USER-ORIENTED MAP DESIGN IN SDI ENVIRONMENT USING THE EXAMPLE OF A EUROPEAN REFERENCE MAP 1:250,000

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Introduction

Good governance at each of local, national, European and global level requires relevant, harmonised and quality geographic information (GI) to underpin the sustainable development of our world. Currently, several initiatives are building Spatial Data Infrastructures (SDI) at the above mentioned levels to provide harmonised spatial data. The task of an SDI is to allow users to retrieve easily task-relevant data from the abundance of existing and up-to-date spatial data maintained by several stakeholders. Any SDI is composed of four components – spatial data, organisational framework, access and standards.

The introduction of modern GI technology into cartography evoked a broad discussion about cartography and maps within the cartographic and geographic information communities. The role and task of cartography have been questioned due to the fundamental changes in information and communication technologies. New methods of data collection, accessing and exploring data, and new map-use environments changed how spatial information is handled within the society and economy. The use of databases to store GI released maps from their storage function, and allowed to generate the maps according to various purposes and user needs. But, at the same time, the cartographic representation was separated from the data. This led to the assumption that creating cartographic representations is a simple production method and the last step in the process chain from data capture to visualisation of GI that can be easily automated and can be performed by other disciplines (Kraak 2006, Meng 2008).

Although, view services are an integral part of the SDI access component – the geoportal, geovisualisation rules for the spatial data supplied through the services are only considered at a very basic level and thus ignoring the importance of visualisation for transforming spatial data into useful GI. Currently, a poor map design results from a too technology- and/or data-driven approach. This needs to be improved by making the cartographic design knowledge explicit and operational. Cartography must take effect here providing a methodology for creating effective cartographic visualisations, and offering design solutions for SDI relevant user types that facilitate gaining useful GI at the interface between SDI and their users as a result of the map viewing and interpretation process.

First of all, the paper looks into the conceptual framework of contemporary cartography and map design. Further, the research agenda on the development of a European reference map in the European SDI is briefly described and first results are presented.

Conceptual framework of contemporary cartography

Cartography is the art, science and technology of making and using maps. Although this definition of maps is not limited to any specific cartographic media (paper, screen, etc.), form (hardcopy, visible, tangible, etc.), or usage, the term is more and more replaced by 'cartographic visualisation' to emphasize the broader notion in contrary to the conception of a traditional paper map. Cartographic visualisation is regarded as a subcategory of geographic visualisation (also geovisualisation). In a general sense, geovisualisation either describes the process or the result of making spatial data visible. Hereafter, the term 'cartographic visualisation' is used to refer to the result of creating a map. And the notion 'map design' is understood as the overall process - from conceptualisation to implementation - of creating a visual tool enabling a communicative map-based acquisition of GI.

Today, map design and map use are greatly influenced by cognitive concepts dealing with the processes of human information processing, and action-related concepts considering the goals targeted by the relevant activities and actions as well as the parameter influencing them. With regard to the consideration of cognitive concepts of human information processing it shall be pointed out that, in contrast to the still widespread opinion, a map contains neither GI nor communicates such information as self-contained information units. Instead, GI is created through cognitive processes as an internal model of imagination in the consciousness of the respective viewer of the map. This concept long since described as constructivist in the communication and cognition theory is according to *MacEachren* of essential importance for cartography, and especially also for the understanding of the geovisualisation processes. He designates it as a semiotic-cognitive concept (MacEachren 1995). The results of an interdisciplinary research carried out by *Swienty* proved that a map stimulates visual reasoning and decision-making of users by activating brain functions along visual processing paths. The map as a system of conventional cartographic signs triggers complex visual impulses in the brain. This visual information processing evokes the selection of relevant visual features, supports higher cognitive processes (e.g. knowledge formation, hypothesis generation, judgement) and introduces relevant physical actions, (e.g. eye movements) (Swienty 2008).

Since the respective user of cartographic representations is in the focus of interest of map making and map use, contributions to the further development of the conceptions of cartography as seen from the user's side are of interest. The goals and tasks of the users associated with the map use are the matter of action-related concepts. *Dransch* has elaborated on this subject a comprehensive approach for user modelling. According to the action-related concept user-specific targets and situations of action as well as the user-specific actions and cognitive processes have to be described and formalised. As a result, there is one profile for each user type, which can be represented as a function on the basis of its model determining parameters. *Dransch* recommends adopting action theory and its methods as an important supplement into the general cartographic theory and methodology, in order to enable a holistic consideration of the users of cartographic visualisations (Dransch 2002). *Nivala* evaluated the suitability of user-centred design (UCD) methods for map design. Her work returned valuable guidelines how to incorporate these methods into map projects (Nivala 2007).

The action-related concepts support the implementation of the cognitive concepts by determining user-specific design parameters. This way it is possible to create user-oriented visualisations of spatial data which are a prerequisite for gaining GI in the consciousness of the user. Considering all this, *Grünreich* summarised that cartography can be clearly distinguished from geoinformatics by the underlying approach of the user's visual-cognitive information processing (Grünreich 2008).

Creating cartographic representations in the SDI context

Today, the content of SDI databases is mostly visualised by applying a simple symbolisation to provide an interface to the underlying spatial data. But to derive well-designed ready-to-use cartographic representations from the spatial data, especially for non-expert SDI users, such as decision-makers and the general public, specifications determining the parameters and rules of the cartographic transformation process are needed.

In the SDI context two phases of creating cartographic visualisations can be distinguished – the design phase and the production phase. In the first phase, design solutions are developed for user types relevant in the SDI context. Finally designed, the solutions are implemented in the SDI. In the production phase SDI users apply these design solutions according to their requirements, respectively.

How to approach creating cartographic representations in the design phase?

The user-oriented map design seeks to answer what spatial problem (aim of map use), which user (map user) would like to solve under which conditions (map use situation) by means of a cartographic visualisation (Freitag 2004).

Spiess introduced the graphic filter concept as a model for the cartographic transformation of spatial data into cartographic representations. Considering the SDI data component as a GIS data collection the concept can also be utilised in the context of SDI. Figure 1 illustrates the development process of cartographic visualisations meeting different user requirements - from simple to complex subject matter, from perception to exploration, and from recognition to communication (Spiess 2003).

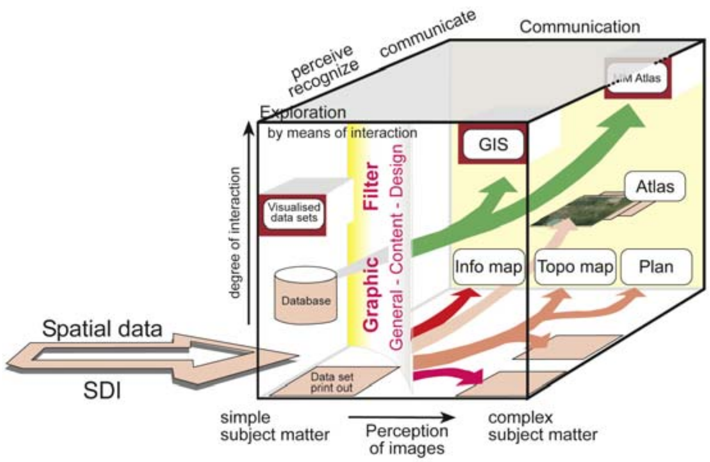

Figure 1 The graphic filter (after Spiess 2003)

Designing the graphic filter is a creative process iteratively developing the final output. In, general the following tasks are performed:

(A) Map conceptualisation and user modelling
(B) Cartographic design including the evaluation of design variants
(C) Implementation of design solution

Map conceptualisation (A) is an intuitive process to be carried out by cartographic professionals. It results in an initial ideation of the final cartographic visualisation and its creation process. The concept is further refined by modelling relevant user types. UCD methods, such as surveys, interviews, observation of users, or the evaluation of existing well-designed products are recommended methods to gather information about the users, their requirements, and the context of use. In the next step (B), these user-specific design parameters are in detail described using three concepts – the general, the content, and the design concept. The general concept determines the prerequisites of further design, such as the purpose and type of the cartographic visualisation, the approach and steps to the design, and the output medium. The decision on the area of interest, the scale, and the format are deeply interrelated, and has an influence on the other two concepts. The content concept specifies the map features and, therefore, the data to present in the cartographic visualisation whereas the design concept determines how the content is presented. The cartographic design task is to make the concepts explicit in geovisualisation rules of the graphic filter. Examples of such rules are listed in Table 1.

Cartographic generalisation	logical expressions for selection, classification, simplification
Graphical representation of the object-sign-reference	symbol library and logical expressions for text placement
Graphical refinements	constraints for legibility, visual contrast, hierarchical organisation
Resolution of graphical conflicts	constraints for masking, drawing order

Table 1 – Examples of geovisualisation rules (after Buckley et.al. 2005)

As Figure 1 clearly shows, the design of the graphic filter requires on the one hand an understanding of the map use, map user and map use situation, and on the other hand the insight into the data (e.g. data model, data content and its aspects of data quality) the cartographic design is applied to. The graphic filter, therefore, can be optimised if the source data is available in the SDI data collection as envisaged in the content concept. Otherwise, the graphic filter needs to be adapted taking into account the availability and usability. Once, the graphic filter is designed the best possible design variant is selected according to the 'best-practice' approach and implemented as a design solution in the SDI (C) for the production of a map, atlas, or GIS. For the implementation, the information model presented by *Buckley et.al.* may be utilised. This model describes from a data modelling perspective the database requirements for creating cartographic visualisations from spatial data stored in GIS (Buckley et.al. 2005). Besides that, the design solution shall be registered with a portrayal registry or map design knowledgebase which maintains successfully tested and proven design solutions for later reuse and work on standardisation.

The task of designing the graphic filter can be either approached from scratch or from the analysis of well-designed and acknowledged maps. The latter can be regarded as the re-engineering approach that is according to *Freitag* often used for topographic maps series, road and tourist maps as well as for atlases (Freitag 2004). Re-engineering is recommended as a pragmatic approach to the design of graphic filters in the SDI context as there exists a wide variety of well-designed and acknowledged maps providing a good starting point for the design task.

Developing a common specification for a European reference map 1:250,000

Based on the above outlined theoretical considerations, the applied research was looking specifically on a user-friendly and understandable presentation of topographic reference data within the European SDI. The following scenario was chosen as the starting point for the case study: An international team of spatial planners got the task to plan a European road connection across borders. To get an overview of the current situation, the team requires a printed map of the area of interest. In such case, a European reference map at scale 1:250,000 with a common symbolisation ready for print-on-demand could facilitate a common understanding of the landscape, and provide the geographical framework to outline first ideas.

Like national topographic maps a European reference map may serve as the foundation users can build their applications on. Ideally, this European reference map is similar in content and design to existing topographic maps and can be created from harmonised national contributions in the European SDI. While for national SDIs it is possible to develop services and products referring to national topographic visual specifications, for the European level there is no such foundation. The current international cooperation to build harmonised pan-European topographic reference data sets, led by EuroGeographics, focuses on the harmonisation of feature and attribute concepts skipping the definition of geovisualisation rules and cartographic representations in the data specifications.

Given these circumstances, the development of a common specification for a European reference map at scale 1:250,000 was approached by evaluating and re-engineering existing topographic map products to make cartographic expertise and knowledge explicit from these well-designed and acknowledged maps and, thereby, to achieve an optimal cartographic design (see Figure 2).

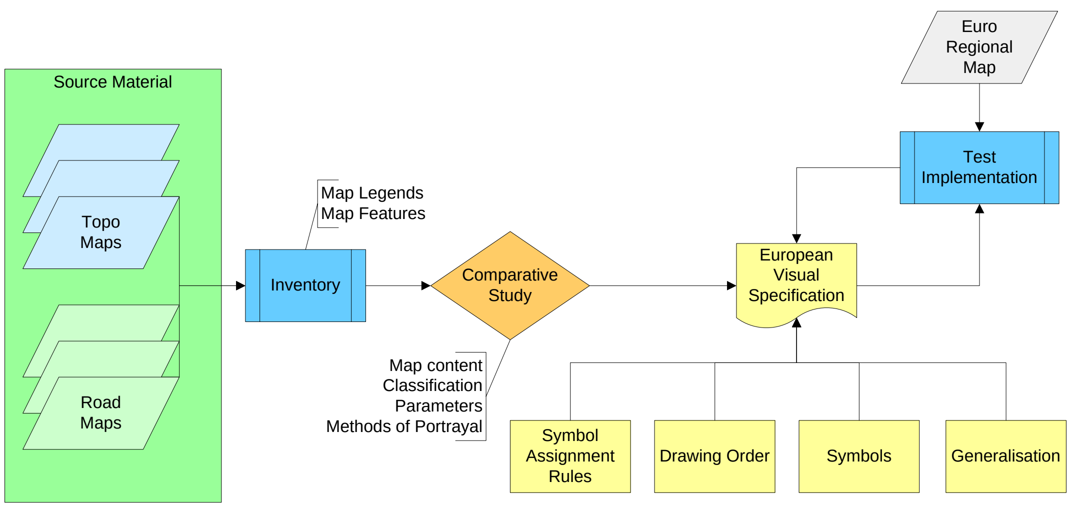

Figure 2 The re-engineering approach aiming at an optimal cartographic design for a European reference map (after Hopfstock 2007)

The as-is-analysis consisted of an inventory and a comparative study of European official topographic maps selected throughout Europe. In addition, commercial road maps were included to enhance and contrast the inventory of topographic maps. The main objective was to investigate the similarities and differences in content and cartographic representations. The analysis gave not only a general overview about the map content and the bandwidth of cartographic representations used in Europe, but offered an insight to the basic principles and elements of their composition.

In general, all map legends were structured into themes. However, a variance in the terminology and composition of the themes was observed. For further work, working themes following the thematic division of the map content presented in (Swiss Society of Cartography 2005) were used. Some map legends were showing only selected aspects of map content according to the intended map use and neglected the description of map symbols assumed as commonly known spatial objects. The review of the map legends revealed that the transportation theme was described in more detail than other themes and priority was also given to the representation of the transport network by means of visual hierarchy on the map. For the comparison of the map symbols, both the descriptions and the map symbols were important to identify the semantics of a map symbol due to the presence of homonyms and synonyms. For most of the source material, descriptions of the map symbol were not only available in the national language but also in English.

The identified spatial object types, their characteristics and preferred method of portrayal provided the base for the development of the design concept. For each map feature, a map symbol was created based on identified common denominators, such as the classification and the preferred methods of portrayal (e.g. geometry, colour, size). This way, a certain similarity in design to existing topographic maps was strived for. Further, symbol assignment rules correlating map features and symbols were established. The drawing order defines the visual hierarchy and relation of symbols indicating in which order symbols are drawn. Together, these geovisualisation rules built the core of the design concept for an ideal European reference map.

Finally, in a sample of six European cross-border areas, the proposed visual specifications were tested under real world conditions to examine their consistency, completeness and feasibility. The use case assumed that a user requires a printed map to get an overview of a certain cross-border region. Table 2 shows extracts of the map samples created from EuroRegionalMap v2.2 data[1] released in 2008. Due to the amount of themes and map features covered by the maps at the targeted scale the test was restricted to the transportation theme as a major topic of topographic maps at medium scale. Additionally, the cartographic representations of international boundaries and settlements were included for reference and orientation.

Even though, EuroRegionalMap data is geometrically and semantically harmonised the wide variety of underlying national contributions revealed several issues regarding map

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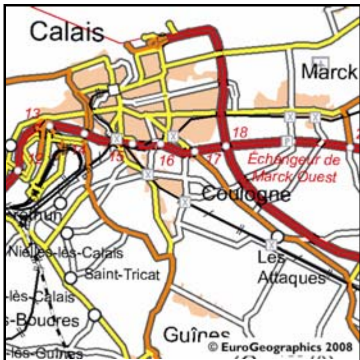
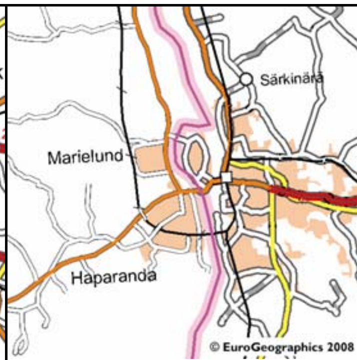
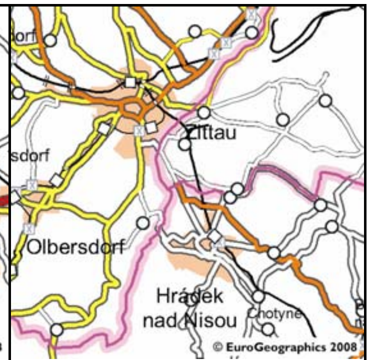
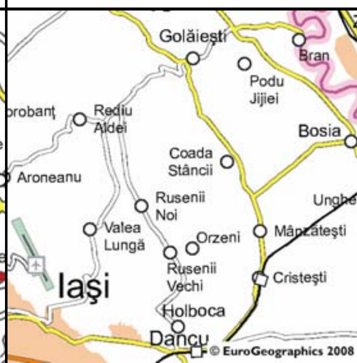
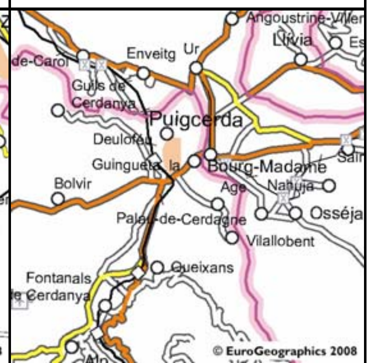
[1] ERM data are copyright of EuroGeographics and the contributing national mapping agencies.

content and suitable geovisualisation rules. The principle of the least common denominator is not recommended as it causes a reduction of map content. For issues, such as missing features and parameters, it was proposed either to adapt the data source or the map content. In case of a mismatch of geometry, the method of portrayal was adapted to include all available data.

Table 2 Map samples across Europe according to the proposed common specification

		
Sample1 Belgium - France – Great Britain	Sample2 Finland - Sweden	Sample3 Czech Republic – Germany - Poland
		
Sample4 Austria – Italy - Slovenia	Sample5 Moldova - Romania	Sample6 France - Spain

In summary, it can be stated that EuroRegionalMap is a suitable data set to produce the transportation theme of a European reference map. The case study clearly showed that for an effective cartographic visualisation

- the cartographic representation needs to be considered as one of the aims in the data collection and modelling process;
- geometrically and semantically harmonised and consistent data across borders is required; and

- cartographic generalisation is a major issue to resolve when a map is produced from multiple national contributions.

Besides that, to provide a European reference map similar in map content to European topographic maps, EuroRegionalMap data is not sufficient. The theme elevation is not covered at all and the theme land cover only partly. Additional data sources are required to integrate this information. The use of EuroDEM, a pan-European digital elevation model covering Europe at an approximate scale of 1:100,000, is considered as a source to derive contour lines and hill shading. The land cover information could be added to the European reference map by combining the vector data with imagery (e.g. IMAGE2000). The test on integrating the additional information is currently ongoing. First results are expected to be ready to present at the conference.

Conclusions

The task of cartography within SDI is to add value to spatial data at the interface between SDI and their users by offering user-oriented design solutions. Cognitive and action-related concepts build the conceptual framework of contemporary cartography and are the foundation to a user-oriented map design that facilitates the successful human-cognitive information processing by the user. *Spiess'* concept of the graphic filter provides a model for the cartographic transformation of SDI data into cartographic representations. It illustrates the challenging design task. As a filtering process it requires the understanding of the user's expectation and the source data. Re-engineering is recommended as a pragmatic approach to the design of graphic filters in the SDI context.

The development of a common specification for a European reference map at scale 1:250,000 followed the outlined process steps of the design phase. The evaluation and re-engineering of well-designed maps provided a systematic and pragmatic approach for the development as it laid down the foundation for a common specification by identifying the principles and elements of map composition of topographic maps across Europe. Consequently, the geovisualisation rules were built upon existing cartographic experience and common acknowledged traditions in Europe as recommended in the INSPIRE methodology for the development of data specifications.

The proposed specification was evaluated at the example of EuroRegionalMap. The test proved that it is technically feasible and viable to produce a reference map. However, a consistent and comparable map content requires semantically and geometrically harmonised data. Moreover, an optimal visual result is more likely to achieve if the cartographic visualisation is considered as one of the aims of data collection and/or modelling. Due to the separation of data producers and map makers this seems unrealistic in the SDI context. The results provide a first design prototype that needs to be completed by geovisualisation rules and map symbols for the remaining map content. Then, design variants need to be tested and evaluated by specific user groups. The successfully tested solution, further, shall be registered with a design knowledgebase and brought to future work of standardization.

In conclusion, it can be stated that the research project raises awareness of the human aspect of using the SDI. Cartographic visualisations are a powerful tool enabling sharing of spatial information and knowledge, collaboration, and decision-making. The results of the research contribute to ongoing efforts on building a European SDI, such as developing GMES core services and establishing the Shared Environmental Information System (SEIS).

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