Effectiveness of 2D and 3D Symbols on Virtual Globes

by **TIANQI LI**

Virtual Globe is a powerful tool for representing geosptial data in 3D environment. It has been widely used in all fields of research. Despite the popularity of Web-based Virtual Globes applications, little empirical study has been conducted on the effectiveness of Virtual Globes and the use of symbols. Only until recent years, researchers started to explore the 2D and 3D visual variables, for example, symbol shapes and orientations, for a more effective design. Nevertheless, none of the former research focus on zoom scale and different user circumstance.

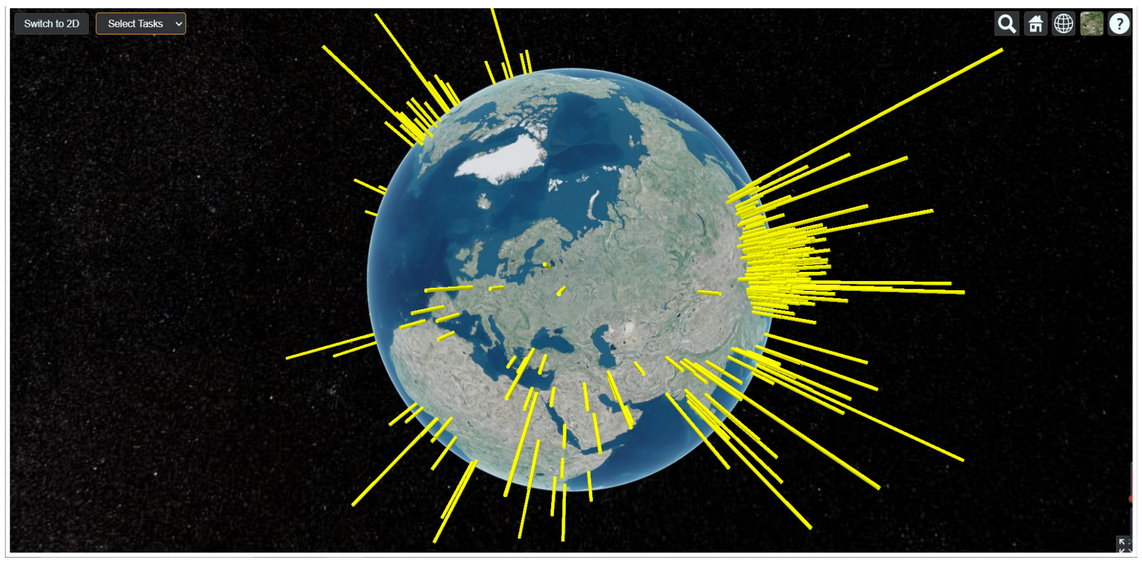

Fig . 1 Web-based Virtual Globes prototype. Created by using CesiumJS. Upper-left button provides switch symbol function. The button besides enable users to select tasks.

SCOPE

The overarching research objective for this study is to understand and explore the effectiveness of 3D and 2D symbols on Virtual Globes under different circumstances based on the existing symbolization guidelines. The influencing variables include 1> the different viewing scales of Virtual Globes and 2> the perception by different user groups. After the release of Google Earth, researchers started to examine the user's preference for point symbols between 2D maps and Virual Globes [1], the effectiveness of Virtual Globes for choropleth maps [2]. Based on the previous study on the effectiveness of visual variables of symbols [3][4], researchers extend the exploration (shape and orientation) to Virtual Globes environment [5]. The effectiveness of the symbols placed on desktop VGs for quantitative visualization is still not thoroughly explored [5].

METHODOLOGY

A Web-based prototype is developed as a tool for visualizing the quantitative data (Fig. 1). The prototype is created by using CesiumJS. 3D cylinders placed with normal direction are selected as 3D symbols, 2D circles placed with tangential direction are selected as 2D symbols. As there is no standard guideline regarding on the "scale" of Virtual Globes, three ranges of camera heights are defined to replace the concept of "small scale", "medium scale" and "large scale".

USER STUDY

A user study with fourteen tasks was conducted to evaluate the effectiveness of symbols. The tasks include extreme value identification and relative size comparison. A post-study with seven questions was added at the end of the study to investigate the subjective feelings of users, including mental load, and aesthetic preference. In total 32 users participated in the user study. Users were divided into cartographer group and non-cartographer group. The user study was conducted both in-person and online.

STATISTIC ANALYSIS

Shapiro-Wilk test is applied to check the normality of response distribution. The result indicates that all the responses do not follow normal distribution. Therefore Wilcoxon test at a significant level of 0.05 is applied to compare the difference between each response to the correct answer. Referencing the method used by Satriadi et al. [5], the Kruskal-Wallis H Test and post-hoc Dunn's test with a Bonferroni correction are applied to calculate the subjective feelings measurement.

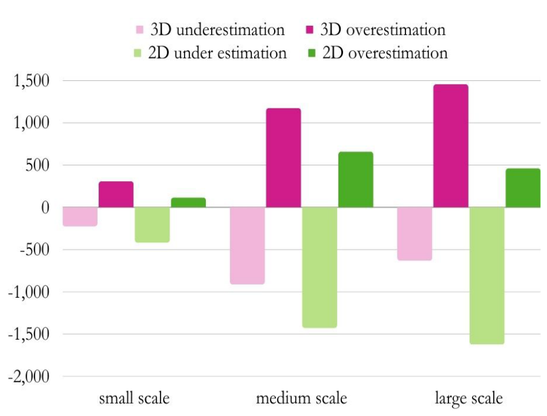

Fig. 2 Accumulated ranked difference for underestimated response and overestimated response when using 3D cylinders and 2D circles. Calculated by using Wilcoxon test.

RESULT

Overall, the result indicates that at small scale, the 3D cylinders are more effective than the 2D circles, and the effectiveness of 3D cylinders becomes worse as the zoom level becomes larger; 2D circles perform badly at all zoom scales, but are preferred by both cartographer and non-cartographer users at large scale for a more pleasant aesthetic design. Cartographers have better perception on 3D cylinders at all scales, while non-cartographer users have better perception on 2D circles. Both user groups are more likely to overestimate the 3D cylinders and underestimate the 2D circles (Fig. 2). The likelihood of overestimation and underestimation becomes larger as the zoom level becomes larger. Users' preference and effectiveness of 2D and 3D symbols do not show significant deviation at medium scale. Cartographer users are more confident when completing the tasks.

CONCLUSION

Rather than indicate a specific zoom point as a design guideline, this study proposes the idea that dynamic symbols changing between 3D and 2D based on zoom levels could be a better design for Web-based Virtual Globes applications. The specific changing point should always consider the purpose of visualization, the targeting users, the density of the objects, and other influencing factors. The outcome of this research could be useful in helping the future design of Virtual Globes for more effective geoinformation communication.

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