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Metaverse: A State-of-the-Art Review in Information Systems

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Abstract

The metaverse represents an immersive and continuously evolving virtual reality that merges physical and digital worlds through technologies such as virtual reality (VR), augmented reality (AR), and artificial intelligence (AI). This paper provides a comprehensive review of the metaverse from an information systems perspective, focusing on its key components, enabling technologies, cross-sectoral applications, and emerging technical and ethical challenges. Through a systematic analysis of scholarly literature, the study explores the integration of the metaverse in domains such as e-commerce, education, healthcare, manufacturing, and entertainment. Additionally, it examines critical issues including data privacy, cybersecurity, interoperability, and inclusivity. The review aims to guide future research agendas, inform strategic development, and encourage responsible innovation as the metaverse continues to shape digital and social landscapes.

Keywords: *Metaverse, Information Systems, Digital Transformation*

Introduction

The metaverse, a term coined in science fiction, envisions a persistent, shared, and immersive virtual realm where users can interact with each other and digital objects in real-time (Tukur et al., 2023). It represents a convergence of physical and digital realities, offering a new paradigm for human interaction, economic activity, and information sharing (Othman et al., 2024). The metaverse integrates extended reality technologies, encompassing virtual reality, augmented reality, and mixed reality, to create immersive experiences where users can virtually experience an alternate life through their avatars (Ali et al., 2023). The metaverse is no longer just a hypothetical concept but a rapidly evolving reality, driven by technological advancements and substantial investments from major tech companies. Its evolution is intertwined with the progression of the internet towards Web 3.0, a new generation of the internet. Its appeal lies in its potential to revolutionize various sectors, including gaming, social networking, education, healthcare, and commerce, by providing unprecedented levels of immersion and interactivity (Farooq et al., 2023; Wang et al., 2025). The metaverse facilitates innovative approaches to employer branding through virtual reality experiences, enhancing employer evaluation and attractiveness among potential job seekers (Bialkova & Ros, 2021). While the metaverse promises many opportunities, it also presents significant challenges, particularly in terms of technological infrastructure, interoperability, privacy, security, and ethical considerations (Dwivedi et al., 2022).

The motivation for this review stems from the increasing interest and investment in metaverse technologies, coupled with the need for a comprehensive understanding of its current state and future potential. Practitioners and researchers have been actively discussing metaverse platforms, but its full potential and meaning remain a subject of debate (Keith et al., 2016). Academics, users, and companies have been showing increased interest in the metaverse (Crespo-Pereira et al., 2023). This review aims to synthesize the existing literature

Vol. 1, No. 1, January 2026, pp. 32-41
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on the metaverse from an information systems perspective, providing a structured overview of its key components, enabling technologies, applications, and challenges. It is also driven by the recognition that the metaverse is not just a technological phenomenon but also a social, economic, and cultural one, requiring a holistic approach to its study and development. The COVID-19 pandemic acted as a catalyst, accelerating the adoption of remote work, online education, and virtual social interactions, further fueling interest in the metaverse as a potential solution for these new realities (Rawat & Alami, 2023). This study examines the technical and non-technical challenges, privacy, policy, and security concerns related to building the metaverse's digital environment (Tukur et al., 2023). Moreover, the analysis aims to guide future research directions, inform strategic decision-making, and promote responsible innovation in this emerging domain.

To provide a comprehensive and structured analysis of the metaverse, this review addresses the following research questions: What are the key components and enabling technologies that constitute the metaverse ecosystem? This question explores the fundamental building blocks of the metaverse, including hardware, software, platforms, and protocols that enable its functionality. The scope of this review encompasses a broad range of topics related to the metaverse, including its definition, history, key components, enabling technologies, applications, challenges, and future directions.

Methodology

A systematic search of academic databases was conducted to identify relevant literature on the metaverse, including Web of Science, Scopus, IEEE Xplore, and ACM Digital Library. The literature was reviewed, focusing on scoping the design of digital and virtual environments, and the metaverse. The extracted data was synthesized using a thematic analysis approach, which involved identifying recurring themes and patterns in the literature. The synthesis focuses on examining the literature from various angles and formulating a research agenda for designing and developing virtual environments.

Conceptual Foundations of the Metaverse

The metaverse is conceptualized as a convergence of physical and digital realities, creating a persistent, shared, and immersive virtual environment where users can interact with each other and digital objects in real-time. Interoperability, a critical aspect, refers to the ability of users to seamlessly move between different virtual worlds and platforms within the metaverse, using the same avatar, digital assets, and identity (Zallio et al., 2023). The metaverse is characterized by asset digitization, scope economics, industry universality, integrated innovation, and the platform ecosystem (Song et al., 2023).

The concept of the metaverse has evolved over several decades, originating in science fiction literature and gradually materializing through technological advancements. Early visions of virtual worlds can be traced back to Neal Stephenson's 1992 novel "Snow Crash," which depicted a 3D virtual world where avatars of real people could interact. The metaverse relies on a diverse range of hardware and software technologies to deliver immersive experiences, including virtual reality headsets, augmented reality glasses, haptic devices, and high-performance computing infrastructure. Robust networking and communication technologies are essential for enabling real-time interactions and data transfer within the metaverse, including high-bandwidth internet connectivity, low-latency networks, and advanced communication protocols. Does the server architecture deliver sufficient power to enable massive numbers of users to occupy the Metaverse without compromising the efficiency of the system and the experience of the users? (Dionisio et al., 2013).

Data management and security are critical considerations for the metaverse, given the vast amounts of user data generated and the potential for privacy breaches and cyberattacks. The

metaverse utilizes psychology and medicine based on advanced AI/ML algorithms to analyze and understand user behavior, which offers users a more immersive experience or can be used in education, training, psychotherapy, and other fields (Rawat & alami, 2023). These challenges also involve ethical and societal considerations, such as data privacy, security, and the potential for misuse of personal information. AI algorithms drive numerous aspects of the metaverse, including avatar creation, natural language processing, content moderation, and personalized user experiences.

Applications in Information Systems

1. E-commerce and Virtual Marketplaces

The metaverse provides new opportunities for e-commerce and virtual marketplaces, allowing businesses to create immersive shopping experiences, showcase virtual products, and engage with customers in novel ways (Guan et al., 2023). Virtual marketplaces within the metaverse enable users to buy, sell, and trade digital assets, such as virtual land, avatars, and collectibles, creating new economic opportunities and revenue streams (Dong & Lee, 2022). This can revolutionize how consumers interact with brands and make purchases, potentially leading to increased engagement and sales conversions (Dwivedi et al., 2022; Guan et al., 2023). The metaverse provides opportunities for e-commerce and education (Guan et al., 2023). Users can participate in online education and training, participate in virtual art exhibitions, and enjoy virtual trips, among others (Wu et al., 2023).

2. Education and Training

The metaverse has the potential to transform education and training by creating immersive learning environments, simulating real-world scenarios, and providing personalized feedback to students. The metaverse can be used to deliver remote education and training programs, allowing students and trainees to access learning resources and interact with instructors and peers from anywhere in the world (Kabilan, 2023). The platform fosters interaction among students, educators, and digital objects, augmenting educational experiences through AI (Pyae et al., 2023). Yet, considerations of user experience, privacy, and content creation necessitate further exploration to completely realize the metaverse's educational potential (Pyae et al., 2023). Addressing the challenges and ethical considerations is of utmost importance as the metaverse advances, to ensure its safe and responsible assimilation into everyday life, most importantly in education (Pyae et al., 2023). While the possibilities of employing the metaverse for educational purposes are appealing, there's a need for usability and real-world application in the sector (Almeman et al., 2025; Pyae et al., 2023). Digital resources offer interactivity and portability, but they also pose technical, infrastructural, and managerial challenges (Pyae et al., 2023). The metaverse can offer personalized learning experiences by analyzing student data and identifying areas of strength and weakness (George & Wooden, 2023). The Metaverse allows the curriculum to customize to the student's needs (Belmonte et al., 2023; Kaddoura & Husseiny, 2023; Zhang et al., 2022).

The metaverse facilitates a departure from traditional constraints of time and location, offering unprecedented learning activities that allow learners to perceive, explore, and create in novel ways (Zhang et al., 2022). In educational settings, the metaverse enables immersive simulations, cultivates creativity and critical thinking, and delivers customized learning experiences (Ali et al., 2025). Active involvement is encouraged in learning environments by integrating education and entertainment (Kaddoura & Husseiny, 2023). The use of the metaverse in education can take on many forms and have different purposes (López-Belmonte et al., 2023). Metaverses can offer experiences that overcome barriers in space, time, and costs, but consideration must also be given to the threats that metaverses present (Dahan et al., 2022; Han et al., 2023).

3. Healthcare

Vol. 1, No. 1, January 2026, pp. 32-41
https://doi.org/10.56861/jsiska.v1i1.182

The metaverse is being explored for various healthcare applications, including medical training, remote patient monitoring, and virtual therapy (Lewis et al., 2024) (Suh et al., 2023). Machine learning algorithms can analyze data generated within the metaverse to provide insights into patient behavior, predict health outcomes, and personalize treatment plans (Ebrahimzadeh & Safa, 2024). The metaverse can be used to create realistic simulations of medical procedures, allowing surgeons and other healthcare professionals to practice their skills in a safe and controlled environment.

4. Manufacturing and Supply Chain Management

The metaverse enables manufacturers to create digital twins of physical factories, simulate production processes, and optimize supply chain operations (Al-Ghaili et al., 2022). In manufacturing, the metaverse will provide the ability to design and test products virtually, reducing the need for physical prototypes and accelerating the product development lifecycle. The metaverse is an environment in which someone could see real and virtualized worlds (Al-Ghaili et al., 2022). By enhancing efficiency, lowering costs, and improving transparency, this change may have a substantial impact (Bag et al., 2023). The development of supply chains and manufacturing processes is one area where the metaverse shows great promise.

5. Entertainment and Gaming

The metaverse offers new opportunities for entertainment and gaming, allowing users to participate in immersive virtual experiences, interact with other players, and create their own content. The use of virtual reality and augmented reality technologies can enhance the gaming experience and provide players with a greater sense of presence and immersion. The metaverse is seen as a platform through which experiences can be offered while also facilitating interactions in the virtual world (Baker et al., 2023; Dong & Liu, 2022). The metaverse is being utilized as a virtual venue where businesses may reach out to clients and offer them cutting-edge, immersive experiences that transcend conventional constraints and limitations.

The fundamental building blocks of the metaverse

1. Hardware

The hardware components of the metaverse are what allow users to access and interact with the virtual world. Virtual reality headsets, augmented reality glasses, and haptic devices are examples of these. Optical communication technologies offer a promising path to meeting the Metaverse's need for high data transfer rates and low latency (Belmekki et al., 2023). These technologies enable users to fully experience the metaverse's immersive and interactive qualities and create a seamless and engrossing digital experience (Kourtesis, 2024; Xu et al., 2022). Brain-computer interfaces are also being investigated to improve user experience within the metaverse, using a user's behavioral, psychological, physiological, and observation information to improve the system's usability and performance (Zhu et al., 2023).

2. Software

The software components of the metaverse consist of the platforms, tools, and applications that enable the creation, delivery, and management of virtual content and experiences (Al-Ghaili et al., 2022). Game engines such as Unity and Unreal Engine are commonly used to develop 3D environments and interactive experiences within the metaverse. AI-powered tools can also automate content creation tasks, generate realistic avatars, and personalize user experiences within the metaverse.

3. Platforms

Metaverse platforms provide the infrastructure and services that enable users to access, explore, and interact with virtual worlds and digital content. These platforms often incorporate features such as social networking, e-commerce, and content creation tools, allowing users to

connect with others, create and share content, and participate in virtual economies (Lee et al., 2021). These platforms offer a wide range of experiences and opportunities for users, from attending virtual events and concerts to collaborating on projects and building virtual businesses. The metaverse is a virtual environment that transcends and parallels the real world, integrating the virtual and physical realms in terms of social, economic, and identity systems (Wu et al., 2023). There are no longer any temporal or spatial constraints thanks to the virtual world, which offers an immersive experience and makes it possible for users to take part in a variety of activities.

4. Protocols

The metaverse is interoperable because of protocols that enable data, assets, and identities to be transferred across different virtual worlds (Dionisio et al., 2013). Standardized protocols for avatar representation, asset ownership, and data exchange are essential for ensuring seamless interoperability between different metaverse platforms (Cheng et al., 2022). Decentralized identity solutions based on blockchain technology enable users to manage their digital identities and credentials across multiple metaverse environments.

Challenges and Future Research Directions

The metaverse faces significant technological challenges, including the need for higher bandwidth, lower latency, and more powerful computing infrastructure (Hashash et al., 2023). Developing more efficient rendering algorithms, compression techniques, and networking protocols is crucial for improving the performance and scalability of the metaverse. Advancements in artificial intelligence, computer vision, and natural language processing are needed to create more realistic, interactive, and personalized metaverse experiences. In order to guarantee ethical and safe Metaverse practices, more research is required to fully address the social, economic, and legal issues.

The metaverse raises significant security and privacy concerns, including the risk of identity theft, data breaches, and harassment. Robust security measures, such as encryption, multi-factor authentication, and intrusion detection systems, are needed to protect user data and prevent unauthorized access to metaverse environments. Privacy-enhancing technologies, such as differential privacy and homomorphic encryption, can help protect user privacy while still enabling data analysis and personalization (Calderón-Fajardo et al., 2024). It is important to consider potential security and privacy concerns in the metaverse, and it has been suggested that the most straightforward approach to addressing these concerns would be to restrict user access; however, this strategy would negate the metaverse's benefits (Zhao et al., 2022). Activities and interactions in the metaverse will generate massive amounts of data, which raises privacy issues that will require careful development of governance decisions, privacy policies and new community norms (Gómez-Zará et al., 2023).

Ensuring that the metaverse is accessible and inclusive to all users, regardless of their abilities, backgrounds, or socioeconomic status, is essential for realizing its full potential. Developing accessible hardware and software solutions, such as adaptive interfaces, captioning, and sign language interpretation, is crucial for accommodating users with disabilities. Promoting diversity and inclusion in the design and development of metaverse content and experiences can help ensure that all users feel welcome and represented. Further investigation is needed into the capacity of the Metaverse to reduce prejudice and precisely replicate actual experiences (Mónaco & Sacchi, 2023).

Future research opportunities in the metaverse span a wide range of disciplines, including computer science, engineering, social sciences, and humanities. More investigation has to be done on the Metaverse's capacity to simulate actual experiences and lessen bias (Mónaco & Sacchi, 2023). In order to comprehend and construct the Metaverse, thorough research into these concerns will be helpful (Song et al., 2023). The metaverse offers opportunities for users

Vol. 1, No. 1, January 2026, pp. 32-41
https://doi.org/10.56861/jsiska.v1i1.182

to build financial wealth, create new things, and show a different side of themselves, but consistency and interdisciplinary research are needed to develop the metaverse beyond a simple 3D environment (Dwivedi et al., 2022). The metaverse holds great promise for altering how people interact with technology and one another, but it also presents significant challenges that must be addressed to fully realize its potential (Al-Ghaili et al., 2022; Mónaco & Sacchi, 2023). Additional research and case studies are needed to support and grow our knowledge of the Metaverse because current knowledge and comprehension are mostly based on theories and assumptions (Song et al., 2023). Addressing the security and privacy issues involved with metaverse technologies requires considerable investments in education and training (Zhuk, 2024).

Conclusion

This review has provided a comprehensive overview of the metaverse, exploring its key components, enabling technologies, applications, and challenges. The metaverse is a rapidly evolving and transformative technology with the potential to revolutionize many aspects of our lives. High-tech firms have entered the metaverse arena, with Meta being perhaps the most well-known of those who have invested in the space (Cheng et al., 2022). The metaverse offers immersive experiences by combining physical and digital reality, which is one of its main characteristics. Interactions in the metaverse have the potential to promote community building and social interaction, while also improving experiences across a range of industries, including education, healthcare, and entertainment (Bajić et al., 2023; Sami et al., 2023).

The metaverse has significant implications for research and practice across a wide range of disciplines. More research is required to fully address the social, economic, and legal issues involved with Metaverse activities in order to guarantee ethical and safe Metaverse practices. Researchers should focus on developing new technologies, applications, and business models for the metaverse, while practitioners should focus on implementing and deploying metaverse solutions in various industries and contexts. The travel sector, for instance, includes the products, services, and experiences related to travel, lodging, entertainment, and the appreciation of cultural, social, and environmental resources (Mónaco & Sacchi, 2023).

As the metaverse continues to evolve, it is important to approach it with a critical and interdisciplinary perspective, considering its potential benefits and risks, and ensuring that it is developed and used in a responsible and ethical manner. To guarantee that the metaverse develops in a secure and sustainable manner, there is an urgent need for strong governance, ethical oversight, and inclusive design (Kontis & Ioannidis, 2025). Additional research on the metaverse is required to address issues of security, privacy, accessibility, and inclusivity in order to completely realize its potential.

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