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Krishnasamy, Rameshnath; Vistisen, Peter; Nikolic, Lana Tankosa ; Hemmingsen, Lars; Scarpelli, Martina

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The Meta-stage: Utilizing Metaverse-Enabling Technologies for Hybrid Co-Presence Experiences

Rameshnath Krishnasamy¹[0000-0002-5144-8388], Peter Vistisen¹[0000-0002-9194-2946], Lana Tankosa Nikolic², Lars Hemmingsen² and Martina Scarpelli²

¹ Aalborg University, Rendsburggade 14, 9000 Aalborg, Denmark

² White Hole Theater, Ammunitionsvej 4, 8800 Viborg, Denmark

Abstract. This paper introduces the concept for ‘The Meta-stage’ – a concept for live performance arts through the so-called ‘Metaverse’. The Metaverse can be seen as the effort to further facilitate the digital transformation in a scale potentially comparable to the WWW protocol - a vision of an immersive Internet as a unified, persistent, and shared space, with the Meta-stage being a subsequent specialized part of this whole. The paper introduces how the iterations of the Meta-stage have evolved, and how the engagement with the cultural sector, including performing and visual arts such as theater and live performances with an audience, is becoming entangled in the Metaverse. Through a research-through-design overview, the paper explores, which design principles can be established for cultural and public events in the Metaverse?

Keywords: Hybrid Co-Experience, Extended Reality (XR), Metaverse.

1 Introduction

The term 'Metaverse' finds its origin in Neal Stephenson's 1992 science fiction novel, 'Snow Crash,' where it denotes a virtual reality space in which users engage within a computer-generated environment (Stephenson, 1992). Despite the widespread use of this term, a universally accepted definition of a metaverse remains elusive, with interpretations varying from a lifelogging space to a mirror world (Almoqbel et al., 2022; Benedikt, 2008; Narin, 2021).

While some conceptualize the metaverse as an ideal vision yet to be fully actualized (Metaverse Standards Forum, 2022; Radoff, 2021; Zyda, 2022), others interrogate how this vision aligns with the virtual worlds that have been the focus of academic study for decades (Almoqbel et al., 2022). The Metaverse is often juxtaposed with a future vision of the internet that transcends the static pages of the World Wide Web, evolving into a dynamic and increasingly immersive environment facilitated by technologies that merge physical and virtual spaces. This transformative initiative endeavors to construct a metaverse where individuals can engage in real-time interactions with both each other and computer-generated environments. Thus, the 'metaverse' signifies an extensive, immersive virtual environment, though its exact definition remains fluid and warrants further investigation.

In their paper, 'Defining the Metaverse: A Systematic Literature Review' (Ritterbusch & Teichmann, 2023) Georg David Ritterbusch and Malte Rolf Teichmann describe the metaverse as a three-dimensional online environment wherein users interact within virtual spaces independent of the real world. This description aligns with various academic definitions, both past and current, (Almoqbel et al., 2022; L.-H. Lee et al., 2021; Mystakidis, 2022; Ritterbusch & Teichmann, 2023). Through a comprehensive literature review, they propose the following definition:

Metaverse, a crossword of “meta” (meaning transcendency) and “universe”, describes a (decentralized) three-dimensional online environment that is persistent and immersive, in which users represented by avatars can participate socially and economically with each other in a creative and collaborative manner in virtual spaces decoupled from the real physical world (Ritterbusch & Teichmann, 2023, p. 12373).

We use this concise definition as a starting point for understanding the state of the technical and technological arenas in which the current conception of the term Metaverse is situated. Although the concept of a Metaverse can be captured in the definition above, the full potential remains uncertain and undetermined, yet to be examined and explored. In other words, a *true* Metaverse does not yet exist, as none of the existing virtual worlds are sufficiently decentralized or support a creator economy to a significant degree, which is repeated as core parts of realizing a Metaverse (Almoqbel et al., 2022; Metaverse Standards Forum, 2022; Ritterbusch & Teichmann, 2023). Although the infrastructure is not yet fully developed, it is clear that the Metaverse and the broad field of standalone and interconnected technologies are already present in many different contexts (Ritterbusch & Teichmann, 2023). Emerging technologies such as Extended Reality, 5G connectivity, and Artificial Intelligence have moved the frontier of the Metaverse closer at an increasing speed (S.-M. Park & Kim, 2022; Wang et al., 2022). This technological development is parallel to the increasing level of interest and investment from big tech corporations (Kraus et al., 2022; Rospigliosi, 2022). This engagement entails, that while the fully operationalized vision of the metaverse has yet to be developed, and corporations still have no definitive proposal for how to adopt and collaborate across (still) proprietary platforms, the next frontier of the internet is on the horizon.

Given the recent surge in interest and media attention, it is sensible to explore individual potentials to inform a unified Metaverse infrastructure. This paper directs its focus towards the cultural sector, with the aim of examining past, present and the inevitable future potentials for this sector. The cultural sector, which includes many performing and visual arts such as theatre and similar live performances with an audience, will also be entangled in the Metaverse through enabling technologies (Dixon, 2006; Jernigan et al., 2009). Creators have long combined digital technologies with live performances (Dixon, 2006; Jernigan et al., 2009; Sargeant, 2013), and more recent examples show how audience participation and performative interactions can be part of a live theatre performance that encourages social transactions and active participation from the audience. Theatre is but one example within the cultural sector where Metaverse technologies will enter as a future part of the performance, and one

which there is prior knowledge to build upon (Dixon, 2006; Jernigan et al., 2009; Mystakidis, 2022; Simpson & Foster, 2022). It is reasonable to assume that other areas, such as participatory decision processes, virtual town meetings, citizen panels and World Cafés will also adopt Metaverse technologies, over time. Within this space the next section will introduce the study's approach to addressing the cultural sector through a specific Metaverse-enabling platform concept.

1.1 Introducing the Meta-stage: Investigating Isolated Instantiations of the Metaverse Infrastructure

Our aim is to investigate how emerging Metaverse-enabling technologies might benefit the cultural sector. Our approach is a research-through-design study centered around the conceptual framing of several technologies collectively referred to as 'The Meta-stage'. Through our investigation into a specific aspect of the Metaverse, we aim to provide a foundation for future inquiries into potential design principles for cultural and public events within this digital realm. This exploration carries significant importance, as the guidelines derived from this study could shape the representation, experience, and interaction of cultural events within this rapidly evolving digital landscape.

The cultural sector, encompassing performance and visual arts such as theater and live audience performances, is anticipated to undergo strategic integration with the Metaverse soon. This integration appears plausible considering the escalating digitization of these domains and the immersive capabilities of the Metaverse. With its capacity to facilitate shared, immersive experiences, the Metaverse presents a novel platform for cultural experiences.

This study expands upon the current implementation of the 'Meta-stage'; a combination of Metaverse enabling technologies, carefully selected for live theater performances. So far, the implementation of the Meta-stage has been developed and used for two live performances with a third iteration coming up.

We examine ways in which engagement and immersion can be leveraged to deliver an experience that connects audiences temporally with actors performing in live events, despite spatial separation, by extending on past research into the same context, but with dated technologies, for example (Y.-C. N. Lee et al., 2013; J. Y. Park & Lim, 2022; Reaney, 1999). This context and technological configuration provide potential for transferability and interoperability, elements which a future vision of an interconnected Metaverse could capitalize on. Through a research-through-design overview, the paper explores, which design principles can be established for cultural and public events in the Metaverse?

2 State of Art

2.1 The Metaverse: Echoing the Past

The emergence of the Internet and World Wide Web has fundamentally transformed how we communicate, learn, and disseminate information. However, computer-based

communication predominantly remains static, still reliant on traditional tools like keyboards and monitors. Emerging modalities, such as multiparty video conferencing and large-scale collaborative virtual environments, have yet to fully replace more conventional methods like email due to inherent restrictions.

Cutting-edge innovations, like head-mounted virtual reality (VR) systems and see-through augmented reality (AR) displays, hold great promise and have begun to see more widespread adoption. These systems offer immersive experiences that far surpass the traditional PC and monitor interface but come with their own unique challenges. They can be notably difficult to install, configure, and maintain. Furthermore, these systems frequently necessitate specialized hardware and significant physical space, which restricts their usage largely to dedicated research facilities. As a result, their broader impact on the landscape of human-computer interaction remains limited.

Additionally, these immersive environments often operate as standalone systems and those supporting peer-to-peer communication necessitate high-bandwidth networks, which curtails their collaborative potential. Such communication is often feasible only between identical environments, further limiting the scope of collaboration and rendering these systems unsuitable for standard settings like offices or classrooms.

Addressing these challenges requires a multifaceted approach. Cost reduction, utilization of commodity parts, user-friendly design, and self-configuration capabilities are critical to make these systems a viable alternative for traditional office computing environments. Developing innovative communication models and efficient protocols for managing the Metaverse could significantly enhance the large-scale deployment and usage of these systems.

Interestingly, the notion of interoperability is a recurring theme in industry definitions, suggesting that a true Metaverse does not yet exist as it is absent in current virtual worlds. This raises questions about the conceptualization of the 'Metaverse' in academic discourse and its alignment with industry visions.

2.2 The Meta-stage: Presenting Future Stage

The Meta-stage emerged from a vision to bring virtual reality (VR) into theater experiences. The Meta-stage was conceptualized by a company collective – The White Hole Theater, who envisioned, designed and developed the Meta-stage. It was iteratively developed from basic motion capture and face-tracking technologies, ultimately incorporating fully-fledged VR environments replete with interactive game elements. In many respects, the Meta-stage mirrors past theater productions reported in research studies (Iudova-Romanova et al., 2023; Y.-C. N. Lee et al., 2013; J. Y. Park & Lim, 2022; Reaney, 1999) that explored the use of current and emerging computer technologies in theater production.

The aim is to explore how the concepts of engagement and immersion can be utilized to foster a connection between audiences and actors during live events. Metaverse-enabling technologies facilitate this connection, overcoming temporal and spatial separations. The VR theater context and technological infrastructure provided by the Meta-stage present an opportunity to examine the transferability and interoperability of such

a setup. This investigation can contribute to the future vision of an interconnected Metaverse in various contexts and scenarios.

The primary goal of conventional VR technology in numerous applications is to replicate real-world scenes and conditions, with a focus on immersion. The commercial use of VR includes training pilots, ship captains, surgeons, and mechanics, prototyping new machines, and advancing architectural development. These applications typically aim for heightened realism to accurately simulate real-world scenarios.

While the Meta-stage does not aim for realism, it seeks to capitalize on immersion. It draws the audience into the play and enables interactions that facilitate an active participatory experience. This approach allows the audience to become co-creators with the actors, becoming part of the play or influencing the story that unfolds on the Meta-stage.

The early conceptual model for the Meta-stage (**Fig. 1**) is a physical stage where the actors wearing motion capture suits perform a live theatrical performance for the audience. The actors are rendered in a virtual environment, using a point cloud animation style, representing the avatars they enact. The audience can view the live performance traditionally from seating next to the stage and view the virtual content on large screen displays positioned around the stage at vantage points, or they can participate in virtual reality wearing head mounted displays, for a more immersed experience. Furthermore, the performance is live streamed, enabling audiences to view it from anywhere through both remote VR and 2D screens via virtual production setups.

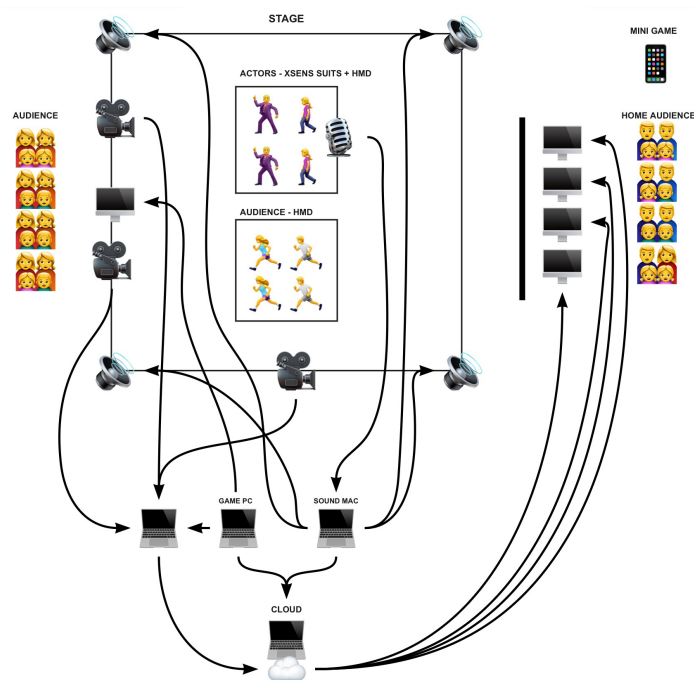


Fig. 1. The audience on both sides of the stage, with the actors (as purple emoji's) and the audience wearing VR HMD's (visualized as the running/active emojis)

2.3 The Meta-stage ‘Tech Stack’

The current implementation of the Meta-stage consists of the following technical components:

- **Qualisys** (qualisys.com) provides precision motion capture and 3D positioning tracking systems that offer solutions for capturing and analyzing movements in sports, clinical science, biomechanics, animation, virtual reality, robotics, and more.
- **ARKit** (developer.apple.com/augmented-reality/arkit/), a framework developed by Apple, facilitates the creation of augmented reality experiences on iOS devices. It simplifies the task of building an AR experience. This is achieved by combining device motion tracking, camera scene capture, advanced scene processing, and display conveniences. It allows for the creation of many kinds of AR experiences using the front or rear camera of an iOS devices.
- **Xsens** (movella.com/products/xsens) is a supplier of 3D motion capture products, wearable sensors, and inertial sensors based on miniature MEMS inertial sensor technology.
- **Photon Engine** (photonengine.com) is a backend-as-a-service (BaaS) for multiplayer game development. It provides a global cross-platform multiplayer game backend for various platforms including Android, iOS, .NET, Mac OS, Unity 3D, Windows, Unreal Engine, and HTML5. This service is cloud-based, making it a scalable solution for game developers.

The diagram in **Fig. 2** shows the tech stack for the current implementation of the Meta-stage.

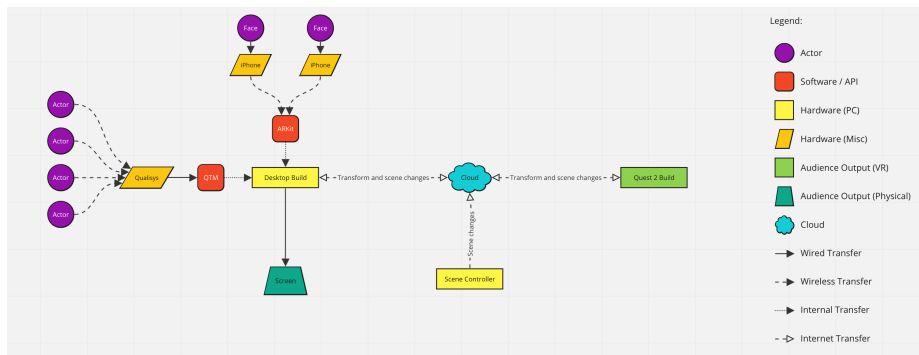


Fig. 2. The diagram illustrates the tech stack, comprising Qualisys, ARKit, and Photon Engine setup, combined with a physical stage

In future iterations, we intend to substitute the Qualisys system with OptiTrack (optitrack.com), an alternative high-performance optical motion tracking technology. Thus, in upcoming iterations of the VR performance 'The Battle,' audiences can participate in the live performances from various locations. This not only bridges the gap of physical distance but also enables interaction as if they were in the same location. This

is made possible by the fusion of these technologies and the context that shapes the social interaction.

3 Concept Overview

In this paper, we present a case study of an ongoing live VR theater performance, "The Battle," which utilizes the Meta-stage to depict a historical event in medieval Denmark. This event was a battle, fought by three prospective kings of Denmark, which took place in Viborg in 1146. The victor of this battle would become the future king of Denmark and decide where the capitol of the country should be. The historical event is dramatized through a live re-enactment of the battle between the three aspiring kings. In addition to the Meta-stage physical stage and metaverse enabling technologies setup presented in previous subsections, the audience is given the opportunity to vote for the would-be king they believe should win the battle. This 'counterfactual' approach allows exploration of potential alternate histories that could have emerged had a different contender won the battle. As such, the play also incorporates elements of learning and reflection for the audience and integrates it through playful interaction where the audience are included into the play and allowed influence of the story's ending.

The Battle leverages Metaverse-enabling technologies to create a hybrid realm where virtual reality and the physical stage intersect. It is within this hybrid space that both audience and actors experience the Meta-stage performance—a form of hybrid co-presence, as it were.

Hybrid co-presence experiences, in this context, generally refer to the sensation of being together in the same place at the same time, a phenomenon often discussed in the realm of VR, AR, and online experiences where real-world and virtual interactions blend.

In this scholarly discourse, we introduce the novel concept of the 'Meta-stage'—a unique fusion of a tangible performance arena, expanded and enhanced by metaverse-enabling technologies such as motion capture, virtual reality, and virtual production. Our interpretation of 'The Metaverse' is comprehensive, recognizing it as an emergent concept that encompasses not just entirely virtual worlds, but also a spectrum of realities—virtual, augmented, and mixed. In accordance with this perspective, we examine the Metaverse as a network of digital platforms (Ritterbusch & Teichmann, 2023), providing new channels for human connections and performative potential in real-time, across various devices and platforms (Proulx et al., 2022; Park & Kim, 2022).

The Meta-stage is envisioned as a model for such platforms, specifically designed for theatrical performances within a hybrid environment. In this setup, actors in motion capture suits perform before live audiences who witness the spectacle through their own eyes and augmented reality via virtual reality headsets. At the same time, the performance is live streamed to remote audiences immersed in virtual reality environments. This setup allows audiences to become part of the performance through game-like interactions at key moments, thereby influencing various aspects of the live spectacle.

Thus, the Meta-stage serves as a fusion of live non-digital performance, enhanced virtual reality motion capture performances, and far-reaching virtual reality experiences for remote audiences—all dynamically influenced by audience interaction.

We further illustrate the application of the Meta-stage through its use in three cultural heritage-themed theater performances in Denmark from 2021 to 2023. These performances creatively intertwine historical narratives from 1146 with contemporary scenarios, utilizing this hybrid performance approach (White Hole Theater, 2021).

3.1 Iterations of the Meta-stage

The current implementation of the Meta-stage and the performance, 'The Battle,' are part of an ongoing series of tests and developments, which started in 2021 and are projected to conclude in 2026. The Meta-stage performances started with smaller-scale setups and shows in 2021, where the system was conceptualized and built. Since then, the stage has been expanded and used for 'The Battle' in 2022, with 'The Battle 2' slated for performance in 2023.

The technical setup is subject to ongoing research and development, with new features like live streaming to audiences' homes and VR headset compatibility. These enhancements necessitate rigorous testing of both technical capacity and technological capability. The latter includes a close look at the resulting user experiences.

3.2 Iteration 1 – ‘Arnolds Vision’

In June 2021, the production team, White Hole Theater, extended an invitation to audiences to traverse time and experience in Viborg and Stænderpladsen as it was in the year 1146, where the actual historical events took place. This immersive performance, named "Arnold's Vision", sought to provide a unique theatrical journey into a historical setting. Arnold's Vision was the first glimpse of the production, with a full launch planned for 2024. The event, stretching from sunset to sunrise, immersed participants in a night resplendent with spiritual encounters and prophetic visions.



Fig. 3. Images from the test screening of ‘Arnolds Vision’

The technological aspect of this experience hinged on the use of a VR headset, which transported participants 800 years back in time to the very spot they stood upon. An actor, adopting the persona of Arnold (a skjald), guided the audience (Lygtemanden) around the area, weaving tales about the place, its people, and the era. With the aid of a motion capture suit, the actor's movements were mirrored in the virtual world, thus breathing life into the character of Arnold in this immersive historical adventure. This first iteration consisted of motion tracking with Xsens, face tracking with ARKit and Photon Engine for the virtual reality environment and content.

3.3 Iteration 2 – ‘The Battle 1’

Merging live performance and virtual reality, the first version of 'The Battle' was enacted by four actors donned in motion capture suits on an outdoor stage located in Stænderpladsen, Viborg. These actors were supplemented by five extras, all outfitted with VR headsets. The movements of the actors were captured and transmitted to a server, which in turn controlled the actions of the main characters within a meticulously reconstructed 3D universe of Viborg, circa 1150. This reconstruction was carried out in partnership with the Viborg Museum and Denmark's premier medieval experts.

Like 'Arnold's Vision', a group of five audience members were invited to immerse themselves directly in the on-stage action. Equipped with VR headsets, these audience members took control of avatars, joining the fray either as part of ‘Team Knud’ or ‘Team Valdemar’, or playing the role of a monk assisting Bishop Svend with the Mass preceding the battle.

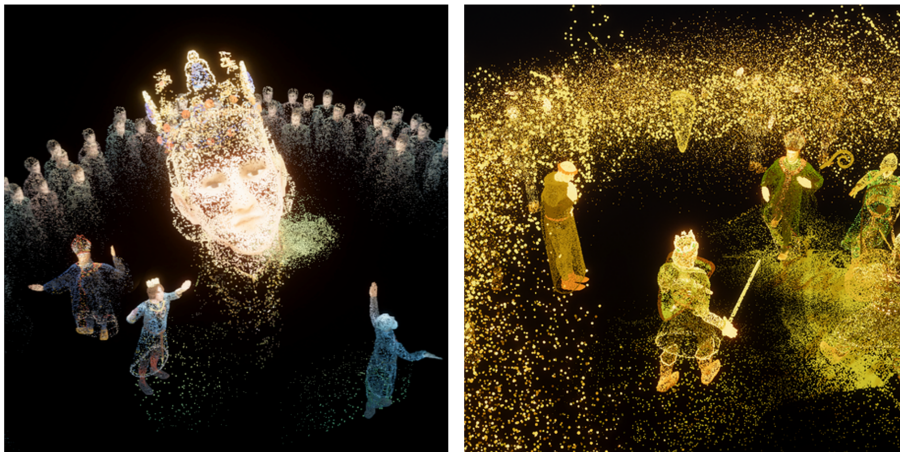


Fig. 4. Images from scaled up tech stack being utilized for multiple VR audiences as well as live streams of ‘The Battle 1’.

The remaining audience could either witness the performance in person at the square or remotely via live streaming. Regardless of their location, all audience members had the capacity to influence the outcome of the performance. By sharing their perspectives

through a Zoom link, they could actively participate in the battle for the Danish throne, thereby enhancing the immersive quality of this unique VR theater experience.

3.4 Iteration 3 – ‘The Battle 2’

The forthcoming rendition of 'The Battle', scheduled for June 2023, will incorporate mini games, enabling audience participation throughout the performance. This addition aims to examine user agency within the performance and explore its influence on the interpretation of various outcomes, as well as on the immersion of both the on-stage and remote VR audiences.

This version also delves further into priming and orienting audiences to the narrative world and aesthetic visualizations. As demonstrated by previous research, inadequate orientation for first-time users of novel technological experiences can detrimentally impact the user experience (Vistisen et al., 2017). This is particularly significant with emerging technological experiences, where user expectations can be challenging to anticipate.

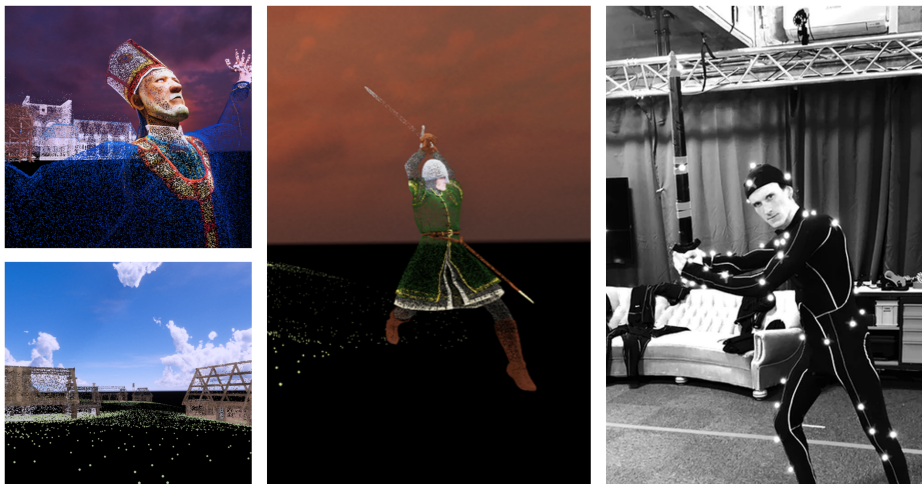


Fig. 5. Images from ‘The Battle 2’ utilizing the new improved motion tracking in the tech stack as well as both a building-focused and a weapons-focused mini-game as part of the performance

This iteration builds upon the previous version of 'The Battle', featuring advancements in motion tracking and novel game elements designed to introduce audiences to the narrative world through interaction. Specifically, the mini games will engage VR audiences in mundane tasks, such as carrying wood, gathering weapons, and baking bread, facilitated by controllers with teleport movement. Furthermore, this iteration will be live-streamed, enabling remote audiences to participate from various locations.

3.5 Iteration 4 – ‘Three Kings’

'The Battle 1' and 'The Battle 2' represent the initial parts of White Hole Theatre's epic drama 'Three Kings'. The insights gathered from the three preceding iterations will inform a minor iteration in 2024, aptly named 'Valdemar's Story', which will pave the way for the final production, 'Three Kings', scheduled for 2026. In this final performance, the boundaries between audience members, the physical stage, and the Meta-stage will be thoroughly explored and tested. This process aims to gauge the potential of future digital theatre formats by leveraging the accumulated experiences from the entire tech stack.

4 PERSPECTIVES / DISCUSSION

4.1 Reflecting on the Meta-Stage Iterations

The Meta-stage has thus far affirmed the potential of contemporary metaverse-enabling technologies in crafting immersive and engaging narratives. However, a thorough evaluation of the resultant user experiences and the distinct impacts of different elements within the technology stack is yet to be undertaken. The incorporation of game design to stimulate active audience participation through interaction is a promising approach, but the implications of such engagement on user experience remain largely unexplored. The Meta-stage's past iterations have showcased a systematic integration and refinement of technical facets through performances, culminating in a level of maturity conducive to user testing. This progression sets the stage for a more detailed examination of user experiences in relation to the technologies employed. Such an analysis is crucial for understanding the realm of possibilities before addressing broader questions, such as the transferability to other contexts and interoperability, which are essential steps towards a unified metaverse.

4.2 The User Experiences

This study has mapped out the tech stack that enables the Meta-stage – a combination of metaverse enabling technologies that are utilized to create a live performance on a hybrid stage. Through the four iterations the common motivation has been to understand the current state of the potential of the Meta-stage both conceptually and in practice. In order to fully develop a perspective on this, the next step is to study the resulting real life user experiences from a hybrid stage setup that invites audiences to view the performance as a theater show and encourages them to step into a fully immersed virtual reality where they can experience the theater performance as a part of the gathering of townfolk that witnessed the events of the battle of the three kings.

The Battle 2 performed in 2023 is a steppingstone towards the fourth larger scale iteration ‘Three Kings’ in 2026. Therefore, it is important to understand the user experiences so that they may inform future iterations of the planned production in terms of interactive elements as well as the technical setup.

We will focus future studies on evaluating the user experience of the audience present at the physical stage – both with and without VR headsets, and the audiences that are tele present via live stream.

In essence, the objective is to conduct a feasibility study to ascertain audience perceptions of the experience, using these insights to inform future iterations for the 2024 and 2026 shows. As previously mentioned, we aim to examine transferability and interoperability by understanding the resulting user experiences. These insights will contribute to shaping the future of the metaverse and its potential applications.

4.3 A Meta-stage for Transferability and Interoperability in the Metaverse?

The term "metaverse" is continually evolving due to ongoing technical and technological advancements. These progressions persistently alter the landscape of potential interactions, communications, and collaborations within the metaverse. With the recent surge in media attention, the metaverse has captivated the collective consciousness of researchers, industry professionals, and the general public alike, making it a fascinating research focus.

This study aims to report on a specially built stage designed for cultural contexts, specifically live stage theater performances. However, the broader ambition is to gain insights about the possibilities, limitations, implications, and challenges that need to be addressed in the near future while also envisioning the distant future of the metaverse. The immediate focus is on how studies around the user experiences of the Meta-stage can inform future iterations of the Meta-stage and benefit other similar contexts, such as public events.

Long-term considerations relate to the question of interoperability within the metaverse. This involves exploring how entities within the metaverse can conform to a protocol that ensures an open, decentralized and interoperable metaverse.

5 CONCLUSION

This study presents a novel conceptualization of the metaverse, the Meta-stage, which integrates a range of metaverse-enabling technologies. The ongoing development of the Meta-stage has reached a stage of maturity where user testing is beneficial for investigating the user experiences that emerge from interactions within the Meta-stage.

his approach offers a unique interpretation of the metaverse, potentially providing insights into how to develop and enhance metaverse interactions. Such insights could contribute to the formulation of design guidelines for cultural and public events that take advantage of metaverse and metaverse-enabling technologies, thereby enabling the transfer of knowledge to other contexts. Furthermore, the future trajectory of the Meta-stage and research conducted within this framework could yield valuable knowledge to inform the broader development of the metaverse.

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