Methods to Measure Map Readability

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1 Introduction

Several countries are currently working on setting up geoportals as part of their national spatial data infrastructure (SDI). A key ability of these geoportals is that the user should be able to view (and download) data from several sources from one access point. This will certainly make the access to geospatial data easier. However, there is also a cartographic challenge that has to be solved. Since the user will be able to view data from several sources at the same time we have to establish methods that support cartographic visualisation of data from multiple sources. For example, this study is part of a Swedish national project *the planning portal*. This portal will enable the user, e.g. a local planner, to view planning information overlaid on a topographic map.

To improve the readability of maps from geoportals we could (1) select layers with appropriate content / resolution and (2) perform real-time generalisation. These two processes should be triggered by legibility constraints (see e.g. Harrie and Weibel, 2007).

The aim of our studies is to improve the knowledge about these legibility constraints and how these constraints could be used to improve the map readability. In this extended abstract we report what has been done so far, and a short description of our future direction.

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2 Parts finalised so far

In two studies (Harrie and Stigmar, 2008; Stigmar and Harrie 2009) we have developed, implemented and evaluated measures for map readability; some measures are our own, others are borrowed from e.g. Li and Huang (2002) and AGENT(1999). Below follows a short summary of our second study (for details, see Stigmar and Harrie 2009).

First we developed measures that reflect different aspects of objects' and relations' complexities. Based on the characteristics of the measures they can be subdivided into three *measure types*:

- *amount of information*, which is based on the amount and size of the map objects,
- *spatial distribution*, which is based on the density and distribution of the map objects, and
- *object complexity*, which is based on the shape and size of the individual map objects.

The map objects, in their turn, can be subdivided into *information types* based on their geometrical properties and if they concern the background or foreground of the map. In this study we use the following four information types (c.f. van Smaalen 2003, in Mackaness and Ruas 2007):

- *Minor objects* consisting of smaller stand-alone point, line or area objects. Symbols that are stored as points in the database are approximated with their minimum bounding rectangle in the study.
- *Line networks* consisting of line objects (such as roads, rivers, borders and boundaries) forming networks.
- *Area objects* forming tessellations.
- *Field-based data* consisting of e.g. contour lines.

Table 1 shows how the readability measures are used. Some readability measures are only defined for one or two information types, while others are defined for all objects.

Table 1. A compilation of the measures and their application for the information types (rows) and measure types (columns).

	Measures of amount of information	Measures of spatial distribution	Measures of object complexity
Minor objects	• Number of objects • Number of points in the objects • Object line length • Object area	• Spatial distribution of objects • Spatial distribution of points • Number of neighbours • Individual density	• Object size • Line segment size • Angularity • Polygon shape
Line networks	• Number of objects • Number of points in the objects • Object line length • Object area		• Line segment size • Line connectivity • Angularity
Area objects forming tessellations	• Number of objects • Number of points in the objects • Object line length	• Number of neighbours	• Object size • Line segment size • Angularity • Polygon shape
Field-based data	• Number of objects • Number of points in the objects • Object line length		• Line segment size • Angularity
All or some objects	• Number of object types	• Proximity indicator • Homogeneity in a group • Degree of overlap	

When the measures where defined the test was made in four steps.

1) The measures were implemented in a Java program built on the open source packages *JTS Topology Suite* (JTS) and *JTS Unified Mapping Platform* (JUMP) (JUMP project 2009). In order to create Voronoi regions we use the c-program Triangle (Shewchuk 1996, 2002) integrated using Java native interface (Gordon 1998).
2) Using this Java program numerical values for the measures were computed for some map areas. The map areas were around 10 cm^2 and the maps were in scale of 1:10 000 or 1:50 000.

3) A user study was conducted. In the user study planning experts were performing a preference test with some parts of a usability test.
4) An evaluation was performed on the measures. In this evaluation we studied the correspondence of the measure values, and the result of the user study. E.g. Figure 1 shows one of the results for the measure "Degree of overlap" (roughly defined as the total area of intersection of buffers around objects divided by the total area).

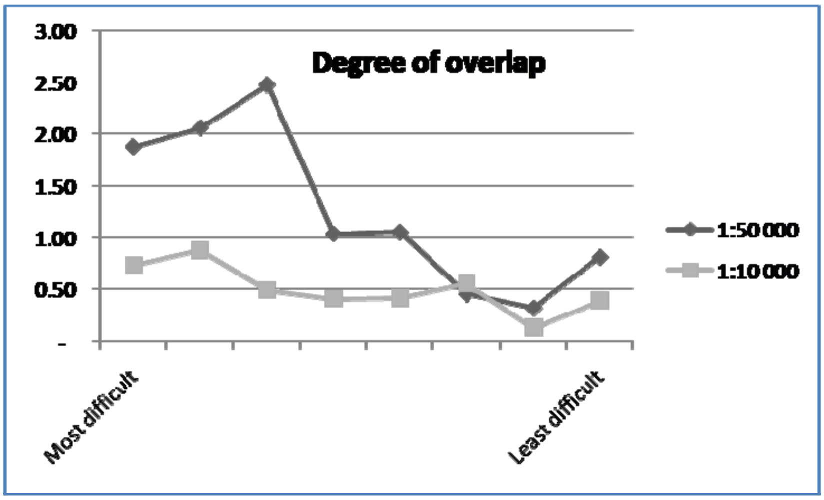

Fig. 1. Correspondence between test subjects' rankings (given horizontally as ranks between "most difficult" and "least difficult") and computed values of *degree of overlap*.

3 Future plans

Based on the previous studies we have quite good knowledge about to what extent the measures describe the map readability. However, we need more knowledge to make real use of the map readability. Our aim is to include the measures in the following workflow:

1) Identify regions in the map with poor readability

This is important since most maps are inhomogeneous, and hence the aggregated values of the measures for a whole map does not reflect the readability of certain part of the map. The solution is to identify the regions that are difficult to read, and then compute the measure for each of these regions. The studies we have done so far (in identifying regions) are based on the following assumptions: (1) a region where the information is dense is difficult to read and (2) information density can be measured by the number of points per area unit. Based on these two assumptions we have used point clustering techniques, e.g. the DBSCAN algorithm (), to identify dense regions. The first results are promising but we need more studies (including verification from user studies) to evaluate the approach.

2) Combine the values of the measures into a common readability index

In the studies we have conducted so far about map readability measures we have seen that certain high values of a measure do not necessarily mean poor map readability. E.g. a user can normally cope with much information if they can group the information into meaningful features (e.g. a dense building area is not necessarily a problem from a map reading perspective since the map reader simply regards it as a built up area). To approach this problem we would like to create a map readability index based on the values of the measures. Based on what we have seen so far, a simple linear combination of measure values is not appropriate for creating a readability index. A possible approach would be to use some kind of neural network. Our first choice is likely ARTMAP (Carpenter et al., 1991) since it has nice properties to classify arbitrarily ordered vectors (in our application containing measure values) into predefined categories (in our application map readability index values).

3) Let the map readability index and the values of the measures act as legibility constraints for the selection of layers and in the generalisation process.

This is, as stated above, the final aim of our studies. But we have not yet started with this work, as it is dependent on the success on the steps above.

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