

MAPS' SCALE IN DIGITAL CARTOGRAPHY

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Abstract

The meaning of map scale increases in the digital environment, despite the fact that the maps can be visualized in different map scales. Three kinds of map scales are examined, which are relatively independent of the maps, visualized on the display:

- **Scale of the map field space** – the current map scale, visualized on the screen.
- **Scale of the map content**, which defines:
 - **Particularity of the data** - the object quantity in each class, which are presented in the model and the number and the type of characteristics, with which they are described;
 - **In-detail representation of the information** - depends on the distances between the object and its sign, for instance, for the lines it depends on the degree of simplification of the outlines during generalization;
 - **Geometric accuracy of the data** - as described by the precision of the data sources and by mistakes made during the data entry.
- **Scale of the signs space**. The signs can have their own scale, different from the map scale. For example, the sign size can present some characteristics of the its object.

The paper maps have one scale, because as described above three map scales are conditioned and connected. In the digital environment the value of each sign from the given map scales, must be defined, in order to receive a specific cartographic image. Several examples of mistakes in digital maps are shown, caused by the use of a unified map scale.

The scale of the maps on a paper is strictly defined – it represents the ratio of the size of the map sheet to that of the mapped territory. Dependent upon it are the utmost representation in detail and particularity of the map, its maximum graphical loading as well as the accuracy with which we take the measurements.

An impression is given in a digital environment that there is not any clearly defined scale because:

- One digital map may form of different scale whether being it onto paper or on the display;
- One works with the real and actual coordinates of the objects;
- Practically unlimited number of objects and their characteristics may be represented in separate layers;
- The accuracy of the measurements depends on the precision of the output data only, not on the scale.

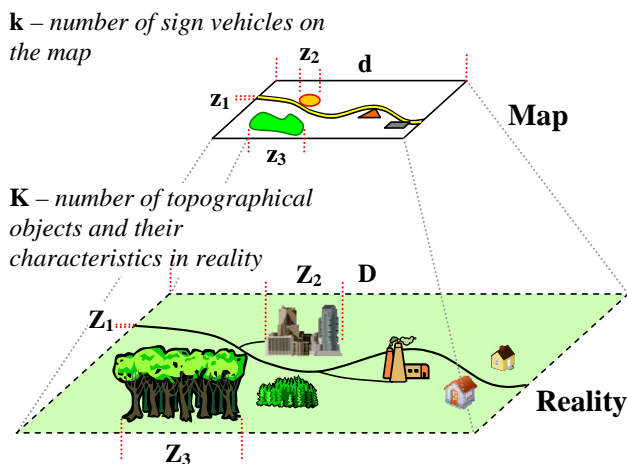


Fig. 1 Three scales on the maps

The lack of scale of the maps in a digital environment is just seeming. Instead of decreasing its significance the concept of scale in digital cartography does increase its role.

The digital maps have got three types of scale: scale of space, scale of content and scale of signs. Let us first have a look at Fig. 1. There is a certain number of topographical objects K onto a particular section of the ground surface, each of them with its individual dimensions Z_1, Z_2, Z_3 etc.. With the aim of making a map we reduce the size of the section (D) to the size of the map (d) thus defining the *scale of space* $M_{space}=d/D$. The ratio of the number of objects and their characteristics from the reality K and those of the map k set the *scale of content* $M_{cont}=k/K$. We represent each and every object chosen by a particular sign. The

scale of signs M_{signs}^i is then introduced in relation to the ratio of dimensions of each pair “object-sign”. Only for some of the area objects $M_{signs}^i \equiv M_{space}$. In the case of the non-scale and linear signs usually we have $M_{signs}^i > M_{signs}$.

The maps plotted on paper have got three types of scale as well, though they are closely interconnected between each other. The physical size of the sheet of paper (as determined by the scale of space) does limit the other two types of scale. There may be placed a finite number of signs with limited size within the space of the map sheet. When we would like to increase the size of the signs (for instance when making a wall map) we shall have to reduce the number of the objects represented and vice versa: if we would like to represent more objects then we have to decrease the size of the signs. With preset scale of space at hand the scale of content and the scale of signs are proportionately interconnected: in case of a change with one of them, the other should also be corrected.

In a digital environment the scale of space is dynamic – we could represent the map in different types of scale. Nevertheless, with each particular visualization all the limitations of the maps on paper begin to take effect, including that of the connection between the three types of scale. In order to represent the map onto the display there shall have to be selected part of the objects and their signs so that the resulting image /projection/ is legible.

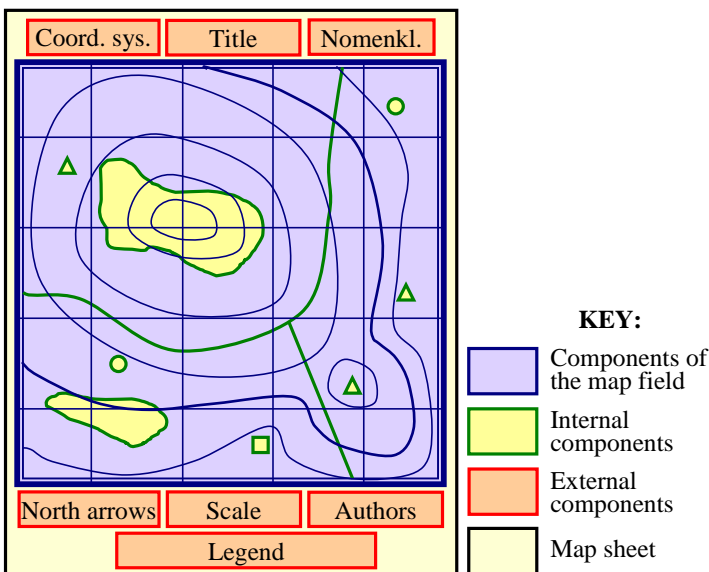


Fig. 2 An example for components of the map

1. SCALE OF SPACE

Each map contains three types of components (Fig. 2): *map field*, *internal components* (cartographic signs) and *external components* (heading, legend, out-of-frame layout and arrangement etc.). The map field is a mathematical model of the space being mapped down. It bears the scale of space. When the cartographic signs are put down within the map field then they automatically get attributed with two characteristics: *location* (connecting them with the object represented by them) and *scale*, through which the signs are getting interconnected into a uniform cartographic product.

The external components do not get influenced by the scale of space. The size of the heading and the inscriptions in the legend are being determined according to the available free space and the type of the map and not according to the scale.

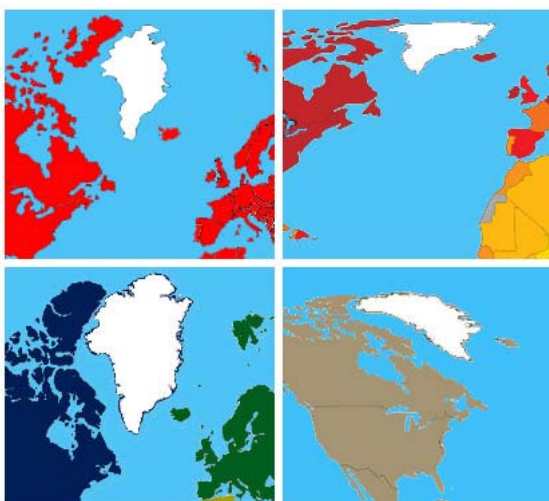


Fig. 3 Greenland island on four maps

Fig. 3 shows fragments of four maps having got approximately one and the same scale. Due to the cartographic projections used the shape and the size of the island of Greenland are too different. On account of that fact the map field represents the mapped space not only through the scale but through the projection, the reference surface and the coordinate systems as well. They all are components of the field and together represent a mathematical model of the space represented onto the map.

2. SCALE OF CONTENT

The map is a model of a certain part of the reality. The scale of content determines how much similar is the model of quantity of information as for the object represented on the map¹.

Fig. 4 shows two maps, having got one and the same scale of space though different scale of content.

The scale of content shall be viewed in three aspects:

▪ **Particularity of the data** – the quantity of the objects of each

class, being represented in the model, and the number and type of characteristics by which they are being described. This parameter is controlled by normative and qualification indices of selection;

¹ The information, directly input, is taken into account not that could be derived from the map.

▪ **In-detail representation of the information** – it depends on the degree of smoothing-out of the contours upon generalization. This parameter depends to a large extent on the scale of space as well as on the *intended use of the map* (on the road map the elements of transport shall be generalized to a smaller extent), *the manner of use* (in case taking of measurements would not be envisaged, the contours then may be further smoothed out) and the *sign system* (the signs onto the wall map should be larger so that they could be viewed from a larger distance; that is why they require a higher degree of generalization as compared to a desktop map of the same scale).

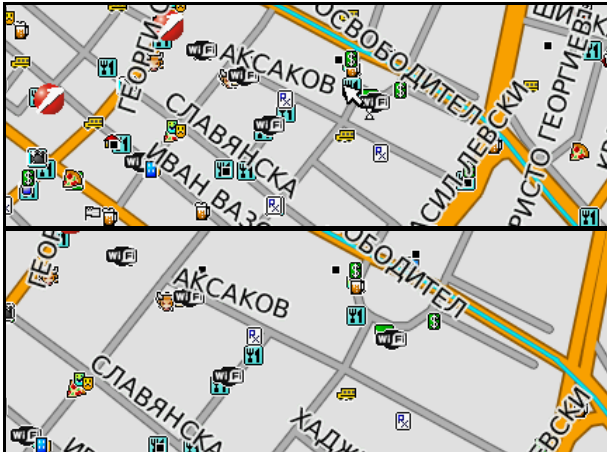


Fig. 4

▪ **Geometric accuracy of the data** – it is determined by the accuracy of the sources of information and by the mistakes made upon inputting the data. This parameter determines the limit to which could be reasonably increased the size of the map, printed on paper.

may be described by one parameter – according to the ratio of the information represented onto the map to the entire available information about the objects of the reality. The scale of content shows the degree to which the generalization of the data has been made. In case of dynamic maps it may be defined as a ratio of the data output on the screen to the entire information in the digital map.

There is conformity between these three characteristics in case of quality made maps. That is why the scale of content

3. SCALE OF SIGNS

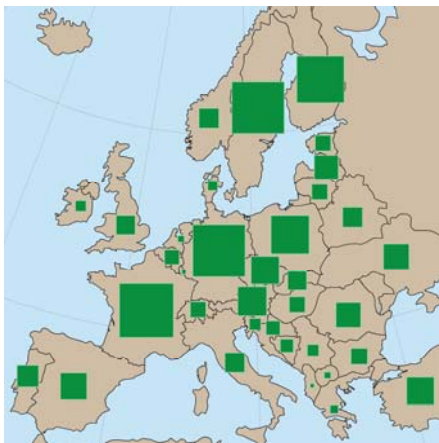


fig. 5 European forestry population by country (2006)
<http://personal.frostburg.edu/>

When a sign is placed within the map field, it shall then succeed to its parameters, including the scale of space. Many signs though have got a different scale of their own depending on:

▪ *The individual characteristics of the object represented.* For example these are the maps using **diagrammatic maps** (Fig. 5). There each sign shows certain characteristic of its object, which does not depend on the scale of space and the scale of content.

▪ *The significance of the object amongst the rest of the objects represented onto the map.* The linear signs may be represented by a thicker or thinner line, depending upon their significance in the context of the map. For instance, the main roads are being represented by thicker lines onto the map, though actually they could also be not broader than the minor ones.

Fig. 6 shows that the road from point A to point B is thickened in view of the intended use of the map.

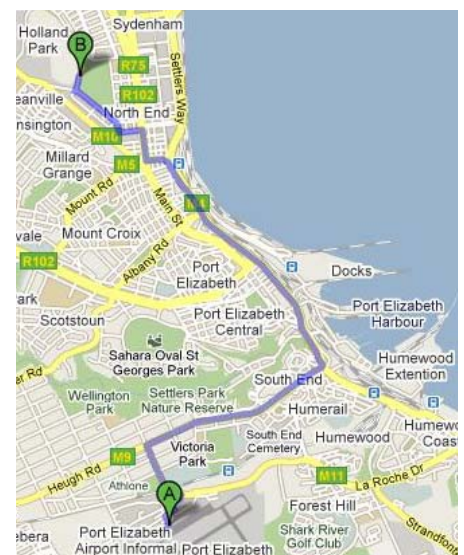


Fig. 6

▪ *The possibilities of distinction and legibility of the signs onto the map.* In case of reduction of the scale of space twice, the size of the inscriptions and the non-scale signs shall not be decreased or be decreased to a small extent. Fig. 7 shows fragments from topographic maps making it evident that in case of change in the scale number twice, the size of the non-scale signs is being slightly changed.

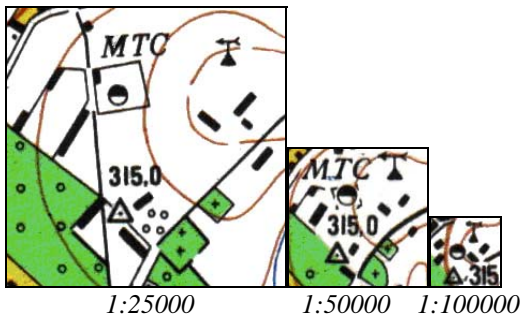


Fig. 7

▪ *The type of the signs.* Should the scale of space be changed, the area, linear and non-scale signs change in a different way. The size of the area signs and the physical size of the linear signs are decreased accordingly with the change to the scale of space. The thickness of the linear signs and the size of the non-scale signs and the inscriptions are being controlled for reasons of legibility. Furthermore, there is allowed for certain magnifying the size of the area signs (when they represent some significant objects) or a little reduction (when they get overlapped with other signs). That is why their scale of signs does not completely correspond to the scale of space.

The scale of signs may be viewed in two aspects: *spatial*, representing the size and shape of the sign, and *visual*, representing the graphical weight of the signs onto the map. The two scales of signs are equally substantial upon determining the general scale of each sign. *The spatial scale* of the sign is determined by: 1) the ratio of the size of the sign to the object (M_s); 2) the form of the sign defined as a ratio of the area S to the perimeter of the sign P ($F=P/S$), correlated to the same factor as for the circle ($k=F/F_{circle}$). With the circle the perimeter – area ratio is the smallest one



Fig. 8 Influence of sign's shape over the sign's scale

out of all the figures, and this factor is 1. All other signs, not having a round shape, shall have a factor of more than one. The introduction of the factor of shape is called for due to the fact that upon generalization a conflict is at hand not only in case of overlapping but in case of unallowable proximity between the signs as well, when their contours get merged. This is why the instructions require that a distance of 0.2 to 0.5 mm be present between the signs. Thus is formed a border area of the signs, which depends not only on the area of the sign, but on its shape as well (Fig. 8).



Fig. 9

The visual scale depends on the color of the sign and on its filling: the signs in brighter and more contrasting colors as compared to the background do attract and hold the attention (Fig. 9), and the signs, the area of which is entirely filled could be seen better than those having got contour only (Fig. 10). On account of this the scale of signs depends also on a factor of brightness and *distinction of the color in relation to the background* (Col) and of transparency or of a percentage of filling of the sign (Tr).



Fig. 10 Sign filling

The totality of the parameters of the signs as discussed hereinabove determines their graphical weight upon visualization. The generalized value for the scale of each sign may be obtained by the formula, as follows:

$$M_i = k_i * M_s_i * Tr_i * Col_i \quad [1]$$

When a real-time automatic generalization is being carried out, it is important to be calculated both the scale of each individual sign and that of the sign system as a whole (all the signs used upon the particular visualization). This might allow for determining the graphical loading of the resulting image and hence the required extent of generalization. In this case there may be applied the formula, as follows:

$$M_{Signs} = \frac{\sum_{i=1}^n k_i * M_s_i * Tr_i * Col_i}{n} \quad [2]$$

In addition to the quantity of the signs and their scale, the graphical loading depends also on the allocation of the signs within the map field. With the navigation maps under urban conditions the signs are usually piled up along the streets and the interior part of the residential quarters is free. This is why upon determining of a particular graphical loading there have to be determined the *entropy of the image*.

4. INTERACTIONS BETWEEN THE THREE TYPES OF MAP SCALE.

When making maps on paper, the role of the scale is mainly limiting – it determines the maximum quantity of the data and the size of the signs; the accuracy of measurements by a map etc. These limitations drop out as regards digital environment. The map user, all by himself, may determine the scale and the content, which are to be placed onto the screen. With some systems he may also change the sign system of the map. (Fig. 11)

With the dynamic digital maps there appears a new issue. They cover larger territory and content than that could be visualized on the screen. The map maker projects the content and the sign system without being aware how shall actually appear every screen view defined by the user. Depending upon their needs the users set a scale for visualization, content and sign system. And as they usually have not got any specialized cartographic training undergone, the parameters chosen by them might lead to a map which could not be read. That is why it is necessary that the cartographic systems should suggest an optimal variant between the user-chosen *scale for visualization* (the scale of space), *the degree of generalization* (the scale of content) and the *sign system* (the scale of signs).

Most of the navigation systems change the size of the area and linear signs, though retaining constant the size of the non-scale signs, irrespective of the scale of output onto the map. This binds the makers to design the signs with very small size making it difficult for their searching and perceiving. Some systems for visualization of dynamic maps in the Internet directly connect the scale of the signs with the scale of the image. In case of very small scale the sign represents a single dot on the screen and with very large – it may occupy the whole screen.

In order to be avoided these visualization failures, there shall have to be abided by a balance between the three types of scale, which shall be expressed by the following formula:

$$M^2_{Space} = C * M_{Cont.} * M_{Signs} \quad [3]$$

Whereas: M_{Space} is the scale of space;

$M_{Cont.}$ is the scale of content;

M_{Signs} is the scale of the sign system;

C is a constant due to the difference in the scale numbers and shall show the desired level of graphical loading. It is determined for the basic scale under which the map has been made.

The application of this simple dependency between the map space, the quantity of information therein and the size of the signs allows for the generating of an image with optimal graphical loading. If the user should change one the scales therein, for instance if he would like the visualization of any additional information on the screen, then the system should respond by a change to the scale of the resulting image.

5. CONCLUSION

The modern Internet and navigation maps allow the user to change their scale, content and sign system. This freedom of use often leads to some unexpected results – there we may get a map the signs of which get overlapped and become illegible. The modern systems for visualization of dynamic maps do not allow for the removal of these conflicts as regards the resulting image.

Three types of scale of the digital maps have been considered herein: *scale of space*, described by the map field; *scale of content*, determining the entirety, the in-detail representation and the accuracy of the cartographic model, and *scale of signs*, showing their graphical weight.

These three types of scale allow – upon visualization – to be taken into account the space on the map, the quantity of information and the size of the signs. Through them there may be calculated the graphical loading of every image and – taking into consideration the connection between the scales – the user may be suggested variants for avoidance of conflicts.



Biography of the author

Stanislav Vasilev was born at Sofia on March 7, 1964. He graduated at University of Architecture, Civil Engineering and Geodesy in 1990. From 1993 as yet he is lecturer in the selfsame university. In 1997 he defended a PhD dissertation: “*Generalization In Digital Environment*”. In 2003 S. Vasilev is chosen to Associated Professor in department of Photogrammetry and Cartography. In 2008 he defended a ScD thesis: “*The Basics of the Map Semiotics*”

Its professional interests are in *theoretical cartography, map semiotics; sign system, generalization; automated cartography; mobile maps.*