Accessibility in the Metaverse: Are We Prepared?

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Abstract. *Metaverse is a new paradigm and is under construction where social, immersive Virtual Reality platforms will be compatible with several kinds of applications. However, solutions must be developed to ensure that people with disabilities access the metaverse. This work aims to present an overview of research on accessibility of immersive systems and outline challenges and opportunities so that the Human-Computer Interaction community can reflect and intensify research in this area.*

1. Introduction

The Metaverse is under construction where social, immersive Virtual Reality (VR) platforms will be compatible with massive multiplayer online video games, open game worlds and Augmented Reality (AR) collaborative spaces [Mystakidis 2022]. According to this vision, users can meet, socialize and interact without restrictions in an embodied form as 3D holograms or avatars in physical or virtual spaces. According to [Matthew Ball 2022], the Metaverse is a new paradigm, going beyond VR or Augmented Reality (AR) and, it should be: persistent; synchronous and live; open to everyone without any cap on concurrent users; with a fully functioning economy and direct ownership of assets; an experience spanning the digital and physical worlds; interoperable; full of different experiences created by different types of contributors. Ball underlined that the Metaverse should also be open to humans with disabilities, who are different contributors [Matthew Ball 2022]. However, Ball did not explicitly mention a specific disability and did not detail how accessibility and inclusion should be achieved.

Therefore, this work aims to present research developed in accessibility in the Metaverse and answer the research question that motivates this work: *are we prepared to provide experiences in the Metaverse to persons with disabilities?* We intend to discuss the challenges and opportunities, in addition to helping the Human-Computer Interface (HCI) community to foster discussions on how to ensure that people with disabilities have access to the Metaverse. In order to achieve this objective, we selected works through an ad-hoc literature review process together with the review of the references of each work. The scope was defined to investigate works that support people with disabilities, such as people with visual and hearing impairments, among others. The limitations that may be presented due to some socioeconomic, legal or cultural circumstances are outside the scope of this work.

This work is organized as follows: in Section 2 we present an overview of research on accessibility in the Metaverse. In Section 3 we discuss challenges and opportunities and answered our research question. Finally, conclusion and future work are presented in Section 4.

2. Levels of Accessibility

The purpose of this section is to present an overview of works that supports people with disabilities to access the Metaverse. We organize the works in relation to the type of disability, that is, research that support visually impaired people will be grouped into vision modality, research aimed at hearing impaired people will be grouped into hearing, and so on. This organization was inspired by the taxonomy of interaction modalities for eXtended Reality (XR) [Augstein and Neumayr 2019], which correspond to the ways in which humans interact and communicate with computer systems.

2.1. Vision

Vision is perhaps the most important human sense, and other senses usually only support vision. Accession of VR by society was marked in the 2010s, when computer science advancements led to the development of the first affordable VR head-mounted displays or headsets, Oculus Rift, HTC Vive and Google Cardboard, propelling immersive VR to the next technological level towards becoming mainstream [Mystakidis 2022]. Nowadays, consumer-grade wireless, stand-alone VR headsets are the norm. Enterprise-grade Mixed Reality (MR) headsets e.g., Microsoft HoloLens, Magic Leap and AR wearable smart glasses have also emerged [Barteit et al. 2021]. Although these devices have evolved from the point of view of hardware (displays, processing, memory sizes, high-speed networking, tracking systems) and software (rendering algorithms, computer vision, artificial intelligence, etc.), what were the solutions developed to support people with visual disabilities?

For people with low vision, post-hoc options can be applied to any application running on-device, such as the ability to magnify text content, enlarge fonts, invert colors, or change control-display ratios. SeeingVR [Zhao et al. 2019] demonstrated how many common vision-related accessibility settings (e.g., magnification, contrast adjustments, etc.) can be applied to virtual scenes; developing standards that all VR developers can adhere to in order to allow accessibility settings to apply universally across any VR application is another important topic for the community to consider. ARIANNA+ is a system that allows visually impaired people to easily navigate in indoor and outdoor scenarios simply by loading a previously recorded virtual path and providing automatic guidance along the route, through haptic, speech, and sound feedback [Lo Valvo et al. 2021]. Another application is the use of Video See-Through (VST) head-mounted binocular display [Peli et al. 1991], which is composed of three video cameras, on which image enhancement algorithms could be implemented to improve low vision people's ability to recognize faces and perform other daily tasks.

Moreover, it is also necessary that solutions support the description of visual content for other modalities, such as hearing and touch. For instance, as it is common that closed-caption file formats allow embedding of captions in online videos and the alternative text ("alt text") field in HTML and other document formats, the metaverse must also have the ability to render content in alternate modalities [Mott et al. 2019]. SeeingVR added metadata analogous to alt text into VR scenes, allowing objects to be described and text to be read aloud to people with vision disabilities [Zhao et al. 2019].

Regarding touch, Microsoft Research's Canetroller [Zhao et al. 2018] demonstrated how rendering virtual objects haptically, including simulating materials' properties and textures, could enable users who were completely blind to successfully navigate and understand virtual scenes when paired with a novel haptic controller that mimicked the interaction of a white cane.

Voice recognition can be defined as the ability of a machine to identify words or phrases from spoken language and convert them to a machine-readable language [Ali et al. 2017]. [McGlashan and Axling 1996] described VR that uses familiar interface to interact with an object such as physical actions, an input from a controller. Combining voice interface to manipulate an object directly can result in improving immersive experience, where a user can act upon the virtual world by using voice commands and the system can react by speaking or by initiating changes in the virtual world.

2.2. Audition

Recent advancements in Augmented and Virtual Reality (AVR) have made it a potential technology to improve communication with Deaf or Hard of Hearing (DHH) people in real-time. It is a chance for research with strong social impacts as it enables the social inclusion of impaired people in theater entertainment, conferences and all sorts of live presentations [Teófilo et al. 2018]. Some AVR solutions developed [Mirzaei et al. 2012, Berke 2017, Teófilo et al. 2018] improve live communication between deaf and ordinary people by turning ordinary people's speech into text in a device used by the deaf communicator. In some situations, the deaf also can write texts to be turned back into speech, so the ordinary people can understand.

[Luo et al. 2012] designed and implemented a MR application which simulates in-class assistive learning and tested at Chinas largest DHH education institute. The solution has two main components, one component is the assisting console controlled by a hearing student, the other component is the virtual character displaying viewport which fulfills assistance. The hearing impaired student side of the system has a virtual character shown on the user content screen which can take predefined actions, while the hearing student side of the system has a control User Interface (UI) shown on the user content screen to manipulate a virtual character at the other end to perform such actions.

Work reported in [Paudyal et al. 2019] proposes a VR classroom experience that facilitates live interpretation. During live sessions, DHH students can ask questions, receive feedback and have interactions with other students. EarVR analyzes 3D sounds in a VR environment and locates the direction of the sound source that is closest to a user [Mirzaei et al. 2020]. It notifies the user about the sound direction using two vibro-motors placed on the user's ears. EarVR helps DHH persons to complete sound-based VR tasks in any VR application with 3D audio and a mute option for background music.

2.3. Tactition

Recent efforts have explored how to improve the accessibility of VR games for people who use wheelchairs. A survey by the Disability Visibility Project [Paciello 2014] found that people who use wheelchairs might have difficulties performing actions such as crouching or moving while playing VR games. WalkinVR is a driver for SteamVR games that allows users to move their virtual avatar using controllers instead of physical locomotion [WalkinVR 2022]. WalkinVR also allows users to shift the height of controllers in VR, and to create a virtual controller to replace a physical one.

[Gerling et al. 2020] surveyed wheelchair users about their thoughts on VR accessibility and found that survey respondents had concerns about the accessibility of VR, but they also appreciated that VR might offer a means for escaping reality and enjoying new experiences. The authors used insights from their survey to create three prototype VR games for wheelchair users.

Researchers have investigated the accessibility and suitability of head-mounted displays (HMDs) for people with upper-body motor impairments. Work reported in [Malu and Findlater 2015] conducted a larger investigation of the accessibility of Google Glass and created a touchpad input system to control the device. In their study investigating the acceptability of Google Glass for people with Parkinson's disease, [McNaney et al. 2014] found that their participants experienced difficulties with the device recognizing their speech, and with performing tap gestures.

2.4. Olfaction and Gustation

Gustatory and olfactory stimuli are widely neglected, although the sense of smell and taste influences many of our daily life choices, affects our behavior, and can catch and direct our attention [Dozio et al. 2021, Ranasinghe and Do 2016]. However, research has been developed to implement these stimuli to computer systems. Researches such as [Dozio et al. 2021] and [Ranasinghe and Do 2016] discuss the main perspectives and challenges to be explored by the HCI community. Although they are essential for improving the user experience in the metaverse, olfaction and gustation are output stimuli and are unlikely to be used as an alternative for people with disabilities to communicate with computer systems.

3. Discussion

An open challenge is for the community to agree upon and define the metadata necessary to allow multimodal representations of content so that an appropriate representation can be chosen based on a user's abilities [Mott et al. 2019]. Metadata that encode objects' haptic properties, such as their materials and textures, will be important for creating realistic haptic renderings for people with limited vision. The addition of such metadata also has great potential for a large range of applications that can benefit the general audience of metaverse users, such as adapting content for temporary or situational impairments, creating "spectator interfaces" that log or describe the content to users.

The lack of open metadata is a kind of adoption barrier for making the Metaverse available to DHH people. Another limitation is relying on sign language interpreters to make content accessible. As an alternative, Artificial Intelligence (AI) mechanisms can be a solution for implementing avatars that simultaneously translate content into sign language.

Prior research on the accessibility of HMDs highlights the importance of identifying accessibility barriers for emerging technologies and the need to design and test alternative input methods [Mott et al. 2020]. However, VR systems employ more advanced input controls that can pose additional accessibility barriers to people with limited mobility. In addition, VR HMDs are bulkier and heavier than Google Glass, and VR HMDs tend to cover the eyes completely.

Therefore, considering the studies analyzed in this work, we conclude that there is still a long way to go so that people with disabilities can access and take advantage of the features and experiences that the Metaverse provides. Thus, answering our research question that motivated this study, we are not yet prepared to guarantee accessibility in the Metaverse.

4. Conclusions and Future Work

This work aimed to present research developed to facilitate the accessibility of people with disabilities in the Metaverse. Challenges and research opportunities were presented in order to help the scientific community in discussing and reflecting on how current problems can be solved and providing better experiences in the Metaverse for people with disabilities. We understand that the main contribution of this work is to encourage more discussions by the HCI community and propose mechanisms that guarantee access to the Metaverse by anyone.

As future works, we intend to carry out a systematic mapping of the literature and systematically characterize the state of the art of primary studies on accessibility to the Metaverse.

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