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Points-to-polygons and reverse animations for enhanced visual analytics on multiscale thematic maps

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Multiscale thematic maps are commonly characterized by an abrupt change in the image during the transition from one level of detail to another. This is associated with a simultaneous change in both the geometry of the spatial units (for example, from point settlements transition to areal municipal districts, or from municipalities to provinces), and symbology (for example, point symbols are replaced by choropleths). The abrupt change in representation makes it difficult for the researcher to correlate the distribution of the indicator at different levels of detail.

Transformation between graphical representations is among the urgent topics in both cartography (Lin and Gong, 2018) and information graphics (Lee et al., 2023). The aim of the research is to develop a methodology, algorithms and software to create cartographic animations of the "points-to-polygons" and "polygons-to-points" type. In particular, animated transitions between the three cartographic representations that correspond to the images on the Figure 1 are investigated.

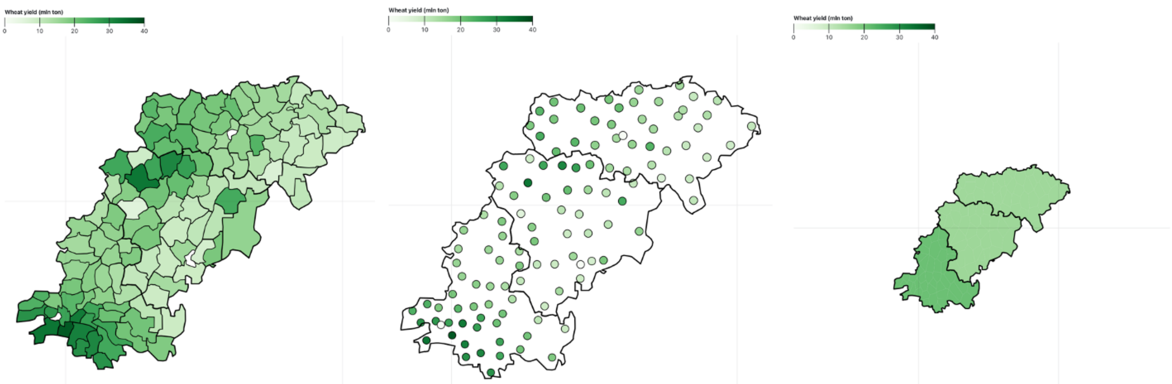

Figure 1. Reference cartographic representations:
a) detailed choropleth (left), b) point symbols (center) and c) generalized choropleth (right).

The transition from detailed choropleths to point symbols and vice versa (Figure 1 a-b-a) may be related to the need to change the localization of a symbol — for example, when changing from relative units to absolute units, or when reducing map scale so that they become insufficiently visible on the map. The transition from point symbols to larger map units and vice versa (Figure 1 b-c-b) is common in spatial analysis, where data on irregularly located points (stationary or not) are aggregated by areal units. The inverse process can be used to illustrate exactly how the aggregated data were derived — to show the mechanism of their generation. In particular, point aggregation can be used in multiscale mapping when it is not possible to show individual locations, and it is useful to aggregate the associated data within encompassing areas.

We consider point symbols represented by circles. To interpolate from polygons to circles, the circles themselves must be represented not by graphical icons, but by full-fledged spatial objects in which the circle contour is discretized with a given accuracy. Let us set the parameter $0 \leq s \leq 1$where 0 is a polygonal state, 1 is a circle state. In this case, the algorithm of transition between two states with a given step will look as follows:

1. Form two sets of (x, y) coordinates for s = 0 and s = 1, and find between them the optimal correspondence that preserves the direction of contour traversal as much as possible and minimizes shape distortions during transformation.
2. Organize the cycle by s from 0 to 1 with small steps, on each of which we obtain the coordinates of the intermediate figure as $(x, y)_d = d(x, y)_1 + (1 - d)(x, y)_0$.
3. Animate the results during visualization.

The results of the algorithm application on the example of municipal data are shown in Figure 2.

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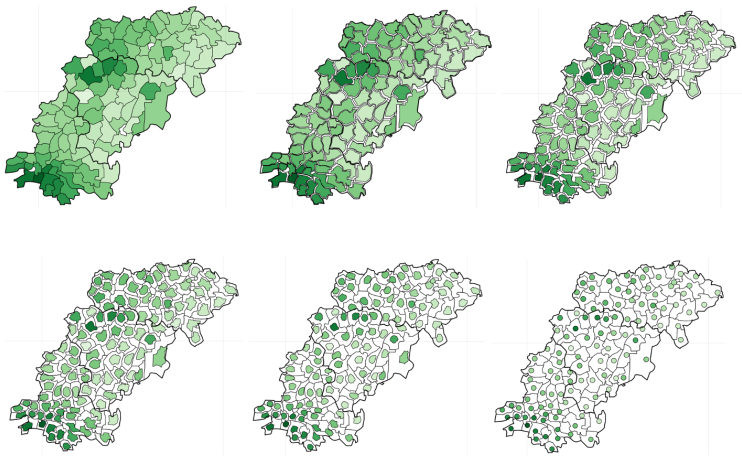

Figure 2. Intermediate states of transition between choropleth and point symbol representation on the map (scale is fixed).

When interpolating map representations during point data aggregation or the reverse process, the geometric configuration is complicated by the fact that the 1:1 ratio no longer takes place, and instead N point objects must be distributed over M polygonal objects, $N \neq M$, and commonly $N \gg M$. To implement such animation, it is necessary to ensure a smooth transition of one set to another. For this purpose, a special technique has been developed. At the preliminary stage the following actions are performed:

1. Determine the belonging of each point to its aggregating polygon. Divide the points into subsets according to their belonging to each polygon.
2. For each subset of points, draw a Voronoi diagram, setting the bounding rectangle of the corresponding polygon as its outer boundary.
3. Cut the resulting diagrams with bounding polygons.

After the preliminary procedure is done, we have a partitioning of M polygons into N Voronoy cells. This reduces the original problem to the previous case represented in Figure 2. At the same time, since the [dis]aggregation process is typical for multiscale mapping, an additional animation by scale is introduced. Results are represented in Figure 3.

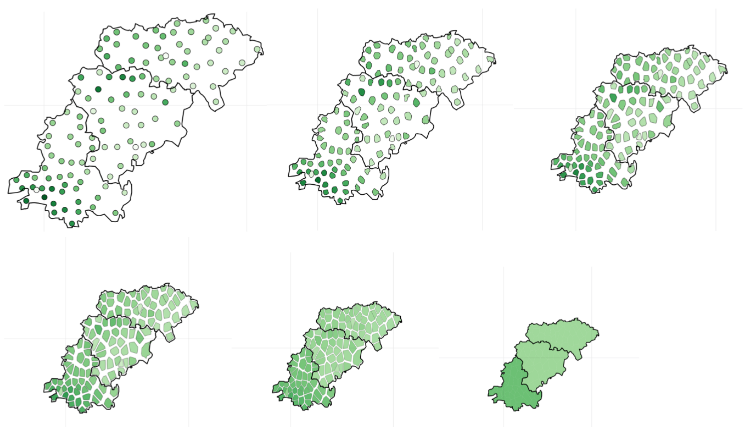

Figure 3. Intermediate states of transition between point symbol and chropoleth representation on the map (scale is changed).

Developed algorithms were implemented in JavaScript programming language and can be further integrated into existing web-mapping libraries. We plan to investigate other types of animations between cartographic representations, and also to conduct a user study to assess their effectiveness in analytical tasks.

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