

**ABSTRACT**

A mini-map constitutes a fundamental tool supporting orientation and navigation within a virtual topographical space. Despite the widespread use of this solution, the relationships between its design features and the efficiency of spatial task performance have not yet been comprehensively examined in research on navigation in virtual environments. Existing studies rarely address the optimization of mini-map design parameters in the context of movement within a three-dimensional environment generated from official topographic datasets, which indicates a significant research gap.

This doctoral dissertation focuses on the analysis of navigational efficiency in relation to the design features of a mini-map. Navigational efficiency is defined as the shortest-distance and shortest-time completion of a route within a virtual topographical space. The aim of the study was to determine how variation in the mini-map's screen position, geometric shape, and orientation relative to the user's direction of movement affects time and distance parameters as well as the structure of spatial route choices. The empirical basis of the research consisted of user studies in which participants performed navigation tasks along designated routes in a three-dimensional spatial model developed on the basis of the BDOT10k database. Eight variants of the mini-map were assigned to equal experimental groups, enabling comparative analysis under controlled conditions.

Methodologically, the study adopted an integrated approach combining tools of digital cartography, statistical analysis, and perceptual research. The analysis of time and route-length parameters was complemented by quantitative cartographic visualization of movement patterns using ribbon flow diagrams and sequential flow visualizations, which enabled the identification of spatial dominants and route selection strategies. The application of eye-tracking techniques made it possible to relate quantitative measures to patterns of visual attention organization during navigation.

The results indicate that variation in mini-map design features has a significant impact on navigational efficiency. Differences were identified in route length, task completion time, and the structure of spatial choices depending on the applied mini-map variant, particularly under conditions of increased street network complexity. The dissertation systematizes the relationships between mini-map position, shape, and orientation and the measurable and spatial characteristics of navigation, introducing an integrated research framework that combines statistical analysis, cartographic visualization, and perceptual analysis. The findings provide a foundation for the formulation of informed design principles for cartographic navigation interface elements in three-dimensional digital environments and contribute to the interdisciplinary advancement of research on geovisualization efficiency.

**Keywords:** mini-map; navigational efficiency; virtual topographical space; BDOT10k;