Faculty Research

XR Technology in GIScience

White Paper Author:

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Overview

Extended reality (XR) is a term used to describe augmented reality, mixed reality, and virtual reality technologies. XR technologies can be used as a teaching tool to mimic real-world experiences typically encountered in the physical environment (Alnagrat et al. 2022). These immersive experiences will allow students to connect with distant places that may otherwise be inaccessible, such as through virtual field trips, or by interacting and communicating with virtual objects and representations. Information retention has shown to improve with the use of immersive technologies, such as XR, because they increase student participation and support varying learning styles (Makransky et al. 2019).

Purpose of the Research

Having a vested interest in increasing engagement of undergraduate and graduate learning through the use of XR Technology, I recently completed a literature review to find out more about how XR technology is being used in the field. The purpose of this white paper is to understand broad use of XR specifically within the spatial sciences. Using recently published literature, this white paper seeks to address two questions: 1) How are XR technologies being used for geospatial education? and 2) What are the current challenges of integrating the technology?

Method

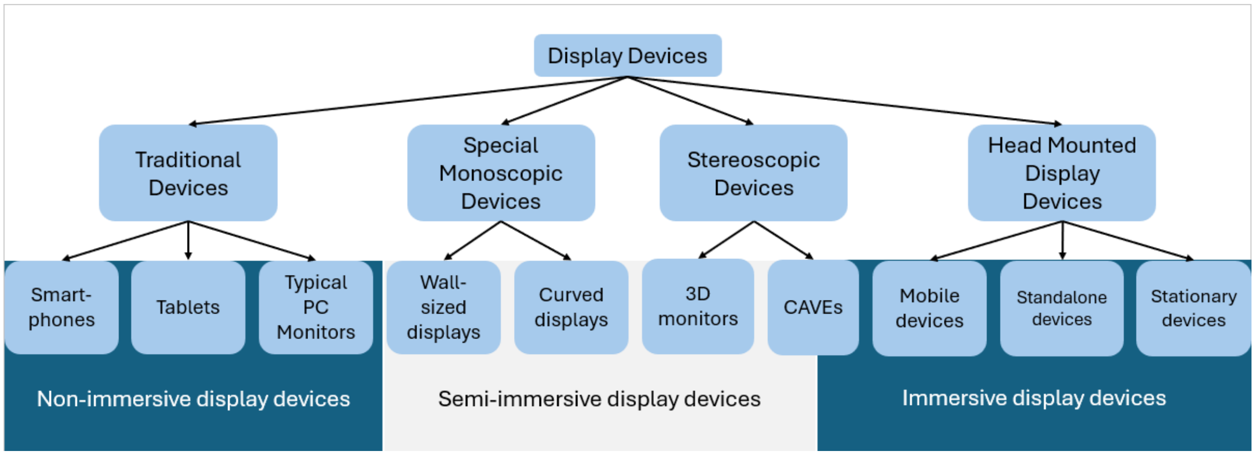
In the review of the literature, I examined a variety of work and the findings of this white paper draw from those. In particular, the work of Çöltekin, et al. (2020) with supporting literature from Alnagrat, et al. (2022) and Makransky, et al. (2019). The results of the literature review were synthesized under three main perspectives as developed by Çöltekin, et al. (2020). These include Technology, Design, and Human Factors each introduced and discussed in more detail in the Findings and Discussion section of this white paper.

Findings and Discussion

Technology

The use of different immersive technologies is the driving force behind XR technology. XR technologies have been used to teach spatial thinking, data interpretation, to simulate training environments, and as decision support tools. Formally defined, there are three main levels of immersion within the XR domain. These include non-immersive, semi-immersive, and fully immersive. However, immersion is not solely bound by the device used and often include user interactions and visualization design. Figure 1 organizes the three main levels of immersion.

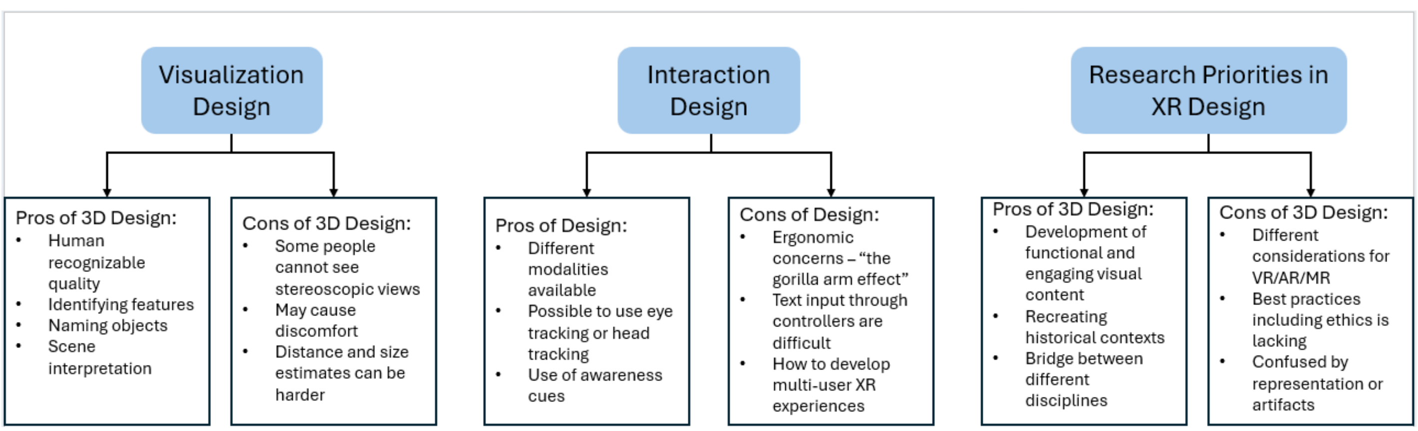
Figure 1. Taxonomy of the levels of immersion



Design

Design within XR Technologies is complex and can include many different parameters. Development of design elements can include how users will interact with the technology, what they will see, and what they should learn after interacting with the technology. With such broad objectives, Çöltekin et al. (2020) defines design through three main trends: visualization design, interaction design, and research priorities in XR design. Figure 2 below highlights some of the pros and cons to consider when designing materials using XR technology.

Figure 2. Three main design trends



Human Factors

Because the use of XR technologies is human-centered, human factors play an important role in developing and using any new technology. These include user abilities, limitations, behaviors, and known processes to help inform overall design. If users do not see the benefits of using a new technology, they are less likely to adopt them. In line with best practices identified through the Human Factors and Ergonomics Society, the authors identified six categories to consider before using XR technologies. These include aesthetics, comfort, contextual awareness, customization, overall ease of use, and cognitive overload. Users' knowledge of the technology, spatial abilities, age, and previous exposure to technologies such as video games can influence behavior and potential uptake within educational settings.

Existing Limitations and Challenges

Challenges with the use of XR technologies have been studied as their implementation and use in education becomes more prominent. While this paper does not seek to answer the existing challenges, the four that are relevant to integration within GIScience and education are outlined below with suggestions on considerations.

- Challenge.7¡.Cost.of.Equipment

The upfront costs of equipment can be prohibitive to many groups seeking to use XR technologies as part of their engagement process. Different modalities (i.e., VR/AR/MR) have varying levels of costs and should be examined to match learning outcomes that are sought to be achieved with the technology type specifications and requirements, and overall costs. Possible cost-saving strategies include using existing devices that have XR capabilities built in, leveraging open-source or free resources such as web-based applications and content developed for educational environments, and exploring affordable options that meet budget availability (e.g., Google Cardboard for VR displays).

- Challenge.8¡.How.can.we.create.inclusive.XR.displays?

Considering human factors is an important element to overall design and use of XR technology. Users' may have varying cognitive and perceptual factors that restrict them from viewing the intended environment or displays. This includes, but is not limited to, being able to see the 3D (stereoscopic) display, color deficiencies, or other limitations to motor skills. Using Gestalt design principles, such as understanding how people view patterns and perceive objects, and Bertin's visual variables, with the use of object orientation, textures, and color improvements should be analyzed and considered to increase inclusivity with the use of XR displays. External tools such as the Chromatic Vision (CV) Simulator (free to download on mobile devices) have been developed to allow users to experience how environments or objects appear to people with color vision deficiencies. Similar tools should be identified and used to help improve access to broader audiences of users.

- Challenge.9¡.Cognitive.Overload

Just as with GIS maps or applications, there is a point when too much information is being conveyed that the intended audience cannot clearly understand the overall messaging. The same is true with displays using XR technology. The cognitive load capacity may vary across individuals and specific groups of people. Suggestions from the literature include creating displays of virtual scenes with lower fidelity to ease viewer attention and focus. Other suggestions include specific customizations or personalization tailored to groups that may help to address or reduce possible discomfort.

- Challenge.0¡.How.should.ethics.be.included?

Addressing the potential biases and data limitations is a critical component to advancing the field. While most of the focus should be on the foundations and technical elements, understanding issues around risks, trust in data, privacy, and copyright restrictions should be included at some level within the curriculum. Having active discussions with students around these issues will provide clarity on identifying and understanding existing challenges and future implications.

Conclusions

This white paper primarily examined the work of Çöltekin, et al. (2020) with supporting references to Alnagrat, et al. (2022) and Makransky, et al. (2019). The results from the literature review highlight trends and considerations under the three topic areas of technology, design, and human factors. While the use of XR technology in education has shown to improve overall student engagement, it is not the only technology that should be used within student learning. The strength in the technology is its adaptability and use in combination with theory and other engagement techniques. The challenges identified in this white paper will persist and will be important to consider and address before educational engagement is conducted using XR Technologies for education.

References

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