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Developing a conceptual framework for usability evaluation of cartographic design principles in Mixed Reality applications

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Abstract:

The increasing availability of Mixed Reality (MR) devices with diverse capabilities has inspired researchers in the geo domain to explore new possibilities in cartographic applications within immersive environments while leveraging established cartographic design principles (Bertin, 1983; MacEachren, 2004). Existing MR applications seamlessly blend the physical and digital realms to form an environment where virtual and real-world objects can coexist and interact in real-time. By overlaying digital information, graphics, and 3D objects onto the user's real-world surroundings, it generates a hybrid reality that enables users to engage with both the real and virtual worlds simultaneously (Çöltekin et al., 2020; Kraus et al., 2022). However, the primary hurdle for designers of such immersive applications is the need for more knowledge regarding the usability metrics for cartographic design principles since there is a lack of knowledge on how these elements affect users' cognitive and visual perception of displayed content, which is vital for accurate communication of spatial information (Kveladze et al., 2019). Besides, in an immersive environment, symbols arranged around the user can be perceived in 3D with the help of a binocular stereo perspective through monocular depth cues to enhance the perception of visual variables size, shape, texture, etc. and communicate map content with the reader (Goldstein, 2010; Marr, 1982).

As Kveladze (2015) notes, only a limited combination of paired visual variables and depth cues can be used to represent qualitative and quantitative information in a 3D visual environment. This combination is different from the traditional static and two-dimensional geospatial representations, as Kettunen et al. (2012) itemised and evaluated through geopictures parameters in the context of map reading for wayfinding. To convey specific information effectively, it is essential to consider perceptual properties and choose appropriate parameters for visual variables since they are a crucial part of the design process. Differing from Kveladze (2015), Zhang et al. (2023) explored visual variables in Augmented Reality (AR) and stated that blending real and virtual environments complicates visualisation. Different factors, including strong light, can obscure virtual scenes, diminishing the effectiveness of visual variables. For instance, traditional maps have fixed colour values that are consistently rendered, providing a reliable and steady visual representation. However, in immersive representations, colours serve as base values with real-time rendering that is affected by various factors, including lighting conditions, material properties, the surrounding environment, and the positioning of the camera. Given the intricate interplay of factors, a particular colour appearance can vary in immersive environments, especially when depth cues, such as shadow and reflection come into play. Such variability may result in inconsistencies in user perception, and colour designated to accentuate a specific element may be perceived differently under various lighting conditions, potentially leading to confusion or a reduction in the effectiveness of the intended highlight.

Moreover, the visual variables change in size based on perspective due to the viewer's distance and spatial scaling, which affects how symbols are perceived. In traditional maps, the size variables are static and easily interpreted. However, in immersive environments, the apparent size of objects changes as the user moves closer or farther away from them. This dynamic resizing can disrupt the ordered perception of size variables, making them less effective for conveying information of relative importance. Besides, the size variables measured in pixels or meters can lose their intended meaning in immersive environments (Interrante et al., 2006). For example, a symbol meant to depict a large area might appear small when viewed from a distance, while a small symbol might seem disproportionately large when viewed up close. This challenge might add complexity to the use of size as a dependable visual variable in immersive contexts.

It is noteworthy that the experiment described by Zhang et al. (2023) exclusively utilized basic abstract symbols, overlooking the potential impact of more intricate and textured symbols, which could offer distinct guidance effects. Complex symbols with detailed textures and designs have the potential to provide more intuitive guidance and be easier to interpret in an immersive environment. However, the effectiveness of these more sophisticated symbols has not been explored yet. Therefore, it is essential to conduct user studies and further explore the information visualization capabilities

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of paired visual variables and depth cues for immersive applications. Such research can help bridge the existing knowledge gap, ensuring that immersive representations are as effective and intuitive as traditional maps. By understanding how users perceive and interact with map visualisations in immersive environments, developers can create more accurate and user-friendly immersive experiences.

As stated earlier, effective and efficient immersive visualisation heavily relies on cartographic design principles. Therefore, this study addresses the pressing need to optimize these design principles for the specific characteristics of immersive applications, as their usability is profoundly dependent on these factors. For instance, application elements must be easily distinguishable from one another in accordance with figure-ground theory. They also should be sizable enough to be visible and navigable from a user's point of view. Besides, application elements should support user interaction, empowering users to manipulate the content of the immersive environment and showcase relevant contextual information based on their location and task performance. Interactive features such as selection, filtering, and annotation are pivotal in enhancing data visualization. These features should be intuitive and responsive to sustain user engagement and optimize information extraction. Accordingly, the objective of this study is to develop a conceptual framework for designing a methodological workflow for comprehensive data visualization strategy and user experience research. The framework's focus will be on evaluating the usability of cartographic design principles in MR applications to assess the efficiency and effectiveness of map representations for information extraction and knowledge communication. Finally, the research will provide recommendations as design guidelines for optimal combinations of visual variables and depth cues to visualize various aspects of maps in an immersive environment effectively.

References

Bertin, J. (1983). *Semiology of Graphics: Diagrams, Networks, Maps*. The University of Wisconsin Press.

Çöltekin, A., Lochhead, I., Madden, M., Christophe, S., Devaux, A., Pettit, C., Lock, O., Shukla, S., Herman, L., Stachoň, Z., Kubíček, P., Snopková, D., Bernardes, S., & Hedley, N. (2020). Extended Reality in Spatial Sciences: A Review of Research Challenges and Future Directions. *ISPRS International Journal of Geo-Information 2020, Vol. 9, Page 439, 9*(7), 439. Doi.org/10.3390/IJGI9070439

Goldstein, E. B. (2010). *Sensation and perception*. Eight edition, Brooks Cole Publishing.

Interrante, V., Anderson, L., & Ries, B. (2006). Distance perception in immersive virtual environments, revisited. *Proceedings - IEEE Virtual Reality, 2006*, 1. Doi.org/10.1109/VR.2006.52

Kettunen, P., Irvankoski, K., Krause, C. M., Sarjakoski, T., & Sarjakoski, L. T. (2012). Geospatial images in the acquisition of spatial knowledge for wayfinding. *Journal of Spatial Information Science*, *5*(5), 75–106. Doi.org/10.5311/JOSIS.2012.5.85

Kraus, M., Fuchs, J., Sommer, B., Klein, K., Engelke, U., Keim, D., & Schreiber, F. (2022). Immersive Analytics with Abstract 3D Visualizations: A Survey. *Computer Graphics Forum*, *41*(1), 201–229. Doi.org/10.1111/CGF.14430

Kveladze, I. (2015). Space time cube design and usability [University of Twente]. In *Dissertation* (Vol. 268). Doi.org/10.3990/1.9789036538596

Kveladze, I., Kraak, M.-J., & van Elzakker, C. P. J. M. (2019). Cartographic Design and the Space–Time Cube. *The Cartographic Journal*, *56*(1), 73–90. Doi.org/10.1080/00087041.2018.1495898

MacEachren, A. M. (2004). *How Maps Work, Representation, Visualization and Design.* The Guilford Press, NY, USA.

Marr, D. (1982). *Vision: A Computational Investigation into the Human Representation and Processing of Visual Information*.

Zhang, G., Sun, J., Gong, J., Zhang, D., Li, S., Hu, W., & Li, Y. (2023). Exploration of visual variable guidance in outdoor augmented reality geovisualization. *International Journal of Digital Earth*, *16*(2), 4095–4112. Doi.org/10.1080/17538947.2023.2259874

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