International Cartographic Association
Association Cartographique Internationale

Advancing Cartography: Exploring 3D Visualization and Interaction in Immersive Virtual Reality

Zdeněk Stachoň [a,*], Ondřej Kvarda [a], Gabriela Godišková [a], Petr Kubíček[a], Čeněk Šašinka [a]

[a] *Department of Geography, Faculty of Science, Masaryk University - 14463@mail.muni.cz, 451448@mail.muni.cz, gabriela.godiskova@phil.muni.cz, kubicek&geogr.muni.cz, ceneksasinka@gmail.com*

* Corresponding author

Keywords: 3D Visualization, User Interaction, Virtual Environment

Abstract:

This research explores the evolution of cartographic visualization from traditional 2D representations to the innovative application of immersive virtual reality (iVR) for advanced 3D cartographic visualization. With the emergence of computer technology and Geographic Information Systems in the second half of the 20th century, cartography began to involve the third dimension. However, these 3D representations were constrained by 2D interaction interfaces, such as computer monitors, keyboards, etc., limiting the full potential of natural interaction within 3D spaces.

iVR technology represents a groundbreaking advancement, providing users with a fully immersive 3D experience (Stachoň et al., 2025). It supports intuitive interactions, such as hand gestures and body movements, effectively overcoming the limitations of traditional interfaces. This innovation enhances spatial data perception and cognition by simulating real-world environments within virtual spaces, commonly referred to as "six degrees of freedom".

Despite its advantages, iVR presents challenges, including user adaptation to novel interfaces, alternative perspectives (see Figure 1), potential physical effects like nausea, and significant hardware requirements. The way the 3D map is displayed in iVR relative to the observer remains one of the main unresolved issues, and only a few studies have addressed this problem to date (e.g., Yang et al., 2018; Ghaemi et al., 2022).

Additionally, the integration of cartography with iVR remains a relatively unexplored area, requiring empirical research to develop effective iVR visualizations.

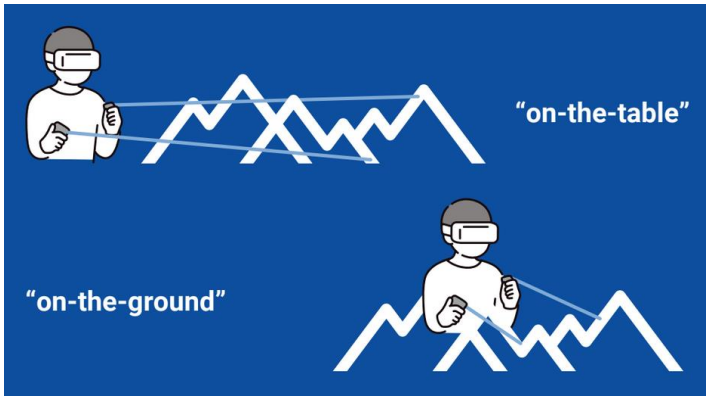

Figure 1. Example of alternative user perspectives in iVR.

This study addresses these gaps by creating a collaborative platform using eDIVE (eDIVE, 2023) software within the Unity engine. This platform is designed to evaluate various 3D cartographic visualization methods and interactions in iVR. It facilitates the manipulation and analysis of georeferenced data in GeoJSON format, establishing a dynamic environment for user studies. Furthermore, the platform incorporates logging capabilities for interactions and eye-tracking data, which are crucial for understanding user behavior and refining visualization techniques.

The proposed study focuses on comparing 3D multivariate cartographic visualization methods within iVR (Figure 2) to non-immersive approaches. Key evaluation criteria include user interaction, response accuracy, and task completion speed. The findings offer valuable insights into 3D cartographic visualization and interaction design within immersive virtual environments, showing the way for future advancements in the field.

Abstracts of the International Cartographic Association, 10, 273, 2025
32nd International Cartographic Conference (ICC 2025), 17–22 August 2025, Vancouver, Canada.
https://doi.org/10.5194/ica-abs-10-273-2025

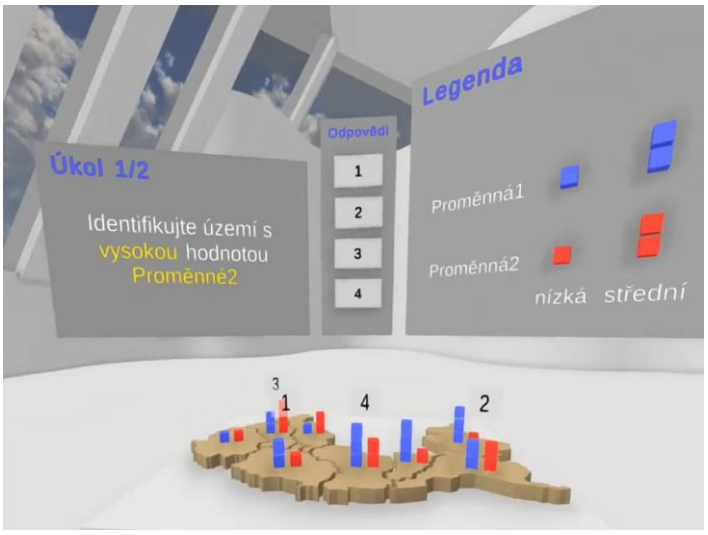

Figure 2. Example of study environment.

Preliminary results from earlier experiments conducted in single-user mode support the feasibility and effectiveness of the approach. These results indicate:

- A variation in the effectiveness of bivariate visualizations, depending on the design and interaction method.
- The importance of adapting visualization strategies for different user groups, leading to the design of adaptive immersive environments.

These findings validate the immersive design strategy and form the foundation for the next phase of research: supporting collaborative use of cartographic visualizations in multi-user immersive environments.

Acknowledgements

This contribution was supported by the Johannes Amos Comenius Programme (P JAC), project No. CZ.02.01.01/00/23_025/0008717, A Mobile Society: Opportunities and Risks of New Forms of Mobility for Czech Society and Economy.

References

eDIVE, 2023. eDIVE Platform. https://gitlab.fi.muni.cz/grp-edive/edive-platform

Ghaemi, Z., Engelke, U., Ens, B., Jenny, B. 2022. Proxemic maps for immersive visualization. Cartography and Geographic Information Science. 49. 1-15. https://doi.org/10.1080/15230406.2021.2013946.

Stachoň, Z., et al. The Possibilities of Using Immersive Virtual Environments in Research on Wayfinding. International Journal of Human-Computer Studies. 2025, 103442, n. 196, pp. 1-20. ISSN 1095-9300. https://dx.doi.org/10.1016/j.ijhcs.2024.103442.

Yang, Y., Jenny, B., Dwyer, T., Marriott, K, & Chen, H., and Cordeil, M. Maps and Globes in Virtual Reality. 2018. Computer Graphics Forum. 37. https://doi.org/10.1111/cgf.13431.