Accessible Metaverse

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An accessible Metaverse is defined as the intentional design of the Metaverse to ensure inclusivity, accommodating users of all abilities through the integration of digital accessibility principles, diverse engagement, and a commitment to continuous improvement, thereby fostering equal participation and enjoyment for everyone.

Keywords: Metaverse ; accessibility ; digital accessibility ; virtual reality

1. Introduction

The concept of the Metaverse has garnered considerable attention recently, particularly owing to substantial advancements in virtual and augmented reality technologies. The Metaverse is an integrative ecosystem of virtual worlds offering immersive experiences to users that modify pre-existing experiences and create new value from economic, environmental, social, and cultural perspectives. It is defined as a continuous and interconnected blend of physical and virtual realms facilitated by technologies such as virtual reality and augmented reality, where users engage in multisensory interactions within persistent and shared immersive environments [1]. In this interconnected digital realm, users can engage in real-time interactions with each other and with computer-generated environments, resulting in the blurring of boundaries between the physical and digital worlds [2]. Often described as a fully immersive and interactive space, the Metaverse offers users the opportunity to explore, create, and participate in diverse activities [3]. Neal Stephenson first coined the term Metaverse in his 1992 science fiction novel “Snow Crash” [4]. This concept has transcended the realm of fiction. It is becoming a reality due to rapid technological advancements and the increasing popularity of virtual reality (VR) and augmented reality (AR) experiences. With the Metaverse, individuals can interact and engage with others from around the world, thereby eradicating the barriers of physical distance [5]. This virtual reality space presents infinite possibilities for communication and collaboration, facilitating seamless teamwork and innovation across various industries. The Metaverse in education offers potential applications for blended learning, language learning, competency-based education, and inclusive education but faces challenges and requires further research [6]. Furthermore, the Metaverse could transform the entertainment industry by providing a new level of immersive experiences and redefining how we consume media. Individuals with autism or intellectual disabilities can use it to enhance their communication and social skills [7]. The ongoing development of the Metaverse is expected to significantly transform our daily lives, professional pursuits, and recreational activities, thereby heralding a new era of interconnectedness and virtual exploration. The Metaverse, as envisioned by some experts, is a fully simulated virtual world, while others see it as an augmented reality overlay on the real world [8]. The virtual Metaverse is anticipated to be widely used for gaming, socializing, shopping, entertainment, business, and education. The augmented Metaverse, on the other hand, is regarded as a substitute for mobile phones and a gateway to digital content [9]. The potential application of blockchain technology in decentralizing and resolving control issues in the Metaverse is currently under discussion [10]. However, concerns have also been raised regarding the cost of access, the potential for misinformation, the digital divide, object and identity persistence, and the possible negative impact on real-world relationships and obligations [11][12].

The concept of the Metaverse offers tremendous potential for fostering a more inclusive and accessible digital realm. Although some initiatives have provided recommendations for enhancing the accessibility of virtual and augmented reality content [13][14], complete accessibility solutions seem to be relatively absent. Ensuring equal opportunities for individuals with disabilities in virtual environments entails addressing a variety of obstacles. One significant challenge is the lack of accessibility across numerous virtual reality (VR) platforms and applications [15]. For instance, individuals with visual disabilities may encounter difficulties navigating virtual environments that rely heavily on visual cues, underscoring the need for features such as audio descriptions or haptic feedback. Without such provisions, their ability to fully engage in digital exploration of the Metaverse is impeded. Similarly, those with mobility disabilities may face challenges in VR platforms requiring intricate physical movements or not supporting assistive devices. The use of extended reality (XR) technologies can result in sensory overload for neurodivergent individuals, and such individuals may face difficulties in

accessing XR technologies due to the lack of integration of accessibility requirements in current software development practices [16]. Addressing challenges related to the Metaverse for educational purposes involves considering potential accessibility and integration difficulties for individuals with learning disabilities [6]. As the Metaverse continues to develop, it is essential to prioritize and implement inclusive design practices to accommodate the diverse needs of all users. This emphasis on inclusivity can transform the Metaverse into a space in which everyone can actively participate in virtual experiences, regardless of their abilities. Despite extensive research on VR and augmented reality (AR) for disability [17], translating these advancements into widely available market-ready products appears to be relatively infrequent.

2. Accessible Metaverse

The concept of the Metaverse has captured the imagination of researchers and technologists alike, offering a glimpse into a future where virtual and physical realities converge. It has gained significant attention in recent years, with much speculation about its potential to transform how we interact with technology and each other. Despite its growing popularity, the Metaverse is still in its nascent stages of development, and there is no clear consensus on its eventual form. According to Ref. [18], the Metaverse is a proposed future virtual universe that is characterized by the integration of various digital platforms and the provision of immersive experiences through multidimensional interactions and is envisioned as a space that includes augmented, extended, and virtual realities, and is intended to offer users a rich and engaging experience. The current vision for the Metaverse is deeply rooted in the values and preferences of Generation Z, a demographic group known for its fluid online and offline identities. It is reinforced by deep learning-based recognition models and virtual currency [19].

The creation of an immersive and interactive Metaverse depends on the development of virtual reality (VR), augmented reality (AR), artificial intelligence (AI), blockchain, and other technologies [20]. These technologies enable virtual reality experiences, the ownership of digital assets, and decentralized governance. Their implementation is of utmost importance in achieving the desired outcome of a Metaverse. Corporations such as Meta (formerly Facebook), Microsoft, and Epic Games are allocating significant resources toward developing and advancing Metaverse technologies and platforms [21]. This increased investment expedites the progress of these technologies and draws additional interest and attention to the Metaverse. The Metaverse provides a decentralized virtual identity, immersive experiences, interactive functions, a mature economic system, the ability for arbitrary creation, continuous self-evolution, and upgrading. It holds significant potential for growth in social interactions, office environments, education, and gaming [22]. The study of the Metaverse has made notable progress in four key areas: technological development, practical applications, marketing and consumer behavior, and environmental sustainability [23]. These findings hold valuable implications for businesses seeking to capitalize on the potential of the Metaverse. The Metaverse has been studied for its potential in propaganda, solving environmental problems, and achieving sustainable development goals [24]. It has also been studied in education, focusing on topics like roadmaps, dimensions, training, current initiatives, and data [25]. The Metaverse can be used in education for people with disabilities by integrating various information technologies into smart education ecosystems, forming new education modes like virtuality-reality symbiosis, trans-spatial fusion, and collaborative inquiry [26], while also enabling technologies like extended reality and the internet of everything to impact educational services [27]. The Metaverse is a social ecosystem that interconnects the physical and virtual realms, thereby eliciting inquiries about identity, privacy, and security [28]. In the context of the Metaverse, it is of utmost importance to guarantee a secure and safe environment as users participate in social and economic activities within this virtual space. Furthermore, the need for high synchronization and low latency arises as a critical factor in enhancing the user experience and fostering a sense of immersion.

Accessibility and inclusion are critical factors that cannot be disregarded in the realm of the Metaverse [29]. The growth and development of digital environments necessitate the guarantee of equal opportunities for all individuals with different abilities and backgrounds to participate and prosper within them [30]. It is crucial to foster an inclusive environment in the Metaverse, where barriers are eliminated, and every individual has the opportunity to voice their opinions and establish their presence [31]. The Metaverse presents an opportunity to ensure equitable access for all humans, including people with disabilities. Despite the uncertainty of current options available for these individuals in the Metaverse, the research explores potential augmentations and inclusions that can be implemented to ensure their participation in virtual space. It is imperative that people with disabilities are not excluded from the Metaverse. In examining digital accessibility for individuals with disabilities, the prevalent challenges identified were not only technical issues, security and privacy concerns, and operational hurdles but also a notable absence of case studies or practical examples addressing the gap in creating an accessible Metaverse. This omission underscores the need for real-world applications and solutions to better understand and tackle these barriers. Evidence in the literature indicates a prevalent focus on AI-driven digital accessibility for visual disabilities, which highlights a significant gap in addressing other types of disabilities [32]. Individuals with disabilities often experience limited access to information and communication technology (ICT) and internet

connectivity, which can be attributed to various factors such as financial constraints, physical impediments, low levels of digital literacy, and inadequate support [33]. This underscores the pressing need for a realignment of efforts towards a more comprehensive examination of disabilities, urging researchers to broaden their scope and enhance data collection efforts involving individuals with other disabilities, mainly physical/mobility and cognitive. The identified shortcomings in existing systems with respect to adherence to accessibility standards serve to emphasize the pressing need for a fundamental shift in the design of solutions that prioritize the needs of individuals with disabilities. The current web accessibility standards for Metaverse platforms are insufficient in providing digital accessibility for individuals with disabilities [34]. This is due to the absence of specific guidelines and best practices for Metaverse platforms [35] and the limited knowledge of how to modify existing accessibility features to suit virtual environments. Many countries do not have appropriate laws and regulations to ensure the safety and well-being of all participants [36]. To address these challenges, it is essential to thoroughly understand the specific needs and prerequisites of individuals with disabilities to develop effective accessibility solutions for the Metaverse.

The absence of awareness and understanding of accessibility requirements among Metaverse developers can lead to obstacles and limitations within the virtual world [31]. A lack of comprehensive understanding of accessibility can result in unintentional exclusion of certain groups of people from fully participating in the Metaverse experience [29]. This can lead to feelings of exclusion and frustration, particularly for individuals with disabilities who may encounter difficulties navigating or interacting with the virtual environment. Furthermore, the lack of awareness can perpetuate societal biases and stereotypes, further marginalizing already underrepresented communities [37]. Thus, it is imperative that education and training on accessibility become an integral component of the development process so that Metaverse platforms are designed with inclusivity in mind. As technology continues to advance and the virtual world becomes increasingly integrated into our daily lives, we must establish and enforce suitable laws and regulations to safeguard the safety and welfare of all stakeholders. Regrettably, numerous countries lack policies or regulations to address these issues [36]. Consequently, it is essential to conduct research to provide evidence-based support for developing and implementing such policies.

The development, research, adoption, and use of the Metaverse raises various ethical and legal concerns [38]. A crucial ethical aspect is focusing on digital identity, which plays a key role in managing the balance between anonymity and pseudonymity in the Metaverse. Privacy is also a significant consideration, especially for individuals with disabilities dependent on assistive technologies for digital interaction [39]. Additionally, intellectual property poses challenges, notably for content creators and developers relying on copyrighted materials or trademarks in virtual settings [40]. Finally, addressing bias is imperative in the realm of digital accessibility. Another challenge with implementing inclusive design principles in immersive and interactive Metaverse environments is the complexity of creating accessible features that cater to a wide range of disabilities. In designing and developing products, designers and developers need to consider multiple considerations, such as the requirements of individuals with visual and hearing disabilities, mobility disabilities limitations, and cognitive disabilities, as well as the needs of neurodivergent individuals, those with autism, and senior citizens. The extent of accessibility and inclusivity in the Metaverse is greatly influenced by its creators' and developers' biases, viewpoints, and priorities. If these designers possess unconscious biases and stereotypes towards individuals with disabilities, these will be reflected in their product and how people with disabilities are involved in the process [41]. As a result, individuals with disabilities may be forced to accept a suboptimal user experience, while non-disabled individuals are afforded the best possible user experience. The Metaverse is likely to present additional challenges in terms of privacy and security [42], particularly for individuals with disabilities who depend on assistive devices that might be vulnerable to exploitation. Moreover, the cost of accessing the Metaverse, including the necessity of high-end virtual reality technology, may prove prohibitively expensive for those with limited financial resources [33]. To address these issues, it is crucial to have a deep understanding of the needs and preferences of individuals with disabilities and the technical expertise required to integrate accessible features seamlessly into the Metaverse experience. Additionally, the dynamic and ever-evolving nature of Metaverse environments presents unique challenges in ensuring accessibility [43]. Therefore, it is essential to constantly reassess and update accessibility standards to ensure that individuals with disabilities can fully participate in the Metaverse. Collaboration between accessibility experts, developers, and users with disabilities is critical in this process, as it enables the identification of barriers and the development of innovative solutions. By prioritizing accessibility, the Metaverse can become a more inclusive and empowering space for all users, regardless of their abilities.

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