Immersive Technologies: challenges of the inclusive design in times of natural hazards and climate change

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Abstract

This paper addresses inclusive design in immersive technologies. From this perspective, we intend to expand the discussion on inclusive design among researchers and developers of immersive technologies. In addition, we intend to promote reflection on the importance of implementing inclusive design in projects involving climate change awareness and natural hazard mitigation. From the development of this research, we realized that, in general, the contributions of accessibility guidelines, inclusive design principles, and the research agenda represent a solid basis for discussing the opportunities and challenges related to the use of immersive technologies in emergency situations, ensuring that they do not exclude people with disabilities.

Keywords

Climate Change. Inclusive Design. Natural Hazards. People with Disabilities. Immersive Technologies

1 Introduction

In recent decades, there has been a growing global concern about climate change, leading to the need for strategies to slow down these changes [16]. An example of this is the United Nations Framework Convention on Climate Change (UNFCCC[1]), which was signed in New York on May 9, 1992, and ratified by Brazil through the enactment of Decree 2.652 [8]. The convention emphasizes the commitment of member countries to environmental issues, with annual meetings held at the Conference of the Parties (CoP). Among these commitments is the "protection of the world's climate for present and future generations of humankind" [8]. As stated in Article 2, the objective of the UNFCCC is "the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. This level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner" [8].

According to the United Nations, the growing environmental imbalance caused by human activity results from the increase in CO2 levels in the atmosphere, which is the main component of the greenhouse effect. This is the primary driver of global warming and it influences the incidence of natural disasters (e.g. landslides, wildfires, and floods), which negatively impact the economy and the quality of life of the population [15]. For example, in Brazil, the state of Rio Grande do Sul was recently affected by heavy rains that had a significant impact on the local economy and resulted in the deaths of at least 170 people, and the evacuation of over 600 thousand residents [27].

Considering the need to raise awareness about risks and mitigate the impact of severe environmental events on society, studies have demonstrated the potential of immersive technologies in assisting this process. These technologies enable people to experience simulations of real-world phenomena, such as understanding the risks associated with natural hazards [2, 29–31].

However, technological advances that contribute to new modes of interaction with information (e.g. hand-held and head-mounted immersive devices) are subject to the current image-driven and hyperconnected culture. In this context, people with disabilities who are part of a constantly changing society are not always included in these new technologies. Consequently, a significant portion of the population – 18.6 million people in Brazil [22] – is deprived of a range of new technological resources and becomes even more vulnerable to risks. For instance, they may not be notified of high-risk areas that should be avoided or may not have access to updated protection information during natural disasters.

For this reason, there is a need to foster a discussion with computing and IT professionals about the importance of implementing inclusive design in the development of immersive technologies. It is believed that promoting a dialogue about accessibility and inclusion with experts – especially researchers with lived experience – elicits empathy and reflection on the development of immersive technologies that benefit everyone [18]. Thus, the aim of this work is to: 1) expand the discussion on inclusive design among researchers and developers of immersive technologies; and 2) promote reflection on the importance of implementing inclusive design in projects involving climate change awareness and natural hazard mitigation.

2 Background

Unlike other technological platforms that have mature accessibility guidelines and technical recommendations for their implementation, accessibility in AR and VR is still the focus of a recent joint effort by consortia [33], associations [4], and research groups [1]

[1]Available at https://unfccc.int.

from around the world. It is also important to highlight that a crucial element in consolidating helpful guides is the participation of different communities of people with disabilities in line with the principle "Nothing About Us Without Us" [14], making the work even more complex.

Research and recent reviews also address accessibility in AR and VR from other perspectives. Dudley et al. [14] propose "inclusive immersion" as an extension of the concept of inclusive design for AR and VR technologies. They provide a comprehensive review of articles that contribute to the theme of inclusion in Extended Reality (XR) environments through recommendations, taxonomies, technologies, and techniques that maximize their use for the broadest possible portion of the population. The authors further describe the contributions of the articles by categorizing them into works related to different perceptual abilities (blind people, people with low vision, and people with hearing loss), cognition (people with intellectual disabilities and neurodiversity), and mobility (people with motor disabilities and balance issues). They also explore the use of AR and VR in training, simulation, health, and other areas. Finally, the authors synthesize six common design principles behind inclusive immersion: output redundancy, input redundancy, integration of assistive technology, customizability, enhanced assistance, and inclusive design.

Creed et al. [12], on the other hand, describe the application of a sandpit technique alongside representative groups (e.g., researchers, developers, Assistive Technology specialists, people with disabilities, and others) to build a research agenda for inclusive AR and VR. This agenda is organized based on types of disabilities and accessibility barriers from both software and hardware perspectives: physical disabilities, visual impairments, cognitive disabilities and neurodiversity, and hearing impairments. Each of these topics, in turn, includes research subtopics that can be addressed, such as customization and dynamic mapping of the abilities of users with physical disabilities (software) and mid-air haptic interaction via ultrasound to improve feedback for users with visual impairments (hardware).

Altogether, the contributions of accessibility guidelines, inclusive design principles, and the research agenda represent a solid foundation for discussing the opportunities and challenges related to the use of immersive technologies in emergency situations, ensuring they do not exclude people with disabilities.

3 Challenges and Opportunities

Several reasons may lead to the lack of accessibility of an AR/VR application during its development, such as the lack of standard practices, experts, and access to users from specific demographics. In this section, we will cover a couple of AR/VR scenarios that remain to be explored within accessible contexts. Due to the lack of user experiments involving people with disabilities, we believe these are valuable research gaps for future endeavors.

3.1 Accessible Evacuation Interfaces

Be it in training, simulation, or live guidance scenarios, AR and VR have been used and studied in evacuation scenarios for disasters such as earthquakes, fires, tsunamis, and radioactive accidents [3, 23, 26]. However, the accessibility of these scenarios is rarely discussed. Although addressing that AR is suitable as an assistive navigation for people with visual impairments, Lovreglio & Kinateder [23] acknowledge that these were only validated as "traditional solutions for training and navigation purposes", as opposed to evacuation scenarios. Diao & Shih [13] developed an AR pathfinding system specifically focused on a dark environment evacuation scenario. Their solution, however, only provides visual feedback to the users, augmented on a hand-held device, thus limiting its usage by people with visual impairments.

In order to study the usage of evacuation elevators in deep underground metro stations, a VR scenario was created and tested by Mossberg et al. [26]. The authors believe this to be important for people with movement impairments, such as wheelchair users, stating that the implementation of evacuation elevators could mitigate this issue [26]. However, participants from this demographic were not reported to be included in the study. Similarly, Arias et al. [3] tested simulated fire evacuation scenarios in VR environments. Besides the inclusion of a few people in their late 60s and early 70s in the experiments, no age-related disability factors were discussed in the study [3].

Given the recent improvements in accessibility for VR [32] and AR [19] systems, we believe it is crucial that future AR/VR evacuation studies are made to be more accessible and inclusive of different conditions and impairments.

3.2 Immersive Teleguidance

Remote guidance systems have been used as a potential form of assistive technology for people with visual impairments [5, 10]. They typically rely on verbal instructions given by a remote operator who can view live video from a camera held by the user. Test results with users have shown a reduction in task completion time and an increased sense of safety and confidence during navigation [9]. While video transmission has been successful in providing remote support for navigation in outdoor environments, indoor navigation presents additional challenges, which is oftentimes the focus of evacuation studies [3, 13, 23, 26]. Indoor environments require more frequent and reliable assistance as well as greater accuracy [11]. This can be addressed through suitable immersive interfaces for both the user and the guide, asymmetrically in AR and VR, respectively.

In evacuation contexts, the identification of pertinent objects or hazardous zones would ideally be carried out by appropriate computer vision algorithms. However, the current state of the art is still considered unreliable for practical real-life implementations [28]. In this regard, many people engage in collaborative accessibility [7] by actively co-creating accessible environments, either in person – through companions, relatives, or friends – or remotely, using remote guidance services such as VizWiz [6] and Be My Eyes [21]. While highly useful, current remote guidance systems rely only on video streaming and voice chat, which can respectively be more limited than immersive environments [24] and sonification feedback [25].

More specifically, spatialized audio AR methods [34] can be developed for users with visual impairments users, as well as a digital replica of their current location in VR [35], so that the remote sighted guide can better understand the situation and offer guidance

cues that are more precise. This has been explored in an indoor guidance use case [17, 20], although not for evacuation purposes. This approach could result in more immersive, accurate, and rapid experiences for users with visual impairments and their sighted collaborators [7], especially in evacuation, where the time available to evacuate a building or a disaster scenario safely is limited, before its conditions become unsustainable [23].

4 Final Considerations

Despite the fact that people with disabilities have been following the technological advances that have occurred in recent decades, we still observe major challenges for this segment of the population to interact with computer systems (including those that provide user immersion). In this sense, we believe that this complexity is mainly related to the lack of adoption of strategies (such as the implementation of inclusive design in projects to develop these technologies) that do not offer satisfactory interaction for everyone. In addition, we believe that this scenario may be aggravated by the following factors: lack of financial investment to develop immersive technologies that are inclusive; an insubstantial representation of people with disabilities in their design and development processes; lack of available data on their use by people with disabilities; lack of experience of technology designers on how people with disabilities interact with devices; and, finally, false assumptions about this segment of the population generated by the low detail of information in the demographic census. Despite the increasing use of immersive technologies being explored in various fields, such as medicine, entertainment and education, there is still a need for more studies in health and environmental safety and evacuation areas. This is particularly concerning in relation to the inclusive design of immersive technologies. As for future work, we plan to conduct a systematic literature review to gain a deeper understanding of the topic, especially in relation to its use in natural hazard scenarios involving individuals with disabilities.

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