International Cartographic Association
Association Cartographique Internationale

Shaking Up Maps: Evaluating Earthquake Visualization with Vibrating Symbols

Paweł Cybulski [a,*]

[a] *Adam Mickiewicz University, Poznań, Poland; Faculty of Geographical and Geological Sciences, Department of Cartography and Geomatics, p.cybulski@amu.edu.pl,*

* Corresponding author

Keywords: vibrating symbols, animated symbols, eye tracking, earthquake visualization, empirical cartography

Abstract: Earthquakes are among the most formidable and hazardous geological events, capable of causing profound impacts on human lives, animals, infrastructure, and the environment. While they frequently occur across various regions of the globe, moderate to large earthquakes often strike unexpectedly, leaving little time for preparation. Advances in seismology and cartographic technologies have introduced animated visualization methods as a transformative tool for presenting earthquake data on the web. These dynamic approaches not only captivate users visually but also enhance our understanding of complex spatio-temporal phenomena, such as seismic activity (Karl, 1992). Furthermore, they offer the potential to elevate public awareness, improve preparedness, and strengthen crisis management strategies, surpassing the limitations of traditional printed maps. By leveraging interactive dynamic maps, users can more effectively explore and analyze the spatial and statistical relationships within earthquake distributions.

In recent years, cartographers and visual scientists have advanced methods for representing quantitative data by employing visual variables and dynamic techniques, such as dynamic point symbols (Tinghua, 1998; Lai & Yeh, 2004). These innovations bring new challenges to cartography, as animated symbols inherently draw significant visual attention. Consequently, it is essential to empirically evaluate the effectiveness of these solutions in specific geographic applications, such as the spatio-temporal visualization of earthquakes.

To begin with, a comprehensive analysis of earthquake web maps is necessary to identify the most frequently presented information and its relevance. Given their wide accessibility, web-based maps play a critical role in shaping public understanding and opinion. Evaluating the cartographic presentation methods and the underlying data is, therefore, a crucial component of this methodology. Based on these findings, tailored solutions in dynamic and interactive cartography can be developed.

Ultimately, such studies must include user assessments that address both objective metrics, like accuracy and efficiency, and subjective factors, such as user experiences and preferences. These evaluations should account for visual strategies employed by users and incorporate their subjective opinions, as preferences often influence the adoption and usability of cartographic products (Slocum et al., 2001; Vondrakova & Vozenilek, 2016).

The primary goal of this study is to empirically evaluate the use of vibrating point symbols for spatio-temporal visualization of European earthquakes. This evaluation encompasses an assessment of their effectiveness, efficiency, and the analysis of eye movement behavior through a comprehensive user study.

To evaluate the effectiveness and efficiency of earthquake maps incorporating innovative vibrating point symbols, this study employs a combination of survey methods and advanced experimental techniques. Surveys remain a foundational approach in cartography, allowing the collection of valuable insights directly from diverse user groups (Cinnamon et al., 2009; Cybulski & Medyńska-Gulij, 2018; Faliszewska, 2012). Ensuring inclusivity, the study aims to reach a wide range of participants, as larger sample sizes enhance the reliability of findings. To achieve this, online surveys are utilized, expanding accessibility and engagement with users across different demographics (Brychtová & Çöltekin, 2017; Schiewe, 2019).

However, recognizing the limitations of online surveys—such as uncontrolled external factors and potential inaccuracies—this research integrates laboratory testing to provide a controlled environment. Laboratory studies also enable the recording of eye movements, offering deeper insights into user interaction with vibrating symbols. Eye-

https://doi.org/10.5194/ica-abs-10-51-2025

tracking techniques, which analyze fixations (points of sustained visual focus) and saccades (rapid movements between fixations), are critical for understanding visual strategies and user behavior when navigating spatio-temporal earthquake maps (Cassin & Solomon, 1990; Dong et al., 2014; Gołębiowska et al., 2017). This comprehensive approach highlights the innovative use of dynamic vibrations in cartography while emphasizing inclusivity and robust empirical assessment.

The study was based on an online survey questionnaire involving 1,167 participants, and an eye-tracking laboratory study with 103 participants. The laboratory experiment included a smaller, more homogeneous group, all of whom had secondary or higher education. In contrast, the online survey featured a much larger and more diverse group, with a broad age range and varying education levels.

When comparing the effectiveness of different map variants, a nuanced understanding emerges regarding user performance and preferences. Searching for static symbols among other static symbols aligns well with users' prior training and familiarity, resulting in effectiveness comparable to searching for dynamic symbols among other dynamic symbols. Static map variants often exhibit greater efficiency, with participants completing tasks more quickly. This efficiency can be attributed to the intuitive nature of static symbols for users who are accustomed to traditional cartographic representations.

However, faster response times associated with static maps do not necessarily equate to precise analysis. The reduced response accuracy observed in static variants suggests that speed may come at the cost of careful consideration. Conversely, dynamic map variants, featuring innovative vibrating point symbols, demonstrate higher precision and accuracy in participants' responses. Although dynamic symbols may require slightly longer response times, their ability to capture user attention and support detailed spatio-temporal analysis underscores their potential as an inclusive and innovative approach to earthquake visualization. This contrast highlights the trade-offs between familiarity-driven efficiency and innovation-driven precision in cartographic design.

References

Brychtová, A. and Çöltekin, A., 2017. The effect of spatial distance on the discriminability of colors in maps. *Cartography and Geographic Information Science*, 44 (3), pp. 229-245.

Cassin, B. and Solomon, S., 1990. *Dictionary of eye terminology*. Triad Publishing Company, Gainesville, FL, USA.

Cinnamon, J., Rinner, C., Cusimano, M. D., Marshall, S., Bekele, T., Hernandez, T., Glazier, R. H. and Chipman, M. L., 2009. Evaluating web-based static, animated and interactive maps for injury prevention. *Geospatial Health*, 4 (1), pp. 3-16.

Cybulski, P. and Medyńska-Gulij, B., 2018. Cartographic Redundancy in Reducing Change Blindness in Detecting Extreme Values in Spatio-Temporal Maps. *ISPRS International Journal of Geo-Information*, 7 (1), 8.

Dong, W., Liao, H., Xu., Liu, Z. and Zhang. S. B., 2014. Using eye tracking to evaluate the usability of animated maps. *Science China Earth Scienes*, 57, pp. 512-522.

Faliszewska, A., 2012. Badania czytelności kartograficznych anamorfoz powierzchni. *Polski Przegląd Kartograficzny*, 44 (3), pp. 225-238.

Gołębiowska, I., Opach, T. and Rød, J. K., 2017. For your eyes only? Evaluating a coordinated and multiple views tool with a map, a parallel coordinated plot and a table using an eye-tracking approach. *International Journal of Geographical Information Science*, 31 (2), pp. 237-252.

Karl, D., 1992. Cartographic Animation: Potential and Research Issues. *Cartographic Perspectives*, 13, pp. 3-9.

Lai, P.-C. and Yeh, A. G.-O., 2004. Assessing the Effectiveness of Dynamic Symbols in Cartographic Communication. *The Cartographic Journal*, 41 (3), pp. 229-244.

Schiewe, J., 2019. Empirical Studies on the Visual Perception of Spatial Patterns in Choropleth Maps. *KN – Journal of Cartography and Geographic Information*, 69, pp. 217-228.

Slocum, T. A., Blok, C., Jiang, B., Koussoulakou, A., Montello, D. R., Fuhrmann, S. and Hedley, N. R., 2001. Cognitive and Usability Issues in Geovisualization. *Cartography and Geographic Information Science*, 28 (1), pp. 61-75.

Tinghua, Ai., 1998. Dynamic Symbol and Dynamic Map. *Geomatics and Information Science of Wuhan University*, 23 (1), pp. 47-51.

Vonrakova, A. and Vozenilek, V., 2016. User issue in geovisualization. *Proceedings of the 16th International Multidisciplinary Scientific Geoconference (SGEM 2016)*, Albena, Bulgaria, Informatics, Geoinformatics and Remote Sensing Conference Proceedings, SGEM 2016, vol. III.

https://doi.org/10.5194/ica-abs-10-51-2025