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3D-Geo-Vis: A Geovisualization Tool for Visual Analysis of Thematic Data in 3D

Jakub Zejdlik [a,*], Vit Vozenilek [a,b]

[a] *Department of Geoinformatics, Palacký University Olomouc, 17. listopadu 50, 771 46 Olomouc, Czechia, Jakub Zejdlik - jakub.zejdlik@upol.cz, Vit Vozenilek - vit.vozenilek@upol.cz*
[b] *Department of Geoinformatics and Cartography, University of Maria Curie-Sklodowska, al. Krasnicka 2d, 20-718 Lublin, Poland, Vit Vozenilek - vit.vozenilek@upol.cz*

* Corresponding author

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Abstract:

Although the use of the third dimension in thematic cartography is becoming increasingly widespread, the effective visual analysis of spatial 3D data often encounters limitations regarding user interfaces and the ambiguous application of visual rules. This paper builds upon the fundamental concepts of graphic variables (Bertin, 1967), further developed by Roth (2017) and others, and extends them into the environment of 3D web thematic cartography. The precise rendering and real-time user manipulation of these variables—such as dynamically adjusting extrusion height, symbol size, or colour ramps based on data attributes—are crucial for the clarity and cognitive accessibility of 3D scenes, as well as for an effective visual analysis.

The paper presents the web application 3D-Geo-Vis 2.0 (Figure 1), detailing its transition from an initial prototype to a fully integrated, centralized visualization environment developed utilizing the ArcGIS Maps SDK for JavaScript. Thanks to the SDK, it is possible to load layers from ArcGIS Online using JavaScript and directly access their properties, which, among other things, allows editing of graphic variables "on the fly" directly in the browser. The application is publicly available (https://jakubzejdlik.github.io/3d_geo_vis_2). This structural transition was directly informed by the results of comprehensive user testing conducted on the initial prototype. By employing the standardized User Experience Questionnaire (UEQ), valuable quantitative data regarding overall user satisfaction, interface efficiency, and clarity were gathered. This data-driven approach successfully highlighted specific usability bottlenecks. Particularly, the results revealed increased cognitive load and spatial disorientation caused by navigating between separated methodological pages. Consequently, during its ongoing development, the user interface was heavily optimized to maximize scene readability and streamline the visual analysis process. Specifically, a distracting side panel was eliminated in favour of a centralized layer manager and a collapsible symbology panel that can be freely opened and closed on demand, ensuring that user attention remains focused on the 3D environment rather than solely on parameter adjustments. As a result of these optimizations, the application abandons fragmented pages in favour of a cohesive, user-centered interface where users can seamlessly manage and analyse their data without losing context.

Figure 1. 3D-Geo-Vis 2.0 – example of 3D graduated symbols.

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Built on open-source code available via GitHub (https://github.com/jakubzejdlik/3d_geo_vis_2), the application allows users to dynamically add their own layers from ArcGIS Online directly into the interactive 3D scene, encompassing thematic data, elevation models, and 3D building models. Within the virtual globe's environment, seven 3D geovisualization methods (Zejdlik & Vozenilek, 2025) can be combined and explored: horizontal planes, point clouds, vertical planes, 3D surfaces, 3D graduated symbols, prism maps, and voxels. The core functionalities of 3D-Geo-Vis 2.0 include algorithmic automation, which instantly calculates optimal default parameters for graphic variables (e.g., diameter, extrusion) and automatically zooms to the bounding box of the uploaded data. Furthermore, the tool provides users with comprehensive control over their datasets by allowing them to dynamically choose which data attributes drive the thematic visualization and text labels. Additionally, a centralized layer manager allows the user to easily toggle layer visibility, open the symbology editing panel, or remove a layer from the environment. The application ensures reproducibility through a sharing functionality that generates a unique URL link, preserving the complete state of the visualization scene, including rotation, zoom level, active layers, and the exact configuration of graphic variables. To ensure a smooth learning curve, the tool is accompanied by integrated methodological support (Figure 2) detailing the applied methods and variables.

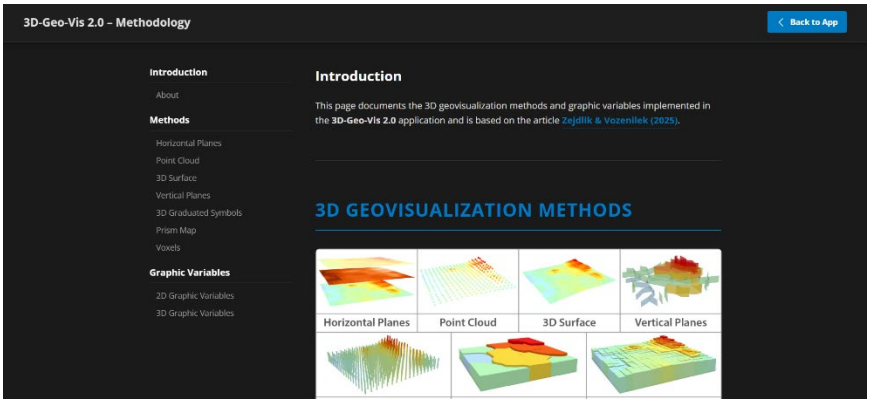

Figure 2. Application methodology describing 3D geovisualization methods and graphic variables.

From a cartographic perspective, the optimalization provided by 3D-Geo-Vis 2.0 is not based on just a technical improvement, but it is a fundamental step towards enhancing the cognitive accessibility and readability of 3D scenes. By removing visual noise from static panels and unifying controls, the user's attention returns to the very core of cartographic communication – the visual analysis of spatial data. This change allows for more efficient application and perception of graphic variables, such as extrusion height, symbol size, or colour scale, in real time, which is crucial for the correct interpretation of thematic information in a complex 3D environment. The centralized interface thus confirms in practice the lasting relevance of traditional cartographic rules even in web applications, where smooth manipulation of data without loss of spatial context directly reduces the risk of disorientation and increases the accuracy of user judgment.

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