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User Study of Heat Maps with Different Levels of Generalisation

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Abstract:

Due to Web 2.0 and neocartography, heat maps have become a popular map type for quick reading. Heat maps are graphical representations of geographic data density in the form of raster maps, elaborated by applying kernel density estimation with a given radius on point- or linear-input data. These maps were imported into cartography from data visualization techniques. Their growing popularity comes from their attractiveness and ease of creation, using various mapping libraries. Despite being commonly applied, it has not been evaluated whether they are an effective solution as maps for quick reading in a web environment. Similarly, it has not been verified to what extent their level of detail is a key issue. Therefore the aim of this study was to compare the usability of heat maps with different levels of generalisation for basic map user tasks.

We conducted a user study in Poland with 412 high school students (16-20 years old). Each respondent answered the questions individually through a web application (Figure 1). The participants were divided into four, almost parallel, groups with approximately 100 people in each. Each participant solved one of the four possible tests, which were randomly selected when the application started. The tests differed in generalisation levels (4) and area variants (2) of the heat maps in order to avoid a learning effect. These areas, although different, were of a similar degree of difficulty, so the results are comparable.

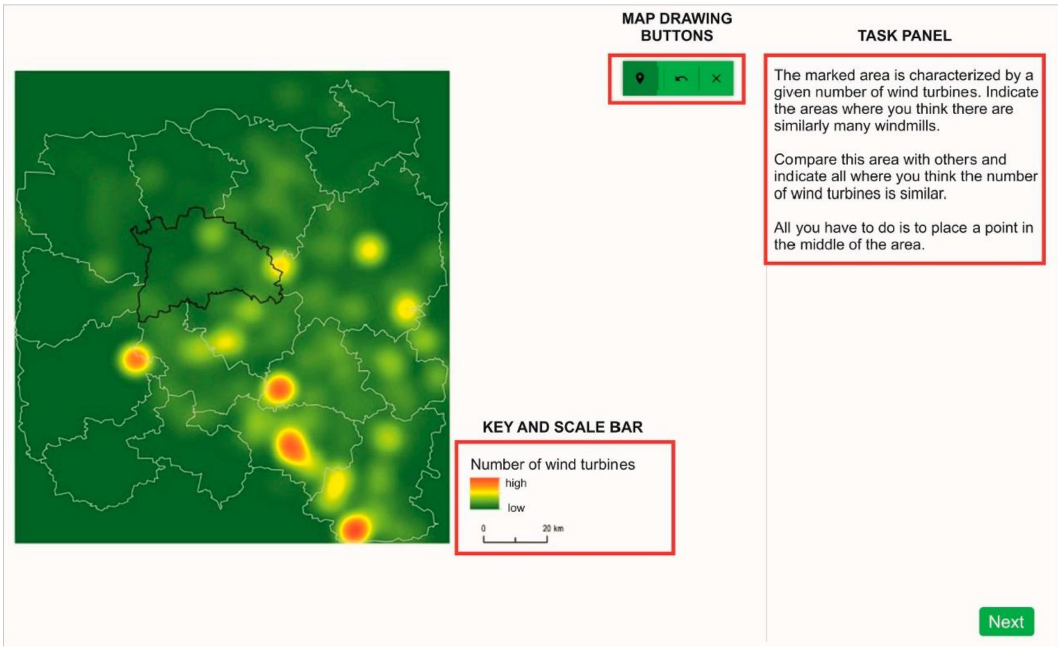

Figure 1. View of application with an example of the tested map and question.

As said, we compared heat maps with four different levels of generalisation, i.e. radii of 10 (HM10), 20 (HM20), 30 (HM30), and 40 (HM40) pixels. Five metrics were examined, two objective metrics – the correctness of the answer, response time, and three subjective metrics – response time self-assessment, task difficulty, preferences. We posed the following research questions: 1. How does the heat map's generalisation, defined by the size of the kernel radius,

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influence its effectiveness?; 2. What are the discrepancies between differently generalised heat maps in the context of efficiency and perceived efficiency?; 3. How do users perceive heat map difficulty depending on a generalisation level?

The results of the study show that the average effectiveness understood as the correctness was low (20%), which confirms the observations made by Netek et al. (2018), and Nelson and MacEachren (2020) that heat maps are not suitable for reading the exact value from the maps. Participants, who answered questions with help of less generalised maps (HM10, HM20), achieved better results than those using more generalised maps (HM30, HM40). The accuracy of answers was dependent on the level of heat map generalisation: X2 (3, N = 2454) = 29.145, $p < 0.001$, Cramér's V = 0.109, $p < 0.001$. Pairwise comparisons showed that the relation between variables occurred in four cases when comparing less generalised maps (HM10, HM20) with more generalised (HM30, HM40). Maps with lower radii presented data effectively.

When it comes to efficiency, understood as response time, general results show no significant differences between using heat maps with different levels of generalisation: significant: H (3) = 1.898, ns. However, in the case of response time assessment, results show the differences in while using heat maps with different levels of generalisation: H (3) = 13.434, $p < 0.010$. According to post hoc comparisons, maps that differed significantly from one another (in favour of more generalised maps) were HM20 and HM40 ($p < 0.050$). Thus, a higher level of generalisation resulted in higher perceived efficiency by heat map users.

In terms of the difficulty of the test, the results show that differences between heat maps with different levels of generalisation were significant: H (3) = 28.242, $p < 0.001$. Post hoc comparisons indicated that the maps which differed significantly from one another were HM10-HM40 ($p < 0.001$) and HM20-HM40 ($p < 0.001$). Participants assessed tasks conducted with help of the most generalised maps as the easiest.

Based on the presented results, it can be concluded that under certain conditions, heat maps can be considered a useful technique of presenting spatial data. At the same time, we remain aware of the limitations of the study. Heat maps are often used as interactive tools, and our study focused on display-only static maps. We believe that further studies could be devoted to heat maps in interactive environments and comparison of heat maps to other map types.

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