Formalizing rules for automatic symbol translation in representation of city structure and road network on multiscale maps

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Abstract. Formalization of changes in map symbology is necessary for automation of multiscale mapmaking. This study aims to find and formalize some dependencies between changes in geometry and content of objects and changes in their symbology. Two elements of topographic maps are considered in case studies: city structure and road network. Usefulness of the results is assessed and possibility of future research is discussed in concluding part

Keywords. Multiscale maps, formalization, symbology.

1. Introduction

Multiscale mapping assumes that level of detail and symbology change interactive depending on scale (Brewer Buttenfield 2007). Geometric generalization is rather well automated (Li 2007), however for most cases it does not allow production of reliable results in real-time mode. At the same time processes that transform symbols and graphic variables, aren't formalized enough and it hinders their automation. A consequence of it is that the traditional technology of multiscale maps design assumes manual design of each scale level.

Our research aims to search and formalize some dependencies between changes in geometry and content of objects and changes in their symbology on topographic maps.

2. Methodology

2.1. General considerations

As there can be nearly infinite number of possible graphic solutions, we decided to develop one formal sequence of symbol transformations in each case study that follows most commonly used methods of multiscale map design. Transitions of graphic variables between map scales are usually gradual, and symbols in consequent levels of detail usually have some identical or close graphic variables: color, width, shape etc.

We simulate symbol conversion of each phenomenon as serial modification of the initial visualization method with certain parameters. It is supposed that the objects displayed on a map are stored in a database with multiple representations linked through hierarchical links.

The common practice is to gradually dissolve object stroke and make fill darker to keep good object perception. For symbol with fill and stroke (it can be both polygon and bordered line) translation can be coarsely formalized by the following set of rules:

1. If the symbol uses two colors (stroke and fill), a vector connecting these two colors is built in color space, and further change of colors occurs along this vector. The limitation is that initial colors must have identical or neighboring hues (for example, yellow and orange), but can have different saturation and lightness. Another limitations is that stroke color should be darker, so blending them will lead to darker fill color.
2. If gradual disappearance of a stroke is supposed, it is possible to bring together each time colors of fill and stroke along this vector according to changes in geometry (size of polygons, lines density) in a proportion k:1, k>1, (fill color is preferable).
3. When colors of fill and stroke converge then transformation can be continued by decreasing lightness of color and (optionally) increasing its saturation according to changes in geometry.

2.2. City structure

In case of the city structure it is reasonable to differentiate 4 hierarchical levels: houses, quarters, blocks of quarters and settlements. In turn, the road network can include lines of several hierarchical classes.

Using these principles, design of settlements can be performed using the following algorithm (Figure 1).

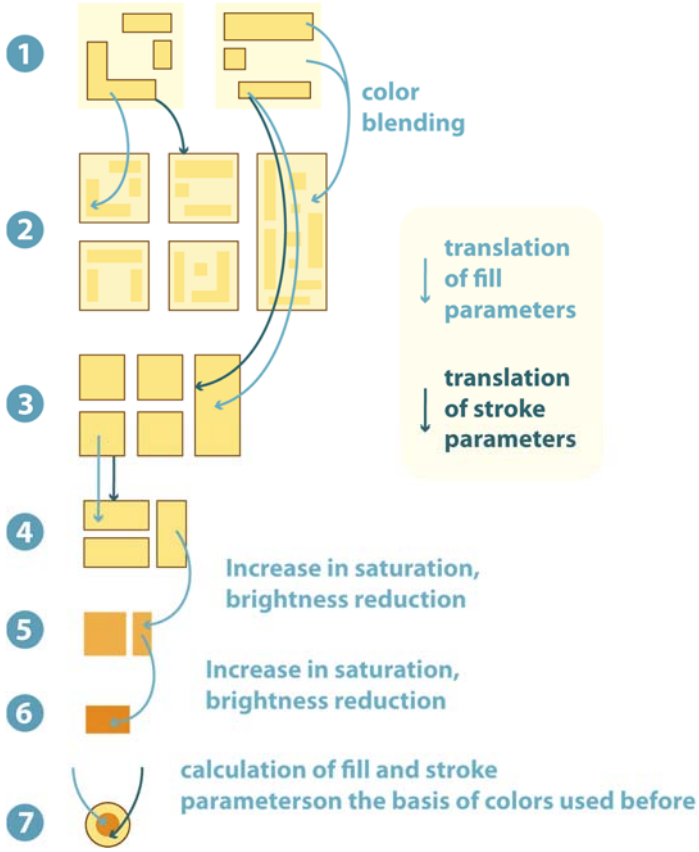

Figure 1. Algorithm of settlements graphic transformation

This algorithm was used for manual design of structure of the settlement with a condition of the maximum visual smoothness of scale transitions. 8 scales from 1:8 000 to 1:1024 000 were designed using OpenStreetMap data and data from 1:100 000, 1:200 000, 1:500 000 and 1:1 000 000 topographic maps. Changes in graphical variables and geometry of polygons between levels of detail were recorded.

We tried to find dependence between the average area of polygon and lightness of its fill color, and the derivative of this function that reflects the dependence of changes instead of absolute values. The following function was found for our design:

$$\boldsymbol{ResL} = \frac{Ln^3(\boldsymbol{ResS})}{\boldsymbol{K}} + \boldsymbol{M} \quad (1)$$

Where:

$$\boldsymbol{ResS} = \frac{S_{i+1}}{S_i}, \boldsymbol{ResL} = \frac{L_{i+1}}{L_i};$$

$\boldsymbol{S_i}$ – initial average area of a polygon at i-th level of detail;

$\boldsymbol{S_{i+1}}$ – new average area of a polygon at i+1-th level of detail;

$\boldsymbol{L_i}$ – initial filling lightness;

$\boldsymbol{L_{i+1}}$ – new filling lightness.

Coefficients $\boldsymbol{K}$ and $\boldsymbol{M}$ depend on character of used data and initial design. ResS ≥ 0,133 in our case. We also analyzed dependencies between average area of a polygon and its achromatic lightness factor (Figure 2), that was calculated as:

$$\boldsymbol{B} = \frac{\mathbf{10}}{\mathbf{100} - \boldsymbol{b}}$$

where b — achromatic lightness of color. We see that there is quite good correlation between values. However, quarters do nor dominate in image of city structure at 1:8 000 scale. This role is played by buildings. This fact is a reason that the color of quarter is not changed between 1:8 000 and 1:16 000 scales (left graph on Figure 2). Right chart on Figure 2 was constructed using buildings for 1:8 000 scale. Such formalizations can help to automatically manage lightness of polygons depending on their geometric characteristics. Changes in another characteristics, such as hue and saturations should also be investigated.

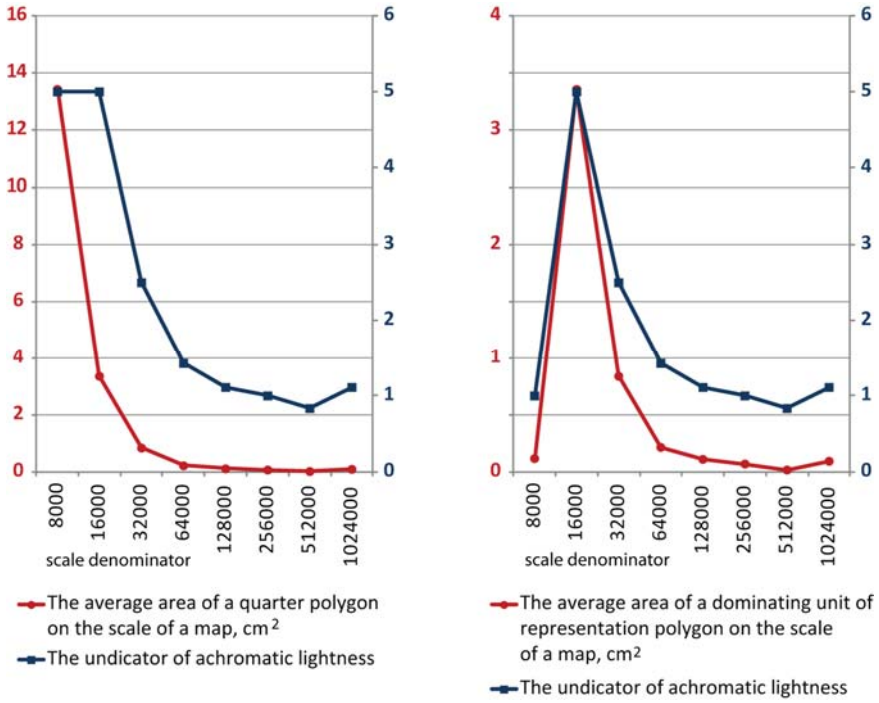

Figure 2. Dependencies between average area of a polygon and its achromatic lightness

2.3. Roads

The quantity of road classes varies with scale and territory. However, when a number of classes is larger than three, *k* of the largest classes should be recognizable in all scales and have the minimum changes of external appearance. We accept *k*=2.

All roads except the most small-sized class are designed as stroked lines, and *k* largest classes have more bright and saturated colors (it is made manually). Remaining classes are designed as follows: lightness of a color increases, and the thickness of line decreases for lower classes.

To mix the colors of fill and stroke the liner gradient is constructed using the following principles (Figure 3, left):

1. “The convergence point” divides the linear gradient connecting initial stroke and fill colors in proportion 1:3.
2. Both parts of a color scale are segmented into the number of map scales that cover road life cycle, and each subsequent part of a

segment in m>1 times more than previous (numbering begins from large scales).

Symbol translations for roads follow the sequence of actions (figure 3, right):

1. Fill and stroke parts of line are thinned proportionally, their colors are mixed using defined color gradient
2. Fill and stroke colors converge.
3. Line thickness and lightness for road class is decreased
4. Road class becomes translucent
5. Road class is eliminated.

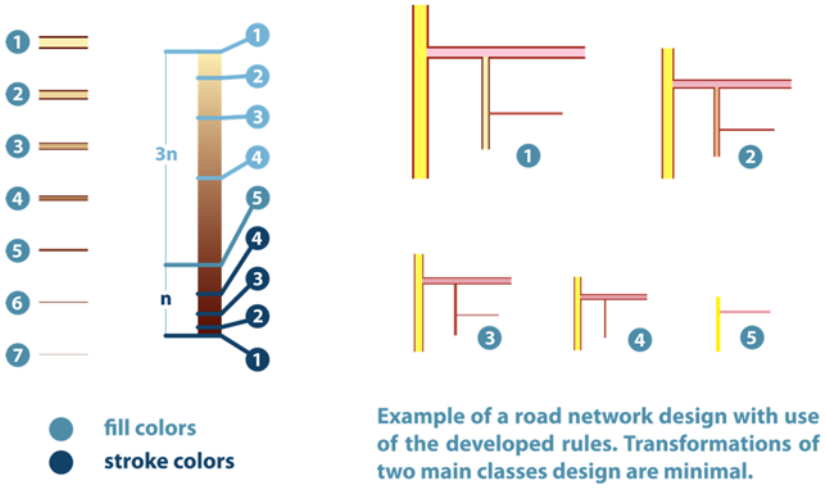

Figure 3. Chain of road network conversions and color blending mechanism

Not all classes of roads pass all steps. So, the largest classes are restricted to steps 1-2, and the most small-sized – 2-5.

On the basis of this chain manual design of a road network was made, and parameters of design were recorded. For two principal classes dependence between thickness of the line and saturation of its fill color was found (Figure 4).

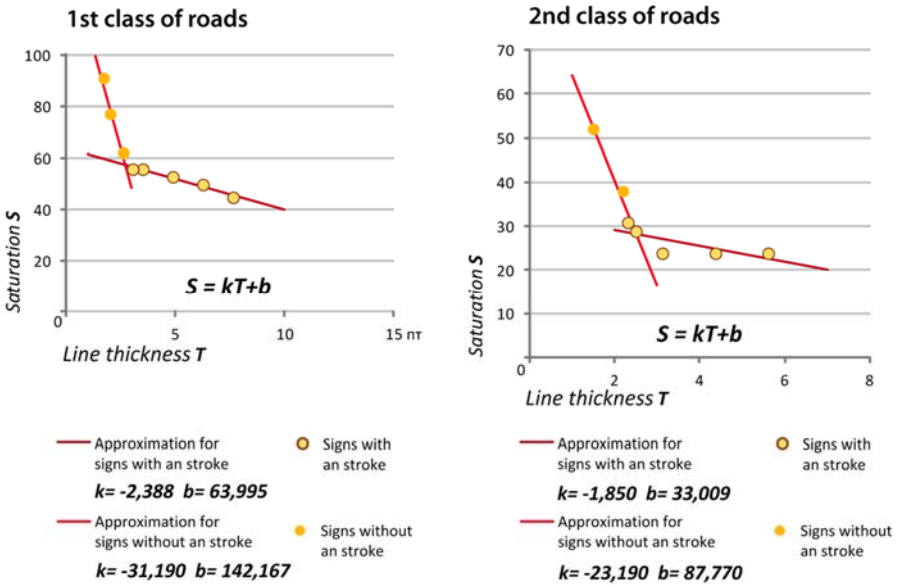

Figure 4. Dependence of saturation of filling of the line on its thickness

The negative coefficient ***k*** which is responsible for an inclination of a straight line, depends on the speed of graphic changes, that is is defined by a level of generalization of data and designs, and ***b*** coefficient linearly depends on the selected color tone. Also dependence of thickness of the line on density of roads of an appropriate class was found (Figure 5).

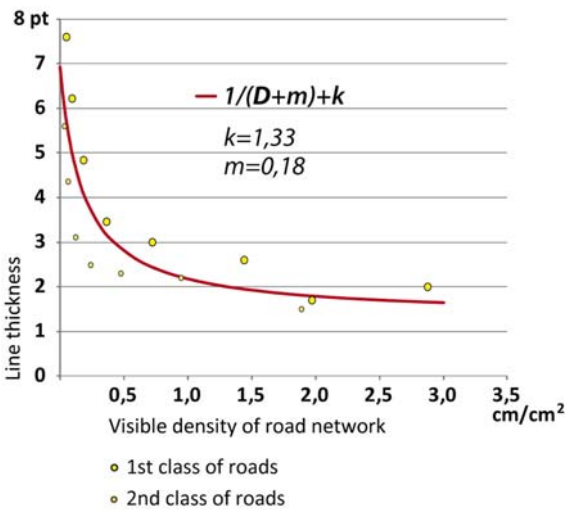

Figure 5. Dependence of thickness of the line on density of roads of an appropriate class.

The hyperbolic shape of a graph on Figure 5 is influenced by the fact that line thickness can't be reduced infinitely, and the line becomes thinner, the it is less opportunity for its further thinning. The exact shape of the graph depends on coefficients, which are caused by the initial design and used data.

3. Conclusion

Some rules are offered and formal dependencies are found for special cases that tie changes in scale, geometry and simple fill/stroke symbology together in multiscale topographic mapping. They can be programmed and further applied to automatically translate settlements and transportation network symbology from large scales to small. However they are not universal and based on a limited experience with case studies. Results need to be tested with various data and different options of initial design. Besides, for full application in automation similar investigations for remaining elements of topographic maps should be conducted.

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References

Brewer C.A, Buttenfield B.P. (2007) Framing Guidelines for Multi-Scale Map Design Using Databases at Multiple Resolutions // Cartography and Geographic Information Science, No34(1), pp. 3-15

Li Z. (2007) Algorithmic Foundation of multi-scale spatial representation. CRC Press, 310 p