming increasingly complicated and a subject of research and attention. In virtual worlds, non-verbal signs, body movement, dialogue pauses, and facial expressions affect communication with other users[6, 7].

This study examines the multiple dimensions of spatial iterations in the metaverse, using digital museum environments as an example. It analyses the user's interaction with the museum space, the artworks within it, and the connections that may form between users or groups of users. It also examines how avatar experience—novice, expert, or museum guide—affects the activity. Finally, access devices' effects on user experience, virtual environment perception, interactivity, and engagement are examined.

2. Related Work

Recently, academic articles on the metaverse have increased due to rising interest. Academic and non-academic scholars have studied the new virtual worlds, applying their findings to real-world circumstances. In , a Mars-themed virtual exhibition environment was constructed to enable social interactions between participants using avatars, mimicking video game dynamics. Using avatars to navigate[8]. Virtual exhibition spaces in the metaverse are being adopted due to the advancement of cutting-edge technologies and museums' desire to offer visitors more engaging, dynamic, and interactive activities and experiences to enhance exhibitions. These environments inspire people to interact with exhibitions and each other, building community and shared learning[9]. The authors' planned approach in for future museums allows visitors to virtually 'walk' through historical sites and interact with detailed reconstructions of significant events, allowing them to explore rare artefacts and fragile ecosystems without risking damage and enriching knowledge. VR and holographic technology have also improved museum and educational visitor engagement and learning. In, the authors proposed hand gesture-based content control to increase holographic display usability[10].

Meanwhile, VR-based 3D modelling and museum interaction technologies have increased visitor satisfaction and engagement. Museums' audience engagement has changed due to digital technology. Online materials and digital access allow museums to transform visitor interaction and learning. According to, VR technology improves users' experience of spatial presence, which is crucial for immersive VR applications. Avatars provide real-time social interactions between users, facilitating involvement across geographical and physical boundaries[11, 12]. Thus, visitors can browse exhibitions, take guided tours, and connect with users worldwide as if they were in the same spot[13].

Many have studied avatars and their Metaverse interactions to engage users. Due to its prominent role, many platforms have included avatar functionality to enhance users' virtual experiences. Roblox employs more realistic 3D animated avatars that can vibrantly communicate emotions. Users can choose an avatar from different degrees of realism [30]. Zepeto, a platform that promotes self-expression and social interaction, lets users personalise their avatars with hairstyles, makeup, accessories, clothing, and footwear. Due to its adaptability, Zepeto has enhanced user engagement and virtual interactions[14]. These examples demonstrate how avatars are crucial to metaverse social interactions. Realism, for social interactions in a computer-mediated environment, avatars should reflect the person's appearance and behaviour; anthropomorphic avatars are more believable and attractive to users.

3. The interaction in metaverse

As the metaverse rapidly evolves as a new immersive space, avatars are revolutionising virtual world interaction, allowing people to relate, work, and have fun differently. Despite their conceptual similarity, avatars and metahumans differ in their characteristics, use, and complexity. Metahumans, sophisticated digital models created using photogrammetry, artificial intelligence, and motion capture, are a step beyond avatars. Motion capture accurately recreates metahumans' skin textures, facial expressions, and body movements. Motion capture uses special suits with markers (active or passive), sensors, and multiple cameras to capture body and facial movements.

After processing the movement data, specialised software creates a digital skeleton replicating the movements. Then, the recorded movements are applied to an avatar or metahuman. Metahuman creation and use are still rare due to their complexity and cost. Avatars' simplicity, intuitiveness, and accessibility have led to more metaverse use. Avatars, though simpler, allow users to choose aesthetic aspects like body shape, clothing, accessories, and, in some cases, movements and behaviour, and are used in community settings to improve social interaction and collaboration. Avatars can explore environments and reinvent museum spaces in the virtual museum context. Avatars can be customised to represent visitors and explore spaces, linger over works, participate in guided experiences, or be museum guides. In this context, avatars can be analysed on three levels: avatar-environment, avatar-artworks, and avatar-avatar.

Avatar-museum interaction depends on the museum space, architecture, and exploration. Depending on the desired experience, one can create paths that users must follow or leave free to move around. Dynamic spaces like exhibition halls or interactive museum areas can be fully experienced by using interactive screens, activating multimedia content like audio, video, or projections, or opening doors or changing the layout. In addition, metaverse museums can highlight extraordinary architecture, allowing avatars to 'fly', teleport, or change perspective to see hidden details.

The metaverse's most engaging interaction is between avatars and art. Most traditional museums limit interaction to preserve the CH on display and respect its historical and artistic value. Visual observation is the only interaction allowed. Visitors cannot create any creative interaction with the work. Still, they can analyse it from different angles to understand its details and meanings, whether sculpture, paintings, or pictures. Thus, real museums prefer non-invasive viewing and prohibit touching and flash photography to avoid damage from wear and tear, fingerprints, and external agents.

With virtual spaces, this perspective and visitors' approach to the works on display change drastically. Metaverse museums offer more creative possibilities for interacting with paintings and sculptures than traditional museums due to the digital nature of the works and the lack of physical constraints. In the metaverse, avatars allow users to explore works more closely. All metaverse three-dimensional reproductions can be rotated, enlarged, and lifted up to see hidden details.

Technology offers many possibilities for paintings: as the avatar passes by, paintings can be activated to show animations, stories, or explanations about the work and its historical context; visitors can click on specific points in the painting to learn more about symbolic or technical details; and even analysis techniques can be simulated to show elements not visible to the human eye. Avatars can also change colours or add temporary elements to show how artistic choices affected the work and its perception. In the metaverse, ancient vases, tools, and utensils become living, interactive objects, helping us understand their function, history, and cultural significance.

Users can visualise vases or tools in historical simulations to understand their use and context. Simulations allow avatars to hold a Neolithic axe and cut virtual wood, experiencing the ergonomics of the object, or manipulate fragments of an object to reconstruct it, as with fragmented vases found in archaeological excavations. The metaverse lets us see how objects looked new, before age and damage. In these cases and in painting, the level of detail can be infinitely expanded, allowing us to see engravings, cracks, wear, and microscopic decorations that are not visible in real life. Clicking on a vase may reveal an animated scene of a potter or an ancient banquet. Visitors can learn about an object's creator, technology, and historical context. Prehistoric animal traps and pottery wheels can be animated to show how they were used.

Like in reality, avatars can dynamically interact in the metaverse, making museums places of cultural and social exchange. These interactions can be enhanced by digital tools that foster community and active participation. Avatars can talk about art, history, and socialising. This builds community and bonds between visitors and enthusiasts beyond temporal and geographical barriers. Metaverse museums can host conferences, artistic performances, and workshops where avatars interact with experts, artists, and other visitors to build relationships. In interactive activities, avatars can collaborate and communicate via text, audio, or digital gesture chat. To enhance the interaction, they can tilt their head to show interest or raise a hand to ask questions.

Changing avatars or groups of avatars affects their roles in museum spaces, shaping the collective experience. Avatars can guide visitors through exhibits and explain works and historical contexts. Humans or artificial intelligences can interact naturally with these avatars to tailor content to visitors. Other avatars can play artists and use virtual spaces to exhibit their digital works, perform immersive performances, or interact with the public to explain their creations. Directly communicating with the public lets them explain their work, answer questions, and get real-time feedback. Guest avatars, or museum visitors, can freely explore the spaces, interact with the art, participate in discussions, or be guided by others.

Turns of speech are one of avatar interaction's most intriguing and complicated aspects. Turns of speech are how conversation participants alternate speaking and listening without overlapping. It underpins real-world and virtual interpersonal communication. This alternation follows implicit or explicit rules that vary by context, communication method, and culture to avoid overlap. Real-world characteristics and signs indicate a round passage. In a conversation, the speaker uses verbal and nonverbal cues like a change in intonation, a pause, or a look to suggest that they are about to give up, while the listener can use hand gestures or facial expressions to take the floor. These signals are easily recognisable in real life, which can cause significant issues in the virtual world. Technological factors and interface characteristics change word turns in virtual spaces like the metaverse. These environments present unique face-to-face communication challenges. One of the biggest challenges is the lack of complete non-verbal cues. Virtual environments often lack eye contact, facial expressions, and gestures, making it harder to manage natural speech turns, leading to awkward pauses or overlaps in a conversation. Thus, effective speaking turn management in virtual museums promotes inclusivity, allows everyone to express themselves, improves communication, and reduces social inertia.

Artificial intelligence systems can assign speaking turns based on the order of requests, the length of previous speeches, or the perceived importance of the contribution. In addition, shift request systems can be added to online and video call apps so users can "raise a virtual hand" or request to speak through the interface. Requests are displayed chronologically for fair distribution. Your avatar could also indicate your desire to talk visually or audibly. Indeed, raising an arm or moving the head can signal the other players to stop. In the case of large groups of avatars, such as guided museum tours or conferences, artificial intelligence can monitor and manage interactions by analysing who has spoken, their speech length, and the order of requests. To make interactions more straightforward, visual indicators like lights or icons can indicate who is speaking or queuing to intervene.

4. Case Study Application

In conclusion, metaverse museums have changed how art and culture are experienced, combining technology, human interaction, and experiential design. These virtual environments can overcome physical and geographical barriers and make CH accessible to global audiences. Users can inhabit dynamic three-dimensional spaces, customise their avatars to express themselves, and interact with artworks using interactive tools beyond traditional museums. Animations, narratives, and additional content enhance the aesthetic experience and encourage active participation and collaboration in digital works.

These spaces have potential but also drawbacks. These spaces require high-speed internet, compatible devices, and digital skills, which are not widely available. VR headsets and other immersive tech-

nologies are expensive, which can limit access in educational or resource-poor settings. Additionally, scalability and accessibility must be integrated throughout development. Despite this, the metaverse offers possibilities beyond geography. Hybrid storytelling, gamification, and education can happen in virtual museums. Users collaborate to solve historical puzzles, reconstruct artefacts, and participate in thematic debates to create cultural meaning.

Deeper learning is promoted by stimulating individual and collective creativity. The constant evolution of virtual headsets, VR, and AR devices promises to make the experience more fluid, immersive, and interactive. Finally, the metaverse iteration redefines audience, art, and space, making the museum a dynamic ecosystem. Virtual museums are more than just places to visit; they create global communities where people and technology come together to enhance the cultural experience and create new connections, learning, and inspiration.

5. Declaration on Generative AI

During the preparation of this work, the author(s) used GPT in order to: Formatting assistance. After using these tool(s)/service(s), the author(s) reviewed and edited the content as needed and take(s) full responsibility for the publication's content.

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