QUALITY ELEMENTS FOR CARTOGRAPHIC DATA PRODUCTS

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ABSTRACT

ISO standards 19115 and 19113 on metadata and quality on geographic information together with standards on quality measures, testing and reporting (ISO 19138, ISO 2859, ISO 3951 and ISO 19114) give a proposal about metadata and quality descriptions. Standards are wide in scope and need further development when applied in different circumstances and environments. Metadata standard is especially wide and gives a comprehensive framework for describing GI data sets. Quality part of the standards, however, would need some development work which is already done in several groups aiming to definitions of quality measures and test methods. One limitation of the quality standard is that it has been clearly designed for geographical data stored in databases. However, many data sets that are transferred from producers to users and re-users are not pure collections of separate geographical entities but rather ready-made cartographic products. Those products require – in addition to already standardized quality elements – also quality elements that describe the cartographic features and the entire cartographic product.

1. INTRODUCTION

This article is a part of documentation made in a development project in which a quality model for geographic information at The Finnish Defence Forces (FDF) was created (Ingberg, 2004; Korhonen, 2004; Ingberg & Virrantaus, 2005). The concept of "quality model" means in this context the descriptions of geographic data sets collected together as well as an implementation. The descriptions of data sets have been made according to the ISO standards of quality of GI (ISO 19113:2002, ISO 19114:2003). The implementation has been made in Excel environment and the application is available in the Intranet of the Finnish Defence Forces. In The Finnish Defence Forces a big renewal of information systems is going on. In all information system development activities Finnish Defence Forces follows NATO standards, which are based on ISO standardization as well.

Finnish Defence Forces do not create their own geographic information but purchases the majority of both maps and other geographical data from governmental organizations and private companies. For example the Finnish Topographic Data Base, which is collected and maintained by the National Land Survey has been entirely copied to the databases of FDF. Environmental data sets come from the Environment Institute, vegetation data from the Forest Research Institute and geological data from the Finnish Geological Survey. At FDF there is a wide collection of geographical data both in database form but also as ready-made cartographic products. The problem at FDF is that no guidelines exist on how to define the requirements of the geographical data sets when for example an invitation for tenders is written. The purchasing processes have mainly been based on the personal contacts and experience on acceptable quality from certain, well-known organizations. However, when the competition in the field of geographic data production is all the time increasing – and also becoming as an international activity - new, unknown actors come to the market and it is necessary to formalize the purchasing processes. A formal and standardized quality description of the data sets is necessary. ISO standard now gives a good basis for this development. ISO standard on the quality of geographic information, however, has mainly been developed to fit for database type data, which is modelled as separate objects. Many datasets, however, are entire cartographic products with several attributes that characterize the map product as a whole. At FDF the users had presented strong expectations for the quality model and cartographic data products cannot be left outside. Especially the users’ requirements for descriptions of “fitness-for-use” regarding data contents and scales as well as scalability of the product state strong needs for defining additional quality elements and ways of describing cartographic quality of data sets. In addition to the quality elements expressed by numeric or textual attributes of map objects, feature types or perhaps the entire map, some additional problems occur. Quite often the quality of a map is not constant but rather spatially varying. On the other hand, when the question is about map products and visual use also the presentation of the quality for the users is a question. The mentioned problems lead us to the field of visualization and presentation of quality. This issue is briefly discussed in the end of this article.
The objectives of this research

The objective of this research was to define quality elements for cartographic data products. The quality elements would be used as additional elements together with those defined in the ISO standard 19113 on geographic data quality. The cartographic data elements would concentrate on the visual representation of the data; this can also be expressed as the definition of the used map language. Visualization takes form on the actual map as well as on the legend. Suitable measures and useful presentation methods for the quality elements was also to be developed in the research.

The following research problems were defined:

-What are the required quality elements that describe the quality of a digital map product?
-How those quality elements can be measured and evaluated?
-How the values of the cartographic quality elements can be documented and presented to the users as a part of a quality model of GI?

2. MATERIALS AND METHODS

Materials

This research was made for FDF, which means that the variety of geographic data sets that is used at FDF was analysed. Quite soon it was evident that in military use ready-made cartographic products were in an important role. In this article the focus is in cartographic quality elements, thus here we only document the cartographic data sets, which were analysed. These materials were selected among the most important map products, and they were: Topographic map in scale 1:50 000, Road Map in scale 1:250 000, Military Aviation Navigation Chart in scale 1: 500 000 and a customized Topographic Map (which includes also features of nautical charts) in scale 1:50 000. These maps were in raster form and produced for cartographic use. All maps were analysed both as digital products on the screen and as traditional, printed paper maps.

In this document we use also some results from another research project in which the uncertainty of a terrain analysis application was analysed (Horttanainen, 2003). In that project soil maps were in major focus and their uncertainty and quality were also analysed. The Military Soil Map in scale 1: 20 000 was among the studied materials. Military Soil Map is in raster form and includes classified information about 9 soil types.

The quality elements of ISO 19113 were used as the starting point and reference material for the research. A lot of other ISO standards were used, the list of used ones is documented in (Ingberg, 2004).

Methods

In order to define the correct cartographic quality elements, which would be also useful for the users several user interviews and questionnaires were performed. In the interviews the main focus was in identifying the quality elements but we also wanted to document quality descriptions of the cartographic products in question because the final goal was to create cartographic quality elements that could be used in the quality model.

The method used in the interviews was based on the Storytelling –method in which the persons who were interviewed were describing the applications, data sets, users and quality problems in their own words. The possible quality elements that could be used in describing the quality features were recognized. Also the descriptions of the quality were documented during the interview.

The suggested cartographic quality elements were then analysed and compared to the cartographic knowledge about visualization and map design. The factors of map design presented by Tyner (1992) as well as the visual variables of Bertin (1974) were the most important theoretical basis, but a lot of recent cartographic literature was used in order to find candidates for quality elements (Korhonen, 2003).

When the cartographic quality elements were defined we analysed the possible measures for them and also the method of evaluating the quality. This was made based on theoretical and conceptual research approach. The last step was to develop suitable presentation methods for the quality elements. In addition to numerical and textual description we wanted to suggest map presentations; this was based on the results of another research projects in which the spatially varying uncertainty of soil maps as well as analysis results were researched (Horttanainen & Virrantaus, 2004).
related research to the problem of visualizing cartographic quality are documented in (Kremenova et al., 2004) and (Salonen, 2005; Janlòv et al., 2005).

3. RESULTS

General results

The general results were that in analysing the cartographic quality we have to deal with questions associated with positional accuracy as well as thematic and temporal quality measures, however in another point of view than in the standardized quality elements – more related with the map use and total data contents of the product. Because a map is more complex than one data type, also the quality measures are more complex than those used for simple data objects.

Quality related to map use and data contents. Cartographic data products are often used as background maps and reference material on which some objects of interest are then presented. These maps can be either in vector or raster format. Maps are used both in the office and in the field. Thus the objects of interest can come from the database, having very accurate location by coordinates – then also the requirements of the background map positional accuracy are high. Objects of interest can also come from the field observations, which can be either measured by positioning equipment and having accurate coordinates, or observed manually and thus having only the relative accuracy which can be obtained by comparing the map objects and their location to the objects in the reality. The last use-case leads to the requirement of relatively high data density instead of positional accuracy. The data contents of the map must be much more detailed than in case where the map is not compared with the terrain. The importance of map features becomes a quality element. The other aspect of map use is the suitability for a specified use. Some cartographic data sets are produced for a specific use and thus cannot be used generally. Several quality elements like “scalability” and “generalization” factors are necessary.

Thematic accuracy. In some map data sets like soil maps the thematic accuracy (correct classification) is important, however, soil maps do not carry any quality information, because of the manual mapping process (Sunila & Krisp, 2005). Soil map data is used for example in military terrain analyses and the result of such an analysis is a combination of several data sets. It would be necessary to receive soil map with quality measures about the reliability of the classification into soil classes. This is especially important and challenging because soil mapping produces very strongly spatially varying quality. In this example thematic accuracy is mixed with positional accuracy (imprecise boundaries).

Temporal accuracy. In some applications, like simulators and for example in the military situation picture the temporal accuracy of the cartographic data is relevant. On the other hand simulators require high visual quality and good resolution. Colour, generalization and symbology factors are relevant.

Quality elements

In the following the identified cartographic quality elements are described as well as the way of measuring and evaluating. The elements are divided into two groups, visual and side quality elements. Some of the elements are similar to metadata elements described in the ISO 19115, but we want to emphasize that they are here considered to be in another role, not for descriptions of the product but for evaluation of the quality of it.

Visual quality elements

Visual elements are: importance factor, general layout factors, scalability factors, colour factors, generalization factors, and symbology factors.

Importance factor. The importance of cartographic objects on the maps. For each data set the different feature types are classified according to their importance. Used classes are 1=necessary, 2=useful but not necessary, 3=of marginal importance/useless.

General layout factors: Data intensity and suitability to the medium. Data intensity can be described in relation to the cartographic product in a specific use and ranked between “too dense”, “suitable” or “too sparse”. Suitability to the medium means that certain data sets are only for paper printing, for screen or maybe for small-screen media.
Scalability factors: Scale interval and precision of measurements. A scale interval can be given for the data set and it describes the limits in which the data is readable on the correct medium. Precision means the precision for measurements, how accurate measurements the user can make by using the map in the range of its scale interval.

Colour factors: Hue, value and saturation. These factors used may define a lot about the overall visual look of the map. The requirements on colours can be expressed by using HSV – or RGB-models. The colour design on a map can be evaluated for example by verbal descriptions like “too saturated”, “too much white/black”, and “too many hues”.

Generalization factors: amount of generalization, quality of generalization. Amount of generalization can be expressed only in words like very detailed, detailed, average, general, and very general. The quality of generalization can be expressed by very natural/very good, average, very artificial/very poor.

Symbology factors: size and width, shape and texture, the orientation of texts. Size and width are the measures of some specified point symbols on the map. They can be very small, small, medium, big, and very big. Shapes and textures of well-designed symbols are easily detected and discriminated; measures of the quality of symbols simple, medium, complicated. Orientation of texts depends on several things on the map design, orientation of texts can be good, average or poor.

Quality of side elements

Cover: identification of the product, clarity, colours. Good map cover shows clearly which map is in question. Quality values can be good, average, and bad.

Legend: the logical sequence of the legend, the amount of information in the legend. The logical sequence of the legend can be evaluated by logical, average, confusing. The amount of information in the legend can be too much, good, too few.

Compass arrow: the clarity, accuracy and length of the arrow. Values respectively: clear, not clear.

Scale information: the existence of scale lineation. Scale lineation can be missing/existing. The placement of the scale lineation can be good or poor.

4. DISCUSSION

Spatially varying quality elements and their measurement and presentation

For some map data sets very detailed quality descriptions are required. In case the quality is very much location dependent it would be most confusing only to describe it by one value. Several possibilities exist for management of spatially varying quality. In the following some of them are introduced with references to our research and other examples.

Index maps and quality values. Spatially varying quality can be simply described by index maps and related quality values. This method is used for example in the quality description of the Finnish elevation model (www.maanmittauslaitos.fi/Default.asp?id=148&docid=1376). The positional accuracy of the elevation data has been described by an index map, in which each map sheet gets an accuracy value presented by the mean error classified into three classes. The quality depends on many factors like mapping method and time.

Probability of correct classification and correct boundaries per map sheet. In soil maps the quality means not only accuracy but also imprecision. Imprecision means that no exact measures for example of positional accuracy of soil polygon boundaries can be given, but rather some measure of the imprecision and so-called transition zone between adjacent soil polygons. For modelling purposes this leads easily to fuzzy models. However some measures are required and the simplest way is to put them imprecision into one value of “level of certainty” of the map sheet in question. This measure has been developed in the research of Sunila and Krisp (2005) and is based on expert knowledge collected by interviews.

Spatially dependent quality layer. The most detailed description of map quality can be given by another map layer. In case we need really exact description of the reliability of the map like in very critical decision-making, we cannot rely on general descriptions. In the research by Hottanainen and Virrantaus (2004) such a measure was proposed in case of military terrain analysis results reliability. In Fig 1 an example of the original map layer and related uncertainty layer are shown.
### Table 1: The visual quality elements of a map. Some of the quality elements can also be used as metadata elements. In the table example we try to explain the difference of metadata and quality descriptions. Some element can be used as metadata with description of the value of the element and as a quality element by giving an evaluation of the quality of the map product in question for that quality element point of view. Examples of possible values of quality measures are given. It must be recognized that one element can be used as metadata element and as quality element; when it is metadata the only descriptive information is given in values, but when it is a quality measure then the value shows some estimate of the quality evaluation.

**Visualization of the quality of map objects.** Visualization is an important way of presenting the quality values for the users. In the development project of the Military Situation Picture – application we have made some tests about visualization of both positional and thematic quality of objects (Figure 2) (Janlóv et al., 2005). The imprecision of soil data can also be visualized in a map format by presenting the “transition zones” between the imprecise map polygons (Figure 3) (Kremenova & Sunila, 2004).

#### 5. CONCLUSIONS

This research was recently made and until this has not been presented widely. So, it is not an exact suggestion of additional quality elements, but rather a paper for discussion about the necessity of additional elements to the quality standard. As shown in the Table 1, some of the identified quality elements are very close to some metadata elements but in role of quality evaluation they are used in a different way – not as descriptive elements for documentation but as measures for evaluation of quality. Also the visualization of reliability of the map should be taken as an example and
motivation for discussion about the importance and difficulty of spatially dependent and varying quality elements as well as the user requirements for presentation of the quality.

Our opinion is that the ISO standard on quality should be developed and extended in order to cover also the requirements of maps as entire cartographic products. We also think that the spatial variation of quality should be taken into consideration. Visualization of quality is most important for the users of maps, so more research and development is required in that field. We hope that this article leads to critical comments and discussion.

Figure 1. Uncertainty of classification in cross-country mobility analysis in two different areas during different seasons. The darker the value the bigger the uncertainty. The result layer is in the leftmost column and the uncertainty layer is in the rightmost column. The values of $\rho$ show different spatial dependency parameters in the simulation made and have no special meaning in this context. Examples are from (Horttanainen, 2003; Horttanainen & Virrantaus, 2004).
Figure 2: An example of presenting thematic and temporal quality values of military map symbols. Full colour means a reliable observation and the symbol with only 50% colour is not reliable observation. A sign with full saturation means observation “at present”, a transparent sign means “history” and the fuzzy sign means “predicted location of the sign”. Examples are created in the development project for Military situation picture and are described in (Salonen, 2005; Janlöv et al., 2005).

Figure 3: An example about visualizing the imprecise boundary on the visibility analysis polygon. Example is created in the development project for Military situation picture and described in (Salonen, 2005; Janlöv et al., 2005).

Figure 4: An example of a transition zone of soil polygons as a model and visualization of imprecise boundaries. Example is taken from (Kremenova & Sunila, 2004).
REFERENCES


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