Lecture Notes
in Geoinformation and Cartography
Subseries: Publications of the
International Cartographic Association (ICA)

Anne Ruas *Editor*

Advances in Cartography and GIScience. Volume 1

Selection from ICC 2011, Paris

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Series Editors: William Cartwright, Georg Gartner, Liqiu Meng, Michael P. Peterson

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Foreword

The International Cartographic Association (ICA) has existed since 1959. Initially centered on Cartography, the themes of the Association have changed from year to year integrating new research and technical domains such as web services, location based services or the digitalization and analysis of historical maps. The ICA has 28 commissions and organizes an international conference on Cartography and GIS every two years. This international conference lasts 5 days and gathers between 1000 and 2000 attendants. The ten previous conferences were in Bournemouth (1991), Köln (1993), Barcelona (1995), Stockholm (1997), Ottawa (1999), Beijing (2001), Durban (2003), A Coruña (2005), Moscow (2007) and Santiago de Chile (2009). In 2011 the ICA conference takes place in Paris and for the first time the best ICC papers are published in the new Springer subseries, Publications of the ICA.

For the ICC2011, a large international and French scientific committee has been appointed to select the papers and the poster presentations. More than 900 papers were submitted, among which 245 papers were entered for possible ICA Journal or Springer book publication. Of these 245 long papers, only 33% were accepted by means of a double blind review process to ensure a top quality publication. These proceedings thus present the very best ICC2011 papers. The large number of submissions illustrates the importance of the GIS and mapping community all over the world, and we believe that this volume of proceedings is a valuable mirror of our community.

The book is composed of 62 papers, organized in 12 sections shared in two volumes. The digital version of this proceeding is available on Springer web site.

The first papers deal with map design and analysis. They present methods to map acoustic information, to analyze semantic information via cloud visualization techniques or even to analyze society through the legend of their topographic maps. The second section deals with the use and user issues, focusing not only on the analysis of user needs to identify map content but also on the usability evaluation of geoservices. Section three highlights collaboration tools and processes to either integrate different data sets, or alternatively to propose collaborative and interactive tabletops. Section four focuses on solutions of how to find the appropriate data or services once a need has been defined. Solutions mainly lay on the constitution of ontologies of geographical concepts, names or services. Section five is devoted to generalization. This large section (9 papers) illustrates the dynamism of the research community in this field, encompassing algorithmic solutions in order to select points, to generalize river and road networks, isobathymetric lines or polygons. A further paper describes a comprehensive method to combine different generalization processes.

The second volume begins with papers related to Map GIS and Education including, for example, the use of Chernhoff face (a schematic human face) to represent variables, and the use of a web server to teach GIS. Section seven presents 7 papers on historical data. There is a real challenge to explore, digitize and analyse historical data. Another paper presents, for example, a GIS for archaeology to support excavation site research. Others provide solutions for the referencing of historical maps so as to facilitate the access and analysis of such data. Section eight presents 2 papers on map projections, one using an empirical process to discover the best projection for existing maps. Section nine presents current work on planet and space cartography, encompassing the conception of appropriate symbology, the integration of multisource data or the determination of nomenclature for extraterrestrial landscapes. The last three sections focus on specific analysis. Section ten describes methods to create information from image processing or to map the resulting information. Section eleven is centered on DTM and terrain analysis, with a paper concentrating on the analysis of glacial areas. Last but not least, section twelve offers models and methods to study specific applications such as urban growth, traffic, epidemiology or language distribution. Some simulation methods are discussed here. Urban growth models including road network expansion and land use development are presented.

The extraordinary diversity of papers presented in these proceedings illustrates the dynamic nature and creativity of cartography and GIS today. We hope this volume will be the first of a long and valuable series.

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This volume is the result of the extraordinary review process done by the international and French scientific committees of the ICC2011. 245 papers have been reviewed in 4 weeks by two reviewers, organised into 36 different themes. I wish to thank Samia Belbachir to help me recieving the papers and reviews on time and Helène Richard who help me for the selection process.

I wish to thank François Lecordix, Madame Lecomte from the Comité Français de Cartographie and Charlotte Hoarau from the COGIT Laboratory who helped me for the editing process.

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Map Design and Map Analysis

Maple – a Web Map Service for Verbal Visualisation using Tag Clouds Generated from Map Feature Frequencies

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Abstract

Tag cloud visualisation has been introduced in the seventies. In current Web 2.0 applications this method is a very popular visualisation technique. This paper presents an approach that uses this technique in combination with maps. Our method augments cartographic representations with additional verbal content, which is one of the strongest instruments available to cartographers to communicate spatial information. The idea is that only few words extracted from the semantics contained in the features of the underlying map are suitable to characterise the map section as a whole. To demonstrate the approach we used the OpenStreetMap dataset. In order to allow a variety of web map clients to use the results of the method, we realised the prototype by implementing it as a Web Map Service (WMS) based on the according Open Geospatial Consortium (OGC) specification.

1- Introduction: History of Tag Clouds and Related Work

More than 30 years ago, Milgram and Jodelet (1976) introduced the technique of drawing words at different font sizes to present a visual overview of a text corpus. The results of their work on a "collective mental map of Paris" are shown in Figure 1. The method they used may be seen as the origin of "tag cloud visualisation".

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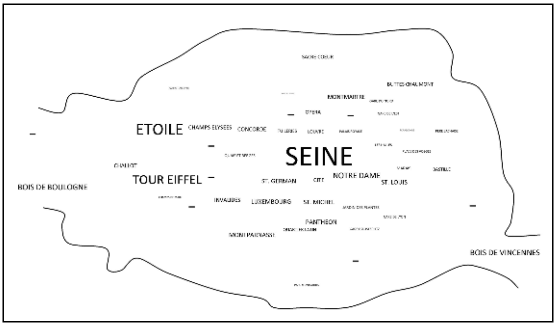

Figure 1: Introducing tag clouds to cartography: Milgram and Jodelet's "collective mental map of Paris" (Milgram and Jodelet 1976)

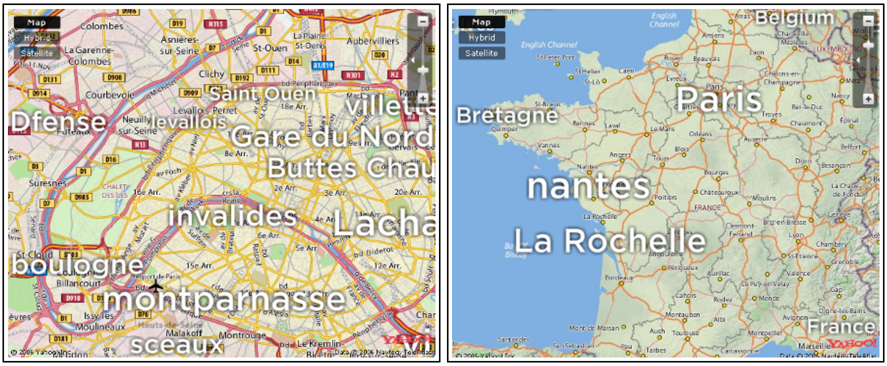

Figure 2: Web application World Explorer:1 Landmarks automatically generated from clustered Flickr photo locations and their assigned tags. Bigger labels indicate bigger cluster sizes

In the age of computer visualisation, this technique has become very popular, especially with the rise of Web 2.0. A general overview of different layout algorithms for the generation of tag clouds is given by Viégas and Wattenberg (2008). Several researchers have recently published on tag cloud visualisations for cartographic contexts.

The approach of Ahern et al. (2007) exploits the public Flickr2 photo collection. Tagged images with assigned GPS coordinates are used to compute clusters of popular tags, i.e. regions with a disproportionately high density of photos and the dominant tag of each such region are calculated. The tag label of each cluster is placed centred at the centroids position of a cluster and the label size is scaled according to the size of the cluster.

[1] http://tagmaps.research.yahoo.com/worldexplorer.php.
[2] http://www.flickr.com.

Figure 2 shows results of the application World Explorer, which implements this approach. A cartographic base map is overlaid with the computed labels, which results in a map of what we would call popular landmarks. We have chosen this name because the labels are based on places most frequently photographed by the users of the Flickr photo platform. The approach may be used on multiple scales. Results are similar to those of Milgram's collective mental map with a bias towards tourist attractions.

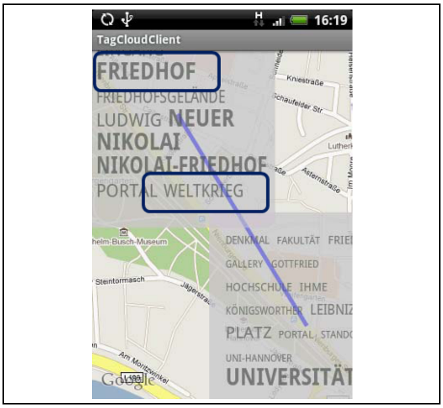

Figure 3: Visualisation of geospatial and non-geospatial context information using tag cloud visualisations generated from geo-referenced German Wikipedia articles, modified after Paelke et al. (2010)

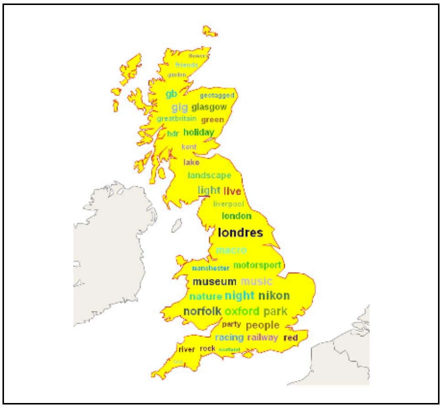

Figure 4: The Taggram method – a layout algorithm that adapts the shape of a tag cloud to an arbitrary geometric region (Nguyen and Schumann 2010)

Paelke et al. (2010) use content of geo-referenced Wikipedia articles to represent context information on maps. They compute tag cloud visualisations from articles that can be located within a specified map section via the coordinates given in the article. Figure 3 shows a result of this work. The benefit of this approach is its potential to show geospatial as well as non-geospatial *context information*. It can be seen, for example, that the terms "Friedhof" (German for "cemetery") and "Weltkrieg" (German for "World War") appear in the same tag cloud and will thus be associated with each other by the user of the application.

Nguyen and Schumann (2010) present a layout algorithm for tag clouds that adapts the shape of the cloud to an arbitrary geometric region. Figure 4 shows a result of this so-called taggram method.

2- The Approach: Using OGC WMS standard for On-Map Word Cloud Visualisation

The objective of the approach we present in this paper is to verbally visualise the main semantic information that is contained within a map. For this purpose we use the word cloud technique as an information analysis method in combination with maps. This method makes use of adding verbal content to the map, as this is one of the most powerful communicational resources available to cartographers.

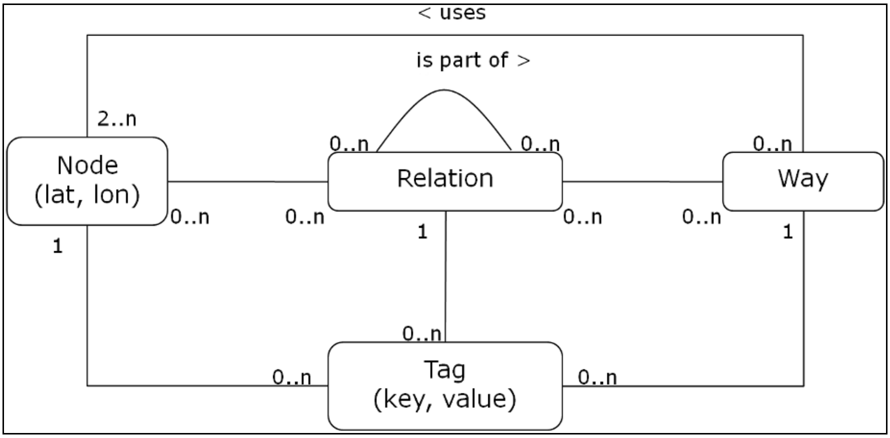

Figure 5: Section of the OpenStreetMap database schema: Node, Way and Relation represent geometric entities that can be annotated with zero to n Tag entities specifying their semantics

For the demonstration of our approach we use the OpenStreetMap (OSM) dataset. Figure 5 shows the section of the OSM database schema that models geometric objects and their semantics. In fact the OSM tags are the semantics of the dataset. OSM tags consist of a key-value pair and specify map features. They are linked to geometric objects. Each geometric object can be associated with a multitude of tags that specify its meaning. Tags can have references to points (table node), lines and polygons (table way) or complex objects (table relation).

Figure 6 shows a flowchart of the implementation of the application that overlays an OSM base map with a word cloud processed for the current map extent. OpenLayers serves as a WMS client and the OSM Mapnik layer as a base map. The map client requests the server by sending a getMap request that conforms to the Open Geospatial Consortium Web Map

Service specification (Open GIS Consortium 2001). The server queries a mirrored OSM database, which results in a list of tags and tag frequencies within the bounding box of the getMap request. In the case of point objects, tag frequency increases with every occurrence of this tag in conjunction with a point object. In the case of line and polygon objects a tag frequency, rises with the number of vertices of line and polygon objects that are associated with this tag.

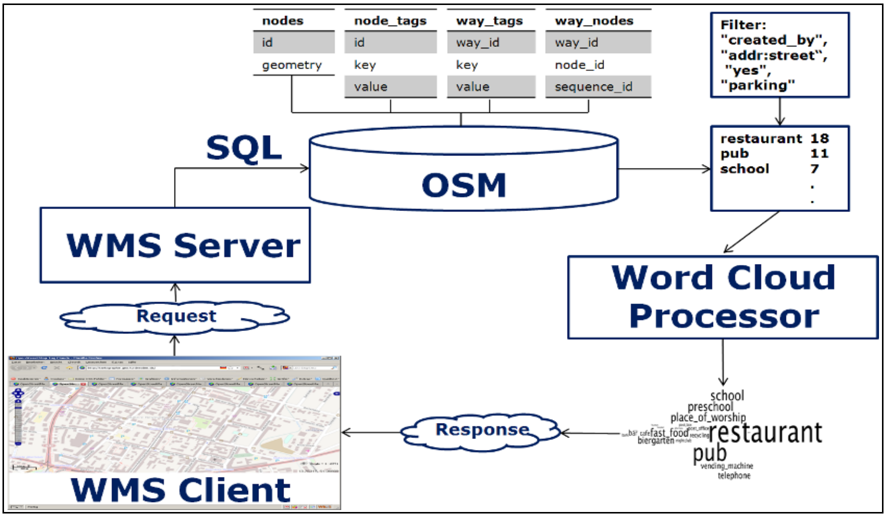

Figure 6: A Flowchart of the process that generates the word cloud layer

OpenLayers, which we used as a WMS client, allows switching between different layers. In the communication with the WMS server, switching between different layers is realized by the layer parameter of the getMap request, which allows the client to specify which keys and/or values will be presented by the overlaid word cloud. As some keys such as “created_by” and “address” occur with disproportionately high frequency, we added the possibility to delete certain tags from the tag frequency list. The filtered list is then processed by the word cloud layout software. The produced image is sent back to the client as the getMap response.

The algorithm which is used to layout the word clouds was described by Viégas et al. (2009). An implementation is available via an executable version[3] of the engine that drives the popular word cloud visualisation website

[3] Available at: http://www.alphaworks.ibm.com/tech/wordcloud/download.

wordle. [4] Figure 7 shows the result of a word cloud visualisation of the titles of the presentations held at ICC 2009. *Maple* – the name of the application – is an adaption of the name *wordle* to the context of cartographic *maps*.

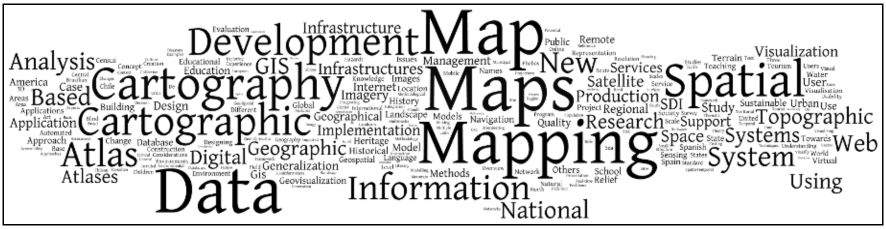

Figure 7: A word cloud highlighting frequently used terms within the titles of the presentations held at ICC 2009

3- Resulting Maps and Discussion

Figures 8, 9, 10 and 11 show the results of the implementation. Figure 8 presents a map and an overlaid word cloud, which is computed for the area of the "Neustadt" district of the German city of Dresden. It shows the frequency of occurrences of tag values associated with map features having the key "amenity". The fact that Dresden Neustadt is a nightlife district is quickly deducible even for a map user who does not know the area, because "pub" and "restaurant" show up in a big font size.

Frequencies of values of map features with the key "highway", which includes all types of streets and footways, are shown in Figure 9 for an area in southern Dresden. It is obvious, that the OSM dataset provides very much detail even on public footpaths and that this map section represents a mostly residential area.

A word cloud processed from the key frequencies within the centre of the German city of Leipzig is contained in Figure 10. It illustrates why the OpenStreetMap project really deserves *StreetMap* being a part of its name. The tags "highway" and "name" that normally co-occur on street features are the biggest keys within this cloud. It has to be mentioned that the keys "created_by" and "address" have been filtered. The tag "railway" is also big as Leipzig's main station is within this map extent.

[4] Wordle – Beautiful Word Clouds, available at: http://www.wordle.net.

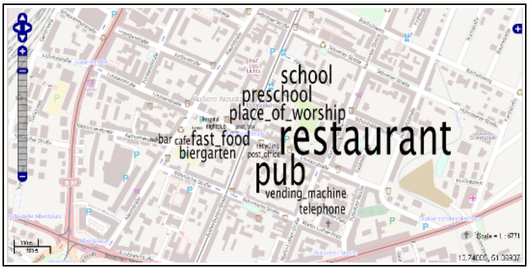

Figure 8: OSM Mapnik base map and an overlaid word cloud computed from the values of the key "amenity" in the area of Dresden Neustadt

Figure 9**:** OSM Mapnik base map and an overlaid word cloud computed from the values of the key "highway" in the area of southern Dresden

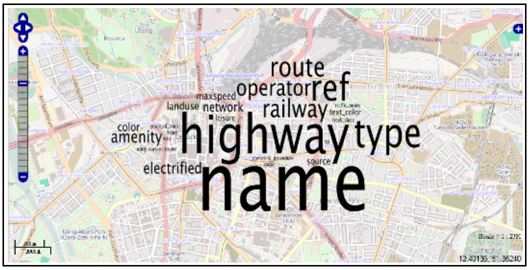

Figure 10: OSM-Mapnik base map and an overlaid word cloud computed from the OSM keys in the centre of the city of Leipzig. Keys "created_by" and "address" are filtered

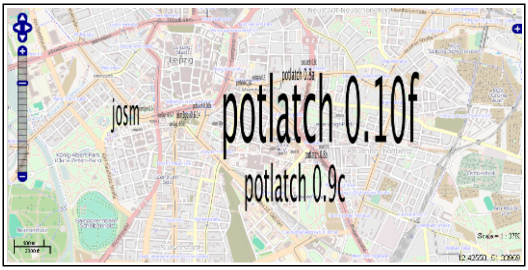

Figure 11**:** OSM Mapnik base map and an overlaid word cloud computed from the values of the key "created_by", which indicates the tool that was used to edit data, in the centre of Leipzig

Figure 11 shows a map overlaid with the names of the OSM editors that have been used within this area. It is remarkable that there are considerable differences between different regions as different local OSM mapping communities seem to prefer different OSM editors to edit data. These results may turn out to be interesting for the mapping community especially for the development and documentation of OSM edit tools.

The tag cloud visualisation method allows the analysis of both object *types* and object *values*. Figure 10 is an example for object type visualisation and Figures 8, 9 and 11 are examples for object value visualisation.

Table 1 shows typical computing times for word cloud processing at different scales within an area of high density of OSM objects. Test environment was a machine equipped with an AMD Dual Core Opteron 2.6 GHz processor and 1 GB RAM. Times for processing of the word cloud from the tag frequency list are nearly scale-independent, whereas times for database queries increase exponentially with decreasing scale. For the prototype, a copy of the part of the OSM database that covers the area of Germany was used. This includes currently just 5% of all data of the database. However there are still about 40 million entities in table 'nodes', 5 million entities in table 'ways' and 80.000 entities in table 'relation' that need to be queried. Additionally, there are about 8 million entities in table 'node_tags', 14 million entities in table 'way_tags', and 300.000 entities in table 'relation_tags', which need to be analysed for every word cloud request.

Word clouds are intuitively perceptible and by their nature do not suffer from the labelling problem of bar charts, tree maps or bubble charts. Furthermore they are able to present the gist of a word corpus. Cons are that long words as well as words with many ascenders and descenders get undue attention and that it is not possible to read exact values. The layout algorithm of a word cloud is more sophisticated than the layout algorithm of a tag cloud as it uses the typographical whitespace more efficiently.

The big advantage of using a standardised WMS implementation is that a multitude of existing WMS clients can directly integrate the results. Our implementation even allows making use of the getMap transparency parameter and hence an overlay that does not completely hide the examined map is possible.

A disadvantage of the word cloud visualisation displayed directly on a map is that map readers are used to associate text shown on a map with the directly underlying situation. In the case of an overlaid word cloud that describes the whole map section, this can lead to misinterpretation. Hence, this method may be more useful when displaying just one district, whereas for the case of displaying a whole town, it might not provide significant insights. It would be possible to solve this issue if the word cloud would not be directly overlaid on the map but would be shown in a separate space of the application.

Scale	Area (km^2)	Overall computing time (sec)	Database query time (sec)	Cloud processing time (sec)
1:36000	20	103	95	8
1:18000	5	37	29	8
1:9000	1.25	10	3	7
1:4500	0.32	7	0	7
1:2250	0.08	7	0	7

Table 1: Computational time for word cloud processing at different scales, test environment: AMD Dual Core Opteron 2.6 GHz, 1 GB RAM

Using the tag frequency in relation to vertices within a map area underestimates the relevance of large objects having few vertices and overestimates the relevance of small objects having many vertices. This affects lines as well as polygons which consume much map space with few vertices and accordingly lines and polygons that consume little map space with many vertices. This bias is relevant for the cases where the overlaid word clouds are intended to visualise the main semantic information of a map section like in Figures 8 and 9. Instead of using tag frequencies, the estimation of relevant tags within the word cloud visualisation can be improved if length of lines and areas of polygons associated with specific tags are used as a weight. For use cases where we only want to present statistics of a dataset like in Figures 10 and 11 the vertex related frequency estimation is sufficient.

4- Conclusions and Future Work

We have presented a method that able to present the main *semantic information* included within a certain map section using a word cloud visualisation technique that visualises map feature frequencies on a map. Up to a certain degree this technique is able to *verbally* characterise the real world environment presented in a specific map section. Our demonstration is based on the OSM dataset but the approach is also applicable to other cartographic databases, e.g. data provided by national mapping agencies. Even non-primarily cartographic datasets such as Twitter could be analysed.

Future work needs to address query performance, especially for the scenario of a huge global OSM dataset and queries on mid- and small-scale map extents. Furthermore, verbal descriptions of the meaning of the OSM tags could be taken from the OSM wiki website to produce more vernacular word clouds.

Last but not least, an empirical study needs to be carried out to prove whether map users are able to interpret word clouds overlaid on maps and benefit from this additional information. A study conducted by Lohmann et al. (2009), which compares different tag cloud layouts with a focus on human task-related performance, could serve as a starting point.

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Audio Cartography: Visual Encoding of Acoustic Parameters

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Abstract

Our sonic environment is the matter of subject in multiple domains which developed individual means of its description. As a result, it lacks an established visual language through which knowledge can be connected and insights shared. We provide a visual communication framework for the systematic and coherent documentation of sound in large-scale environments. This consists of visual encodings and mappings of acoustic parameters into distinct graphic variables that present plausible solutions for the visualization of sound. These candidate encodings are assembled into an application-independent, multifunctional, and extensible design guide. We apply the guidelines and show example maps that acts as a basis for the exploration of audio cartography.

1- Background and Objectives

Human, cultural, and environmental sciences are concerned with the effects of sound in urban environments. They examine medical and social problems of acoustic immission caused by increasing transportation and industrial production. For example, the World Health Organization (WHO) documents several direct relationships between constant noise nuisance and medical or psychological damage, such as hearing impairment or high blood pressure (WHO 2009). In the political arena, the European Union (EU) released the directive 2002/49/EC (END) to attend to the expanding

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noise exposure. Since 2002, European agglomerations are legally obliged to conduct noise mappings and to publish the results on maps (EU 2002).

In physics, improvements in computing and simulation algorithms enable the advanced geometric modeling of micro- and macro-scale sound propagation, such as in streets or large urban areas (Kang 2007). Psycho-acoustics analyzes the subjective perception of sound and emphasizes the influence of urban parameters, such as the contentment with the residential area or the importance of the sound source (Lercher 1998). With an anthropogenic and sociological background, an international research network works on soundscape analysis where linkages between environmental sound and society are explored (soundscape-cost.org 2011). Concurrently, the International Organization of Standardization (ISO) develops standards for the perceptual assessment of soundscape quality and discusses definitions and methods (ISO 2010). Also, planning disciplines developed a conspicuous awareness of auditory aspects of urban and architectural designs (Arteaga and Kusitzky 2008). Some of these research results attracted public interest to the extent of triggering several national and international initiatives, such as local action groups or the International Noise Awareness Day (Deutsche Gesellschaft für Akustik e.V. n.d.).

Each of these domains deals with different facets of the sonic environment. Whilst each focuses on spatial characteristics of sound, they develop individual means of its description. These might be considered different languages for visually describing properties of sound. Their incompatibility means that, when it comes to an exchange of perspectives, interdisciplinary discourse is difficult. Appropriate tools for supporting this activity do not exist.

The objective of this study is to provide fundamental building blocks for communication, documentation, and presentation to involve all stakeholders concerned with the sonic environment. This includes systematic visual encodings and mappings of acoustic parameters into distinct graphic variables as plausible solutions for the visualization of sound. Consequently, the codifications lead to the compilation of guidelines according to specific tasks. They are assembled into an extensible visual design guide as the basis for audio cartography as a visual communication framework for the systematic and coherent description of the sonic environment.

2- The Visualization of Sound

The human process of external cognition uses graphical representations to describe and exchange mental concepts (Scaife and Rogers 1996). The creation of visual metaphors for information depicting structures of the real world aims to reveal patterns, amplify cognition, and generate insights whereby insight enables discovery, decision-making, and explanation (Card et al. 1999, Ware 2004). These principles specify the missing components in connecting the diversified knowledge of the sonic environment. The display of sound in varying contexts would enable the visual utilization of acoustic information and provide a solid common level of communication. Based on extensive research of multidisciplinary perspectives on the sonic environment and their visual communication techniques, the visualization of sound has to meet the following challenges.

2.1 Envisioning Sound

Envisioning sound involves the fundamental problem of designing visual presentations of information that has no clear relation or association to familiar physical geometries (Bugajska 2003). Sound is an audible and invisible entity, and human perception is not familiar with its visual interpretation. Depictions of acoustic data range from musical notations and synaesthetic images as subjective visual perceptions of music to aesthetic visual installations of acoustic signals in the field of artistic visualization (Woolman 2000, Baron-Cohen and Harrison 1997, Nicolai et al. 2008). Although these concepts mainly relate to musical compositions, they can be assigned to the visualization of sound in large-scale environments. The universality and uniformity of music notations underline the requirement to develop a general and consistent visual encoding of acoustic information. Synaesthetic perception, even when it is rare, suggests the capability to transfer an auditory stimulus to a visual metaphor. Artistic transformations of sound highlight the possibility to visualize abstract acoustic data in an appealing and aesthetic way.

2.2 Mapping Sound

Over millennia, maps have been powerful instruments to communicate geographic spaces that are too large or too complex to be seen directly (MacEachren 1995, Dodge et al. 2008). Existing communication techniques indicate that mapping sound is an appropriate instrument for an integrative and interdisciplinary documentation of the sonic environment. One of the main tasks of the END is the publication of noise maps to communicate immediate problems of noise exposure to the general public (EU 2002). Concepts developed in multimedia cartography add audio visual features to noise maps to facilitate their understanding (Scharlach 2002). Cartographic visualizations within soundscape research highlight acoustic spatial identities or auditory effects of the sonic environment by using simple black-and-white points, lines, areas, or graphic semiologies (Southworth 1969, Servigné et al. 1999). Cutting-edge simulation approaches implement sound propagation based on punctual or spatially extended sound sources. This allows for the graphic representation of sound in relation with other topographical objects, such as buildings (Michel 2008). Graphical intersections with other topographical objects are important to provide orientation in the setting, give insight into the spatial dimension, or reveal interactions of the acoustic parameters. Consequently, the visualization of sound demands an integrated map design that suits the perspicuous presentation of both acoustic and topographical objects.

3- Approach

The heterogeneity of disciplines dealing with characteristics of the sonic environment opens up a huge range of involved stakeholders, such as domain experts, scientists, planners, decision-makers, people concerned with noise, and the general public. Therefore, we need a cross-disciplinary communication framework that is suitable for multiple applications according to specific questions or target audiences. This includes a medium- and application-independent concept to guarantee its general qualification and usage. Furthermore, the design has to operate on a broad range of media formats, such as paper or computer-based and mobile devices.

Our approach is to develop a simple graphical language that connects the above mentioned knowledge levels. This consists of an appropriate set of graphical constructs that describes this highly complex topic. Within our methodology, we abstract data and vocabularies utilized by potential target groups and derive discrete acoustic parameters to standardize the description of the sonic environment. Subsequently, we visually encode the parameters by systematically assigning graphic variables. Hence, we obtain an exemplary set of encoding guidelines that is assembled into an application-independent, multifunctional, and extensible design guide. In the end, we apply our encoding and generate sample maps within two case scenarios.

4- Abstraction

Abstractions help to derive generic descriptions of sound and simplify the complex structure and dynamic behavior of it. We consider a cross-disciplinary selection of acoustic information that is measured, computed, or described and throughout used in science and practice. They are based on formally structured requirements elicitation with experts, specifications by legislature, and field studies (Kornfeld 2008). Each parameter describes a particular aspect of an acoustic situation. Although they rely on a specific background, the compilation and combination of them prepare for an integrated view on the relevance of environmental sound. The list is intended to be continued:

- *Geometric shape of sound*: The natural shape of sound is a wave traveling through air. Due to large scales, this is abstracted to a simple geometric shape of sound.
- *Sound source*: The END defines major sound sources primarily responsible for high noise levels (EU 2002). Descriptions in soundscape research also relate to properties of particular sources (Schafer 1977). Setting up categories and subcategories depends on the certain use case.
- *Dominant soundmark*: Sound sources that silhouette against the audible environment are expressed as soundmarks. Dominant soundmarks completely mask other sounds (Schafer 1977).
- *Sound energy*: Geometric sound propagation calculates emitted sound energy of a source. It serves as a useful linear measure to detect sound intensity which summates all immitted sound energy at a particular location.

- *Sound pressure level*: Sound pressure level on a logarithmic scale in Decibel (dB) serves as a common noise indicator. For example, the END calculates A-weighted long-term average sound pressure levels (EU 2002).
- *Frequency spectrum*: A sound source emits waves of different frequencies measured in Hertz (Hz). With frequency on a logarithmic scale the distribution of sound energy over frequency is defined as frequency spectrum.
- *Spatial reach*: Soundscape surveys often map the spatial reach or extent of an auditory perceived sound (Schafer 1977).
- *Noise limit value*: There are regional, national, and international noise limit values that are both recommendations and stipulations by law. For example, the WHO observes sleep disturbances at noise levels above 40 dB (WHO 2009).
- *Rhythm*: Sound is a four-dimensional phenomenon and undergoes spatio-temporal changes. Soundscape research considers this characteristic by describing sound sources in terms of their rhythm (Schafer 1977).

5- Visual Encoding

With the technique of visual encoding, we systematically assign graphic variables to the previously defined acoustic parameters informed by cartography and information design. We employ plausible codifications according to established practice based on perceptual and cognitive principles (MacEachren 1995, Bertin 1974, Cleveland and McGill 1984, Mackinlay 1986). The objective of the encoding is to provide a unique and discernible graphic counterpart for each parameter which matches its physical characteristics and variability. In the case of correct encoding, the graphic variables allow recognition, permit estimation, and exhibit association with the underlying phenomena. It must be possible to utilize and read the graphic variable alone as well as in combination with other dependent variables. The aim is thus a systematic and modular usage of the variables for reoccurring visualization needs within various domains.

5.1 Geometric Shape of Sound

The encoding of the geometric shape of sound employs basic graphic elements, i.e., points, lines, and areas and matches the type of its spatial dimensionality (Fig. 1). We achieve further variations by applying the variable shape to the graphics (Bertin 1974, Wright 1944). Punctual presentations are useful to present locally discrete phenomena, e.g., sound particles. The usage of line segments is suitable to delimit areal phenomena, such as contour lines of noise pollution or when sound is modeled as rays. Additionally, spatially extended sources, such as streets are assumed as line segments. Areal presentations indicate the geometric shape of sound as a spatial continuous phenomenon and are commonly used in noise mapping (MacEachren 1995).

Figure 1: Basic graphic elements varied in shape

5.2 Sound Source

The parameter sound source is presented by the graphic variable color hue as it is useable for nominal parameters (Bertin 1974). By this means, we match the perceptual variation in the referent with the perceptual variation in the phenomenon and allow for qualitative description or comparison of sound sources. With a two-level hierarchy of sound sources we require both an encoding of source categories with equidistant color hues and an encoding of source subcategories with color hues that cluster around the associated category's color hue. We use the CIELuv color model where distances between colors are proportional to perceptual discrimination (Wood et al. 2010, Wijffelaars et al. 2008). Additionally, all color hues consist of 100 % saturation to allow a further encoding of this variable. Based on a qualitative analysis of audio recordings, we come up with an exemplary categorization of sources (Fig. 2). We transfer auditory stimuli into visual metaphors by associating a source with a color hue and display traffic with blue, economy with yellow, human activity with red, and nature with green. Blue symbolizes exhaust gases of vehicles that usually come along with the emission of sound. The color yellow indicates artificial or chemical production and serves as a visual equivalent for sources connected to economy. Red associates people and matches sound caused by human activities. In general, green is a symbol for nature and adequately presents environmental sound sources.

Figure 2: Color hues envision (sub)categories of sources

5.3 Dominant Soundmark

We present nominal point symbols as possible candidate encodings for the visualization of dominant soundmarks that can be pictorial, associative, or geometric (Robinson et al. 1984). We provide a set of associative point symbols for dominant soundmarks as they are nominally described discrete phenomena (Fig. 3). The auditory perception of dominant soundmarks and the interpretation of their corresponding symbols are highly subjective and context-sensitive so that our candidate solutions serve as sketches.

Figure 3: Associative nominal point symbols present dominant soundmarks

5.4 Sound Energy

We apply the graphic variable saturation to present linear sound energy (Morrison 1974). This is achieved by connecting the variable with color hue to simultaneously present sound energy and the corresponding source (Fig. 4). Our visual encoding considers attenuation of emitted sound energy due to absorption and varies the saturation of the color. Perceptual variation in color hue and saturation is non-linear, but using the perceptual CIELuv color model we are able to vary saturation in a perceptually-linear manner (Wijffelaars et al. 2008).

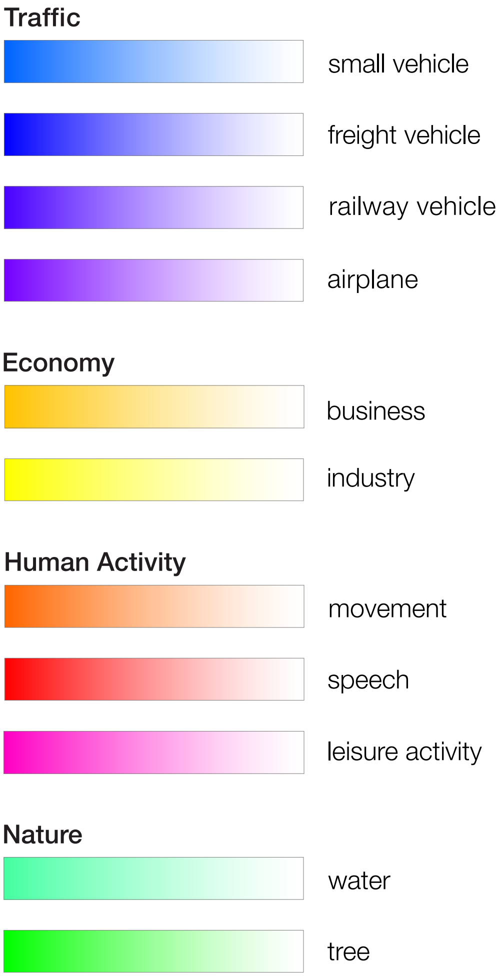

Figure 4: Color hues are perceptually-linear varied in saturation

5.5 Sound Pressure Level

Although END noise mapping is standardized, the color schemes used for the presentation of sound pressure level differ extremely and particularly lack in an appealing design (Working Group on the Assessment of Exposure to Noise 2008). Frequently, public authorities apply contrasting or unintuitive colors recommended by ISO standards that contradict established cartographic practice (Brewer 1994). We suggest an encoding that adopts functional requirements but results in an effective sequential color scheme (Fig. 5). We insert perceptual steps of saturation to match the logarithmic nature of sound pressure level. The candidate color schemes are approved and validated by user or usability studies (Harrower and Brewer 2003). A sequential color scheme indicates order and qualifies for the presentation of numerical or ordinal parameters. As sound pressure level is a logarithmized and normalized derivation from sound intensity, the visual encodings differ concerning their variation of color saturation. We employ sequential schemes consisting of single hues to assure the compatibility with the visual encoding of sound sources.

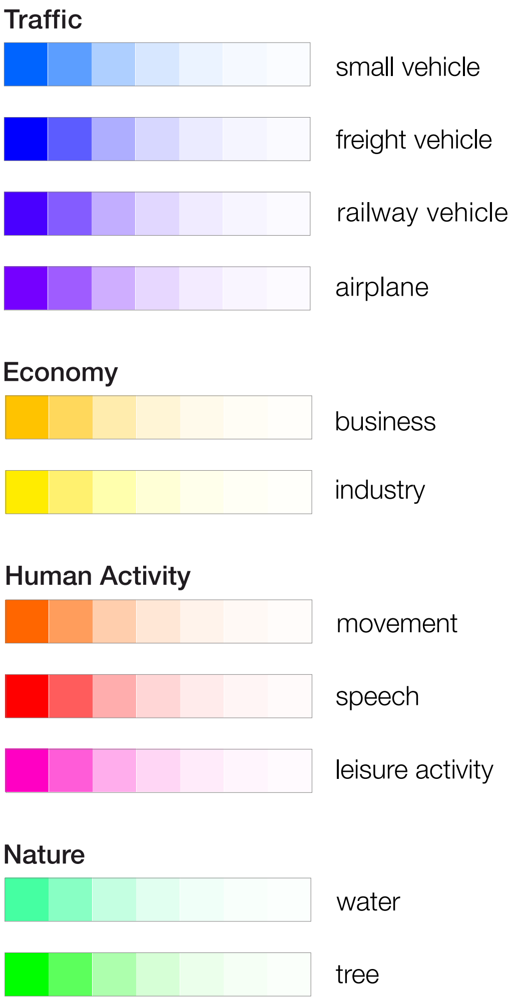

Figure 5: Sequential color schemes with perceptual steps of saturation based on single hues

5.6 Frequency Spectrum

We encode the parameter frequency spectrum with the graphic variable texture. Our encoding covers an irregular point texture, and we vary the density of the texture as the ratio of texture units to the background according to the spectrum width (Fig. 6). Thus, a narrow frequency spectrum generates a low ratio of texture units whereas a broad spectrum produces a high ratio of texture units (Caivano 1990).

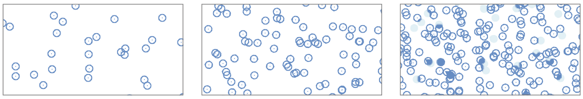

Figure 6: Irregular point textures display width of narrow, medium, and broad frequency spectrum

5.7 Spatial Reach

Spatial reach implies the auditory perception of a sound and is usually specified by geographic coordinates. As the parameter relies on subjective perception, we consider uncertainties in the underlying information and need a modifiable visualization concerning its clarity. Therefore, we encode spatial reach with the variables size and crispness (Bertin 1974, MacEachren 1992). A possible realization adopts color hue from a specific sound source to qualitatively determine the source and to geographically describe its spatial reach or extent (Fig. 7). The color hue is varied in crispness to selectively filter edges or fills of an object.

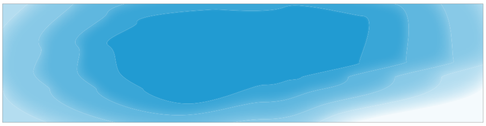

Figure 7: Variations of size and crispness mark the spatial reach of a perceived sound

5.8 Noise Limit Value

The parameter noise limit value requires a conspicuous encoding to underline the relevance of the underlying information. Blur immediately directs visual attention to relevant areas (Kosara 2001). Thus, we consider blur as a possible encoding technique to generate sharp areas exceeding critical noise levels while blurring the irrelevant areas. As blurring relies on context to create focus, the visualization requires the embedding of the parameter into a spatial setting (Fig. 8).

Figure 8: Sharp display of areas exceeding critical noise limits while unconcerned areas are blurred

5.9 Rhythm

Concerning the visual encoding of spatio-temporal rhythm, we compose a geometric point symbol as the parameter refers to spatially discrete sound sources. We draft an abstracted clock as a familiar metaphor and divide its surface into adequate or requested time units, such as one hour or one day. Then, we chart temporal variations of sound energy on the clock by saturating the source's hue according to the emitted energy at a specific time (Fig. 9). This encoding allows for the static visualization of spatio-temporal rhythm of stationary sound sources and enables their presentation on maps as point symbols with showing other topographical objects simultaneously.

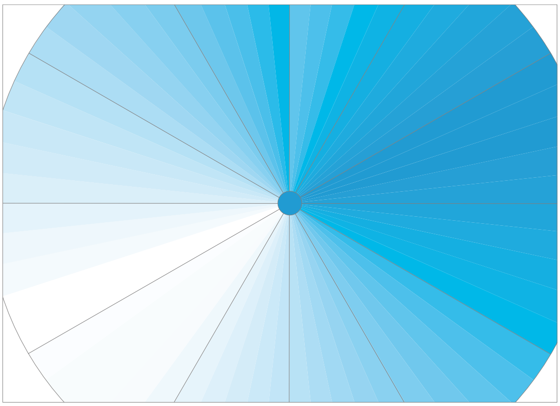

Figure 9: Geometric point symbols reveal temporal variations of sound energy

According to our encodings, we build a high-level design guide for the visualization of sound (Fig. 10). Due to different cultural and social contexts, this implementation allows for design related modifications of the variables. In particular, the choice of color has to be balanced according to specific framework requirements, such as cultural sensation of aesthetics, potential color blindness, or education and socialization background of users. Therefore, alternative arrangements are practicable when they stick to the systematic encoding of the parameters.

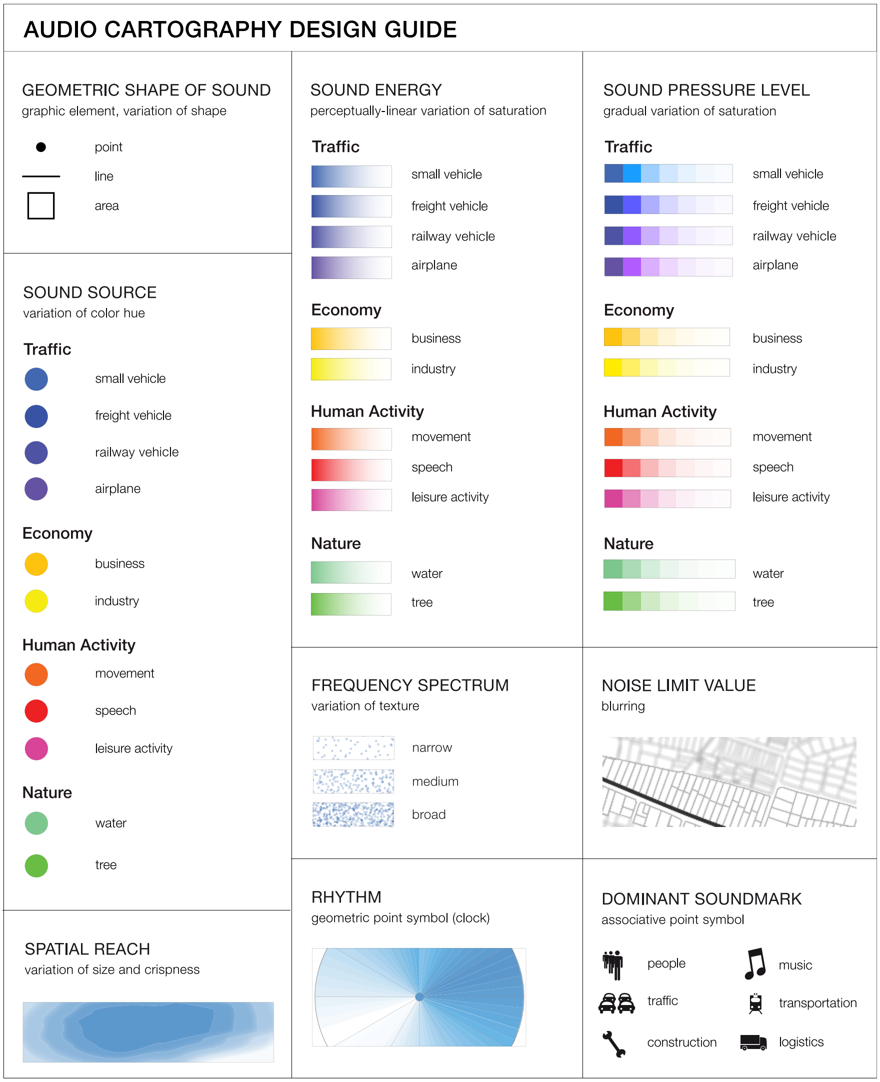

Figure 10: Design guide for audio cartography

6- Mapping Examples

Conform to our encoding guidelines we map acoustic parameters and generate two cartographic examples.

6.1 Noise Mapping

The map shown in Fig. 11 relies on noise mapping data from the END and presents A-weighted sound pressure levels in an investigation area in Hamburg, Germany. Accessing previous abstractions, we derive geometric shape of sound, sound source, and logarithmic sound pressure level as significant acoustic parameters. In this case, an areal presentation of sound corresponds with an areal calculation of the sound distribution. The END dictates the separate presentation of each source so our map features traffic emissions with blue. As computations merge traffic noise, the exhibition of subcategories is not needed. Public authorities cover sound pressure levels from 45 dB(A) to >75 dB(A). Thus, we create a sequential color scheme consisting of seven classes. Furthermore, the color-coding of sound sources prepares for the simultaneous presentation of multiple sound sources which is barely explored within noise mapping (Fig. 11 shows an exemplary implementation).

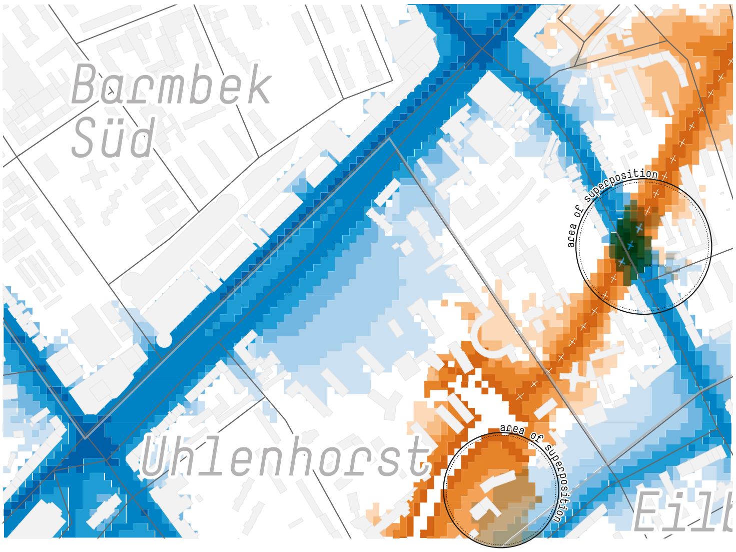

Figure 11: Map features sound pressure levels of sources

6.2 Simulation of Sound Propagation

Fig. 12 traces back to a research project dedicated to the simulation of sound propagation in cities. The algorithm is based on ray tracing methods and models the emission of sources within a small section of the above mentioned area. This application focuses on a simulation of the spatial distribution of rays and presets default emission input values, such as number of rays and power of the source. We derive geometric shape of sound, sound source, and linear sound energy as relevant acoustic parameters. We utilize line segments to describe the distribution of sound. Instead, we use dashed lines to illustrate the scattering at building façades. As this application implements source placeholders, we apply the color hue of traffic emitters to map the sources. We consider a perceptually-linear variation of saturation that emanates from absolute values, i.e., a range from 100 % to 0 % saturation. It is possible to adjust the variation range when concrete input and output data are valuable. We decrease transparencies of the color-coded rays to match the resulting energy value of the reflected sound due to absorption. Transparency allows for graphical superpositioning of emitted sound energies to detect sound intensities at specific receiver locations. Beyond that, the change of opacity of the color hue meets the absorption coefficient of the reflecting material.

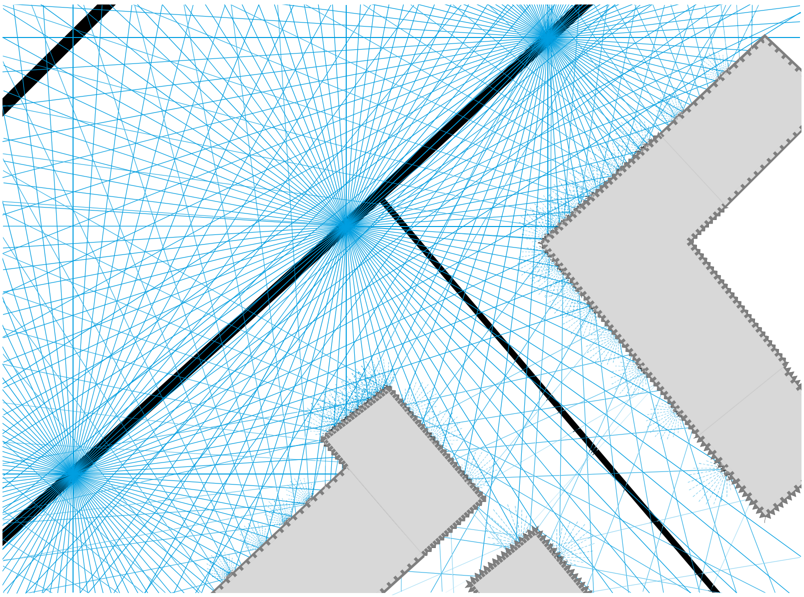

Figure 12: Map depicts distribution of rays and varies color hue according to their sound energy

Together, we yield exemplary cartographic presentations that describe aspects of the sonic environment. Further hypothetical examples of visualization are conceivable, such as spatial reach or soundmarks within soundscape research or the depiction of noise limit values in combination with demographic and socio-economic data.

7- Conclusion

This contribution addresses the shortage of appropriate tools supporting an interdisciplinary discourse about the sonic environment by providing a visual communication framework for its systematic description. We created fundamental building blocks for the spatial visualization of sound and offer guidelines for an audio cartography.

The guidelines meet essential design challenges as they provide the means to envision and map sound in large-scale environments. We are able to transfer auditory stimuli systematically to visual metaphors by accomplishing a consistent visual encoding of acoustic parameters. A multifunctional and –disciplinary usage of the design is expected by facilitating a modular usage while fostering the continuation or modification of the guidelines. In subsequent work, we apply our encodings and mapped them onto cartographic presentations. We show that our suggestions support an integrated map design and graphical intersection with other topographical objects.

We aim at an automation of our guidelines based on certain use cases. This approach assembles the compilation of design patterns and libraries which would enrich the functionality of audio cartography. It would be of great value to get empirical feedback via crowdsourcing as a possible means of validation.

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Classifying, Analysing and Experiencing Maps

A tentative humanistic approach

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Abstract

This paper is based on the assumption that the contents of all maps are emanating from three different sources:

1/ visual observations
2/ abstract thinking and
3/ human imagination.

Each individual map has a specific combination of these basic elements. This combination is visualised with help of a triangle diagram. Based on the proportions between these three components we can classify all maps and analyse them in different ways. In this paper the analyses go in two different directions:

- An analytical one, i.e.
  - the classification itself,
  - meta mapping, i.e. a registration of the coverage of the maps in space and time within in each category of maps
  - "information analyses' i.e. understanding of the map´s contents and intellectual structures and their connections with the related fields of research.
- The second main direction is analysing
  - people's the experiencing of maps and – in relation/connection to this –
  - people's experiencing the human environment (mental mapping).

The specific relation between the three components is then the key element which connects all studies concerning one and the same group of maps. One crucial point that is necessary to emphasize from the beginning:

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several different maps can have the same combinations of these three basic elements. Awareness of this factor is necessary especially when delimiting the groups of maps to be analysed in a specific case and when interpreting the results. When observing this restriction, however, this chain of analyses hopefully will provide an improved survey of the relations between different categories of cartographic products and studies and also improved understanding of the connections between the creations and experiencing of them. Another application of this way of reasoning is that we can reverse the process. We can follow how within a functionally or otherwise defined group of maps – i.e. sea charts or maps showing the continents - the relations between the three basic elements change during time (e.g. how observations and calculations replaces the elements of imagination). The trajectories connecting these separate combinations within the triangle diagram can give a deeper insight of the development of cartographic thinking. This later aspect is, however, not treated in the present paper. The exception is a trajectory showing the development of hypothetic person's mental map through his lifeline.

This paper is a part of an ongoing project, the revising and completing of the book "Human Cartography" (1987)

1- Introduction

The Roman god Janus used to be portrayed as one head with two faces, one turned towards the future and the second one to the opposite direction, to the past. The both faces of the god are identical. Janus could be an adequate symbol for the art and science of cartography but it would require some alteration: the two faces must be somewhat different. One of the faces would be extrovert, sharp-eyed, having a focused, determined and controlled expression. This face would represent the side of the cartography, which is not only central for its nature but currently mostly emphasized and developed. This side represents the technical and abstract aspects of cartography, exact observations, careful measuring, precise definition and treatment of information with that kind of precision which belongs to the natural- and engineering sciences.

The other face would be similar but would have a somewhat different expression. It would be more introverts, observing also through the "inner eye", the eye of imagination, fantasy, dreams, religious interpretations of the world and contemplation of the own activities and their results – a more humanistic approach.

This paper is an attempt to bring this two faces closer to each other in a coherent model of thinking. The more contemplative "inner eye" is recognised and treated as a factor with comparable importance to the other two – observation and abstraction. This face of cartography was never denied but because of its elusive nature is hard to analyse it in a systematic way. This is probably the reason way it is living its life in the concealed side of the cartographic theory's world. Yet: when you speak on a close person-to-person level, not only to cartographers but also others, with interests in maps, sooner or later you discover an array of deep, emotional, but frequently almost deprived echoes from the depth of their minds which are related to the "inner eye". The current, almost exponential technical development dominates our minds. But in order to make its fruits not only really useful but also sweet and enjoyable we must allow that our inner eye to prevail.

2- Classifying and analysing maps

2.1 Departure point: three extreme categories of maps

When classifying maps according their sources we can discern three extreme categories

- ***Maps based entirely on direct visual observations***. This case is illustrated by figure 1A which shows a palaeographic map, incised in a smooth stone flab on the top of a hill in middle Italy, some 7000 years ago. The map shows a village; the houses, fences, garden plots and even people (see also Appendix). Today we should call it a thematic map. The author of the map was obviously standing on that hilltop, looking down on the village and depicting his observations in a rather durable way. It is based entirely on his visual perception of this scenery
- ***Maps based entirely on abstractions.*** "Abstraction" implies here results of geodetically or geographical measurements, collection of statistical and other data by e.g. field registrations, enquiries etc. "Abstraction" includes here also geographical phenomena created by the abstraction of

the human mind, e.g. political boundaries, administrative divisions etc, i.e. geographical elements with sole source is the human mind, not in physical realities - even if they may relate to them (an abstract political boundary may coincide with a river).

Abstract knowledge can be the result of the cartographer's own efforts, but – mostly – the result of acquiring other people's collected experiences, not least by education.

This category of maps is represented by figure 1E. This is a contour map of the peninsula of Molle in southern Sweden. The contour lines are emphasised by colour shading of the intervals between them. The map is based on measurements of heights of chosen points of the terrain. The contour lines are calculated by interpolation between them. The map is plotted on the very first ink jet plotter ever, the prototype at the University of Lund around 1970. Contour lines do not exist. They are shier abstractions. The only physical element is the shore line which is also calculated on the basis of aerial photos or terrestrial measurements. Even the shore line itself is an abstraction. Other examples of maps based (mainly) on abstractions are political maps, showing boundaries between countries and the internal division of them in administrative areas. Division of a region into statistical districts is another example.

- ***Maps based on human imagination, fantasies and religious believes***. This category of maps is exemplified by a part of a map on Middle Earth by J.R.R. Tolkien (Fig. 1G). The land does not exists, hence nobody have visual observations of it. The picturing of the landscape has some connection to the real world, but no one ever have seen mountains like these except on some very specific maps. The choice of this example however not an ideal one with its special connections to the physical realities. In spite of this is yet used because of its associative value. A T-in-O map reflecting the medieval imagination of the world could be perhaps closer the "absolute" imagination – if there is something like that. Very young children's intuitive picturing of the world with their frequent mixture of fragments of correct information and immediate emotional experiences getting expressions in characteristic sketches are rather close to this category. Painters and other artists´ work show often this type of landscape of fantasy, but not frequently in map-alike form.

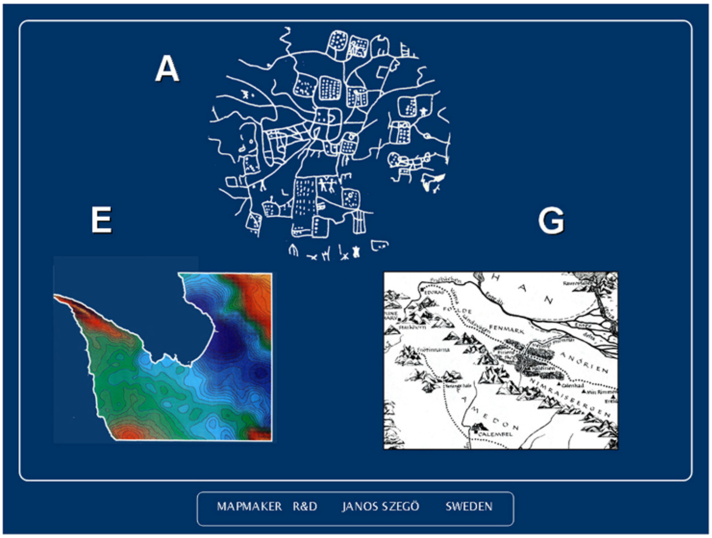

Figure 1: ”Seen”(A), ”Known”(E) and ”Imagined”(G). Three extreme cases of maps according the origin of their contents. “Seen” refers to maps based entirely on visual observations. “Known” means maps based entirely on calculations and abstract thinking. The human “Imagination” is the only source for this map.

2.2 Classifying maps according to the relations between the three main components

It is the basic assumption behind this paper that the contents of all maps are the result of a specific combination of these three main factors. Every single map has its own composition of them as decisive element. Hence all maps can be represented by a dot in a triangle diagram.

Figure 2 shows the three previous examples as corners of a triangle-plot. Each of them i.e. A, E and G represents all maps, based on only one single element – maps based either on visual observations only (2A) abstractions only (2E) and imaginations only (2G).

All points along the axes of the diagram represent maps based on a pair of elements. All other points within the diagram’s surface represent maps based on a specific combination of the three elements.

A few examples illustrate further the idea behind the diagram.

Figure 2B is a part of a Swedish topographic map from around 1815, made by plane tabling, drawn on sight (but redrawn afterwards). The drawn maps were geodetically positioned by astronomic measurements; otherwise it would qualify to a position in the corner of the diagram (i.e. based entirely on visual observations).

Figure 2C is a topographic map from 1984. It is based on aerial photographs, which were rectified, interpreted and completed with terrestrial measurments. The visual contents of the map are dominating yet the interpretation and treatment of this information is indirect. The map contains important abstract information as geographical names, administrative boundaries and grid net. Hence the map is balanced between visual and abstract components which defines its position in the approx. middle of the axis

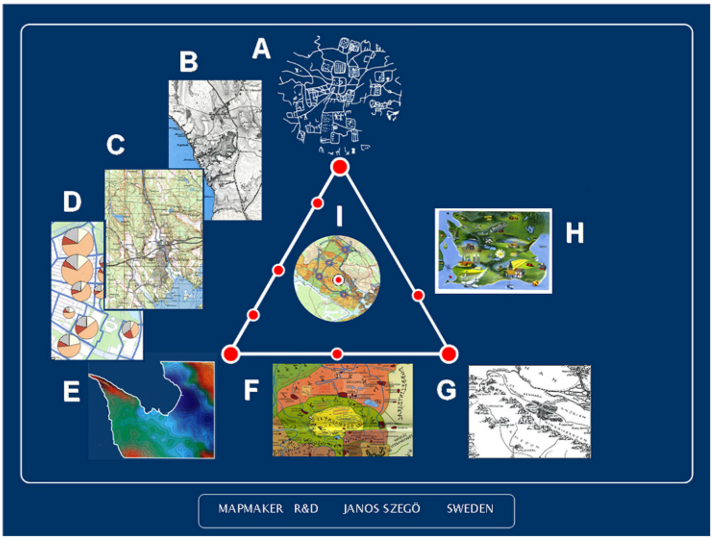

Figure 2: An array of maps with different relations between the three elements above.

Figure 2D is a thematic map on the population in the city of Malmoe in southern Sweden. The base map shows the building blocks of the city and some large parks, but it is dominated by the boundaries of the districts for statistical purpose and the pie charts showing the composition of the population. The maps content is dominated by abstract information. Hence the dot representing it is close to the corner "Abstractions".

Figure 2E and figure 2G was analysed previously. Figure 2F is new, however. This is a part of a map, depicting an imaginary landscape of mathematics'. The districts on the map represent different correctly defined mathematical notions. So even if the content of the map is entirely abstract, these abstract elements are translated into an imaginary landscape – a combination of abstract and imaginary thinking.

Another type of imaginary thinking is represented by figure 2H. This is a greeting card, showing Skane, the southernmost part o f Sweden. The picture is an artistically playful description of different characteristic elements in the landscape. They are all visible, part by part, directly – when visiting the sight – and indirectly, when looking at maps, but never in that way. This picture is emanating from the visible landscape but portrayed entirely according the imagination of the artist.

Figure 2I is the only example of a map based on all three elements of maps. Figure 2I is a part of a regional plan. It shows the physical landscape and elements in a traffic plan. It contains physical, visual elements of the landscape, knowledge of its way of functioning (abstract elements) and imaginative elements of it possible and desirable developments. Yet please notice that in the same position could a plan of a battle be shown, with pictures of the terrain, the actors of the scene, the practical preconditions of a battle (abstract knowledge) and imaginary element (different possible developments of the coming battle).

3- Analytical approaches

3.1 Metamaps

The example in Figure 3C is (a part of) a single sheet of a topographic map. Its character i.e. its composition is registered as point "a" on the plane of CLASSIFICATION maps i.e. the maps as artefacts. Its coverage (e.g. extension defined by coordinates of its corner points) – and time for its creation is registered and represented as a dot in position "b" - on a plane, parallel to the plane of the CLASSIFICATION (Figure 4). This is the plane of METAMAPS. Not only the map as a finished product but also all components of the map – different sets of data making together up the map - are also registered according to their extent, time of creation, quality etc. Figure 4b represents, however, not only this single sheet of a topographic map. It represents *all topographic maps* with similar qualities created anywhere and anytime. The dot on the plane of METAMAPS represents all information on the extension of each and every map sheet belonging to this category of maps.

Figure 3C, 4C etc exemplifies in first hand a specific series of topographic maps covering Sweden and created with the same qualities during a shorter production period. It used to be depicted as a rectangular grid net covering the surface of Sweden. These maps are regularly replaced with an updated series with a few years interval. Even the previous generation maps can be represented a similar rectangular grid net. So these reference grid nets make up a series of layers, representing the history of this particular topographic map. In practical terms they form a – rather impressive – register. This register is represented by the red symbol "b" in Figure 4.

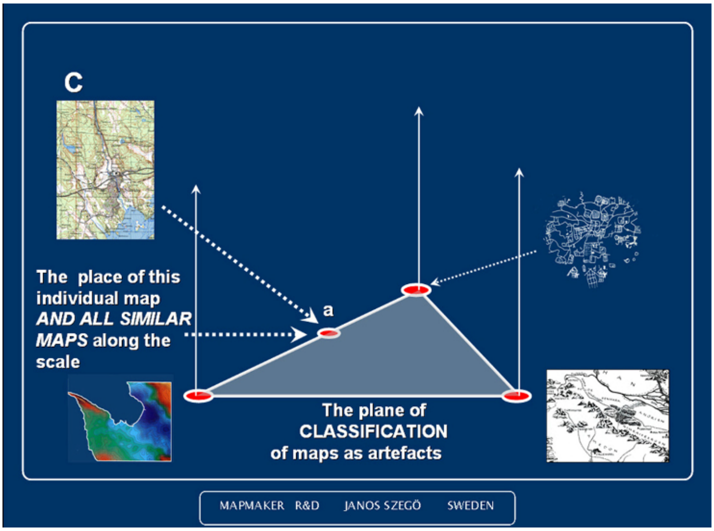

Figure 3: A part of a topographic map represent a combination of visually observed and mathematically calculated elements. Its position on the scale coincides with several other similarly composed maps.

Other, similar maps cover more or less the entire globe. They were created during a long period of time. Data considering all those maps, their geographical extension and time aspects is theoretically represented by the same location on the plane of METAMAPS.

There are far more maps and cartographical creation which could be located in point "a" in the plane of maps as artefacts. This point represents not specifically topographic maps of this specific appearance but all maps of the same relation between contents of origin – abstract and visually experienced elements and element of imagination.

Thus the point “b” represents a huge amount of maps. So do all other points in the triangular surface. The lower right corner of the triangle plot e.g. represents all maps based mainly on the pure imagination of human mind. Their identity and contents is represented – according this paper – in a single point in the corner of the METAMAP plane. The same could be said not only of all points along the edges of the diagram but also on all points within its entire surface.

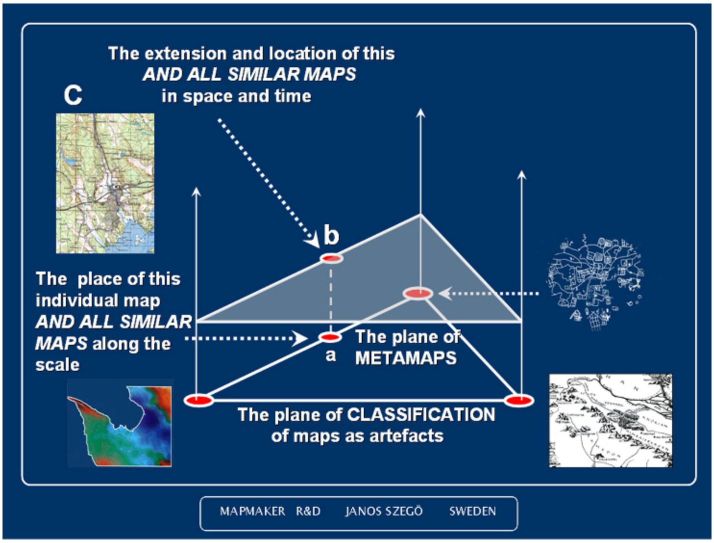

Figure 4: The plane of METAMAPs is parallel and conforms to the plane of CLASSIFICATION. It contains all surveys of the maps classified on the plane of CLASSIFICATION in corresponding position. The METAMAP describes not only geometrical extent, time of creation etc of the maps but also the properties of the data upon which the maps are built.

3.2 Information analyses

Analysis of a topographic map can be limited to one single map sheet and study its internal qualities – “deep analyses”. It can however include groups of maps whose scope is defined from case to case. The delimitation of these groups can be made from the METAMAP plaine´s location “b”. Such an analyses can e.g. comprise the spatiotemporal development of the topographic maps in a specific scale interval within a single nation during a few decades or – at the other end of the scale - the development of topographic mapping on global scale and under a whole specified historical era. All these analyses are represented by the red dot “c” in the plan “INFORMATION ANALYSES” in Figure 5.

Analyses of this type could be e.g (for a topographic map): Which factors are decisive for choice of the map´s content? Which factors guide the visual strength of different components of the map when designing it? What is the influence of the reproduction techniques when displaying different elements? Are there “a hidden agenda” when creating the map? We can also compare the coverage of – in this case – the topographic maps in different regions, how they developed in time and space etc. The metamap level in Fig 5B contains the necessary information in a systematised manner. The development can then be related to a historical, political or military background.

It is necessary to emphasize again, that point “a” represents several other types of maps than the topographic one used here for exemplification above and analyses based even on them will be represented by point “c”.

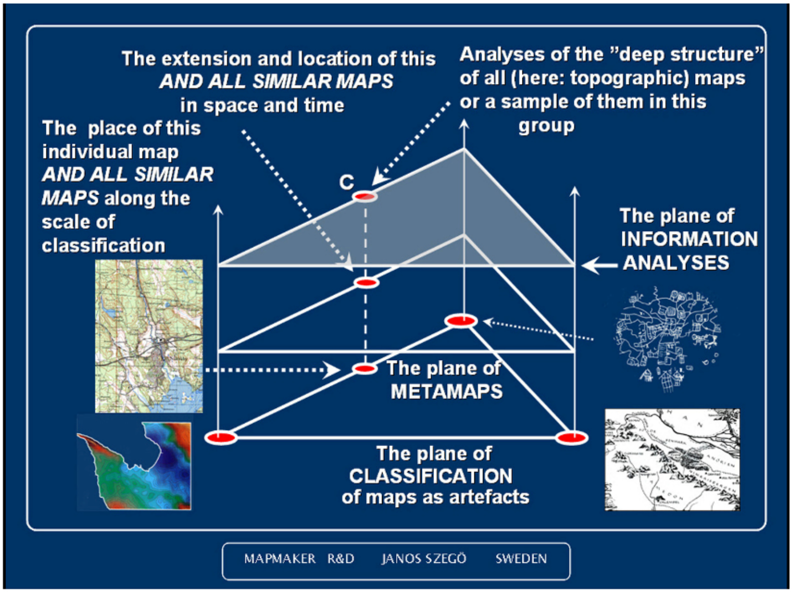

Figure 5: The plane of INFORMATION ANALYSES contains all studies based on all maps with identical composition of contents, in this case each studies based on this and similar topographic maps, the metamaps showing their extent and development during time etc and other related studies.

4- Experiencing & creating maps and the outside world

4.1 Experiencing and creating maps

When we study maps based on visual information and abstract knowledge our experience is enriched by our less rational parts of our mind. When we look at a map with historical connotations – e.g. Fig 6B (see also Fig 2B) - our fantasy adds elements to the map that we not always are aware of. The fascination of old maps probably depends on this effect. The arrow in Figure 6 pointing from "d" to "e" and from "f" to "g" is an attempt to visualise this enriched experience. The second symbol at the arrows heads symbolise the experienced contents of the maps rather then the maps real contents.

Even a current topographic map, as map C, can activate memories and awaken associations when we look at it. A green shade on the map can very well recall memories of wandering in forests as well as a blue wavy line may remind us on fishing tours in the past (see "h" to "k").

Even a statistical map can have associative values, even in a lesser extent but still. The background map together with statistical symbols may very well remind us of experiences in that particular area. Even the pie-charts may recall memories when we try to connect the symbols content to reality.

Similar deviations from the factual contents to experienced contents in maps are not map are not only possible but also probable. Map 1E is in itself such a deviation from pure abstraction to cartographic expression. The Tolkien-map probably is inspired by maps, read by Tolkien himself. The pictorial card from Scania is hardly independent of topographical maps. These and other influences could be visualised in the same manner as in Figure 6.

Figure 6 is inserted in the 3D-diagram in Fig 7 as the plane "CREATING and EXPERIENCING MAPS".

The same combination of the visible abstract and emotional elements are probably is present even when people *create* maps and similar artefacts. It is obvious that the creator of a cartographic product, based mainly on visual observations must also deal with the process of creating abstractions.

The Stone Age mapmaker incises his map based on visual observations only. Yet he must translate the lines of fences, paths and outlines of buildings to lines – an astonishing intellectual effort of abstraction ("e" in Fig. 6). We can not know but is not improbable that the emotional experience of the surrounding landscape inspired him to make the map also, perhaps initiated it. Most certainly that incised map inspire the fantasy of the reader of today – even when we meets it only in reproduction. The fine-tuned colouring of the old Swedish topographic map - not visible in this simplified copy shown in figure 2B – certainly mirrors the emotional experience of the landscape of the cartographic officer working in the field. A modern mathematical cartographer who calculates a new global projection grid works with pure mathematical abstractions – yet in his mind the Earth must be present as something he not only has seen on maps or globes but also envisioned in a not quite scientific way.

A reasonable interpretation of the three examples above is then that experiencing any cartographic product – either as creator or onlooker - most probably contains all the three components presented on the diagram. Hence when we depict such an experience in the diagram the representative point will always lay *inside* the three axes, never *on* them.

That because all the three elements are present both in the creational process and in experiencing all true cartographic products.

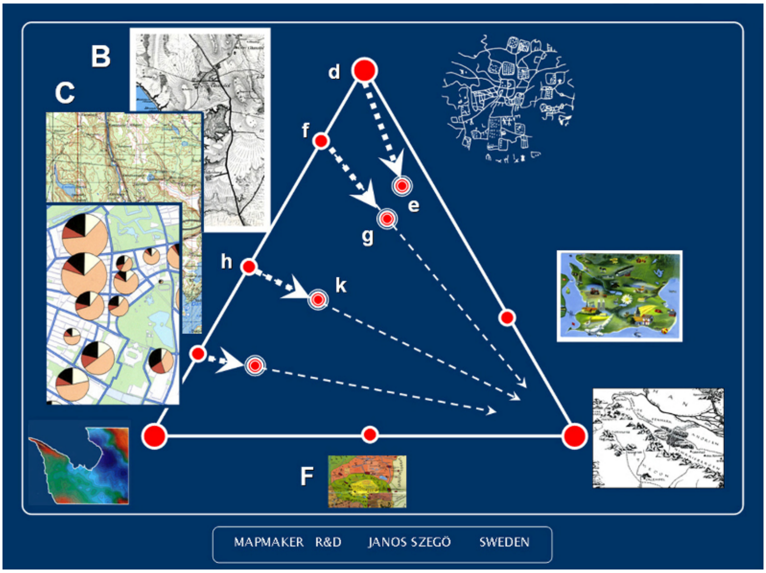

Figure 6: Reading maps activates the human imagination. The interpretation of their abstract contents recalls also memories, associations etc and transforms the reading of maps to experiencing them. The same happens even when creating the maps.

Or in other, less technical terms: the creators of most cartographic artefacts experience the same interaction between visually perceived facts, abstract notions and emotionally elements in their minds as the reader when taking part of the same maps.

Of course it is not impossible to design cartographic products with exclusion of fantasy, imagination or feelings. That would place the map created in that way on one axis of diagram. It is thinkable; however, if they exist, those are probably the maps we used to experience as poorly designed ones.

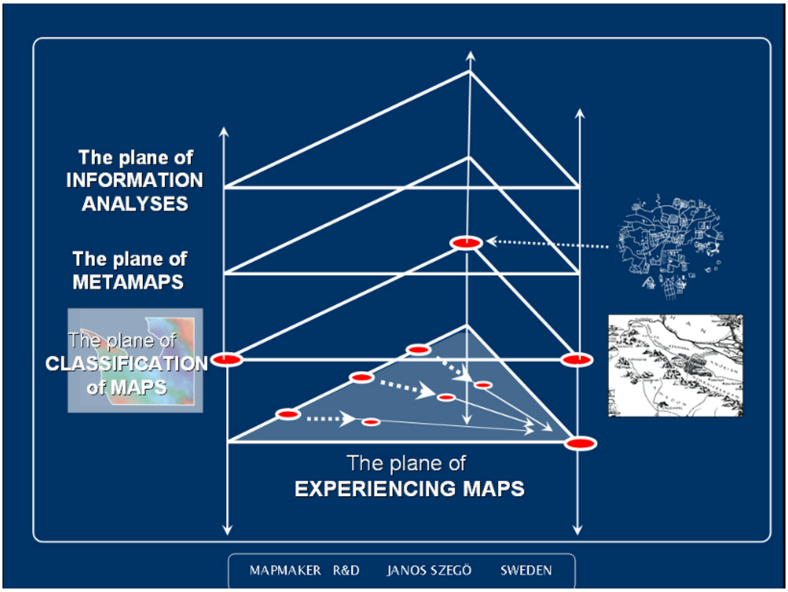

Figure 7: Experiencing maps is seen here as a similar derivate of classification as the METAMAPS but not in the analytical but the synthetically direction.

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4.2 Mental maps

Figure 8 is an attempt to visualise the development of our “inner map” in a very broad sense of the word and with heavy simplifications. The mental map in our minds follows us during our whole life, but it is so rich, so complex, so elusive and so dynamic that we never can transfer in it to “hard copy”. The current explosive development may perhaps give a chance for this in the future. The Google Earth may give a hint of one of many possible developments.

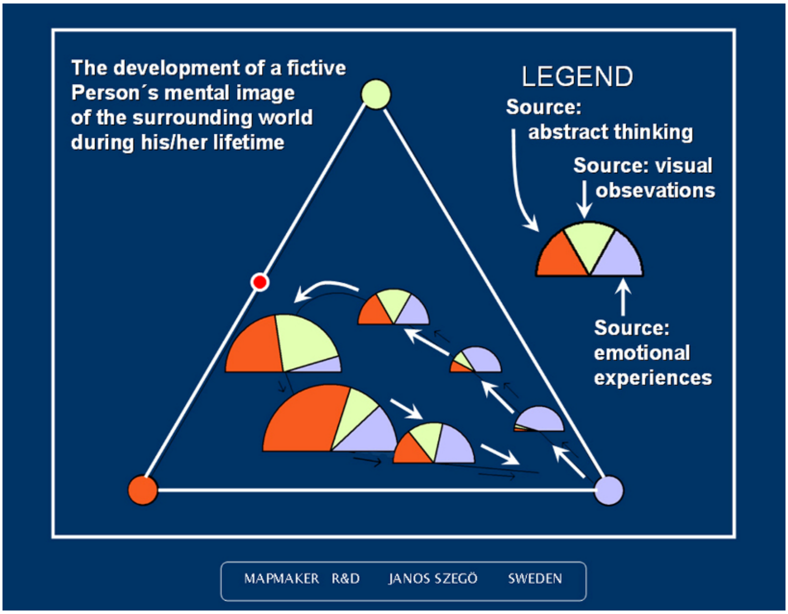

Figure 8: The mental image of our surrounding world is an internal map of human mind. It is built up of the same three components as other maps, but their contents change not only from individual to individual but also during different ages for one and the same.

The semicircles represent the mental image of the surrounding world of a hypothetical person in different stages of his/her life from very early child-hood, through adultery to high ages. The size of the semicircles shows the amount of information acquired and stored. The different sectors show the composition of these information-masses regarding the three components, visual-, abstracted- and imaginary elements. These three elements comprise both the outside world – e.g. experiencing landscapes through direct visual observations – and indirect experiences – e.g. visual experiences through studying maps, atlases and other descriptions of the world.

This (very) hypothetical person in his early childhood builds up his mental image by direct, emotionally coloured impressions. The direct, visual impressions supposed here to merge into these emotional experiences. The early visual and abstract components grow however and later the visual and not least the abstract components grow most intensely. At the high point of life the abstract knowledge is (supposed to) dominate but the emotional components are gaining weight again. The aging person looses some of his factual memories but the emotional components become more and more predominant – the returning and through experiences of a lifetime enriched memories weight more and more in his mind.

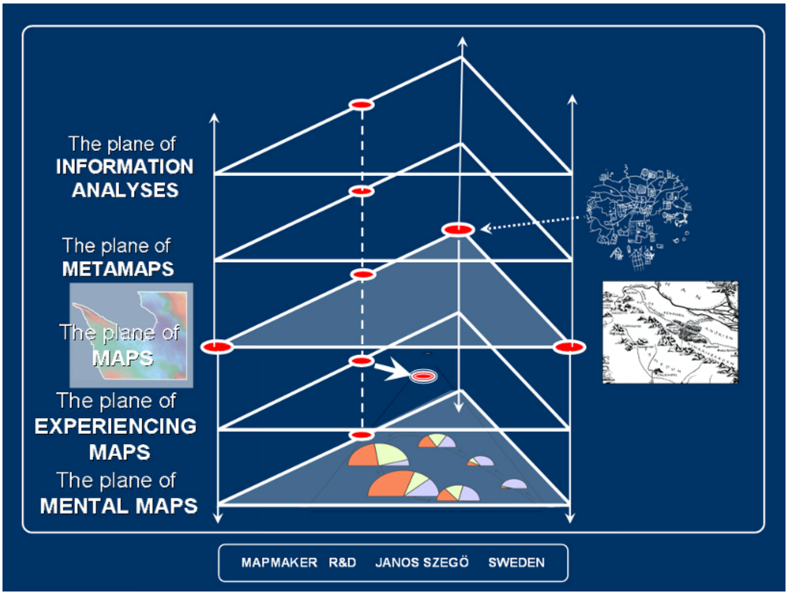

Figure 9: Classification of maps by contents leads in two different directions: the analytical (upwards) and the synthetic ones.

This is of course a very crude example of a possible development, just to illustrate a possible visualisation of the process. Different personalities have certainly different trajectories through the triangle-surface and different composition of their mental maps.

The plane of MENTAL MAPS in figure 9 shows figure 8 as a part of the whole scheme in 3D.

5- Applications and further developments

How can the above presented concept be applied?

In its present form it is first of all a system for orientation. Different cartographic products can be allocated within the system and its/theirs relation to other cartographic product categories can be established (see e.g. the red dots in the different planes along the vertical line in Figure 9).

This is more an application of the *principle*. To a more *operative* application of the system several steps of development work must be taken.

In first place the "CLASSIFICATION" level most be calibrated. When it comes to cartographic products along the "Seen - Known"-axis the task is comparatively simple and mostly the question of "fine tuning". Even here is, however, necessary to deal with questions of great importance and complexity. What do we mean by "seen"? Is it exclusively a physical person´s observation of physical objects in the field? Or does the term include knowledge acquired through studying photographic or other representations also? Studying maps, which were compiled by visual observations? How do we classify these *indirect* visual experiences?

A tentative, preliminary working hypothesis here is that the closer a map is located to the triangle diagram's corner "seen" the more the direct observation may apply. The closer the "abstraction" ("Known") corner a cartographic product is located, the more the "indirect" way of seeing is present. In the middle of scale topographic and geographic maps can have an important role. Even in the corner point of "pure abstraction" we may find visual elements: the above mentioned constructor of a new grid net visualizes the geometry of his results not only in his mind but also diagrammatically.

The calibration of the scales in the diagram of "CLASSIFICATION" request perhaps the hardest but also the most interesting part of the work within this model. In this process we must penetrate our ideas thoroughly what we think maps are about, what they contain and what happens when the mapmakers create them. This reasoning may turn out to be the most important result of this study – if it happens.

The questions above address of course some of the most central parts in cartographic theory. But the complexity of those questions is so huge and our way of working with them includes so complex processes that we probably can not treat them with scientific exactness from the beginning. Perhaps it is necessary to use a partly intuitive ("hazy") approach and hope that we later on can analyse them with higher degree of precision.

To go further to the plans of METAMAPPING and of cartographic INFORMATION ANALYSES are far easier but demands a lot of heavy systematic work. A precondition is, however, that the questions of different types of cartographic products occurring at identical coordinates in the "CLASSIFICATION" plane are solved.

Further "exploratory" efforts are necessary when dealing with the planes "CREATING and EXPERIENCING MAPS" and "MENTAL MAPS". A possible way is to ask cartographer to recall, contemplate and afterwards describe the process when they created or studied cartographic artefacts. These efforts may be rewarding not only for winning insight to the nature of maps and mapping. The author of these lines wrote in several occasions introductory notes to atlases, books and even a doctoral thesis describing that kind of personal experiences, those "inner sights". The reactions to these notes were not only the most frequent but also the strongest, warmest and most inspiring in whole his professional life. This is not only a question of personal inspiration and satisfaction. It is also an indication that here is a something deeply rooted in the minds of not only professionals but also of surprisingly many people outside their ranks. It is worth deeper exploration. It would be regrettable, if the fact that they can not be treated by scientific exactness from the beginning would prevent us to follow this difficult but probably rewarding track.

This paper is a tentative study. It is developed as a would-be part of the (hopefully) coming revised and partly rewritten version of the author´s "Human Cartography" from 1987. The re-writing of the book is in progress. The ideas, sketched here will – once more hopefully – be further developed and integrated in the book. The time is, however, most limited. If the ideas and ways of thinking presented here have real fruit-bearing capacity, a younger generation may develop it further. If not they will fade away.

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1G Tolkien J F R Sagan om ringen. Norstedts Förlag 2001. Finland By courtesy of Norstedt Förlagsgrupp AB, Stockholm, Sweden, 2011-01-31

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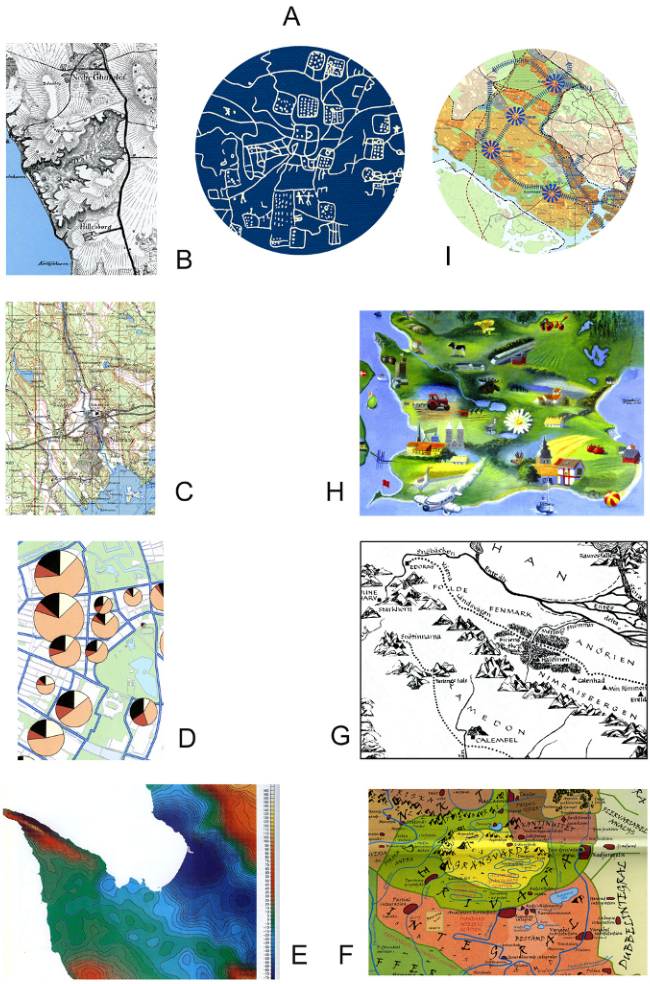
APPENDIX. INSERTED ILLUSTRATIONS

(somewhat enlarged)



Aesthetic Aspects of Early Maps

Inspiration from Notes by Univ. Prof. Karel Kuchař

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Abstract

The contribution is a tribute to Czech Univ. Prof. Karel Kuchař and reminds us of the 35th anniversary, counted from his last public lecture named Aesthetics of Map Production. Unfortunately, Prof. Kuchař was not able to elaborate the issue of aesthetic aspects of cartographic production in further detail. The aim of this contribution is to categorize and summarize this knowledge. The first part mentions the traditional, and we can also say never-ending, discussion on cartography and early maps being a form of art. It is followed by a summary of aesthetic aspects of (not only) early maps (map format, sheet composition, use of space, shapes of map fields and structure of outlines, form of compositional elements, map contents, cartographic language, thematic cartography methods, use of colour and font in maps, author's style and handwriting). Finally, several pieces of evidence are offered confirming that "early maps" and "computer map production" are not incompatible.

1- Introduction

In autumn 2009 (12 November) it was 35 years since the last public lecture was given by prof. Karel Kuchař (1906–1975), who worked for almost 50 years at the Faculty of Science of the Charles University in Prague (Figure 1). The lecture was given to an expert group of the Czechoslovak Geographical Society and dealt with a relatively rare aspect of cartographic

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production, i.e. the aesthetics of map creation. Prof. Kuchař was very interested in the issue, especially in the last years of his career. His colleagues note that his sense of aesthetics was exceptional (this is confirmed by cartographic work created or edited by him) and he considered it rather an important part of cartography, he gradually made it an independent cartographic discipline (Král 1975, Medková 1976). He was inspired by prof. Eduard Imhof from Switzerland, whom he knew. Today, after 35 years, his interest will probably seem even more topical, especially when we consider what kind of "cartographic works" and "maps" are created by GIS users and a number of lay people, who use the unprecedented opportunities offered to them by digital cartography.

Figure 1: Univ. Prof. Karel Kuchař, 1970s

Even though the author of this paper was not aware of K. Kuchař's interests at that time, it was probably his liking of humanities that brought him in 2001 to write his graduate thesis about „The Aesthetics of Cartographic Production". Doc. R. Čapek was asked for help and in his archive he found handwritten notes taken by him during the above mentioned lecture. K. Kuchař was his teacher. This paper is based on these notes (approx. 10 handwritten pages) and focuses on *early maps*, which were K. Kuchař's lifelong affection (e.g. Fabricius's map of Moravia from 1569, Maps of Czech Lands till the mid-18th century, his publication Our maps from old times till today (Naše mapy odedávna do dneška) or the Early Maps of Bohemia, Moravia and Silesia, written in English).

The approach mentioned is based on the assumption that early maps have higher potential to fulfil an aesthetic function due to the character of their creation. The method of *analysis of individual components and composi-*

tional elements of (early) maps seem to be suitable (Bláha 2003); see below for illustrative examples. The aesthetic values in cartographic works have undergone relatively big changes throughout centuries. The changes are related to the development of reproduction techniques and new procedures, as well as a significant shift away from classical art because of cultural and sociological changes and, thus, the classification of cartographic products into the so called non-artistic aesthetic. The paper also touches upon the context of computer-aided map creation – a topic that K. Kuchař hardly could have met at his time – and expands his thoughts on the aesthetics of map production.

2- Of cartography and early maps as a form of art

K. Kuchař dedicated an extensive part of his lecture to the issue of *cartography as a form of art*. There is no doubt that he took inspiration for this part from E. Imhof's talk in Amsterdam in 1967 and his paper *Die Kunst in der Kartographie* published in the International Yearbook of Cartography the same year (Imhof 1967). K. Kuchař notes that the term "art" has various meanings: skill, knowledge ("artisan"), or cartography as an artistic activity and its products as works of art ("artist"). The artistic side of maps was refle cted in the past; otherwise, maps would not contain decorative elements, famous artists would not be asked to create them and maps would not be subject to collectors' passion (Kuchař 1974, see also Semotanová 2001).

This is even mentioned in one part of Imhof's paper. E. Imhof asks at the beginning whether cartography has anything in common with art. He believes that the development of woodcut, desktop printers, etc. led to the evolution of graphical arts, while *at that time there was no expert specialisation*, and an artist and a creator of maps was the very same person (similar opinions can be found in R. Rees, 1980: "When science considered cartography, map creation and landscaping related activities they often were performed by the same person") – maps created by Leonardo da Vinci, Albrecht Dürer or Jose Murero can serve as examples. The artistic character of early maps is supported by figurative representation on the map edges, decorative frames, decoration of all compositional elements in the map (see below). Well-known atlases from the 16th to 18th century (Mercator, Ortellius, Blaeu, Sanson, Hondius) offer examples of this artistic decoration. Early maps were intended to decorate walls (Imhof 1967).

R. Rees speaks of so called *mastery in maps*, he says that maps lost their aesthetic function when they became utility objects (Rees 1980). The ever expanding geographical knowledge of map creators also gave rise to the loss of the primary, or aesthetic, function of maps; , "empty space" ceased to exist in them, i.e. the creators did not have such a *free hand* any more (ibid.). However, the activity of an artist assumes freedom of creation, which is limited by this process (Kuchař 1974). In this context we must not forget the evolution of cartographic language and the means of expression of the map. While in the Middle Ages it was difficult to differentiate these means from *landscaping* (S. Alpers in Woodward 1987, deals with what inspiration cartography took from landscaping in more detail), which is certainly related to the above mentioned intermingling of the person of the cartographer and the artist, creativity in map creation becomes gradually more and more limited and information potential is enhanced. Pictures were gradually substituted by conventional characters (Rees 1980), see below for the already mentioned shift from realism.

Approximately since 1600 superficial mapping was gradually substituted by better topographic mapping, thus creating *ever more accurate maps* with dense content, objects are represented via ground plotting, which led the to the overall "chaos" in the graphical design. Some maps were unintelligible due to the labyrinth of lines, figural characters, colours and descriptions. However, chaotic graphical design is not a graphical art and the lower the user-friendliness the lower the artistic level of the map (Imhof 1967). The use of some methods of expression, like Lehmann's hachure, to represent altimetry even potentiated the problems of intelligibility and legibility. It was one of the reasons for this method to be later substituted by contour lines (Bláha 2003).

The *development of reproduction techniques and techniques in general* also contributed to the increase in accuracy of the maps – for example, copper engraving led to much higher fineness of the image. On the other hand, lithography and multicolour printing were used to multiply the number of maps created, not to improve their graphical representation (ibid.). Unfortunately, it can be noted that a similar trend was kept when changing from analog to digital map creation, which is, logically, not mentioned by E. Imhof.

In terms of art, today's maps can be considered symbolic *abstraction*; there has been a shift from *realism* (with its typical image representation of objects and phenomena, hill method as a view of mountains and hills, etc.), it is enough to retain an illusion to maintain the effect (Rees 1980). Nevertheless, early maps (especially medieval ones) clearly contain *symbolism* (for example, maps do not show what the town is like, but rather what it is like to live in it). However, maps are inspired by art even nowadays – shading serves as an example (ibid.).

This is how K. Kuchař (1974) finishes his paper: "The art in cartography is the art of balance, keeping to the right limits (…), the art of balance of the content and graphics, as well as the art of simple and clear expression, in the case of some representation of some objects and phenomena, it is also the art of transferring natural aspects into simplified groups of images."

Since K. Kuchař delivered his lecture a number of experts have dealt with the issue of cartography as a form of art vs. science (e.g. R. Rees, J. S. Keates, J. B. Krygier, D. Endelman, E. Spiess, W. Cartwright, and others). Especially J. B. Krygier (1995) offered an interesting polemic when he contemplated an e-mail discussion on this topic. The discussion led to the following conclusions:

1. cartography is considered either (only) art or (only) science,
2. cartography is considered a mixture of art and science,
3. art and science are considered an insufficient basis to understand cartography.

Krygier is inclined to the third possibility; he criticises the desire of theoreticians to use various dualisms to explain any topic. He provides evidence that the functions of art and science are more similar than different, art and science provide various means to reach the same goals. Hence, he adds, the insistence on the assumed dualism art/science poses many problems when trying to understand cartography. This can be substantiated by the fact that sometimes it is very difficult to place products resulting from human activity on the artistic work – scientific work scale (see discussions of the controversial work called Entropa which was presented by the Czech Presidency of the EU in 2009). The author proposes an alternative: disregard the dualism and deal with concrete possibilities and cases of the closeness of art and science, i.e. re-evaluate the role of aesthetics, design and visual expression in cartography (Krygier 1995).

W. Cartwright (the current ICA president) was in 2008 at the birth of the ICA Art and Cartography working group and participated in the preparations for the expert symposium dedicated to the interconnection of art and cartography in Vienna in February 2008, where artist and cartographers met. This can serve as an example that the issue of the relationship between art and cartography is still alive.

3- What can be beautiful in a (early) map?

K. Kuchař asks this question during his lecture. Because *beauty* is one of aesthetic categories this question is logically appropriate, also in terms of aesthetic assessment. K. Kuchař (1974) chooses a relatively easy way to distinguish between the content and the form (even though a number of theories of art today consider this dualism of content and form as outdated, in cartography it is very illustrative), he focuses especially on form and rendition because the map's content is already given to a certain extent.

3.1 Map format, sheet composition, use of space

Kuchař considers the *map format* (or sheet or map field format) rather essential. Even though it is often given by the area represented, rules used (not only in fine) art can be used to determine it. He deals primarily with the famous golden section (sectio aurea), when the sides of a rectangular format (map) have the ratio of approximately 1.618 03. This phenomenon is discussed in more detail by a number of authors, recently for example by M. Livio (2006).

The *sheet composition* poses another important aspect, where it is important how the surface is filled and whether it is harmonically divided, as well as its overall use (Kuchař 1974). All the compositional elements come into play (frame or bordering of the map field, title, scale, north indicator, key and other space around the map field). Either axis (vertical or horizontal) or central symmetry is used, asymmetric (corner) position of the title can have an especially interesting effect but it is rather difficult to compose the sheet in an asymmetric manner (ibid.). In connection with composition so called optical centre and orientation of the map (horizontal × vertical) on sheet is often mentioned (Bláha 2003).

However, early maps are well-known to *use* empty *space*, either directly in the map field (so called unexplored areas where the lions live; hic sunt leones) or outside it. So called fear of emptiness (horror vacui) is also often mentioned, when map creators strived for a more even filling of the space of the map, which was extremely difficult particularly at the time of little geographical knowledge. The space was filled with decorative compositional elements (see below) or figurative representation, in particular *allegories* of geographic or economic reality (e.g. Müller's maps), historical scenes (in the form of so called parergas), using *personification* of natural phenomena (e.g. Ptolemy's world map, Vogt's map of Bohemia), heraldic coats of arms were popular (e.g. Helwig's map of Silesia), illustrations of flowers, etc. (Figure 2–4) Some maps offered artistic representation of town and landscapes panoramas, so called vedute (e.g. Comenius's map of Moravia); for example, L. Fialová (1970) deals with vedute in more detail. Later, paregas and vedute were omitted and the sheet was filled with a map image or various statistics, later photographs.

Figure 2: J. C. Müller, Map of Bohemia (1720). Author of parergon: V. V. Reiner

Figure 3: A. Ortelius, Zelandicarum Insularum Exactissima et Nova Descriptio [1573]. Antwerp

Figure 4: Ptolemy's world map (in: Liber chronicarum, 1493)

S. Y. Edgerton (1987) notices Ptolemy's legacy in Renaissance cartography: he is exceptionally thorough when working with space and composition (e.g. his world map, mappae mundi). In addition, we can observe work with various *shapes of map fields*, *structure of map networks* (coordinates, street network, etc.). Edgerton also notices specific *map shapes* – e.g. early Christian T-O maps or circle altar maps, like e.g. The Ebstorf map, etc. (Edgerton in Woodward 1987) – Figure 5.

Figure 5: Beat's oval world map [1030].

The fact that the format and shape of the map, sheet composition and use of surface (space) place among essential aspects of aesthetic assessment is certainly related to the fact that the sense of graphical design is reflected in them much more than cartographical knowledge and skills. It is early maps that thanks to their origin (often created by a versatile creator) serve as an example of excellent command of the format, composition and filling of surface (compared to today's maps either overfilled or with too much empty space).

3.2 Realization of compositional elements

Realization of components and compositional elements *as such* in (early) maps can be subject to aesthetic assessment. The study of aesthetic aspects in the above mentioned thesis The Aesthetics of Cartographic Production can build on this principle; the thesis offers many examples (Bláha 2003).

E. Imhof (1967) focuses on the fact that it is the decoration and figurative representation (of all elements) that add to the artistic nature of early maps (Figure 6).

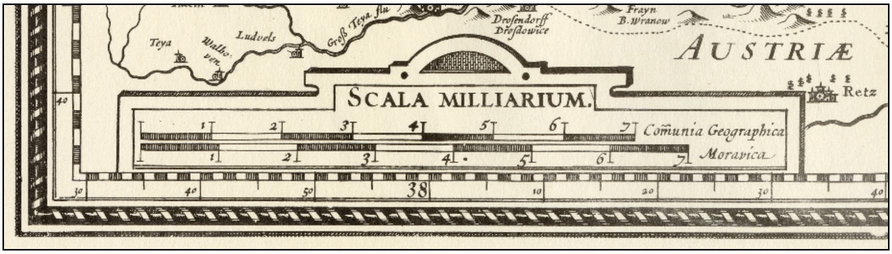

Figure 6: Example of decorative compositional elements in Comenius' Map of Moravia (1627)

Firstly, it is the *frame* (bordering) of the map field that determines the final visage of the map. As K. Kuchař (1974) says in early maps it was not supposed to give material impression, the maps of the Czech lands were carved (wood or metal) with flex cracking.

The *title* and the *legend* are other compositional elements that can be subject to heavy decoration (Figure 7). In many cases the titles have the form of vignettes (the header as an ornamental motif) and they contain various cartouches (ornamental framing). We can see titles in the form of architectonic details of buildings, open books, curtains or canvas, animal skins, etc. The cartouches are also used for map legends.

Figure 7: [T. C. Lotter & G. de L'Isle], Europa [1770]

The scale of early maps (graphical in the majority of cases, the numerical version arrives later) was also decorated and is usually made of various beams with the use of dividers and other measuring devices (Figure 6), even though there are exceptions (e.g. Fabricius's map of Moravia). Decorative north indicators/wind roses must not be forgotten (Figure 8).

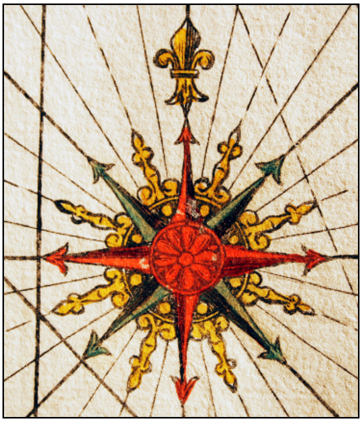

Figure 8: P. Mortier, Costes Meridionales d'Angleterre (1693). Paris

J. A. Welu (in Woodward 1987) deals with decorativeness and cartographic decorations in detail. He focuses especially on the Netherlands, i.e.

Dutch and Flemish cartographers and their atlas works. He gives numerous examples of cartouches and vignettes, decorated frames and parergas. With time they became simplified and their decorativeness got lost.

3.3 Map contents and cartographic language

Contents of early maps is often characterised by inconsistent selection of the elements represented, i.e. from today's point of view there is poor-quality generalization of the contents. Hierarchization is not consistent either (Bláha 2003). Apart from less transparency and legibility this also leads to the already mentioned graphical chaos. Using these criteria early maps are usually not evaluated in a positive way. We can assume that illustrations in the map field did not always serve only to simply fill the empty spaces, as is mentioned above, but they also had an informative function (similarly to today's maps for children and youth), as well as contributed to the overall style of the map (see below). The map field image was therefore more harmonious.

B. Veverka et al. (Veverka et al 2009) has recently dealt with the *cartographic language* of early maps (semiotic analysis) and its evolution. The interest is placed especially on the means of expression used, their rendition (colour, thickness of line elements) and meaning (Figure 9). These studies and others show that gradually there was conventionalization and schematization of the cartographic language. This led to early maps gradually losing their illustrative and artistic character. The representation of georelief strongly influences the aesthetic impression of the map: hill method, silting, hachure, contour lines (Imhof 2007, or Pravda 2005, deal with this issue in more detail). These changes led to significant changes in the appearance of the map image, which is usually related to aesthetic assessment with different results. K. Kuchař (1974) even mentions the efficiency of the isoline method, from which we can assume that he was considering different aesthetic impact even in relation to different *methods of thematic cartography*.

The *aesthetic aspects of the use of colours* in early maps could constitute a separate chapter. In his lecture K. Kuchař (ibid.) speaks primarily of the optical weight of a colour (khaki × yellow), for example in relation with the filling of the map's edges (increase in the strength of the framing). Decorative aspects of colours do not necessarily have to be related to the aesthetic function, decoration as such can carry information (similarly as the above mentioned map contents). Therefore, decoration can support the utility function of the cartographic work (early map). If we speak about the aesthetic aspects of colours in early maps it is important to note the influence by the evolution of (reproduction) technologies and map creation techniques. U. Ehrensvärd (in Woodward 1987) deals with this topic in detail and starts a strong tradition of manually drawn (original) maps, in which the author's handwriting plays an important role (see below). He considers printed maps (woodcut) which are merely colorized a step back. It is clear from artistic point of view this presents a real loss. This "monochromatic age" is relatively long, until the era of coloured printed maps. But even at this time several direct colours are used for printing, or possibly a limited number of colour networks (a sampler of printing rasters used for printing maps). Only the most recent period of digital production and printing equipment enabled us to come back to maps rich in colours (Bláha 2006).

Figure 9: A. Ortelius, Hiberniae Britannicae Insulae Nova Descriptio [1574]. Antwerp

Similarly to colour, the *description, or rather the font used* plays an important role during aesthetic assessment. K. Kuchař (1974) deals especially with the evolution of font in maps and the position of the description in relation to the corresponding network and objects. He believes that wrong choice of font not only influences the overall aesthetic effect of the map (influence on the harmony of graphical expression) but also the legibility and, thus, user-friendliness of the map. D. Woodward (1987) also focuses on the evolution of font in maps and its impact on their aesthetic value. He says that the western civilisation experienced two basic transitions in using font in maps. Approximately from 1500 there is a clear dominance of manually written description in maps, then the development of reproduction techniques leads to gradual take-over of manually carved description (woodcut, copper engraving, lithography, etc.), and after 1800 there is more frequent use of typographic font, which is crucial nowadays. It is obvious that these changes had impact on the overall graphical aspect of the map and the aesthetic value of early maps. D. Woodward provides a number of examples that prove similar evolution as in the case of colours: first decline in originality due to the shift away from handwritten maps and lately richness thanks to a significant increase of types of font.

Evolution of map language, colour and description in early maps does not necessarily have to be followed throughout a long period of time – one cartographic work suffices. This is proven by the evolution of the prints of Criginger's map of Bohemia (1570–1585) – Figure 10. This, of course, has impact on changes in the aesthetic effect of such a map (Bláha 2003).

***Figure 10*:** Evolution of copies of Criginger’s map of Bohemia.
(a) Criginger’s map of Bohemia (1569), (b) Ortelius’s copy (1570), (c) Jode’s copy (1584)

3.4 Style and handwriting in early maps

The *changing style* of early maps is also one of their aesthetic aspects. It is reflected virtually in all the already mentioned elements. As E. Imhof (1967) says by the mid-16th century it was simple, clear and strict view through woodcut in Renaissance, from the end of the 16th and the 17th centuries it were smooth, refined and often grotesque moving baroque pictures, then there is a transition from rococo, through classicism till the era of graphical dissolution into new styles in the 19th century; A. Bačo (2009) deals with these new styles. R. Rees (1980) also mentions the similarity of artistic and cartographic styles. Specific style can be seen, apart from parergas, in cartouche and decorative frames (e.g. baroque and rococo with the motives of mystical women, muscular and heroic men with wild horses, contrasting with romanticism and its shepherds, milkmaids, trees and corn sheaves). The style of some types of early maps is striking at first sight, whether it is zone maps, T-O maps or portolan maps with their typical unmistakable beams of rays (Figure 11).

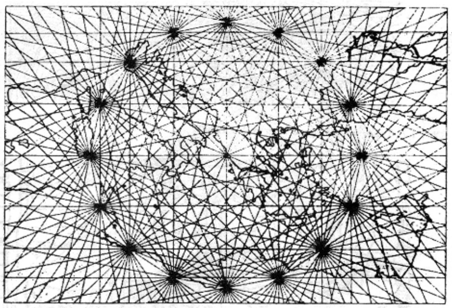

Figure 11: Example of portolan network

Apart from style early maps also show much stronger expression of the *author's handwriting* compared to the current ones. This is due to both their relation to individual expressions of art (see above) and the reproduction method, when the majority of maps was created as a handwritten original (comp. to typographic font, printing techniques, etc.), as well as due to much lower stability of cartographic language without conventional forms and fixed map elements. K. Kuchař (1958) also deals with the handwriting of individual authors of early maps of the Czech lands in detail. In the case of J. M. Vischer he speaks of frequent use of panoramas of real towns and castles which are then placed on a map in the form of picture characters. J. K. Müller's handwriting is considered completely unmistakable, among others because of extensive use of the silting method when representing terrain (replacing the hill method used by then). On the other hand, he criticises M. Helwig, reproaching him for inadequate filling of the space of the map field (for more see Bláha 2003). Thus, the author's handwriting is another aesthetic aspect of early maps.

3.5 Era of computer map creation

Geoinformation systems and the current cartographic production relatively sharply differentiate from the above mentioned (especially in terms of handwriting and artistic character of the work). However, a number of the above mentioned elements of aesthetic assessment can be preserved (form of the product, including its composition, use of space, use of colour and font, map stylistics).

It could seem that early maps and computer map creation are completely incompatible, but it is not the case. Of course, only a fool would try today to create a topographical map using the hill method with decorative parergas around the map field. Nevertheless, the creation of popular maps and diagrams for the public (see plans of ZOOs, castles and old city centres, etc.) and maps of fiction worlds pose an area open for creativity. Even though the influence of cartographers in this sphere is relatively marginal, analyses were made considering the possibility of using computer tools to create such maps, making use of artistic techniques when creating maps for the public (Bačo 2009) and when creating maps of fiction worlds, where there even was comparison with early maps (Hrubý 2008). In the end we can add that also art makes use of computer technology. We can provide an example: products designated for the current graphic designers and illustrators that imitate not only artistic techniques (e.g. Adobe Photoshop) but also make use of tools like brush, pen or sponge (e.g. Corel Painter) including their properties – mixing colours on a palette, diluted ink… When looking at the screen even experts cannot see difference from the "original", what limit the final rendition are printing colours, techniques and materials.

4- Conclusion

This paper originated for several reasons and, therefore, it has several objectives. Firstly, it aims to summarize what can be considered an aesthetic aspect in early maps and what cannot. Even though the list of these aesthetic aspects may not be complete, the paper at least offers a method for their categorisation, giving many examples. Due to space reasons the author decided not to attach more pictures.

Moreover, the paper is supposed to be the culmination of an effort to perform a certain synthesis, or at least provide reference to a number of manuscripts that fall under so called grey literature and that are not always easily accessible. These are primarily notes from a lecture by K. Kuchař from 1974, the author's thesis from 2003, as well as other works yet unpublished in English.

Last but not least, the paper should serve as the author's expression of gratitude to prof. Karel Kuchař's work. Even though the author did not have the possibility to meet Kuchař in person he considers him one of the most prominent cartographers in the former Czechoslovakia. K. Kuchař did not live to see the current times but all cartographic works, i.e. even the current ones, show a certain potential to express aesthetic values. Today's creators of maps should aim to provoke this potential.

Currently, the link between art and cartography is of a much ampler and more complex nature. We deal with, for example, map art, where it is artists themselves who create maps (see e.g. Wood and Krygier 2006), or with merger of literary art and cartography: mapping literature (Piatti et al. 2009). A number of other projects perceive art and cartography as a compact whole. Other projects stimulate creativity of authors, for example the project *Creative maps* at the Charles University in Prague (Bláha et al. 2009). However, this paper intentionally focuses primarily on the concept of artistic means of expression as captured by Univ. Prof. Karel Kuchař and as was usual at the times when the *Aesthetics of Map Production* lecture was delivered.

"Premature and unexpected passing away did not let him (*K. Kuchař*) summarize the knowledge and experience in the aesthetics of cartographic production as he planned, which would surely present a culmination of his activity in the field of cartographic production" (Medková 1976). It makes it even more gratifying to carry on his legacy.

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Representations, Diagrams and Visualizations of Space and Place

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Abstract

Users have a wide choice of artefacts for use in gaining a greater understanding of geography. They are generously provisioned with maps, diagrams, imagery and visualizations that can be output on paper, viewed on screen or manipulated as an interactive product. Generally, in the past these products were generated by a designer/producer prior to actual use. However, relatively recently, 'self-generating' maps have become possible via Web 2.0. These have little or no cartographer input and they are generated from data captured and provided by sensors, cellular telephone data and satellite imagery. They provide immediate geographical visualisations to 'wired' map consumers.

Whilst these maps with self-generated content provide visualisations of massive amounts of data about space almost in real-time, do they provide any information about place whatsoever? Are they just a 'picture' of what is there (in a space), rather than a medium that can facilitate real information provision about place? It is argued that maps and diagrams generally provide a considered representation of place, whilst self-generating visualisations are merely a visual record about 'what is there'.

To providers of geographical information in the form of maps and map-related artefacts, the designer's goal is to produce a representation that informs about a place. However, if maps and diagrams are used to provision users with information about REAL places alongside maps with self-generated content/visualisations about a space, how can users of cartographic products be sure whether space is not confused or substituted for place?

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This paper addresses the use of the growing number of maps with self-generated content and visualizations that are now readily available via Web 2.0. It considers whether this form of cartographic artefact provides a tool for discovering the real nature of place, rather than just a 'pretty picture' of part of the Earth. The paper begins by discussing what is meant by place and space and then provides examples that illustrate the differences between representing certain places with maps and diagrams and just visualising spaces through maps with self-generated content.

1- Introduction

We have traditionally used maps to provide information about space, depicting three, four and n-dimensional data. Rules for their production and use have evolved and producers and users have mastered these rules to develop and publish products and to exploit information resources. We have fashioned a design, development, fabrication and consumption process (and associated procedures) that have enabled essential artifacts to be made available and for them to be used effectively and efficiently. However, with access to global resources and use of transparent systems, whereby for example users can disassociate the source of information from the actual display of that information, the consideration that these artifacts may be required to provide information not just about 'SPACE' needs to be made.

2- Space and place

French Sociologist Michel de Certeau proposed the spatial practices of everyday life in a chapter of his book, *The Practice of Everyday Life* (1984). In the chapter, entitled 'Spatial Stories', de Certeau distinguished between space and place. de Certeau (*op cit.,* 1984, p. 117) saw PLACE as "the order (of whatever kind) in accord with which the elements are distributed in relationships of coexistence". Here elements are defined by their relative positions to each other, making a place "an instantaneous configuration of positions" (*ibid.*), implying "an indication of stability" (*ibid.*). Therefore every PLACE so defined, has a unique geographical characteristic.

SPACE is seen as the opposite of place. de Certeau describes it as existing "when one takes into consideration vectors of direction, velocities and time variables. Thus space is composed of intersections of mobile elements. It is in a sense actuated by the ensemble deployed within it. Space occurs as the effect produced by the operations that orient it, situate it, temporalize (sic.) it, and make it function in a polyvalent unity of conflictual (sic.) programs or contractual proximities" (*ibid.*).

PLACE is stable and not effected by changes or the dynamics of everyday life and SPACE is dynamic and a continually-changing conglomerate entity that exists at any point in time in a form that is defined by environmental, cultural and social 'formula', whereby the coefficients that are used to describe particular spaces (and in fact the formula itself) are in a constant state of flux. de Certeau describes SPACE as "practiced place" (*ibid,* p.117), whereby a place does not come to life unless a user practices it.

3- Mental maps, space and place

Humans develop mental maps of environments, real or imaginary. The use of mental maps for wayfaring and appreciating geography is described by psychology as 'cognitive mapping. de Certeau (1984) indicated that two types of description could be made about how humans use cognitive mapping to visualise how they move in space: observational and operational.

Observational is how we record 'what we see'. We record this observed information for immediate query (*Am I on the right road?)* or for later comparison (*Was the house I saw designed by the same architect as the one viewed last week?*). Operational is represented by 'the map' ("a plane projection totalizing (sic.) operations"), 'the tour' or 'the itinerary' ("a discursive series of operations") (*ibid,* p.119). The map provides a graphic description of a selection of reality that shows a selection (usually made by the cartographer) from reality has been classified, generalised and scaled to show the relative positions of objects to one-another placed in an absolute pictorial 'world' defined by latitudes and longitudes that relate to a map projection (based on a certain mathematical description of the earth) that depicts a compromised view of reality. The tour or itinerary provides a sequence of navigational cues that are aimed at taking the user of the artifact to certain locations – everything outside the defined 'corridor', down which the user is allowed to travel (physically or virtually) is ignored, the 'journey' is paramount. Using the defined geographical 'picture' that is used in the corridor provided by the tour or itinerary only a small view of what reality really is provided and therefore a true appreciation of what constitutes the 'real world', and where the user 'fits' into that world, cannot be had.

4- Models of the world

A number of fundamental spatial concepts have been proposed, to define space and place, including:

- Space and Process - Blaut 1961
- Theoretical Geography - Bunge 1962
- Identification of some Fundamental Spatial Concepts - Nystuen 1963
- Geography, Geometry and Explanation - Sack 1973
- Perceptual space - Downs and Stea, 1977
- Transperceptual space

    a. Small-scale perceptual space (used in maps to represent large-scale space)
    b. Large-scale perceptual space - defined as large-scale space in Kuiper's model of spatial knowledge acquisition (Kuiper, 1978)

- Experiential and Formal models - Mark and Frank 1996a
- Written/Verbal - Mark and Frank 1996b

Developing maps requires working with an accepted model of the world. For example, maps provide graphic descriptions of data to enable map users to visualise geographic data. As the data refers to positions on the curved surface of the Earth (latitude and longitude), the map (plane surface) needs to have certain characteristics, such as equivalence of areas, retention of shape and equidistance. For instance, when calculating areas on a map it is essential that complementary points on a map and the Globe contain the same area. For topographic mapping it is essential that the correct shape of mapped features be retained. Also, for navigation purposes, as the sailing line of a ship on the earth's surface remains constant, it should be projected as a straight line on a map. Here map projections are used to transform 3D information into 2D representations that can be printed or viewed on a computer screen. But, what is more pertinent is what 'view' or model we have of the earth before actually attempting to depict it at all?

5- Maps, diagrams and drawings– representing place

5.1 Maps

Maps can be seen as ‘windows’ for viewing the world. They are generally seen as precise scientific documents that have provided the resources and, later, a record of exploration and discovery, accurate tools of warfare, records of new lands and settlements, depictions of communications and national development and artefacts for tourists and conveyances for armchair travellers. They are useful, accurate and powerful information provision tools. Here, one could talk about any map. However, to be able to better make comparisons with other artefacts, covered later in the paper, an example of a map of the City of London is provided (Figure 1). We now take for granted the information provided through a paper map. We use it as a disposable information commodity. But it works. The representation, here of part of London, provides the user with information that has been selected as being typical of this part of the Earth. We consume this knowledge with the surety that the cartographer has strived to produce an image that is built on accuracy and delivered with clarity. We can read the map, explore each street and lane and gain an understanding of this place in England.

Figure 1: Page from Harrison's Description of England (1877), reprinted from the original of 1593).
Source: University of Victoria Library.
http://internetshakespeare.uvic.ca/Library/SLT/reference/londonmap1.html

5.2 Diagrams

Historically, maps at much larger scales also used illustrations and diagrams, not to fill the void, but to embellish the geographical information shown on what were essentially planimetric maps that depicted things like land ownership or the extent of a map sponsor's estate. However, in some instances, diagrams, which illustrated the essential characteristics of a system, here, public transportation, could impart geographical information more efficiently.

One example of the diagram for representing geography is one of the most widely used maps by inhabitants and visitors to London – The London Underground map (Hadlaw, 2003). By distorting geography the designer, Beck, made the map more usable and an effective communicator about how to move about London. What was underground was important – the lines, stations and interchanges. His concept was to ignore what was above ground (it didn't matter when you were in the 'Tube' and travelling from, say, Piccadilly to Cockfosters on the Piccadilly line) – it was the connections that mattered (Garland, 1994). Beck's training as an electrical draughtsman is obvious when one looks at his conceptual drawing for the map (Figure 2). It is all about lines and connections.

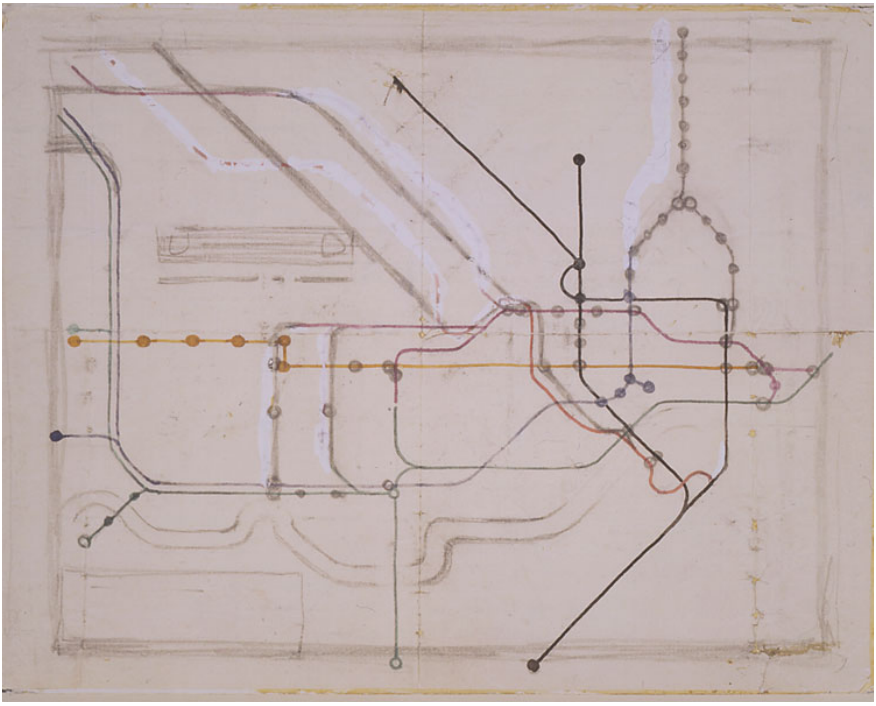

Figure 2: Sketch for London Underground map Henry C. (Harry) Beck (1903-74), 1931. Pencil and coloured ink.
Source: Garland, 1994, p. 16.

Beck's original design moved away from the concept that the maps had to follow the actual geographical route of the lines. By replacing the strict geographically imposed demands that required that representations be placed exactly where they were located with a regular pattern of generally horizontal, vertical or diagonal lines his new 'diagram' showed more clearly the relative locations of the different lines and the sequence of stations. Beck's first published map is shown in Figure 3.

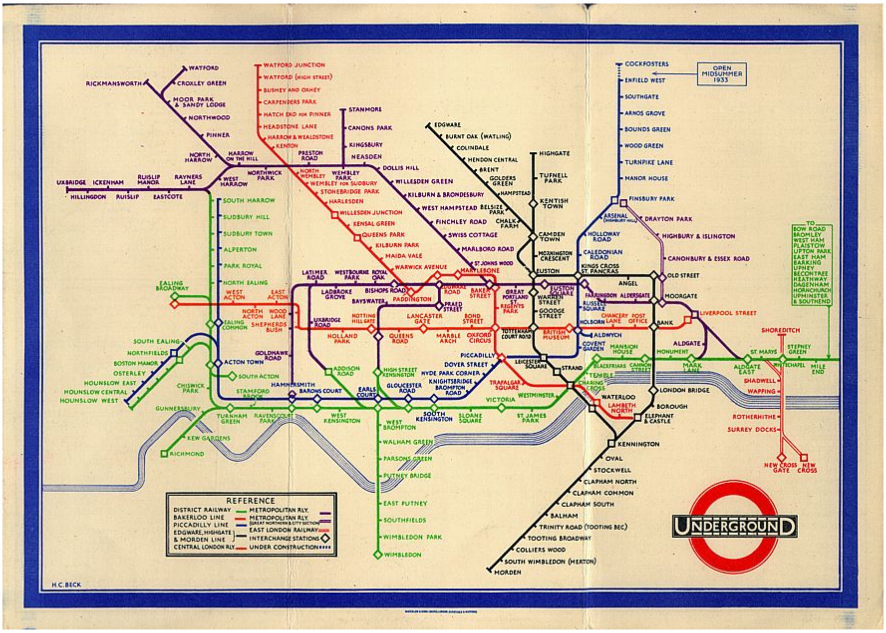

Figure 3: Beck's map – first edition, 1933.
Source:http://www.ltmuseum.co.uk/omnibus/pg/1919b.htm#

This example illustrates how reality (here, the reality of travelling underground) is sometimes better depicted if diagrams (non-realistic maps) are used in preference to geographically correct maps. For the first-time visitor to London, and perhaps also for some long-time London dwellers, their composite mental map of London underground - that place underground – becomes clear from the first viewing of this geographical artefact.

5.3 Drawings - representations of naive geographies

Can users 'fuse' together an image of an entire city, and how it works, from 'main-stream' maps and diagrams and, is that fused mapping image true and accurate? Do these 'simple', but effective, graphic communication devices provide just one window into reality? And, do naive users compose an image of the world when using this graphic window that is not a true image of reality? Or, is something else better?

In some instances a diagram, or cartoon-like drawing can be a better communicator of geography. This is especially true when individuals only have a naïve concept of their geography. Naive geography was defined by Egenhofer and Mark (1995) as "the body of knowledge that people have about the surrounding geographic world" – the primary theories of space, entities and processes (Mark and Egenhofer, 1996). The term describes a formal model of common-sense geography (Mark and Egenhofer, 1996). This would form the basis for developing intuitive and 'easy-to-use' Geographic Information Systems. It "… captures and reflects the way humans think and reason about geographic space and time. Naive stands for instinctive or spontaneous" (Egenhofer and Mark, 1995, p. 4).

If users cannot recognise where they are they endure stress, and search for geographical information to place things in (spatial) perspective (eg finding bearings, orientation to north etc.). According to Golledge (2000, p. 1) "We often assume there is no need to learn this type of geography because we already "know" it! And, we have not bothered to make this underlying geography explicit. Golledge thinks that naïve geography gives an implicit knowledge via environmental perception and that landmark or feature recognition and an awareness of the built environment is part of geographical understanding. He says that "People who claim they 'can't do' geography can provide accurate assessments of their local area. …"Users 'already know it" (Golledge, 2000, p. 1). For example, aspects of the geography of daily life that we "implicitly "know" but have not bothered to make the underlying geography explicit (*ibid*, p. 7). Naïve geography gives an implicit knowledge via environmental perception, using landmark or feature recognition (*op cit*.).

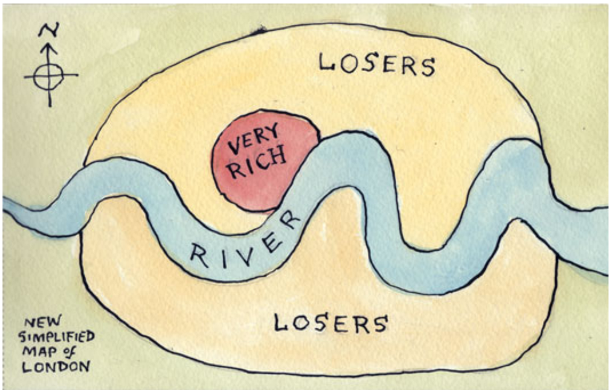

Figure 4: Sketch of a Londoner's mental map of wealth in London. New Simplified Map of London drawn from memory… (by Nad @ flickr).
Source: http://www.allmaps.com.au/unusual-maps/new-simplified-map-of-london/

Using another London example, a sketch of a mental map of a Londoner's perception of where the wealthy live (Figure 4). This simple diagram quickly imparts knowledge about a simple geography of wealth in London. The wealthy live in the west of London, on the north of the Thames. No other wealth exists in this simple naïve geography. This naïve image of where the wealthy live is immediately seen. The place where the wealthy are perceived to live is known and shown.

And even the 'maps' of board games can be used to 'see' wealth in London, albeit in a warped geography. The popular game Monopoly, by Parker Brothers, 'located' one version of the game in London (Figure 5). The game is built around the ownership properties, each having different values, in central London. Whilst the actual locations of places included on the board in London are real, the juxtaposition of each square on the board has been done to satisfy the demands of the game, rather than allowing a true picture of the capital to be shown. Properties are clustered together according to their value, and not their actual relative geographical location – Mayfair and Park Lane sit near to each other, separated by a 'super tax' square. Does this 'map' of parts of London show the naïve mental geography of places in the city?

Figure 5: London Monopoly board. Source: http://www.edinphoto.org.uk/talks/talk_eps_dig_2009_01_05_page_02.htm

Whilst the next example is not from London, it would be remiss to not include it in this paper. It is Saul Steinberg's cover on *The New Yorker* magazine of March 29, 1976 – "The World from 9th Avenue" (Figure 6). In 2005 this cover was awarded 4th place in the American Society of Magazine Editor's Top 40 Magazine Covers of the Last 40 Years. It shows Manhattan's 'telescoped' perception of the USA: beyond 9th Avenue there lies the Great Plains of America, and beyond that the Pacific, China, Japan and Russia – nothing else! The "supposed limited mental geography of Manhattanites" is clearly shown. The boundary of the place of Manhattan is delineated – it stops at 9th Avenue.

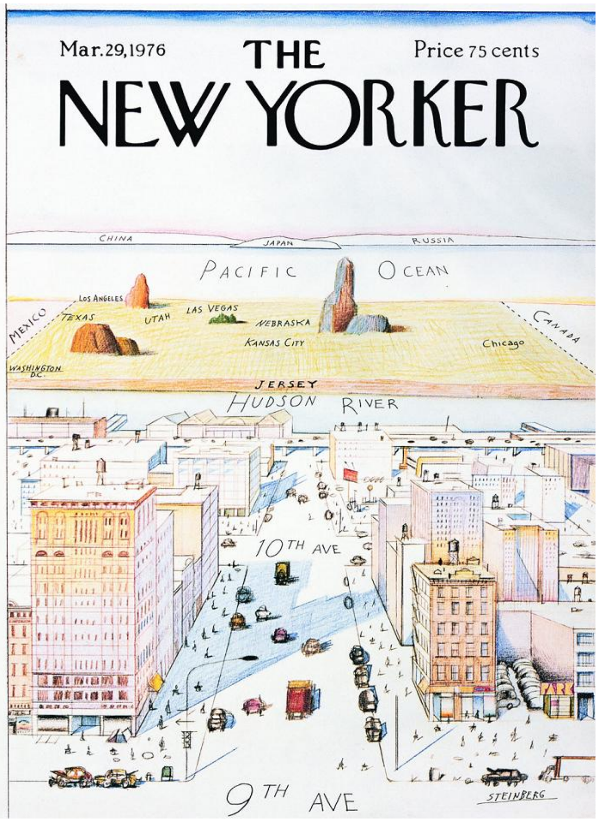

Figure 6: Saul Steinberg's cover on the New Yorker, March 29, 1976. Source: http://www.magazine.org/ASSETS/DB8AB50D9EAA4D1A977E2EC55E7C6378/4.jpg

6- Visualisations, maps with dynamic content and self-generated maps

6.1 Visualisations

Visualisations of the Earth allow instant access to what is happening in a space. We are well used to seeing montages of scenes of the Earth by night, where, by capturing images of city light, areas of intense populations can be seen. The image below is typical of this type of product, showing the Earth by night. Areas of intense populations can be clearly seen due to the intensity of the light being emitted from different continents and regions.

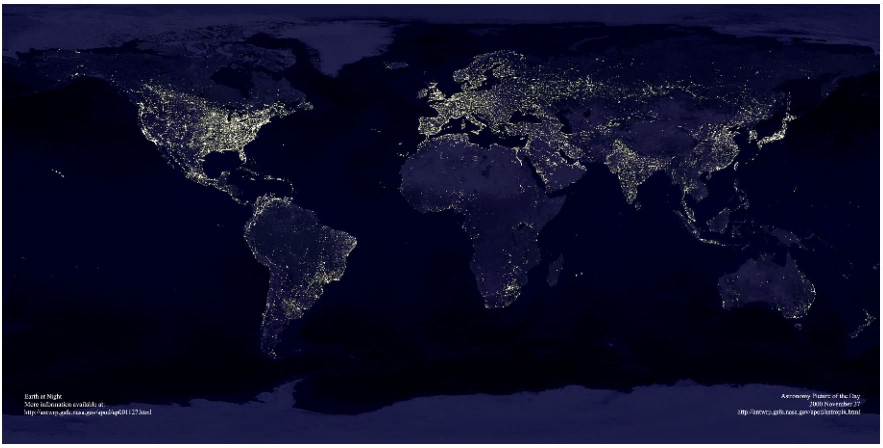

Figure 7: The Earth at night, November 27, 2000. Source: Astronomy picture of the Day. http://antwerp.gafe.nasa.gov/apod/astropix.html

6.2 Maps with dynamic content

An example of a map with dynamic content that provides global information is the Star Alliance animated map (Figure 8). The airline alliance provides a screen saver that shows one day's aircraft movements for all of the flights operated by member companies of the alliance. Readers are able to see the global coverage of the Alliance members and appreciate how international flights are timed to arrive at domestic hubs early morning to ensure connections. The map includes a 24 hour time schema, a day/night colour scheme and colour coding for each of the Alliance flights. Figure 8 shows the high-volume activity in Europe at around noon, whilst the Americas and eastern Asia, Australasia and Oceania has little activity, except intercontinental flights undertaking their long-haul travel.

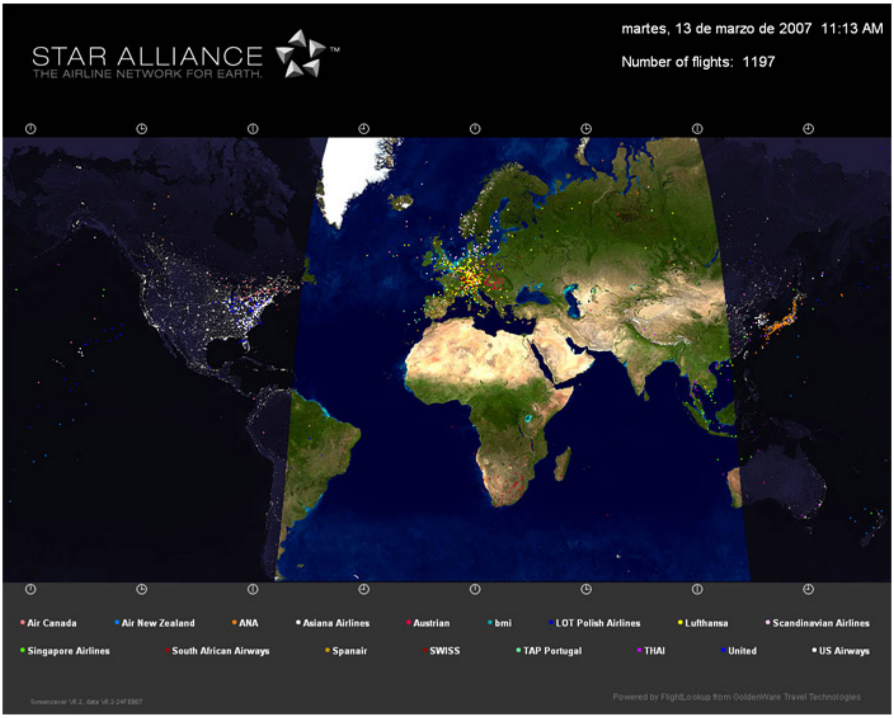

Figure 8: Star Alliance global view of air travel. Source: http://star-alliance-screen-saver-62.de.joosoft.com/resource/screens/91/9100/68315.jpg

6.3 Self-generated maps

Paul Butler, a *Facebook* intern, developed a self-generated map package using data from the social network site. It show the connections between ‘friends’ and, in so doing, a map of the world (via Facebok connected friends’s vectors) was generated. About the results he said …“Not only were continents visible, certain international borders were apparent as well". The visualisation illustrates the lack of presence in central Africa and China. (BBC News, 2010). This particular map had no designer/ cartographer input whatsoever, but it was generated automatically from *Facebook* connections data. Butler's visualisation is shown in Figure 9.

Figure 9: "Visualising Friendships", by Paul Butler.
Source: http://sphotos.ak.fbcdn.net/hphotos-ak-snc4/hs1382.snc4/163413_479288597199_9445547199_5658562_14158417_n.jpg

A more formal data collection method was used in the MIT Real Time Rome project, developed at the SENSEable City Lab. It was heralded by MIT as a product that "promises to usher in a new era of urban mapmaking" … "The goal of Real Time Rome is to use this connectivity to map the city in real time, which may ultimately lead to a deeper understanding of how modern cities function" (MIT, 2006). The product had its worldwide debut at the Venice Biennale in 2006. An image from this exhibition can be seen in Figure 10.

The maps are generated from data collected in real time. It effectively maps data transmitted about the location of cell phones and other wireless technologies. These maps with self-generated content were produced without input from a cartographer, in real-time, from data collected from thousands of devices located throughout the city of Rome. This is a self-generated map. It effectively maps the space of Rome. Does it facilitate a better understanding of the places in Rome?

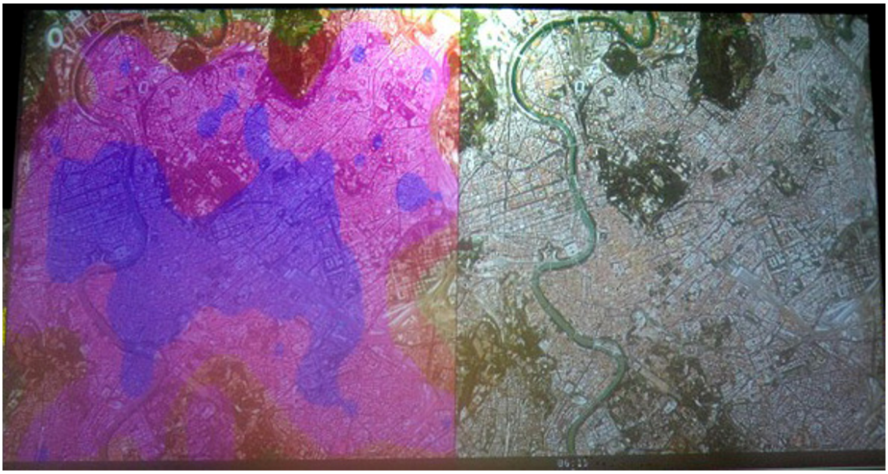

Figure 10: MIT's Real-time Rome. Venice Biennale. Sep 2006.
Source: http://senseable.mit.edu/realtimerome/

7- The 'drawn' map vs visualisations maps with dynamic content and self-generated maps

Earlier in this chapter de Certeau's Space and Place concepts were outlined. To re-cap, he described place as: "an instantaneous configuration of positions" … "is stable and not affected by changes or the dynamics of everyday life. And, Space: "composed of intersections of mobile elements" … "is dynamic and a continually-changing conglomerate entity that exists in any point in time" ... "a 'practiced place', whereby a place does not come into life unless a user practices it" (de Certeau 1984).

Looking at the examples of 'designed' representations and visualisations and maps with dynamic content and self-generated maps, shown in the previous sections of the chapter, how do they relate to de Certeau's Space and Place concepts? Below, in Table 1, is a summary of how each product relates to the concepts.

	PLACE		SPACE		
	an instantaneous configuration of positions	stable and not affected by changes or the dynamics of everyday life	intersections of mobile elements	dynamic / continually-changing conglomerate entity exists in any point in time	a 'practiced place'
Harrison's Description of England (1877)	✓	✓			
Beck's London Underground map	✓	✓			
New Simplified Map of London	✓	✓			
The Earth at night				✓	
Star Alliance network map			✓		✓
Visualising Friendships				✓	✓
Real-time Rome			✓		✓

Table 1. Relationships to relate to de Certeau's Space and Place concepts

What can be seen is that the maps show Place and the maps with dynamic content and self-generated maps show Space. However, each of the maps with dynamic content and self-generated maps does not illustrate each of the elements of Space about which de Certeau wrote.

So, can it be assumed that maps – those products designed and produced as representations of the Earth – are used to show Place, that more stable, less changeable concept? And, that maps with dynamic content and self-generated maps – products generated from 'feeds' from sensors, data relating to communication system use, the virtual links between friends using Web resources like Facebook – are more likely to show Space?

It is argued therefore that the depiction of space using maps, albeit inaccurate and lacking an integral view of the world, can provide much valuable information to users who have not or do not undertake data collection or who are not actively participating in information exchange via social software sites or actively using telecommunications devices. But, as individual cartographers drew these maps, their interpretations of reality differed and also the content of the maps were changed to achieve particular information communication requirements. Maps weren't just maps, they were appended, amended and embellished to serve multiple needs and, in being so manipulated they became repositories of different views of that space. Hand-drawn and copied maps portrayed information in particular ways, and this led to users interpreting these ‘geographical codes’ into particular mental images – mental maps.

As the technologies of discoveries and innovation were applied to communication in general and cartography particularly, artifacts, including maps, were produced automatically, but perhaps in ways that were biased or limited by the technology used to construct, draw or reproduce it. For maps this could lead to information being depicted in ways that were dictated to by other professions or trades – perhaps like surveying or printing in historical map production and dissemenation, and, later computer science, electronic communications and social software site providers. Bias is included in both maps and maps with dynamic content and self-generated maps. However, with maps the professional cartographer/designer strives to minimise this bias through the application of good design concepts and the use of known rules, like the best choice of map projection, symbology, colour schema, etc.

Cartographers do design and re-design their products, for the sake of greater clarity or more efficient information delivery. At the very foundation of what cartographers do is to produce faithful representations of the Earth. What needs to be developed are guidelines and design principles that ensure that visualisations and maps with dynamic content and self-generated maps, which are powerful tools for generating almost real-time information graphics, are designed so that they also represent Place as well as Space.

8- Conclusion

Relatively recently things have changed, maps can be produced not only by non-experts, but by machines as well. As well, maps can be self-generating, changing dramatically how geographical information is depicted. This chapter has presented examples of maps that are excellent depicters of Place, as well as visualisations and maps with dynamic content and self-generated maps that efficiently present information relating to Space. It was argued that how reality is ‘seen’ through a geographical artifact is different when maps or visualisations and maps with dynamic content and self-generated maps are viewed. Maps with dynamic content and self-generated maps do provide a rapidly-produced picture of geography and activities in that geography, but is this enough? Maps with dynamic content and self-generated maps need to be assessed to discover, if they only depict Space rather than Place, if their worth should be questioned and, if they are found to be inferior depictors of geography, methodologies to provide better design must be developed, tested and implemented.

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A Map in a Movie – the Role and the Usage

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Abstract

Almost from the beginning of the cinematography cartographic products were used in movies namely as props, for documentation purposes or as visual shortcuts. Maps play a significant role particularly in "adventure" type of movies, where reality is meeting with fantasy and science with art. There are different approaches how moviemakers handle portraying maps rendered from literature. The portrayal of maps in movies varies from simple look on reproduction of a map to attempts to imprint the feeling of the changing landscape by strictly movie making tools. The more fantasy there is in the story, the more colourful the map presentation can be. As the main goal of moviemakers is to tell the story, the portrayal of the map depends on its significance to the storytelling. The map's portrayal is also dependent on the chosen style of the movie. This paper explores how different approaches of map portrayal in the movie resonate with the story and style of the movie and how different types of map portrayal in movies correspond with map use. There are also discussed possible outside influences on map portrayal. These different approaches are demonstrated on map portrayal in various movie adaptations of H.R. Haggard's novel King Solomon's Mines.

1.Introduction – A Map in A Movie

Where is a space, there can be a journey and where is a journey, there sooner or later arises the need for a map. Use of maps in movies is influenced by moviemakers' views on society, art and history, their cartographic awareness and presumed knowledge base of viewers. From this point of view, it is possible to see movies as the mirror of common carto-

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graphic awareness. Almost from the beginning of the cinematography cartographic products were used as a decoration, or better said, to procure more realistic picture of an intended scene. To this day we can see cartographic products in a variety of movies. A map serves as a symbol of power when hanging behind the sovereign, marks the leader when held in his hand, represents planning when lying on a table. In travelogues, maps were and are used for documentation purposes. Maps play a significant role particularly in "adventure" type of movies, where reality is meeting with fantasy and science with art.

The essence of this type of movies is usually a quest in the widest meaning of the term. As most of these types of movies are adaptations of novels, the first burden of defining the space and its structure is on the writer's shoulders. The writer delivers more or less detailed map description, which can also cover a sketched map published inside the book. From more widely known we can name R.L. Stevenson's Treasure Island, J. Verne's The Mysterious Island or R.R. Tolkien's Lord of the Rings. Even when the map plays a significant role in the story, literary description of its look is usually somewhat sketchy. For example in J.K. Rowling's Harry Potter, there is only one sentence describing the Marauder's map (from Harry Potter and prisoner of Azkaban: *"... a map showing every detail of the Hogwarts castle and grounds ... tiny ink dots moving around it, each labelled with a name ..."*). The concrete visual appearance of the map is left to the reader's imagination. Nevertheless, the writer is where the basic idea comes from. The interpretation and the implementation is work of the director and his team.

As cinematography has in an essence visual quality, moviemakers are pressed to deal with the map display by more visual techniques. The visualization of maps in movies varies from simple look on reproduction of a map to attempts to imprint the feeling of the changing landscape by strictly movie making tools as are aerial shots, arc shots, tracking shots, zooming, etc. Film as a medium ideal for capturing the changing space and time is one of environments with natural inclination to dynamics. Where long distances are to be overcome, moviemakers are in many cases trying to "dynamise" maps by visualizing progress of the taken journey by animation. Maps in these situations serve as visual shortcuts (maybe the most popular are the Indiana Jones movies (1981, -84, -89), but this type of visualization could be seen long before – in famous Cassablanca from 1942). Moviemakers in these cases use maps as a tool.

The more fantasy there is in the story, the more colourful the presentation can be – from simple folding the map to uncover another level of information (Romancing the stone 1984, Fig.4a) to complicated rotating concentric parts (Pirates of Caribbean III 2007, Fig.4b). By the ingenious graphic representations, heroes of the stories are able to travel into unknown worlds. They can use holography springing from an enchanted bracelet (The Mummy Returns 2001) or are perfectly able to orient themselves inside the real 3D model of galaxy (Star Wars: Ep. II 2002, Fig.7a). In movies we can also see something resembling GISs, complete with real time data visualisation (several of James Bond movies or Twister 1996). Overview of early cinematic digital maps, with functions that appeared long before it was possible to create them by cartographers in reality, is given by Caquard (2009).

Another possibility, how moviemakers can deal with a map presence in the story is omit the map altogether or evoke impression of the map without actually showing it. The example of "seeing a map without seeing it" is shown in initial sequences of the movie Indiana Jones and the Raiders of the Lost Ark (1981). Indiana Jones is standing on the riverbank with unfolded paper in his hands. As he is evidently looking for something, the viewer, by association, sees a map in his hands. In reality, there is nothing on that very dirty piece of paper.

It is apparent, that there are different approaches that moviemakers can use when creating visual representation of a map in a movie. As the main goal of moviemakers is to tell the story, the portrayal of the map depends on its significance to the storytelling. The second point of view is how the story is told. The map's portrayal is highly dependent on the chosen style of the movie. This paper explores how different approaches of map portrayal in movies resonate with the story and style of the movie and how different types of map portrayal in movies correspond with map use.

It is possible to draw a simple parallel between cartography and art. Both are trying, among others, to capture face of affairs in one exact significant moment mainly through use of symbolic images. Cartography, rooted in technology and science alike, is in fact reflecting changes in society the same way art does. From the earliest stages of our visual history maps and works of art have served as a testimony. They often originated in the same place and political and social situations. From this point of view, it is not surprising that cartography's dalliance with art is of a longstanding duration. The part of Cartography that is concerned with map aesthetic is the one most influenced by art. Kent (2005) defended significance of aesthetic in cartography by statement: *"…cartographers must continue to apply their aesthetic judgment in seeking to present the subject of their maps in the best way possible…"* It follows Keates (1996) perception of *"a map as an artefact"*, that means object whereon artistic approach is applicable.

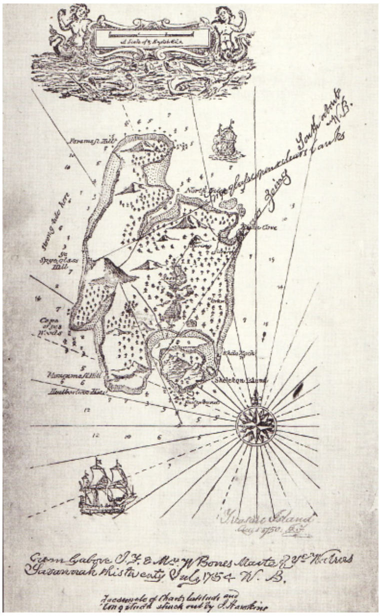
Cinematography with its broad viewpoint can serve as a base representing aesthetics ideals of our time and in this way is a good platform for cartographer to connect with these ideals. It also represents feed-back how maps are viewed by their audience, how they are used and, last but not least, which functions are, or in future may be found, as useful (compare also Caquard 2009 or Caquard and Wright 2009). The following example of various film adaptations of one adventure novel demonstrates how these different backgrounds result in a map portrayal in a movie.

2- A vision of map

To demonstrate changes in the vision of the map in film production, reoccurring theme is needed. And of course a theme that works with map is needed. As was mentioned above – where is journey there will be map. Whole adventure genre is about the journey for something. One of these genre classics is novel *King Solomon's Mines* written by British novelist H.R. Haggard. This novel was several times re-adapted, always with sufficient time lag.

When *King Solomon's Mines* was published in 1885, cinematography was not even a known term (first public showing of "moving pictures" occurred exactly ten years later). The novel was published two years after highly successful R.L. Stevenson's *Treasure Island* and quickly become quite popular (Bleiler 1948). Although both novels include a map, each of them is of a shade different kind. Stevenson offers fairly detailed topography of the entire island (red crosses indicating the location of treasure are mentioned inside the text: *„… three crosses of red ink … and beside this…"Bulk of treasure here."…"*) and leaves it on treasure hunter to find his way (citations from the book courtesy of Maps in Literature database).

Haggard on the other hand gives readers only the most basic and on details poor sketch without even slight additional information about the surrounding landscape. Nevertheless, the map is efficient and is comparable to the most modern navigational maps for mobile mapping (Figure 1a, 1b)

a) 

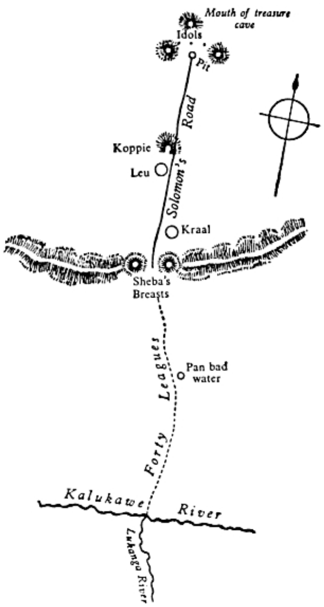
b) 

Figure 1: a) Stevenson's map of Treasure Island, b) Haggard's King Solomon's mines map.

Advantages of sketch maps with landmarks in place of detailed topography for navigation are discussed for example in Staněk and Friedmannová (2007). In context of cinematography, it can be compared to flyovers used in movies as a visual shortcut of the movie plot's movement from one destination to the other. Only landmarks significant for orientation or the plot are perceptible due to deceleration of the camera movement. For example in the movie Mummy Returns (2001), progress through entire Egypt is marked only by four places – Giza Pyramids, the Karnak temple, the Philae temple and the temple of Abu Simbel.

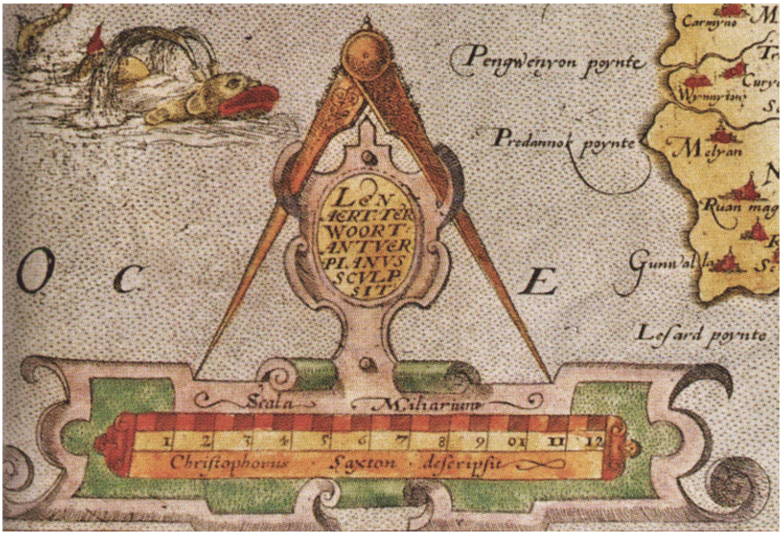
As the book is written as a kind of diary, it follows the progress travellers are doing through narrator's commentary by comparing their position in reality with the map. On the original map, there is no scale, only north indicator; however, the map was plainly drawn in scale, as there are annotations in text (*"...the desert is marked as measuring forty leagues across..."*).

2.1 1937 adaptation – The historical correctness

The novel was first adapted for the screen in 1937 by Gaumont British Picture Corporation, more than 50 years after it was published. There is given, as in all later adaptations, a glimpse at the map. The novel was written in a time period when the British Empire was slowly breaking down, and as such is strongly reminiscent of colonial times. The first movie adaptation is from the period between the World Wars. The nostalgia after greater and more prosperous times together with romanticism strongly influenced the map portrayal in the movie. The portrayal of the map in this early movie adaptation also corresponds with overall still persevering Eurocentric view of that time period.

According to the novel, the original map should have been drawn in 1590 by a Portuguese maker. Maybe this is the reason, why moviemakers felt the necessity to make the map more ornate. There are distinct similarities between representation of the scale on the movie map and on the Saxton's map of Cornwall from 1576 (compare Figure 2a-2b), the linear flourishes of the lettering evokes maps from around 1600 (Barber 2005).

a)



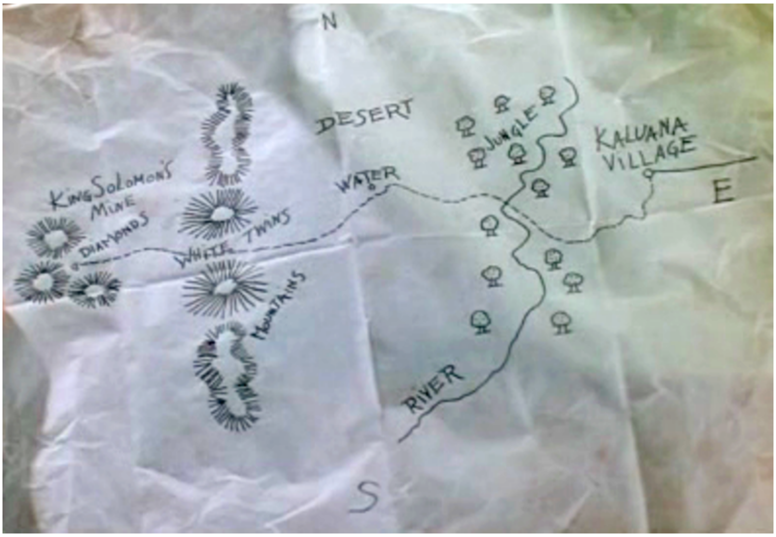
b)

Figure 2: a) The map from 1937 movie (http://www.archive.org/details/king_solomans_mine, accessed 10 March 2009), b) The scale from Saxton's map of Cornwall from 1576 (Barber 2005)

2.2 1950 adaptation – The rule of exteriors

Only 13 years later, in 1950, the movie was reshot by American MGM. The map used in this movie is virtually a replica of the Haggard's original (compare Fig.1b and Fig.3a). The willingness to use such a simple, almost purist map can be contributed to modernistic trends and expansion of abstract art after the Second World War. Through the movie, the beginning of the shift in perception of "primitive cultures" can also be seen. Native African population does not seem as wholly dependent on colonizers as in case of the earlier adaptation nor is source of a "comic relief". This shift from Eurocentric point of view was finished by the map portrayal in adaptation from 1985.

From a cartographer's point of view, the most interesting question is why moviemakers felt the necessity to change the map orientation by rotating it approximately 90 degrees to the left? To understand this, it is necessary to say that the King Solomon's mines map is not the only map displayed in the movie. As the original map has no indication of its location on the Earth, moviemakers felt the necessity to introduce viewers into a broader regional context. This introduction is done by displaying a wall chart of the African continent with inscription "unexplored region" in its centre. The close up on the wall chart displays an area roughly from the Tanzanian and Kenyan coast to centre of the Democratic Republic of Congo – which are regions where the movie was shot. It is probable that the rotation of the King Solomon's mines map was done by movie makers purely for the sake of coordination of the King Solomon's mines map with exteriors used during shooting of the movie. The logical progression of the colonial exploration is from the coast to the continents interior. The region, where shooting of the movie was done, has the coast on the east, so the map was rotated accordingly (compare Figure 1b and Figure3a).

a) 

b) 

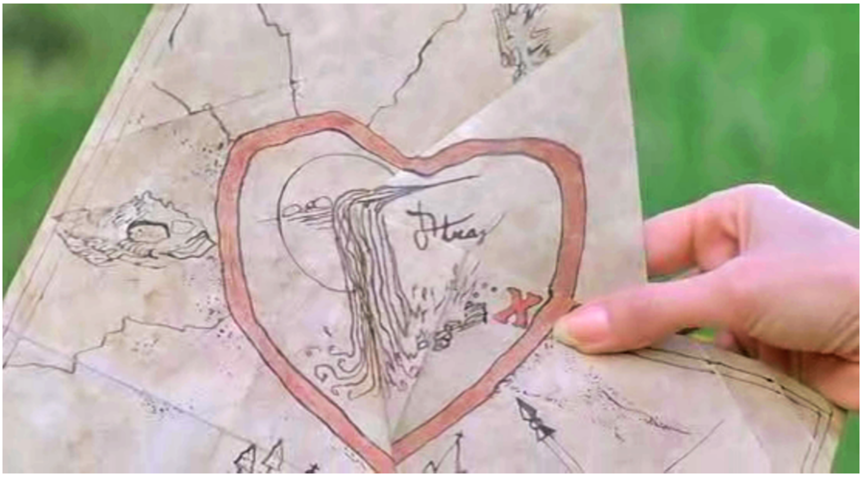
Figure 3: a) The map from 1950 movie, b) The map from 1985 movie

2.3 1985 adaptation – Puzzle it out

In the adaptation from 1985 moviemakers took the idea of the map to the legendary King Solomon's mines onto another level (produced by Cannon Group). They took the name of two hills from original map – Sheba's breasts - and constructed whole map in the form of female figurine, presumably Sheba's. It may be the most peculiar 3D model known (Fig.3b). Maps portrayed in preceding movie adaptations maintained their functionality (to navigate); in this case, the function of the map can be hardly understood. Nevertheless, the style of the map portrayal can be a reflection of a different problematic. As it was written above, the Eurocentric point of view, seemingly hardcoded into the book, was in movie adaptations slowly shifted into Afrocentrism. It can be presumed, that the figurine represents a work of African art, including marks in unknown language. As such, the map can be also viewed as the last step to African emancipation – King Solomon's mines are located in Africa and so the map is also of African origin.

Sheba's figurine in movie adaptation from 1985 represents the type of map, where the definition of the term map is stretched to its limits. This "no-map" or "puzzle map" became for adventure movies something typical. In 1885, it was enough of an adventure to struggle through the hostile environment of an unexplored area. A hundred years later the way to the final location must be hidden (compare also the folding map in Romancing the Stone 1984 or the concentric rotating map in Pirates of Caribbean III 2007 – Figure 4a-b).

There are also "quest movies" with a map without a map. In these cases the treasure hunter must follow a chain of "clues" to reach the destination (for example Indiana Jones movies 1981, -84, -89, National treasure 2004, -07, DaVinci Code 2006, Angels and Demons 2009 etc.). These clues in fact represent landmarks on the hunter's mental map, which is not only spatial but also temporal and cultural. To bring viewers imagination nearer to this mental map, a running commentary or insets of "inner" movies documenting events long past are used. This approach is as well known from popularisation of archaeology (for example BBC's Lost Cities of the Ancients 2006).

a) 

b) 

Figure 4: a) The map from the movie Romancing the Stone, b) The rotating map from movie Pirates of Caribbean III.

2.4 2004 adaptation – Seen unseen

The TV miniseries produced in 2004 by Hallmark Entertainment brought nothing new in a way of the map portrayal. What is in the version from 1950 separated into two maps – Africa and travel map – is here joined into one map depicting very badly about one third of the African continent. The style of visualisation reflects more the 1937 version. The location of the King Solomon's mines was moved from its original location to the east from the drawn path which makes the paths somewhat pointless (Fig.5). Nevertheless, the conservative style of the map portrayal can be also understood as rephrasing of famous and by 20th century modernists' adored statement made by architect L. Sullivan in 1896: *"...form ever follows function..."* (Sullivan 1896). It may actually apply to cartography more than to art, but does it mean, if the function is fulfilled, there is no reason for a change? The movie is in the style of storytelling closer to the 1950 adaptation. The movie in a small and a very romantic way reflects inner African problems and "European" look of the map can be attributed to the presentation of travellers as intruders.

There are many occasions through the movie when we can see the map. Actually, from all of the adaptations, this is the one where the map plays principal role as an object. It is several times almost stolen, travellers are consulting it, there are references of places on the map during quest progression (as are beforehand mentioned Sheba's breasts, but there is also Sheba's eye or Sheba's smile) etc. For all of these actions concentrated around the map, the visual appearance of the map is in the end absolutely insignificant. In the most of the scenes with the map, the map is as a matter of fact not shown. The most of the map is seen during titles, where the map serves as the background.

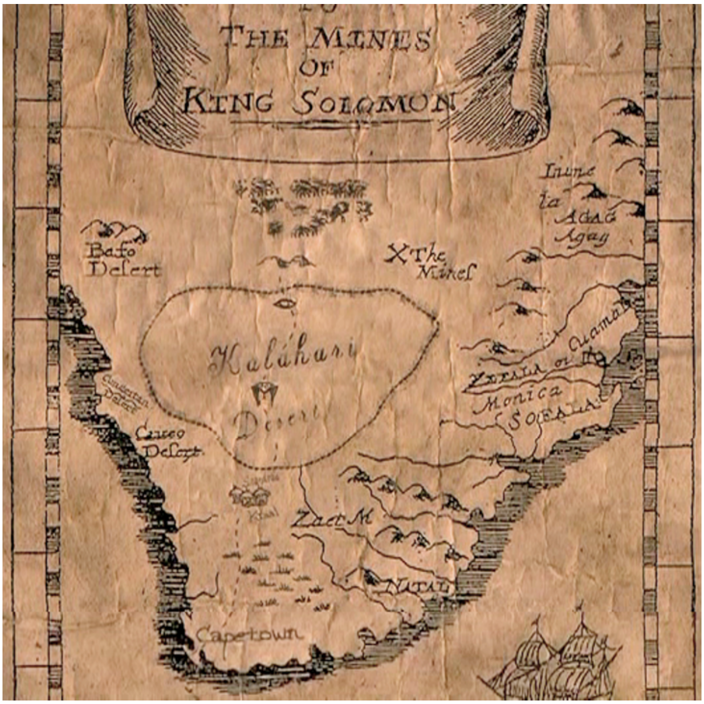


Figure 5: The map from 2004 TV series

There is another point of view why the map looks as an antique map. The aforementioned map supposedly originated in the 16th century and as such, it should look like a map produced in that time period. How the map in the movie looks is how the story is told. The "visage" of the map helps strengthen visual connectivity of the story which also includes costumes, furnishing and so on and the map is basically a prop supporting the movie's desired effect. In the 1985 version of the movie, there was a comical twist to it and so the map is also in a way comical. If a cartographer looks at the Sheba's figurine and sees a 3D model, it is his interpretation deeply enrooted into his knowledge, experience and imagination and it in no way signifies that the movie maker though it more than just a joke.

2.5 2006 adaptation – Charmed by technology

So far the last rendition of the map to King Solomon's mines can be seen in the movie from Flynn Carsen series The Librarian: Return to King Solomon's Mines (TNT 2006). The plot is not based on the original novel; nevertheless, there is a map to the King Solomon's mines. Deviation from a historical adventure to a fantasy enabled use of every accessible technology for the map visualisation. The story of the 1985 adaptation was affected by the strong stream of fantasy themes in cinematography as well, but only in a minor way. The lost diamond mines of the King Solomon from the book changed into the place, where an important African artefact is hidden. In the 2006 version, the function of the mines is even further removed. In a very "Däniken" style we are confronted with supposedly alien technologies.

The shift from map published in original book in 1885 to slightly futuristic 3D rendering awakened by musical key is on one side remarkable, on the other side it also shows, how much our day-to-day visual communication is fixed on realisms. It is also necessary to say, there is a little possibility for anybody to orient himself by the shown map, not only before Solomon's song as a map key is played but even after that. For one, the 3D version of the map is visible only when playing on the key. Secondly, even when rendered, there are no landmarks. Flynn Carsen himself states that he saw the hills from the plane, and there lies the means of recognition. The map has for all its modernism no other role than being a "cool" picture (Figure 6).

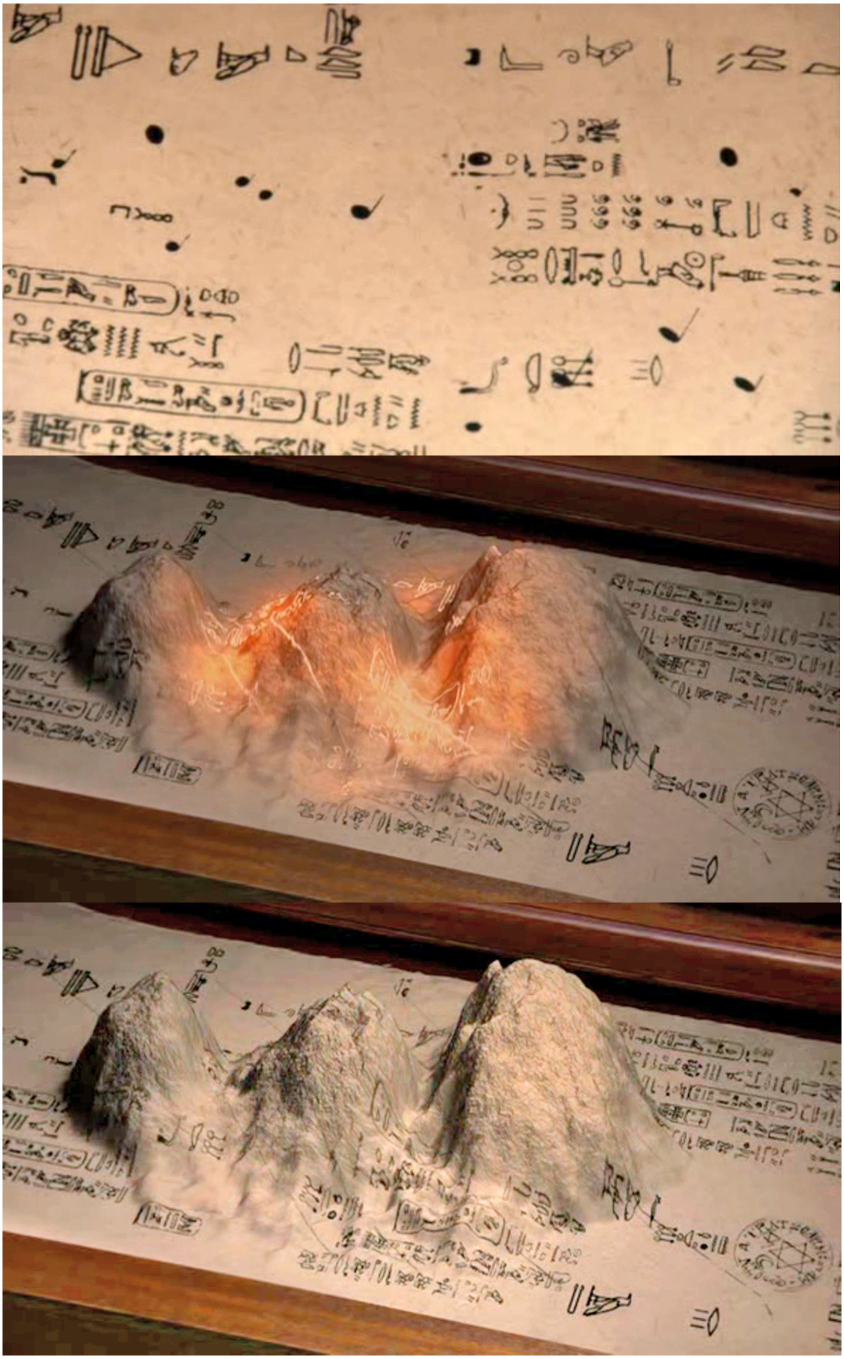


Figure 6: Growing map from the Flynn Carsen movie from 2006

There are other similar examples, where the function of the map was somewhat “lost in translation”. One for all is also a 3D map, in this case not only of a surface, but of the space. In the Star Wars Episode II – Attack of the Clones (2002) Obi-Wan Kenobi on his quest to find the invisible planet literally walks through the 3D model of the space (Fig.7a). From the outside it looks faultless, except for the fact, that every visually received information comes to the observer through one point – his eyes. Orientation is not only about configuration of the objects but also about their position towards the observer. The change of eyes’ position necessarily means the change of objects configuration and consequently the loss of the sense of direction. In an eight years older movie Stargate (1994) it is possible to see a much more realistic and serviceable, though not so visually exciting, space map (Figure7b).

a) 

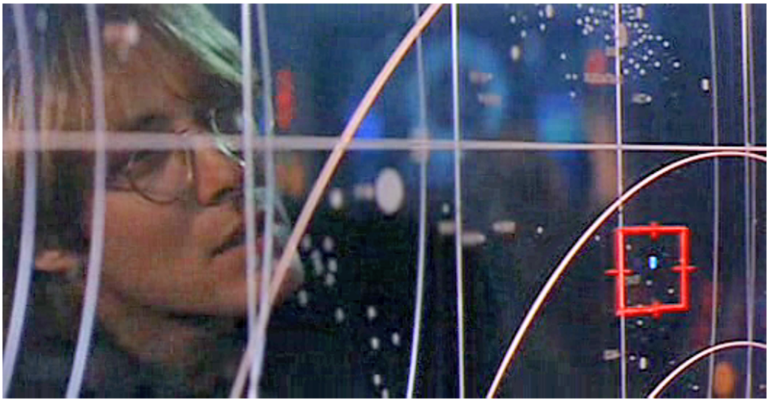
b) 

Figure 7: a) Star Wars – ep.2 (2002), b) Stargate (1994)

3- Conclusion

From studying various representations of map portrayals in focused movies, it is apparent, that a map portrayal in one particular movie is more dependent on general climate in society rather than on the state of cartography as a science. The role of the map is intended to promote vision of the story. It is more decorative then functional object. Real maps are made with respect to user – movie ones with respect to a spectator. For the spectator is important look of the map not functionality. It is significant that the map is mainly emphasizing the antiquity. What is interesting in this respect, the authors attempt an historic allegiance to the contemporary vision of history. Even the attempt to create a non-European form of map can be considered meaningful. A little different is the case with fantasy / sci-fi theme. There is only used modified versions of existing technologies as perceived by the public, but from the perspective cartographic point of view totally senseless.

Art and consequently movies is primarily aiming on human emotions, cartography as a science, on the human mind. *If aesthetic of the movie is derived from the story, aesthetic of the map must be derived from its usability because map has to be not only visually appealing but also understood.* Movies and maps have in common the effort to tell, to communicate, and to be perceived. For this goal they use sometimes similar, sometimes different, tools and approaches. If cartographers seem to be conservative and reluctant to change their approaches, it is at least partially on account of users' demands. The known conception is more understandable and *perception without conception is futile the same way conception is futile without perception*. This fact is also apparent from the map usage in the movies. The style of the movie corresponds with the style of used props. Maps in movies are for moviemakers first off all tools how to communicate with a viewer. If the map's serviceability is sometimes lost, it should in no way reduce our enjoyment from the movie.

Acknowledgments

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King Solomon's Mines (Cannon Group 1985);

King Solomon's Mines (Hallmark Entertainment 2004);

The Librarian: return to King Solomon's Mines (TNT 2006);

Casablanca (Warner Bros. 1942);

James Bond 007 (EON Production, for example The Spy Who Loved Me 1977, Octopussy 1983, GoldenEye 1995);

Indiana Jones (Paramount Pictures, Raiders of the Lost Ark 1981, Indiana Jones and the Temple of Doom 1984, Indiana Jones and the Last Crusade 1989, Indiana Jones and the Kingdom of the Crystal Skull 2008);

Romancing the Stone (20th Century Fox 1984);

Stargate (MGM 1994);

Twister (Amblin Entertainment 1996);

The Mummy Returns (Universal Pictures 2001);

Star Wars: Episode II – Attack of the Clones (20th Century Fox 2002);

National Treasure (Walt Disney Pictures 2004);

DaVinci Code (Columbia Pictures 2006);

Lost Cities of the Ancients (BBC 2006 3 episodes);

Pirates of Caribbean: At World's End (Walt Disney Pictures 2007);

National Treasure: Book of Secrets (Walt Disney Pictures 2007);

Angels and Demons (Columbia Pictures 2009).

A Hazy Mirror? Testing the Reflection of Society in State Topographic Maps

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Abstract

To what extent do state topographic maps mirror society? If maps are to be read as 'texts', by their symbolization of the national landscape, topographic maps should provide a rich and detailed reflection that offers interpretation on many levels. This paper describes an investigation to explore whether national conditions are intrinsically expressed in official 1:50 000 topographic map symbology. A series of bivariate tests of association are conducted between the symbologies of 20 European state topographic maps and a variety of national statistics. Several significant correlations are found, although these tend to indicate general associations rather than explicit links. The findings nevertheless suggest state topographic map symbologies broadly reflect the influence of specifically national circumstances, which ultimately have a decisive impact on their design.

1- Background and Objectives

If the rules of society ensure that maps are at least as much an image of the social order as they are a measurement of the phenomenal world of objects (Harley 1989, p.7), to what extent do topographic maps 'mirror' society? Moreover, if studies concerned with maps of the past require an understanding of their social context and circumstances of production, can current topographic maps, as officially-sanctioned 'good views' of the national landscape (Kent 2008, p.34), offer insights into the societal values

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operating in a country? The view that maps are 'texts' – vehicles for cultural expression – naturally leads to the presumption that topographic maps should provide a rich and detailed reflection of society, offering interpretation on many levels.

As the production of state topographic maps tends to subscribe to the authority of scientific positivism (with its implications for the 'objective' representation of landscape), they are not perhaps as likely to convey societal values as overtly as their more persuasive relation, national atlases; if variations exist in the surface of the Earth, then surely they will exist on topographic maps. But diversity in the appearance of topographic maps cannot result purely from variations in the land. It is *choice* that affects the selection of features and design of individual symbols, which in turn affect the map holistically as a symbol of the (national) landscape. If maps construct their own worlds through the filtering, translation, and hierarchical and taxonomical organization of data (Jacob 1996, p.192), and the very presence of a feature on a map can suggest at least its general relevance, the presentation of higher amounts of detail in describing some features as opposed to others can therefore imply differences in relative importance:

> *In many regions there are important differences in the qualities and characteristics of water, and where this is limited they can be of great importance for both population and agriculture. Although the general category "water" may seem to be adequate, and the distinction between fresh and salt simply inferred from other map information, there are many situations where it needs to be further refined, in order to devise suitable distinctions or categories (Keates 1972, p.173).*

Keates (1989, p.9) later points out that if a particular feature is important in the content of the map, even to the point of being the major map information, then the general category may be broken down into a number of subclasses.

As national mapping organizations (NMOs) are usually responsible for meeting the need to provide adequate spatial information to the state, it seems plausible to suggest that representations of similar phenomena may be compared on a national basis. So, if waterways hold more importance in some countries than others, we would expect cartographers to anticipate this need by providing a higher level of information to its users, perhaps through the introduction of interval data that indicate quantified canal widths. This would provide more detail and hence assign a higher significance to the feature than would a nominal symbol denoting the presence of a canal with no further graphical variation. The degree to which detailed classifications of features are given therefore reflects an assessment of their relative importance (*ibid*., p.159).

This paper describes an investigation to explore the extent to which national conditions are intrinsically expressed in official 1:50 000 topographic map symbology. A series of tests of association are conducted between the symbologies adopted by 20 European state topographic maps and a variety of national statistics, such as land area, employment in various sectors of the economy, HDI (Human Development Indicator) values, cars in use, and countries of origin for foreign tourist arrivals. In performing these explicit comparisons, the tests explore the extent to which the classification and representation of the national landscape – as demonstrated in official 1:50 000 topographical mapping – reflects national characteristics at a detailed level.

2- Approach and Method

The topographic map data used in this investigation are based on those provided by Kent and Vujakovic (2009), which were derived from a classification system for sorting each distinct graphical symbol from a sample of 1:50 000 European state topographic map legends into mutually exclusive categories (Figure 1). Apart from Greece and Luxembourg (where native NMOs do not publish topographic maps at 1:50 000), all countries forming the European Union before 1st May 2004 are represented (the EU 15), along with countries joining the EU on this date, i.e., from the Czech Republic, Latvia, Poland, and Slovenia, and those outside the EU, i.e., from Iceland, Norway, and Switzerland (Table 1). The sample therefore exhibits considerable variation in population size, land area, climate, economic and industrial development, political heritage, and culture.

The scale of 1:50 000 was retained for a number of reasons. Firstly, it represents a good balance between abstraction and mimesis in its representation of the landscape; secondly, it is the most accessible scale throughout the region; and thirdly, most countries in the world possess 1:50 000 mapping, providing scope for a wider application of the study (e.g. to other regions). The static medium of paper ensures that the choices remain fixed and preserved, facilitating the aims.

The method involves performing bivariate correlation coefficient tests of Spearman's rank and Pearson's product moment to investigate associations between map symbologies and the following range of national statistics:

Basic Facts – Land Area (sq. km), Population, Population Density (2004)
Development – Human Development Indicator Ranking and Value (2003)
Economy – Gross Domestic Product per capita (Purchasing Power Parity) (2003)
Structure of Economically Active Population (latest year 1999–2003) –
- Persons employed in:
  - Agriculture, Hunting, Forestry, and Fishing
  - Manufacturing
  - Construction
  - Hotels and Restaurants
  - Wholesale and Retail Trade
  - Mining and Quarrying
  - Electricity, Gas, and Water Supply
  - Transport, Storage, and Communications
  - Real Estate, Renting, and Business Activities
  - Total Labour Force
- Percentage employed in Agriculture, Industry, and Services
- Total Employed

Transport – Domestic Rail Journeys, Cars in Use, Cars per capita (2004)
Tourism – Total Number of Tourists (2003)

(Data sources: *The Economist* 2005 and Bomford et al 2006)

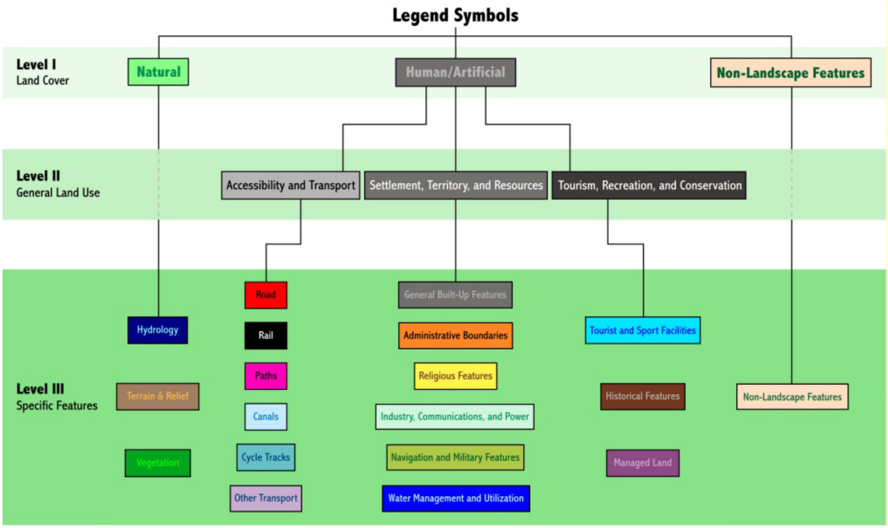

Figure 1: A framework for classifying topographic map symbologies, from Kent and Vujakovic (2009) © British Cartographic Society

Country	1:50 000 Topographic Map Sheet
Austria	Sheet 202: Klagenfurt (Edition: 1998) *Bundesamt für Eich- und Vermessungswesen*
Belgium	Sheet 13: Brugge (Edition: 2, 2002) *Institut Géographique National*
Czech Republic	Sheet 13-11: Benátky nad Jizerou (Edition: 2003) *Césky úrad zememericky a katastrálni*
Denmark	Sheet 1214-I: Silkeborg (Edition: 4-KMS-DA, 2003) *Kort- og Matrikelstyrelsen*
Finland	Sheet 2724: Palojoensuu (Edition: 2001) *Maanmittauslaitos*
France	Sheet 1422: Chalonnes-sur-Loire (Edition: 2, 1982) *Institut Géographique National*
Germany	Sheet L4512: Unna (Edition: 11-DGID, 2004) *Landesvermessungsamt Nordrhein-Westfalen*
Great Britain	Sheet 189: Ashford and New Romney (Edition: D1, 2004) *Ordnance Survey*
Iceland	Sheet 1916-I: Þorvaldsdalur (Edition: 1 DMA, n.d.) *Landmælingar Íslands*
Ireland	Sheet 48: Offaly, Westmeath (Edition: 2, 2003) *Suibhéireacht Ordanáis*
Italy	Sheet 083: Monte Grappa (Edition: 1, 1972) *Istituto Geografico Militare*
Latvia	Sheet 4323: Sigulda (Edition: 2006) *Latvijas Ģeotelpiskās Informācijas Aģentūra*
The Netherlands	Sheet 33-O: Oost Apeldoorn (Edition: 1999) *Topografische Dienst*
Norway	Sheet 1623 III: Roan (Edition: 4-NOR, 1997) *Statens Kartwerk*
Poland	Sheet N-34-124-D: Słubice (Edition: 1995) *Główny Urzad Geodezji i Kartografii*
Portugal	Sheet 27-C: Torres Novas (Edition: 3 IGP, 2004) *Instituto Geográfico Português*
Slovenia	Sheet 12: Jesenice (Edition: 2003) *Geodetska Uprava Republike Slovenije*
Spain	Sheet 963: Lora del Río (Edition: 1st Digital, 2003) *Instituto Geográfico Nacional*
Sweden	Sheet 13-H-SV: Gävle (Edition: 5, 2001) *Lantmäteriet*
Switzerland	Sheet 217: Arbon (Edition: 1999) *Bundesamt für Landestopographie*

Table 1: The sample of maps analysed

In addition to the above list, the languages used in the legend explanations and the top three foreign trading partners (2004) and countries of origin of foreign tourist arrivals (2003) are included. This is intended to provide some idea of how a country's state mapping concerns express a consideration to international users, perhaps indicating the degree of 'openness' to non-native visitors. The range of factors is therefore broad enough to allow a meaningful investigation into possible correlations with various aspects of the symbolization of landscape represented in the maps. A summary of the findings corresponding to each factor is presented in the results section, as well as an interpretation of the main associations found.

The development statistics were compiled with the objectives of temporal consistency and currency, with the maximum participation among countries for each factor. This aims to provide a reliable comparison of as many countries as possible by the same year for each topic. Inevitably, while such conditions could be met for the data, temporal consistency does not extend to the maps, as the sheets vary in age (the mean of the sample is 7.11 years). Consequently, the most recent data sets in the series were chosen rather than those corresponding to the year of publication for each map. While this may seem an unreliable basis for such a comparison, it should be remembered that there are more events to consider in the production of topographic maps than publication dates, as the survey and compilation of material play a dynamic role. As topographic maps are the result of a process rather than a snapshot in time, the maps involved in this study can only reflect what was available at a given period. Although at first it may seem that this would deem any potential association between these maps and the external factors described above unconvincing, changes in topographic map design tend to be slow. Moreover, the current availability of these maps for sale to the public suggests that the NMOs are confident of the maps' relevance to society. The analyses in this study therefore treat the maps in the sample as contemporary products without discrimination by narrow reference to date of survey or any other basis.

The correlation coefficient tests of Pearson's product moment and Spearman's rank explore the degree of association between two variables and both tests are applied in this analysis (using SPSS software). Pearson's product moment correlation coefficient provides a measure (between –1 and +1) of the linear association between two variables (Kitchin and Tate 2000, p.125). The sample correlation coefficient (r) is found from

$$r = 1 - \frac{\sum z_x z_y}{n - 1}$$

where z_x and z_y are the z-scores (distances from the mean expressed as units of standard deviation) associated with x and y respectively.

Spearman's rank correlation coefficient (ρ) provides a measure of the linear association between the two ranked variables which varies between –1 (perfect negative correlation) and +1 (perfect positive correlation) (*ibid*., p.150). Each set of scores is ranked separately from lowest to highest and a Pearson's correlation test (as above) is then calculated on the ranks, making the technique suitable for testing the degree of association between two variables that may not correlate linearly (Hinton 2004, p.279, 280). Hence,

$$\rho = 1 - \frac{6\sum d^2}{n^3 - n}$$

where *d* is the difference between the ranks for observation and *n* Is the size of the sample.

Regarding the quantitative data derived from the maps, comparing the values for each symbol type as a percentage of the total symbology can be more useful than using symbol counts because this gives some indication of the relative meaning associated with each type of feature. While percentage values will be incorporated into these tests, what can offer more significance are those correlations between the raw symbol counts and various development statistics. This provides the added dimension of the relative magnitude of symbologies within the sample. Therefore, both count and percentage data are utilized in the following analyses.

3- Results

3.1 Legend Languages

Before considering factors such as the size of a country, its population density, and employment structure in order to determine the extent to which topographic maps reflect these conditions, the first criterion to be examined is the languages employed in the legend explanations. Table 2 presents a summary of the mother-tongue languages spoken in the sample of countries, while Table 3 indicates which foreign languages appear in the legends of the corresponding maps.

All NMOs acknowledge at least one mother-tongue language by its inclusion as a legend explanation. Belgium, with substantial proportions of both Dutch and French speakers, includes both languages; Switzerland includes German on the map but prints leaflets with explanations in other languages; Ireland includes both Irish Gaelic and English; and even the 6 percent of the Finnish population who speak Swedish as their mother tongue are catered for. The absence of the Russian language on the state maps of Latvia is therefore noticeable, given that for 27 percent of the Latvian population, it is their mother tongue.

A recent European Commission (2006, p.7) survey of 28,634 citizens of the EU 25 plus Romania, Croatia, Bulgaria, and Turkey, found that German is the mother tongue of the highest number of speakers (18 percent), followed by English and Italian (both at 13 percent) and French (12 percent). In terms of foreign languages, i.e., not the mother tongue, the same survey discovered that English is the most widely spoken (based on the percentage of respondents stating possession of sufficient skills to hold a conversation in the foreign language), followed by French, German, Spanish, and Russian (*ibid*., p.12).

Country	Languages in Use as a Mother Tongue
Austria	99% German, 1% Other (Slovene and Croat)
Belgium	60% Dutch, 40% French, <1% German
Czech Republic	Czech, Other minorities
Denmark	Danish
Finland	>93% Finnish, 6% Swedish, <1% Lappish
France	French, Other minorities
Germany	German, Sorbian minority
Great Britain	English, Other minorities (Welsh, Gaelic)
Iceland	Icelandic
Ireland	Irish Gaelic (Gaeilge), English
Italy	Italian, with German, Ladin, French, Greek, Albanian, Other minorities
Latvia	72% Latvian, 27% Russian, Other minorities
The Netherlands	Dutch, <2.5% Frisian
Norway	Norwegian (Bokmål and Nynorsk), <1% Lappish
Poland	Polish, German minority
Portugal	Portuguese, Other minorities
Slovenia	Slovene, Other minorities
Spain	Spanish (Castilian), Catalan, Basque, Galician
Sweden	Swedish, with Finnish and Lappish minorities
Switzerland	72.5% German, 21% French, 4.3% Italian, 0.6% Raeto-Romansch, 1.6% Other

Table 2: Mother-tongue languages used in countries represented in the sample as compiled from European Commission (2006) and Maher (2006)

Foreign Language Used in Map Legend	Frequency of Use	Countries Using Foreign Languages
English	8	Belgium, Denmark, Germany, Iceland, Italy, The Netherlands, Norway, Poland
German	4	Belgium, Denmark, Great Britain, Ireland
French	3	Germany, Great Britain, Ireland
Swedish	1	Finland

Table 3: Foreign languages appearing in the legends of maps in the sample

As English is present as a foreign language on the maps of eight countries and German on the maps of just four, it might seem that map legends are more likely to include those foreign languages which are known rather than those spoken as a mother tongue. It might be assumed that English appears in the map legend for all NATO countries (English explanations are listed first in Icelandic maps), but this is not the case.

According to the same report, the size of a country seems to have a bearing on the foreign language skills and so one might expect smaller countries to employ more foreign languages in their topographic map legend:

> *Language skills appear to be slightly better in relatively small Member states such as Luxembourg, the Netherlands and Slovenia, whereas citizens of Southern European and the two English speaking countries, the United Kingdom and Ireland, seem to have more moderate level [sic] of language skills (European Commission 2006, p.10).*

However, this expectation would only seem to be partly true, for Slovenia does not include any foreign languages on its maps and the Netherlands only includes English, whereas both Great Britain and Ireland employ two foreign languages (French and German). It is possible that factors influencing the choice of these languages may include foreign trading partners and the country of origin of foreign tourists, particularly if their numbers are sufficient and they are regarded as potential users. Table 4 below shows the top three countries of origin of the foreign tourist arrivals in each country alongside the map legend languages.

In Great Britain, the languages in the map legend correspond exactly with those of foreign tourists and trading partners, suggesting a market-driven approach that is partly supported by the high proportion of tourist symbols in the map symbology. In most cases, however, it would seem that NMOs adopt a foreign language that the greatest number of potential map users are likely to understand (which is evident in the maps of Norway and Poland), rather than selecting the language of a neighbouring country, a principal trading partner, or the country responsible for the highest number of tourist arrivals. The sole inclusion of native mother tongue languages in the legend explanation (such as in the maps of Austria and France) perhaps reflects the view that the overwhelming majority of users of state topographic maps are the native population. Such countries may also be those in which other detailed mapping or specialized products are available at a comparable scale (e.g., published by Freytag & Berndt or Michelin respectively in the case of these two countries). Whether it is advantageous to include foreign languages or not, demand for these maps by other non-native users is likely to be perceived as low and so change is unlikely.

Country	Languages Appearing on Map Legend	Foreign Tourist Arrivals, 2003	Trading Partners, 2004 (Imports)	Trading Partners, 2004 (Exports)
Austria	German	Germany, The Netherlands, Italy	Germany, Italy, France	Germany, Italy, USA
Belgium	Flemish, French, German, English (Italics)	The Netherlands, UK, France	The Netherlands, Germany, France	Germany, France, The Netherlands
Czech Republic	Czech	Germany, Poland, UK	Germany, Slovakia, Italy	Germany, Slovakia, Austria
Denmark	Danish, English, German	Sweden, Germany, Norway	Germany, Sweden, The Netherlands	Germany, Sweden, UK
Finland	Finnish, Swedish	Sweden, Germany, Russia	Germany, Russia, Sweden	Germany, Sweden, Russia
France	French	UK, Germany, The Netherlands	Germany, Italy, Spain	Germany, Spain, UK
Germany	German, English, French	The Netherlands, USA, UK	France, The Netherlands, USA	France, USA, UK
Great Britain	English, French, German	USA, France, Germany	Germany, USA, France	USA, Germany, France
Iceland	English (Bold), Icelandic	Germany, UK, USA	Germany, USA, Norway	UK, Germany, The Netherlands
Ireland	Gaelic, English, French, German	UK, USA, France	UK, USA, Germany	USA, UK, Belgium
Italy	Italian, English (Magenta)	Germany, USA, France	Germany, France, The Netherlands	Germany, France, USA
Latvia	Latvian	Germany, Finland, Estonia	Germany, Lithuania, Russia	UK, Germany, Sweden
The Netherlands	Dutch, English (Italics)	Germany, UK, Belgium	Germany, Belgium, USA	Germany, Belgium, France
Norway	Norwegian, English	Germany, Denmark, UK	Sweden, Germany, Denmark	UK, Germany, The Netherlands
Poland	Polish, English (Italics)	Germany, Czech Republic, Ukraine	Germany, Italy, Russia	Germany, France, Italy
Portugal	Portuguese	Spain, UK, France	Spain, Germany, France	Spain, France, Germany
Slovenia	Slovene	Italy, Germany, Austria	Germany, Italy, Austria	Germany, Italy, Croatia
Spain	Spanish	UK, Germany, France	Germany, France, Italy	France, Germany, Italy
Sweden	Swedish	Norway, Germany, Denmark	Germany, Denmark, Norway	USA, Germany, Norway
Switzerland	German (others available as separate leaflets)	Germany, UK, USA	Germany, France, Italy	Germany, USA, France

Table 4: Map legend languages against foreign tourist arrivals and foreign trading partners compiled from Maher (2006)
Top three countries listed in order; tourist arrivals by country of origin; imports by country of production, exports by country of consumption

3.2 National Statistics

Before the findings of the tests of association between development statistics and map symbologies are interpreted, Tables 5 to 12 below present the statistically significant results from the analysis. In these tables, a result in plain type indicates that the result meets the 0.05 significance level and bold type means the result meets the 0.01 significance level (using two-tailed tests).

	SYMBOL CLASS (LEVELS I AND II)		
FACTOR	Human Features	Natural Features	Accessibility and Transport
Population Density (sq km)	0.502		**0.687**
GDP per capita (PPP)		-0.461	

Table 5: Significant correlations between development statistics and symbol counts for Level I and Level II feature types using Pearson's product moment correlation coefficient

	SYMBOL CLASS (LEVELS I AND II)	
FACTOR	Human Features	Accessibility and Transport
Population Density (sq km)	0.506	**0.675**
Cars in Use		0.459

Table 6: Significant correlations between development statistics and symbol counts for Level I and Level II feature types using Spearman's rank correlation coefficient

	SYMBOL CLASS (LEVELS I AND II)	
FACTOR	Human Features	Accessibility and Transport
Population Density (sq km)	0.446	**0.624**
Labour Force: Construction	0.450	

Table 7: Significant correlations between development statistics and Level I and Level II feature types as a percentage of total symbology using Pearson's product moment correlation coefficient

	SYMBOL CLASS (LEVELS I AND II)		
FACTOR	Human Features	Natural Features	Accessibility and Transport
Population	0.529	-0.508	
Population Density (sq km)			**0.711**
Labour Force: Agriculture, Hunting, Forestry, and Fishing	0.456		
Labour Force: Manufacturing	**0.649**	**-0.649**	0.550
Labour Force: Construction	**0.624**	**-0.609**	0.510
Labour Force: Electricity, Gas, and Water Supply	0.536	-0.536	
Labour Force: Transport, Storage and Communications	0.493	-0.470	0.521
Labour Force: Total	0.532	-0.513	0.501
Total Employed	0.531	-0.511	0.493
Cars in Use	0.530	-0.505	0.472
Total Tourists	**0.633**	**-0.624**	0.490

Table 8: Significant correlations between development statistics and Level I and Level II feature types as a percentage of total symbology using Spearman's rank correlation coefficient

	LEVEL III SYMBOL CLASS							
FACTOR	Canals	Managed Land	Paths	Road	Vegetation	Water Management and Utilization	Hydrology	General Built-Up Features
Population	**0.587**							
Population Density (sq km)	**0.631**			**0.743**				
Labour Force: Manufacturing	0.497							
Labour Force: Construction	**0.623**						-0.498	
Labour Force: Mining and Quarrying	0.599				**0.679**			
Labour Force: Electricity, Gas, and Water Supply		0.579						-0.504
Labour Force: Transport, Storage and Communications	**0.616**	0.486	0.536					
Labour Force: Real Estate, Renting, and Business Activities								-0.554
Labour Force: Total	**0.576**	0.460						
Total Employed	**0.601**	0.464						
Percentage Employed in Industry						0.535		
Percentage Employed in Services			0.522			-0.503		
Cars in Use	**0.618**							
Total Tourists								-0.450

Table 9: Significant correlations between development statistics and symbol counts for Level III feature types using Pearson's product moment correlation coefficient

FACTOR	LEVEL III SYMBOL CLASS						
	Canals	Religious Features	Road	Water Management and Utilization	Historical Features	General Built-Up Features	Hydrology
Population	**0.668**					**-0.461**	-0.527
Population Density (sq km)	0.559		**0.669**				
HDI Ranking				0.469			
HDI Value				-0.469			
Labour Force: Agriculture, Hunting, Forestry, and Fishing	0.503						-0.488
Labour Force: Manufacturing	**0.706**					-0.523	**-0.668**
Labour Force: Construction	**0.689**					-0.524	
Labour Force: Mining and Quarrying	0.542						-0.517
Labour Force: Hotels and Restaurants	0.577					-0.556	
Labour Force: Electricity, Gas, and Water Supply	**0.609**				0.471	**-0.702**	-0.543
Labour Force: Transport, Storage and Communications	**0.590**						-0.505
Labour Force: Real Estate, Renting, and Business Activities						**-0.684**	-0.577
Labour Force: Total	**0.635**					-0.457	-0.532
Total Employed	**0.621**					-0.451	-0.532
Percentage Employed in Industry				0.537			
Domestic Rail Journeys	0.577					-0.560	
Cars in Use	**0.681**	0.470					-0.496
Total Tourists	**0.693**	0.468				**-0.569**	**-0.588**

Table 10: Significant correlations between development statistics and symbol counts for Level III feature types using Spearman's rank correlation coefficient

FACTOR	LEVEL III SYMBOL CLASS									
	Canals	Historical Features	Vegetation	Road	Administrative Boundaries	Paths	Tourist and Sport Facilities	Water Management and Utilization	General Built-Up Features	Hydrology
Population	**0.577**								-0.475	-0.510
Population Density (sq km)	0.542			**0.639**						-0.477
GDP per capita (PPP)						0.454	0.507			
Labour Force: Agriculture, Hunting, Forestry, and Fishing			0.470							
Labour Force: Manufacturing	0.556									
Labour Force: Construction	**0.628**								-0.486	-0.556
Labour Force: Mining and Quarrying	0.506		0.705							-0.591
Labour Force: Electricity, Gas, and Water Supply		0.516							-0.508	
Labour Force: Transport, Storage and Communications	**0.583**									-0.498
Labour Force: Real Estate, Renting, and Business Activities	0.583	**0.758**			0.566					
Labour Force: Total	**0.568**								-0.475	-0.486
Total Employed	**0.589**								-0.480	-0.498
Percentage Employed in Industry						-0.498		0.523		
Percentage Employed in Services						**0.597**		-0.500		
Domestic Rail Journeys		0.546								
Cars in Use	**0.608**									-0.499
Total Tourists									-0.522	-0.501

Table 11: Significant correlations between development statistics and Level III feature types as a percentage of total symbology using Pearson's product moment correlation coefficient

FACTOR	LEVEL III SYMBOL CLASS										
	Canals	Water Management and Utilization	Historical Features	Paths	Administrative Boundaries	Road	Religious Features	Vegetation	Terrain and Relief	General Built-Up Features	Hydrology
Population	**0.633**								-0.451	**-0.574**	**-0.660**
Population Density (sq km)	0.498					0.523					
HDI Ranking		0.556						0.457			
HDI Value		-0.552						-0.464			
GDP per capita (PPP)				0.451							
Labour Force: Agriculture, Hunting, Forestry, and Fishing	0.487	0.502						0.457	-0.445	-0.451	**-0.660**
Labour Force: Manufacturing	**0.732**								-0.476	**-0.651**	**-0.783**
Labour Force: Construction	**0.678**								-0.483	**-0.641**	**-0.756**
Labour Force: Hotels and Restaurants		0.577								-0.648	-0.671
Labour Force: Wholesale and Retail Trade										-0.593	-0.600
Labour Force: Mining and Quarrying	0.574	0.546									**-0.670**
Labour Force: Electricity, Gas, and Water Supply	**0.641**		0.585							**-0.754**	**-0.695**
Labour Force: Transport, Storage and Communications	0.566									-0.561	**-0.684**
Labour Force: Real Estate, Renting, and Business Activities	0.621		0.583		0.599					**-0.720**	**-0.729**
Labour Force: Total	**0.611**									-0.561	**-0.678**
Total Employed	**0.599**									-0.558	**-0.687**
Percentage Employed in Industry		**0.604**									
Percentage Employed in Services		-0.489		0.516							
Domestic Rail Journeys	0.562									-0.609	**-0.631**
Cars in Use	**0.632**									-0.567	**-0.664**
Cars per capita		0.494									
Total Tourists	**0.676**						0.504		-0.505	**-0.692**	**-0.754**

Table 12: Significant correlations between development statistics and Level III feature types as a percentage of total symbology using Spearman's rank correlation coefficient

3.2.1 Land Area, Population, and Population Density

These qualities often give a general impression of a country. Larger countries may include more varied climate or terrain, meaning that their topographic maps may utilize a wider vocabulary of symbols to present their homogenization of the landscape. According to Keates (1996, p.256):

> *There are considerable differences in the degree to which topographic features are symbolized, and thus the way in which the character of the landscape is expressed. The size of a country concerned is an important factor. Large countries, such as the United States, have a far greater variety of geographic and topographic characteristics, the nature of which must be accommodated by a standard specification.*

Surprisingly, despite variation in the size of countries in the sample, land area did not correlate significantly with a wide range of aspects from the symbologies.

It is easy to assume that more populous countries may be served by a larger national mapping organization and a more extensive symbology. Furthermore, if the population density of a country is high, the commodity of space is likely to exert a greater value as demand is higher. Larsgaard (1993, p.180) states that 'Population density is often the decisive influence on mapping; almost without exception, the more densely populated is a country, the more likely it is to be quickly mapped'. A test of association between the age of the map and population density, however, found no significant correlation.

Nevertheless, tests incorporating both population and population density yielded significant results, the latter correlating with more aspects of the map symbologies. On a general level, Table 8 indicates that population is positively correlated with the proportion of symbols devoted to Human/Artificial Features, or conversely, more populous countries tend to use fewer symbols to represent natural features. The detail provided by the Level III classification allows this to be related more specifically to the categories of Canals (positive) and Hydrology (negative) in Tables 9 to 12. Table 12 (which involves percentage values), curiously extends these negative correlations to those between population and the proportion of symbols allocated to the General Built-up Features and Terrain and Relief classes.

Population density is positively correlated with factors from all levels of classification, largely with Human/Artificial Features, Accessibility and Transport (Tables 5 to 8), and more specifically, Road and Canals (Tables 9 to 12). One of the highest values of all is the significant positive correlation coefficient of 0.743 between population density and the number of symbols counted in the Road category, as shown in Table 12. It is curious that this test exhibits a stronger correlation than the degree of association found between the Road category and the number of cars in use.

3.2.2 Human Development Indicator Ranking and Value

The Human Development Indicator (HDI) is used by the United Nations to measure human development according to prospects for a long and healthy life, education and standard of living. It combines a number of variables (life expectancy, adult literacy, gross enrolment in primary, secondary, and tertiary education, and GDP per capita [PPP]) to determine an index value between zero and one (Maher 2006, p.vi). In this study, two sets of significant correlations were found between HDI ranking and value and topographic map symbology. These concern the classes of Water Management and Utilization and Vegetation, to the effect that the lower the HDI ranking (i.e., furthest from one) and value, the smaller the proportion of symbols tends to be devoted to these two types of feature (Table 12). As shown in Table 13 below, which uses data compiled from the same tests, countries that are less dependent on agriculture and more on services are more likely to exhibit a higher standard of living as measured by the HDI. The topographic map symbology thus reflects this correlation to a similar extent.

	Percentage Employed in Agriculture	Percentage Employed in Industry	Percentage Employed in Services
HDI Ranking	**0.705**	.434	**-0.700**
HDI Value	**-0.747**	-.395	**0.696**

Table 13: Results of Pearson's product moment correlation coefficient tests between HDI data and general structure of the economy (grey = no significant correlation; bold = correlation significant at the 0.01 level; source data compiled from *The Economist* 2005 and Maher 2006)

3.2.3 Economy

The next series of tests concern the economic data for each country: its GDP per capita (PPP) and the structure of its economy. Gross Domestic Product (GDP) is a measure of the total value of all goods and services output during a single year within national borders and in this case, this figure is divided by the total population. Purchasing-power parity (PPP) is a rate of currency conversion that equalizes purchasing power by eliminating differences in price.

The results from the tests of association show that there is a significant negative correlation between GDP per capita (PPP) and the number of symbols devoted to the Natural Features class (Table 5). Additionally, there are significant positive correlations between GDP per capita (PPP) and the proportion of symbols devoted to the Paths and Tourism and Sport Facilities classes (Table 11). As these two Level III classes are related to leisure, it might be suggested that in wealthier countries, topographic maps at this scale are more of a recreational product than a technical resource, although no significant correlation was found between GDP per capita (PPP) and the Level II class of Tourism, Recreation, and Conservation, which is an aggregation of these two classes and others within the Level III classification.

The structure of the economy is represented by a number of factors at varying levels of detail. In addition to a comparison of individual sectors of employment (such as mining and quarrying and electricity, gas, and water supply) broader indicators such as the percentage employed in agriculture, industry, and services are included as well as figures for the total labour force and population employed. The tests of association found a variety of significant correlations between these data and the symbology of topographic maps in the sample. Generally, there are highly significant positive correlations between the number of people employed in the manufacturing and construction sectors and the proportion of symbols allocated to the Human/Artificial Features class (Table 8). Among the other highly significant results are the positive correlation between the number of people employed in mining and quarrying and the number of Vegetation symbols (Table 9); the negative correlation between those employed in electricity, gas, and water supply sector and the number of General Built-up Features symbols (also Table 9); and the variety of significant positive correlations between various sectors and the proportion of symbols devoted to the Canals class (e.g., Table 10).

These results suggest that the symbology of these maps reflects the character of the structure of employment to a wide extent and in so doing, their design is more likely to meet the needs of a variety of users. The high number of correlations between the economy and Canals symbols may indicate an overall level of industrialization, which is supported by the most highly correlated sectors such as manufacturing, construction, and transport, storage and communications. It is also perhaps reinforced by the negative correlation between the total labour force (and total employed) and the proportion of symbols devoted to the Natural Features class (Table 8). However, while canals are clearly linked to the process of industrialization and remain a critical mode of bulk transfer in countries devoting a higher proportion of their symbology to this type of feature, in Great Britain the high share of the symbology perhaps reflects their use as a recreational resource, especially as features associated with tourism also receive a relatively high proportion (Kent and Vujakovic 2009, p.201).

There is also a significant negative correlation between the number of symbols in the General Built-up Features class and the number of people employed in real estate, renting, and business activities (Table 9). It is tempting to speculate that countries with an emphasis away from these features on their maps adopt more conservative planning policies for the construction of new buildings, with the consequence that the built environment is a commodity that demands a higher degree of management. Such an association, however, is more likely to be spurious than causal.

3.2.4 Transport

The symbol classes associated with transport are not reflected exhaustively in the range of statistics employed here, although figures for the number of domestic rail journeys, cars per capita, and cars in use provide an indication of whether these aspects are reflected in state topographic map symbology. According to Kent and Vujakovic (2009, p.190), countries with a lower symbol count tend to be located on the geographical periphery of Europe (based on the total number of symbols counted in the map legends). But more specifically, transport and accessibility play a key role in characterizing this core-periphery structure:

> *The economic growth of Europe is strongly concentrated at the centre. In France, the UK and Germany the great growth areas are close to the continental centre together with the Netherlands*

> *and Belgium. In Spain and Italy the growth areas are in the north, again reaching towards the centre, just as in Norway and Sweden they are in the south. On the other hand, the relatively under-developed areas of Europe are stretched all along the periphery: Greece, southern Italy, Corsica, Sardinia, most of Spain and Portugal, south-west France, Brittany, Ireland, Scotland, Jutland and eastern Bavaria. One may suspect a link between this striking pattern of economic development and accessibility, which is a result partly of geography and partly of transport (Thomson 1976, p.274).*

Whether or not this implies that the core-periphery structure is caused directly or indirectly by the transport system, it is important to bear in mind that a higher density of transport infrastructure will partly be a consequence of higher levels of economic activity, as well as being a causal factor which tends to facilitate that level of activity. However, in tests of association between HDI and GDP per capita (PPP) data and transport data compiled for this investigation, significant correlations were only found with cars per capita (Table 14 below), which indicates wealth rather than the personal mobility of the population. Although data for the usage of other forms of transport are not included in these tests, it would still be possible to see if any association between transport and development is present in the relationship between transport statistics and the Accessibility and Transport class (and its subclasses) of symbols.

	Domestic Rail Journeys, 2004	Cars in use, 2004	Cars per capita, 2004
HDI Ranking	-0.032	0.097	**-0.546**
HDI Value	0.154	0.070	**0.619**
GDP (PPP)	0.089	0.004	**0.471**

Table 14: Results of Pearson's product moment correlation coefficient tests between HDI and GDP per capita (PPP) data and transport data (source data compiled from Maher 2006)

Significant positive correlations are indeed present between the proportion of symbols dedicated to Accessibility and Transport and the number of cars in use, which provides a more accurate measure of the personal mobility of the whole population than cars per capita (Table 8). Stronger positive correlations, however, were found between cars in use and the number of symbols in the Canals class (e.g., Table 9) and a strong negative correlation between cars in use and the proportion of symbols allocated to the

Hydrology class (Table 12). The significant correlations between cars in use and the Level I classes in Table 8 suggest that the democratization of the car plays a key role as a measure of human presence and industrialization as reflected in topographic map symbology, if not human development.

No significant correlations were found between the number of domestic rail journeys and the number or proportion of Rail symbols. This perhaps suggests that maps are products for serving interests and the unlikelihood that topographic maps are designed with rail users in mind, particularly given the navigational impetus lying behind the design of road symbols.

3.2.5 Tourism

The effect of tourism on legend languages has been described above and this complementary assessment involves a measure of the total number of tourists visiting each country. On a general level, tourists seem to prefer countries exhibiting more symbols allocated to the Human/Artificial Features and Accessibility and Transport classes (as opposed to the Natural Features class) on their topographic maps (Table 8). The tests also found that there were significant negative correlations between the total number of tourists and the proportion of symbols falling within the General Built-up Features and Hydrology classes, although a positive correlation was found with the proportion of symbols devoted to the Canals and Religious Features classes (Table 10). If maps do reflect external influences, these results perhaps suggest that certain factors affect the most popular choices of tourist destination, implying that tourism in Europe is based upon 'culture' rather than nature or wilderness.

4- Conclusion and Future Plans

These results have shown that there are a number of significant correlations between national conditions and elements of the symbology of 1:50 000 state topographic maps. However, these indicate more general associations rather than explicit links. For example, the number of road symbols correlates highly with population density, but not with the number of cars in use. While reasons for this are unclear, it is likely that this largely reflects the influence of specifically national circumstances, which ultimately have a decisive impact on map design.

One possible explanation is that national mapping organizations with greater human and financial resources at their disposal are more likely to produce maps with more extensive 'vocabularies' at a given scale, not least because a broader symbology for paper maps requires more effort and skill to devise, produce, and sustain. However, testing associations between the total number of symbols in the symbology and internal factors that could feasibly affect the operational characteristics of national mapping organizations such as the number of staff, annual budget, degree of state funding, and annual sales, revealed no significant correlation.

The findings of this investigation perhaps also suggest that as 'mirrors of society', state topographic maps cannot be claimed to exhibit any more veracity than as 'mirrors of nature'. If the information topographic maps contain is strongly influenced by what is *perceived* as being of value to a range of prospective users (Keates 1989, pp.148–149), maintaining this particular selection of features also serves the interests of those with the power to initiate changes to their design. State topographic maps are traditionally conservative in this respect and NMOs tend to retain a particular choice of features which they would justify as comprising the most useful, i.e., having the highest number of potential functions (or the highest significance), to the greatest number of users over time. A comparison with another geographical region (perhaps involving post-colonial countries) would perhaps serve to highlight the extent to which this is the case or, conversely, the extent to which current state topographic mapping falls short of meeting the needs of users in symbolizing the national landscape.

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Map Collecting Practices

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Abstract

There has been only limited comparison of the different contexts in which maps have been brought together, and hardly any critical consideration of the contours of map collection. This paper aims to begin to correct some of these gaps by starting to chart the changing contemporary significance of map collecting, to explore its variations and to explain differences in individual map collecting practices. It is grounded in social theoretical approaches to the wider world of collecting and in the literature around post-Harleian critical cartography. The unique characteristics of map collecting are explored, and a detailed comparison of map collecting practices of British antiquarian and everyday map collectors is presented, following an investigation of textual sources and an ethnography of collecting practices and spaces. Differences between the collecting fields of elite antiquarian practices, as against more prosaic everyday collecting suggest that we need to understand map collecting practices as 'placed behaviour', in which economic relations are mediated by local culture and places.

1- Introduction

Writing about collecting has taken a critical turn in the last twentyfive years. Collecting has been read as a reflection of organizational values e.g. Pearce (1995), and of individual psychology e.g. Muensterberger (1994). Researchers have explored relations of collecting to leisure, disposable income, the consumer society (e.g. Belk 1995), and material culture (Miller 1987). Post-modern explanations have interpreted collecting as Debordian spectacle (Gregson and Crewe 2003), or the economy of identity formation (Baudrillard 1995). Perhaps the most important lesson is to follow Elsner

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and Cardinal (1994) and interpret contemporary cultures of map collecting using a bricollage of different approaches.

Mapping studies have also taken a theoretical and cultural turn in the last twentyfive years, with mapping increasingly re-thought (see Dodge et al. 2009). Following on from Harley (1989) research has increasingly focused on the social power of mapping. More recently emphasis has shifted away from 'power talk', towards a nuanced consideration of how maps code the world in different contexts, cultures and times (Pickles 2004). There is a growing emphasis on mapping as a cultural process (see Perkins 2008) and on performance (Brown and Laurier 2005).

In the light of this double critical turn this article offers a preliminary tracing and placing of the contours of map collecting practice.

2- The difference a map makes

Almost all collecting is artifactual and fetishistic (Pearce 1995). All collectors specialize. They want but fear completion, and pursue a systematic activity with a goal in mind. The notion of collecting as a disease, or form of therapy has been frequently employed. Serious collectors are obsessed. The need to acquire or control parallels the addictive nature of the pursuit, and the pleasure of the hunt. Many collectors acquire material for its historical or aesthetic interest. But what is unique about people who collect maps and what difference might a *map* make to collecting?

Maps share unique properties that allow people to draw metaphors between collecting and the process by which geographical knowledge itself becomes established in mapping (e.g. Pickles 2004 :124-126). The hunt for maps can be cast as a quest analogous to the history of cartography itself (Harvey 2001). So for many collectors the map becomes a souvenir, narrating a personal spatial story.

Place becomes translated and 'carried' in the map. Knowledge of the medium and its history may be required to understand the collection. The conservation challenges of older material demand a form of disciplined knowledge and practice. However the format of the map is not always convenient. Wall maps need an appropriate space to hang, and atlases pose storage problems.

Of course the same map may mean different things. As a cultural object, preserved and subsequently collected, a map is likely to take on new connotations. Collecting changes the role of the map: the image may come from one time but the collector is unlikely to live in that time and meanings change.

Given this mutability it is perhaps unsurprising that map collecting is associated with many different kinds of spaces, and that collecting practices need to be understood in relation to local circumstance. For the purposes of this paper the emphasis is upon contemporary British practice and a clear distinction may be made between two distinct types of individual collection: the antiquarian and the everyday.

3- Methods

This paper relies upon a critical reading of a number of different texts. Standard works offer valuable insights into the taken for granted assumptions of map collecting. Moreland and Bannister (1989), Manasek (1998) and Potter (2001) were supplemented by an analysis of web-based 'edicts' for collectors, from map dealers. Journals and newsletters devoted to map collecting form a third textual source, providing anecdotal evidence about the trade and priorities, practices and motivations of collectors. The prime sources were IMCoS Journal (1980-); *Map Collector* (1977 - 1994); *Mercator's World* (1997-2003) and *Sheetlines* 1981–).

In addition to these textual sources ethnographic work involved participant observation at auctions, meetings, visits, map fairs, and map libraries in the UK. In order to add depth to these qualitative data interviews were conducted with map collectors, dealers and librarians and supplemented by published accounts of the experiences of collecting, dealing or curating mapping.

Textual sources are limited to English language material and fieldwork was carried out in the UK. My role as researcher is clearly 'situated'. My research interests lie in critical cartography and contemporary ethnographies of mapping practices, but with a background in map librarianship. I have at various times collected maps, ranging from Ordnance Survey One Inch coverage, to maps on postcards.

4- Map collecting spaces

Antiquarian dealers display their wares in tastefully arranged galleries or shops: only a limited stock is displayed, an expert is available to assist intending purchasers. Shops are to be found in the right parts of major western cities; the most important centres are still London and New York.

Auction rooms are sometimes a place of competition for collectors or dealers. Only larger sale rooms hold regular specialist map sales, these are associated with the international fine arts market. Items are catalogued, described and displayed in a sale space, where they may be viewed. They are usually presented as each lot comes up for sale. The space is carefully regulated: collectors are usually only allowed in the sale room in a viewing, or in the sale itself, and rules of bidding must be carefully followed (French 1992).

The Map Fair is similar to a book fair, with dealers grouped together in a space where they buy and sell antiquarian stock, and where customers view and buy. Commerce is much more explicit here.

The map library or rare books room is also an important haunt for map collectors. Dealers research items; librarians acquire and process material; collectors examine rare items or compile carto-bibliographies; map societies visit or hold meetings in these spaces. Libraries only rarely display their maps, most of the time they are safely stored away from people. Many library spaces are reserved for library or conservational staff. Users are not usually allowed to access material themselves.

The collectors' meeting is a much more variable space, functioning to meet the needs of specific societies and members. There is usually sufficient space to meet and discuss specialities and display or swap maps.

Individual collectors store or display maps in their own private spaces. The more substantial the collection the more like a map library the space becomes. Smaller collections may be displayed framed on walls in the home, larger collections will require appropriate storage, cataloguing, and conservation work.

The Internet has allowed online equivalents of many of these spaces to be established. Discussion lists allow sharing of information, and have come to supplant many of the functions formerly offered by collectors' meetings. Auction sites like e-Bay offer an on-line forum for bidding for maps or selling material. Specialist web sites are maintained by dealers and have increasingly replaced catalogues, whilst societies market themselves on-line. Behaviour on-line is regulated: feedback from users is needed to sell your collection via e-Bay and secure payment facilities are required for on-line credit-based map purchase.

5- Antiquarian map collecting

There has been a long history of antiquarian interest in the acquisition of valuable, old, rare and beautiful maps and in particular in maps produced from copper-engraved plates, printed and subsequently hand-coloured. But they were also mass-produced and sufficient atlases survived in private hands to make them affordable to richer or more discerning collectors.

It is widely accepted that the worlds of map collector and producer were closely associated during the renaissance rediscovery of classical geographical knowledge. Atlases formed the archetypes of map collections, grouping together disparate geographical knowledge. Expansion of production led to an increase in collecting in the seventeenth and eighteenth centuries. Private libraries accumulated geographical knowledge and their collections increasingly passed into public hands: European Royal collections now form the core of major public map libraries. Sufficient atlases survived outside public collections to fuel the development of a market that emerged at the same time as significant disposable income was becoming available to collectors after the second world war.

Until mid twentieth century there were few antiquarian map collectors. The current trade in antiquarian mapping was created by dealers who ‘broke’ atlases establishing an affordable market. The London firm Francis Edwards dominated this sector of the trade in the interwar years through to the 1960s (Scott 1999). R.V.Tooley, the firms’ map specialist became the ‘grand old man of maps’ and, played a significant role in launching the collecting field through his publications.

5.1 Stability: local longevity for a discerning clientele?

In the early years the antiquarian the trade was centred upon London. European dealers visited Edwards to acquire maps and atlases of their regions (Scott 1999). The discerning collector built a relationship with a dealer who scoured the market for specialist wishes. Face-to-face contact was important. Dealers were keen to stress the longevity of their businesses. The trade is still painted as conservative and reliable. Dealers still encourage collectors not to risk getting their fingers burnt at auction and map galleries still exhort collectors to rely upon the dealer as a filter against the ever-present danger of forgeries. The *need for authenticity* is a powerful discourse underpinning the operation of the trade.

As the market disseminated across Europe and to the USA, so craft service came under pressure from global and capitalist forces. New more aggressive players entered the market. Map Fairs have offered an alternative to selling from a gallery. IMCoS the International Map Collecting Society grew from a largely British membership to a much more global force: now around 70% of its membership are not British and over 30% of its membership is American. Its prime event is a four-day annual symposium. Regularly updated web sites sell mapping, e-mail allows dealers to keep in touch with their customer base and e-Bay allows customers direct access to on-line map auctions. Web-based dealing has eroded established power relations between dealers and collectors, allowed new and small entrants equal access to their longer established competitors. But the trade remains anchored to the money and market and the traditional centres of power remain in London, and New York.

5.2 Monetary matters

Dealers' introductions to collectors urge them not to regard antiquarian maps as an investment, but investing collectors and dealers have vested interests in encouraging a healthy growth in prices. Since 1983 prices reached by maps and atlases at auction have been collated and are available in machine-readable form with annual update in (Maprecord 2010). Examination of these records reveals a growth well in excess of inflation for many kinds of antiquarian mapping. Dealers recount an ongoing rise since the 1970s of between 5% and 20% a year in antiquarian maps prices, reflecting growing demand.

The trade was not a neutral participant in this process. Dealers published books seeking to attract new money to the emerging map market (see Baynton-Williams 1969). Some dealers were able to inflate prices in a rising market, notably the largest map dealer in the twentieth century, W.Graham Arader III, who now enjoys a turnover in excess of $10million a year, operates a chain of galleries across the USA and whose fortune exceeds $100million. Meanwhile anecdotes reflect nostalgia for the days when their collections could be acquired for little money on market stalls. By the mid 1990s concerns were being expressed, and especially in the USA, about the limited supply of new antiquarian material for the private collector.

5.3 The regulated cult of the expert

The new collector of antiquarian mapping reads about appropriate skills and behaviour in journals, web sites and instructional collecting books. Dealers' edicts reveal the values of hegemonic map collecting practice. A remarkable sense of social regulation and cultural class emerges from this process, centered on deference to the expert.

The literature venerates the 'grand old men': biographies, anecdotes and even novels create myths about eccentrics in the trade, be they the raffish but charming figures from the past like R.V.Tooley, contemporary dealers like Graham Arader III (see Kennedy 1996), or tales of specialist collectors (e.g atlas collector Roger Baskes (see Baskes 1996)).

The ability to verify authenticity and catalogue a map are important skills for the collector to learn. Carto-bibliographies mark and encourage new collecting areas by establishing targets at which collectors can aim. Few antiquarian collectors have the time to develop skills in these areas, they rely on experts. Skills almost become a form of alchemy: customers' wishes are satisfied by the dealer tracking down the object of desire and making it available to the collector. The myth of 'the discovery' is a powerful force, collectors' tales abound in which a 'new find' is unearthed in a dusty library, or appears on the market, is recognised by the cognescenti e.g. Brenchley (1988). Dealers' skills in divining cartographic rarities allow them to maintain their best 'clients'. The hunt and knowledge combine to evoke expertise, novelty and a focus for story telling.

Meetings of antiquarian collectors frequently hold sessions where favourite maps are presented by owners. These tales often revolve around certainty and control: the map is 'discovered', its significance explained. Selling or dealing is very much *not* a part of this space: instead the expertise and taste of the collector is on display in front of peers, identity is embodied in the object and its narration.

5.4 The social collector

The different actors and institutions in the antiquarian map collecting field are rarely separate or bounded. Librarians become academics, dealers also collect, dealers become librarians, collectors become experts etc. The largest antiquarian dealers either started out as humble collectors, or inherited the business. Maps pass from dealer to collector and back to dealer. Disposal may lead to collections being auctioned off and split up, or bequeathed to a public collection (Karrow 2001).

Tensions exist between these roles. Poorer collectors resent what they perceive to be unaffordably high prices charged by dealers; librarians are appalled at atlas breaking and resent collectors who want to keep their accumulated riches away from public view. However despite the apparently anti-social nature of the desire to accumulate antiquarian maps, social inter-relations are central in antiquarian map collecting practice. Map collecting societies organise regular meetings, visits and conferences and publish newsletters or journals and are thriving (see Barrow 2003).

A brief consideration of IMCoS events illustrates the central importance of continuing face-to-face contact. The key event is the International Symposium, with presentations, visits, receptions and cultural trips. The pace is leisurely, with plenty of time for participants to enjoy each others' company, eat and drink well. Most members attending events are older or richer or both. More men participate, but significant numbers of women attend, very many more than participate in everyday collecting (see below). Visits at the International Symposium evoke the cultural values of the institution, and its members: high, establishment culture is worthy of a visit. More local visits are also appropriately high-brow. These events are recalled in articles and pictorial images in the *IMCoS Journal*.

So an interest in antiquarian mapping signals membership of an elite group. Discerning collectors need money to buy rare and increasingly expensive items; to participate in conferences; to be a client of the 'right' dealer, but they also need taste. Antiquarian collectors' taste is reflected in knowledge of their artefacts, in the nature of the displayed artistic images decorating boardroom, study or library and in their participation in IMCoS. A clear case of social distinction, with cultural consumption and practises marking class position (Bourdieu 1984).

6- Everyday collecting

Market research suggests that only 1% of the British population buy a map in any year and that purchasers are almost all middle class and male (Ordnance Survey 2002). However mass produced everyday printed maps are readily and cheaply available.

There are sufficiently complex patterns of variation amongst these publications to appeal to collectors. Topographic maps display complex publication histories revealed in marginalia and print codes. However mass-produced contemporary mapping differs significantly from antiquarian maps. The aesthetic is hidden in the practicality of the image: contemporary topographic surveys are standardized not aesthetic, a significant change from more artistic antiquarian images, collected for their look. Also many more copies of current mapping are printed than was ever the case in the era of copper-engraved production. Such maps have relatively low second-hand values, usually less than the costs of a new edition.

In the 1970s and partly in response to inflating prices of antiquarian material a growing number of people became interested in collecting these prosaic cartographic images. Specialist collecting organizations were formed to foster knowledge of the collecting field. In the UK the Charles Close Society for the History of the Ordnance Survey (CCS) was established in 1980, ostensibly to encourage the serious study of the history of the national survey and its products, but in practice to meet the needs of a growing collecting market (see Perkins 2006). Paradoxically the ubiquity and ephemeral nature of digital mapping on the web may encourage nostalgic collecting of the fixed published format.

6.1 Completing the sequence

Many collectors of everyday maps choose to focus upon one area. For some the collected map offers, an autobiographical glimpse into past experiences of that place (e.g. Harley 1987). However many everyday map collectors merely aim for a complete collection of maps of their chosen topic. Hodson (1991) describes collecting Lake District OS coverage: acquiring all of the states of ‘standard’ series coverage, but also collecting special editions covering the area. This quest for completion is much more significant for everyday collectors than in the antiquarian field. Such a concern may reflect a world where certainties no longer predominate, and where control over a field becomes an important part of identity. For antiquarian collectors such an emphasis upon completion is usually unattainable, given the costs and rarity of the quarry.

The emphasis upon the ticking off yet another target has consequences. Many more maps are accumulated than may be possible for antiquarian collectors. Many OS collectors trace different states of their chosen OS coverage. In the early years of this collecting field carto-bibliographic activities have been significant, paralleling early emphasis upon listing of antiquarian map states. Monographs have been published by the collecting societies and CCS is notable for the quality of its publications. The experts in the field are the collectors, rather than academics or the trade.

6.2 Not so much a trade…

The ready availability of mapping and limited number of specialist collectors with interests in the area mean little money can be made from everyday collecting. As a consequence no significantly developed trade exists. The CCS maintains a list of dealers in Second Hand Ordnance Survey maps that documents 13 specialists trading in secondhand OS material (Charles Close Society 2004b). Only five of these specialists run web sites, and only one trader maintains significant stock and specialization. He is the only one to have published finding aids or bibliographic materials for the collector. Few of these ‘dealers’ seem to be making much money from buying and selling OS coverage. None are clustered in elite urban areas. Instead they are informal operations, often run from home and on a part-time basis. The ‘trade’ in secondhand OS mapping is much more in the control of the collectors themselves, or else part of other trading places. Maps are sought from general second-hand book dealers, at auction, from car boot sales, charity shops, jumble sales and from other collectors. A relatively small community of collectors swap arcane detail about their collecting interests or request mapping via the specialist e-mail list OrdnanceSurvey@yahoo.co.uk. Deals matter less than knowledge.

Everyday collecting space appears much less regulated than antiquarian collecting. Few edicts for new collectors are published. Instead it is assumed that they will progress through love of their collecting to appreciate the importance of a serious concern with the history of the artefact.

6.3 Serious history?

Just as the rhetoric of antiquarian collectors emphasizes that taste predominates over money, so the everyday urge for completion is hidden in a rather different rhetoric. Everyday collectors mask their systematic obsessions in the dressing of historical study. Proudly displayed on the CCS web site until a recent reworking was a quote from the early constitution of the Society, which welcomes potential members with the statement that '*although the role of serious study in the Society's activities is emphasised, do not be put off by this if your concern is of a more relaxed nature - the curiosity of the casual collector is most welcome for it often prompts the unanswerable question for someone to work on*. (Charles Close Society 2010). The Society now has over 400 members, and the majority of these are probably 'casual collectors', rather than being concerned with 'serious study'. However a surprisingly large number participate by writing for the society newsletter *Sheetlines*: the 88 issues published up to 2010 include significant contributions from around 130 different members.

The serious work of advancing historical knowledge is also reflected in social activities. At first glance CCS programmes seem similar to antiquarian map collecting society activities. CCS members hold meetings, organise visits, publish a newsletter and operate an Annual Map Market. However visits are much more serious and practical than the cultural frippery of IMCoS. Regional groups meet to swap maps, share stories of research and visit institutions. Activities also differ. Show and tell sessions also feature in regularly held map markets, but these are very different from IMCoS presentations. They are much less about individual treasures, 'discovery' and possession. Instead they emphasize recounting progress of 'work'. A CCS Map Market is a commercial space, where exchange of material amongst collectors takes place. The CCS newsletter *Sheetlines* emphasises the detail of the pastime, not the the social context of members participation. Its style reflects the membership: packed with detail, and almost cut-price in comparison to lavish antiquarian publications. Lists and research articles predominate.

6.4 Focused masculine collecting

CCS comprises an altogether more stereotypically male set of activities and discourses. For most members beauty is less important than investigation, listing matters and serious research predominates over wider markers of cultural taste. Most members rely upon *Sheetlines*, or online discussion groups for their social contact (Jarvis 2004). Only a small percentage regularly attend meetings and CCS surveys suggest over half rarely attend.

This rather more asocial focus is a reflection of the membership profile: the overwhelming majority of CCS members have always been male: there has never been more than around 15% female membership. It is men that turn up to CCS meetings, write almost all the articles, and rifle through the boxes of One Inch OS maps at car boot sales. A wider range of people join CCS: wealth is not a factor limiting access. So the world of everyday mapping is gendered and classed differently from that of the antiquarian collector, and with different social practices.

7- Conclusions

As a format of collectable artefacts maps are ambivalently linked with their collectors' relationship to place. This study highlights significant differences in the nature of antiquarian and everyday collecting that stem from different formats, and from different performances of collecting behaviour.

The values of antiquarian collecting are inherently conservative: authenticity, verified historical rarity, beauty, and the display of taste by a largely aging and wealthy group of collectors, who sometimes value their collections as investments. Only the very rich are now able to amass significant numbers of antiquarian maps or atlases. Despite the impacts of globalization and modernization dealers remain an important part of this trade and social contact remains important. Collecting requires specialist knowledge and is well regulated.

In contrast the world of the everyday collector is altogether less aspirational. Maps are cheaper and easier to acquire and the detail of amassing and completing a collection becomes more important. More maps are acquired. The pastime is less regulated and trade is less of a business. Collectors value their own specialist knowledge, rather than relying upon expert opinion. Collecting activities and spaces are more local, and everyday collectors are disproportionately male, with a much wider spread of social backgrounds.

These differences suggest that we need to understand map collecting practices as 'placed behaviour', in which economic relations are mediated by local culture. A reassuring conclusion in an increasingly uniform globalized world.

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The Atlas Toolbox: Concept and Development of a Rule based Map Component for a GIS-VIS Production Environment

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Abstract

In commercial mapping and atlas cartography cost-effective production of maps and atlases is a constant issue in the business concept of commercial cartographic enterprises. A combined GIS and visualisation system can be considered the production environment of choice for quality, cost-effective map production. To strengthen the visualisation component of such system, one concept of particular relevance is that of the atlas toolbox. Using the modular principle this framework allows for the production of maps and atlases by combination of technical or cartographic components and methods. This paper discusses the concept and application of one particular component, the map component, for automated, rule-based quality map construction.

1- Introduction

The development and production of maps and atlases, in particular, is costly and time-consuming. For this reason cost-effectiveness of atlas production has been a constant issue in the business concept of atlas producers. Based on the present state of geoinformation technology (GIT) several concepts have been elaborated to reuse map and atlas components originally developed for one particular map or atlas in other products. Any random review of existing paper maps and electronic maps will show that maps and/or atlases can roughly be assigned two categories: poor map

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graphics, but cost-effective map/atlas production, and quality maps/atlases, but poor cost-effectiveness.

The atlas toolbox (ATB) is one practical solution to the continuing problem of cost-effective production in atlas cartography (Asche 2009a,b). In brief, the ATB provides components and modules to compose atlas maps and complete atlases from existing building blocks. Professional map quality is the principal goal of any professional map production, whether analogue or digital. To produce quality maps and atlases, such contrasting requirements of product versatility, professional cartographic visualisation and economic viability will have to be accommodated in a modular production concept. One particular aspect of the ATB, the rule-based construction of atlas maps using the modular principle is discussed here. Particular attention is given to professional cartographic visualisation of map data.

2- The production environment: GIS+VIS

The use of geoinformation systems (GIS) in cartography allows for the production of map graphics from the corresponding geometry and attribute data in the GIS database. GIS packages available in the IT marketplace fall into two broad categories: commercial software systems (like the market leader ArcGIS) or free and open-source software systems (like the open-source Quantum GIS or GRASS). GIS lack both the graphics functionality and quality characteristic of state-of-the art graphics or map construction packages (such as the Illustrator or Nuages software systems), summarised here as visualisation systems (VIS). That is why quality map production is, to date, mainly based on graphics software systems, either directly or indirectly. In the first case, graphics packages, and to a minor extent, map construction systems, are the sole means of map production. In the second case, VIS packages are used to finalise the raw map visualisations imported from GIS. What would be required instead is a combined GIS-VIS system at the heart of a professional map production environment.

2.1 GIS fundament: data-based map construction

At this development stage of GIT high-performance GIS have established themselves as the core component of a map production environment. GIS provide digital storage, processing and analysis functions of relevant geo-topographic base data as well as attribute datasets of varied geographic and thematic resolution. The actual construction of atlas maps and compilation of complete atlases is performed by object-related combination of data stocks stored in the GIS database. The generation of analogue map-like graphics from selected atlas datasets makes use of the standard presentation functionality of GIS. Any manipulation of the digital atlas datasets can be visualised, thus adding to the variants of GIS maps. If required, the resulting compilation can be supplemented individually by external geodata for specific application projects or at users' requests. Today, a substantial number of digital atlases and AIS are based on this production concept (Asche 2009a,b).

The interconnection of database and map graphics is considered the key asset of GIS, whereas, the lack of map visualisation quality complying with cartographic principles of (thematic) is the fundamental disadvantage of GIS in map production. In fact, the vast majority of resulting maps is suboptimal to inappropriate and thus would rather count as map-like representations. An unsystematic and cursory analysis of the map graphics of GIS-based AIS (national, regional or thematic atlases) confirms this finding (cf. Asche 2007, 2009a, b).

2.2 VIS complement: quality map visualisation

To compensate the shortcomings of GIS map visualisation, the GIS basis is complemented with a high-performance VIS system. In a map production environment this essential component ensures professional cartographic map modelling and visualisation. GIS and VIS components are coupled via software link which, in principle, permits a bidirectional data and graphics transfer. The software link (e.g. MaPublisher) primarily allows for geodata stored in the GIS database in separate layers to be imported into the VIS component in the existing configuration. This facilitates quality map visualisation based on the layer principle familiar from Desktop Mapping (DTM; e.g. Herzog 1988, Whitehead & Hershey 1991). Map models professionally visualised from GIS data using DTM software

are subsequently reprocessed for the designated distribution channels (web, data media, print) and tailored to the targeted user interaction.

Interaction of the GIS and VIS components is embedded in a generic process chain (Wolff & Asche 2008). In this workflow the GIS and VIS components act as a system back- and frontend. The GIS backend allows for the graphic-free processing, storage and management of the atlas stock. The VIS frontend facilitates a graphic-oriented analogue visualisation of the selected atlas datasets fully in line with cartographic quality requirements. According to the application or visualisation requirements the VIS frontend can either be a vector-oriented 2D VIS package or a complex 3D VIS system (Wolff & Asche 2008). The current edition of the Swiss national atlas can be considered an exemplary exponent of the GIS-VIS component solution (Sieber & Huber 2007). To date, a fully integrated GIS-based GISVIS system is not available, since a professional solution would require the automatic derivation of a scalable graphic model from the digital GIS data model.

2.3 Map module: rule-based map compilation

In this context efforts in the ATB research presented here are directed to engineer and automate quality map production in a GIS-VIS environment. This can be accomplished by conceptualising a framework of rule-based quality map production using the modular principle. The development and implementation of the ATB component will significantly contribute to optimal visualisation of map data as well as professional, cost-effective map production. For this reason the ATB concept includes a separate visualisation (VIS) module for professional cartographic map modelling and visualisation (Buckley et al. 2005).

3- The ATB component system

While the GIS-VIS environment outlined above can be considered the technical software basis of professional map production. In contrast, the ATB provides methods, rules and components for the appropriate application of both systems. To account for the variety of tasks characteristic of atlas and map production the ATB is made up of several components, of which the map component is discussed in the following in more detail. All other ATB components are modelled on the structure of the map module. Similarly, the hierarchical order of their stacks and cards can be transformed into a flexible, task-oriented network, as is exemplified below.

3.1 Modular principle

The map component is broken down into a number of modules which, in turn, are composed of a number of stacks, each of which consists of an array of cards (fig. 1).

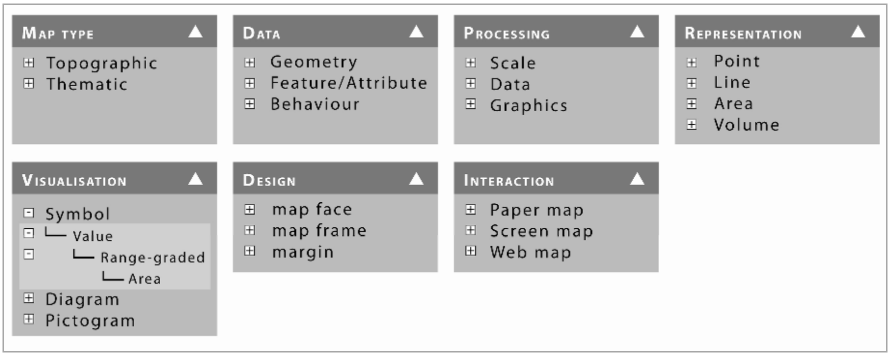

Figure 1: Modular organisation of the atlas toolbox: component, module, stack, card, element, demonstrated for the visualisation module

This structure is generic which allows for a flexible, task-oriented adaptation of the production environment for specific application. If required, new modules, stacks and/or cards can be added to the existing modules and stacks, respectively.

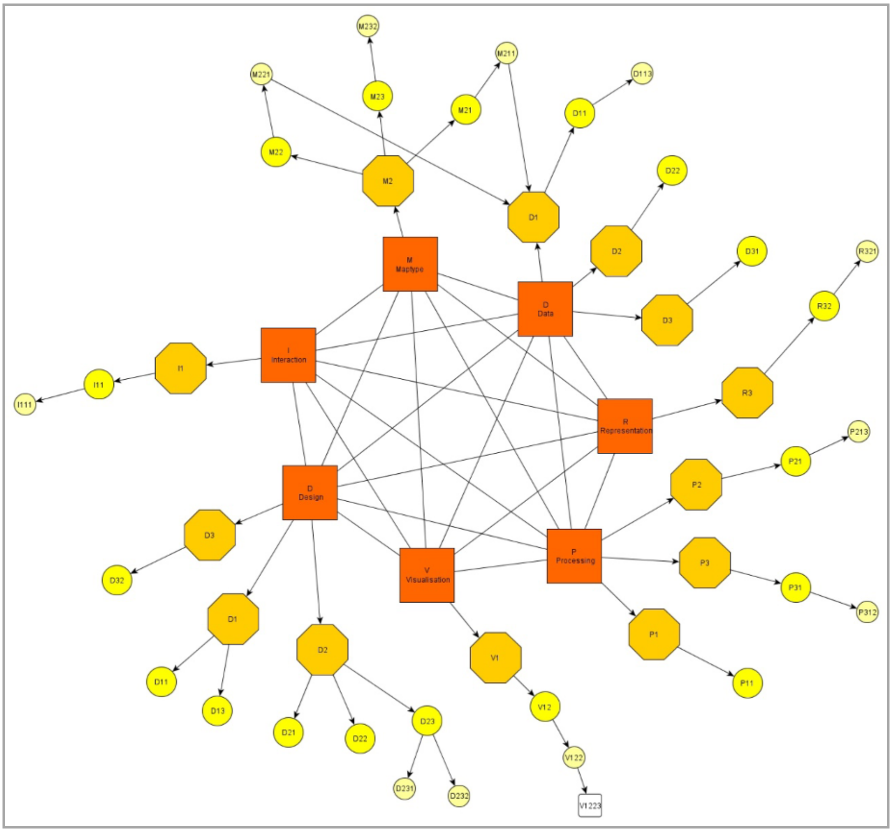

Figure 2: Modules, stacks, cards and elements dynamically linked by hyperlinks, exemplified for the construction of a typical choropleth atlas map: population density. Source: Demographic Atlas of Albania (Bërxholi et al. 2003).

Each card consists of a number of elements which can be considered the basic building blocks of a map. New elements can be added to any one card if necessary. Attributes can be attached to each element for further differentiation. Modules are ordered in a linear sequence which basically mirrors the production steps of the map compilation process. The internal structure of each module is hierarchically ordered in a sequence of layers. This is essential to facilitate subsequent implementation into a software system. An intuitive, easy-to-use graphical user interface will provide step-like directions to compile a map following the rule-based steps of cartographically correct map production (fig. 2).

3.2 Hyperlinks

However, such strict linear organisation is not characteristic of real-world map production. To accommodate for a more flexible, dynamic map compilation process, stacks, cards and elements of each module can easily be connected by hyperlinks. In principle, this allows each card of every stack of each module to interact with any other card in any other stack of each module. To facilitate for professional, quality map generation the ATB-based production process restricts the range of links to a limited number of cartographically correct combinations of cards, stacks and elements (fig. 3). The practical application of the ATB map module in digital atlas map compilation is dealt with below.

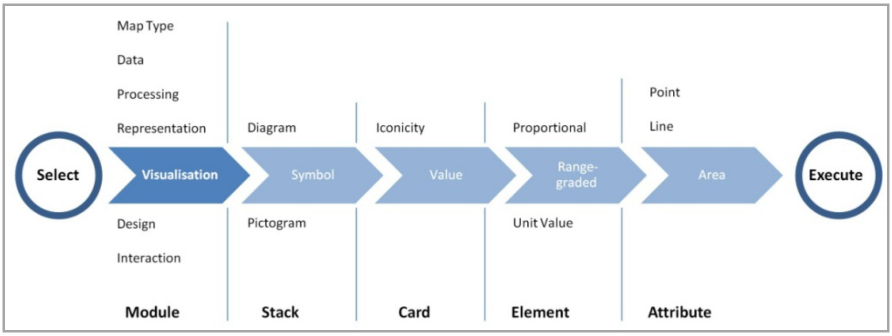

Figure 3: Graphical user interface (sketch) of the atlas toolbox map component: the next step of map generation can be performed only once the previous step has been completed successfully

3.3 Patterns

In commercial map production the majority of maps produced is based on a rather limited number of map types and visualisation patterns due to a limited number of applications, map purposes, and audience. For the repeated construction of specific map types, modules, cards and/or stacks can be assembled to form characteristic map patterns. Such map patterns can be saved as predefined configurations in an ATB pattern library. If required, additional cards (and stacks) can be added to these pre-assembled patterns for a specific map production task.

3.4 Development status

At present, the structure and building blocks of the ATB map component presented here are in their conceptual stage. The modular concept has been developed with a view to create an automated construction process based on an interactive software application. The development and implementation of the ATB map component is currently under way. Conceptualisation and development of the map component is primarily targeted at cartographic businesses the majority of which are small and medium size enterprises (SME). However, the system can easily be modified to provide, for instance, a web-based quality map visualisation service available for the specialist and layperson alike. Due to the complexities and variability of map production a fully operational ATB system can only be expected in the medium term.

4- Applying the ATB: compilation of a choropleth atlas map

The application of the ATB map component is demonstrated taking the composition of a choropleth map from the Demographic Atlas of Albania (Bërxholi et al. 2003) as an example. The map topic selected is population density, the spatial reference is the communal level (fig. 4).

The map compilation process starts by selecting the *map component* in the ATB environment. Once this is done, the relevant modules with their specific functions are selected. The modules are sequentially ordered. In the selection process users are automatically advised to keep to this order if necessary.

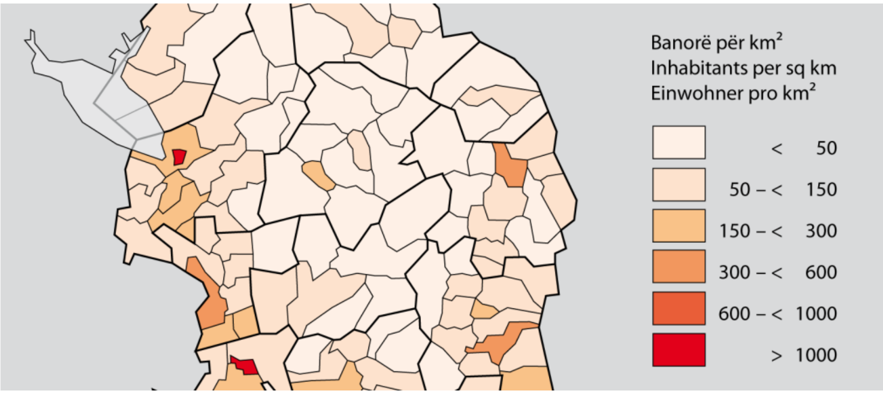

Figure 4: A typical choropleth atlas map: population density 2001 (detail). Source: Demographic Atlas of Albania (Bërxholi et al. 2003).

The *map type module* specifies the exemplary population density map as a thematic map which is made up of a map theme and a base map stack. The map theme stack comprises an array of cards of which the density card is applicable here. The relevant thematic element of that card is population density. Likewise, the relevant element of the base map card is boundaries. The attributes relevant here fall into two categories: natural boundaries, such as the land-water boundary, and administrative boundaries, such as state, provincial, district and communal boundaries.

The *data module* includes geometry, attribute, and behaviour stacks. The relevant card of the attribute stack, linked to the theme card, is that of quantitative data. This card contains qualitative data and quantitative data elements of which the latter is selected. In the geometry stack the relevant card is discrete data which is subdivided into point, line and area data elements of which the latter two are selected and linked to the theme card and base map card, respectively.

The *processing module* comprises map scale, data modelling and graphics modelling stacks. In the map scale stack, the small scale card is selected. The data modelling stack includes scaling and classification cards. The scaling card contains nominal, ordinal and metric elements of which the latter is applicable. For map compilation the metric data modelling element is linked to the area data element of the geometry data stack. In the graphics modelling stack the card selected is the generalisation card which includes scale-oriented and theme-oriented elements. The theme-oriented element is selected for generalisation and linked to the population density card as well as to the boundaries element of the base map card.

The *representations module* includes point, line, area and volume stacks. The relevant area stack comprises area, cartogram and diagram cards of which the cartogram card is linked to the qualitative data card in the attribute stack of the data module and the classification card in the processing module.

The *visualisation module* is composed of symbol, diagram and pictogram stacks. The relevant symbol stack includes cards of iconicity and value. The iconicity card consists of pictorial and geometric symbol elements of which the latter is selected. The value card contains proportional, range-grade and unit-value symbol elements. The relevant range-graded symbol element has an area attribute as the spatial reference unit which is selected and linked to the ordinal scale element of the data modelling stack.

The *map design module* organises the overall graphic arrangement of all selected map elements on a paper map plane or computer screen. This module includes stacks of map face, map frame and map margin. The map face stack consists of base map, grid and lettering cards. The base map card includes elements of partly or fully mapped map face, the lettering card provides for area lettering. The map frame stack includes map frame and no-map-frame cards the latter of which is applicable here. Cards of map legend, map title, map scale and data sources compose the map margin stack.

The *map interaction module* includes paper, offline and online interaction stacks. In the paper map interaction stack the view-only card is relevant.

It is obvious that the chronological description of the map compilation process underlines the hierarchical ordering and structure of the modules. Due to the instrument of hyperlinks this can flexibly be adapted to specific requirements of the mapping task at hand. In an atlas context, depending on the map topic, a number of production steps can be combined by defining reusable map patterns. Taking the population density map as an example, possible patterns are shown in fig. 5.

Extending the pattern concept to the full range of maps in the Demographic Atlas of Albania, 56 maps can be produced by using predefined density map patterns of a total of 65 maps.

5- Embedding the ATB map component in a GIS-VIS production environment

The integration of the ATB map component is part of an ongoing R&D project funded by the German ministry of economics and technology. In the project a main objective of this collaboration is the development of a fully integrated GISVIS environment for commercial map and atlas production. One particular goal of our research efforts in this context is to implement rule-based, automated quality map construction in the production process. All collaborators are aware of the fact that full integration of the VIS component into one complex GIS-based system is a challenging task. However, the lack of integration of the GIS and VIS components, resulting in suboptimal map graphics as mentioned above, has also found the attention of commercial GIS developers (Buckley et al. 2005, Hardy 2009). A major breakthrough, supporting map generation in line with the princples of adequate map visualisation, has not been achieved yet.

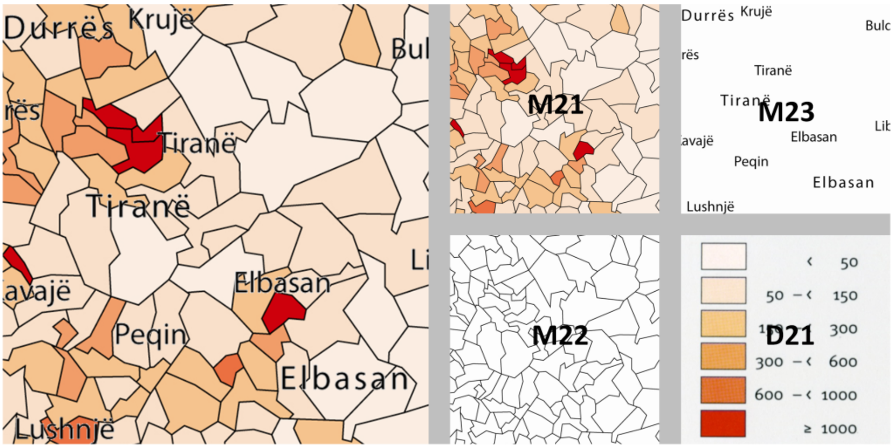

Figure 5: Map patterns compiled from characteristic combinations of stacks, cards and elements, exemplified for the construction of a typical choropleth atlas map: population density. Source: Demographic Atlas of Albania (Bërxholi et al. 2003)

Once finalised, the successful development and implementation of an integrated GISVIS production environment will significantly enhance the cartographic quality of map visualisations and provide consistent production quality throughout map and atlas production, respectively. At the same time investments in cost and time will substantially be reduced – this time not at the expense of map quality. From a professional cartographer's perspective the ATB map component is a long-needed tool to advance versatile, cost-effective production of quality maps and atlases thus creating a realistic business perspective for the majority of cartographic SMEs.

6- Conclusions

The discussion and exemplary application of the ATB map component in the wider framework of a GIS-VIS map production environment shows that systematic, rule-based construction of quality maps can both be upgraded in terms of quality and accelerated in terms of production time. The modular principle makes it feasible for cartographic businesses, particularly of the SME type, to offer quality map productions services at competitive costs. For the geoscientist a modified ATB provides an effective map compilation environment facilitating cartographic visualisations which comply with the fundamental principles of (thematic) cartography and thus are simply effective. While the sustainability of the ATB concept is the subject of ongoing research, the importance of such development can easily be seen, for instance, in a current R&D project with the German Aerospace Centre (DLR) on a Mars information system. In this project, a GIS-based visualisation module is developed to provide mars researchers with a fully operational, easy-to-use mapping tool for quality map production (Nass et al. 2010, 2011). At present, no such tools are readily available in commercial GIS utilised – notwithstanding the recent developments of "cartographic representations" (e.g. Hardy 2009). Once developed, the tools discussed in the ATB map module will also benefit earthly cartographers and scientists.

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Use and User Issues

What do People prefer and What is more effective for Maps: a Decision making Test

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Abstract

Since the roles of intuition and affection in map use and the relationship between these processes and the effectiveness in activities supported by maps have not been completely measured, this paper intends to bring a contribution to the discussion about the relationship between subjective preference and objective performance. A series of experiments with graduation students was carried out, asking students what they would prefer as a desirable type of map to use for an analytical decision-making process and then their performance of this process was measured. To ensure the validity of the experiment, maps used for this study were designed using a social background as their theme, with analysts being asked to decide where to invest public funds. The same experiment was conducted first using a subset of paper maps (1st stage) and then using interactive web maps (2nd stage). Three types of subsets of thematic maps were assigned randomly among the respondents. Statistical tests were applied and the correlation between preference and performance in this experiment was measured. Results for the 1st step show that there is no significant variation due to the technique used in the performance tests, and for this specific subject, there is insufficient evidence to guarantee that user's preference among map techniques can lead or is related to better performance. Also it was noted that performance decreases for a reasoning related task, and maybe this could be related to the need for a deeper analysis of data evolution through time.

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1- Introduction

In the last decade, mainly because of the Internet, cartography and geographic information reached a new popularity level, which considerably increases the "interactivity problem" of geospatial data communication. With interaction more and more present in people's lives, the "old" maps are being replaced by complex visual displays and users interact directly with data, using previously prepared usable interfaces. Facing the challenge of almost real-time information flow, paper maps, now also called traditional maps, are still being used. These old-fashioned static means of representing world geographic phenomena by graphics are respected by people, who seem to consider them as documents free from errors and that express the truth about the world.

However, there are many specific factors that can be decisive in the effectiveness of map communication. These are related not only to a user's characteristics and personal experiences but with the nature of the task being executed with the help of maps. Interaction science foundations can provide several aspects of interest, for example the influence of gender studies, cultural factors, communication theories, power relations, cognitive experimentation and semiotics, for the technology and society relationships. The measurement of what users prefer is an old concern, and has its place in interaction design studies. It is important to remember that nowadays these users can be organized employing a great diversity of personal characteristics and experiences, which presume that there are appropriations not yet imagined for the final products. The "intuition" variable can be explained by all of the previously cited aspects of interest for interaction studies, including reasons for this or that choice and the consequences of it, but one can argue that this variable study lacked systematic validation procedures, such as matching user's intuition of what is better and what is proved to be better to accomplish some specific task. This kind of belief is what MacEachren (1995) termed as connotation of maps, and besides its intuitive characteristic, it clearly plays a very important role in the way meaning is derived from map symbology.

The success of cartographic products depends on a well-achieved combination of meeting what users need, what users want – including what would make its usage an enjoyable experience – and their capabilities. Research in this area can lead map design principles to encompass attractiveness as an important factor related to performance. Besides, to know what visual variables used in mapping techniques are believed to be more efficient to accomplish tasks will lead to reflections about user expectations and what map-makers can do to satisfy them, especially concerning the less-specialized audience products.

MacEachren (1995) affirms that the user's interaction with a map is a complex information processing event and cognitive representations of what is seen are built in order to later provide the basis for understanding the map. So, cognitive science plays an important role in this kind of research: psychology science sees cognition as an interpreter of the world in which we live, in order to provide better knowledge and understanding of it. However, our preferences, related not only to cognition but also to affect, also help us to understand, acting as a system of judgment, indicating what is better for survival (Norman 2004).

This research relies on the belief that people prefer visual variables based on personal experiences and cultural factors, that, in Brazil, led to the intuition that color variation is the best choice to analyze geographic phenomena. The main hypothesis being evaluated is that this intuition is not always directly related to deeper levels of understanding and knowledge about what is depicted, and as a consequence, color would not necessarily be more effective than other graphic variables when analyzing spatial data in order to make a decision, considering the same conditions.

1.1 Visual perception

Visual perception is the ability to visualize and embed the light signals that reach our eyes with meaning. Gordon (2004) reminds that human perception occurs in two distinguishable environments, the natural and the artificial. One is related to all the natural surfaces, textures and patterns which are part of the perception evolution since early ages. The other is formed by the human culture, which deals with language, symbols and several artifacts that are human creations. It seems to be important to take into account both environments, adding a real context to the experiment itself, that, in turn, must look like the situation in which is understood as a feasible map use situation for the map techniques and graphic variables used by them.

Perception is associated and maybe dependent to visual cognition which is the first dominant aspect of dealing with graphic variables for map symbols. The vision itself has stages, which are distinctive: the *preattentive* element of something we see is called immediate because there is no need to focus attention on specific objects in the image: the target simply seems to "pop out" in a effortless manner. *Attentive* stage is sign by sign perception, which could be defined as the arrival of a conscious thinking, despite of the preconscious visual early stage. As cited by MacEachren (1982), symbolization is of interest in cartography because it can be most easily controlled and can produce the most notable change for representation of data. Research on visual variables for maps was mostly based on the work of Bertin (1967) and this author empirically defined classes of graphic variables that would be basic to derive meaning from representations. Visual variables fall into two main functional distinct classes: planar and retinal ones.

The variable location, as Bertin (1967) states, is dominant over any other, since it does not require any specific focal attention and is, according to Green (1998), the only attribute which all visual modules share, making it optimal for depicting correspondences. Maybe the mostly used and subjected to experimental researches visual variables are the retinal *color value* and *size,* which have a perceptual dissociative nature, according to Bertin (1967). Slocum et al. (2009) synthesize cartographic most recent researches and assemble several important works where map-maker can figure out some basic guidelines in color use for maps (Brewer, 1994; Mersey, 1990) and applied size use for maps research (Flannery 1971; Brewer and Campbel 1998; Dent 1999).

1.2 Emotional Map Design

In the design of interaction since the emergence of usability theory, there is a growing interest in how aesthetics can affect performance. Norman (2004) affirms that attractive things makes people feel good which, in turn, makes them think more creatively and will lead to better results in any task. This can be brought to map design, since a map is indeed an artifact with which people interact. If they are not interested, it seems to be unfair to expect high performance levels for any kind of task, especially in a cultural heritage where little use of maps is made in support of everyday activities.

Among others, one issue related to this scenario is education. In Brazil, first contact with maps usually takes place in geography classes at school, held when children are about 11 or 12 years old. Usually, parallel to regular school, it would be desirable that students acquire a sense of space and knowledge about their own geographic world using maps frequently. This use – or its absence – together with what is indirectly acquired from personal experiences, are essential parts of any decision-making process that deals with location. Therefore, any attempt to understand the process of deciding what is best with respect to maps has to consider, in addition to the obvious expected task performance, the user's background.

Hegarty et al. (2009) define the term 'naïve cartography', referring to common-sense intuitions about the best manner in which to visualize geographic data. The same authors argue that whether correct or erroneous, these intuitions will influence behavior and reasoning when working with maps. Both the map design taking user's preference into account and the manner that this user believes to be the best one to deal with a map seems to be important issues for 21st century cartography and can be grouped in emotional map design research, analogous to Norman's field of knowledge in human computer interaction science.

2- Methods

The methodology adopted for this experimental research was developed in order to measure the effectiveness of three different mapping techniques, and as a consequence, three different visual variables: color, size and location. Choropleth, proportional range-graded symbols and dot mapping techniques were used to measure the importance of these graphic variables for decision-making based on spatial analysis.

In the context of the test, users were asked to assume the position of consultant for the municipality of Maringá (PR). To make decisions about where to allocate financial resources, the public health department adopted a participative strategy: Consultants, people generally not related to public departments, are hired to give opinions about how and where the budget is effectively applied. Professional cartographers were asked to produce maps in support, considering that consultants have no specific knowledge of cartography or health care issues. Express instructions about this context were orally presented to the subjects, in a way to make this situation as close as possible to a real one.

Data used in the test is from the "Pastoral da Criança[1]" database[2], corresponding to real data about three different health indicators, which are assumed to be for the years of 1995, 2000 and 2009. These indicators are: "malnourished pregnant woman"; "child mortality", and "malnourished recent-born children". For the choropleth and proportional symbol techniques, data was standardized, while for dot maps absolute values were employed. All data was collected at parish level, which is the smallest area unit for this database. In order to make possible the comparison of the three mapping techniques, the size of area units was made uniform, as not to do so would possibly have had influence on the user's reasoning on phenomena analysis.

Nine choropleth maps were built and three maps per theme were organized in an A4 sheet, each one referring to a different year (Figure 1). In an analogue way, nine range-graded proportional symbol maps (Figure 2) were also disposed in three A4 sheets, each page related to a different health indicator. For dot maps (Figure 3), six maps were built, and the arrangement was to dispose three different health indicators per A4 sheet, for two years: 1995 and 2009. Data was classified using optimal Jenk's method for four or five classes, depending on the indicator and year. These maps are intended to support the decision-making of the subjects and all of them used the same data and stimulated the same mental information-processing activities.

The universe of this experimental research is the universe of graduation students of Paraná - Brazil. Considering a simple random sample, determined using 50% as the true population proportion, a questionnaire was administered to 269 students in Curitiba, Brazil. Groups of between 13 and 40 students were tested at the same time, in similar classroom environments. It was assured that these classrooms were well-lit and with tables sufficiently large to allow the use of four A4 sheets on each one.

Users were randomly assigned to one of the three experimental groups: group 1 consists of subjects making decisions based on the nine choropleth maps; group 2 consists of subjects using the nine proportional symbol maps; and group 3 consists of subjects assigned to use the six dot maps. Groups answered the same questionnaire, which was designed in order to simplify the process of measuring map effectiveness, using the task scores as this measurement.

1 Pastoral da Criança is a non-profit organization related to the Catholic church concerning community health care, especially for underprivileged families and children.
2 www.pastoraldacrianca.org

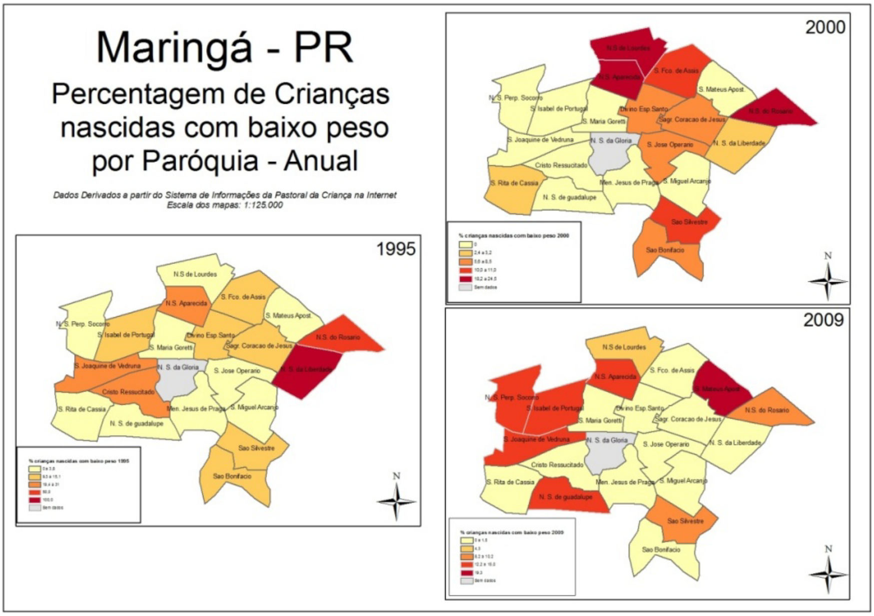

Figure 1: Out-of-scale, choropleth subset of maps for "Malnourished recent-born children" indicator

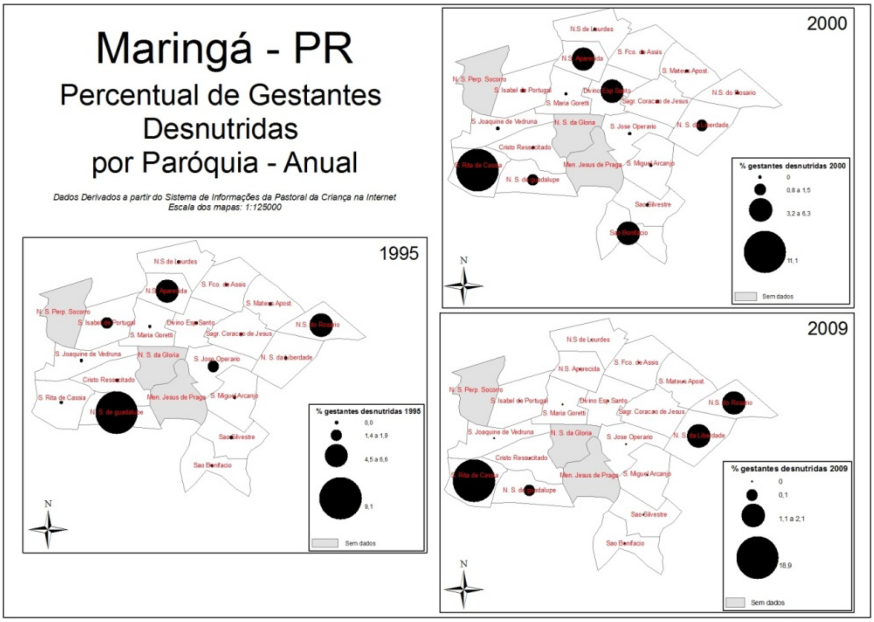

Figure 2: Out-of-scale, range-graded proportional symbol subset of maps for "Malnourished pregnant women" indicator

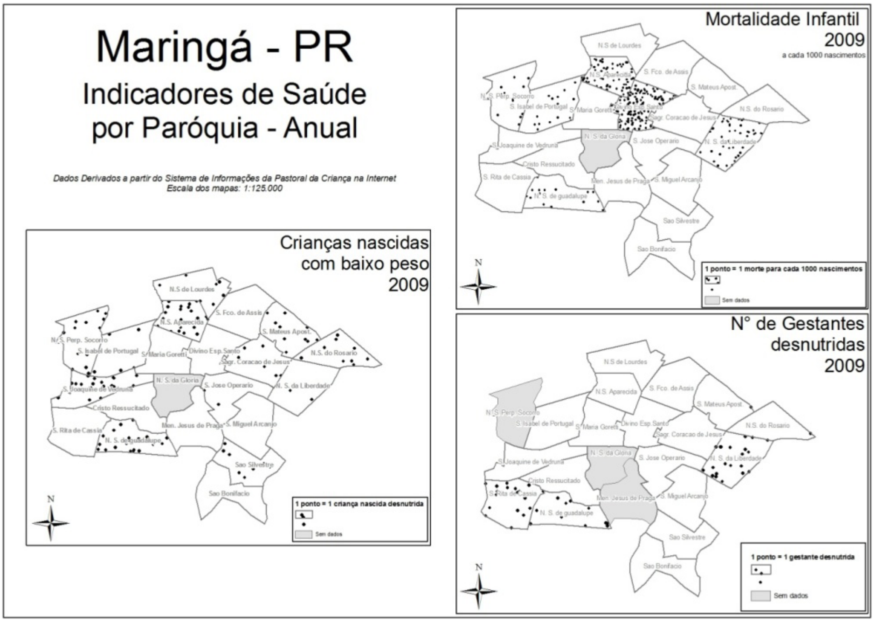

Figure 3: Out-of-scale subset of dot maps for 2009 indicators

The subsets included maps for different years, with the expectation that the analytical decision would take into account the evolution of health indicators over the years. Performance for the test can be divided into three aspects: the first is about preference, here treated together with what is considered more efficient. Subjects are instructed to choose the map they prefer from the three available, which were designed to be similar to ones presented in popular magazines or newspapers, with real data and a well-known base map. This step was designed to stimulate users to point out the preferred cartographic representation at first sight, which involves a pre-attentive visual perception task. Users were asked not to handle the maps – which were inside the last page of the test sheet – before answering this first question.

The second aspect concerns map reading, also called direct acquisition (MacEachren 1982) tasks. This assessment was designed to test the comprehension of broader map contents with 14 simple comparison questions (“a1”, “b2”, “c3” until “o14”), where subjects needed to compare the health indicator differences between parishes and over different years, deciding whether the sentence was true or false. This step was intended to evaluate basic map interaction skills and it was designed to ensure that subjects could distinguish between map units and the associated classes throughout years.

The third aspect for this experiment consisted of the test's main goal: to decide the priority order of parishes to receive cash investment, in order to combat health problems such as child mortality. To measure how effective the map was in supporting this decision process, the list of 23 parishes was presented and subjects were asked to point out which ones must have priority for financial resources allocation. Additionally, there was one question (grouped with the 14 true/false ones) also related to this more complex reasoning process, since it required a considerably larger number of comparisons to be made. This question was evaluated together with the parish ranks and was called "p15".

For this third step, correct answers were related mainly to two factors: first, with the importance users gave to each one of the three health indicators; and second with the evolution of these indicators over the years. Thus, a rank to evaluate parishes was created and they were ordered by priority, resulting in the following severity criteria: Critical (parishes with maximum priority, mainly related to rising or high child mortality levels); Urgent (parishes with high priority, related to at least one of the indicators being high or rising); High priority parishes (related to the absence of desirable indicators reducing to the goal of zero, for more than one indicator); Medium priority (related to the absence of desirable indicators reducing to zero goal, for only one indicator); Low priority (parishes that achieved the zero goal or are very close to that).

According to these criteria, the analyst's choices were weighted (Table 1). Positive weights applies to the considered desirable choices, zero weights were applied to no-data locations and negative weights applied to wrong assumptions, which happens when parishes had no problems with the measured health indicators. Also negative weights were considered in order to prevent guessing, since there were no express instructions about the maximum or minimum number of parishes to be chosen. The maximum score for this stage is 16 points – related to the priority rank – equivalent to choosing the four critical situation parishes or three of them together with all of the urgent ones. The minimum score is 0, even if the analyst picks up only low priority parishes. Additionally, there is 1 point related to the 'p15' question, giving a total of 17 points, equivalent to a 100% performance in the map reasoning task.

Finally, observations about the test were taken, based on commentaries or conversations during the experiments, in order to discover more information about the way students dealt with the whole activity.

Parish	Weight
Menino Jesus de Praga (par1)	-3
São Silvestre (par2)	0,1
São Bonifácio (par3)	-3
S. Miguel Arcanjo (par4)	-3
S. José Operário (par5)	-3
N.S. da Gloria (par6)	0
Sagrado Coração de Jesus (par7)	0,1
São Mateus Apostolo (par8)	1
N.S. do Rosário (par9)	0,1
S. Francisco de Assis (par10)	-3
recida (par11)	**4**
N.S. de Lourdes (par12)	0,1
Cristo ressucitado (par13)	-3
S.M. Goreti (par14)	-3
S. Isabel de Portugal (par15)	0,5
S. Joaquine Verduna (par16)	1
Divino Espirito Santo (par17)	**4**
N.S. da Liberdade (par18)	**4**
N.S. do Perpetuo Socorro (par19)	**4**
N.S. Guadalupe (par20)	1
Santa Rita de Cássia (par21)	1

Table 1: List of parishes and their associated weights. (Bold font is used for the most severe situations, which lead to highest weights)

2.1 Statistical treatment

Simple random sampling was adopted and the size of the sample (269 users) was developed in order to satisfy the condition of 90% confidence level, a study proportion of 50% and a margin of error of 5% (WITTE and WITTE 2005). Three experimental groups were determined: choropleth (chor), dot (dot) and range-graded proportional symbol (prop) users. Differences between correct and wrong answers and among these groups were analyzed by a Kruskal-Wallis ANOVA test, at 95% confidence level, which can determine if there is a significant variation due to the technique used acting like a common analysis of variance. This test is used when there is no evidence of a normal distribution. Also, under the analysis of variance, a multiple comparison procedure was applied in order to identify where the differences pointed out by the Kruskal-Wallis occur, using Fisher's least significant difference (LSD) procedure.

3- Results and discussion

Students who agreed to participate in the test sample seemed to be heavily involved in the subject according to the amount of written comments about questions and maps in the appropriate spaces in the questionnaire. This seemed to ensure the validity of the methodological approach and consequently of the analyzed answers. Most of decisions made by respondents were well explained and had logical reasoning. Errors mainly seemed to occur because of lack of attention and consequently missed outliers, instead of random guessing or disinterest in the questions. Talking with students after the test revealed that they considered the questionnaire easy to answer and the instructions clearly given, and almost no questions about this were registered in the 11 classes in which this test took place, between July and August, 2010.

The two main general performance scores show details about questions that are part of the measurement of effectiveness for the two tasks proposed for this work. For the direct acquisition task (Figure 4), the mean accuracy was about 91.5%. The question with the worst results was 'o14': "At least eight parishes did not reduce "child mortality" to zero in 2009". For the map reasoning task (Figure 5), six from seven of the most cited were critical (most severe) and urgent situation parishes. The 'p15' question was: "in general, there are fewer parishes in a severe situation, what is a signal that the situation about health care in the municipality has been improving through the years".

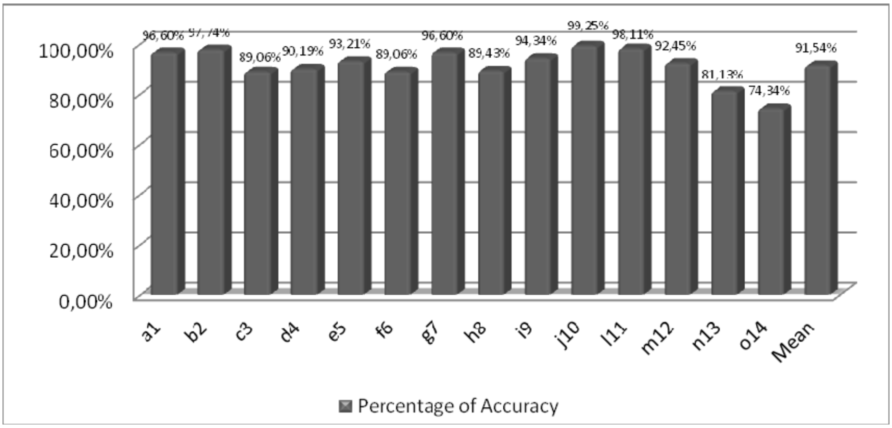

Figure 4: Results for direct acquisition questions

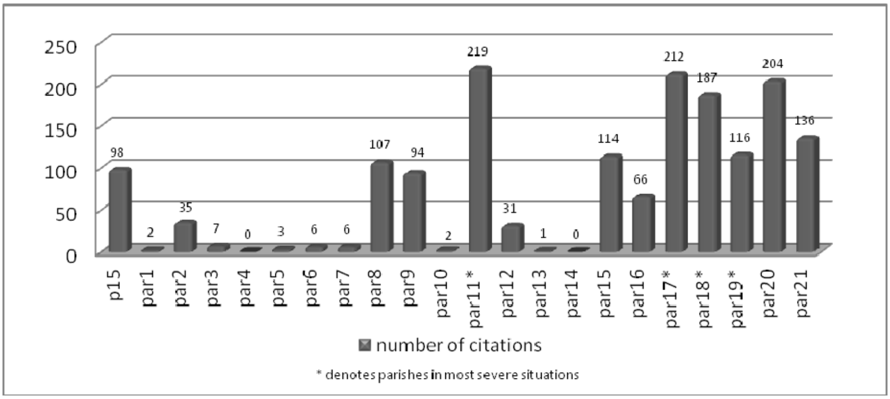

Figure 5: Results for map reasoning questions

3.1 Map Preference

Results show strong preference for choropleth maps (Figure 6), as expected. This can be related to the unusual use of other common media techniques for general-audience maps in Brazil, such as in textbooks, TV and magazine maps. It would be desirable in the future to ask respondents about familiarity with spatial data, and to ask them to describe situations in which they usually encounter and make use of maps.

The Kruskal-Wallis tested the null hypothesis that the medians of the two task results within each of the three levels of map preference are the same. Since the P-value is greater than or equal to 0.05, there is not a statistically significant difference between the medians at the 95.0% confidence level. Therefore, it can be assumed that map preference does not influence the results achieved.

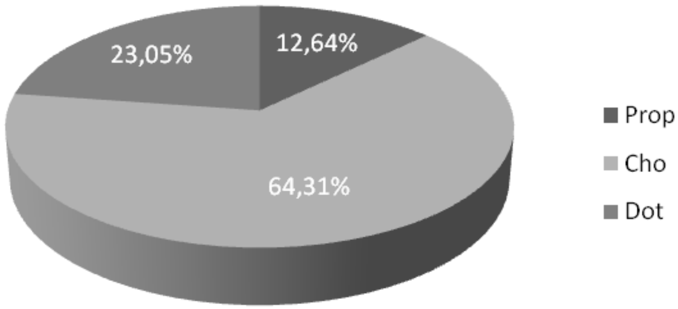

Figure 6: Map preference

3.2 Direct acquisition task

The Kruskal-Wallis test proves that there is a statistically significant difference between the medians of the direct acquisition task results and the experimental groups. The multiple comparison procedure by LSD (Table 2) indicates that the choropleth maps group and range-graded proportional symbol maps group achieved similar results, which are statistically different from the dot maps group. The absolute results for the direct acquisition task results (Figure 7) show a slightly worse performance by the dot maps group for this specific task when compared to the other two groups.

Contrast	Significance	Difference	+/- limits
Cho – Dot	*	0,336232	0,324017
Cho – Prop		-0,164918	0,326829
Dot – Prop	*	-0,501149	0,328589

Table 2: LSD Multiple Range Test for Total Direct acquisition answers.

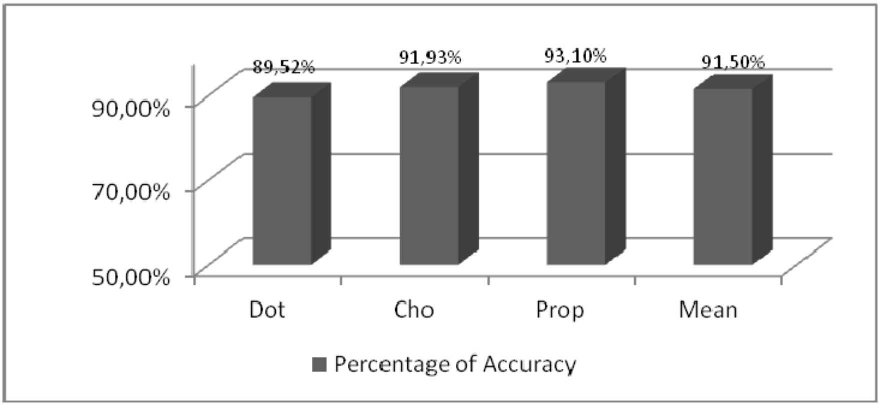

Figure 7: Percentage accuracy for direct acquisition task

The cross-tabulation for results on this task also permitted the consideration of the simultaneous occurrence of map used and preferred map against the sum of correct answers (Figure 8). For this result, it can be observed that users who matched map usage and map preference (DD, PP, CC) did not always achieve answers of higher accurate when compared to non-matching (CP, CD, DC, DP, PC, PD) users. Best results were achieved by proportional maps (PP), but differences were only statistically significant against DC, DD and CC classes. It could indicate evidence that matching preference and use can lead to good results for specific visual variables. However, once there were more than twice as many occurrences of choropleth map preference, and sampling was not designed to support sub-sample analysis, a higher and equally distributed number of respondents would be necessary to confirm this trend. Another possible analysis would be to consider each map technique separately. In this case, for proportional and dot maps (PP and DD classes), it is true that matching cases had better performance, but this was only statistically significant for the proportional map technique.

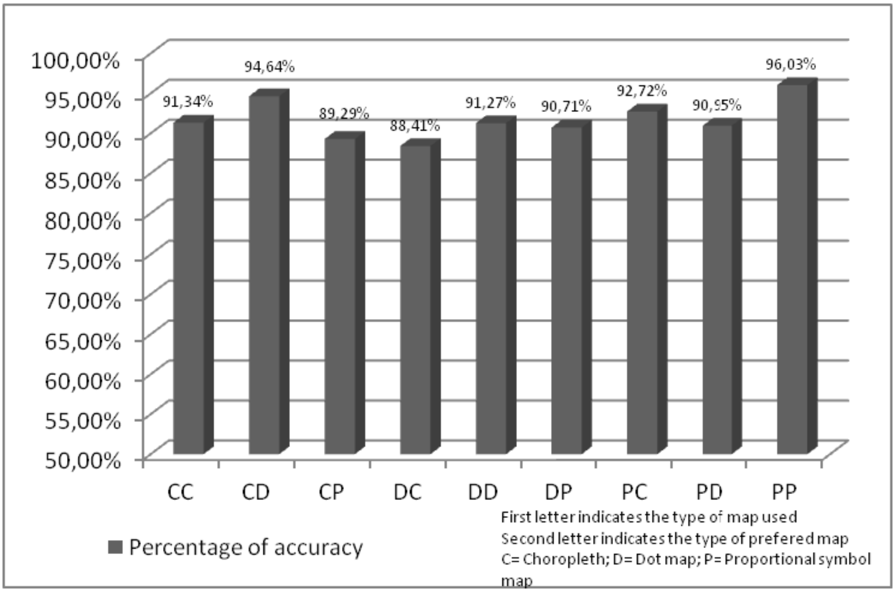

Figure 8: Map usage, map preference and accuracy for the direct acquisition task

3.3 Map reasoning task

For this analysis, results indicate that dot maps had better performance results (Figure 9), and this was confirmed by the LSD ANOVA test table (Table 3), where an asterisk has been placed next to the “Dot” and “cho” pair, indicating that this pair shows a statistically significant difference at the 95.0% confidence level.

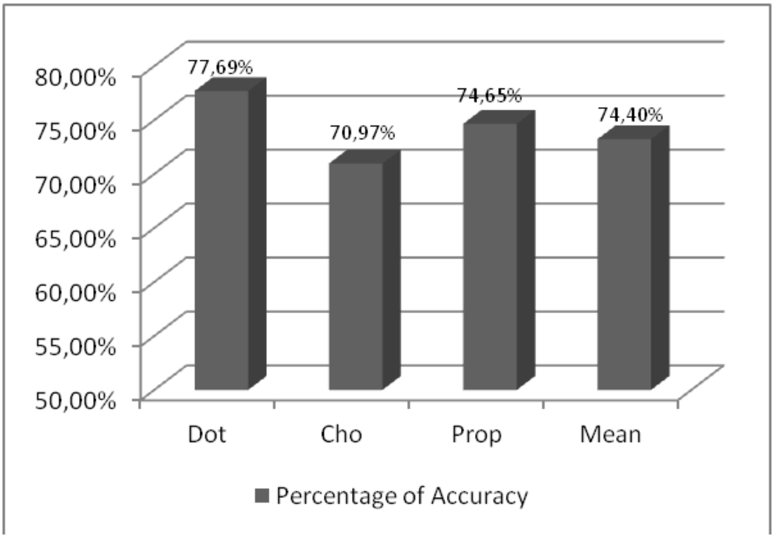

Figure 9: Percentage accuracy for map reasoning task

Contrast	Significance	Difference	+/- limits
Cho – Dot	*	-1,14254	1,06536
Cho – Prop		-0,625525	1,0746
Dot – Prop		0,517011	1,08039

Table 3: LSD mulltiple range test for total direct acquisition answers

Gathering together the map usage and map preference indices, it is possible to measure the percentage accuracy for their matching (Figure 10). Matching proportional maps preference/usage did not repeat the results for the direct acquisition task and there was no evidence to support the idea of a better performance being linked to an analysis made with the support of the desirable map. According to the LSD test, there are no significant differences between all nine different combinations.

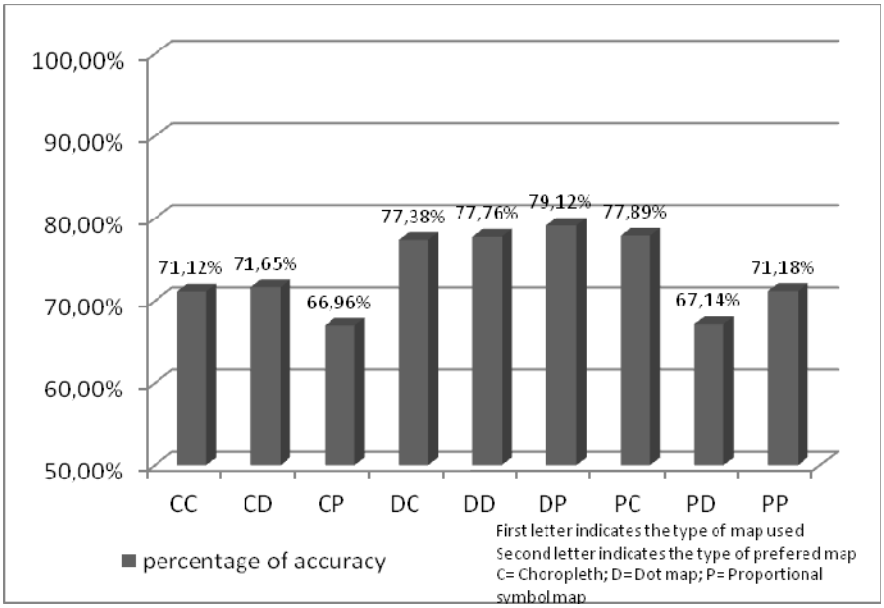

Figure 10: Map usage, map preference and accuracy for map reasoning task

When percentage accuracies for direct acquisition and reasoning tasks are compared (Figure 11), it can be seen that results for the last one are slightly worse. This was expected since the nature of the process – especially considering a temporal evolution analysis – is clearly more complex.

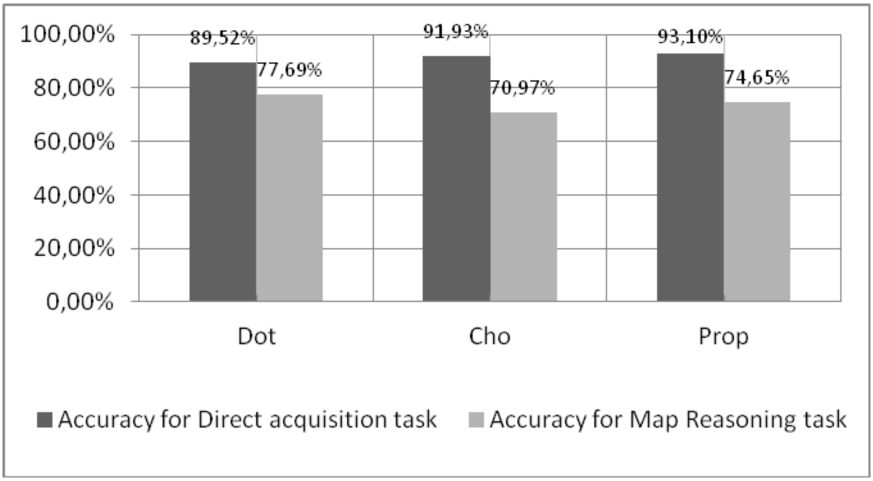

Figure 11: Percentage accuracy – both tasks

4- Conclusions and perspectives

Usability and HCI research applied to map interfaces are growing fields of interest for cartography, and advocates user testing as a main acknowledgment for successful design. Many of the procedures for this kind of user-oriented approach take into consideration user preferences and its importance should be carefully included in map design principles. Here it is important to realize that cartographic communication and map and cognition studies have as one of their main principles the fact that effectiveness is directly dependant on the realms of map-user and map-tasks. Results obtained from this first stage of research cannot be generalized and should only be applied to decision-making processes of a similar nature and if possible for similar user characteristics.

Nielsen and Levy (1994) studied the same subject of this research about computational interfaces and their survey concludes that there seems to exist some strong positive association between user's performance and their average subjective satisfaction. In the present study, the most preferred map was not the most efficient for all tasks and statistical tests demonstrated that there is evidence that subjective preference and the intuition of map-users are not related to effectiveness. However, for some cases – or some visual variables – maybe this relationship can exist, since this study points out that there is a slight indication of success when people handle the same subset of maps that they consider the most efficient, with proportional maps achieving significantly better results.

This article provides objective evidence that Brazilian users seem to prefer colored maps and believe such representations to be more effective for the studied decision-making process. Also for this process, it was noted that performance decreases for reasoning related tasks, and maybe this could be related to the need of a deeper analysis of data evolution through time. If the assumption is correct, this factor is supposed to be minimized by the introduction of animated maps, built for this experiment's 2nd stage, which is currently taking place. Garlandini and Fabrikant (2009) argue that changes in size and color value are easily localized and guide viewers' attention in thematic 2D map displays.

Results of the first stage of the present research are similar to Hegarty et al. (2009), who showed that people seems to prefer more complex forms of representation and this is not related to effectiveness, for different map use tasks. These authors argue that user preferences, even those of domain experts, are not a good indication of effectiveness.

The second stage tests are expected to produce results related to differences between computer displays and paper maps, taking into account a discussion of their advantages and disadvantages for decision-making processes supported by spatial data visualization. Also, the introduction of an animated map display, in order to provide data for map reasoning task decisions, is expected to produce better results. This would be a starting point for deeper research into the effectiveness of map animations on the Internet, related to the most common map-making techniques and visual variables.

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On-demand Cartography for Trekkers

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Abstract

In this paper, we introduce a method for identifying the specific needs of a community from a user survey, and adapting maps accordingly. This method was applied to four different groups of trekkers: walkers, road cyclists, cross-country bikers, and recreational trekkers. Relevant concepts, criticisms and expectations for each group were identified using natural language processing and lexicometry methods and tools. Suggestions for adapting maps focus on data selection and graphic representation. Pedestrian trails were emphasized using trail-marking signs as graphical symbols and adding numbers which refer to additional information. Specific trails were added to the cross-country biking map using the difficulty level indication of ski maps. Moreover, contour lines were highlighted for cross-country bikers to help them to understand relief. The road cyclist map was designed at a 1/50 000 scale with generalized data. The slope of cycling paths was indicated by a diverging color scheme to convey the difficulty of different sections of road. This paper describes part of an on-demand map making process and illustrates it for a specific community, trekkers. It has been shown that it is possible to select data and define radical graphic choices as long as the community is targeted enough to have the same needs and wishes.

1- Background and objectives: on-demand cartography

Users have many reasons to request on-demand maps. The map may have specific uses (walking map, biking map, urban project implantation map,

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specific lighting map); there may be one for a specific group of people like colour blind users. It may be justified by special map-making procedures (for example, low cost map-making, specific media or energy saving e-maps).

On the other hand, on-demand map-making has become increasingly easier because tools are cheaper and cheaper; they are increasingly simple to use. Finally, data is more and more easily accessible, for example, trekking information (trails, difficulty level, length...) that may be added to base maps as thematic information. Indeed, everybody can make maps.

However, the result is often poor quality maps. There are two main reasons. Firstly, the graphic semiology rules are badly interpreted. Secondly, inexperienced people misuse map-making rules which may clash on their actual maps, for example, information volume versus map readability.

In this context, an important issue is to define both the relevant data on a map and its symbolisation, in order to adapt maps to specific needs. We propose a map-making approach based on a users' survey. In this article, maps suitable for trekking - more precisely walking, road cycling and cross-country biking - are defined. The approach and methods that have been developed are introduced in section 2. The results, such as the different suggestions of trekking maps, are shown in section 3. The conclusions and future perspectives are proposed in section 4.

2- Approach and methods: analysis based on survey

The approach adopted is based on textual statistics, statistical linguistics and statistical analysis of textual data. Statistical linguistics (Yule 1944, Guiraud 1954, Muller 1968, Herdan 1964) makes it possible to compare the text to be studied and the reference text on the basis of the frequency of terms used. Information on semantic content of the text to be studied is deduced from the differences in word frequency between the two texts.

Statistical analysis of textual data was established by (Benzécri et al. 1973). Benzécri wants to describe a reasoning based on observation without a priori assumption; thus he defines an inductive reasoning from consequences to principles and develops a suitable tool: correspondence factor analysis (Benzécri 1992).

Many analyses of open answer questionnaires use the tools developed by Muller and Benzécri, for example (Tomasetto et al. 2008). Our analysis of the users' survey is also based on these tools and is demonstrated through a process example, the specification of trekking maps. It includes different steps; first, setting up a users' survey which makes it possible to identify the specific needs of a community and the user's wishes, then, defining maps (data and symbolisation) that correspond to the survey results.

2.1 The users' survey

The users' survey is more precisely described in (Baldit-Schneller and Dominguès 2010). Four groups have been interviewed according to their activity: walking, road cycling, cross-country biking and finally, those who occasionally practice these activities. The interview has been conducted by a coordinator and open-ended questions (the same ones for every group) have been used. The aim was first, to identify the relevant objects and concepts for trekking maps and secondly to identify the user's criticism and expectations about maps within his particular activity.

Four French written survey sub-corpora (including, more or less, 46 000 words) have been compiled by using transcripts of the questions and their replies. Every sub-corpus describes each user's sporting or other activity. Therefore, it is possible to identify the relevant concepts and the user's expectations for every activity. The sub-corpora have been studied with natural language processing (NLP) and lexicometry methods and tools.

2.2 The user's opinion

The lexicometry tools ensure searching the significantly frequent words in every sub-corpus compared to the reference corpus. In this case, the reference corpus used is the four sub-corpora set. The statistic comparison reveals the relevant concepts for every group. The specific words of every activity are presented in the following table.

Concepts	Sub-corpus: walking	cross-country biking	road cycling	recreational trekking
activity	- itinerary	- marked path	- marked path	- stroll ride - marked path
facility used	- track - path	- signposted footpath - track	- road - lane - path	- track
self-orientation		- signposted footpath - path - vegetation	- road - circuit - forest - town	- landmark
slope gradient	- difference in altitude	- contour line	- herringbone pattern - contour line - relief - slope	
scale used	- 1:25 000 - 1:50 000	- 1:25 000	- 1:25 000 - 1:50 000 - 1:100 000	- 1:25 000 - 1:50 000
distance	+	++	++	
graticule	-	-	-	-
readability	++	++	++	+

Figure 1: Specific words used in every sub-corpus. These words have been classified according to their topic. The boxes that belong to the same topic are filled with the same texture. + sign indicates the item is important for users (++ sign shows an even more important item); - sign indicates users think the item is not relevant on map.

activities definition

self-orientation

slope gradient

backup material

distance

graticule

visual map properties

2.2.1 Facility used and self-orientation

Several words with close semantic meanings denoting the facilities used by trekkers, their activity as such and their landmarks for orientation were identified, for example, “path”, “trail”, “loop”, etc… The word “landmark” is frequently used by recreational trekkers; that may be explained by their lack of experience in map reading. They look for landmarks on the map which are easily identifiable on the terrain. All groups think that graticule is useless.

2.2.2 Slope Gradient

Slope is one of the most relevant pieces of information for road cyclists. Slope is not shown on IGN maps but it is implied by the relief shading and contour lines. Road cyclists complain about the lack of slope information; this explains why the word “slope” appears frequently in their sub-corpus. Moreover, they frequently used the word “Michelin” because maps from this publisher indicate the steepness and direction of the slope with herringbone patterns.

2.2.3 Distance

Trekkers who cover long distances (road cyclists, cross country bikers and some walking trekkers) need information about the distance of the trails. This information is not available on IGN maps yet, but it could be useful to them in choosing a trail.

2.3 The user’s tastes

NLP tools ensure making syntactic patterns. In this case, the patterns have been especially employed to study the verb construction used by every group to identify the criticisms and expectations of every map user group. Mood markers that indicate stands (Généreux and Santini 2007; Levin 1993) on cartographical concept or object have been noticed. These markers can show:

- an opinion:	*I think that* *for me*	*je pense que,* *je trouve que* *pour moi*
- a preference :	*I prefer* *I'm found, I'm very found* *more*	*je préfère* *davantage*
- a wish:	*I would like* *if... it would be nice*	*j'aimerais* *si... ce serait bien*
- a criticism:	***to be too much...***	*être trop...*
- an assessment:	***I like*** *I don't like* *it's good* *it's not so bad* *to lack, to miss*	*j'aime bien* *[j'aime/je n'aime] pas* *c'est bien* *[c'est/ce n'est] pas mal* *il manque.*

These examples have been extracted from the corpus:

It isn't attractive, ***it's too much*** *pastel (translated from: ce n'est pas attractif, c'est trop pastel)*

I like *know where I go (translated from: j'aime bien savoir où je vais)*

Criticisms and expectations are synthesized in the following table. In the first part, there are items the users would like to promote and in the second part, the items the users do not appreciate. These items must be taken into account in order to make maps adapted to walking, road cycling, cross-country biking and recreational trekking.

	walking	**cross-country biking**	**road cycling**	**recreational trekking**
	-1:25 000 scale -1:50 000 scale - much information - technical vocabulary	- 1:100 000 scale - tourist information - relief information - distance information - number of vehicles on the road	- 1:25 000 scale - tourist information - relief information - distance information - level of difficulty - bright colours - contrasting colours	- on-demand map - simple map - well spaced out map - simple legend - conventional colours - contrasting colours
	- dense map - Lambert graticule	- scale 1:50 000 - hard-to-read legend - Lambert graticule - not enough contrasting colours - irrelevant information	- 1:50 000 map - too dense legend - Lambert graticule - local boundaries	- complicated map - confusing map - Lambert graticule - pastel colour - too similar icons

Figure 2: User's tastes

3- Results: data selection and semiotics suggestions

In this section, some graphic representations designed to meet user's demands are shown. Our initial map is the French IGN one (cf. figure 3) whose scale is 1:25 000. Our suggestions modify this initial map or are added to it. Firstly the solutions concerning all groups are presented (particularly they do not depend on the scale of the map). In the second part of the section, the specific suggestions according to the different activities are shown.

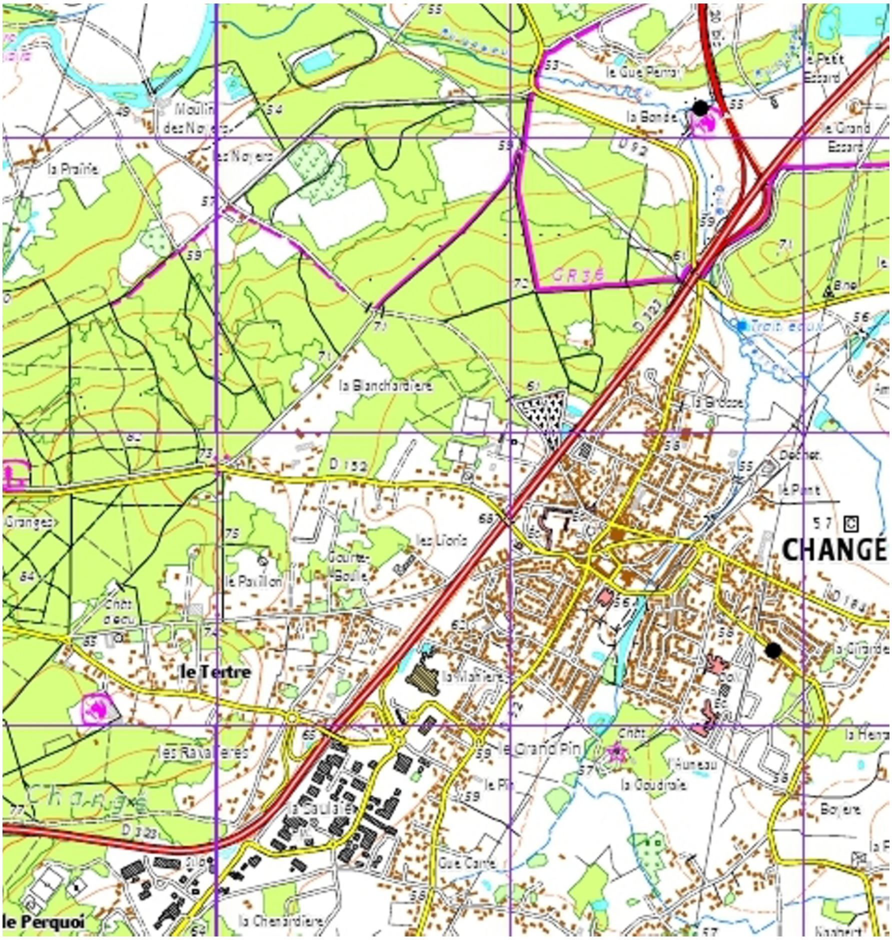

Figure 3: Initial map

3.1 General suggestions

The propositions common to all the groups involve data selection, data graphic representation and toponyms typography.

3.1.1 Data selection

3.1.1.1 Lambert graticule

Users want data selection to be relevant according to their activity. All groups said that the Lambert graticule was useless and impends easy and quick reading (cf. figure 1 – “graticule” line). Therefore it has been removed. Since we think it may be useful, within the framework of map design on the internet, we propose to add it easily and quickly.

3.1.1.2 Points of interest

As shown in the table of figure 2, all trekkers groups need touristic and practical information but at the same time they did not want too dense maps. Indeed, some unnecessary information has been removed for all trekkers like riding centres, golf courses, tennis...

Moreover, the relevant touristic information has been visually associated using the same colour for all point symbols. The purple has been used in order to differentiate this touristic theme regarding all the other themes. Both mechanisms of visual association and differentiation are described in (Bertin 1967).

3.1.1.3 Bicycle paths

Bicycle paths can be used by recreational trekkers, road cyclists and cross-country bikers (to reach the starting point of their trail). But, bicycle paths are only an additional infrastructure, they are not specific trails. Thus, they have been symbolised with the same colour as the points of interest, as additional information, in order to be associated with them (cf. Bertin 1967).

An exception has been done for walking trekkers. Indeed, they never use bicycle paths. So, this unnecessary infrastructure has been removed for them.

3.1.2 Graphic representation

3.1.2.1 Cartographical objects for self-orientation

Each group uses different objects for self-orientation. Users find their bearings by locating different cartographic objects as shown in figure 2 ("self-orientation" line): vegetation, towns, hydrography, and roads. These themes belong to the base map. Therefore, it seems legitimate to associate (in reference to association relation of (Bertin 1967)) these objects visually. According to Bertin's theory, some visual variables are usable: shape, size, hue, value, texture, orientation. In this case, it is impossible to use neither the same shape nor the same size for all the objects because of their variety. Moreover, value, texture and orientation are difficult to use because they are not visible enough for objects that have very distinct surface areas. In this case, hue is the most natural and the easiest visual variable to use.

However, there are some rules for conventional colour use (Cuenin 1972). For example, in Europe, forests and woods are traditionally symbolised by green and hydrology by blue (Jolivet 2009). So there is a conflict between these conventional colour rules and associating objects according to their shared use.

Finally, we chose to stress the conventional colour rules: hydrology remains blue and vegetation green. But all the other cartographical objects that are used for self-orientation are associated because of their shared hue: grey. In addition, to avoid inserting an order relation between these objects, they will be represented with the same colour value. As a consequence, the grey colour reduces the visual impact of all these themes. Thus saturated colours are still available for more relevant themes (cf. section 3.1.1.2.).

3.1.2.2 Road theme

For these users, it is relevant to represent the road theme in grey (cf. section 3.1.2.1.). Thus, the administrative hierarchy (main roads, secondary roads...) that was symbolised by different hues is removed. Anyway this information is unnecessary for trekkers.

Nevertheless, the practicability hierarchy (number of lanes, lane width) is useful for trekkers to choose their itinerary. Here the order between the cartographical road symbolisation used to be marked by size of the cartographical objects. This practice has been maintained too.

3.1.2.3 Contour lines

The notion of altitude gradient is important for all groups (cf. figure 1 – “altitude gradient” line), but none of them need the same graphical representation. The new contour line colour has been made darker, in order to make the reading easier. As cross-country biking sportsmen use contour lines much more, other relevant suggestions are proposed for them (cf. section 3.2.3.).

3.1.3 Toponyms

Toponym typography is an important aspect for map readability (Krygier and Wood 2005). According to the survey, toponyms allow trekkers to locate themselves, but on maps typography is neither varied nor suitable for to the object designated by its toponym. In order to make easier the link between the cartographical object and its toponym, two improvements have been done in our initial map regarding the old map used during the users’ survey:

It may be difficult to link the object with its toponym because all toponyms have the same colour (hue and value). Therefore the letter colour could vary with the object theme (cf. figure 4): wood toponyms could be written with the vegetation theme colour i.e. green, river or lake toponyms with the hydrology theme colour i.e. blue, town toponyms with the building theme colour i.e. grey.

The toponym relevance has been highlighted by font size and uppercases, for example, the demographic town relevance for the building theme, the covered area for the vegetation theme.

Nevertheless, toponym understanding is made difficult because of the depth of typography hierarchy. Thus we suggest organizing a more readable toponyms hierarchy by restricting the number of levels. Five levels of hierarchy have been defined thanks to font, size, bold and italic characters (cf. figure 4).

Figure 4: Two examples of toponyms typography

3.2 Propositions according to the different activities

3.2.1 For walking, cross-country biking and recreational activity

Walking, cross-country biking and recreational activity users have to share the same infrastructure or the same trail whatever their speed. In addition, cross-country bikers have a bike. Road sharing by pedestrian users and bikers may be difficult and this must be indicated on the map.

There is thematic data for pedestrian trekking that may be useful to add to the base map. The data comes from national trekking federations. The French, Belgian, Spanish and Dutch federations use the same kinds of trails: GR[1] i.e. signposted footpath, GRP[2] i.e. signposted footpath route to explore a region and PR[3] i.e. walks and treks. These federations mark the trail on the terrain by conventional signs. Moreover, the marking system indicates levels of difficulty. GR and GRP trails have nearly the same level of difficulty. They share the same conventional symbols but have different

[1] in French: chemins de Grande Randonnée

[2] in French: chemins de Grande Randonnée de Pays

[3] in French: Promenades et Randonnées

colours. PR trails are less difficult and they have their own symbol set. We propose using the same symbols as the terrain ones to mark the signposted footpath on the map (cf. figure 5). Lastly, these GR, GRP and PR paths are emphasized graphically because of their trail continuity: the signposted footpath trails visibly overlaps road lines and all other cartographical objects (cf. figure 6).

3.2.2 For road cyclists

In this section, some aspects specific to road cyclists are described and figure 9 presents the result map.

3.2.2.1 Data selection

Scale suitable for road cyclist

Road cyclists cover longer distances than the other groups. That is why they prefer to use 1:50 000 maps. This scale permits global visualization of their marked path. Therefore, generalized data of the same area has been used for this group.

Points of interest

New specific data has been added to the traditional point information in order to meet road cyclists' expectations i.e. the location of bike repairers. Moreover, three relevant kinds of points of interest have been highlighted in compliance with road cyclists' expectations: accommodation locations, catering locations and panoramic view locations. These four themes form relevant contextual information for road cyclists. Indeed, their corresponding symbols must be seen at the first reading level.

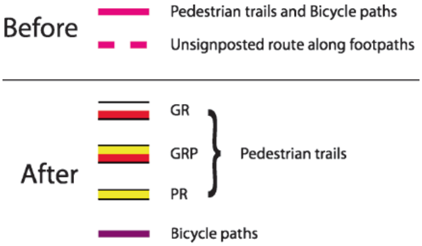

Figure 5: Improvement of pedestrian trails symbolisation.

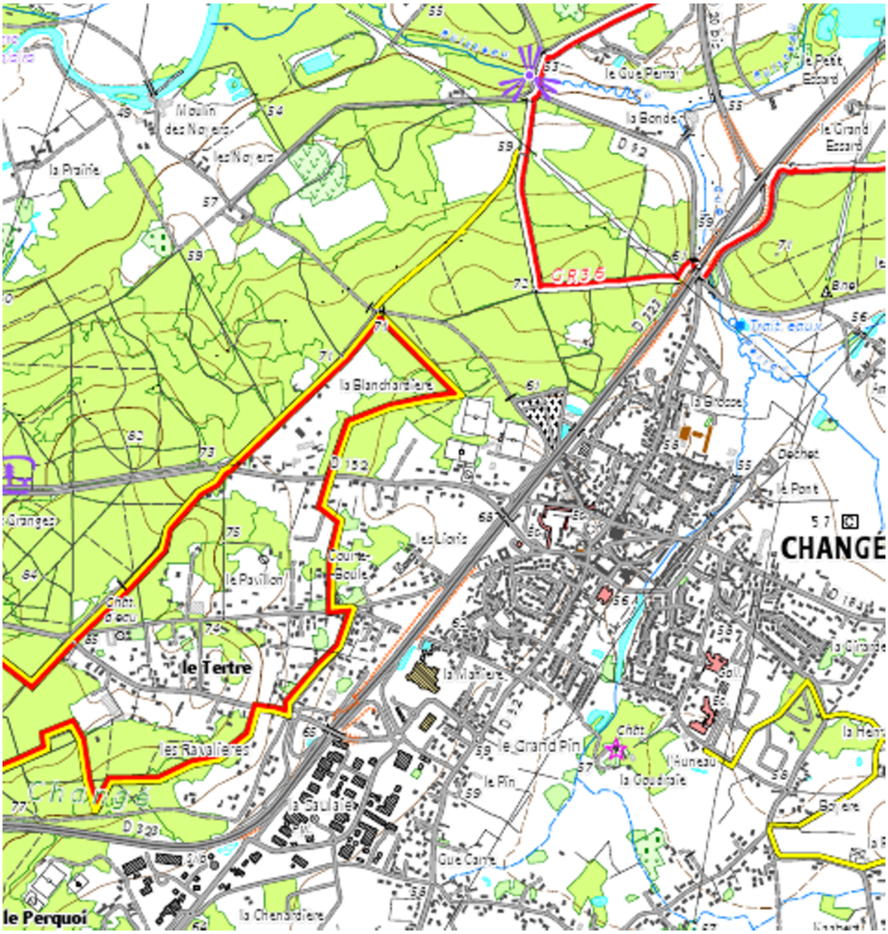

Figure 6: Pedestrian trekkers' map

3.2.2.2 Graphic Representation

Representation of altitude gradient

Concerning altitude gradient, the relevant information for cycling users is the slope (cf. figure 1 – "altitude gradient" line). Our suggestion is a symbolisation of the slope by means of the filling colour on the linear objects representing cycling paths. Bright colours are used in order to highlight cycling paths and to ensure a strong contrast with the topographic background. Four slope levels have been fixed:

- descending sections, i.e. sections with an important negative slope
- flat sections, i.e. sections with a small slope, negative or positive
- ascending sections, i.e. sections with a steep slope
- hard ascending sections, i.e. sections with a very steep slope

A colour has been allocated to each level in order to translate the difficulty of such a slope range. Figure 7 shows the legend slope symbolisation suggested.

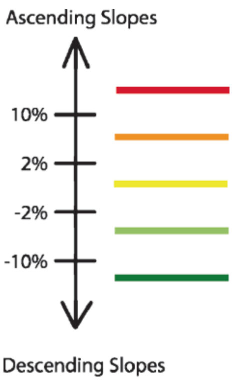

Figure 7: Legend slope symbolisation.

Road accessibility for cycling activity

Road cyclists need asphalt ways which are adapted to their use and particularly to their vehicle: paths, footpaths, lanes, tracks are not recommended for them. Moreover, it is forbidden to cycle on highways. Consequently, we propose visually associating all the roads which are not accessible for road cyclists. In order to convey the discontinuity of the road network, dotted symbolisation has been used to symbolise all these unsuitable roads (cf. figure 8).

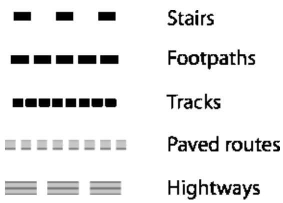

Figure 8: Dotted symbolisation for non accessible roads for road-cyclists.

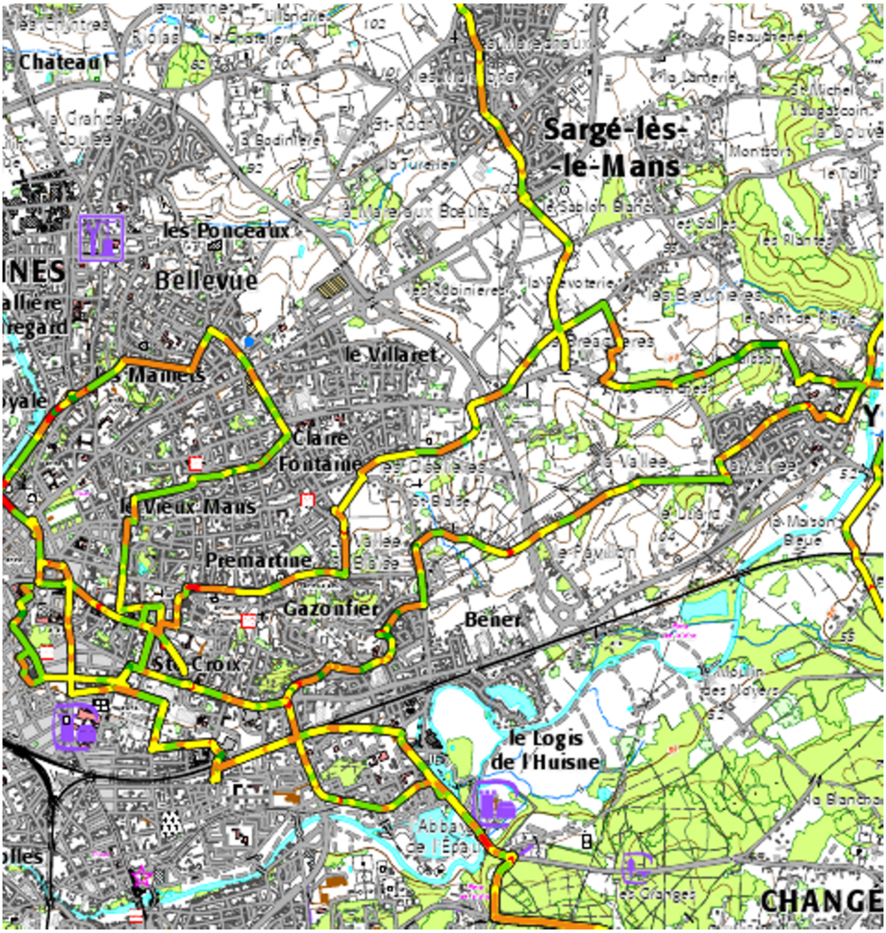

Figure 9: Road cyclists' map

3.2.3 For cross-country bikers

In this section, some aspects specific to cross-country bikers are described and figure 11 presents the result map.

3.2.3.1 Data Selection

Sharing trails with other trekkers

Cross-country bikers travel on their own trails but they also use pedestrian trails like GR, GRP and PR in France. Therefore, both kinds have been added to their maps. Thus, they can plan their route bearing in mind all trails that they can use and those they may share with pedestrian walkers.

3.2.3.2 Graphic representation

Representation of altitude gradient

Cross-country bikers use contour lines to understand relief and altitude gradient (cf. figure 1 – "altitude gradient" line). Contour lines are considered as very useful but hard to read by cross-country bikers on the existing maps. They expect a map with more highlighted and structured contour lines:

- The colour of the contour lines should be darkened as for the others walkers. Thus, the contrast between contour lines and the base map or the vegetation is increased.
- The contour lines must be thickened. This will differentiate even more the contour lines with landmarks.

Both of those representation modifications aim at highlighting contour lines.

On the other hand, the differentiation between main contour lines and others should be increased. That is why main lines have been thickened more than the others. Thereby, w hierarchy between different contour lines is better illustrated. This improves the structure of the representation and the readability.

Representation of difficulty levels

One of the cross-country bikers' expectations is to visualize the difficulty level of their future trail (cf. figure 2). Thus, we suggest reproducing the difficulty level representation that is widely used on ski maps, i.e. green for very easy trails, blue for easy trails, red for difficult trails and black for expert only trails (cf. figure 10).

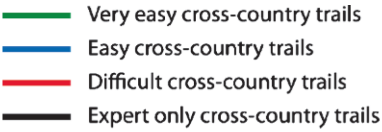

Figure 10: Difficulty levels for cross-country bikers.

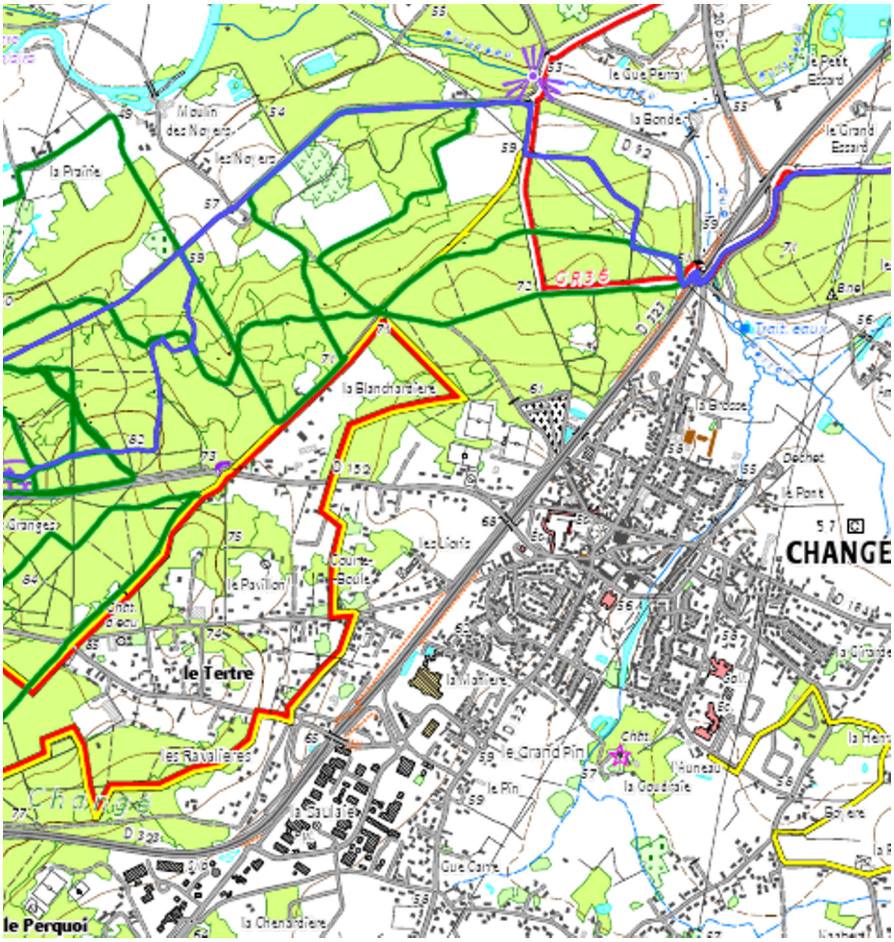

Figure 11: Cross-country bikers' map

3.2.4 For recreational trekkers

Recreational trekkers are not used to reading maps. Indeed, they need practical information and easy-to-read maps even more than the other trekker groups (cf. the recurrent use of the word "simple" in figure 2). Finally, they can use signposted footpaths, or bicycle paths.

Therefore, data selected for them is the following: pedestrian trails, bicycle paths and as much practical information as possible. Pedestrian trails have been symbolised like for pedestrian trekkers (cf. section 3.2.1.). This symbolisation is perfectly adapted for recreational trekkers because of the link created between the field and the map. The link makes the reading easier and helps recreational users to orientate themselves.

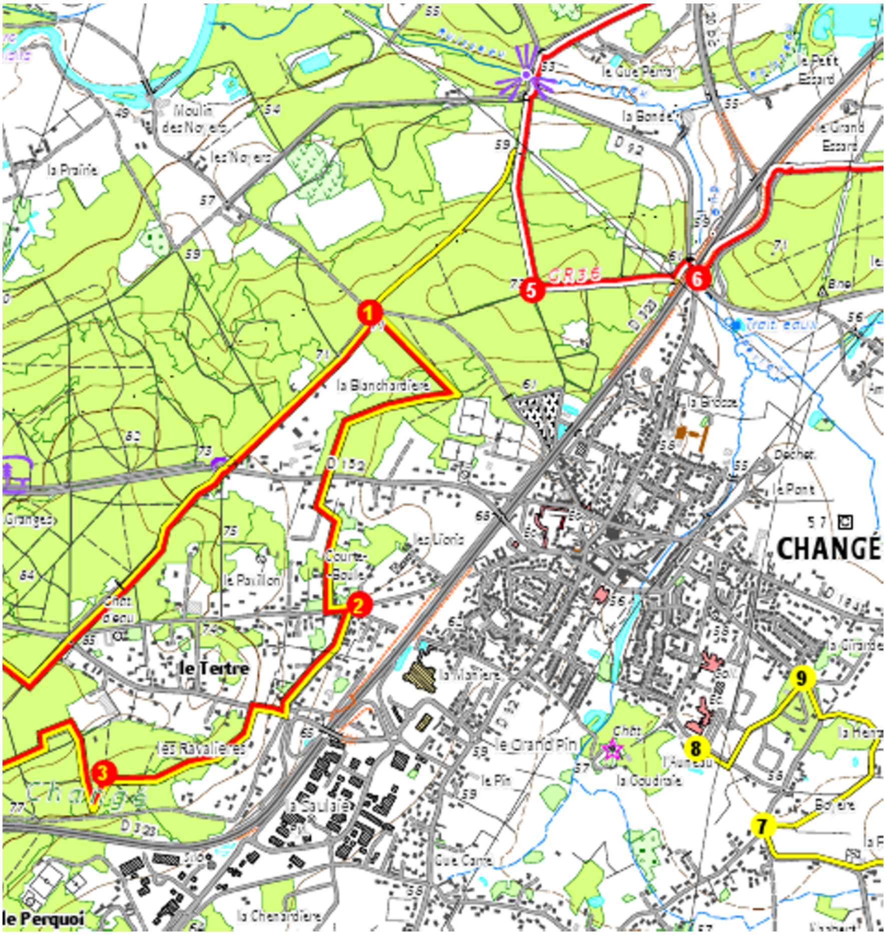

Figure12: Recreational trekkers' map

On the other hand, tourist or cultural information has been added to the map. In order to avoid a dense map, reference numbers have been added on the map (cf. figure 12) and the corresponding information is optional, i.e. it is attached to the map by a literal description that the user could read. These reference numbers are symbolised by the same colours as the pedestrian trails in order to be easily associated with them (cf. Bertin 1967). Reference numbers corresponding to the GR, the GRP and the PR are respectively symbolised by white circled with red, by yellow circled with red and by black circled with yellow. In this case, the visual impact of the colour is used both to highlight the point information and to associate it as additional useful information. The abstract shape use increases the discrimination of the reference number symbols (Forrest and Castner 1985).

4- Conclusions and plans for future work

According to the survey, trekkers use maps prior to the trek (to prepare their outing) and during it. Therefore, our work context is part of on-demand map making on the internet; that is to say, the trekker can make a map suited to his needs on the internet and print it to use during the activity. We would have used internet opportunities such as animated maps, but field use excludes solutions that are only available on the screen. New mobile devices (small screen media, e-paper (Cecconi 2007)) may be used during the trek. They would make it possible to use these map, but they introduce others problems such as battery power and saving energy for displaying the information (Hoarau 2010) or semiotics rules for small screens (Paolino et al. 2007).

Our suggestions are aimed at a specific audience: trekkers. The survey has shown what trekkers' criticisms and expectations are. It was designed to identify them without any preconceived ideas. The users' survey showed some incompatible requests which were prioritized. Suggestions were designed to meet the most important requests. Consequently, we were able to make original choices such as reducing the visual presence of the highways. These choices are relevant in such a limited context but would be impossible for maps which are made for more general public. The importance we gave to each request could be discussed in other contexts. There could be several different ways to respond to one request; for example, slope classes could be symbolized with other diverging colour schemes.

The maps have been designed on the basis of the survey results. In the future, they should be assessed by trekkers in another survey.

Finally, this work could be part of an on-demand map-making process that is in progress: the results may be used as default suggestions for a public identified as trekkers; the same approach may be used to meet different needs.

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Benefits through Linking of analogue and digital Maps

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Abstract

Despite their popularity electronic maps on mobile devices have not eliminated the use of paper maps. Conventional paper maps can offer a quick overview due to their large format while the map content on mobile devices is adjusted to the limited display size. However the electronic map applications provide many additional functions that paper cannot offer. The authors provide arguments for the linking of the two worlds through explaining how the advantages of both media complement each other. Hence, an approach to bridge the technological gap between analogue paper and the electronic domain is presented. A technology developed by Swedish company Anoto is used to enhance regular paper with an unobtrusive dot pattern enabling an electronic pen with a camera to determine its position on the paper. The potential benefits of this technology are discussed on the basis of two application scenarios that can demonstrate the feasibility of the linking of digital and analogue media and its benefits for the map user.

1- Background and objectives

Map applications on mobile electronic devices such as smartphones and PDAs have been strongly propagated during recent years. The advantages that these devices offer are obvious. Many popular functions like voice guided navigation and automatic routing have only been possible since the advent of mobile electronic devices in combination with GNSS. Despite

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their popularity electronic maps have not completely eliminated the use of paper maps. Conventional paper maps can offer a quick overview due to their large format while the map content on mobile devices is adjusted to the limited display size.

Sellen and Harper (2001) investigated the question whether the paperless office is a myth. To examine the value of paper for the user they made use of the concept of "affordances" that goes back to the ecological psychologist J. J. Gibson (Gibson 1979). Despite the fact, that paper maps are already being replaced by digital solutions in some domains, for example in naval navigation (DeVogel et al. 2001), one might still ask whether paperless navigation is a myth. In this particular case some incidents show that, despite the obvious benefits of the digital system, paper might still be needed as a fall back solution (Backwell 2010). Reilly et al. (2006) interviewed students with respect to their preference for maps in paper form or on electronic devices. Test persons with a preference for electronic maps mentioned the ability to cover a larger total area, to have control over the zoom level of the map and the existence of a search function as reasons for their choice. However, electronic devices like smartphones have not been particularly designed for map applications. Hence, the maps had to adjust to the conditions of the device that has been designed to be preferably compact. The compact dimensions of the display stand in contrast to the large formats of maps in their traditional form on paper. Ishikawa et al. (2008) examined people's wayfinding behavior and spatial knowledge acquisition while using GPS-based mobile navigation systems, paper maps or direct experience of routes. Users of paper maps performed significantly better in wayfinding tasks and in sketching a map of the previously unknown test area. They discuss that the small screen map may be a factor that negatively effects the user's orientation in space compared to users with a larger map view on paper. Gartner and Hiller (2009) come to a similar conclusion. Dillemuth (2009) tested the use of maps in an empirical study. Contestants were given access to a map of a fictional area via a display while the map view had different sizes and only showed a part of the whole map. The rest of the map was accessible through panning. After studying the map contestants had to answer questions concerning their spatial knowledge about the fictional area. Those with a limited map view performed especially worse in answering questions about relative distance and relative direction compared to those who could view the whole map at once. Those test persons in Reilly et al. (2006) that were in favor of the paper map described the map view as easier accessible and easier to adjust for instance through rotating or folding. Besides these technical aspects emotional factors should be taken into account as well. Levy (2001) describes the affinity of paper documents that exists due to their tangible nature or due to the ability to simply leave notes or annotation on the medium.

Given these studies, one can keep hold of several affordances of paper maps and compare them to the affordances of electronic mobile devices (table 1). One should consider if the affordances of paper maps and digital navigation systems together can help to better serve the goals of the user by creating *combinations* of the best of both the paper and digital worlds (Sellen and Harper 2001).

Affordances of paper maps, guides	Affordances of electronic devices
Flick through several pages (guide)	Access larger amounts of information
Read across several documents at once	Access and display multimedia content
Make annotations on the document	Modify documents and create new ones
Get an overview of an area of interest (map)	Get additional information linked to a document
Grasp, fold the map	Use computational resources for services like navigation, route guiding
Work collaboratively on one document	Remote communication with other users
Source of static information	Access dynamic information
Independent, easily accessible	Dependant on battery power, network connection, familiarity of the user with the technology

Table 1: Affordances of paper maps and electronic devices

In recent years there have been several research activities involved in the combination with paper and digital media. An integration of functionality of electronic maps and paper maps is described by Paelke and Sester (2007). Digital interactive paper has been a subject in the Global Information Systems Group (Globis) at ETH Zürich. Thereby an event guide for a festival in Edinburgh that included a map has been developed based on Anoto technology. Besides that a digitally enhanced version of a commercial tourist guide has been tested (Norrie 2009). At Stanford University an interaction with a map and a digital pen has been developed, that enables users to access geotagged photos by tipping on the map with the pen. Equally a map to support biologists in their field work has been developed

(Yeh et al. 2006). Further approaches exist that enhance maps by means of RFID tags (Reilly et al. 2006). The largest continuous Anoto pattern is exhibited in the Ars Electronica Center in Linz, Austria where a 6 x 3 meters city map serves as an interactive city- and geographic information system, called SimLinz, that enables the user to access diverse media and information like real-time data and allocate them geographically in the city (AEC 2009). A commercial application with the Anoto pattern in combination with maps is offered by the company Adapx. Their solution enables printing of maps with Anoto pattern out of ArcGIS. User records that are created with the digital pen on that map can be automatically synchronized with the geo data set in the GIS. The printed legend serves as a toolbar for instance to create new objects (Adapx). Compared to this the maps in the NavAD project shall allow information access as well as input of new information through the analogue medium.

Where experience with test users of digitally enhanced paper maps are published, they tend to be positive with respect to the underlying basic principle (Norrie and Signer 2005, Reilly et al. 2006, Yeh et al. 2006). In a test case of Norrie and Signer (2005) contestants were reluctant to positioning the pen on the map as they did not want to write on it. This reaction is to be taken into account when employing the pen more as a pointing tool rather than a writing tool.

2- Approach & methods

Basis of the digitally enhanced paper map is the technology developed by the Swedish company Anoto. A patented unobtrusive dot pattern (Anoto pattern) is printed on common paper. The pattern's carbonaceous black ink reflects infra red light and this way can be read by a special electronic pen with an embedded camera. The Anoto pattern and the electronic pen are shown in figure 1. The pen only uses a 1.8 x 1.8 mm excerpt of the pattern to determine its position on the paper with a resolution of 0.03 mm. Recorded images are analyzed at 100 frames/s while every image contains at least 6 x 6 dots of the pattern that are oriented according to an imaginary grid where the dots are slightly shifted from the intersections of the grid lines. The whole Anoto pattern can cover an area of 4.6 million km² which is about 73 x 10^{12} A4 pages (Kauranen 2004).

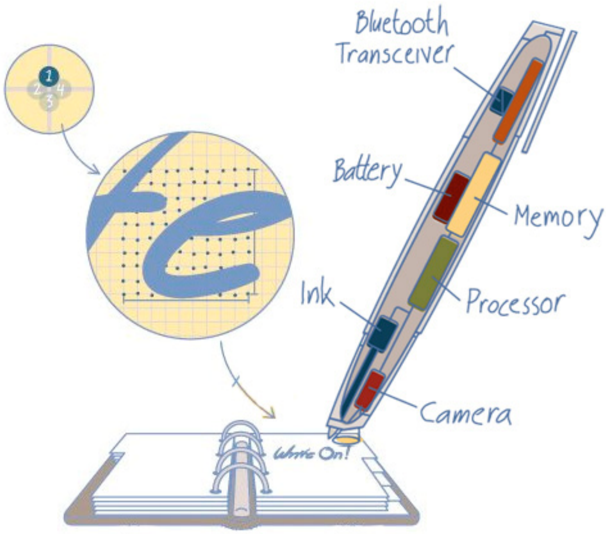

Figure 1: The Anoto pattern with digital pen (Anoto)

Applications of this technology include mainly digital forms. There are systems that can recognize handwriting and allocate the writing in the digital system according to the writing position on the paper. Likewise the marking of checkboxes can be recorded. These forms are used today in the medical domain, in facility management or logistics for instance (Anoto).

Certain challenges arise when printing the Anoto pattern together with a colored map. The black ink is reserved for the dot pattern and cannot be used in the map graphics as long as one does not use special coal free ink. Anoto recommends a limited number of certified printers for which the functionality of the pattern is guaranteed. The maps for the NavAD project however are created with means of common uncertified color laser printers without special ink. Possible interference of the map graphic with the dot pattern is minimized by adopting the map layout to the requirements of the pen as far as possible. This means that dark colors in the map are omitted or replaced by other lighter colors, which poses a challenge for the cartographic design.

The main task for the interaction with the pen and the digital map is to transfer the relative paper coordinates into absolute geographic coordinates. There are basically two ways to achieve this: One can use the so called copied pattern, meaning that for all prints the same Anoto pattern space is used and the pen cannot distinguish between different sheets or pages. This way one would have to store the geographic extends of the map field in a two-dimensional code that comes with the map like for instance a barcode, QR-Code or Data Matrix. Reading and interpreting of the code can be implemented by using the integrated camera of mobile devices and existing software. There are also digital pens that can read barcodes. The other option would be using unique pattern by printing a different Anoto pattern on every map. This might seem cumbersome but due to the total size of the Anoto pattern it is not likely that the pattern will ever be used up completely. Which solution is to be used depends on the scenario or business model to be implemented since higher license fees might go along with the unique pattern model.

Communication between pen and mobile device is carried out via Bluetooth. The transfer of data is initiated by the user by pointing the pen at a special button printed on the paper – a so called pidget. This brings about certain limitations for the interaction with the system. The device is not giving any feedback while the user is acting with the pen on the paper. To solve this one could access the streaming technology by Anoto where a permanent communication channel between pen and device exists enabling real-time interaction, however not every digital pen and especially not every mobile device is capable of this. In the simple case when marking the pidget the relative coordinates are send to a server where they are decoded and further processed before sent back to the device where a listening application will initiate the feedback on the device. In the application within the NavAD project there are three servers involved in this process. One acts as an application service handler to interpret the Anoto specific file format .PGC. This task is performed by the preexisting ActiNote® platform developed by project partner Actimage. The decoded pen data is then sent in form of an XML document to an application server that notices which request the user demands and processes the coordinates according to their application. A route request for instance might require a trajectory optimization since the pen records a lot more points than required for navigation. The transformation from relative to geographic coordinates will also take place here. The conditioned coordinates will then be sent to the listening application on the device via a push web service. This BlackBerry Push Technology is especially helpful in this scenario as it can trigger an event on the mobile device from the server side without the device having to poll for it. When working with BlackBerry the third server, the BlackBerry Enterprise Server, becomes necessary being a communication gateway between the device and the rest of the world. The communication loop is illustrated in detail in figure 2.

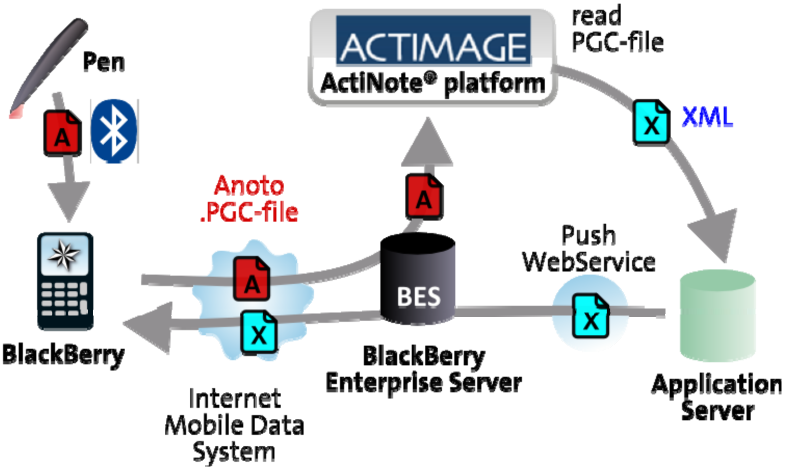

Figure 2: Processing of pen data in the NavAD system

To demonstrate possible applications for this technology two test scenarios shall be investigated. They are tourist maps and maps for mobile data caption. The reason for the tourism scenario lies in the assumption that paper is still the main medium used by tourists when visiting a foreign city (Norrie and Signer 2005). Further, electronic devices don't do justice to the way tourists interact with maps: They often travel in groups with a high degree of interaction and cooperative planning within the group. This social interaction is an integral part of the positive experience. Collaboration around a smartphone or PDA with a small display that cannot be read from all angles is cumbersome compared to a paper map (Brown and Chalmers 2003, Norrie and Signer 2005). Some contestants in Reilly et al. (2006) state they prefer paper maps while travelling and use electronic maps rather for travel prearrangements.

The mobile data caption scenario shall investigate how the described technology can be integrated in existing work flows, e.g. the data capture in road maintenance. In this case mobile workforce detects and records road damages that need to be entered into a digital system to be managed. This capturing process is often still done with pen and paper (Ahtinen et al. 2007) requiring further efforts for post processing. This can mean the scanning of forms and sketches on paper resulting in a homogeneous digital file that makes it difficult to distinguish between old and new content. The introduction of Anoto technology can simplify this post processing workflow by making the scanning obsolete and delivering new data inputs as a separate layer of data to the system.

3- Results

For the tourism scenario an A2 city map of Munich, Germany has been designed that will interact with a digital map. To avoid problems due to different underlying map projections in the paper and digital map, OpenStreetMap is chosen as source of map data both for the printed map as well as for the electronic device. Since the intention is to have a map that can be printed with Anoto pattern on regular laser printers without special ink, the map design had to be adjusted. To find out which map contents interfere to what extend with the pattern a vector version of an existing city map has been taken for testing and has been adjusted in an iterative manual process. In a first test print critical areas on the map were identified where the map information obscures the Anoto pattern making it unreadable for the pen. In order to minimize this effect some or all of the following measures needed to be performed for these map areas: lightening of the background color, replacing of black and grey in labels, signatures and contours with blue or pale purple or omitting it where possible, reduction of the font weight, decluttering of labels and signatures. For some sections this process had to be repeated after the readability of the pattern had been checked again since one did not want to omit too much information of the map in one step. The resulting map compared with its original can be seen in figure. 3.a and 3.b. The lessons learned from this process give guidance when developing a special map design based on OpenStreetMap.

Figure 3.a: Original map design (Colin and Dittmann 2005)

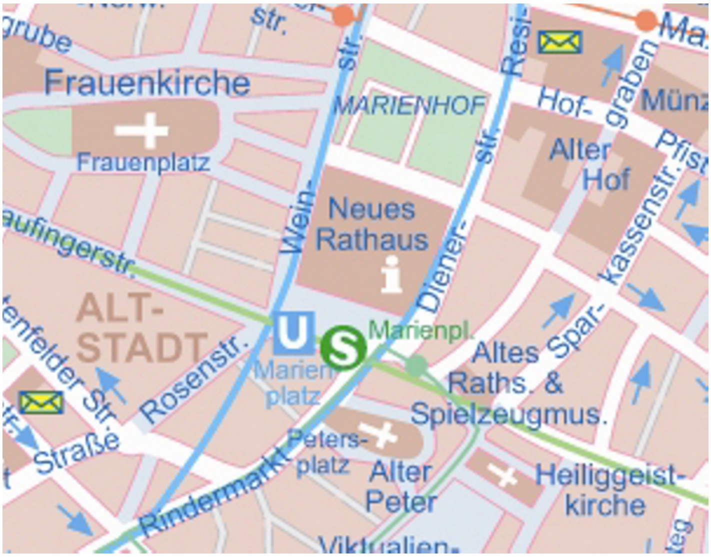

Figure 3.b: Map design from Fig. 3.a adjusted to the needs of the pattern

Small symbols to interact with the map are printed on the paper (Figure 4), either together with the map or on a separate document. They enable access to functions of the map application on the mobile device which is developed using the APIs from Nutiteq (Nutiteq) and CloudMade (CloudMade). For navigation the two functions "new route" and "where am I" are implemented. The first enabling the user to point to a place on the map that will then become the destination the mobile device navigates to, starting from the current location provided by the embedded GPS receiver. The "where am I" button on the map gives the user a grid location on the paper map that corresponds to the location given by the GPS of the device. Further a local search is implemented where the user can point to symbols of common interests such as food or hotels etc. and mark an area on the map. The system will then search relevant objects in the intended area. A laminated version of the map prototype turned out to be useful since the lamination does not interfere the reading of the pattern and marks and writings with ball pen can be wiped off easily.

Figure 4: Pidgets for map interaction

In the mobile data capture scenario a form with attributes that describe and classify road damage is created. The form also contains the Anoto-Pattern. Prior to an inspection the user has to select the area in his GIS and print it as a map on the form. On the street the user can draw the outline of the damaged area on the map and tick all the attributes that apply. When synchronizing the pen with a PC, the drawn shape and the attributes are processed and stored in a database.

The form uses the Anoto Copied Pattern, meaning each form uses the same coordinates to determine the position of the pen. To draw on different maps those coordinates have to be translated in the selected map-area and therefore size and parameters have to be stored when the map is printed. A plugin to Intergraphs GeoMedia GIS is developed to store this information and to provide a unique ID and print it alongside the map. It is also used to read and process the gathered information from the pen after the transmission. Besides storing the attributes, the drawn geometries are simplified by the Douglas-Peucker algorithm and outlines are closed if necessary. Now the captured object and its attributes can be viewed and edited in the GIS (Figure 5).

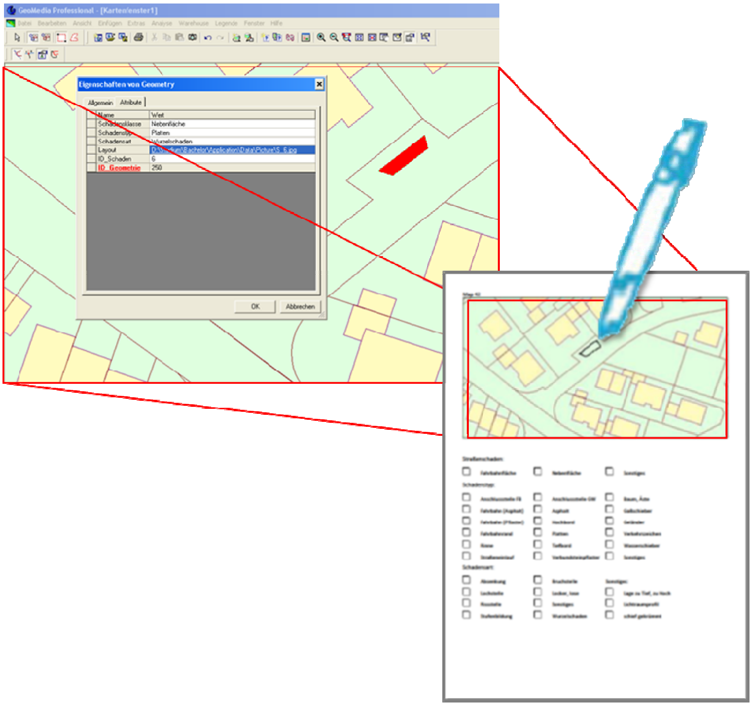

Figure 5: Link of digitally enhanced form with GIS

4- Conclusion and future plans

A detailed compilation of previous scientific work and user studies on paper maps compared to digital maps has been presented. Regarding this work one can state that linking tangible information like paper maps with information and interactions that are familiar in the digital world is a challenge that accommodates our desire for information and security – a feeling that is supported through the tangible. These thoughts were incorporated in the development of prototypes that demonstrate a technical solution to link paper with digital media and that indicate that the two can be linked in a beneficial way. Clearly, the prototypes are in an early stage of development at this point and still need to be tested with potential end users to further examine the possible improvements in information access and input that this system offers. This project further assumes a possible near future scenario presuming that electronic mobile devices with GPS and digital pens are available to a large user group. In such a scenario of ubiquitous computing one might ask whether the paper map in particular will take a new role. As the comparison of the affordances shows, paper maps till nowadays have been designed to give overview, orientation and information, the latter as precise and complete as possible, the affordance of giving information could probably be better fulfilled by electronic networked devices. Hence, one can think about whether the design of present city maps for instance is overloaded for such a scenario. The use of the Anoto pattern implies a reduction in content on the printed map. It has to be examined whether this even has a positive influence on the ability to get orientation from the map with some users. When learning more about how users interact with paper maps and digital devices one will come to more conclusions about how paper maps and digital applications need to be designed for the two to work ideally together and complement each other.

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Understanding the Influence of specific Web GIS Attributes in the Formation of non-experts' Trust Perceptions

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Abstract

The Web has facilitated wider access to spatial information and allowed non-experts to view, use, access and build maps using Web GIS technology. There is a significant number of Web GIS applications which are open to the wider public including people without any GIS knowledge. The complexity of Web GIS interfaces, the risk and uncertainty they incorporate and the limited knowledge of non-experts in spatial data handling and GIS operations influence the perceived trustworthiness of these systems. Previous scholars, such as Monmonier (1996) recognised the importance of trust in map design, however there has been no research into how trust can be improved for Web GIS applications. Three studies were conducted in order to investigate what elements influence non-experts' trust perceptions and how specific Web GIS trustee attributes should be designed in order to improve trust. The results not only demonstrate the importance of further trust research in the Web GIS context, but also show that trust can be improved through interface design, which is an ethical need in order to support non-experts' trust assessments.

1- Introduction

It has been almost twenty years since the introduction of the Web, which contributed to the democratisation of Geographical Information Systems

A. Ruas (ed.), *Advances in Cartography and GIScience. Volume 1: Selection from ICC 2011, Paris*, Lecture Notes in Geoinformation and Cartography, DOI 10.1007/978-3-642-19143-5_13,

(GIS) (Dunn 2007). Prior to this, mainly experts used GIS, but the Web has facilitated wider access to spatial information and allowed non-experts to view, use, access and build maps using Web GIS technology (Skarlatidou 2010). Haklay and Zafiri (2008) note that since the 1990s the number of people that use a GIS in their daily routines has increased and Unwin (2005) uses the term *"accidental geographers"* to refer to these non-experts GIS users who have no GIS knowledge or expertise.

Although the first research paper dealing with Human Computer Interaction (HCI) issues in the GIS field was published in 1963 (Haklay and Skarlatidou 2010), it was mainly the development of Web GIS, Collaborative GIS and Public Participation GIS (PPGIS) applications that created the need to incorporate HCI issues, such as usability, within the GIS field. Recent studies in the area of Web GIS, amongst others, demonstrate the usability deficiencies of non-expert user interaction (e.g. Skarlatidou and Haklay 2006; Nivala et al. 2008), the importance of Usability Engineering (UE) (e.g. Haklay and Tobón 2003), the significance of a User-Centred Design approach for the identification of non-experts' needs and expectations (e.g. Kramers 2008), and that the physical environment, the technological, social and user contexts should be all taken into consideration in Web GIS design (Skarlatidou 2010).

The complexity of Web GIS interfaces and the limited knowledge of non-experts in spatial data handling and GIS operations create additional HCI implications (e.g. concerns about the perceived trustworthiness of these systems). Trust influences human-computer interactions, as people relate to computers in similar ways to other human collaborators (Fogg 2003). In the online context trust was defined as a trustor's (person's) willingness to rely on a trustee, which can be an online system or online information (Chopra and Wallace, 2003). Online trust has been researched from an HCI perspective, particularly for e-commerce and existing studies suggest that a trust-oriented interface design focusing on elements which influence the users' trust perceptions (i.e. logos, colours) can improve the systems' trustworthiness.

While the trust literature demonstrates that people engage more with systems that they perceive as trustworthy and avoid those they mistrust (Sillence et al. 2006), there is limited knowledge about what influences non-experts' trust perceptions when they interact with Web GIS. There are several Web GIS applications that incorporate the elements of risk and uncertainty that influence the user's willingness to rely on the system. For example, in the environmental PPGIS domain, Web GIS are commonly used to provide the wider public with environmental information and to allow citizens to participate in decision-making processes about problems that influence their lives. These systems should not only be easy to use but should be also trusted by their end users.

Two previous studies have been conducted in the context of trust in Web GIS (Skarlatidou et al. 2010a; Skarlatidou et al. 2010b). Three problematic aspects of these studies are that, firstly it was difficult to isolate the Web GIS component and assess in detail the trustworthiness of specific Web GIS elements because the non-expert participants had limited knowledge and experience in this domain. Secondly, although studies supported the identification of several elements which influence non-experts' trust perceptions, the number of participants was too small to further draw any definite conclusions. Thirdly, affective trust was not considered.

In an attempt to address these problems, three studies have been conducted to further understand what influences non-experts' trust perceptions, using a larger population sample and focusing only on the Web GIS component. The first study, an online survey aimed to identify non-experts trust perceptions about specific trustee attributes. The second study focused on affective trust perspectives and especially the use of colour in Web GIS, which has not been previously researched. Finally, a co-operative evaluation was conducted to comparatively assess the trustee attributes in three different Web GIS applications.

2- Background

Fogg (2003) suggests that computers' credibility matters when computerised systems *"instruct or advise users, report measurements, provide information and analysis"* (*p126*), which arguably applies to Web GIS. The increased complexity of these interfaces and their non-expert user base mean that investigation into the interface elements which influence peoples' trust perceptions is necessary to improve their perceived trustworthiness.

Several elements should be considered in the context of online trust. A trustor is the person willing to rely on the trustee (Web GIS) having the confidence that the trustee will act according to his benefits (Kini and Choobineh 1998). Context plays a significant role as it establishes risk and uncertainty which are trust preconditions; the trustor undertakes some risk as it is uncertain whether the trustee will act according to the trustor's benefits.

In one of the oldest allusions to trust, Plato suggests that people trust others only if they have a fear of detection and punishment, which prevents them from stealing or harming. Thus, risk and uncertainty make the trustor vulnerable but trust is upheld *"in the confidence that the trusted will not exploit this vulnerability"* (Bailey 2002, *p1*). In Web GIS risk and uncertainty - with the latter being an inherent characteristic of spatial data- further depend on the context. For example, the risk is different when someone uses Google Maps for driving directions compared to when a user accesses environmental information through a Web GIS and processes it for decision-making purposes.

Other significant trust components include the trustor's propensity to trust and their trusting beliefs, and the trustee attributes which *"reflect different components of trustworthiness"* (Grabner-Kräuter et al. 2006, *p237*). Skarlatidou et al. (2010a) explain that the trustee attributes refer to two categories: the perceptual attributes (the source and its reputation) and functional attributes (evidence that a trustor collects through interaction and assessment of the trustee's quality e.g. aesthetics and usability).

HCI studies suggest that both types of attributes can be improved through interface design. Egger (2001) proposes the use of trust cues related to branding and improved usability. Shneiderman (2000) suggests the use of references of past performance and stresses the importance of usability. Karvonen (2000) links aesthetics to trust and explains how the beauty of simplicity influences usability and online trust. Other trust features include external links, photographs, videos (Wang and Emurian 2005) and feedback mechanisms (Ba and Pavlou 2002).

Web GIS have their own characteristics, which should be considered. Skarlatidou et al. (2010a) conducted an expert evaluation on the What's In Your Back Yard (WIYBY) website and developed a list of trust-based guidelines. The guidelines refer to both the user interface and the Web GIS component and have five design dimensions, which refer to both the user interface and the Web GIS component. According to the authors, elements such as the map size, and colours may influence trust perceptions.

In another study, Skarlatidou et al. (2010b) recruited ten non-experts to evaluate the WIYBY website to understand what elements influence their trust perceptions. After interacting with the system, participants completed a questionnaire to measure the following: usability, aesthetics, user experience, trustworthiness and user expectations concerning the use of trust cues in Web GIS. Although participants thought that the system was not transparent, it was found that perceptual attributes (source and its reputation) had a stronger influence in the formation of trust perceptions. The same finding was also observed in another evaluation with ten non-expert users using the Spatial Decision Support System *"Where to dispose of Britain's nuclear waste"* (nuclear SDSS) by Leeds University. The strong influence of the perceptual attributes found in both tests contradicts previous studies, but the participants' sample size was too small to draw any conclusions. Moreover, trust has both cognitive and affective dimensions, and Skarlatidou et al., (2010b) did not investigate affective trust, especially in relation to colour.

The strong impact of colour on emotions is widely recognized. For example, red has been associated with excitement and green with relaxation but also guilt (Ballast, 2002). Emotional responses to colour are highly influenced by contexts of use (Valdez and Mehrabian 1994). Colour can enhance how information is conveyed on maps and trigger emotional responses (Jones 2010). Colour can either help or hinder map readers to extract specific details from a map and interpret general patterns (Brewer et al. 2004); the wrong colour scheme can result in seeing patterns that do not exist or missing patterns that do. An interesting example is George Arkell's Map of Jewish East London from 1901 (Vaughan 2007) where as a result of the colours used, the Aliens Act of 1905 was introduced to reduce Jewish immigration. Misleading the map reader through colour can reduce trust in the information and is thus an important element of cartographic design.

Kim and Moon (1998) studied e-banking interfaces, and they reported that the main clipart and overall colour layout of the interface affected the perceived trustworthiness of the website, as some colours conveyed trustworthiness (e.g. cool and pastel colours, low brightness). This finding has not yet been tested in the context of Web GIS, where colour can play an important role on the perceived maps' trustworthiness.

3- Methodological approach

Three studies were conducted in order to investigate:

1. What Web GIS trustee attributes influence non-experts' trust perceptions?
2. How do colours influence non-experts' trust perceptions for Web GIS?
3. Can the users recognise and assess the trustee attributes in different Web GIS environments and how their trust perceptions and satisfaction levels are influenced?

3.1 Study 1: Online Survey

In our previous studies (Skarlatidou et al. 2010a; 2010b), we found that important Web GIS trustee attributes, which influence trust, are the: legend, colours, logos, map size, scales and map tutorials. It should be noted that all participants in our previous experiments mentioned in Section 1.2, linked trust to these elements and this is evident from think aloud and post-test questionnaire data. For this study, an online survey was conducted to investigate whether these trustee attributes are important for a wider population sample of non-experts. Participants were required to have no previous GIS education. Links to the survey were provided through social networking websites. Respondents were informed that the data will remain confidential; in order to encourage participation no questions about the age and the gender of participants were included.

The survey started with general questions about prior experience with GIS applications. Participants were asked if they have ever used paper and online maps and if they trust them and to describe their trust concerns and the elements they look for before trusting an online map. Likert scale items (1: Strongly Disagree to 5: Strongly Agree) focused then on the specific trustee attributes under investigation (Table 1.1). Duplicates and negative wording were used to ensure that respondents pay attention to the questions and minimise any bias introduced by the questions. Table 1 lists the items in order of how many people agreed with the statement, with the negatives and duplicates being removed.

1.	I would trust an online map with clear data source logos.
2.	I would not trust an online map if I cannot understand the legend.
3.	I would trust an online map if a tutorial is provided explaining how it was constructed.
4.	A big map size on the screen showing a wider area on the map increases my trust.
5.	Colours play an important role before I trust an online map.
6.	Different scales of the same area can increase my trust for the online map.

Table 1: Trustee attributes examined in the online survey (without negatives and duplicates)

3.2 Study 2: Colour

Study 2 comprised two stages. The first was an online survey, posted through social networks, with five short questions. Each question showed the same map data but with different colour schemes (Figures 1- 5), of which four (Figure 1- 4) were designed using ColorBrewer.

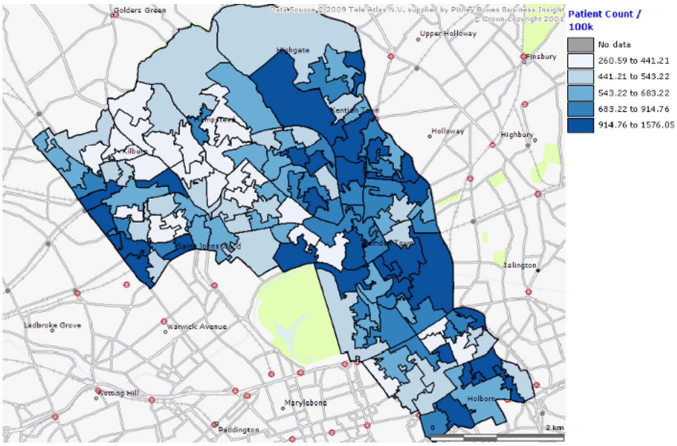

Figure 1: Map of patient count per 100,000 population for alcohol-related conditions, 2008-2010

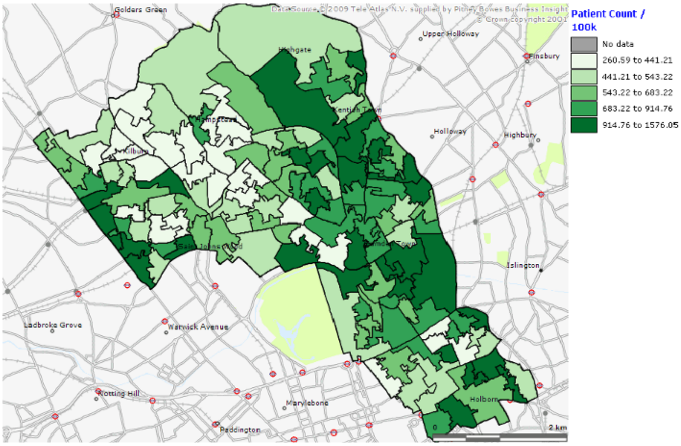

Figure 2: Map of patient count per 100,000 population for alcohol-related conditions, 2008-2010

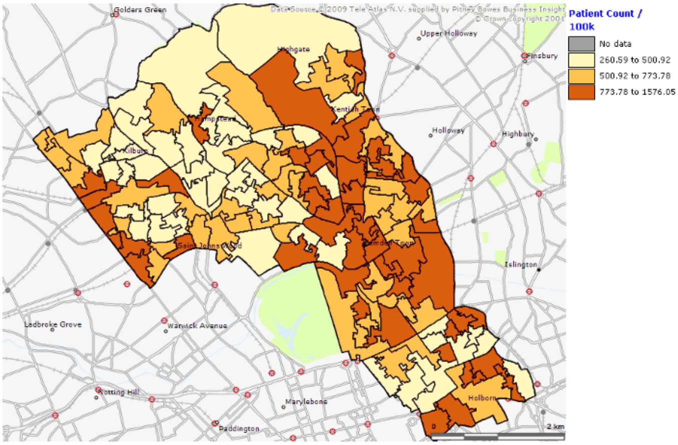

Figure 3: Map of patient count per 100,000 population for alcohol-related conditions, 2008-2010

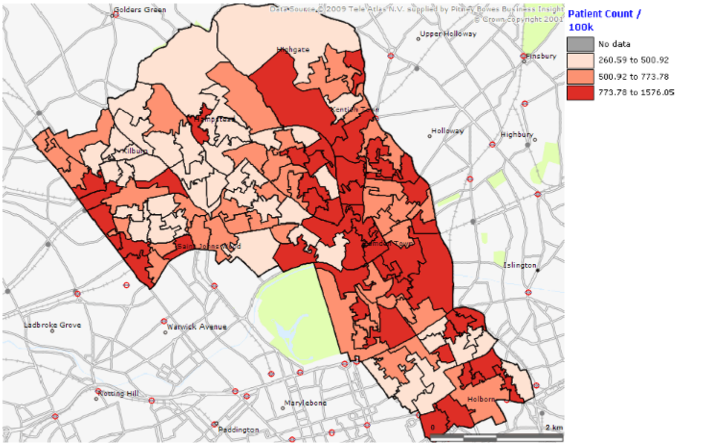

Figure 4: Map of patient count per 100,000 population for alcohol-related conditions, 2008-2010

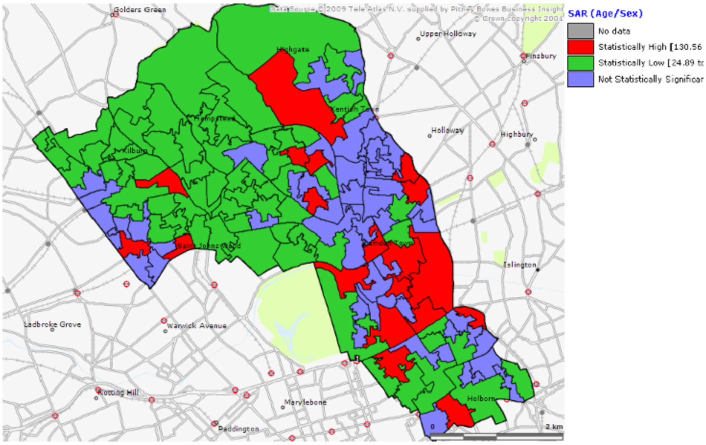

Figure 5: Map of admission rations, standardized by age and sex, for alcohol-related conditions, 2008-2010

For each map, participants rated the strength of their emotional response on a Likert scale[1] for each of Plutchik's basic emotions[2] (Plutchik 1980). This permitted effective and efficient assessment of participants' emotional responses. Participants were then invited to indicate if they liked the map and explain their emotional response. It should be noted that although

[1] The scale used was: Very weak, weak, moderate, strong, very strong (1-5).

[2] Plutchik's basic emotions are: joy, trust, fear, surprise, sadness, disgust, anger and anticipation.

different emotions were examined the focus in the rest of this paper is on trust.

In a second experiment participants were shown each map for three minutes, with a three minute break to erase the emotions from the previous map. Participants were asked if they liked the map; and to describe and explain their emotional response. Questions were open to remove any bias introduced by Plutchik's emotions in the survey. Participants were not shown the map's title or key because the online survey indicated that people found it difficult to separate their emotional response to the colour from their emotional response to the subject matter. This experiment was carried out five times, with groups of three participants, with the maps shown in different orders. All participants were students without colour deficiency.

3.3 Study 3: Co-operative Evaluation for the comparative assessment of trustee attributes

Although study 1 provided a rich insight into which of the elements under examination, influence non-experts' trust perceptions, non-experts may still have very different perceptions about each attribute's representation. Thus, the third study aimed to provide the users with three different Web GIS applications (London Profiler –LP; London Air Quality Network – LAQN and England Noise Mapping – ENM) in order to comparatively assess each trust component and understand which one they prefer in terms of trust, since each application provides different visualisations for each trustee attribute. For example, LP's map fills the screen, ENM's map is 589x388 pixels and LAQN's map is 362x276 pixels. No restrictions of participation were established other than participants should be non-experts and London residents to ensure the same understanding of the geographic area provided.

Since the aim was not to identify usability problems, but to understand the users' opinion about each trustee attribute it was necessary to ensure that the observer interacts with the users and turns the users' attention to the specific trust components. Thus the method of Co-operative Evaluation (CE) was used and ten non-experts were recruited.

All websites studied provide a Web GIS component and incorporate risk and uncertainty as the users can make decisions based on the information provided. For example, the ENM provides environmental information about noise pollution in London so a potential user can decide where to buy a house based on the data. Similarly LAQN provides information about air quality in London and LP provides information such as crime and health data for the wider London area.

In the first stage a questionnaire was completed by each participant to gather demographic data (e.g. user's background, prior experience in Web GIS, gender). Also participants were provided with the same Likert-type items (Table 1) used in the online survey to understand what they believe about each trust component. In the second stage participants were given three simple tasks, one for each Web GIS application (in different order), and they were asked to verbally express their trust perceptions.

Finally, participants were asked which interface they trust the most and why and also their perceptions about the trustee attributes. For example, for the legend item (and for all other elements) the following questions were asked (Table 2). With the guidance of the observer they were then asked to assess each trust component on each application separately.

Legend item			
How important is the legend before you trust an online map?	**Which one of the three interfaces you prefer the most in terms of the legend used?**	**Which one of the three interfaces you trust the most, considering the legend used?**	**Please make any suggestions as for how the legend can be improved on each interface.**
1.Not at all 2. Relatively Important 3. Very Important	1. London Profiler 2. London Air Quality Network 3. England Noise Mapping	1. London Profiler 2. London Air Quality Network 3. England Noise Mapping	

Table 2: Post Questionnaire – Legend Example

4- Results

4.1 Study 1: Online Survey

25 non-experts replied to the online survey[3]. 20 out of 25 answered that they trust paper maps, and 15 answered that they trust online maps, while three answered that they do not trust them and seven were unsure. In terms of trust, non-experts were most concerned with information updates and the data source provider. Attributes such as the reputation of the website and its popularity (e.g. *"I use well known maps expecting that somebody will have spotted any mistakes and corrected it"*) influence trust. In summary the following elements were mentioned by the respondents: updates, level of detail, coherency, source, professional and clear look (e.g. *"If it looks professional I'd trust it"*), and accuracy[4].

Some respondents explained that they trust the skill of the cartographer and others mentioned that look for different elements based on the purpose of using the map (e.g. *"if it is for legalities I check for the Ordnance Survey logo"*). A common strategy they develop before trusting an online map is to look for reference points they can recognise (e.g. *"Some times I spot a place I know and see if its representation makes sense"*). The following Table 3 provides a summary of the non-experts' responses concerning the specific trust-related items under investigation, again without the duplicates and negatives, that were included in the original questionnaire.

[3] 30 experts also replied but their answers were not considered, as this paper focuses on non-expert interaction.

[4] Although none of the participants explained how they assess it.

	Disagree/Strongly Disagree	Neither	Agree/Strongly Agree
a. I would trust an online map with clear data source logos.	1	2	22
b. I would not trust an online map if I cannot understand the legend.	1	4	20
c. I would trust an online map if a tutorial is provided explaining how the map was constructed.	3	3	19
d. A big map size on the screen showing a wider area on the map increases my trust.	5	6	14
e. Colours play an important role before I trust an online map.	7	5	13
f. Different scales of the same area can increase my trust for the online map.	3	4	18

Table 3: Summary of responses (Study 1)

4.2 Study 2: Colour

Although different emotions were explored, the study revealed that trust was the strongest emotion reported by participants, particularly for the Red/Blue/Green map (Table 4). Comments suggest it was trusted because the colours were easily distinguished and this increased confidence in map interpretation. Only six participants from the second experiment liked the Red/Blue/Green map, while nine disliked it.

	Very strong	Strong	Moderate	Weak	Very weak	Rating Average	Standard Deviation
Blue Map Trust	**2.6%**	**30.8%**	25.6%	23.1%	17.9%	2.77	1.158
Green Map Trust	5.9%	14.7%	32.4%	17.6%	29.4%	2.50	1.237
Red Map Trust	0.0%	16.2%	45.9%	24.3%	13.5%	2.65	0.919
Orange/Brown Map	6.1%	6.1%	36.4%	27.3%	24.2%	2.42	1.21
Red/Blue/Green Map Trust	**3.1%**	**34.4%**	34.4%	6.3%	21.9%	2.91	1.332

Table 4: Trust emotion for each map provided

The blue map was the most liked, and it scored second for the emotional response of trust that it conveys. The users interestingly used the words *"accurate, honest, trustworthy and least surprising"* to describe it. The green map was the only one for which *"trust"* was not the strongest emotion. Respondents reported feeling *"excitement, anticipation, comfortable, safe, interested, intrigued"*. The orange/brown map received the weakest emotional responses and it was the least trusted map.

Compared to the other maps with a sequential colour scheme, red scored highly for emotions more strongly linked to positive affect, but it received the second highest score for sadness. With some of the strongest emotional responses of all the maps, it may be concluded that the red map was the most engaging for participants in the study.

4.3 Study 3: Co-operative Evaluation for the comparative assessment of trustee attributes

In the CE experiments, five males and five females participated. Seven out of ten non-experts are in the age group of 25-34, two in 18-24 and one in 35-44. Six out of ten users are intermediate computer users, two experts and two advanced. All of them use the internet on a daily basis but six out of ten use Web-mapping applications occasionally and four frequently. Participants answered the same questions that they were asked in Study 1.

Table 5 summarises their responses before and after interacting with the applications.

	Not at all		Relatively Important		Very Important	
	Before	After	Before	After	Before	After
a. Logos	1	0	5	6	4	4
b. Legend	0	0	3	3	7	7
c. Tutorial	2	1	2	3	6	6
d. Map size	3	1	3	2	4	7
e. Colours	2	1	5	4	3	5
f. Scales	0	3	6	3	4	4

Table 5: Responses for trustee attributes before and after CE experiments.

Six out of ten users trusted LP the most, although their first impressions were mostly negative (e.g. "I have no idea what I am looking for. The map is huge"). Four users trusted ENM the most, while none of the participants trusted LAQN. The following Figures (6, 7) describe what the users think for each trustee attribute on each application. For example, although users liked the LP legend the most, they trusted the ENM legend.

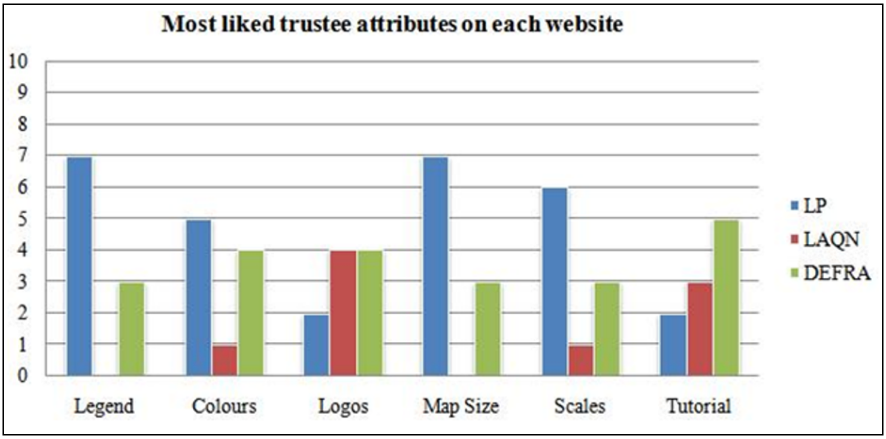

Figure 6: Users' preferences for each trustee attribute (most liked).

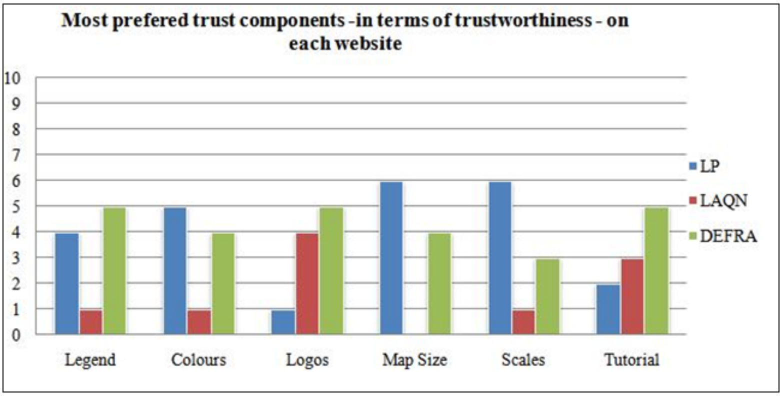

Figure 7: Users preferences for each trustee attribute (most trusted).

5- Discussion

The results of Study 1 reveal that non-experts trust paper maps more than online maps, which shows the need to research trust and improve the trustworthiness of online maps, because of their increased popularity and use. More evidence that trust should be further investigated is provided by Study 2, since the strongest emotional response of participants was related to trust.

It was already explained that the trust-related elements under investigation described in Table 1, were found to be important in our previous inductive research approach and after the investigation of two Web GIS applications (WIYBY and nuclear SDSS). From Study 1 it can be concluded that the majority of respondents thought that all these trustee attributes are important in the formation of trust perceptions, however when the respondents' were asked to describe the elements they consider before trusting an online map, they failed to recognise all of them. Based on the responses, the most important Web GIS trustee attribute is the existence of logos, followed by legend, map tutorials, different scales, big map size and colours. Colour was considered as the least important, although it was revealed by Study 2 that the strongest emotion triggered by colour was trust.

Similarly in the CE the majority of participants agreed that all trustee attributes are important for the formation of their trust perceptions, in the following order: legend, scales, data source logos, and map tutorial. After accessing the three websites the users' perceptions about the importance of the trustee attributes changed to: legend, logos, map size, tutorials, colours and scales.

LP had the most-liked legend (Figure 8) but interestingly the most trusted was the ENM legend, which participants found easier to understand, as it explains base map features and it looks professional. For the LAQN legend most users commented that they could not understand it, thus they did not trust it.

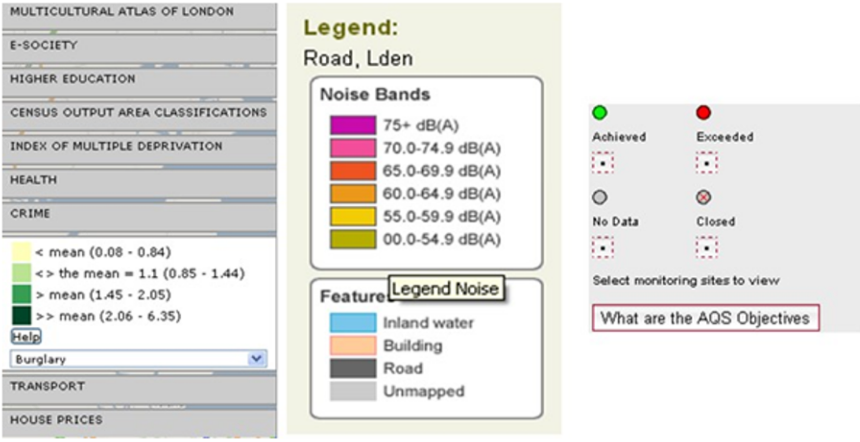

Figure 8: LP, ENM and LAQN legends (from left to right).

The least trusted website for logos was LP, which does not list the provider's logo on the map's page. Participants commented that the logo should be more obvious. An interesting finding is associated with the map size. First, the users' perceptions about the importance of map size changed after accessing the applications. Moreover, although the first impression of LP's map size was negative, at the end of the test the users liked and trusted it the most. LAQN, with the smallest map size, was not liked and trusted.

The existence of different scales was considered as particularly important in both the online survey and the pre-test questionnaire. However, after accessing the applications the users thought that it was the least important trustee attribute. The most liked and trusted website in terms of scales provided was LP, which uses Google API, while LAQN provides only two scales and was criticised as *"useless"*. No map tutorials are provided, but ENM and LAQN provide textual information for the maps and the data.

LP has a Help button (Figure 8), not identified by users, thus the website was the least preferred and trusted for this attribute.

Study 2 revealed that non-experts do not trust the colours they like the most, which contradicts the findings of previous studies, where it is suggested that beautiful interfaces are perceived as trustworthy (Karvonen 2000). This finding shows the distinctive characteristics of online map use. Easily distinguished colours give confidence in map interpretation (e.g. Red/Blue/Green map). In Study 3, users liked and trusted the colours provided by LP the most, although the same green shades were used for the Green map Study 2, which was the least trusted. It should not be ignored that this was a comparative assessment of the trustee attributes and the colours used in the other two applications were highly criticised by the participants. Several participants suggested using distinctive colours instead of different shades of the same colour, corroborating the second study's findings.

6- Conclusions and future plan

All three studies showed that the trustee attributes investigated are important in the formation of non-experts trust perceptions; furthermore, for some trustee attributes (i.e. colours and legend), designing for trust cannot be achieved in parallel to designing likeable interfaces. Also, all three studies reveal the importance of trust in this context. Although it can be as simple as designing bigger maps, focusing on a trust-oriented interface design to improve the trustworthiness of Web GIS is of particular importance when designing for non-expert users.

It should not be ignored that since Web GIS applications are used within wider contexts there are several additional trustee attributes that should be considered, as described by the trust guidelines in Skarlatidou et al. (2010a). In addition, this paper used the comparative assessment of the trustee attributes to help users realise their importance but also to understand how different representations of these attributes influence trust (e.g. what map size or colours are more trustworthy?). A more reliable approach would involve a controlled experiment where each trustee attribute would be tested separately, with the development of different interfaces for the same application.

The online survey revealed that several non-expert users trust the skill of the cartographer, even though it is now possible for anyone to develop a Web GIS application. One of the most significant trust concerns of non-experts, revealed during Study 1, is the recency of the map and information provided, although during the experiments none of the participants assessed how data are collected and updated. Based on this feature the most trusted Web GIS should have been the LAQN, which collects data by monitoring sites and updates every two hours, followed by ENM and LP, which provides statistics dated to November 2007. The results however, do not follow this pattern demonstrating the importance of a trust-oriented interface design.

Monmonier (1996) discusses trust issues, but when it comes to online maps these are even more significant. There is a clear ethical need, to protect and support non-experts' trust assessments before they make a decision to rely on online maps. This can be achieved by improving their spatial skills (i.e. effective tutorials), where further research is required. Also the GIS community should consider the establishment of trust standards and the subsequent development of trust-inducing features for Web GIS, which would assure users that an application is trustworthy.

Acknowledgements

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Usability Evaluation of a Map-Based Multi-Publishing Service

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Abstract

The paper presents the usability evaluation of a map-based multi-publishing service for outdoor leisure activities. The multi-publishing service allows users to access the same spatial information contents through different channels, such as printed maps, map applications for the web or mobile phones and other interactive media. These channels together form an interface for the geospatial information. The users may use the channel or the combination of channels that is best suited for the current situation. The user experience is constituted across the channels, thus the channels need to be networked and the seamless interaction between the channels needs to be ensured.

The case study presented here illustrates how the usability evaluation methods of thinking aloud and questionnaires are exploited to achieve results for concrete input for the iterative design process of a map service. Examples of resulted suggestions to improve the service include: determining how to further develop the user interfaces of the respective channels or determining in what way the map design should be improved to better serve the user needs. The evaluation was conducted for the channels of a web map application, a mobile map application on an iPhone and printed maps.

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1- Introduction

New opportunities for map-based services in different use contexts are emerging. Map users also seem to be more demanding than ever before regarding map-based services (Cartwright and Hunter 2001). Just guiding the user through an unfamiliar environment is simply not enough anymore; instead, the service should also be engaging, fun and aesthetically pleasing (Sarjakoski et al. 2009a). In a map-based service, just like in any other service, the role of emotional aspects in the interaction is high. Qualities such as aesthetics, excitement, challenge or delight are equally as important in a service as cognitive and functional aspects (Battarbee 2004). The experience of using a service is always related to the users and the use context; therefore, it is important to identify the possible users and take that into consideration in the design (Vaajakallio et al. 2009). The user group for interactive maps has increased rapidly compared to the traditional printed map users (Schobesberger 2009). With user research and the user-centred design (UCD) approach, the values, expectations and preferences of future users may be found and then supported in design through form, visuals and other qualities (Battarbee 2004).

A map-based multi-publishing service may include channels such as printed maps, map applications for the web, mobile phones and other interactive media. These different channels together form a uniform interface for the map-based information. In a multi-publishing service the user may use the channel or the combination of channels that is best suited for the current situation. According to Sousa and Voss (2006) users value the opportunity to choose the channel by themselves in their current need. From a user's perspective the different channels should appear as a single service, and therefore a seamless service experience across the channels should be ensured (Sousa and Voss 2006). In a map-based multi-publishing service the same geospatial information is delivered from a single data core and adapted into all the channels (Fig. 1). On top of that in a successful multi-publishing service the key issues are to network the channels and to make the channels share a common visual identity (Flink 2009).

Figure 1: In a multi-publishing service, the channels may share resources such as the geospatial information

The concept of a map-based multi-publishing service is relatively new and studies on methods for evaluating such services are still missing. However, conducting usability evaluations for the whole multi-publishing service is essential, as the user experience is constituted across the channels. Usability evaluations of map applications for the web and mobile phones and printed maps as such are numerous, as is discussed in the following section. Studying the usability of interactive maps always includes an evaluation of the user interface design as well as the map itself, since these cannot be separated due to the nature of interactive maps. Consequently, we want to include both of these aspects in our usability studies. The map-based multi-publishing service evaluated in our case study was developed by exploiting the UCD process, which included conducting user studies and utilising several UCD methods, such as design probes, persona- and scenario-creation, defining design drivers and user requirements (Sarjakoski et al. 2009b). The usability testing described in Section 3 was part of the final stage of the concept development process for the map-based multi-publishing service.

1.1 Previous Studies on the Evaluation of Interactive Maps

Commercial web-mapping sites have been studied by Skarlatidou and Haklay (2006) and Nivala et al. (2008). Skarlatidou and Haklay (2006) utilised the thinking aloud- method, pre-test and post-test questionnaires and also measured the time the users took to conduct the tasks with several web map services. The results introduced the average time spent with the different web-mapping sites for specific tasks as well as the success rate for the web maps. Nivala et al. (2008) evaluated the usability of web-mapping sites in a study that aimed to identify potential usability problems, which were then grouped according to their severity. In contrast to many studies that focus solely on the user interface, this evaluation places plenty of importance on the observations of the map visualisation itself.

When using the mobile map applications, the user needs to interact not only with the map but also with the surrounding environment (Van Elzakker et al. 2008). Van Elzakker et al. recommend the combination of laboratory and field testing in order to obtain deeper knowledge of different usability issues than could be found through using either approach on its own. The usability of topographic maps on a Personal Digital Assistant (PDA) has been addressed by Nivala et al. (2003), who describe the process of usability evaluation that was conducted as a field test in a national park. Heidmann et al. (2003) utilised the UCD approach for the development of a mobile location-based map application within a fair context. From the usability study, abstraction and simplification were derived as central design guidelines for interactive maps. Kaasinen (2003) examined location-aware mobile services and presented the user needs for such a service.

Maintaining the user-centred approach throughout the design process is essential for successful design. In the field of geoinformatics, studies that involve all stages of a UCD process are still rare. The studies by Kramers (2007) and Van Elzakker and Wealands (2007) are examples of work that involve all such stages. Kramers (2007) introduced a user-centred development for the Atlas of Canada. The process consisted of three principal stages: an examination of business requirements, detailed user requirements research, and product and systems design. Van Elzakker and Wealands (2007) presented a case study of a UCD process for a mobile location-based service for tourists. The key phases in this UCD process were user profiling, user task analysis and evaluations.

1.2 Background of the Study

In this research we evaluated the map-based multi-publishing service prototype that was the outcome of the 'Multi-Publishing in Supporting Leisure Outdoor Activities' (MenoMaps)-project carried out at the Finnish Geodetic Institute, Department of Geoinformatics and Cartography from 2008 to 2010. The aim of the project was to carry out research on the utilisation of web-based multi-publishing for the purpose of outdoor activities. The follow-up project 'Map Services for Outdoor Leisure Activities Supported by Social Networks' (MenoMaps II) is carried out from 2010 to 2013 (Sarjakoski et al 2010). The MenoMaps II-project aims to explore new possibilities for map-based leisure services for outdoor activities within the context of hiking in nature. The map-based multi-publishing service prototype will be further developed during the MenoMaps II project and it will be exhibited in the Nuuksio Nature Centre in Finland at the end of 2012.

2- Methods

Usability evaluation of a multi-publishing service may be conducted one channel at a time. For our research, we completed usability tests for a web map application, which we here call simply a Web Map (Kettunen et al. 2011), a mobile map application on an iPhone (Kovanen et al. 2009) as well as for printed maps (Oksanen et al. 2011). Potential end users participated the tests. A combination of methods - thinking aloud and questionnaires - were used.

Thinking aloud (Boren and Ramey 2000) is a method often used in usability research. In thinking aloud the users perform designated tasks with the tested system, while all the time verbalising their thoughts out loud. The test situation is usually recorded to support the data analysis. Observing the users doing tasks is more useful in finding usability issues than relying on subjective opinions of the service (Nielsen 1993). With thinking aloud, we are able to get an understanding of how users see the service as well as an understanding of their major conceptions of the service (Nielsen 1993).

A questionnaire given prior to the evaluation is to obtain background information on the participant, such as age, gender and previous experience with the tested service. A questionnaire right after the thinking aloud tasks is valuable because it helps reveal subjective opinions and user satisfaction with the service. When the questionnaire is filled in right after using the tested service, the answers usually are more valuable (Root and Draper 1983). The questionnaires used in the usability evaluation seek to find out what the test users think about the tested service and what features they particularly like or dislike about it (Nielsen 1993). Questionnaires seem to be a popular way of studying the printed maps. For instance, Ortag (2009) used questionnaires for an experiment on three slightly different topographic maps with both professionals and average users. Some ready-made questionnaires exist, such as the System Usability Scale (SUS) presented by Brooke (1996). The SUS is a ten-item Likert scale with statements covering a variety of aspects on system usability, such as the need for support and training and the complexity of the tested system. In our case study, we utilised the SUS after the thinking aloud tasks. We also developed questionnaires to study printed maps delivered from the MenoMaps service in order to obtain specific information for our research.

3- Case Study on Evaluating the Channels of the Service

In the case study, we studied the ease-of-use and usefulness of the MenoMaps multi-publishing service for hikers by using the methods of thinking aloud and questionnaires. The usability of the user interfaces of the applications as well as observations regarding the map contents and visualisations are included in the study since from the user point of view the user interface and the interactive maps cannot be separated.

3.1 Usability Evaluation

Usability tests were conducted separately for the three different channels of the map-based multi-publishing service: the Web Map, the mobile map application on an iPhone and the printed maps (Fig. 2). The channels share the same geospatial information and visual identity. The evaluation of the web and mobile channels was conducted in a qualitative manner, while the printed maps were tested using a quantitative method.

Figure 2: The usability evaluation of the MenoMaps prototype included three channels: a web map application, a map application on an iPhone and printed maps

3.1.1 Usability Evaluation of the Web Map and the Mobile Map Applications

The evaluation of the web map and mobile map application were conducted in a laboratory environment. The evaluation included pre-test and post-test questionnaires and tasks with the applications utilising the thinking aloud method. Six potential users, three female and three male users, took part in the usability evaluations. The participants were from 32 to 58 years of age and they all had a history of leading various kinds of hikes. We organised the evaluations for web and mobile maps one participant at a time with a single usability practitioner. The same set-up and the same participants were involved in both settings.

The participant was asked to fill out a background information form about their age and gender, their background as hikers, habits of using maps, and so forth. The thinking aloud method was then introduced and the tasks were given to the participant one at a time. The tasks were based on a scenario of a friend who wanted to go for a hike in Nuuksio National Park (Fig. 3). The tasks required the user to use various functions, such as finding additional information on the trails, listening to sound landscapes, or drawing their own routes. Participants carried out the tasks individually with the usability practitioner observing and recording the answers. The participants talked out loud to express what they were thinking as they performed the pre-defined tasks. In total, the web test included six tasks and the mobile test five tasks.

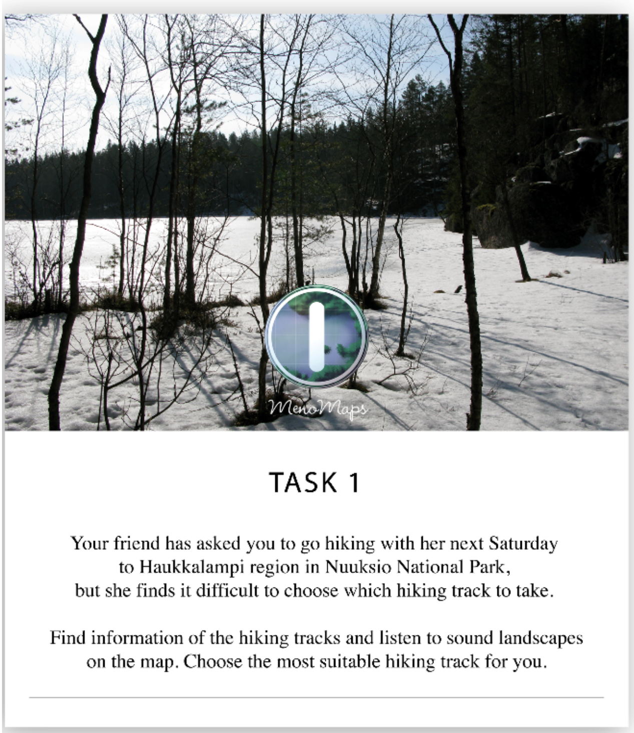


Figure 3: The first task in the web evaluation introduced the overall scenario and gave the participant a simple goal to reach

After the thinking aloud tasks, the participant was given a questionnaire concerning the tested maps. The slightly modified questionnaire was based on the System Usability Scale (SUS) (Brooke 1996).

The evaluation of the Web Map and mobile map application provided a large amount of qualitative data recorded on video, which we transcribed, word-for-word, into text. From this material, we wrote down each problem or comment on a single piece of paper as an individual observation (Fig. 4).

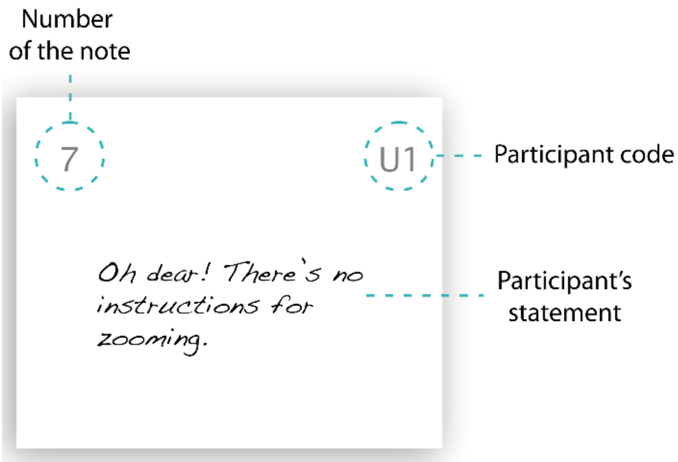


Figure 4: Each observation, labelled with participant code and the running number of the notes, contains a participant's statement about the service

To analyse the user study material, we placed the individual notes into an affinity diagram (Beyer and Holtzblatt 1998). We placed the notes onto the diagram one note at a time and looked for other observations that appeared to belong together. When related notes started to form groups, we gave the notes a title to represent the group. The notes finally formed a hierarchy in which similar issues and themes were grouped together. We did the analysis separately for the web and mobile tests.

3.1.2 Usability Evaluation of the Printed Maps

We evaluated the printed maps by utilising questionnaires that were distributed to an information centre in Nuuksio National Park. Four different maps of the Haukkalampi region in Nuuksio National Park accompanied the questionnaire. Three of the maps were test maps created at the Finnish Geodetic Institute (Oksanen et al. 2011) and one of the maps was part of a 'Karttakeskus Nuuksio-Luukkaa outdoor map' available on the market. Two scales (1:12 000 and 1:20 000) of each map were provided in one A3-sized pamphlet.

The questionnaire included background questions on age, gender, nationality and the participants' habits of using maps as well as spending time in the nature. The more specific questions regarding the four maps were to find out about the participants' preferences between the different maps. The questionnaire asked participants to choose, for example, the most useful map, the most boring map, the map they would prefer to use, or the map they would need the most help with. We also asked the participants how much they would be willing to pay for the maps they received (an A3-sized printed map). The question provided the examples of 0€, 0.5€, 2€ and 5€. The participants' preference of map scale is also interesting and one question asked them which scale (1:12 000 or 1:20 000) they preferred in the rather small area of the Haukkalampi region.

We analysed the questionnaires from the printed map evaluation by counting and comparing the answers for each question. We received a total of 166 completed questionnaires, 136 of the participants were Finnish and they were from 20 to 73 years of age. Seventy-one of the participants were women and 93 were men (two of the participants did not provide their gender).

3.2 Results of the Usability Evaluation

We utilised the results of the usability evaluation to further develop not only the different channels, but also the map-based multi-publishing service as a whole. We first examined the results separately channel by channel and finally from the point of view of the entire multi-publishing service.

3.2.1 Results for the Web Map and the Mobile Map Applications

Analysis of the Web Map resulted in suggestions in the following main groupings:

- New features
- User experience
- Individual content
- Map data

The group 'New features' includes topics such as keeping the information up-to-date, concerning, for example, route descriptions, sound landscapes and the accessibility of the trails. Participants suggested new features, such as being able to receive current information about other hikers visiting the same area. The users also suggested that the service could benefit from user-generated information, such as the current state of fireplaces. The novel features that were introduced in the Web Map, such as the sound landscapes (Laakso and Sarjakoski 2010) or animations, were received with interest, but at the same time, with a certain amount of uncertainty regarding their usefulness in route planning.

The title 'User experience' includes several detailed suggestions in order to improve the user interface; for instance, making the terms used clear and intuitive, having enough contrast in the text, making the symbols more easily readable and adding an overview map.

'Individual content' implies that various options for personalisation should be included in the service. For example, the users wished they could choose the colour and type of things they might add to the map, such as lines, areas and icons. In this way it would be clear which icons or paths are their own creations. Users also suggested that it should be possible to activate the marked trails to inform other users which route has been chosen in case they wanted to share their map.

The participants in the usability evaluation had plenty of opinions about the map contents. The MenoMaps service provides several maps also to the web and mobile applications (Fig. 5): the Topographic map, the Forest map, the Relief map, the Winter map, the Orthophoto map, the Infrared orthophoto map and the Oblique view map (Oksanen et al. 2011). As we expected, users considered the most traditional looking maps, such as the Topographic map, to be the safest and most suitable for orienteering. Users thought that other, more experimental maps, such as the Forest map or the Winter map, were good additions which complemented the traditional types of maps. The main critique about the different background maps was that the main purpose of each of the maps was not clear: for example, the users found it difficult to imagine what to do with an Infrared orthophoto map. Some of the maps, such as the Forest map, were often misinterpreted. This suggests that a legend is needed to ensure the usability and safety of use.

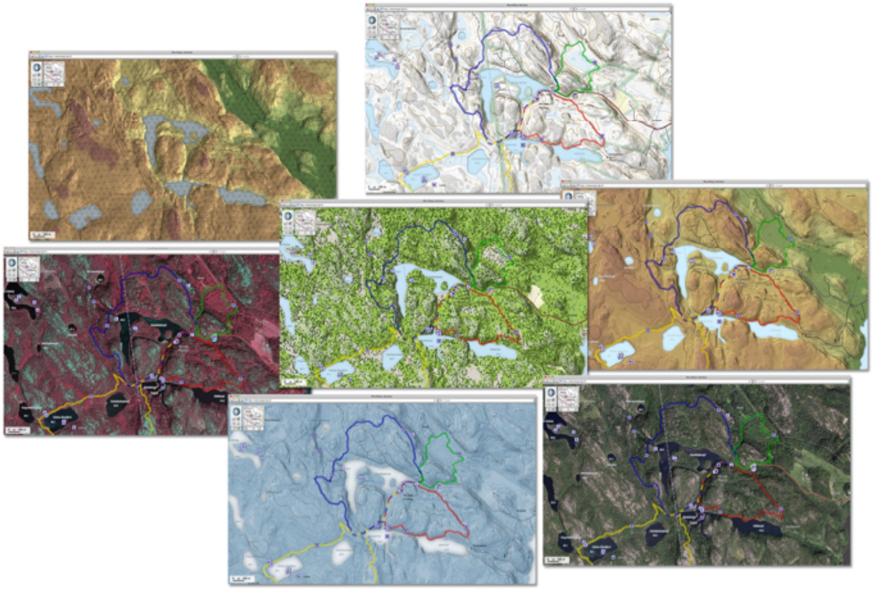


Figure 5: The map series delivered by the MenoMaps service

We grouped the results from the evaluation of the mobile map application into the following principal topics:

- Hardware
- Contents
- User interface

The 'Hardware' group contains all of the technical issues, such as the downloading of the maps, problems with the Internet connection and issues with the iPhone itself.

'Contents' includes various observations pertaining to visualising the contents, such as the trail markers, text and icons and how they should not be overlapping, as well as observations on the usefulness of the contents. The users argued that the usefulness of different background maps and additional features such as the sound landscapes on the mobile map, needs to be clarified. The sound landscapes as well as photos or videos should be relevant and provide further information about the location. Users wished there would be up-to-date information about things like cafés, fireplaces and bus timetables. Current information on the condition of the trails (such as flooding on the pathway) would also be valuable.

A relevant finding from the ‘User interface’ group is that the number of actions the user needs to perform should be minimized, meaning that when activating a function, for example an animation, it should be performed using a minimum number of steps. All actions should also give feedback and the actions as well as the user interface should be consistent. The mobile map and the web map applications still lacked a search function at this stage of development. A possibility to search locations by typing their name into a search field or choosing them from a list would be essential for making the map service more usable.

To achieve results from the post-test questionnaires for the Web Map and mobile map application (Fig. 6), we calculated an overall value of the system usability by using the SUS formula (Brooke 1996). The satisfaction with both the Web Map and the mobile application was relatively high. The users thought both of them were fun to use and that utilising them for hiking would be easy. As the evaluation was first conducted with the Web Map, followed by an evaluation of the mobile application two weeks later with the same participants, it could be observed that the participants had adopted the idea of the multi-publishing service quickly and that they expected the both channels to look alike and work in the same manner.

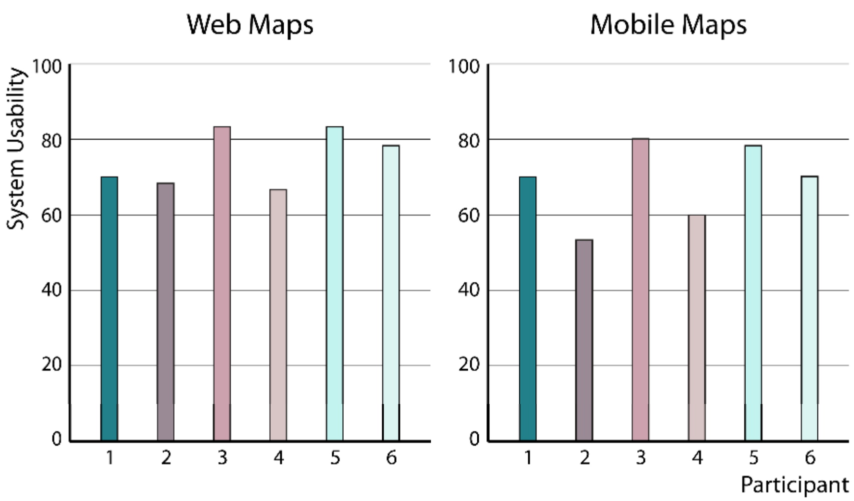


Figure 6: The system usability scores for each participant show user satisfaction with the Web Map and mobile map application

3.2.2 Results for the Printed Maps

The questionnaire for the printed maps included questions concerning the four different maps provided as well as general questions on what kind of maps the users prefer to use (Fig. 7) and how often they use maps (Fig. 8). We analysed a total of 166 questionnaires.

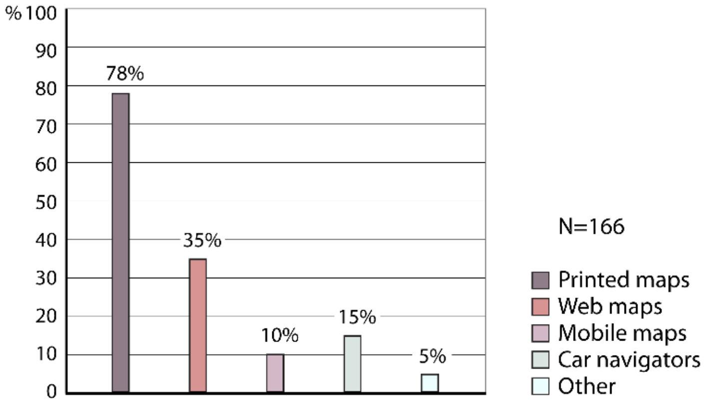


Figure 7: The types of maps the participants preferred to use

In Figure 7 it can be seen that printed maps are the most popular types of map, with web maps being second. The category other maps (5%) refers to for example GPS devices. Fig. 8 shows how often the participants use maps. Most of them reported that they use any kind of maps fewer than once a month.

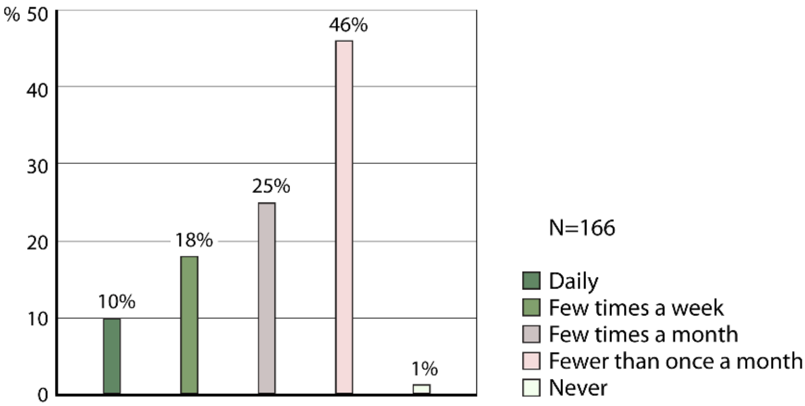
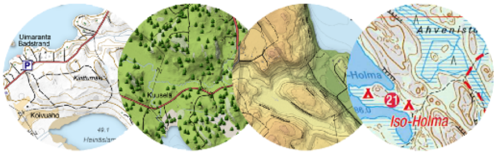


Figure 8: The frequency of map usage by the participants

The comparison of the four maps (Fig. 9), the Topographic map, the Forest map, the Relief map and the Outdoor map, led to many opinions. As expected, the most familiar maps were the already much-used Outdoor map (54%) and the simplified, but still traditional looking Topographic map (41%). The Topographic map was clearly the easiest to read (46%), with the second easiest being the Outdoor map (21%). The most surprising map chosen by the majority of users was the Forest map (63%), but 60% of the users also chose it as the least useful map, 61% as the map that has the least amount of information and 59% as the most irrelevant map. The Forest map was also the map the participants would need the most help with (33%), with the Outdoor map being second (29%). In addition, the Forest map was the most beautiful map (45%), with the Relief map coming second (40%). The ugliest map was the Outdoor map chosen by 50% of the participants. The most intuitive map was the Topographic map (37%) and it was also chosen as the map that the participants would prefer to use (39%). The most trustworthy map was the Outdoor map (53%). Participants considered one to two Euros to be a suitable fee for the A3 printed map. Participants would be willing to pay up to 2.30 Euros for the Outdoor map, which was the most expensive map.

The answers were rather equal between the maps, but participants favoured the most traditional type of maps, the Topographic map and the Outdoor map. From all the answers, 67% of participants would rather use a map at the scale of 1:12 000 instead of 1:20 000 in the limited area of the Haukkalampi region.



	Topographic Map	Forest Map	Relief Map	Outdoor Map
The most familiar map	41%	3%	3%	54%
The most surprising map	3%	63%	31%	4%
Map that is the easiest to read	46%	15%	18%	21%
The most interesting map	21%	27%	30%	23%
The most boring map	19%	30%	27%	25%
The most useful map	38%	4%	6%	52%
The least useful map	5%	60%	30%	6%
Map that has the most info	20%	4%	6%	70%
Map that has the least info	8%	61%	28%	3%
The most beatiful map	12%	45%	40%	4%
The ugliest map	21%	13%	16%	50%
The most modern map	32%	18%	29%	22%
The most intuitive map	37%	17%	18%	29%
The most irrelevant map	8%	59%	24%	9%
Map I would trust the most	39%	2%	7%	53%
Map that I would preferably use	39%	8%	15%	38%
Map I would need the most help with	13%	33%	26%	29%
Map on which the accessibility of the terrain is the easiest to read	21%	10%	22%	48%
How much would you pay for the map? (e.g. 0€ / 0,5€ / 2€ / 5€...)	2.00 €	1.50 €	1.40 €	2.30 €

Figure 9: Result of the comparison of the printed maps

4- Conclusion and Future Plans

The MenoMaps multi-publishing service, as well as the different channels, is being further developed and the results of the usability evaluation are considered in this process. The consistency of the multi-publishing service is certainly one of the key issues to ensure and it is also one of the greatest challenges in designing multi-publishing services. From the usability evaluation, it was noticeable how much the users emphasised the importance of keeping all of the information up-to-date. The users adopted the idea of the multi-publishing service quickly and they expected the different channels to look alike and work in the same manner.

In the future, we will conduct more usability evaluations within the topic. Currently, the evaluation of the mobile maps has been conducted in a laboratory and not in the wild. Further usability testing of the mobile application needs to be carried out with the participants hiking in the nature. It is also necessary to ensure the usability and seamless service experience across the channels.

Acknowledgements

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Tool and Processes to Collaborate

Contemporary and Collaborative Web Concepts as part of a Geo-Knowledge Tool to Assist Park Management

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Abstract

A research project is investigating if access to an existing, georeferenced park management data archive can be enhanced through the concept of a geo-knowledge tool (GKT). The tool is built using the collaborative and participatory notions of Web 2.0, and associated, potentially useful, user contributed information. Can the existing traditional data be amalgamated with non-traditional data sources - available on the Web or generated through participatory Web 2.0 tools - to produce an effective tool for data access and enhance the existing archive?

A case study is used to develop a conceptual GKT and a demonstration prototype. Initial results illustrate the decision making process and data needs - the basis for the GKT to which non-traditional data sources are added. An analysis of six digital public data archives shows that there is a range of potentially relevant information available on the Web, although a means to assess data quality and usefulness will be beneficial. Results of a park visitor survey reveal that about two thirds of visitors may be willing to participate in collaborative activities organised by park management, provided the task on hand and the purpose are specific.

1- Introduction

Parks Victoria (PV), the organisation that manages parks on behalf of the Victorian Government in Australia, possesses a vast amount of data collected over the years. The data are held in different formats and are stored

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in various databases and information systems, and in different locations, accessible by some or all staff. The existence of some data may only be known to the people involved in their creation. All data are georeferenced - linked to geographic locations ranging from the whole park network to individual parks or a location within a park. The data archive however is not used as effectively as it could, and the data are not always readily accessible when needed for decision making.

This paper reports on a research project that is developing a methodology for providing access to this data archive through the concept of a *geo-knowledge tool* as a data interface. The research project regards a geo-knowledge tool (GKT) to be a digital information or knowledge system providing access to the data in part based on their geographic links. The GKT design is being undertaken with use of contemporary Web 2.0 concepts and Web based applications, and apart from data access will also allow for data storage, capture and visualisation.

The research project is part of an overarching interdisciplinary research project being undertaken at RMIT University in Melbourne, Australia under the umbrella of *Affective Atlas* (Cartwright et al. 2008). PV is a collaborator on both research projects.

The paper first outlines related background information - aspects of Web 2.0, the geographic relevance and a summary of knowledge systems - before iterating the overall objective. The next section outlines the methods and approach that are being applied, including the consideration of alternative data sources and the use of a case study. This is followed by initial results of some research tasks thus far: fire management information requirements, alternative data sources, and a park visitor survey. As the research project is still underway, the final section gives a preliminary conclusion before outlining the future direction.

2- Background

The GKT will include Web 2.0 concepts and is a *geo* tool. Hence elements of Web 2.0 and the geographic relevance need to be explained so as to better understand underlying theories applied. A summary of knowledge systems links it to the proposed GKT - a collaborative, geographically orientated knowledge system.

2.1 Web 2.0

Web 2.0, also called the New Web or Social Web (Tapscott and Williams 2008), refers to current Web applications that encourage user participation and collaboration resulting in user contributed information (UCI) (Hardey 2007; O'Reilly 2005). Users are central to Web 2.0 because they interact with each other, sharing and generating information. It has been recognised that this UCI, some of it georeferenced, can potentially be useful and enhance existing information (O'Reilly 2005; Vickery and Wunsch-Vincent 2007). It is in part the collectiveness of the action that plays a role (Tapscott and Williams 2008): pooling individual bits of information to form a collective intelligence, a key component of Web 2.0 (Chatti and Jarke 2009).

Drawing on the notions of collaboration and collective intelligence, crowdsourcing (Howe 2009) refers to a large group of individuals collectively completing a project rather than a small group of experts. Web 2.0 can provide the participatory tools. Special projects have applied crowdsourcing principles, and examples range from asking the public's assistance with identifying galaxies (see zoo1.galaxyzoo.org), mapping the world (see openstreetmap.org) and mapping bird observations (see ebird.org).

Elements of Web 2.0 are increasingly being employed by organisations and disciplines, at different levels and for various purposes to suit their needs (Dawson 2009; McAfee 2006).

An example of UCI is tagging – adding descriptive keywords to digital data and a feature found in many Web 2.0 applications (Anderson 2007). Geotagging attaches a geographic description and thus creates a geographic link. The information hidden inside tags and geotags, if aggregated and analysed, can provide insight into user behaviour. Putting this into the context of this research project, if park visitors were to upload photos from their visit onto a website and tag them, this may show where in a park visitors go or where the most popular destinations within a park are. This knowledge in turn can assist with park planning or improving visitor services at those locations.

2.2 Geographic relevance

PV is a geographically distributed organisation. Its total park network comprises about 17% of the state of Victoria or close to 3000 national parks and other parks and reserves (Parks Victoria 2009). It has a centrally located head office and various regional management offices. Geography also plays a role within parks. Not only do park rangers move around parks as part of their everyday duties, so do visitors. The spatial location of park assets is similarly important - where are the locations of Aboriginal heritage sites? Where was that rare bird last spotted? What was the spatial extent of the 2009 bushfire? These are mere examples of questions that require an answer in a spatial context.

Location generally has become a widely used attribute (Unwin 2008), and location technologies are a core element of the new Web (Gordon 2007). With mapping tools, technologies and geospatial platforms like *Google Earth*, *Google Maps* and Microsoft's *Bing Maps* freely available via the Web and via mobile devices, georeferenced data can readily be visualised in different ways and using a variety of tools. Mobile devices like phones and cameras are also increasingly enhanced so as to be location aware and the information they generate often has geographic metadata attached. O'Reilly (cited in Turner and Forrest 2008) is using the term *Where 2.0*, so defining the geographic aspect inherent in many Web 2.0 applications and UCI.

2.3 Knowledge systems

For centuries people have attempted to manage or organise information or knowledge, developing what can be called knowledge systems that assist in finding or accessing information more effectively. Tracing a path from Melville Dewey's Decimal System to organise books (OCLC 2009), Vannevar Bush's hypothetical *Memex* for linking scientific data (Bush 1945), and the hypertext of Nelson (1992) that combined with hyperlinks drives the Internet and World Wide Web (Zimmer 2009), leads to Al Gore's Digital Earth - "…a multi-resolution, three-dimensional representation of the planet, into which we can embed vast quantities of geo-referenced data" (Gore 1998, para. 4). Gore's conceptual geographically oriented knowledge system would organise the growing amount of georeferenced data and provide data access based on the geographic links. Mapping mashups and other web mapping applications used to display georeferenced data are in effect small versions of the Digital Earth Gore envisaged (ISDE5 2007). And organisations such as Google and Microsoft are developing aspects of Gore's concept through their mapping technologies.

With the arrival of Web 2.0, geographically oriented knowledge systems can now be collaborative and participatory.

3- Objective

The primary objective of the research project is to enhance access to and utilisation of PV's existing data archive. This will be achieved by developing a methodology for building a GKT as a means to access data. The main question that is being addressed is if applying contemporary and collaborative Web 2.0 concepts can benefit such a tool.

What will also be investigated is whether UCI as well as existing information available on the Web can enhance PV's existing data, and improve knowledge or fill gaps. Thus, it will be assessed whether non-traditional data sources can be amalgamated with mainstream data to form part of an effective knowledge tool to potentially assist decision making.

For this research, users are viewed from a broad perspective and are not just Web users but instead can be PV staff, park visitors or the general public.

4- Methods and approach

There are two main phases to the research project: the initial exploratory phase for information gathering (completed) and the implementation phase (underway). Some outcomes of the first phase were described in the background section. It included a review of Web 2.0, knowledge and knowledge systems and other topics related to the research. Projects that apply Web 2.0 and geographic Web tools were examined to support the project rationale and to learn from, whilst site visits to PV's head office and the project study area are ongoing to gain insight into aspects of the organisation and park management.

The current implementation phase centres on the primary goal of developing a methodology for a GKT. It has two key components: developing a conceptual tool and building a demonstration prototype to evaluate the effectiveness of the theory applied. A case study is used to manage the task at hand, focusing on Wilsons Promontory National Park (WPNP), one of the parks managed by PV, and a portion of its data - fire management data.

The conceptual model considers a broad range of data, users, tools and applications that can potentially form part of the GKT. It is developed using findings from the exploratory phase and results from case study specific tasks such as a visitor survey at WPNP and an exploration of non-traditional data sources, in particular existing Web archives.

The demonstration prototype is based on a portion of the conceptual GKT with selected data, functionality and user group. After its development, it will be evaluated and refined as required.

4.1 Applying non-traditional data sources

The aforementioned term *non-traditional* data warrants clarification. In the era of the New Web, information is not just provided by *experts* anymore. Instead, information can be sourced via the Web through digital data archives that are created and made publicly available by organisations and through social media tools like blogs, wikis, and media sharing sites. New information can also be actively generated by providing participatory and collaborative tools (Web 2.0 tools) for people to use.

It will be explored if these non-expert, non-traditional data sources can benefit the GKT. Although the base data for the GKT is PV's existing data archive, instead of merely relying on this organisational data from *trusted* experts, alternative data sources not traditionally used will be considered. Fig. 1 shows examples of potential data sources that the GKT could draw on, with a focus already on the case study area WPNP.

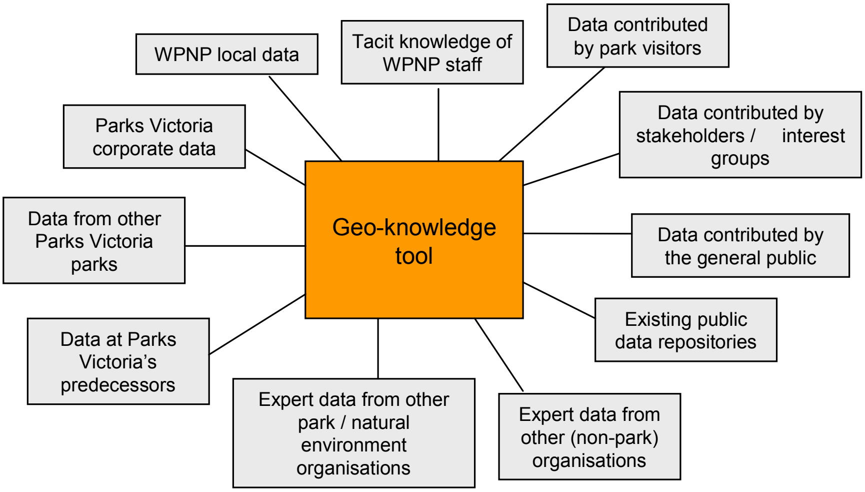

Figure 1: Potential data sources that can be used for the GKT.

The elements in Figure 1 are mostly self-explanatory but some may require clarification. Starting at the bottom right of Fig. 1 and moving in an anti-clockwise direction:

- Expert data from other (non-park) organisation refers to organisations that have their own area of expertise that could be relevant to PV, such as knowledge management or human resources;
- Existing public data repositories refer to information on the Web made available by, for example, media organisations, state libraries and museums. Some have made at least part of their data available online for easy access;
- The final three - data contributed by the general public, stakeholders or visitors - would be the result of adopting Web 2.0 concepts that allow park visitors, staff or the general public to contribute information where they traditionally may not have been able. Stakeholders or interested groups could include friends of the park groups, trail bike riders or recreational fishermen that use the park.

4.2 The case study

WPNP and fire management data will be the focus for the case study of the implementation phase. WPNP, located about 200 km southeast of Melbourne, is an important tourist destination in Victoria. The park houses many different flora and fauna species, some vulnerable and rare, and plays an important role in protecting Victoria's biodiversity (Parks Victoria 2003).

A component of one of PV's core management areas, fire management plays an increasingly important role (Parks Victoria 2009). It has two key aspects: protection and using fire for ecological reasons (Department of Sustainability and Environment 2006). The focus will be on controlled burning, conducted to reduce the impact of bushfires but also to protect natural values and biodiversity through ecological fire management practices. These planned burns require extensive background information and follow strict decision making processes before they take place. Systems and tools are in place to assist with this and to provide access to key data sources. At the same time, it is recognised that there may be information gaps and that the only data available relied upon may have limitations for a range of reasons. These can include the availability of anecdotal fire history records only, or flora and fauna records that rely on sightings but without the resources or opportunity to take a more rigorous approach to maintain and improve these.

As a results of recent severe bushfires, fire management and controlled burning are somewhat topical issues on the current agenda of park managers in Victoria (and Australia generally). Having chosen this as a test topic for the GKT seems prudent, so that an enhanced system for relevant data access may be developed.

A fully developed GKT could be used by all PV's staff, as well as park visitors or the general public - through designated terminals at a park visitor centre for example. The case study will focus on the use of the GKT by park rangers at WPNP.

5- Results

With the implementation phase underway, there are initial results for some of the case study focused tasks.

5.1 Fire management information and decision making

Fire management at PV is a cascading framework (Department of Sustainability and Environment 2006) that abides by the legislative requirements outlined in various State Acts, to provide policies, strategies and planning at a broad, state wide level down to park specific plans and actions. In order for the GKT to provide a park ranger with useful information needed for fire management activities, it is important to understand the decision making process and information requirements. Figure 2 is a generalised model of the decision making process for an individual burn plan - required for conducting controlled burns in a park.

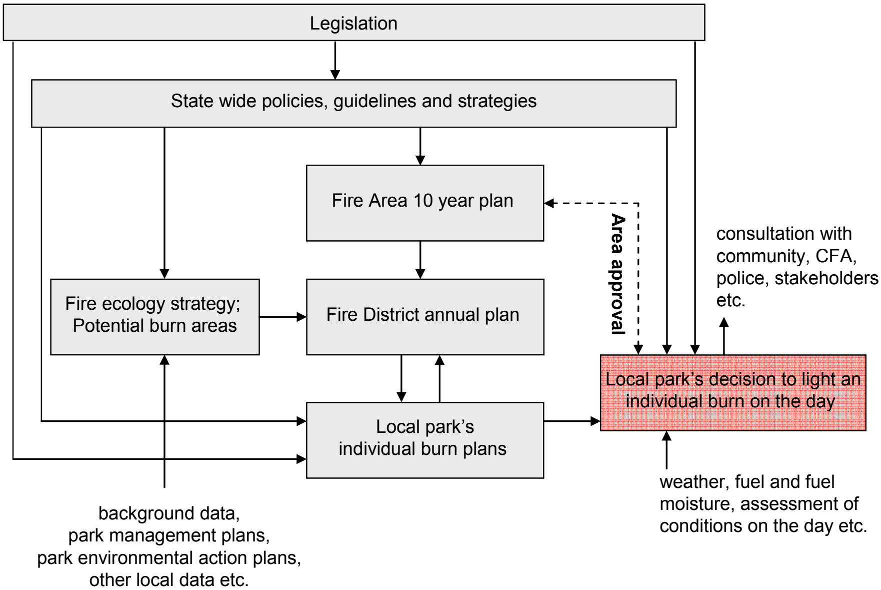

***Figure 2*: Generalised decision process for lighting a controlled burn in a park.**

Figure 2 shows that apart from legislation and other key documents, a range of people and organisations are also consulted. Furthermore, a variety of other fire management related data, tools and systems are part of the process. These combined form the base for the prototype, to which other data are added.

5.2 Alternative data sources

The alternative data sources identified in Fig. 1 broadly encompass information not traditionally used or relied upon. They include existing, publicly accessible data archives available via the Web such as those of media websites like the Australian Broadcasting Corporation (ABC) (www.abc.net.au) or the Melbourne newspaper *The Age* (www.theage.com.au), state or national libraries that have online catalogues to search with some content available digitally, and other organisational websites. Table 1 shows the results for six digital data archives that were searched using keywords *Wilsons Promontory* and *Fire Management*.

	Wilsons Promontory search results	*Fire Management* search results
ABC (www.abc.net.au)	24	59
State Library of Victoria (www.slv.vic.gov.au)	359	159
National Library of Australia (www.nla.gov.au)	149	819
Trove (trove.nla.gov.au) (The search was restricted to Australian online content)	83 books, journals, magazines etc.; 408 pictures and photos; 24 maps; 44,959 Australian newspaper articles (years 1803-1954)	1571 books, journals, magazines etc.; 303 pictures and photos; 30 music, sound and videos; 39 maps; 522,944 Australian newspaper articles (years 1803-1954)
Bushfire Cooperative Research Centre (www.bushfirecrc.com)	7	481
Flickr (www.flickr.com) (The search was for *Wilsons Promontory* only; no doubt there will be extra results with personalised tags like *TheProm*, *WilsonsProm* etc.)	7417 photos (full text search); 5833 photos (tag search)	872 photos (full text search); 936 photos (tag search)

Table 1: Search results for six digital data archives.

There is a range of other websites that can also have potentially useful data. To name but a few: Museum Victoria's Bioinformatics website (http://museumvictoria.com.au/bioinformatics/), Birds Australia's Atlas & Birdata tools (http://www.birdsaustralia.com.au/our-projects/atlas-birdata.html), and the Australian Fire and Emergency Service Authorities Council's Knowledge Web (http://knowledgeweb.afac.com.au/).

Of course, the numbers in Table 1 mean little without a sense of the quality or usefulness of the information that can be retrieved. An assessment model will be developed as part of the research that aims to provide a method for attaching such indicators to these resources. Potential data attributes for quality indicators could be the data source, data contributors and the level of PV control involved in UCI, whereas the usefulness of data could depend on the level of access (is it a mere digital record or can it be viewed online) or how users can sift through search results. These data attributes are not straightforward to assess however and can be variable or subjective. For example, information from reputable organisations may show bias whereas personal blogs may be written by educated amateurs. It is feasible that some of the alternative data sources will end up being regarded as *additional information* that is made easily available in the event someone is interested in further information. Or the end result could be an evolving model: as the data source is used, users can add their personal quality or usefulness ratings for others to consider. As development of the assessment model is still underway, the figures in Table 1 for now aim to highlight the potentially useful *other* data that exist.

5.3 Park visitor survey

Contributions from park visitors and other stakeholders are another alternative data source. Information obtained from this group can include images or comments about their recent stay uploaded onto the Web; specific knowledge that amateurs may possess (and are willing to share via a Web enabled collaborative forum), or the sharing of fishing conditions by recreational fishermen using mobile devices. They could also be recruited for crowdsourcing projects.

To gain insight into park visitors' perception of Web 2.0 and their perceived willingness to participate and contribute, a visitor survey was conducted at WPNP. The survey took place over a three day period in September 2010. 83 people completed the questionnaire - 49 females and 34 males divided into four age groups: 18-30, 31-45, 46-60 and 61 and over. The youngest and oldest age groups were slightly underrepresented because of the Victorian school spring break chosen to conduct the survey. Of the 83 participants, 78 used the Internet. 59 of these 78 were aware of or familiar with Web 2.0 with differences observable by age group (see Figure 3).

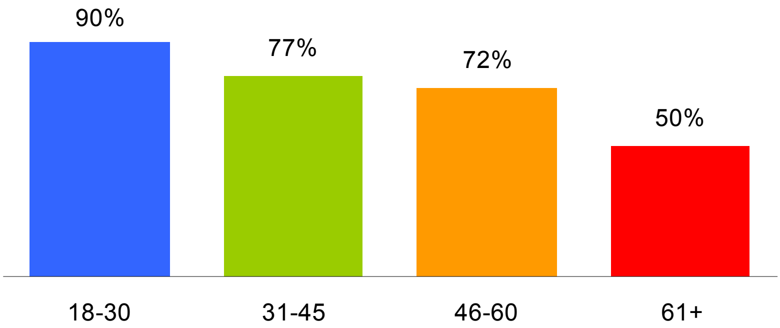

Figure 3: Percentage of people aware of or familiar with Web 2.0 by age group.

A primary goal of the survey was finding out if people were likely to participate in projects PV or WPNP would hypothetically organise. Three of the 17 survey questions that asked this directly are focused on here. The first of these questions asked if people would be happy to share their photos or videos from their visit through a Web based photo or video-sharing site. 51 out of 77 respondents (six did not answer the question) would do so in principle, 18 respondents said *no*, whereas eight needed more information first. The 18 respondents who would not contribute were semi-evenly spread over the four age categories, ranging between 17% (46-60) and 26% (31-45).

A second question asked if people thought they would use WPNP social media tools like a blog, feedback forum, *Twitter* etc. 34 out of 80 respondents said that they would, but only ten of these 34 said they would actively participate themselves whereas the remaining 24 would only read or look at other people's contributions. 28 out of 80 said *no* and 18 had to think about it. 50% of the age group 61 and over would not participate, while none of the youngest age group said they would not participate (two said maybe) - 33% of 31-45 and 36% of 46-60 year olds would not do so.

However, when further asked how often they thought they would participate, only seven would do so semi regularly - at least once a week or a few times a month. The majority would only use the tools around a trip to WPNP, a couple of times a year or only a few times and then no more. Although this does not inspire optimism, at least visitors would participate when going to the park. This could be the time when they possess potentially valuable information such as animals or flora they may have spotted or feedback on the condition of walking tracks or other visitor experiences.

Finally, a third question asked if people would be willing to carry a mobile GPS enabled device during their visit to assist park management. A total of 52 out of 80 respondents indicated that they would, whereas 26 answered *no* and two *maybe*. All 18-30 year olds would participate, but only half of the 31-45 year olds were willing to do so this time, with about 65% in the other two age groups agreeing to do so.

5.4 Preliminary analysis of survey responses

Looking at these three questions, whether park visitors would potentially participate in crowdsourcing or use Web 2.0 tools could depend on whether it is a one-off situation with a specific purpose or not. The first and third questions imply that photos are uploaded after a trip or a GPS device is carried during a trip - one-off events with a particular task in mind. In both cases about 65% of respondents said they might participate. The second question however was more general - would people use WPNP social media tools - without any specific purpose or why or what it would entail. Only 42% said *yes* this time, with another 22% responding *maybe* pending additional information. Figure 4 shows the varying responses to the three questions analysed.

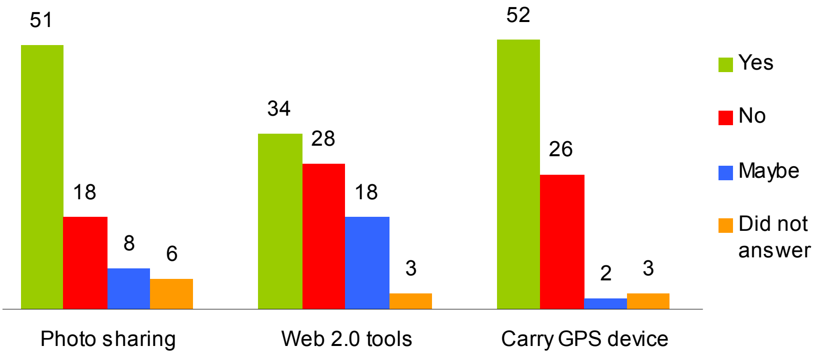

Figure 4: Number of yes, no and maybe responses to the three questions about visitor willingness to participate.

The third question arguably has the clearest task and purpose, carry a GPS device around during your trip to assist park management, and bar two, all participants replied *yes* or *no*. The photo sharing question had ten respondents that demanded more information before they would commit, as the purpose of the task was less clear then that of question 3. The 18 respondents with *maybe* for the second question, the most general one, could become participants once the task and purpose is made clear. This is perhaps backed up by the fact that 75% of these *maybe* respondents also indicated they would use the tools only around a trip to WPNP, thus creating a purpose. If the further information they required to make a *yes* or *no* decision was something like - *could you please visit our website and add any feedback or observations from your trip to our blog to help us…*- people may actually do so. The trigger therefore appears to be a purpose and a specific task associated with a trip to the park. This is something to bear in mind if the GKT were to become accessible to the public, or if PV or WPNP were to consider crowdsourcing opportunities.

6- Conclusion and future directions

The collaborative and participatory ideas of Web 2.0 are being implemented by varying organisations in different ways to suit their needs. A diversity of projects is seizing the collective intelligence of the public using crowdsourcing. The way forward for this research project is if it can adopt these concepts to enhance the existing data archive. Can park visitors enhance flora or fauna data simply by visiting the park, taking photos, sharing their experiences on a Web forum, by equipping them with GPS enabled mobile devices during their visit, or by participating in a special crowdsourcing project to gather data? The range of projects that have been encountered during the exploratory phase suggest that the opportunities are there if the occasion arose for PV to use crowdsourcing or Web 2.0 tools to gather information from these non-traditional sources. The results of three key visitor survey questions indicate that people may participate if it involves a particular goal or task. The successfulness of such an approach could depend on various issues such as what communication tools are used (*Facebook* and *YouTube* were the most used applications by the survey respondents), appropriate methods to target different age groups, and catching people during a trip to the park rather than relying on them visiting a website. Including visitors on an email list during their trip so that specific, purposeful requests can be send when participation is sought could be a solution to the latter.

The research into Web 2.0 suggests that the attitude towards the New Web is generally regarded as positive. Initial results from the visitor survey also indicate this, with over 75% of people having positive ideas about the participatory nature of the Web. However, it has also been accepted that there are some negative issues associated with Web 2.0, something park visitors similarly recognised. These include issues relating to privacy, copyright and the quality of user generated information.

It is too early to say anything about applying alternative data sources, other than that public digital data archives relevant to WPNP or fire management do exist. How, and if, their quality and usefulness can be assessed, and if they can enhance PV's existing data archive, is yet to be determined.

7- Future directions

With the research project being over the half way mark, the next steps are to focus on the remaining tasks still to be completed. These include:

- Develop a conceptual model of the GKT. This is in progress with an initial model produced and assessed by stakeholders, awaiting further refinement;
- Develop a method to assess data quality and usefulness applicable to the alternative data sources;
- Develop a demonstration prototype based on a portion of the conceptual GKT (basic guidelines for data, tools and functionality have been drawn up thus far); and
- Evaluation of the prototype by selected PV staff, and following their recommendations, amending the prototype as appropriate.

There are a number of other issues to be taken into account, such as the aforementioned privacy and copyright issues in relation to user generated information, accessibility, and user access restrictions (log-in options). It is envisaged that these will form part of the conceptual GKT as recommendations or suggestions for future consideration. If PV decides to expand the demonstration prototype or develop an actual GKT in the future, these issues would need to be addressed and relevant strategies and policies formed to deal with them accordingly.

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Integrating User-contributed Geospatial Data with assistive Geotechnology Using a localized Gazetteer

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Abstract

We present a methodology for using cartographic-based processes to alert the vision-impaired as they navigate through areas with transitory hazards. The focus of this methodology is the use of gazetteer-based georeferencing to integrate existing local cartographic resources with user-contributed geospatial data. User-contributed geospatial data is of high interest because it leverages local geographic expertise and offers significant advantages in dealing with hazard information in real-time. For blind and vision-impaired people, information about transitory hazards encountered while navigating through a public environment can be contributed by end-users in the same public environment, and quickly integrated into existing cartographic resources. For this project, we build collections of user-contributed geospatial updates from email, voice communication, text messages, and social networks. Other necessary technologies for this project include text-to-voice software, global positioning devices, and the wireless Internet. The methodology described in this paper can deliver usable, cautionary reports of hazards, obstacles, or other time-variable concerns along a pedestrian network. Using the George Mason University campus as a study area, this paper describes how transitory events can be presented in usable form to a vision-impaired pedestrian within a usably short period of time after the event is reported. Buildings and other destinations of interest can be registered in a robust, eXtensible Markup Language (XML)-based, localized gazetteer. Walking networks, parking lots, roads, and landmarks are mapped as vector-based digital information. Any events or changes to the base map, whether planned and disseminated through official channels or

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reported by end-users, can be linked to a location in the network as established by the attributes cataloged in the localized gazetteer, and presented on an existing base map or in an assistive technology environment. For mobile applications, a vision-impaired pedestrian with a Geographic Information System (GIS) and a Global Positioning System (GPS)-enabled assistive device can receive an alert or warning about proximity to reported obstacles. This warning might include other information, such as alternative paths and relative directions to proceed, also referenced through the localized gazetteer. This research provides insight into challenges associated with integrating user-contributed geospatial information into a comprehensive system for use by the blind or vision-impaired.

1- Background and Objectives

The International Cartographic Association (ICA) Commission on Maps and Graphics for the Blind and Vision-Impaired People has been an important outlet for publication associated with tactile map production and use. Many papers focus on design, production, and evaluation (i.e., Tatham 1991, Eriksson 2001, and Perkins 2001) while a few others focus more broadly on issues such as standardization (Tatham 2001) and assistive geotechnology (Coulson et al. 1991). In Coulson et al, the authors emphasize that existing geotechnology can be used to automate the production of tactile maps. This is an important starting point, because assistive environments that can quickly and automatically incorporate additions and changes to an environment are particularly useful for individuals navigating through space. Transitory obstacles that present a hazard or barrier to navigation are a distinct challenge, because they generally appear as unplanned events and cannot generally be depicted with a standard tactile map environment, where updates may take several days or perhaps weeks. Because hazards and obstacles appear and change often, it is important to use sources of data that are frequently contributed and have temporal relevance.

Dr. Michael Goodchild, in his 2009 keynote address to the Association of American Geographers (AAG), described the value of user-contributed or volunteered geographic information (VGI), citing two of the most important aspects 1) its leveraging local geographic expertise for wider purposes and 2) its temporal relevance (2009a). Goodchild developed the concept of user-contributed geographic information and identified it as an important trend in environments with large, active end-user communities (2009b). Although typical end-users are not trained cartographers or tactile map experts, the geographical expertise and temporal relevance of contributed geospatial information makes it extremely valuable. Based on the ideas of Coulson et al. (1991) and Goodchild (2009), we are creating a methodology to incorporate real-time user-contributed geospatial information into existing accessibility-oriented mapping systems. The functional centerpiece of this methodology is the use of a localized gazetteer, which allows mapping of placename-based descriptions into geographically referenced map locations. These georeferenced end-user contributions can be incorporated into existing mapping systems oriented towards blind and visually-impaired persons, and triggered by proximity as a blind or vision-impaired end-user navigates through a mapped location. Our methodology focuses on near real-time incorporation of environmental obstacles or hazards, but recognizes that the approach can be useful in joining a variety of user-contributed information to existing mapping systems.

2- Approach and Methods

Our methodology for delivering user-contributed geographic information to blind and vision impaired individuals follows a process shown in Figure 1. This flow of information starts with observations in a geographic environment. These observations are time-stamped and contributed through voice communication, email, text message, or through social media updates. The observations are analyzed for geographic content, generally through geoparsing for local placenames, distances, spatial prepositions, and temporal information. The observations are then matched to entries in a localized gazetteer developed for the university campus with features associated to a geographic location. The location, consisting of a georeferenced footprint connected to a placename, is plotted on a network or integrated into a map display. The location is available as a text-to-voice prompt on an accessibility map of the local campus. The location can be explored using standard mouse interaction from a fixed location or can be triggered using a location sensitive application that issues a proximity alert and a text-to-voice prompt. This allows for the display of transient obstacles or hazards on a map, and for those obstacles or hazards to be communicated to the blind and visually-impaired using assistive mapping interfaces described by Golledge et al. (2006).

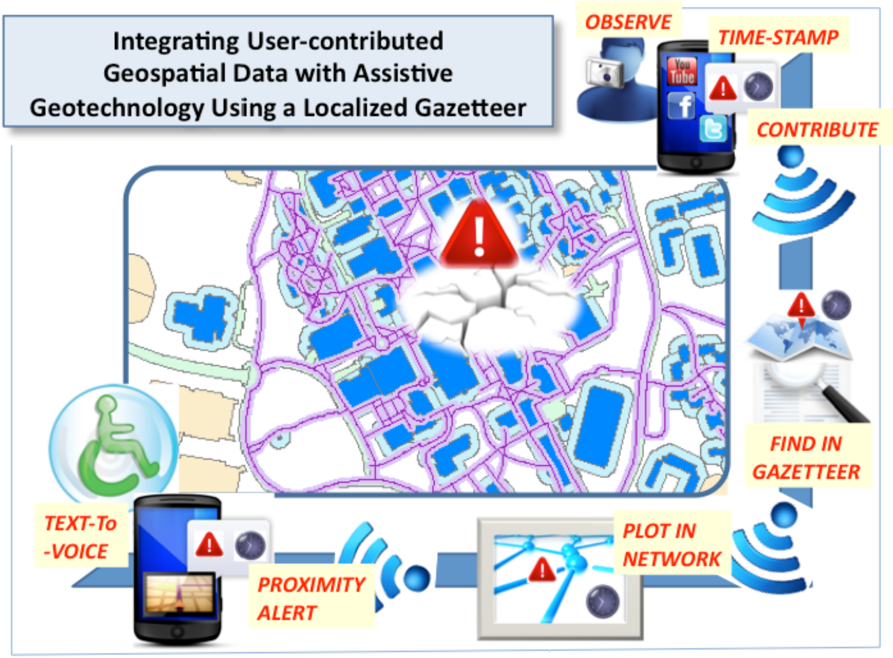

Figure.1: Process for integrating user-contributed geospatial data with assistive geotechnology using a localized gazetteer

Figure 1 captures a specific scenario in which this functionality might find utility. A pedestrian in the environs of campus might discover a temporary obstacle and desire to share this easily with other pedestrians. Possible obstacles might range from sidewalk construction to a large student rally. With a basic text message using commonplace and natural descriptions (e.g., "near the Engineering building") and perhaps a camera image, he could register the obstacle. That information is time-stamped and compared to a localized gazetteer for locating the obstacle in GIS-understandable geographic space. Alternative paths are identified using standard network path algorithms. This synthesized information is made available on a subscribed syndication for any GIS/GPS-equipped users. Other technologies for text-to-voice can specifically alert and inform the blind and visually-impaired.

Our localized gazetteer forms the linkage between user-contributed observations that generally use placenames and existing cartographic resources contained primarily in ArcGIS. The result is a map-based display system that contains both existing geospatial data and updates contributed by end-users.

Observations contributed by volunteers or end-users take many forms, but generally end up translated into text, which is geoparsed for relevant placenames, directions, distances, and geographically-relevant prepositions and prepositional phrases, such as ‘nearby’, ‘next to’, and ‘on top of’. Observations can also be obtained using a technology such as GeoRSS (Geographically Encoded Objects for Really Simple Syndication). GeoRSS is a process of extracting geographical information, such as latitude and longitude, from any geographically tagged feed. These feeds are useful when one wants to keep track of regularly changing information such as news and traffic conditions. There are two encodings of GeoRSS. GeoRSS-Simple is the simplified version of encoding whereas GeoRSS Geographic Markup Language (GML) has more features, including the availability of more than one specific coordinate system. In order to extract geographical data from social network feeds such as Twitter and Facebook, the locational information has to be in the feed itself. This requires third party software since both aforementioned applications are still developing geo-tagging on their formats. Much controversy exists over privacy concerns as well as location accuracy, but GeoRSS and related geotechnologies form an important aspect of the observation collection process, and we have developed some procedures for masking sensitive or private information associated with end-users that contribute information.

After observations are collected, a list of relevant placenames is obtained from our localized gazetteer, which contains a comprehensive list of official campus feature names, colloquial variants of placenames, abbreviations, coded placenames, and common foreign-language variants of placenames. The observations are then associated with spatial footprints of the features from the localized gazetteer and plotted on a map.

The Geoparsing software tool being developed for this project uses VB.NET together with MapWindow GIS OCX (Object Linking and Embedding Control eXtension) control. MapWindow GIS is an open source GIS application under the Mozilla Public License, started at Utah State University, Logan, Utah (Ames et al. 2008). Since MapWindow GIS is an open source software package, GIS programmers are permitted to configure, use, and improve the software code for their specific needs. There are two GIS programming paradigms in MapWindow GIS: standalone applications and plug-ins (Aburizaiza and Ames 2009). For this project, the standalone development approach was utilized. A screenshot of the Geoparsing tool developed with MapWindow GIS is shown in Figure 2.

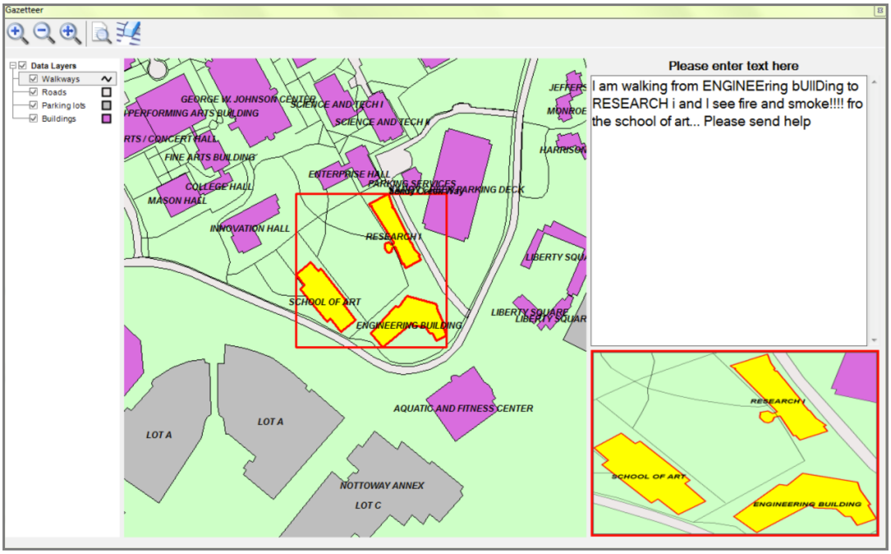

Figure 2: Screen capture from Geoparsing Tool showing a geographic selection from a text entry as keyed to the localized gazetteer

The geoparsing tool accepts text entries and generates a list of all possible strings associated with placenames in a localized gazetteer. Concerns regarding insufficient or inaccurate text-entry, such as character case, special characters, and duplicates are accounted for in the processing used in the tool. Intensive testing for text entry errors and special cases has significantly improved the association rate of text entries to locations in the localized gazetteer. Geoparsing of the data pinpoints the geographical feature placenames with location coordinates for further spatial analysis (Hill 2008). The tool then identifies those features on a geographically referenced map, displayed using the MapWindow OCX control. Added functions for the tool include capturing the path between the spatial features identified in the localized gazetteer, and parsing useful distances and directions from texted propositions, modifiers and cardinal directions, such as near, towards, or north.

As mentioned, we use a localized gazetteer to match text-based or voice-based descriptions containing placenames associated with observations to a spatial footprint. Our localized gazetteer is built using a data model, structured on concepts from Hill (2006). The gazetteer data model contains items of primary interest to blind individuals navigating through the local environment; namely, buildings, roads, walkways, parking lots, and landmarks. Table 1 and Table 2 provide summary descriptions of our gazetteer data model for buildings. Table 1 contains entries for feature naming characteristics, which describe how any feature is referred to in a variety of different settings, and Table 2 contains entries for the feature association characteristics, which describe how the feature is related to larger groups of features and sub-elements within a single feature.

Item	Description	Note
Official_Name	Designated official name	To georeference with official map data sources
Original_Drawing_Name	Text label from official map or drawing	To georeference with official map data sources
Abbreviation	Standard feature abbreviation	To use for linkage in the gazetteer if used as a common verbal descriptor
Vernacular1	Slang or informal name for feature	To use for linkage in the gazetteer if used as a common verbal descriptor
Vernacular2	Jargon or technical name for feature	To use for linkage in the gazetteer if used as a common verbal descriptor
Vernacular3	Coded or numbered name for feature	To use for linkage in the gazetteer if used as a common verbal descriptor
Formerly_Named	Previous feature name	To account for re-naming of buildings (e.g., for memorials or re-purposing)
Foreign_Language1-5	Name in foreign language	5 common translations based on student demographics

Table 1: Gazetteer Data Model – Building Naming Characteristics

Item	Description	Note
Contains_subelement1	Office or Department Name	Include as many sub-elements to describe those contents of the building which have common verbal descriptors
Contains_subelement2	Retail or dining facility	-
Contains_subelement3	Entertainment locale	-
Contains_subelement4	Special work center	-
Part_of1	Enclosed within or attached to another feature	Denotes physical enclosure or attachment
Building_Cluster_Name	Formal building clusters	From generalized areal descriptors
Event_Grouping	Functional or event-based groupings	For transitory but pre-planned obstacles

Table 2: Gazetteer Data Model – Building Association Characteristics

The naming and association characteristics shown in Tables 1 and 2 are modified for landmark, walkway, roadway and parking lot features that contain specific linear referencing and linear network information, entrance names, and unique association characteristics.

Since the localized gazetteer is intended to be the information engine for the assistive process, its construction required unique tailoring. Well-known gazetteers such as the U.S. Geographic Names Information System (GNIS) from the U.S. Geological Survey (USGS) assign to a geographic feature its official name, including variants or former names, with geographic reference data (Hill 2006). Geographic features can be classified in notional groups or given additional designations or textual descriptions, such as historical site (which might refer to a feature that is no longer in existence), as is performed in the Geographic Names Project from USGS. For this localized gazetteer to optimize its benefits to assistive geotechnologies, its data model, shown in Tables 1 and 2, focuses on additional ways that a feature might be orally or verbally expressed. This structure which captures naming alternatives as described in Tables 1 and 2 more robustly connects a name to its geo-referenced location.

Sources of naming alternatives come from the members of the local population themselves. George Mason University (GMU) is a linguistically diverse campus, attracting faculty and students from over 130 nations. From the 2009 GMU student body of 32,500 total students, 1700 are from outside the United States with only 80 of these from native English speaking countries. The largest non-English single language student population is Chinese, numbering 283 students (GMU 2010). The faculty is linguistically diverse as well, with over 9% of the 5300 staff and faculty from other countries. Large numbers of American students and faculty are non-native English speakers. Local demographics indicate that as many as 35% of the American students would speak Spanish, Chinese, Korean, Arabic, Hindi or another as their first language (US Census Bureau 2010).

Students, both English- and non-native English-speakers were queried about common vernacular usage. Foreign students and faculty provided cultural and linguistic perspectives on the placenames used to refer to locations around campus. One cross-cultural observation was the widespread use of a building's English name even in discussions held in languages other than English. This was less common in discussions about areas that were functionally described, like parking lots. These student and faculty inputs augmented naming data from other more official sources, such as university campus facility mapping products, university offices' web-listings, and the campus telephone book. Some limited site surveys confirmed these official sources.

University locations and the means to identify them follow both a geographic and a functional hierarchy. As an example shown in Figure 3, twelve individually named dormitories are clustered into Presidents Park. Students of all linguistic backgrounds commonly refer to this area by this name, because of its natural association for a set of buildings which are geographically co-located, functionally equivalent, and carry thematically similar names, such as Jefferson, Roosevelt and Truman. Because of its large population of students, references to Presidents Park would be a common cluster term identified in the operational use of the localized gazetteer.

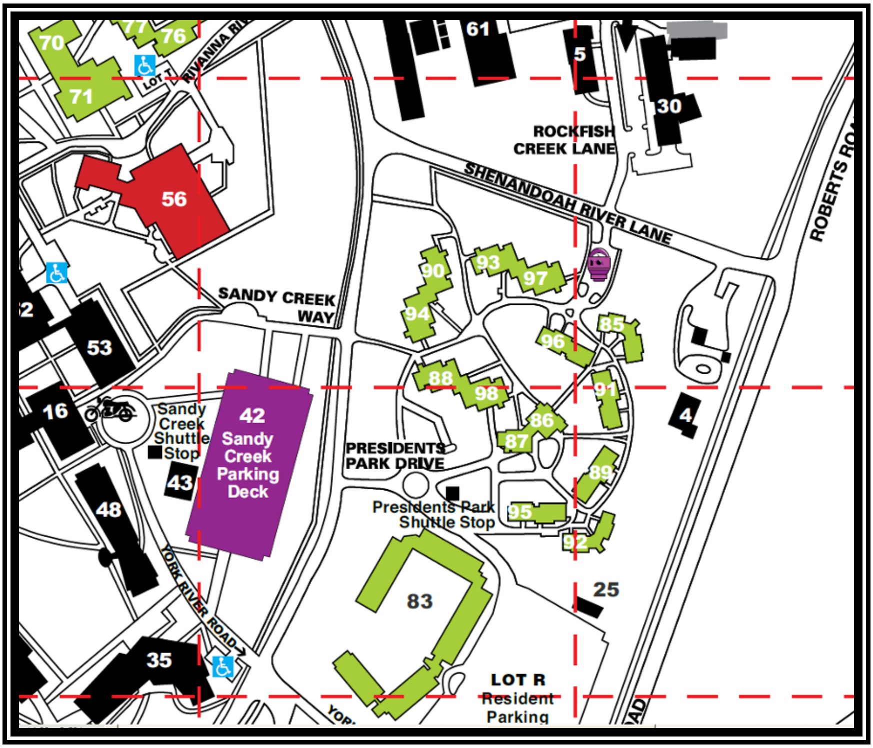

***Figure 3**:* Map Detail from George Mason University, Fairfax campus. Note the Residence Hall complex along Presidents Park Drive, comprised of buildings numbered 85 through 98. Building 48 is Research I. Building 56 is Student Union Building II (GMU 2011)

For an effective localized gazetteer, the association of University buildings to their contents should be captured. Reference to a known location inside a named building is a common means to locate oneself. The data model shows this attribute as "Contains_ …" (Table 2). As an example, a University building named Research I (shown in Figure 2) contains, besides offices and classrooms, the following entities:

1. College of Science Dean's Office
2. Department of Geography & Geoinformation Science
3. Geographic Information Science Center of Excellence
4. Center for Earth Observing & Space Research
5. Center for Geospatial Intelligence
6. Joint Center for Intelligent Spatial Computing
7. Center for Spatial Information Science and Systems
8. Laboratory for Natural Hazards
9. Super Computing Facility

Another example of content is the Student Union Building II shown in Figure 3. Besides lounges and student study areas, it contains the Meal Plan Office, the Photo Identification Office and the student mail service center. Each of these sub-elements of their buildings is included in the localized gazetteer because of their utility in providing a geo-reference.

Other attributes of naming include former names which endure in vernacular usage for years after a building has been renamed. Some structures adjoin buildings but have no distinct name. The observatory connected to Research I (shown in Figure 3 as a noticeable appendage to building 48) is an example of this. It would be included in the localized gazetteer. More transient events might be associated with a building and could be added as an event grouping in the localized gazetteer.

A further consideration for the application of this localized gazetteer is what structures to include in it beyond the obvious buildings and parking lots. For the localized gazetteer to provide its greatest value, it should cover the widest areas of highest use as well as those with the highest safety or security risk for the population. Although a university campus may have a well-defined boundary, the access to the campus and adjacent areas should be considered for inclusion. Additionally, unnamed areas should be added to the localized gazetteer based on an analysis of safety. For example, the western edge of the Fairfax campus at GMU holds numerous athletic fields which are isolated. These places should be described in terms that the students use, even if no official name exists. Prominent landmarks are common reference points and should be included, such as a clock or water tower.

Although our gazetteer data model forms a starting point for a functional system, we are constantly discovering new ways to modify it to make our system better. User feedback is critical, particularly because the system relies on end-users to become involved with communicating about changes to navigation corridors and the presence of obstacles or hazards to navigation.

We are analyzing ways to provide positional privacy in the system, and masking of user identities, preferring an opt-in approach to self-identification, being aware of the many issues associated with motivations of end-users and concerns about negative social dynamics. A major ongoing effort is the integration of time stamps and temporal relevance into the system.

3- Future Plans

At present, our two primary sources of user-contributed geospatial information are the campus alert system and pedestrians who transit campus on daily basis. We plan on growing the community of end-users and geospatial data contributors by advertising the presence of our system through our local campus disability services office and through the local campus planning office, which routinely provides information about sidewalk closures associated with construction. We also plan on integrating other auditory and haptic cues for obstacles and hazards, based on earlier work reported by Rice, Jacobson, and Golledge (2005). We also intend to refine the temporal aspects of the methodology described here. End-users typically lack an understanding of the temporal dynamics of obstacles or hazards other than a present-tense existence, i.e., “there is a hazard here right now”. In many VGI-based systems, end-users don’t have a way of specifying a temporal end-point for their contributions and their appear to be few resources directed at follow-up. A few authors, including Goodchild and Glennon (2010) have discussed temporal issues, noting the primacy of temporal relevance and the benefit of VGI, while maintaining a balance between errors associated with false positives and false negatives. A general approach to filtering and managing end-user contributions is to treat the most recent update as the most relevant, and to phase out contributions after a set period of time. This general approach, however, presents a number of problems when updates come from sources where material has been rebroadcast or repackaged by news aggregation websites, causing it to appear more recent and therefore more relevant. We are still working on temporal issues and hope to have a better way of defining relevance and end-points for contributions.

Other future goals for this research include the refinement of the methodology to deliver in-situ obstacle or hazard information to blind and visually-impaired individuals, and to improve the locational aspects of the information to suit the cognitive needs of the blind or visually-impaired individual transiting across our local university campus. Refinements to the geoparsing tool will include improved text recognition and functional interpretation of distance and direction. Other technologies to incorporate are text to voice web services similar to Google Voice functionality. Additional goals with extensibility into broader areas of user- contributed geographic information include an assessment of accuracy.

Volunteered geographic information and participation from end-user communities may have a significantly transformative effect on GIS and applications oriented toward accessibility. As end-users become more inclined to transform their observations into VGI contributions, visually-impaired and blind individuals will benefit. We hope to provide significant contributions toward this evolving process and look forward to future developments.

Abbreviations

AAG: Association of American Geographers
GeoRSS: Geographic Really Simple Syndication
GIS: Geographic Information System
GML: Geographic Markup Language
GMU: George Mason University
GNIS: Geographic Names Information System
GPS: Global positioning System
ICA: International Cartographic Association
OCX: Object Linking and Embedding Control Extension
USGS: United States Geological Survey
VB: Visual Basic
VGI: volunteered geographic information
XML: eXtensible Markup Language

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Augmenting Quantum-GIS for collaborative and interactive Tabletops

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Abstract

This paper presents our QGIS-MT, an extension of Quantum GIS (QGIS) for interactive tabletops. First proposed is an interactive and collaborative environment that allows several users to interact simultaneously on a multi-touch surface. This environment aims at favoring communication among users and at enhancing social awareness and the decision-making process. Next presented are the results of an interview with GIS users, which gives support to the proposed approach. In addition, presented here is a novel interaction technique, called Finger-Count Shortcuts that lets you navigate and activate numerous commands quickly and easily by performing simple finger gestures. Finally, there is a detailed discussion of how Quantum GIS was integrated into this environment and how our QGIS-MT plug-in providing multi-touch capabilities and Finger-Count Shortcuts were implemented in standard GIS menus.

1- Introduction

The complexity of Geographic Information Systems (GIS) has constantly been increasing. Users can now access a huge amount of geographical data (e.g. from satellite imagery or databases), which requires appropriate solutions for storing and visualizing data (Kothuri. et al. 2002, Kraak et al. 1996). Moreover, the number of features keeps increasing, now including not only basic navigation and editing tools, but also numerous specialized tools (e.g., for spatial analysis, hydraulic modeling, etc.) Finally, it is important to make it possible for several users to work together and to facilitate

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the decision-making process. Improving the usability of GIS through these aspects is important, since GIS are used in various critical contexts such as emergency risk management (e.g. in case of natural disasters, terrorist attacks, etc.).

In this article, we study how novel Human-Computer Interaction (HCI) techniques can improve GIS usability, especially for making command selection easier and for enabling collaborative work. We propose an interactive setup (Figure 1) that enables co-located collaboration around an interactive tabletop. Compared to personal computers, tabletops favor social awareness, facilitate communication among users and make it possible for several users to interact with the same data. Moreover, interactive tabletops, and more especially multi-touch tabletops, provide a way of interacting that is more natural and intuitive than traditional mouse and keyboard interfaces. For instance, the "pinch" gesture, which has been popularized by modern smartphones, allows users to zoom just by expanding two fingers.

While interactive surfaces offer useful advantages for GIS, they also involve some drawbacks. Intuitive gestures can only be used for a limited set of commands (pan, zoom and rotate) while GIS software was designed to provide lots of features. Classical graphical widgets such as menus or tool palettes are not well adapted to interactive surfaces (Bailly et al. 2010) because of insufficient accuracy, occlusion by the user hand, the difficulty to reach them (on large tables) and the lack of keyboard for entering text. New interaction techniques are thus needed to exploit all the potentialities of interactive tabletops for GIS applications.

We propose QGIS-MT, an extension of Quantum GIS (QGIS) for multi-touch tabletops. QGIS-MT makes it possible to use QGIS on multi-touch surfaces and favors collaboration. QGIS-MT also introduces a novel interaction technique, called Finger-Count Shortcuts, which allows users to navigate and activate numerous commands quickly and easily by performing simple finger gestures. QGIS-MT hence improves the usability of QGIS on interactive tabletops.

The article is organized as follows: first, existing collaborative setups used in the context of GIS are presented, as well as the specifications of our interactive and co-located setup. Then, there is a report of the results of an interview with GIS users on their needs and the utility of our setup. Next presented is a novel interaction technique that makes it possible to access the features that were retained from the interview. Finally, there is a detailed discussion of how to implement QGIS-MT.

Figure 1: A group discusses the implantation of street furniture

2- Interactive and Collaborative Setup

Collaborative work is often necessary in GIS. For instance, major emergency events like natural disasters, industrial accidents or terrorist attacks require a timely and a coordinated response effort from a number of different experts (e.g. a GIS expert, a cartographer, an urban planner, etc.). Collaborative GIS can also be useful to share skills with less experienced users (such as managers or politicians) or to communicate with the public.

Some studies have proposed to augment GIS by providing remote or co-located collaborative capabilities to overcome the limitations of the classical mono-user paradigm. After presenting them briefly, we will describe our own interactive and collaborative setup.

2.1 Remote GIS

With the increase of broadband connectivity and data storage on DMBS, most GIS (such as ArcGIS) allow several users to work on the same data set, but only one user could modify a vector data at a given time by means of a system of locks (Vretanos 2005). GroupArc (Churcher et al. 1996) enables several users to interact on the same vector layer, but only one user can actually edit data, while the others are aware of modifications, but can only leave comments. Shengjun and Yuan's system allows several users to manage different entities on the vector data (Shengjun, Yuan 2008) with a versioning system to keep track of data submission which avoids duplications of work by keeping every participant synced.

Remote groupware GIS (such as ArcGIS Server) is useful for distant users and is increasingly widespread. However, in many cases, collaborative work is performed in a single room by a co-located team. While remote groupware GIS helps users to maintain current and historical GIS data, it does not fully exploit the human ability to communicate and to interact together.

2.2 Co-located GIS

Collaborative work on geographic information is quite natural as shown in situations where paper maps are deployed on a table during a meeting. Participants are then located face to face around the paper map. They can communicate, make annotations, take decisions and are constantly aware of other people's actions, While paper maps favor collaboration, they do not offer the high level of interactivity provided by GIS (NB: some attempts have however been made to augment paper maps with digital pens (Yeh et al. 2006)).

The goal of co-located groupware GIS is both to provide a high-level of interactivity with numerous and powerful features but also to allow users to collaborate easily and efficiently. This requires re-thinking the traditional way of interacting, i.e. by using a PC with a relatively small screen, a mouse and a keyboard. Large interactive surfaces are now commercially available (DiamondTouch, Surface, Immersion). They offer several advantages (Gutwin et al. 1996) that are quite useful for GIS (especially for crisis or emergency risk management) such as:

- Informal awareness: knowing who is around and what he/she is doing,
- Social awareness: keeping track of communicational information about others,
- Group structural awareness: information about people's roles, responsibilities or status,
- Workspace awareness: the perspective of one worker observing/interacting with others.

However, few studies have been carried out in this field. Hofstra et al. performed a theoretical overview, which showed the potential applicability of interactive surfaces to some of the process in disaster risk management in the Netherlands (Hofstra et al. 2008). They only tested pan and zoom features, which are definitively not representative of the complexity of a GIS, but this study was done to design a commercial product (Geodan Eagle 2008) for crisis risk management. The hardware setup is based on the Microsoft Surface and the software reposes on the Microsoft's Citizen Safety architecture. Users can both visualize and navigate in 2D and 3D scenes, but they cannot add/edit geographical data into the live database. Users can also change modes to get messages from ground operatives in a different window.

Another research project uses an interactive tabletop for Emergency Operation Centers (EOC) for supporting both team and individual work (Bader et al. 2008). This system provides three main features: a) a second large display is used to provide extra information; b) each participant can use a tablet that can be placed at arbitrary locations on the tabletop to provide personalized perspectives in the information space; c) 16 gestures can be performed on the surface of the tabletop (but the authors do not indicate how they are used, except for navigational gestures). Using these gestures requires an initial learning phase. This may be problematic during a crisis situation as some users may have limited technical experience.

2.3 Our interactive and collaborative setup

2.3.1 Hardware setup

Our setup is based on an Immersion Ilight multi-touch tabletop (Immersion 2008). This technology provides a display of 72x96cm (1400x1050 pixels), which is suitable for the visualization of relatively large amounts of geographical data. The size of the Ilight tabletop is optimal for efficient collaborations (Ryal et al. 2004) because it is not too large (this would make it difficult for participants to communicate), nor too small (participants would not have enough private space). For instance, Figure 1 shows several participants positioned face to face around the table during a meeting where they share information and take decisions.

The Ilight tabletop not only allows oral communications or social awareness. It also allows for several users to interact without the burden of having one person play the role of a moderator in charge of controlling the system (a constraint that would be frustrating and time consuming for teamwork). All participants can thus interact directly with the system by touching the tabletop, a situation that is likely to be more efficient for supporting users' ideas and exploiting their respective skills. Besides, direct touch rather than mouse and keyboard interaction allows users to more easily notice their partner's actions (Hofstra, et al. 2008).

Finally, this setup supports multi-touch interaction, this making it possible for several users to interact simultaneously with the GIS. For instance, several participants can annotate different elements on the same map (and work on different parts of the map simultaneously) as shown in Figure 2.

From the hardware point of view, our setup differs from Geodan Eagle by its size [the Ilight screen (72x96cm) is larger than the Microsoft Surface (55x69cm) and by its height (Surface is a coffee table while Ilight must be used with participants standing up)]. This larger visualization space and the fact that users do not have to bend down are likely to improve usability. However, the main difference with Geodan Eagle is about interaction. In the next section, we will propose a novel interaction technique to activate numerous GIS commands quickly and easily by performing multi-touch gestures.

Figure 2. Thoughts and annotations on implanting self-service electric car rental stations in Paris.

2.3.3.Software setup

Our approach did not consist in developing a specific GIS but in adapting an existing one to our hardware setup. We chose to run Quantum GIS on the Immersion Ilight tabletop. Quantum GIS (QGIS) is a multi-platform desktop GIS software that offers numerous features making it one of the most advanced and user-friendly open source GIS.

QGIS supports a wide range of sources and data formats such as Shapefile, WMS, WFS and raster images. Moreover, it provides several "Export" capabilities such as paper outputs. QGIS offers classical visualization and navigation features such as pan, zoom, rotate and various advanced tools for editing data such as the "automatic layer simplification" feature. Users can also analyze data through advanced statistical and geometric functions. Finally, QGIS provides an efficient plug-in system, a feature we used for augmenting it with advanced interaction techniques.

While QGIS provide many features and a user-friendly interface (Figure 3), it was developed for the PC and not for multi-touch tabletops. In particular, traditional graphical widgets (menu bar, docks, palettes, etc.) are not very well suited for direct touch interaction on tabletops because they suffer a number of drawbacks (Bailly et al. 2010):

- Occlusion. The hand and the fingers may hide parts of the display.
- Accuracy. The large surface area of finger-screen contact may induce selection errors when touching graphical objects on the screen.
- Lack of keyboard. In the absence of a keyboard, it may be difficult for users to enter text, while keyboard shortcuts are not available for activating menu items.
- Reachability. The length of the human arm being what it is, the menu bar may be difficult to reach.

We thus propose novel techniques for simplifying the interaction with QGIS on interactive tabletops in order to overcome the abovementioned shortcomings and to allow technical and non-technical users to perform a large set of tasks (including common navigation tasks, but also more complex tasks such as editing, annotation or statistical analyses) by performing simple gestures.

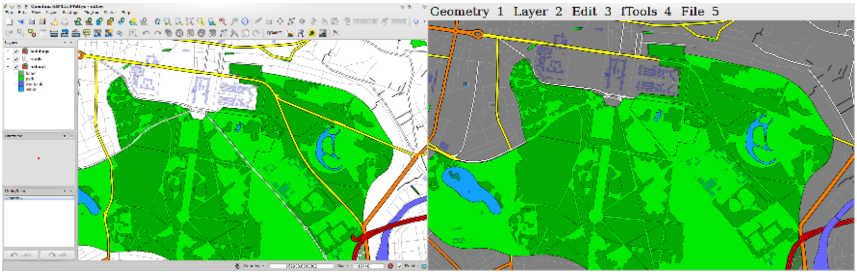

Figure 3: The Quantum GIS (left) and QGIS-MT (right) main windows

3- User needs and command selection

QGIS provides a large number of features and all of them are obviously not useful when interacting on a tabletop. For instance, the PC is better suited for writing long documents because of its keyboard. But some tasks such as layer editing are likely to be really useful in collaborative scenarios. We thus conducted an interview to learn which features would be especially valuable when working collaboratively on a tabletop.

3.1 Interview

Ten GIS users, 2 being QGIS users, participated in a face-to-face interview about their use of GIS. Nine of them came from spatial data analysis or production. During the first part of the interview, they were asked about features they often use on their desktop GIS software. During the second part, they were asked about their experience with GIS or large paper maps during typical collaborative scenarios such as meetings or presentations. We also asked them to compare GIS and large paper maps, to describe their respective advantages and drawbacks, and to explain which features or behaviors would be helpful for them. Finally, we presented our interactive co-located setup and discussed the usefulness of this environment and how it could be improved. We now report the main results.

Desktop GIS software. All participants first mentioned the need for efficient navigational features (pan, zoom, rotate). They also said they frequently used different kinds of selection tools such as rectangular selection, inverted selection or attribute selection. Finally, they mentioned the importance of data editing (such as cut/copy/paste operations) and the different types of data joining (such as geospatial and attribute joins).

Meetings or presentations. Most participants noticed that paper maps were generally more useful than desktop GIS software during collaborative scenarios, in particular to point at an element or to perform annotations under discussion. For instance, one participant said that "adding information on paper maps by drawing is quite simple". They also mentioned the navigation problems related to paper maps compared to GIS software. They, for instance, explained that it is necessary to handle several paper maps with different scales to "zoom", such manipulations being time consuming. Participants underlined that it was sometimes frustrating not to be able to interact with the presenter system. As an example, several participants said "it is difficult to precisely explain to the presenter where he must move the view". In small groups, it is common to see attendees switching places with the presenter to interact with the system, and repeated moves tend to be awkward and time consuming.

Co-located and interactive GIS. All participants showed interest in this project and insisted on the need for efficient and intuitive navigational tools. Some of them mentioned gestural interaction on the iPhone: e.g., one finger to move the map, two fingers for zooming and rotating, etc. They also explained they would like to add contents to their basemap during the meeting in order to avoid having to enter data afterward from written notes. The capability to draw annotations would be appreciated in the case of complex and time consuming analyses and users would also like to have access to measurement tools (for angles, distances and areas).

These results confirm those obtained in (Hofstra et al. 2008), which reveal the need of co-located GIS for providing the best of paper maps and desktop GIS software, that is to say interactivity and collaboration. This study also highlights the need for numerous features, contrary to what is generally available in existing co-located prototypes and products. According to these results, we will now present a novel interaction technique that addresses the above-mentioned questions.

3.2 Finger-Count Shortcuts: a novel interaction technique for QGIS

Gestural interaction is especially relevant for interactive surfaces not only for practical reasons (such as the absence of a mouse and a keyboard), but also because of various advantages such as ability to exploit spatial memory effectively (Wobbrock et al. 2009). Most gesture vocabularies on interactive surfaces are based on straightforward connections with their referents, this making them easy to learn. However, the number of "natural" gestures is limited and too small for selecting the numerous commands that are needed in real applications. Arbitrary gestures (gestures without direct connections with their referents) offer more possibilities, but require guidance to learn. Interaction techniques such as Marking menus (Kurtenbach et al. 1991) or their variants (Bailly et al. 2008), which are based on arbitrary gestures, have been proved very efficient, because they combine circular menus (for guidance) and gestural interaction. This makes it possible to favor a fluid transition from novice to expert usage. However, a common problem with Marking menus on interactive surfaces is that they use drag events. They may thus conflict with gestural interaction techniques based on pan, rotate or pinch gestures.

Finger-Count Shortcuts (Bailly et al. 2010) is an alternate technique, which was recently proposed for avoiding those problems. It makes it possible to use common pan, zoom, rotate gestures together with arbitrary gestures for selecting numerous commands. It is based on a very simple principle: the selected command just depends on the number of fingers that the user places on the interactive surface using his left hand and his right hand. Besides, as explained below, this technique fits well with traditional menu systems, so that it can serve to enhance existing systems without the need to redesign them from scratch. This paper proposes an improvement of Finger-Count Shortcuts that is specifically adapted for the QGIS software.

Finger-Count Shortcuts (FC shortcuts) work as follow. Each N-finger touch with the non-dominant hand is associated with a menu of the menubar, the correspondence being recalled to users by a digit displayed next to each corresponding item (Figure 4). Likewise, the dominant hand is associated with an item in the currently selected menu. Hence, the user simply selects an item by putting N fingers with each hand in contact with the interactive surface. The corresponding command is activated when the user lifts all his fingers. This technique makes it possible to quickly explore the different menus just by adding or removing the appropriate number of fingers. The current operation can be canceled by first releasing the non-dominant hand.

Contrary to classical graphical widgets (the traditional menubar, palettes, docks, etc.), this technique does not force users to point at small elements: interaction can be performed away from the place where the menu is displayed. Occlusion, accuracy and reachability concerns (which were presented above) thus vanish. Moreover, it was shown that users can quickly learn the association between FC shortcuts and the corresponding features (Bailly et al. 2010), a feature that is useful for non-technical experts and necessary during time crisis.

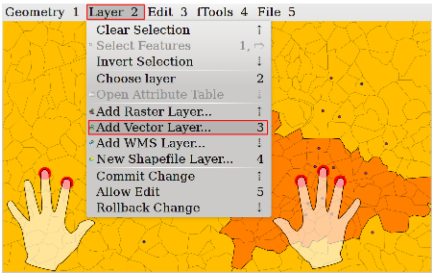

Figure 4: Performing a simple command

Navigational Tasks. FC shortcuts do not conflict with common panning, zooming and rotating gestures. Panning only requires one finger and zooming/rotating operations in fact corresponds to the specific FC shortcut, where one finger is used for each hand. As a consequence, zooming/rotating corresponds to the first item of the first menu of the menubar, as shown in Figure 5. In other words, FC shortcuts do not break habits and provide a general framework for associating gestures to menu items.

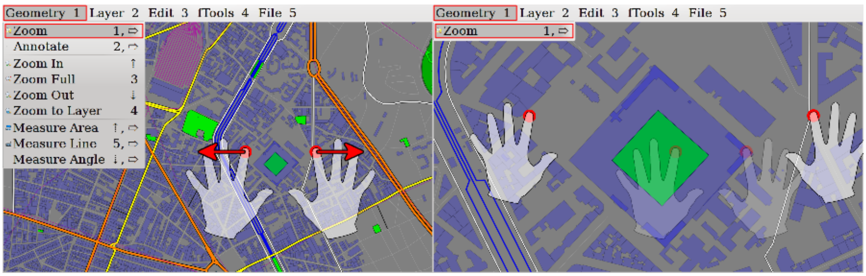

***Figure 5*:** Zooming in QGIS-MT

Number of commands. As the system just counts the number of fingers in each hand, the technique provides 5x5=25 items in a two-level hierarchical menu (such as a menubar and the associated pull down menus). This number can be increased in two different ways. First, menu items can still be selected in the usual way, just by clicking on them. As for desktop applications, not all commands need to have an associated shortcut. However, as QGIS requires a large number of frequently used commands, we developed a new mechanism called Relative Finger-Counts. It makes it possible to select menus items that do not have a dedicated FC shortcut by first selecting a neighboring item that has a shortcut, then moving the right hand up or down before releasing it from the table surface. This is shown in figure 6 where “Save Project As” is reached by first selecting “Save Project”, and then moving fingers to the North.

Another improvement is Contextual Finger-Count shortcuts. By double tapping on an interactive element (e.g. a building on a map), a pop-up window is opened and the user can select its properties such as symbols, by performing FC shortcuts in this window. The pop-up is large enough to contain 10 fingers. Hence, users can not only select up to 75 items of the global menubar system but also change the properties of interactive elements by performing multi-touch gestures.

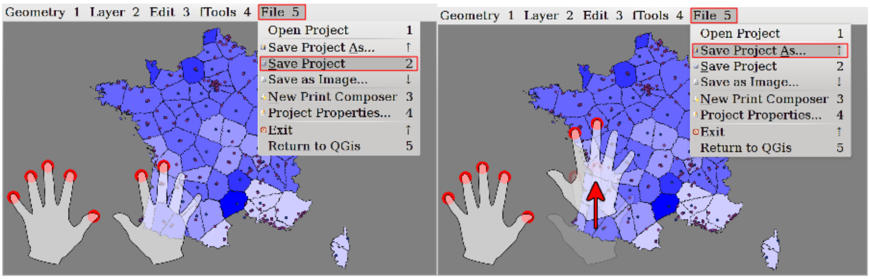

Figure 6: Saving projects in QGIS-MT

Direct manipulation. Some commands require direct manipulation: the user must not only select a command but also set one or several values interactively. FC shortcuts allow to do both in the same gesture. For instance, the “Select Features” command requires the definition of a selection zone. The user first presses 2 left hand fingers and 1 right hand finger to activate this command (Figure 7), then directly moves his fingers on the screen to set the position of the selection zone corners, and only releases them when the correct position is obtained. This feature avoids using modes and the many errors they tend to provoke (Raskin 2000).

Figure 7: Selecting features in QGIS-MT

Multi-users. Users can not only interact in turn but also simultaneously. The latter case requires the system to detect which hands belong to the same user. This is done in a simple way in our implementation, just by partitioning the surface into different areas, one for each hand of each participant (typically, 8 areas if 4 users are around the table). More sophisticated schemes could also be used, through vision-based hand recognition or by using dedicated hardware as with Diamond Touch tabletops.

4- Implementation: QGIS-MT

QGIS uses the Qt framework (qt.nokia.com) and provides a plug-in system in C++ to extend its features. We thus developed a C++/Qt plug-in for QGIS, called QGIS-MT (Figure 8).

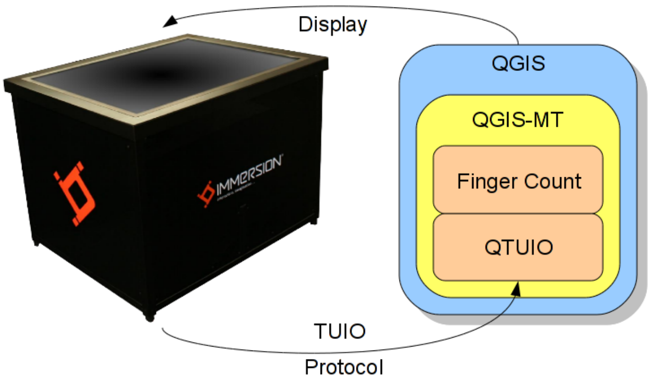

Figure 8: QGIS-MT environment architecture

TUIO protocol. QGIS and the Ilight tabletop communicate via the TUIO protocol. TUIO is an open protocol for multi-touch surfaces allowing touch events to be sent to the application over the network (Kaltenbrunner et al 2005). TUIO has been adopted by various academic (NUI group) and commercial (Flash) projects and can be used on a wide range of hardware setups.

As Qt provides support for multi-touch input, we developed a library for translating TUIO messages to the Qt native multi-touch events used in our plug-in.

QGIS-MT plug-in. This plug-in creates a full screen window which is displayed on the tabletop and detects the position and the number of finger contacts, which are then used by the menubar of the application.

Finger-Count Shortcuts rely on the application menubar, which was modified according to the needs of our new technique. First, it is able to activate appropriate commands according to finger contacts. Second, item rendition was slightly modified to provide appropriate feedback to users: FC numbers are displayed instead of keyboard shortcuts, horizontal arrows indicate a command that allows direct manipulation and vertical arrows indicate that the item can be selected using *Relative Finger Count.*

Finally, the application provides 57 frequent commands that can be activated by performing gestures. These commands are organized in 5 menus (“Geometry”, “Layer”, “Edit”, “Tools” and “File”) and more commands could be added if needed.

5- Conclusion

We proposed an environment and a novel interaction technique for augmenting the QGIS software. Using an interactive tabletop, our environment favors communication among users, enhances social awareness and facilitates the decision-making process. Our interaction technique, called Finger-Count shortcuts, facilitates navigation and quickly allows to activate numerous commands by performing simple multi-touch gestures. QGIS-MT, a plug-in that augments QGIS with multi-touch capability via FC shortcuts, was also presented. Finally, an interview was conducted with GIS users to choose a coherent set of commands that are especially well suited for collaborative work on tabletops.

As a next step, we intend to carry out user studies to assess the benefits of this environment with realistic scenarios. We also plan to add on new capabilities, such as the ability to use a smartphone or a tablet that would serve as a private space for interacting with the surface.

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Diamond Touch: www.circletwelve.com

Geodan Eagle: www.geodan.com

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Microsoft Surface: www.microsoft.com/surface

Looking for the appropriate data or services

Ontology-Based Discovering of Geographic Databases Content

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Abstract

Nowadays, the amount of geographic data is permanently increasing. One key issue to take advantage of these data is to be able to evaluate their fitness for use and their complexity. We describe in this paper a system enabling a user to discover the content of geographic databases based on a formalization of their specifications, i.e. enabling the user to discover which entities of interest are represented in a given database, and how they are represented. The system uses a global 'domain' ontology describing the topographic real world entities, which can be queried by the user to express his/her needs. Some local (or application) ontologies are used to formalize the content of database specifications. They are annotated with concepts from the global ontology. The described system is implemented as a web application and includes a web mapping solution for the visualization of data samples.

1- Context and objectives

Since the advent of Geographic Information Systems (GIS) we can observe their growing importance both in terms of data acquisition, geo-localized applications or spatial data dissemination (Craglia et al. 2008). This growth allows various domains such as urban planning, environment,

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social sciences and many others to more and more grasp phenomena with a geographic component. Applications used to analyze these phenomena usually require the use of multiple geographic databases, which may represent the same geographical space but in different ways. One of the major limitations in the reuse of geodata is that a given geographic entity can be conceptualized and represented in different ways, depending on the database producer's point of view. The representation in databases of real world entities is related to the approach adopted in the conceptualization of these databases and in the establishment of their specifications (Fonseca et al. 2003). This consequently leads to a certain level of "semantic heterogeneity of data" (Partridge 2002). Discovering data and assessing their fitness for use thus becomes an issue of first importance (Flewelling 1999)(Bruin et al. 2001). The goal of the approach presented in this paper is to be able to answer a query of a user who is wondering where and how are represented, in one or several geographic databases, the entities of the real world that may be of interest for her/him.

Mapping agencies, such as IGN (Institut Géographique National) in France, usually produce and supply various geographic databases. All these databases represent the geographical space, but each of them with its own specification. The variety of data and the complexity of specifications may cause some difficulties for any user in assessing and understanding the content of these databases. Moreover, the rise of the Internet and associated technologies allows a growing accessibility to spatial data via web portals, such as the Géoportail[1] in France. Even if this allows users to better understand the available data, a number of information are not available through geoportals for a more knowledgeable user, such as a user specialist of a given field who wishes to assess and compare the content of available databases with respect to her/his specific needs. In this context, researches are undergone in the COGIT laboratory in IGN, particularly in the framework of the GéOnto project (Constitution, alignment, comparison and exploitation of heterogeneous ontologies). This project deals with the issue of geographic data semantic interoperability and has, among others, two objectives: building an ontology of topographic concepts and

[1] http://www.geoportail.fr/

formalizing in OWL[2] – the Ontology Web Language - the content of databases specifications.

The objective of the system described in this paper is precisely to capitalize on the ontologies developed in the GéOnto project framework, and to combine them with the latest web technologies in the field of dissemination of spatial data, via an application allowing a user to discover, in a simple way, databases which are the most appropriate to his/her needs. The purpose of this system is to provide, through a user-friendly interface, complex information on geographic data, previously not accessible or only accessible by reading the complex specification files. More precisely, the goals of our system are the followings:

- Guiding the user in specifying which information is of interest for her/him with terms from the domain ontology (e.g. river), rather than technical terms used in the database schema (e.g. 'hydrographic section' or even 'hydr_lin').
- Retrieving in the database data corresponding to the user's need.
- Providing additional information about the data: which real world entities are represented (e.g. all the watercourses or only those with permanent flow); how they are represented in the database (in which class, with which attribute values?); and how are they distinguished from other entities (e.g. does the information in the database allow to make the distinction between man-made canal and natural watercourses?).
- Visualizing the data corresponding to the user's need using web mapping techniques.

Several ontology-based systems have already been proposed for geodata discovery and retrieval (Paul and Ghosh 2006), (Nambiar et al. 2006), (Lutz and Klien 2006), (Klien 2008). However, none of them used specifications-based semantic annotation of geodata to provide users with detailed information about data semantics. If some user is looking for data about forests, our systems will not only explain that forests are represented in the 'Wooded area' feature class, but also that the wooded area

[2] http://www.w3.org/TR/owl-features/

represented in this class corresponds to forests of area greater than 5 hectares in the real world.

The remainder of the paper is organized as follows: first, a presentation of our approach and an introduction to the elements necessary for the understanding of the system is done. Then, the system architecture is detailed, and finally the implementation of a prototype and some results obtained with IGN data are showed.

2- Approach and methods

2.1 Preliminary notions

For the sake of clarity, let us first describe the following core elements of our system: the geographic database specifications, the topographic domain ontology and the specification ontologies.

2.1.1 Geographic databases specifications

Like any database, geographic databases are described by their schema. Classes are named by common geographic words, which usually refer to geographic concepts. Their instances, geographic features, are described by attributes and a geometrical representation (usually point, line or polygon). However, each geographic database represents the specific point of view of its producer about the geographic real world (Fonseca et al. 2003). As an example, if a class is named 'Road', it may actually designate only hard-surface roads, or alternatively include loose-surface roads, such as trails, footpaths or forest rides; moreover, it may or not designate only main roads with at least two lanes. Actually, a geographic database is associated with a certain level of detail. Therefore, only relevant geographic features are captured in this database. Besides, in vector databases, the geometric representation of a given geographic feature may vary: a road may be represented by a line drawn along its axis, or by a polygon representing the surface it covers.

Since data capture for a given database is often done by several persons, special attention has to be paid to the homogeneity of data meaning within the database (i.e. of the link between data and what they represent). All selection and representation criteria are thus described in specific textual documents, as little ambiguous as possible, namely the database specifications. They are used as guidelines for database capture and may be very rich but complex (see example in Figure 1)[3].

[3] All examples in this paper originate from actual specifications (from IGN France), originally in French and translated here for the sake of clarity.

Building

Definition : Building of area greater than 20 m^2

Geometry : 3D polygon

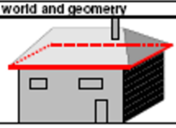
Attributes :
- Identifier
- Data source
- Category
- Nature
- Height

Extensional definition: Look at values of attributes <category> and <nature>

Selection: All buildings of area greater than 50 m^2 are included.
Buildings of area lying between 20 m^2 and 50 m^2 are selected depending on their environment* and on their appearance** .
Buildings of area lower than 20 m^2 are not included. If they are very high, or if they are represented on the 1 :25000 scale map (e.g. monument, antenna, etc.), they are represented by an instance of the class "punctual building".

* Isolated small buildings which are 100m away from a dwelling house, and of area greater than 20 m^2 are included, whereas small buildings located in an urban area are not (e.g., small garage, etc.).
** Small buildings which look precarious (e.g. cabin, hut, etc.) are not included.

Geometry: Outer boundary of the building as it looks from above (most of the time, it is the roof boundary).
Inner courts, which are wider than 10 m, are represented by a hole in the surface representing the building.

Description	Real world and geometry	Geometry
Geometry of a house		

Several contiguous buildings, with the same <nature> and the same <category>, are considered as one single building (only the outer boundary is captured). Two contiguous buildings are represented separately in the cases when:
- the height difference between them is greater than 10 m (or 3 floors) ;
- each single building area is greater than 400 m^2 ;

Geometric constraint: Two contiguous buildings with different attributes values are represented by two surfaces with a common boundary.

Attribute: Category

Definition: Type of a building according to its function and its appearance.
Type: Enumerated.
Values: Administrative / Industrial, agricultural, and commercial / Religious / Sports / Transports / Other.

Category = « Administrative »

Definition: Building with an administrative function.
Extensional definition: City hall | District police administration building| Sub-district police administration building

Category = « Industrial, agricultural or commercial »

Definition: Building with an industrial, agricultural or commercial function or typical appearance.
Extensional definition: slaughter-house| workshop | awning | electrical power plant | factory chimney (>20 m^2) | shopping center | stable | warehouse| industrial hangar | blast-furnace | hypermarket | department store| works| flour-milling works | car park | radar station | relay station | sawmill | glass-house | silo | factory

Figure 1: Excerpt of the specification of the BDTOPO® database (IGN 2002)

Specifications are the most detailed available source of knowledge about geographic databases content. They describe the meaning of each element of a database schema or, i.e. the semantics of a schema. However, as they are mainly written for human readers, these specifications are only available in natural language. So, they are not directly tractable. Providing a formal representation of these specifications would enable to take advantage of the knowledge they contain for a better comprehension of databases contents and for data integration purposes (Mustière et al. 2003).

2.1.2 The topographic domain ontology

Our approach requires a shared taxonomy of geographic concepts described in the studied databases (or several and aligned taxonomies, however this issue is out of the scope of this paper for the sake of simplicity). For our study, we use a bilingual (French/English) taxonomy built at the COGIT laboratory from a semi-automated analysis of geographic terms encountered in several data specifications (Abadie and Mustière 2008). This taxonomy of the topographic domain contains more than 760 concepts. In the future, we aim at using a richer ontology, in terms of number of concepts and in terms of description of those concepts. The production of this ontology is one of the goals of the undergoing GéOnto project (Mustière et al. 2009). The enrichment of the original taxonomy is made thanks to the analysis of two types of textual documents: technical specifications of geographic databases and travelogues. It is based on automated language processing techniques, ontology alignment and also on external knowledge like dictionaries and gazetteers of place names.

2.1.3 Specification ontologies

Our approach also relies on some ‘specification ontologies’, which are local ontologies that formalize the content of the specifications of each considered geographic database. The methodology used to build these ontologies is described in (Abadie et al. 2010). This methodology stipulates that each geographic database should be associated with a ‘local specification ontology (LSO)’, which describes its content. The ontology first contains a transcription of the database schema into OWL formalism. Then schema classes are annotated with concepts from the global ontology. Additional knowledge taken from the database's specification, such as selection criteria used to populate the database, is added in the axioms used to annotate the feature classes. For example, the fact that "only watercourses that are permanent and wider than 10 meters are represented in the feature class 'River' of the database", or that "the geometry of features 'River' corresponds to the centreline of the modelled watercourses" is formalised. The specification ontologies make an explicit link between the real world entities defined in the topographic domain ontology and their representation in the geographic databases. In order to ensure enough homogeneity in the way to formalise the geographic databases specifications, a common semantic model represented in OWL, called 'specification ontology (SO)', and providing a unified view of the formal geographic database specifications is also defined in (Abadie et al. 2010). This ontology reuses existing ontologies of the geographic domain such as GeoRSS-Simple[4]. Figure 2 illustrates an example of formalization, where the entities of the SO ontology are preceded by the prefix 'so:', those belonging to the ontology describing a local database are preceded by the prefix 'lso:', and those belonging to the topographic domain ontology are preceded by the prefix 'topo:'. As we can see, the feature class 'Other_water_point', which refers to a class of the database schema, represents, in the real world, entities which are 'Loss', 'Wash-house', 'Watering-trough', 'Well' and 'Basin'. These real world entities are defined in the topographic domain ontology. Moreover, these entities are represented in the database as points, i.e. they have a geometry type which is a Point. Also, we see that additional restrictions are defined on some entity classes: only basins that are longer than 10 meters are captured in the database.

The specification ontologies and the topographic domain ontology are the heart of our system. The former constitute the interface between the databases and the system and the latter constitutes the interface between the user and our system.

[4] http://mapbureau.com/neogeo/neogeo.owl

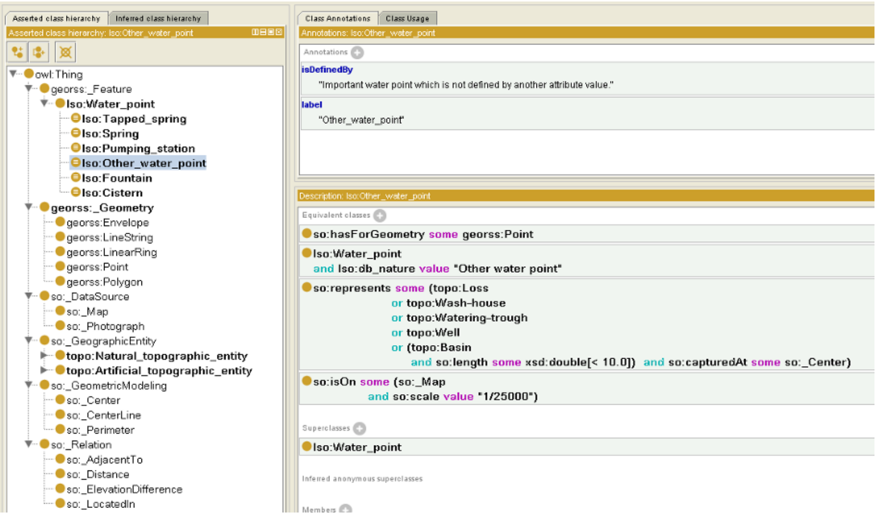


Figure 2: Example of geographic databases specifications formalization edited with Protégé[5]

2.2 System architecture

Figure 3 shows the global architecture of our system. As explained before, our system allows a user to better understand geographic databases content thanks to the use of ontologies that formalize the specifications associated with these databases. It also allows a user to visually compare geographic datasets throw a web mapping solution allowing the visualization of the data sought by the user. In this system, the user expresses his/her query using terms from the domain topographic ontology. This way, s/he is able to know about several geographic databases' content since they are described using the same vocabulary.

[5] http://protege.stanford.edu/

Our system runs on a client-server architecture, including a web mapping solution for data visualization in the client's side. It is composed of three important modules.

1. The search module: this module guides the user, through an auto-completion solution, to express his/her query, i.e. to specify which data s/he is looking for using terms designating concepts in the topographic domain ontology. Indeed, the interest of the topographic domain ontology is two-fold: it is supposed to contain a shared vocabulary rather than a technical one, and all formalized specifications of databases rely on it. The topographic domain ontology is thus used to express user's needs and is a pivot in our system.

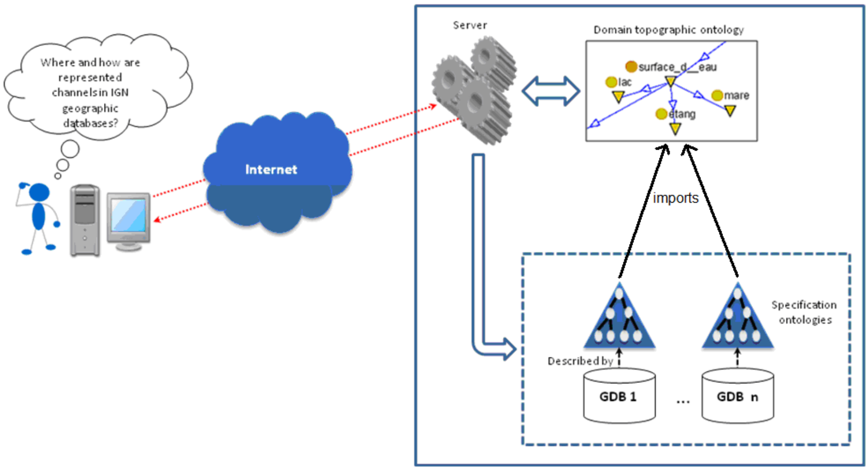


Figure 3: System architecture

2. The information extraction module: once the user selects the label of a given geographic concept of interest, the system extracts, from the local specification ontologies, information about the data referred to by this term. This piece of information, including definitions, geometries of represented objects etc., is sent to the user.

3. The cartographic module: the system uses information obtained from the specification ontologies to retrieve data corresponding to the user's need in the different geographic databases. Data are sent to the user for visualization through a web mapping solution.

Illustrating example: Let us consider the example on figure 2, and suppose that the user wants to know where and how are represented basins in the databases annotated with this ontology. From the free text 'basins' filled by the user, the system proposes him/her the term 'Basin' included in the topographic domain ontology. Next, the system retrieves all classes of the local specification ontologies which are annotated with the concept of basin, such as the class 'Other_water_point', among others. After that, the system retrieves data from the table 'Other_water_point' of the database, where basins are stored, and sends them to the user as well as other information from the local specification ontology such as the type of geometry of the data (here basins are stored with points in the database), and the capture constraints on basins (here the database includes only basins that are longer than 10 meters). Finally, a web mapping solution allows the user to visualize capture constraints and available data themselves, in order to evaluate if they fit to his/her needs. This may be simultaneously done for several datasets, and thus enables a precise comparison of specific interests of each dataset.

3- System implementation

The proposed system is a web application allowing serving a large number of users (Figure 4). A prototype has been implemented using two specification ontologies associated with two IGN databases (BDTOPO® and BDCARTO®). These ontologies are represented in OWL 2 and are actually restricted to the hydrographic theme. Programs running on the server are implemented in Java, using the OWL 2 API[6] for parsing ontologies. For the web side, JSP, HTML and JavaScript languages and JQuery library are used. The web server used is Apache Tomcat, since it can interpret JSP pages. The cartographic server used by the system is Geoserver[7], since it is developed as a J2EE application and can be executed on a Tomcat server. This way, the system requires only one server. Postgres with the Postgis extension is used as database management system. Two geographic datasets were used, subsets of data from the BDTOPO® and

[6] http://owlapi.sourceforge.net/
[7] http://geoserver.org/display/GEOS/Welcome

BDCARTO® products. The system uses also the WMS protocol for data displaying and the Géoportail API in its cartographic part, in order to access to IGN base maps.

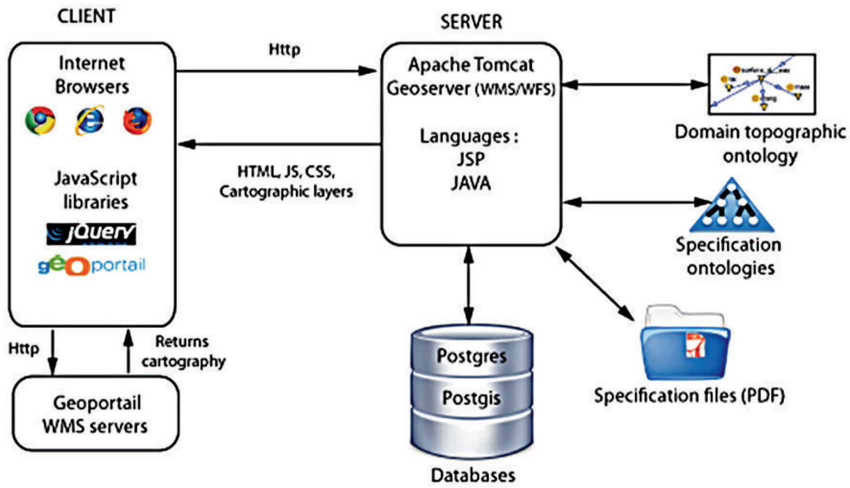


Figure 4: implementation of the system

The web interface of the implemented system is shown on figure 5. It is composed of three parts: the first part consists in a text-field for entering the query as in a classical search engine where the user can specify which data she/he is interested in (here 'channels'). The second part (on the left) consists in a set of tabs; each tab corresponds to a database and provides information about data interesting the user in this database. The third part is the cartographic visualization of the data corresponding to the user's need in each database. When the user switches from one tab to another one, the cartographic visualization of the corresponding data is automatically updated.

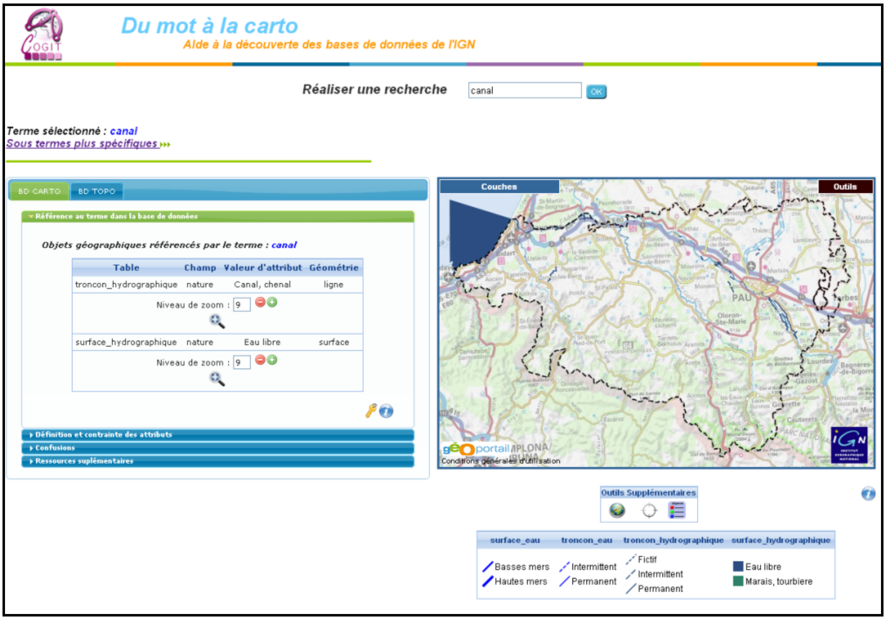


Figure 5: the web interface of the implemented prototype

The search module was implemented using the auto-completion script available in the JQuery library, which works asynchronously and displays results as a list of terms. In Protégé software - ontology editor -, concepts cannot contain spaces or quotes; they are generally replaced with underscores as shown on figure 6. However, in our topographic domain ontology, concepts are associated with labels, represented as OWL annotations, both in English and French. So, for ergonomic reasons, in our auto-completion procedure we display these labels instead of the concept names themselves.

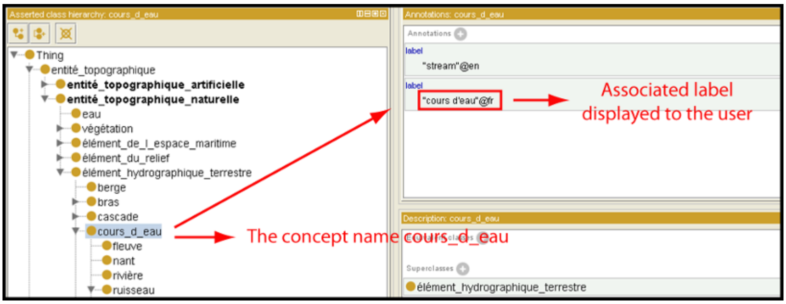


Figure 6: Labels associated with the topographic domain ontology concepts

In order to take into account typos when the user enters his/her query, the system computes a distance between the typed string and the concepts names in the domain topographic ontology, using the Levenshtein edit distance (Levenshtein 1965) which was normalized in our system using the method proposed in (Yujian 2007). This way, the closest concepts' labels will be proposed to the user. For example, if the user types 'canel' instead of 'canal' (which means channel in French), then the system will still find 'canal' as illustrated on figure 7. The system also allows the user to refine her/his query by proposing to her/him terms designating concepts that are specializations of the concept 'canal' in the topographic ontology as shown on the figure 8.

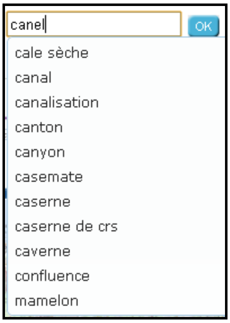
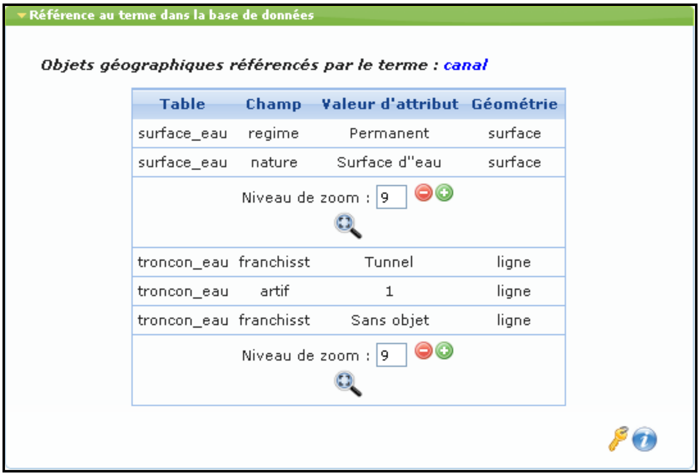


Figure 7: auto-completion system

Figure 8: terms for query refining

The information extraction module extracts from the specification ontologies, information about the data referred to by the term specified by the user. In the case of 'canal' the system will extract information about precise localizations of channels in the databases and other information like the type of geometry of channels in the database (polygons or polylines). All those pieces of information are sent to the user and displayed as shown on figure 5. For each considered database, information display is organized in an accordion composed of four sections.

The first section (figure 9) indicates which features of the database refer to the term selected by the user: it describes how these features are represented in one or several classes, and with which attribute values they are modeled. Here, channels are described in two different classes 'water_surface' and 'watercourse', that may be shown to the user, and objects representing channels in the class 'watercourse' have in particular the specific attribute value 'artificial = true', which allows to distinguish them from natural watercourses.



Référence au terme dans la base de données

Objets géographiques référencés par le terme : ***canal***

Table	Champ	Valeur d'attribut	Géométrie
surface_eau	regime	Permanent	surface
surface_eau	nature	Surface d''eau	surface
Niveau de zoom : 9			
troncon_eau	franchisst	Tunnel	ligne
troncon_eau	artif	1	ligne
troncon_eau	franchisst	Sans objet	ligne
Niveau de zoom : 9			

Figure 9: information on data localization in the database

The second section present more in detail specifications related to the considered features (figure 10); A first part details definitions of attribute values used to model the specific concept. A second part shows the constraints that should be satisfied by geographic entities in order to be included in the database (here, channels are represented by surfaces only if they are wider than 7.5m).

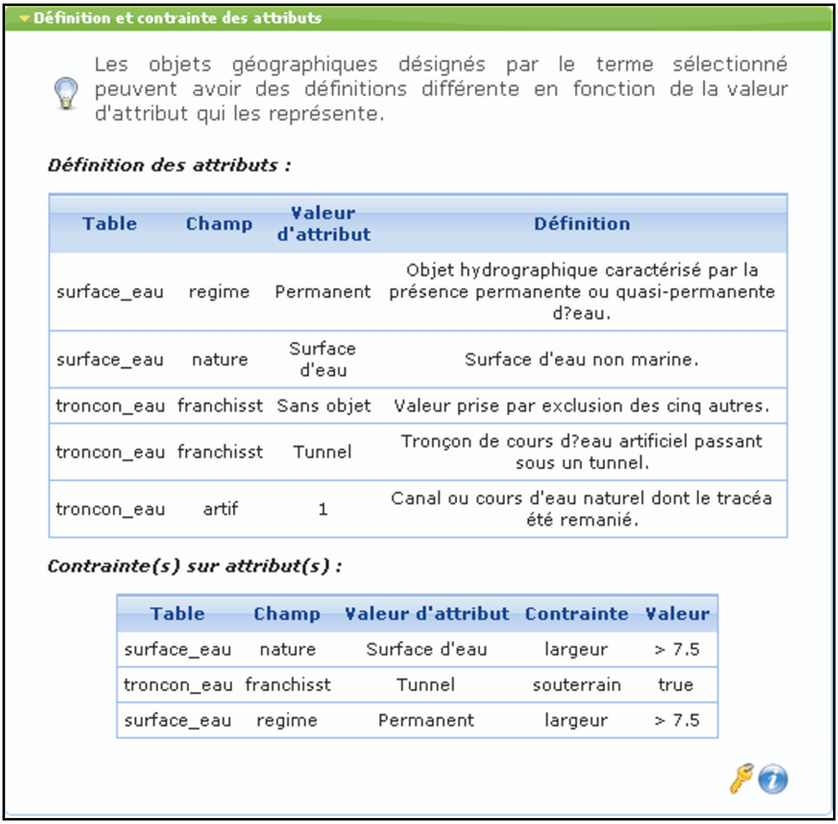
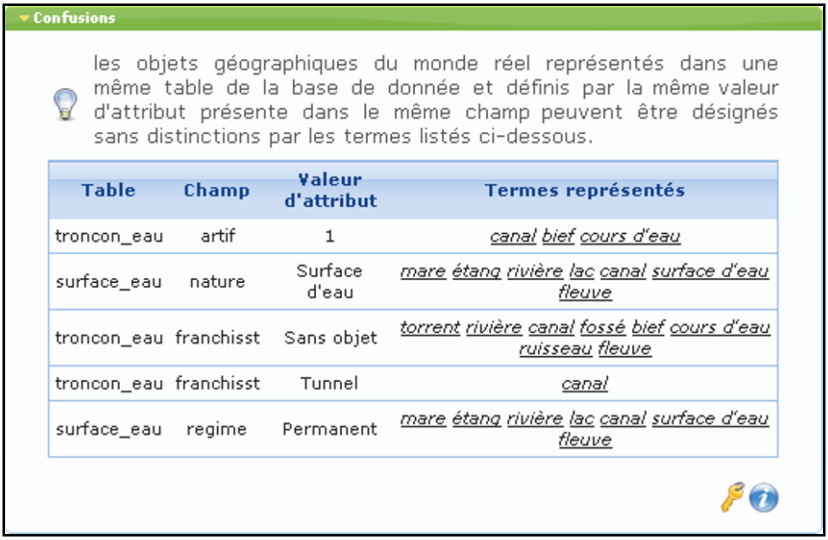


Figure 10: definitions and constraints on data included in the database

The third section (Figure 11) lists, without distinction, all real world entities which are represented in a given table with the same attribute values. For example, watercourses with field 'artificial=true' may represent either channels, reaches and watercourses ('canal', 'bief' and 'cours d'eau' in French), without any possibility to distinguish between them. This is a way to explain the granularity of attributes describing the nature of objects, which may be of importance for the user.


Confusions

les objets géographiques du monde réel représentés dans une même table de la base de donnée et définis par la même valeur d'attribut présente dans le même champ peuvent être désignés sans distinctions par les termes listés ci-dessous.

Table	Champ	Valeur d'attribut	Termes représentés
troncon_eau	artif	1	canal bief cours d'eau
surface_eau	nature	Surface d'eau	mare étang rivière lac canal surface d'eau fleuve
troncon_eau	franchisst	Sans objet	torrent rivière canal fossé bief cours d'eau ruisseau fleuve
troncon_eau	franchisst	Tunnel	canal
surface_eau	regime	Permanent	mare étang rivière lac canal surface d'eau fleuve

Figure 11: confusions

The fourth section provides additional available information. The user can download original textual specification files corresponding to his/her query, and is able to view a subset of the database, and download it in KML format in order to be able to use it on any GIS software.

The cartographic module is implemented using to the Géoportail API, and the displayed layers are controlled by the system according to the term selected by the user. In order to display only geographic objects corresponding to the user's need, the system filters the WMS layers served by Geoserver, using CQL queries which allow the creation of layers with the Géoportail API. The system displays automatically the layers corresponding to a specific database when the user switches from one tab into another one.

In addition to functions offered by the Géoportail API, new ones were implemented in our system, like retrieving a place using its address, adding vector layers or images in order to allow the user to compare his/her data with those proposed by our system, etc.

Thanks to our system, it is now possible to compare different databases content with regards to a specific user's need. The implemented prototype allows comparing the BDTOPO® and BDCARTO® contents. For example, if the user wants to know which databases better represent channels, s/he can quickly have detailed information about channels in each database and visualize channels in both databases as shown on figures 12 and 13.

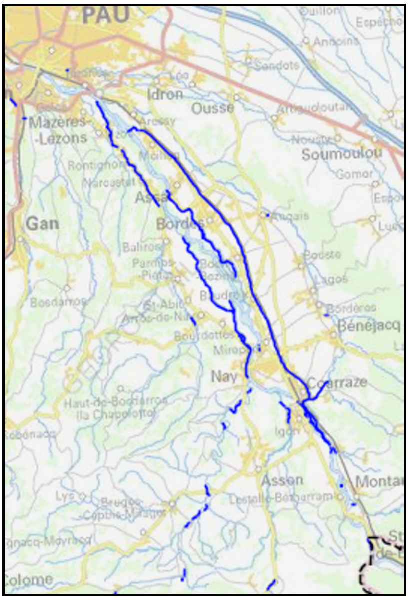


Figure 12: Channel representation in BDTOPO

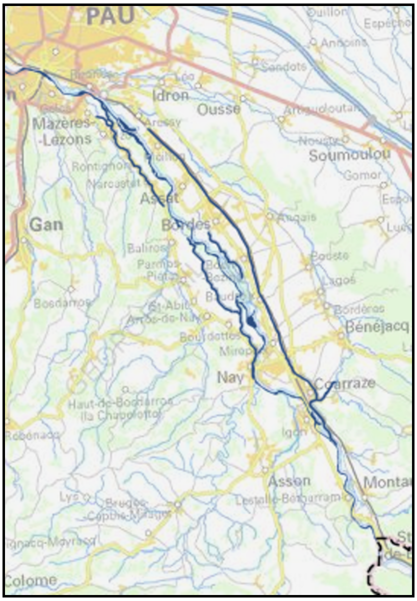


Figure 13: Channel representation in BDCARTO

4- Conclusion and perspectives

We proposed in this paper an ontology-based system for discovering geographic databases content. The use of ontologies in this context is a promising approach to facilitate the discovery of geographic data in the web. The proposed system allows a better comprehension of the geographic databases content, thanks to the formalization and an appropriate display of their specifications coupled with a web mapping solution allowing a visual comparison of the data of interest. The implemented prototype of the system using data from the IGN shows the feasibility and usefulness of the approach for geodata understanding and comparison. In the future, we plan to improve the system with respect to several aspects.

For expressing his/her need, the user has actually the possibility to select one concept's name from the topographic domain ontology. It would be interesting to allow her/him to select more than one concept's name in order to be able to compare data representing different geographic entities.

For example, allowing comparing data which represent both channels and roads. Moreover, the auto-completion method could be improved, for example by returning to the user concepts' names in a form respecting the taxonomic structure of the topographic domain ontology. This would allow the user to better specify which data s/he is interested in.

Information returned to the user come from the specification ontologies, which are represented in OWL 2, the latest version of OWL language. Indeed, these ontologies formalize a large part of databases specifications, but some expressions like "The attribute 'width' of the feature class 'Hydrographic segment' takes the value 'small' if this '*river section's width'* lies between 0 and 10 meters" can typically not be directly represented in OWL since they are constraints between fillers of two different properties. As a consequence, it is necessary to follow the evolution of the ontology web languages in order to continually improve the formalization of the databases specifications.

The implemented prototype is actually restricted to the hydrographic theme of two geographic databases from IGN. It would be interesting to extend it to other geographic databases from IGN and outside IGN in order to allow users to compare databases issued from more different conceptualizations and points of view.

Acknowledgement

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Place Names Ontologies

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Abstract

In this article is discussed possibility of development of place name (toponyms) ontologies as knowledge background for building semantic web. Place name is complex object. Place name conceptual domain ontology approach is discussed as possibility to develop platform for Semantic Web and better Internet interactions. Elements of global ontology and domain oriented ontologies are discussed on the examples of UNGEGN World Geographical Names Database, EuroGeoNames (INSPIRE) European infrastructure of geographical names and Croatian experiences. Influence of ISO/TC 211 geographic information ontology standards on standardization of geographical names is discussed. The main relationships between place name ontological objects are defined. Examples are given for: functional, inverse functional, transitive, symmetrical, antisymmetric, reflexive and irreflexive relationships. The ISO/TC 211 geographic information standards, INSPIRE and EuroGeoNames are also using UML schema as object oriented semantics in description of the place name model.

1- Introduction

Place name or toponym is defined by United Nations Group of Experts on Geographical Names (UNGEGN) as proper noun applied to a portion of the surface of Earth or of any other planet or satellite that has recognizable

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identity (Kadmon 2002). Infrastructure for Spatial Information in the European Community (INSPIRE) is defining geographical name as proper noun applied to real world entities (INSPIRE 2009). If we limit our observations on the Earth (e.g. geographical names), as INSPIRE is doing, the fundamental difference is that UNGEGN is defining named place as the portion of the surface of Earth that has recognizable identity, and INSPIRE is defining named place as real world entity. These differences can cause different interpretations of formal representation of named places in a universe of discourse and difference in definition of conceptual domain ontology.

Place name is complex object. Its definition includes more elements. The second level on the Figure 1 is essential for place name (toponym) definition. The name should be assigned to place (feature/object). Time is usually not explicitly defined. But, without time distinction between historical and present toponyms cannot be made. Because standardization of geographical names is bounded to present geographical names without time entity it cannot be formally defined.

The third level is defining concept of a universe of discourse. It is interpretation of real world and in the case of the definition of toponym, it has a lot of limitations. The toponyms are defined in different epochs, mostly the centuries ago. In that time linguistic relations and definitions were different. Today linguistic is frame for judging toponym from todays' linguistic point of view. Feature type, shape and position are defining idealization of real place that is named. Feature catalog as definition of feature types is set of final number of feature classes, and definitions of feature types are defining perception of real world object. Feature shape is defining shape of real world feature, and geometrical presentation of feature shape is limited by density of features, scale, etc.

Ontologies may be developed at different levels. Global, domain, and application ontology levels can be recognized (ISO 2010a). A global ontology defines approach to identify philosophical, general ontological perspective. The domain ontology defines concepts that are specific to a body of knowledge and in this work to problem of place names. It requires more detail development focused on knowledge base. Application ontology defines concepts that are specialized within a given context or a specific usage. Diagram on the figure 1 is giving background for defining global place names ontology. Place names are interdisciplinary problem that join different ontologies.

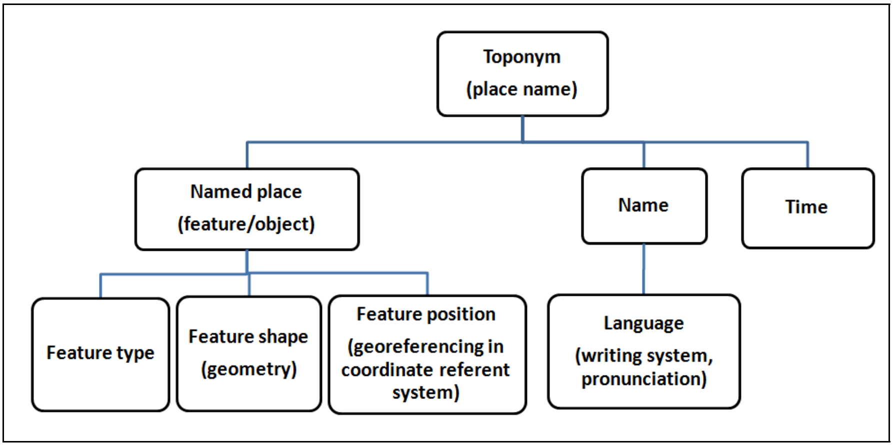

Figure 1: Essential entities of toponym.

ISO geographic information standards are using feature catalogues and application schema in description of semantics of geographic information. This kind of approach corresponds to the application ontology level. Ontological approach of the problem support interoperability across toponym language, feature type, feature shape, feature position and time. It would allow association of concepts across applications and domains, and give background for solving problem of place name as complex problem that is defined in more disciplines.

Today interactions on the web of data are based on application principles, and sharing data among applications can be done only if it is explicitly defined (developed) in each application. Semantic web using domain ontologies interpretation of data is giving opportunity of more improved sharing the data trough web. Using ontological approach of data and Semantic Web, the heterogeneous data can be directly accessed through web by different applications. A description of heterogeneous data in different ontologies is making basic definition of concepts implemented in Semantic Web. Ontology approach is scalable in the sense of expanding existing ontology with new concepts and in the sense of adding new ontologies in the domain.

In this work, is practical part mainly done using the Protégé v.4.1.0 software as an ontology-developing environment tool (http://protege.stanford.edu).

2- Ontology

New ISO/TC 211 work item proposals in the series of geographic information standards on ontology (ISO 2010a and 2010b) are defining ontology as basic platform for description of geographic information in terms of feature based application schema. It is defining ontology as formal representation of phenomena of a universe of discourse with an underlying vocabulary including definitions and axioms that make the intended meaning explicit and describe phenomena and their interrelationships. Ontology is giving possibility to connect different views of the real or hypothetical world that includes everything of interest; e.g. universe of discourse. Because idealization of real world in to universe of discourse, in the information-communication technology (ICT) more ontologies about the same part of reality can be developed. To make possible implementation of new concepts and new ontologies, ontological models are developed scalable to allow easy integration of new knowledge bases. Ontologies are allowing integration of heterogeneous data of different communities by relating them considering their semantic similarity.

Ontology is approach based on knowledge bases, and semantic web is transforming knowledge in machine recognizable system. Because of that ontology is dealing with more fundamental object and relations than geosaptial semantic. That is the reason why new knowledge basis (ontologies) could be integrated in the domain.

The ISO geographic information standards and INSPIRE are using object oriented UML conceptual schema language to describe conceptual model. UML models implicitly contain ontologies.

In ISO standardization, development of ontology approach is intended to provide fundament for General Feature Model (GFM) as general, modular models that can be joined by ontologies. These standardization approach will also influence standardization of geographical names.

3- Semantics and semantic web

Semantics as the study of meanings is establishing relationship between real world and data. It is important in the field of geographic information because the meaning of data is essential for their consistent integration in model. Semantics is connecting phenomena (features/objects) and signs (on the maps and visualizations) using the concepts, and concepts are defining knowledge base or ontology. Ontologies constitute knowledge base of the semantic, and can be used to integrate heterogeneous data. Because of that ontology is a fundamental for semantic interoperability.

Sharing the data among different applications is possible only if they are developed for that purpose. Semantic Web is defining common format of data in different sources and how the data are related to real world objects. W3C standardized Semantic Web as web of data (W3C-Semantic Web 2009). The Semantic Web is using the Web Ontology Language (OWL) to implement ontologies on the Web (W3C-OWL 2009).

The Semantic Web consists of a Web of data and information that can be processed by computers (W3C Semantic Web 2009). It can use keywords in queries search in the large information structure. Semantic web languages are developed on the foundation of extensible markup language (XML). World Wide Web Consortium (W3C) is supporting Semantic Web languages: Resource Description Framework (RDF), RDF Schema (RDF-S), Web Ontology Language (OWL), Rule Interchange Format (RIF) and RDF Schema (RDF-S). The Web Ontology Language (OWL) is giving opportunity to use more ontologies in one semantic Web system. Semantic Web is data understandable and can be processed by machines, providing more interaction between the different data sources on the Web.

Ontology is fundament for development of web of data; e.g. Semantic Web. Semantic web allows development of higher interoperability of geographical information, and the goal of the Semantic Web is to improve interoperability by developing systems that can support trusted interactions over the network. It can be seen as system that allow interoperability between different resources that are defined trough the same ontological model and semantic web.

4- Web ontology language (OWL)

There are more different languages for representation and modeling ontologies (Jones et al. 2003). Each of them should be compatible with existing web standards (as XML, RDF) to facilitate sharing of information with other searching components. It should have adequate possibility to express ontology representation and to easily extend it. Some of these languages are based on XML (XOL, SHOE, RDF), some on descriptive logic (KIF, CLASSIC) and other on both (OIL, DAML+OIL, OWL). The last group languages are mostly used because they are compatible with existing web standards.

The Semantic Web introduced the Web Ontology Language (OWL) to formalize the description of ontology on the Web in a format that machines and applications can read. OWL is W3C semantic markup language for publishing and sharing ontologies over web. It is developed to define ontologies and improve interoperability between them. OWL is more and more used to define consistent geographic information ontologies.

5- Building place names conceptual domain ontologies

Ontology is a conceptual model that defines concepts of a universe of discourse, and feature is abstraction of real world phenomena that define a universe of discourse. Because of that, ontology is usually using features (concepts) as object in domain ontology connecting them with relationships. Conceptual domain ontology is a systematic representation of knowledge domain; in this work on the knowledge basis about place names.

There is strong motivation to build the place name ontology because place name is complex already after its definition, and demand interdisciplinary approach. The scope of the place name ontology is defined by the area of knowledge the ontology will cover connecting different disciplines. The place name conceptual ontology is the human readable ontology while the OWL ontology is machine readable.

In this work, the scope of the place name ontology is defined as place names of the Earth surface topographic features of a scale 1:200 000 or greater. It will include topographic features named in bigger scales topographic maps (e.g. 1:200 000 or greater). That scope is developed considering EuroGeoNames and Croatian examples.

5.1 Relationships rules

To define place name ontology, relationships between objects should be defined (Horridge 2009, Kovacs at al. 2006). There are many relationships that can be defined among place name ontology objects. Here are defined some of them. Relationships are presented by OWL properties. There are object and data type properties as two main types of properties in OWL. Object properties are relationships between two objects. There are functional, inverse functional, transitive, symmetrical, antisymmetric, reflexive and irreflexive relationships. Data type properties are relationships between objects and data values. There is also annotation property that can be used to add descriptive information to classes and objects.

5.1.1 Functional relationship

Functional relationship is defined if object A has the same relationship to two objects, than these two objects must be the same (see Figure 2).

Example: Zagrebačka gora is variant name of Medvednica, the same mountain (feature) in the real world. Peak (Sljeme) is part of the Mountain (Zagrebačka gora), and Peak (Sljeme) is part of Mountain (Medvednica), then if Mountain (Medvednica) and Mountain (Zagrebačka gora) is the same thing relationship is functional.

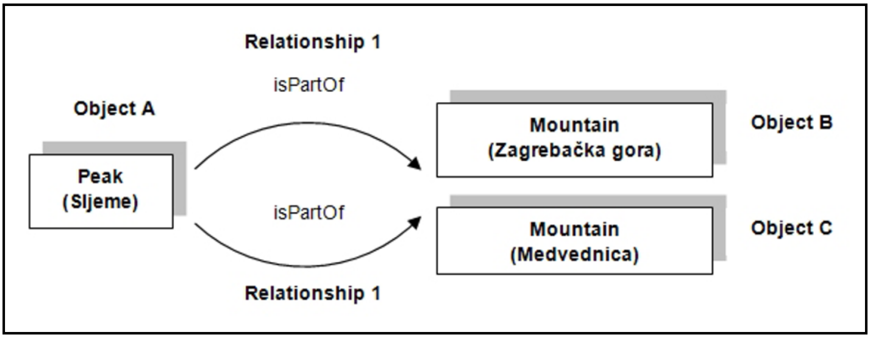

Figure 2: An example of the Functional relationship.

5.1.2 Inverse Functional relationship

Inverse Functional relationship is defined if object A has relationship to a object B, and object C has this relationship to the object B, than object A and object C must be the same thing (see Figure 3).

Example: Mountain (Zagrebačka gora) has part Peak (Sljeme), and Mountain (Medvednica) has part Peak (Sljeme), than if Mountain (Medvednica) and Mountain (Zagrebačka gora) are the same thing relationship is inverse functional.

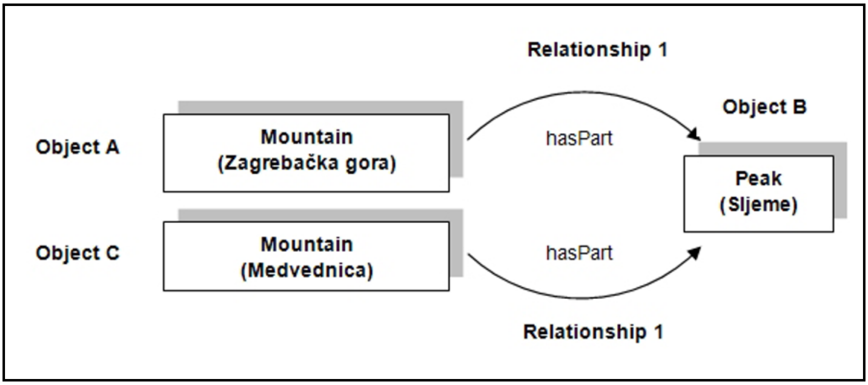

Figure 3: An example of the Inverse Functional relationship.

5.1.3 Transitive relationship

Transitive relationship is defined if relationship term has the ability to pass on other relationships and characteristics of other objects (see Figure 4).

Example: Town (Zagreb) contains District (Trešnjevka) and Town (Zagreb) contains Street (Ozaljska), then if District (Trešnjevka) contains Street (Ozaljska) relationship is transitive.

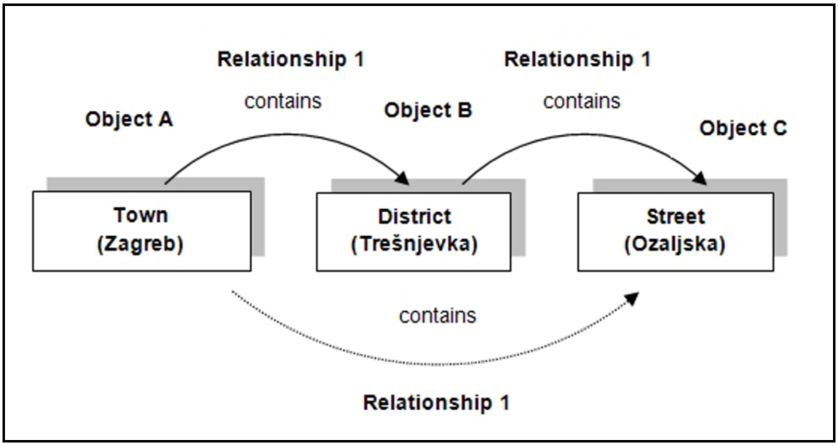

Figure 4: An example of the Transitive relationship.

5.1.4 Symmetrical relationship

Symmetrical relationship is defined if for a relationship, the object and the subject may be exchanged without changing of the meaning (see Figure 5).

Example: County (Istarska županija) is connected to Town (Pula), and Town (Pula) is connected to County (Istarska županija), if this is the truth, relationship is symmetrical.

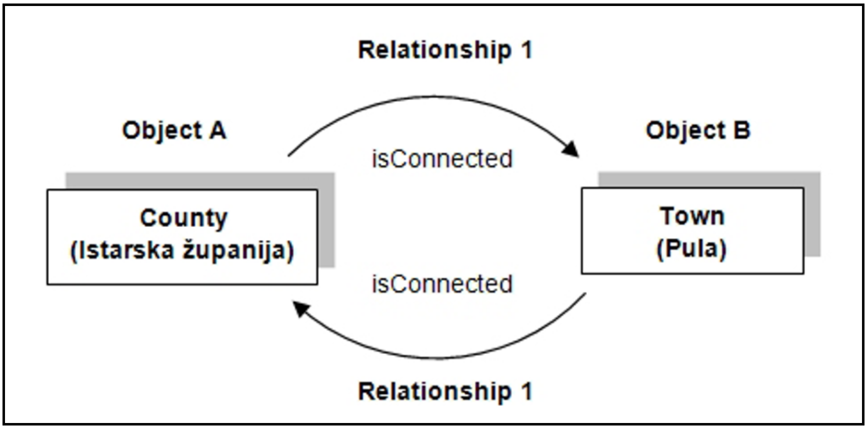

Figure 5: An example of the Symmetrical relationship.

5.1.5 Antisymmetric relationship

Antisymmetric relationship is defined if object A has a relationship to object B, than object B can never have this relationships to object A (see Figure 6).

Example: Sea channel (Hvarski kanal) is part of Sea (Jadransko more) and Sea (Jadransko more) is not part of Sea channel (Hvarski kanal), then relationship is antisymmetric.

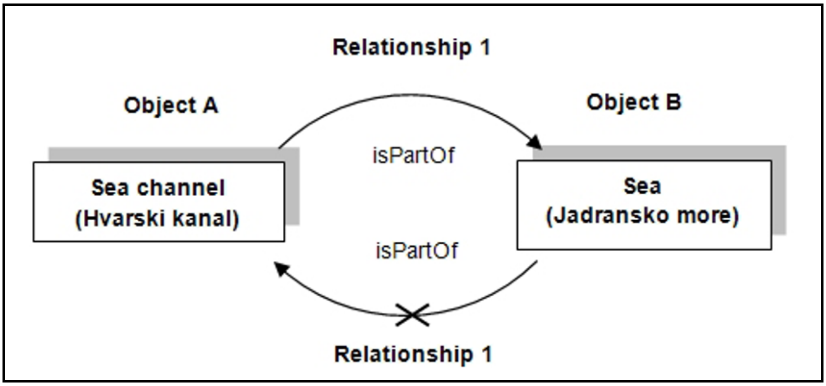

Figure 6: An example of the Antisymmetric relationship.

5.1.6 Reflexive relationship

Reflexive relationship is defined if object A has relationship to itself (see Figure 7).

Example: River (Sava) is part of River (Sava) and relationship is reflexive.

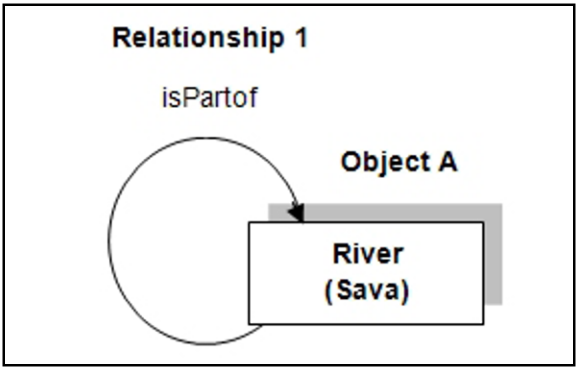

Figure 7: An example of the Reflexive relationship.

5.1.7 Irreflexive relationship

Irreflexive relationship is defined if object A can never have this relationship to itself (see Figure 8).

Example: River (*Sava*) cannot be smaller than River (*Sava*) and relationship is irreflexive.

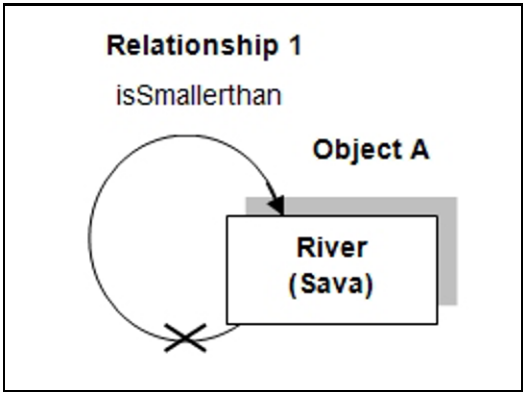

Figure 8: An example of the Irreflexive relationship.

Between ontology domain elements could be developed big number of relationships. But, there should be made balance between complexity of domain and functionality. Because too complicated ontology could lead to complex database querying. Unfortunately, standardisation on this point is still not adecquatly developed. New ISO new work item proposal on ontology should standardize relationships.

6- UNGEGN World geographical names database

UNGEGN World Geographical Names Database contains basic geographic names for each UN member country. It is multilingual, multiscriptual georeferenced geographical names database. It contains the names of the countries in the short and formal form, main and major cities (population over 100,000) in the national language and six official UN languages. It also contains language and sound files with pronunciation of major cities. The user interface has been published on the Internet address http://unstats.un.org/unsd/geoinfo.

UNGEGN World geographic names system did not introduced ontological approach. Here is made reconstruction of hierarchy relations of conceptual model is given on the figure 9.

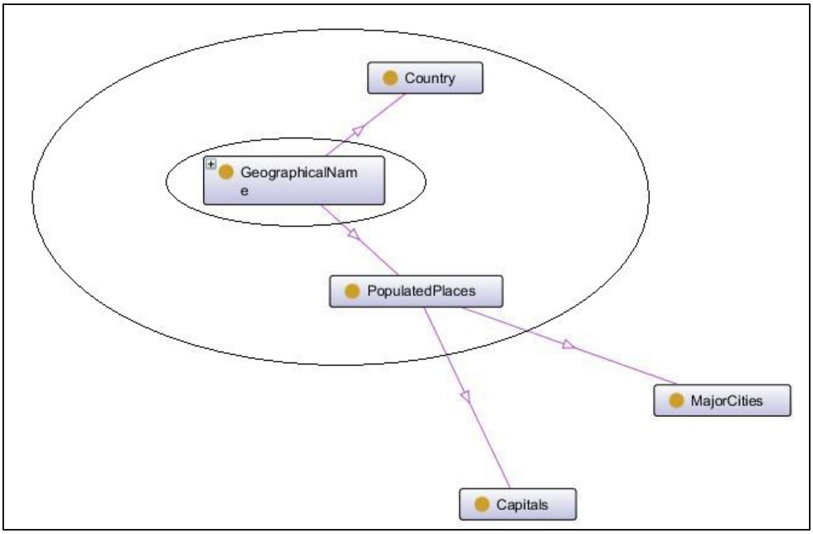

Figure 9: Hierarchy of the ontology concepts of the UNGEGN World Geographical Names database features.

Hierarchical relationship in ontology is only one of many relationships that can be included in ontology. Basically, it is giving answer on the question “Is subclass a kind of class?” or subclass relationships.

Hierarchical relations are important in conceptual model, but they are not the only one. Because of that ontology can become unmanageable considering size and complexity. Relationships have influence on simplicity of queries. Simple relationships are requesting simpler queries, and that is one more argument to make relationships as simple as possible. To avoid these ontologies could be spitted into modules. Each module of ontology is describing part of the total domain.

7- Inspiere and eurogeonames

EuroGeoNames has defined infrastructure for geographical names in Europe. It is developed as one of the fundaments of the INSPIRE. EuroGeoNames and INSPIRE are treating geographical names in formalized, well defined and structured way. It is treating geographical names as separate data set in context of other INSPIRE data sets. EuroGeoNames and INSPIRE do not consider ontology of place names. It would provide basis for web of data. They are defining geographical names in the context of EU Regulations and ISO specification. EuroGeoNames is defining system on the level of object oriented semantics (UML schema). It is regular way of developing data in the INSPIRE system.

EGN global ontological domain is not explicitly defined in EGN documentation, but it can be taken out trough essential EGN data and required/mandatory (and optional) content of EGN Local Services. EGN gazetteer is understood as a list of geographical names, postal codes or street addresses (EGN 2009). EGN domain for ontology can be reconstructed using essential gazetteer and EuroGeoNames system entries: names, feature types and geographical „footprints", and content of EGN Local Services. Required/mandatory and optional content of EGN Local Services are:

- Required/mandatory content: name, variant name, short name, different languages, language, extent, position, coordinate referent system, date of creation, feature classification according to the EGN feature classification, local feature classification, organization(s) responsible, he date of last modification of any of the stored properties of the name, the status of the name and the unique identifier of the associated spatial object/feature,
- Optional content: the historical start/end dates of a name, the pronunciation of the name (IPAs and/or audio-files), the data source, the local status of the name, the national unique IDs (name- or feature-related), the grammatical number of the name, the gender of the name, the script

used for the spelling, the transliteration scheme used, the complex geometry of the spatial object / feature (lines, polygons).

In this work is EuroGeoNames ontology concept domain defined using two hierarchical levels. Eight classes on the first level are further granulated (see Figure 10).

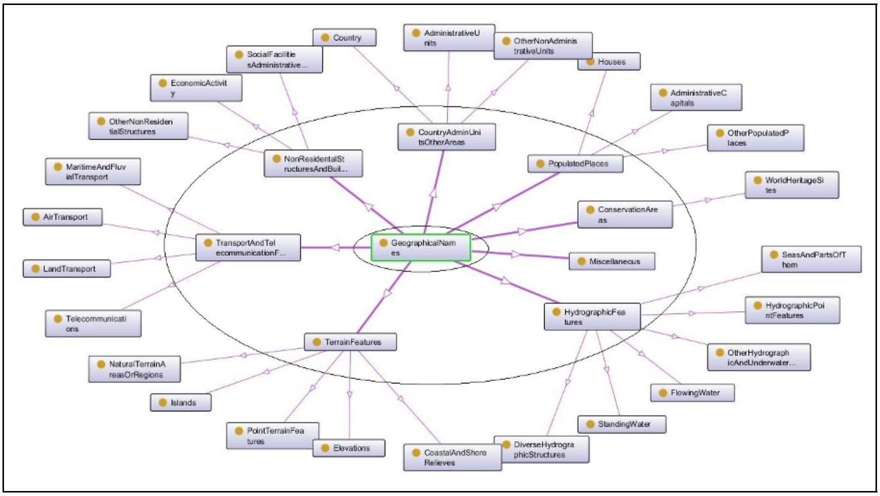

Figure 10: Hierarchy of the ontologies concepts of EGN features.

Each named place can be associated with one or several geographical names. It could be the names in different languages or in different forms. Each geographical name can be properly written in one or several scripts (Latin/Roman, Greek, Cyrillic, etc.). Because nature of place names, there ontological relations could be complicated and complex. Ontology model should be kept as simple as possible to not lose overview of ontological objects and relations. Too complicated ontologies could be spited in more ontologies.

8- Hierarchy of croatian place name concept ontologies

Comparing UNGEGN, EGN and Croatian place names feature catalogs, Croatian feature catalog is using more features. Because ontology domain element are feature, in Croatian case ontology domain will have more elements than UNGEGN and EuroGeoNames case. On the figure 11 is a hierarchy relationship of the ontologies concepts of topographic features given. Topographic features are matching scale of about 1:200 000. It is, for example, defining "County center is kind of town, and town is kind of Settlements".

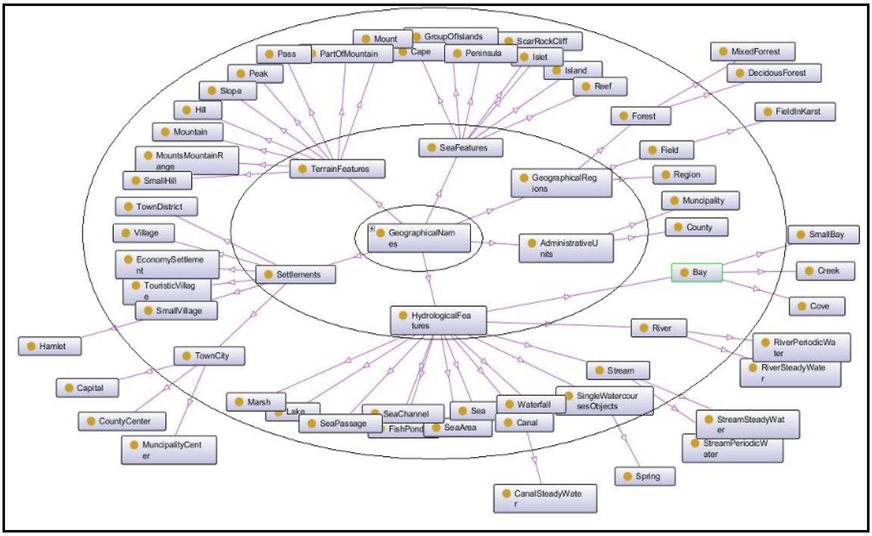

FIgure. 11: Hierarchy of the ontologies concepts of topographic features.

Ontological approach of place names in Croatia are used in the moment as new approach of building place names data model and publish them to the web. Using open source programs is place names ontology domain defined using topographic feature as domain elements. After domain elements and relationships between them are defined, direct output in web of data languages code could be made.

The comparison of EuroGeoNames, UNGEGN and Croatian domain ontologies could not be made completely because it could not be reconstructed all relations between features defined in each of the system. Here are presented ontological hierarchical relations between topographic features for each of the system as one of relations among ontology domain elements. Comparing them could be recognized more hierarchical levels and more complicated connections between features and database model.

9- Conclusion and future plans

Ontology and Semantic Web are giving opportunity to make interoperable different sources of data on the Web. Different communities can share the data. That is important for complex object as place name that involve more disciplines in its definition. Ontological approach can improve interoperability between communities. One of the main advantages of ontological approach is scalability in the sense of expanding existing ontology by additional concepts and joining other ontologies in the existing ontology domain. In that way new community groups can enter their knowledge base in existing ontology domain. Ontological approach is not used in UNGEGN and INSPIRES treatment of place names, but it could contribute to development o place names standardization. Ontological approach could allow publishing of data directly on the web. They would not be dependent of application and easily integrated in spatial data infrastructure.Development of new ISO/TC 211 Geographic information/Geomatics ontology standards will influence standardization of place names and other standardization topics. Ontological approach is giving new basic for development of Spatial Data Infrastructure (SDI).

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Standardization of geographical Names in Croatia

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Abstract

In the article is given overview of processes of standardization of geographical names in Croatia. Standardization of geographical names depends on global and regional standardization processes. Activities of Croatia in the United Nations Group of Experts on Geographical Names (UNGEGN), world umbrella geographical names standardization body, are described. Croatian Geodetic Institute (CGI) in cooperation with State Geodetic Administration (SGA) is caring activities in UNGEGN. Gazetteer of Croatia is produced, and Gazetteer service is published on the Internet. Croatia joined a EuroGeoNames (EGN) system of European geographical names infrastructure. EGN is regional process of standardization geographical names. It is a part of the European spatial data infrastructure (INSPIRE). Croatian part o EGN system is developed by the Croatian Geodetic Institute. Standardization of the geographical names on the national level is defined trough National Spatial Data Infrastructure. Croatia introduced new map grids in a new projection terrestrial reference system. Names are assigned to the new map sheets. Developed Croatian geographical names database is one of the first elements of the Croatian National Spatial Data Infrastructure.

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1- Background and objectives

Geographical names are assigned to features (objects) to articulate the space around us, to determine position and orientation in space and to serve as basis in communication. Geographical names have been developing during the centuries. Their consistent use is basis for efficient communication and socio-economic development. Because of development during the centuries, geographical names reflect historical and cultural development of each area, and they are part of the cultural heritage. Geographical names are defining not only features, but also individuals, groups and nations. Everyday communication, rescue operations, urban planning, documents related to space, spatial relations and other everyday activities contain information about space. Geographical names are one of the most widely used tools in recognition of the place and orientation in space. For example, if on the Baška Slab, a first written document with Croatian name on Croatian language as proof about King Zvonimir's gift of the parcel to the St. Lucy church on the island Krk in the year around 1100, did not write geographical names (Krbava, Lika, Vinodol, ...), it would be very hard or even impossible to identify persons, spatial relations and link them with events.

The importance of geographical names, their recording and standardization are recognized by United Nations (UN). For the purpose of standardization of geographical names on maps, UN founded *United Nations Group of Experts on Geographical Names (UNGEGN)* as a permanent expert body for standardization of the geographical names.

Standardization of geographical names is defined by UN Resolutions (UN 2009a, 2009b) as activity aiming at the maximum possible uniformity in the form of geographical name by means of national standardization and/or international agreement, including the achievement of equivalences between different writing systems.

European Union (EU) developed EuroGeoNames (EGN) as system of European geographical names infrastructure. It is a part of the European spatial data infrastructure (INSPIRE) and regional process of standardization geographical names. European system of geographical names infrastructure (EuroGeoNames) is one of the first steps in creation of INSPIRE. It is defining geographical names in the interrelations with other basic sets of data. INSPIRE has 34 themes of data divided in three annexes. Geographical names as data set have important role in INSPIRE. They are part of INSPIRE Annex I themes: coordinate reference systems, administrative units, transport networks, cadastral parcels, hydrography and geographical names.

Standardization is complex process giving economical and practical benefits (Hećimović at al. 2009a). Geographical names are getting more and more important and special attention is devoted to them. Because of that, geographical names are one of the main parts of global, regional and national spatial data infrastructure. It is defined by UNGEGN, *Infrastructure for Spatial Information in the European Community (INSPIRE)* and *National Spatial Data Infrastructure (NSDI) of the Republic of Croatia*. The main documents of UNGEGN, INSPIRE and NSDI that are defining geographic names as part of spatial infrastructure are:

- *UN Resolutions*,
- *Infrastructure for Spatial Information in Europe Directive of* the European Parliament is defining geographical names as part of obligatory spatial data infrastructure,
- *The law on state survey and the real property* cadastre of the Croatian Parliament (Official Gazette 2007) is defining national spatial data infrastructure (SDI) of the Republic of Croatia.

State Geodetic Administration (SGA) is after *The law on state survey and the real property cadastre* responsible for founding and guiding Gazetteer. It is responsible for publishing official topographic maps, guiding cadastre and Register of spatial units of the Republic of Croatia (Official Gazette 2000), and Croatian Hydrographic Institute is responsible for publishing sea maps. These are the main sources of the official toponyms in Croatia.

UNGEGN as global and INSPIRE as regional European body are influencing standardization of geographical names on global, regional, national and local level. There are small differences in fundamental toponym/geographical names definitions between UNGEGN and

INSPIRE. Place name or toponym is defined by United Nations Group of Experts on Geographical Names (UNGEGN) as proper noun applied to a portion of the surface of the Earth or of any other planet or satellite that has recognizable identity (Kadmon 2002). INSPIRE is defining geographical name as proper noun applied to real world entities (INSPIRE 2009). If we limit our observations on the Earth (e.g. geographical names), as INSPIRE is doing, the fundamental difference is that UNGEGN is defining named place as the portion of the surface of Earth that has recognizable identity, and INSPIRE is defining named place as real world entity. These differences can cause different interpretations of formal representation of named places in a universe of discourse and difference in definition of conceptual model.

2- United nations group of experts on geographical names

Because inconsistency of geographical names on topographic maps, United Nations (UN) recognized importance of standardization of geographical names soon after UN was founded after the 2nd World war. UN established *United Nations Group of Experts on Geographical Names (UNGEGN)* as one of seven permanent expert's body of the *United Nations Economic and Social Council (ECOSOC)* (UNGEGN 2010). One of the main goals of the UNGEGN is to stimulate national and international standardization of geographical names, supporting national standardization efforts, promotion of national standardization efforts and adoption of unique writing system. UNGEGN is supporting national standardizations of the geographical names trough national boards for standardization of the geographical names and by recognizing administrative processes. Croatia is member of the *East Central and South-East Europe Division* (ECSEED) of the UNGEGN (see Fig. 1). UNGEGN is global body and it is divided in 23 linguistic/geographic Divisions. Function of the Divisions is to join experts with similar linguistic/geographic backgrounds and in that way to go deeply in the problem of standardization of geographical names.

Figure 1: Countries members of the ECSEED.

Croatia is chairing East Central and South-East Europe Division (ECSEED) of the UNGEGN since Ninth United Nations Conference on the Standardization of Geographical Names in 2007. State Geodetic Administration and Croatian Geodetic Institute are institutions responsible ECSEED chairing. More about ECSEED activities could be found on the ECSEED Division web site (http://ungegn.cgi.hr).

3- Ungegn world geographical names database

UNGEGN World Geographical Names database contains basic geographic names for each UN member country. It is multilingual, multiscriptual geo-referenced geographical names database. The user interface has been published on the Internet address http://unstats.un.org/unsd/geoinfo. It contains the names of the countries in the short and formal form, names of the main and major cities (population over 100 000) in the national and six official UN languages. It also contains language and sound files with pronunciation of major cities. State Geodetic Administration and Croatian Geodetic Institute takes care of the Croatian data in the UNGEGN World Geographical Names Database.

4- Eurogeonames european infrastructure of geographical names

EuroGeoNames (EGN) is a system of European geographical names infrastructure (EDINA 2007). It was developed through the eContentPlus project funded by the European Union (EU). The project was developed by a consortium led by the German Bundesamt für Kartographie und Geodäsie (BKG) (Zaccheddu and Afflerbach 2008). Today is EuroGeoNames system under the EuroGraphics jurisdiction and BKG is operationally responsible for the maintenance and development. EuroGeoNames system is a part of INSPIRE development trough European Spatial Data Infrastructure (ESDIN) project. It is realization of the INSPIRE Directive. European Spatial Data Infrastructure (ESDIN) is based on the National Spatial Data Infrastructures in the member states. It is EU eContentPlus project that has mission to harmonize and maintain pan-European data for some of the INSPIRE Annex I themes: coordinate reference systems, administrative units, transport networks, cadastral parcels, hydrography and geographical names.

EGN is providing harmonized access to a multilingual pan-European data infrastructure for the citizen, governance and value-added services. It supports all officially recognized minority languages.

EuroGeoNames and INSPIRE are treating geographical names in well structured way. It is treating geographical names as separate data set in context with other INSPIRE data sets. INSPIRE is defining geographical names in the context of EU Regulations and ISO specification. EuroGeoNames is defining conceptual model on the level of object oriented semantics (UML schema). It is way of developing data in the INSPIRE system.

In the EGN system is included thirteen countries (see Fig. 2). Croatia was not part of eContentPlus EU project that developed EuroGeoNames (Ormeling 2009). During development of Croatian part of EGN, assistance was given from developers. Croatian Geodetic Institute has developed Croatian national EGN system and incorporated the Croatia in to the EuroGeoNames system. EuroGeoNames web service can be called from website http://www.eurogeonames.com/refappl (Knibbe 2009). Croatian interface should be called by selecting the language at the top right corner of this web site. Croatian database of geographical names is located on the Croatian Geodetic Institute.

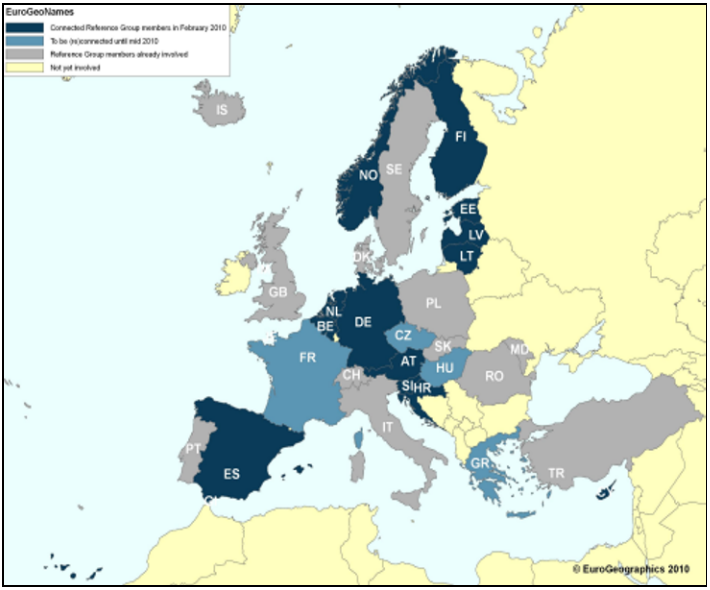

Figure 2: EuroGeoNames countries.

EuroGeoNames is still not an official product of the EuroGraphics, such as EuroRegionalMap, EuroGlobalMap and EuroBoundaryMap. Join meetings of *East Central and South-East Europe Division (ECSEED), Working Group of Toponymic data files and Gazetteers (TDFG WG) of the UNGEGN* and *EuroGeographics-EurogeoNames workshop (EGN)* will be held from 9th to 11th February 2011 in Zagreb. State Geodetic Administration and the Croatian Geodetic Institute are institutional organizers of the meetings. The meeting should contribute to the faster development of EuroGeoNames in to the official system/product of the EuroGraphics. More about the joint meetings can be found on official web site of the meetings http://ungegn.cgi.hr/ungegn20/session20.html.

5- Register of the names of the new official maps sheets of the Replublic of Croatia

For new Croatian map grids in the new Croatian projection terrestrial referent system (HTRS96/TM) the new nomenclature is assigned to each map sheet. Nomenclature contains name of the sheet. The map sheet name is used to make easier orientation of the map sheet in the space using the name of the well known geographic objects (features), which is on the map sheet. To choose the most appropriate name for the map sheet, criteria of judging candidate toponyms are defined (Croatian Geodetic Institute 2008a, Hećimović and Štefan 2009). Compared are toponym and feature elements as: importance of the geographical feature, usage of the similar toponym, number of inhabitants for oikonyms, usage of toponym as the name in old map sheets, etc.

The names are assigned to the new maps sheet in the scales 1:250 000, 1:100 000, 1:50 000, 1:25 000, 1:10 000 and 1:5 000 which covers the Croatian territory (Croatian Geodetic Institute 2008b). Names are not assigned to map sheets of bigger, cadastral scales (e.g. 1:2000, 1:1 000 and 1:500) because in big scales are dominating micro toponyms, and it is hard to find publicly well known toponym. Endonym of the dominant object that is appearing on map sheet is assigned. Names have been independently determined in the scales: 1:250 000, 1:100 000, 1:50 000 and 1:25 000; e.g. independently are determined: toponym-250K, toponym-100K, toponym-50K and toponym-25K. Because hierarchical structure of nomenclatures map sheets names in the scales 1:10 000 and 1:5 000 are used from the map sheets in the scales 1:50 000 or 1:25 000 in which the map sheet is hierarchical layer.

The best-known geographic features are oikonyms (names of settlements). They are therefore commonly used by naming map sheets. However, when there is no any populated place (oikonym) on the map sheet or other toponyms are dominant on the map sheet (e.g. mareonyms (names of features connected to seas), oronyms (names of higher features, as muntains), regionyms (names of regional features) etc.) this rule was not followed. Table 1 gives an overview of the names of maps with respect to the feature (object) and scales. Oikonym is the most dominant class. Croatia has relatively long coast and because costal topographical relations mareonyms are also used as map sheet names in all scales. Oronyms and regionyms are mostly used in scale 25k because some Croatian regions are not densely populated and there is no settlements (oikonyms). Two hydronyms are used in the scale 25k. It is more exception because they are near border with other countries, and the name of the map sheet should be name of the topographical feature on the territory of Croatia.

Feature (object)	Scale			
	250k	100k	50k	25k
oikonym	12	52	159	512
mareonym	1	4	13	38
oronym	1	0	1	13
regionym	1	0	2	10
hydronym	0	0	0	2

Table 1: Summary of the map scales names with respect to the feature (object) classes and the scales

New map grids with nomenclatures can be found on the Internet address http://listovi.cgi.hr/. On the site are new map grids described in details (Hećimović and Bakalbašić 2009, Hećimović et al. 2009b, Hećimović and Jakir 2009).

6- Gazetteer of the Republic of Croatia

According to the United Nations Group of Experts on Geographical Names the gazetteer is a list of toponyms arranged by alphabetical order or another principle with information about their location, feature and possibly their variant name, and contains other information. Gazetteer contains reference data used with the maps. However, geographical names are not only part of the map. They are an important communication tool that reflects the historical and cultural development of an area. Gazetteer contains endonyms. It standardizes geographical names in official documents, registers, cadastre, encyclopedias, atlases, on radio, television, newspapers and other media. It collects, records, processes and publishes geographical names. The first database of the register of geographical names on the CGI was made in the year 2004 (Croatian Geodetic Institute 2004).

The Gazetteer is continuously updated with new names of the larger scale. In the moment Gazetteer includes geographical names of Croatian territory that match the scale 1:200 000. The Gazetteer contains all names of: counties, cities/municipalities, settlements, cultural heritage of Croatia under UNESCO protection, airports, national parks, nature parks, other protected natural objects (features), new official map sheets names in the scales 250k, 100k, 50k and 25k, the names used in the EuroRegionalMap, EuroGlobalMap v.3.0, etc. Although there are no official registers, the names of all islands, rivers, lakes, mountains, peaks and other dominant geographic objects (features) in accordance with the scale are introduced. Table 2 gives an overview of the named features in the main feature group.

Each Gazetteer record contains: a record number of geographical names sorted alphabetically, the name of geographic objects (features), the administrative area of the geographical feature (object), E East and N North coordinates in new Croatian projection terrestrial reference system (HTRS96/TM), the classification of geographic objects (features) and the geographic objects (features) code (Štefan et al. 2009).

Group	Nr.
Geographical units	169
Landforms	940
Water, land and sea	745
Islands, peninsulas, islets and reefs	682
Buildings and other facilities	51
Areas	606
Populated place	7649
Transportation network	9

Table 2:. Named features in the main feature group

Group populated place is the most dominant in the Gazetteer. It has subclasses: town, city, capital, county center, municipality, settlement, village, touristic village, economy settlement, etc. The next feature group the mostly used in map sheet naming are: landforms, waters, islands, peninsulas, islets and reefs and areas. The number of named places in each feature class depends on geomorphology of the country, scale and feature density.

7- Croatian gazetteer internet service

Croatian geographic names information system is developed in accordance with international (UNGEGN, EuroGeoNames and INSPIRE) and the National Spatial Data Infrastructure (NSDI). Croatian Geodetic Institute has published Gazetteer web service on the Internet address http://cgnd.cgi.hr:8081 (see Fig. 3). The Gazetteer contains endonyms. In the moment, Gazetteer data are based on topographic map of the scale 1:200 000 and other sources. Proportional to the scale is also catalog of geographical features (objects). The service provides search of geographical names on the Croatian territory by name or part of the name, according to the classification of geographic objects and spatial search by counties. Name querying is not case insensitive (e.g. query for „Knin" or „kNiN" or „knin" are giving the same results). As additional option „identical" or „contain" type of query could be chosen. Identical querying will give results with identical geographical names, and „contain" will give geographical name that contain requested text. Spatial querying after counties is giving opportunity to search for names only in selected counties. Visualization of a name could be made choosing Google Map background (see Figure 4) (Jakir and Hećimović 2009). Service enables to report on or off-line correction of the name or name attributes. Service is also enabling to make on or off-line proposal of the new geographical name.

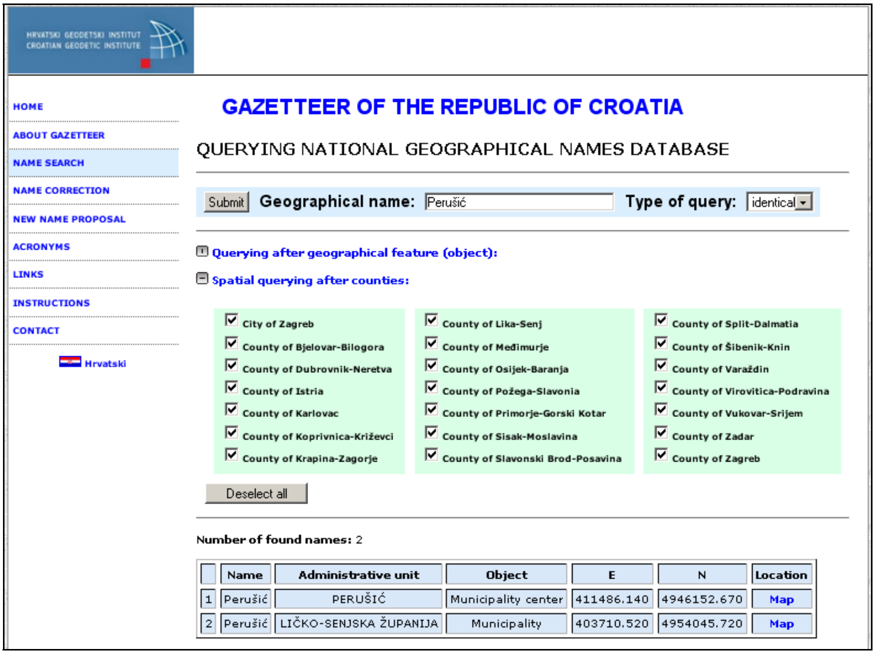

Figure 3: Croatian Gazetteer users Internet interface.

To easily locate name in space to each geographical name is assigned administrative unit. Administrative unit can be: Republic of Croatia, county or town/municipality. The first two classes are given explicitly (Republic of Croatia and county), and other administrative units are towns/municipalities. Administrative unit of Republic of Croatia is assigned to dominant national objects lying in two or more counties (for example Adriatic sea, river Sava, mountain Velebit, etc.), and county is assigned to objects spreading through two or more towns/municipalities. But, if some small object spreads trough two or more towns/municipalities (e.g. small river in the border area of two municipalities) this rule was not followed. In these cases to administrative unit is assigned municipality in wich geographical object is more dominant.

Mapping between Croatian and EuroGeoNames feature systems is made and for the queried name is given feature classification after EuroGeoNames system in ten languages: English, German, French, Italian, Spanish, Dutch, Hungarian, Slovenian, Slovakian and Czech.

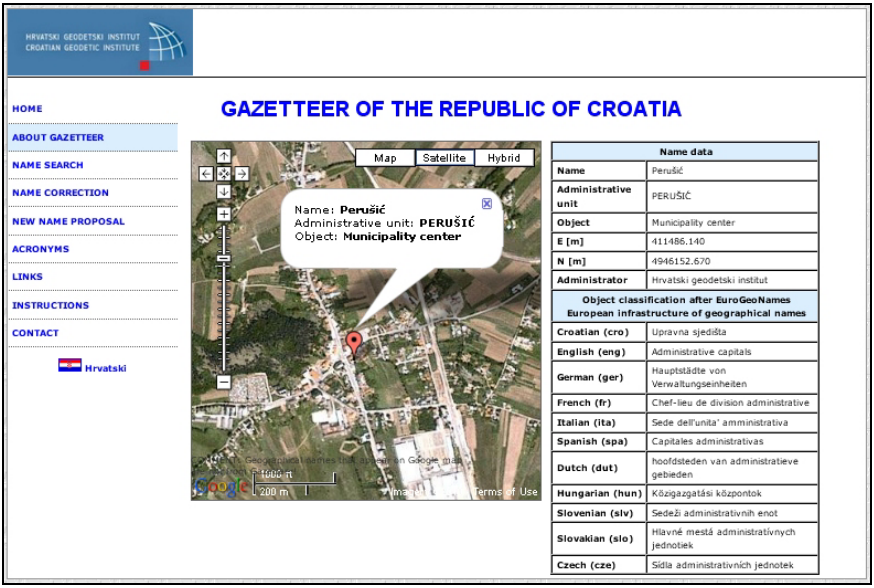

Figure 4: Name visualization in the Croatian Gazetteer users Internet service.

The gazetteer, database and services are continuously developed. This internet service is one of the part of the national spatial data infrastructure.

On the Internet pages of the United Nations Statistics Division http://unstats.un.org/unsd/geoinfo/country_links/map.htm is published link to the Croatian Gazetteer service.

8- Conclusions

Because of the activities in UNGEGN, the umbrella organization for the standardization of geographical names, Croatia has become a recognized country in the field of standardization of geographical names. Joining the EuroGeoNames, European geographical names infrastructure, one of the breakthroughs of the Croatia in to the INSPIRE, the system of the European spatial data infrastructure that is obligatory for EU countries is made.

Creating the Register of the names for the new map sheets and publishing Web pages of new map grids http://listovi.cgi.hr, Croatian Geodetic

Institute has contributed in resolving problems related to the process of adopting new geodetic datum and map projections in the Republic of Croatia. Creating a Gazetteer of the Republic of Croatia the Croatian Geodetic Institute has developed one of the basic documents of the national standardization of geographical names. Publishing web services of the Gazetteer one more Internet service that complements Croatia as information society is developed.

Activities at the international and national level in the field of standardization of geographical names are defining platform for further development in this area in Croatia and the basis for the integration of the Croatia in international systems in the field of standardization of geographical names and spatial data infrastructure.

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Location and Cartographic Integration for Multi-Providers Location Based Services

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Abstract

Since the development of Geographic Information Systems (GIS) and the increasing popularity of mobile devices, many standardization bodies such as OGC (Open Geospatial Consortium) had proposed the implementation of Location Based Services (LBS) applications. Furthermore, map service providers started to use the correspondent devices for visualizing geographic data essentially based on the users' location, his contextual information and his profile. However, many geographic databases (GDBs) could offer slightly different data/metadata for the same requested service. Advanced LBS have to improve interoperability among them. In this paper, we had elaborated many reasoning algorithms and build/match extended geo-ontology framework for the integration of homologous objects on mobile devices. Our approach is illustrated by a tourism LBS case study and could be applied for any geographic domain where position, place name, semantic details and visual aspects' (icon, texture, color, etc.) ambiguities will be integrated automatically through our platform.

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1- Introduction

Nowadays, the co-existence of many and heterogeneous geographic databases covering the same area, implies to study how these data/metadata should be integrated in order to avoid duplicated results on the screen. Interoperability is the key aspect to elaborate in such situation. It is defined by OGC as the “capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units” (OpenGIS, 1996).

At the application level, a motivating example, as shown in the figure1 below, had inspired us to direct our study towards a major problem which is related to location and cartographic integration of same geo-located service from many providers. Let us consider a user’s request to find the nearest restaurant in his area. First of all, he might encounter the answer of an American restaurant listed by two different providers, not exactly located at the same place (50 meters of difference). The same restaurant is named “the Roadster Diner” in the first one and “Roadster” in the second one, with few differences in their semantic details and represented differently as cartographic symbols (icons) on different proprietary base maps. This inconsistency in spatial and non-spatial information from both providers is a fact and we must know how to deal with it in order to visualize both as the same integrated object.

Figure 1: Example of the same LBS restaurant from two providers (candidates for integration)

In order to solve most of the problems related to the use case scenario listed above, we propose a fully interoperable system with the following components:

- Subsystem for Location Integration: using specified algorithms for geographic and place names' integration such as Euclidian and Levenshtein distances and a semantic ontology reasoner via Protégé for their semantic details integration.
- Subsystem for Cartographic Integration: using a new type of geo-ontology, named CartOntology, for formalizing explicit knowledge about our domain of interest (touristic points of interests POI) and adjusting the map conflation, semantically and visually, based on the user profile's ontology, his geographic zone or context information and the graphical semiology constraints.

This paper is structured as follows: Section 2 provides a description of the problems being raised from the use case scenario. Section 3 presents an overview of the related works. In Section 4, we discuss and evaluate our contribution. Section 5 details all the implemented solutions for location and cartographic integrations. Section 6 concludes the work with some perspectives.

2- Our Case Study-Limitations

When a person is moving in an unknown area and making a search, only maps can provide desired information in a precise and concise way. Google Maps, Bing, Via Michelin, Mappy, OpenStreet-Map, and many others are cartographic publishers trying to visualize the geographic information on 2D/3D base-maps. However, most of them are still retrieving data from one single GDB. What if this GDB is not updating its information very often (Google street view case) or had been hacked and many details were changed? Collecting information from many GDBs is trustworthy and more accurate if we know already how to deal with some inconsistencies between homologous objects, candidates for integration.

The scope of our work is to ensure location and cartographic integrations for LBS information supplied by many providers. In other words, homologous objects should be integrated to avoid duplicated icons on the mobile screen. Some deficiencies might be encountered as detailed in (Karam et al. 2010) which are related to 1) the lack of real time updates in GDBs for place names and semantic details, 2) GPS precision and different reference systems for geographic positions and 3) proprietary base maps and different legends for each service provider.

3- Related Works

Currently, we can find visual portals listing services from many providers in alphabetical order or according to user's preferences (Laurini et al. 2008). This interface is not user-friendly if we have a long list of services to scroll down. Another visualization is to represent services by shapes and the correspondent providers by their colors but we are limited to maximum ten colors for better perception thus ten providers. Another approach is based on a 3D perspective street view map where the services are listed as place names with arrows. Overlap of place names in 3D and cognitive difficulties had lead to the usage of icons instead of place names with info window to show their semantic details.

On the other hand, ontology engineering is considered as providing solutions to semantically integrate several data sources. From Artificial Intelligence to Semantic Web, conventional ontologies are defined as a collection of concepts C, Instances I, Properties P, Axioms A and relations defined on these concepts to represent the knowledge in a certain domain of interest and provide reasoning and inference mechanisms (James et al. 2010). Medellin, Serna, Vargas and Ruiz in (Medellin et al. 2009) had mentioned how the use of ontologies offers some advantages for the integration of geographic information on the web. Fonseca, Camara and Monteiro in (Fonseca et al. 2006) had considered that if the use of ontologies is part of geographic information system (ODGIS, Ontology-Driven GIS), it can present multiple interpretations or roles of a same geographic feature (e.g. lake for the department of water is different in meaning as for the environment scientist or a tourism department). ODGIS acts as a system integrator of the model with many levels (top level ontology/domain, task ontologies then application ontology). We can use ODGIS framework to interpret images or icons with other kind of geographic information in a smooth and flexible way.

In order to facilitate the user creation and edition of ontologies, tools like Protégé[1] or G-Match had appeared for building and/or merging ontologies towards a domain reference one.

Many researchers had discussed the state of the art of conventional ontologies and geographic ones including tourism and made comparisons about the available tools for building and/or matching and aligning ontologies. Besides, Spatial Ontology Community of Practice (SOCoP[2]) provides a good forum for exposing and coordinating geospatial ontologies.

However, due to the limitation in paper size, the related works for geo-ontologies will not be detailed in this article.

We will just focus on the novelty in this domain that could be used for our purpose.

Furthermore, we want to present what OGC had implemented as standards for generating maps:

- According to OGC specification, a Web Feature Service (WFS) provides an interface allowing requests for geographic features across the web using platform-independent calls. The response for a "Get Capabilities" request returns capabilities such as: name, title, longitude/latitude, etc. WFS rely on Geographic Markup Language (GML), in order to insure interoperability, but does not allow alone for semantic interoperability, thus the need for semantic integration ontology behind.
- The Web Map Service (WMS) is a standard protocol for serving geo referenced map images over the Internet that are generated by a map server using data from a GIS database. It produces maps as image or SVG (Scalable Vector Graphic). Individual maps can be requested from different servers and accurately overlaid to produce a composite map via WIS (Web Integrator Service) but this type of integration will keep the copyright and other built in proprietary visual aspects of each provider's map (e.g. legend, source, scale, etc.).

[1] http://protege.stanford.edu/

[2] http://www.socop.org/

- Another OGC standard XML-based known as Symbology Encoding (SE) gives several cartographers the ability to share the cartographic description of a map layer. An expert will predefine symbologies to be shared on a map layer and pushed them as features in WFS. With OGC tools, the cartographer can export the result of his work as XML based files which have the capacity to construct several types of maps. As example of symbolizer elements which specifies how to draw the symbol, we can cite: area, point, line, polygon, text, raster. For encoding complex line styles, colored fills, text labels, etc. (Tenet 2008) so we can easily generate adequate map-legends according to symbology encoding descriptions (feature type styles and coverage styles). What is just needed for OGC is to work on a better alignment with ISO 19117 at this level

4- Discussion and Implemented Solutions

After this overview, we can discuss and evaluate better our main contribution in this research area.

First of all, we decided to visualize location based services on desktop and mobile screens by contacting many service providers. In our platform, we supposed that the geographic objects are points (0D).

To ensure that two objects for the same location based service, listed by two different providers, are candidates for integration and should be visualized once, different solutions at different levels were selected and adopted:

4.1 Section 1: Main Contribution for Location Integration

4.1.1 At the geographic integration level, to decide whether two punctual objects are the same and need to be integrated, the Euclidian distance dE is used. So as far as the distance between object 1 and object 2 is less than a threshold of 5 m for example, we can then suggest that these objects are homologous. However, the choice of the threshold is very important. More details were mentioned in (Karam et al. 2010).

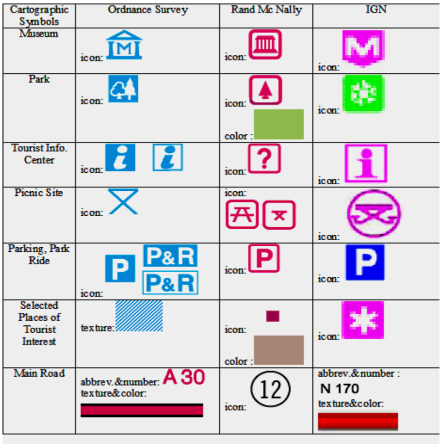
4.1.2 For the place names' integration, the fusion technique uses the Levenshtein distance to compare the place names (String of characters) of two objects from two different providers (Karam et al. 2010).

4.1.3 Semantic integration between these two objects is related to their metadata/data differences (e.g. phone, email, website, etc.). To avoid duplication of the service details from two different providers, Levenshtein distance algorithm had been used to check for homologous information and the agreed results were deducted from a matching table in our framework MPLoM (Multi Providers LBS on Mobile devices). A semantic ontology-driven approach could be implemented via Protégé as a second more intelligent solution using inference reasoning. For example, if a pedestrian wants to know what restaurants can offer "Hamburger", the platform should list all the restaurants of type American or Fast food.

4.1.4 We can assume that difficulties in location integration had been partially solved by the above solutions. The final decision for homologous objects depends on the output result of the belief function with Dempster operator. Geographic positions, place names and semantic details results are assigned each one a certain weight, reflecting the degree of candidates' homogeneity towards integration. Dempster operator will combine the three different weights and as far as their sum is high, the probability to consider both (Karam et al. 2010).

4.2 Section 2: Main Contribution for Cartographic Integration

Once the integration problems were solved at the information level, we will consider the integration at the cartographic visual level. One should be able to visualize on the screen a unique base map whose components are retrieved from the various providers contrary of what is shown in Fig. 2 and 3 below.



Cartographic Symbols	Ordnance Survey	Rand Mc Nally	IGN
Museum	icon:	icon:	icon:
Park	icon:	icon: color :	icon:
Tourist Info. Center	icon:	icon:	icon:
Picnic Site	icon:	icon:	icon:
Parking, Park Ride	P&R P&R icon:	icon:	icon:
Selected Places of Tourist Interest	texture:	icon: color :	icon:
Main Road	abbrev.&number: A 30 texture&color:	icon: 12	abbrev.&number : N 170 texture&color:

Figure 2: Excerpts of legends from three different providers: Ordnance Survey, Rand McNally and IGN

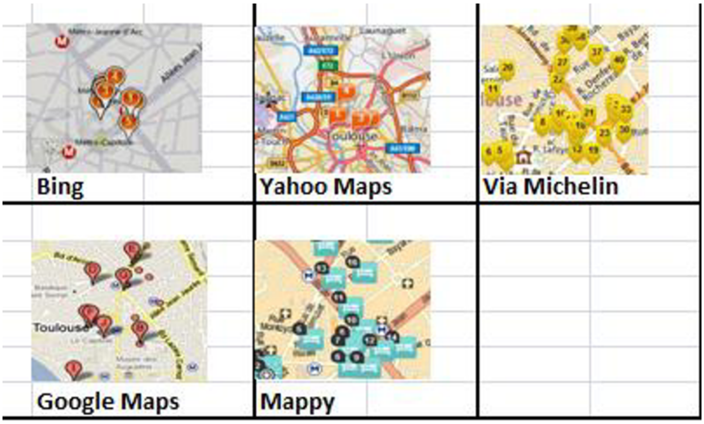


Figure 3: Hotels in Toulouse from different portrayal layouts

Two different scenarios could be implemented: Symbology Encoding or CartOntology with visual concepts. We had taken the challenge to propose and implement the second scenario.

4.2.1 Scenario 1: Applying Symbology Encoding Concept

From (Tenet 2008) and (Ertz et al. 2010) we can notice that we can build up the map context as below:

- Define one or more possible base layers
- Define one overlay for the track and one for way points
- Define a layer of point of interests (POI)
- Define the symbology of each layer by use of Symbology Encoding according eventually a set of predefined symbologies for points, lines, texts, areas, etc.
- Define initial map extent and spatial reference system
- Describe metainformation, layer name, date, author, source, orientation, legend, etc.

The XML SE file which is the dictionary collection of the POI visual attributes (icon, color, texture, number, label, etc) can be inserted as part of WFS file that includes via GML tags all the semantic details and geographic coordinates of the different POIs.

WMS will then visualize on the collected base maps, the mash ups of the POIs retrieved from WFS file with SE visual symbols. The author name, source, date, orientation, scale, legend, etc are inserted as modules on the base-map.

The drawback of this solution is that each base-map will include its own metadata and if we want to contact many providers, the integration of many base-maps via WMS will keep the copyrights for each map provider such as source, legend, date, etc. for marketing purpose. Besides, the symbology encoding XML file is defined manually by the admin-cartographer as reference and we can't accept the proprietary symbols of each provider. Otherwise, we must include a knowledge database to collect and match all the Symbology Encoding files from the different providers towards a domain global one. This knowledge database is a kind of geo-ontology for icon-based retrieval that we decided to implement it in our solution.

4.2.2 Scenario 2: Applying a new type of Ontology with visual concepts

From (Domingues et al. 2009), we can find that it is possible to develop a geo-ontology framework for color assignment to maps on demand. In order to develop automatically a map based on the graphical semiology rules, the users' preferences for colors and the outputs of the Chromatic

Circle (Chesneau, 2006) and Derain Algorithm (Derain, 1905), Domingues et al. had implemented ontology of colors for this purpose.

(James et al. 2010) had proposed directions for the application of ontology matching techniques to solve different interoperability issues in the area of image annotation and retrieval so we can replace ‘image’ with ‘icon or texture’ for example and test the feasibility of their framework. In the context of semantic image annotation, ImageNet and LSCOM are two examples of multimedia ontologies where the concepts are the nodes of the WordNet ontology and the instances are the images, or the visual attributes in our case, in the associated databases labeled by these concepts.

We can deduce that ontologies are convenient to represent visual knowledge or map legend but we should bridge the semantic gap problem between the semantic level and the visual level representations. This can be solved by 1) matching ontologies at the semantic level with ontologies at the visual level, and 2) matching multiple visual ontologies in order to extract a common visual model for linguistic descriptions of images or icons.

Besides, we can apply “variable selection techniques” in machine learning that can serve to rank the input variables (for example, the different icons for same POI service) by their importance for the output visualization, according to user’s evaluation criteria, his context/profile and other semiology constraints. Belief weights could be applied within OWL file (BeliefOWL) for each symbol to ensure ranking as well.

We decided then to develop a new type of geographic ontology framework to build and match semantic and visual aspects of the providers’ legends towards a domain reference one for LBS. Because we are dealing with ontologies, we will use the tags ‘properties’ of OWL (Web Ontology Language) standard to include the visual attributes of each POI concept such as his icon, color, texture, font, number, etc. instead of normal XML tags as per SE. Other interpretation was to extend OWL with a new tag called Symbol in order to code the visual aspects for each concept as detailed below. This later is implemented in the platform.

By respecting the proposed paradigm: “the visual ontology of concepts”, each provider shall have its own local ontology that should be populated via a Graphical user interface (GUI) implemented for this purpose. This is done by inserting manually their semantic and visual service attributes based on their legends, semantic concepts for the name of POIs and aside the visual aspects of the correspondent symbol.

As OWL can handle only textual concepts, it needs to be revised in order to describe visual aspects as well. (Karam et al. 2010) had well explained our scenario. A more invasive suggestion is to propose an extension of OWL standard; we named it CartOWL in order to describe in a dedicated and organized file all the visual concepts and their relationships of equivalence and inclusion.

Once the local ontologies corresponding to the LBS providers' cartographic visual concepts are generated, then the matching/alignment step should start.

The full prototype will be able to parse the CartOWL output files and align them towards one reference knowledge base (domain ontology) so that we can ensure map conflation results on mobile devices.

Belief function must be applied as well through CartOWL in order to achieve the best compromise between the domain ontology and other constraints that may interfere such as the user's profile (nationality, map preference, age, etc.), the context of his geographic zone, the graphical semiology rules and color contrasts v/s visibility, the device limitations and the need for generalization, adaptation and dynamic maps, etc. So, in order to prioritize visual attributes from one provider among others, highest weights will be assigned to them as per the belief theory in the CartOWL tags. Psycho-cognitive test for efficient icons-recognition, without legends, will help us to assign such degrees of preference or weight and prioritize an icon among many representing the same service.

Some screenshots of our building/matching prototype are shown below (Fig. 4):

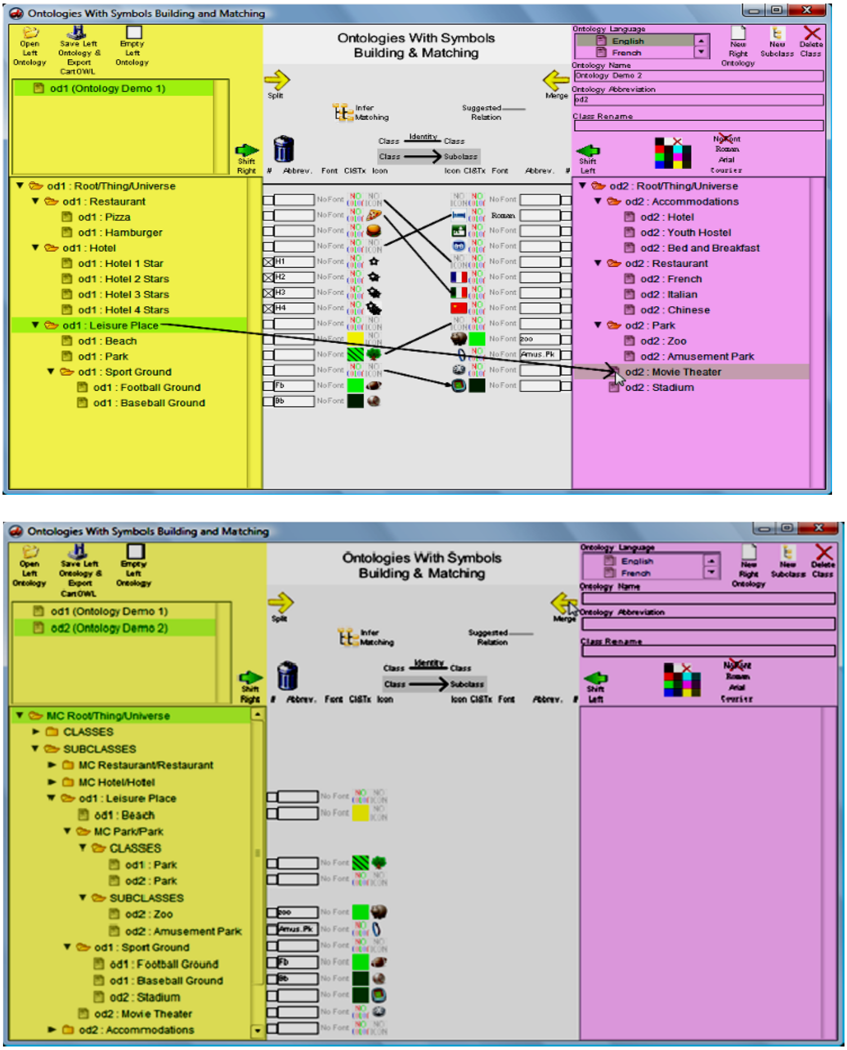


Figure 4: Building/Matching part of the application (focus on the “Leisure Place” class)

Finally, we had adopted this scenario comparing to the SE (Muller 2006) and OGC standards for the following reasons:

1. We don’t neglect the proprietary visual aspects and legends for each provider and his base map so that the provider, the administrator and the user can benefit from this work.

2. We don’t ask the provider to build his own XML file dictionary as for the SE standard. However, the administrator had been charged to do this manually by referring to his map legend only.
3. For scalability reasons, it is more efficient to go for a semi to automatic framework matcher. The administrator will then ask each provider to give him its OWL file of legend symbols easily built from a visualization interface such as Protégé.
4. Our Framework have the import/export tool for OWL files and can easily match the semantics at the concepts level then the visual aspects at instances or properties levels between two ontologies.
5. Our framework will align any new ontology with the resulted global one automatically.

The final OWL file named CartOWL will include all the referenced symbols as XML based (same idea as Symbology Encoding XML file). However, this file will be adjusted as well based on users’ profile ontology (age, nationality country, culture) for the choice of adequate icons/base map and the graphical semiology rules applied in the color ontology developed by (Domingues et al. 2009) for the choice of colors.

For the time being, building/matching these ontologies with visual aspects is done manually by a domain expert. However, we can develop automatic reasoner and extend Protégé or G-Match in order to include the visual attributes and do the matching semantically based on concepts-names matching algorithms (word by word, keyword, external thesaurus as WordNet[3], string distance matching, semantic Google distance etc) then collect the icons such as ImageNet[4] labeled by the same concept name and set a certain variable weight for each icon to prioritize our selection. This weight is corresponding to the result of a psycho-cognitive test distributed to users for best icon-recognition without legends.

The complete solution as proposed above should be validated by our MPLoM platform. Its main purpose is to test the feasibility of the location and map symbols’ integrations into a unique visual portal on mobile devices and desktop.

[3] http://wordnet.princeton.edu/
[4] http://www.image-net.org/

The phase 1 of MPLoM implementation covers the location integration from two different providers offering pull and push services.

The pull services which are the nearest hotels and restaurants are visualized on a 2D background Google map and the components are overlaid as Google markers(R for restaurants and H for hotels); the details for each clickable restaurant marker or hotel are presented textually on the mobile device. A user interface is created to get all the preferences of the clients (e.g. name, age, nationality, major, email, credit card, language, etc.) and save them into a middleware admin database. Thus, the client's request with all the needed parameters will be forwarded via Java servlet to the concerned tables in the providers' databases (Karam et al. 2010).

Both providers' databases are created in PostgreSQL with the PostGIS feature for spatial usage. Each user's request will be then subdivided into two sub requests, one for each provider in order to collect the available data.

Output data for each requested service type, will be saved as a GML file, precisely in cGML format (compact for mobile device). All cGML output files, one per provider, will be collected in the middleware admin database. XQuery, from W3C body, is used to parse these cGML files, in order to integrate the details of homologous objects and append the heterogeneous ones into a unified cGML file response.

The MPLoM executable file, or in other words, the LBS middleware installed on the mobile device (an S60 Nokia emulator in our case), can then easily match and display on the screen, each cGML tag accordingly.

In order to implement a weather forecast push service, we choose a different approach: The MPLoM LBS middleware connects to the available weather forecast web services, which responses can be easily integrated, due to the fact that they are in xml format.

We had implemented as well a catalog service in the mediator database to list all the metadata about the providers and their offered services (service type, free or not, the frequency of updates, covered countries, languages, etc.). This kind of metadata catalog would be very useful: based on the user's request and preferences, we can implement a pre filter step, in order to access only the adequate providers, and thus minimizing the response delay on the screen.

Figure 5: MPLoM phase 1: Nearest LBS Hotels on Nokia Emulator with only Location integration

For Phase 2, we used the output of the domain visual ontology file CartOWL and we parse it with XQuery so we can visualize the correspondent symbols for each point of interest on the screen. This is the same idea between WFS and Symbology Encoding file. Unified CGML and unified CartOWL files will present the total mash ups on the adequate base map.

However, for integrated homologous objects, we collect all their icons into one macro icon with Halo around and an aggregator sign “+” which means that their information are integrated and they are included in the info window. The user can at any time switch back to know the details from a certain provider rather than the integrated result.

Figure 6: MPLoM phase 2: Nearest LBS Restaurants on Desktop PC with Location and Cartographic integration (Base Map for Bing 2D)

Figure 7: MPLoM phase 2: Nearest LBS Restaurants on Desktop PC with Location and Cartographic Integration (Base Map Google 2D) and Info Window for ALL providers

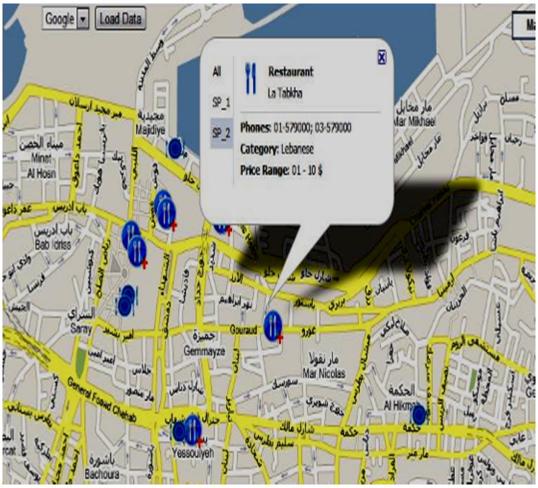


Figure 8: MPLoM phase 2: Nearest LBS Restaurants on Desktop PC with Location and Cartographic integration (Base Map for Google 2D) Info window from SP2

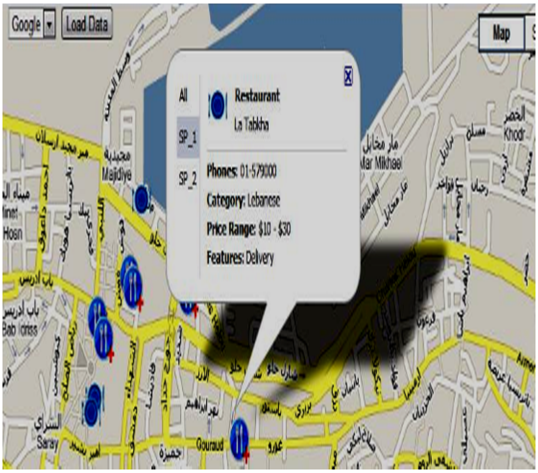


Figure 9: MPLoM phase 2: Nearest LBS Restaurants on Desktop PC with Location and Cartographic integration (Base Map for Google 2D) Info window from SP1

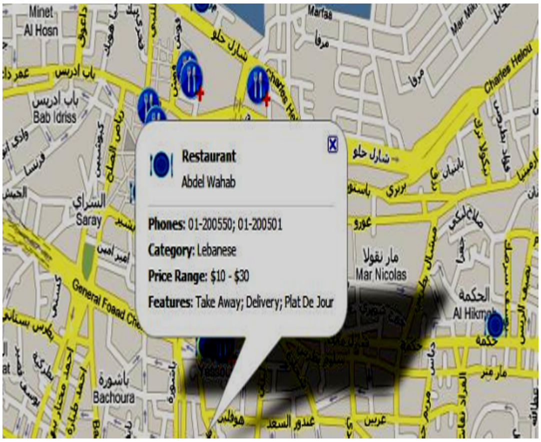


Figure 10: MPLoM phase 2: Nearest LBS Restaurants with Info window for one different object

5- Conclusions and Future Work

In this paper, we presented MPLoM, a platform we had implemented, to test the feasibility of location and cartographic integrations for the same service listed by many providers on a mobile screen. Belief theory, geo ontology, geo web services and other fusion reasoning are mainly used. We also suggested many solutions to achieve the interoperability of geographic databases at the application layer. Comparing our approach to OGC standards, we believe that Symbology Encoding can play a backup solution for common dictionary of symbols instead of implementing our building/matching ontology framework with CartOWL output file. Besides, our Unified Compact GML file will contain same features but in compressed tags as WFS file. Finally, instead of calling WMS for mapping purpose, we had implemented via JavaScript and AJAX, our MPLoM source code for mash ups on Google maps and Bing.

Future enhancements should be done: 1) for the extension of G-MATCH (Zhou 2003) or Protégé open source to include visual concepts such as color, icon, texture, number, etc, and not only semantic ones and being able to do the geographic auto- matching for semantic and visual concepts without any problem, 2) for the development of Visual Attributes recognition algorithms for automatic legend-based retrieval as per J. Bertin's knowledge concerning visual variables (orientation, texture, hue, shape, etc.) and human perception (map semiotics) and 3) for the development of composite geographic web services towards a complete interoperability without any human intervention and the semantic geo web services domain ontology to perform matchmaking between the descriptions of a required service and the advertised ones with intelligent orchestration.

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Generalisation

Interactive Scale-dependent multidimensional Point Data Selection using enhanced Polarization Transformation

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Abstract

Different fields such as Geovisualization, Web mapping or thematic and topographic cartography all need to incorporate a most recognizable and faithful representation of the real world by different map objects at different scales. The objective of this work was to enhance the existing point selection method - the Polarization Transformation - to an automatic scale-dependent point data selection method for multidimensional point data sets, which is implemented in an interactive (Web-) user interface. Benefits of the new method are that in the resulting point selection the global as well as the local characteristics of the spatial point distribution and of the spatial point density are preserved; both for 2D- and 3D- point data sets. Within an interactive user interface the user can upload a point data set, define either the achieved output scale or the wanted number of points to be selected. Then the determined results using the enhanced polarization approach are shown in 2D or 3D to the user. In this work an existing 2D point selection evaluation method for points, based on Voronoi areas, was enhanced for 3D point selection evaluation by using Voronoi volumes. Thus the evaluation verified the similarity of point density and distribution before and after the point data selection.

1- Background and objectives

The power of maps lies in their ability to abstract geographic space, and that different levels of abstraction reveal different patterns and properties

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inherent among the geographic phenomena being represented. The ability to abstract data being ever more important in today's information society – in which the volume of data exceeds our insatiable appetite for more (Mackaness et al. 2007).

Already Eckert (1921) began to consider the necessity of cartographic generalization. Further theoretical background of cartographic generalization of map objects can be found in Bjørke (1996), Mustière and Moulin (2002) and Hake et al. (2002). In this approach for point selection the Polarization Transformation (PT) is used and for each point a global and a local characteristic is defined.

Research in this field draws on expertise in exploratory data analysis or visual analytics, interface design, agent-based methodologies and cognitive ergonomics. Some of our own pre-studies within interactive visual tools for analyzing point datasets can be found in (Peters and Krisp 2010, Krisp and Peters 2010, Krisp et al. 2010 and in Krisp et al. 2009). Investigations in this paper may support visual analytics approaches currently examined in a number of research projects, e.g. VISMASTER (2010) and NVAC (2010).

Bertin (1983) believed that visualization is not effective unless it allows an immediate extraction of the essential information. Many traditional data visualization techniques which proved to be supportive for exploratory analysis of datasets of moderate sizes fail when applied to large datasets. According to Andrienko and Andrienko (2007), two approaches can handle with huge data sets. One approach is data aggregation which considers the clusters instead of the original data. The second approach is data selection which focuses on a portion of characteristic data items. Unfortunately, none of the two approaches can satisfy the needs of exploratory data analysis. These needs are described in Bertin (1983): Exploratory data analysis requires a consideration of the data on all levels: overall (considering a dataset as a whole), intermediate (viewing and comparing collective characteristics of arbitrary data subsets, or classes), and elementary (accessing individual data items). Andrienko and Andrienko (2007) suggested therefore a combination of data aggregation and data selection, i.e. to show the entire data set and arbitrarily defined subsets in an aggregated way. They provide a solution using an adapted parallel coordinate plots. In this work an interactive tool is developed, which enable the user to perform point data selection.

Selection is concerned with the semantics of the features rather than their location attributes and as such represents the abstraction of the symbolic aspects of the map (Edwardes et al. 2005). Selection involves the identification of objects to retain or eliminate from the database (Slocum 2005). In fact, both locational and semantic attributes must be considered for selection.

The goal of point selection is also to avoid over-plotting and unreadability. After point selection the size of the displayed points can also be increased to achieve a better visibility and legibility. In the past research in generalization of point data via point selection has focused on the development of automated and assisted techniques (e.g. Weibel and Jones 1998). The algorithms developed for such applications must be operational for use with large data volumes, but the absolute levels of performance are not critical (Burghardt et al. 2004).

In the point selection process the main goal is to keep the information content (entropy) of the original data as good as possible. What kind of information exists in point data? In the literature there are four types of information contained in (point-) map features: statistical, metric, thematic and topological information (Sukhov 1967 and 1970, Neumann 1994, Bjørke 1996, Li and Huang 2002).

Statistical information of a map considers all the occurrences of the map features as unique events and all map events are equally probable. It is simply computed by counting the number of map features. But the spatial distribution is not considered. The topological information is considered by the connectivity and adjacency between map features. Thereby different types of relations between the map features exist. Table 1 shows the work conducted by Yan and Weibel (2008). The metric information considers the variation of the distance between map features and consequently their densities.

These information types of points and point cluster can be quantified using different measures (Ahuja 1982; Ahuja and Tuceryan 1989; Yukio 1997, Langran and Poicker 1986, Flewelling and Egenhofer 1993, Van Kreveld et al. 1997).

Types of information	Measures
Statistical	Number of points
Thematic	Importance value
Topological	Neighboring points *(e.g. Voronoi neighbors, fixed radius neighbors, k-nearest neighbors, etc.)*
Metric	Absolute local density Relative local density Distribution range

Table 1: Relations between measures and types of information (Yan and Weibel 2008)

Within cartographic generalization a number of point selection algorithms can be found in literature, among others the Settlement-Spacing Ratio Algorithm, the Gravity-modeling algorithm, the Distribution-coefficient control algorithm, the Set-segmentation algorithm and the Quadrat-reduction algorithm, which all are proposed in Langran and Poicker (1986). Further algorithms are the Circle-growth algorithm by Van Kreveld et al. (1997), the Quadtree-based algorithm by Burghardt et al. (2004) and a Simplification algorithm by De Berg et al. (2004). The Settlement-Spacing Ratio Algorithm and the Circle-Growth Algorithm are also described and evaluated in Li (2007). Yan and Weibel (2008) summarized, evaluated and compared these algorithms and introduced a new algorithm based on the Voronoi diagram where all four types of information (statistical, thematic, topological, and metric) are transmitted in a point generalization process.

The Polarization approach, proposed by Qian (2006), is a further algorithm for point generalization and it is the basis of this approach and described in more details in the next chapter. Table 2 gives an overview about the transmitted information of each point-generalization method.

The Set-segmentation algorithm and the Quadrat-reduction algorithm require a high level of human intervention. As shown in Table 2 all algorithms which consider the transmission of thematic information use an importance value for each point of the original data set. What if there is no importance value, if all points have the same value or if just very few of the points have a different importance value? Thus the Circle-growth algorithm, the Settlement-Spacing Ratio Algorithm, the Voronoi-based algorithm, the Gravity-modeling algorithm and the Distribution-coefficient control algorithm do not work at all. In these cases the importance value of each point need to exist and differ from each other. Thus the selection is based on the variation of the importance values.

point-generalization algorithm	Statistical Info (nr. of points)	Thematic Info (importance value)	Topological Info	Metric Info
1. Settlement-Spacing Ratio algorithm	x	x	x	distance
2. Gravity-modeling algorithm	x	x		distance
3. Distribution-coefficient control algorithm	x	x	x	distance
4. Set-segmentation algorithm	x		x	distance
5. Quadrat-reduction algorithm	x		x	distance
6. Circle-growth algorithm	x	x	x	distance
7. Quadtree-based algorithm	x		x	distance
8. Simplification algorithm	x			distance
9. Voronoi-based algorithm	x	x	x	local density, distribution range
10. Polarization approach	x		x	polar distance, polar angle

Table 2: Analysis of the existing algorithms

Concerning the transmission of topological information, the Polarization approach is the only one which maintains the global and the local characteristics (distribution, density) of the generalized point data set.

So far none of the existing algorithms deal with points in 3D space or dynamic points in 2D or 3D. Nowadays geo-data acquisition of static and dynamic points in 2D or 3D need new point selection methods concerning the higher dimensions. In this approach it is attempt to fill this research gap.

2- Approach & methods

Within the Polarization Transformation, described in Qian et al. (2006), first of all a Polarization center (P_c) will be determined computationally. That point P_c has the maximum average length to all other points.

Now the distances of each point to Pc and their relative orientations can be calculated and displayed in the polar coordinate system (□i ; rc,i) shown in (Figure 1):

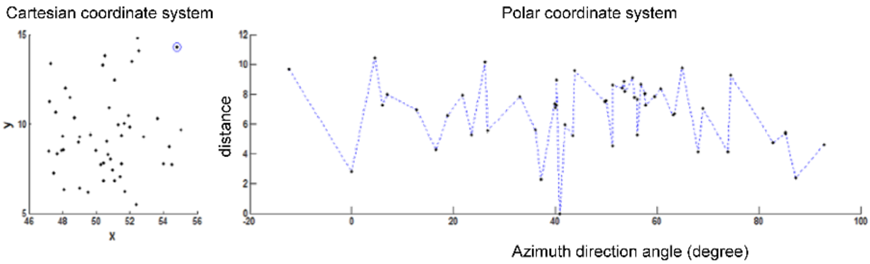

Figure 1: A sample point data set in the Cartesian and in the transformed Polar coordinate system

The resulting polar coordinate system then will be unfolded as a spectrum line. After the transformation, each point from the original cluster has become a node on the spectrum line delimited between 0º and 360º along the horizontal axis, and between the minimum and maximum polar radius along the vertical axis. Now the spectrum line can be segmented into segments. Therefore Qian et al. (2006) predefined thresholds of the polar angles empirically, depending on the number of points and on the azimuth direction angles to the neighbor points in the polar coordinate system.

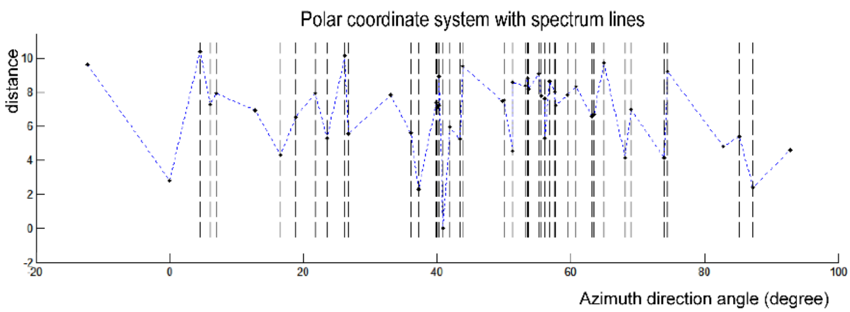

Figure2: Example of a segmented spectrum line

Figure 2 shows an example of the segmented spectrum-line.

Then the spectrum line in the polarization space is simplified by preserving characteristic nodes and eliminating unimportant nodes. The polarization transformation approach is described in more detail in Qian (2005), in Qian (2006), in Qian et al. (2006) as well as in Qian et al. (2007).

The PT-approach, however, does not predefine the number of the points which have to be kept/eliminated for a certain map scale range. We tested the existing PT-approach of Qian (2005) with different randomly distributed point data sets, using different amounts of point numbers. The resulting percentages of the eliminated points are shown in Table 3.

Number of points	Number of eliminated points	Eliminated points in %
200	1	2
2000	18	0,9
5000	23	0,46

Table 3: Examples of test data

What is the use for generalizing point data sets by a selection of never less than 98 – 99,5 percent? The reason for these results lies within the empirically set angle threshold $\Delta\alpha$ in Qians PT-approach (Qian 2006).

Our enhancement aims to adapt the PT to enable point-generalizations for user-defined scales or user-defined number of kept/selected points. Also we enhanced the PT-approach to consider multi-dimensional point data sets. Thereby we keep the advantage of PT, to preserve global as well as local characteristics of spatial distributions. We improved the determination of the angle threshold $\Delta\alpha$ by defining $\Delta\alpha$ as an element of all differences of the neighbor azimuth direction angles of the spectrum line depending on the achieved number of kept/eliminated points.

Our approach is an interactive (Web-) tool which allows to input any static or dynamic 2D- or 3D-point data set (x,y,z,t) and generalize the points in real time either by defining the number of points to be kept/eliminated or by a given achieved output scale. In this paper we also provide an evaluation of our point selection method.

Töpfer and Pillewizer (1966) investigated their empirical formula or “radical law” which allows determining the number of features which should retain within a selection process. An extension of Töpfer’s radical law (principles of selection) was developed by Burghardt and Cecconi (2007) and allows an interpolation between two source scales as given in a Multirepresentation Database. With Töpfer's radical law the number of kept points (N_T) of the original points (N_S) is calculated by a given map scale (S_S) and a given reduced scale (S_T) as followed:

Formula (1):

$$N_T = N_S \cdot \sqrt{\frac{S_S}{S_T}}$$

Töpfer called the equation also "law of natural dimension"

- N_T = number (N) of cartographic features represented on a map
- N_S = original number of points
- S_S = initial scale (scale1)
- S_T = reduced scale (scale2)

We used Töpfer's radical law to calculate the number of the points which have to be kept for any user-defined reduced scale (scale 2).

2.1 Detailed description of the enhanced PT:

In our interactive tool first the point data set can be read in. In the case that several points have exactly the same coordinates the data set will be changed to containing just unique points. The user can define the desired output dimension, 2D or 3D. In case of different time series the user also can use an interactive slider (see Fig. 4) to define the moment of time so that the corresponding coordinates will be read in. Then the user has to define the initial scale. Furthermore a maximal possible reduction scale (S_{Tmax}) was calculated using Töpfer's radical law while keeping a minimum of 4 points:

Formula (2): *Töpfers law*

$$S_{T\max} = S_S \cdot \frac{{N_S}^2}{16}$$

Now the reduced scale or the number of points to be eliminated will be defined by the user. In case of a defined reduced scale (whereby the scale value has to be smaller than S_{Tmax}), the number of points which have to be kept and the number of points which have to be eliminated are calculated based on an initial scale and based on the reduced scale, again using Töpfer's radical law using equation (5).

In the next step of our algorithm the polarization-centre (P_c) which has the maximum average length to all other points will be calculated using equation (1). Then all azimuth angles from the polar centre P_c to each point will be calculated using equation (3). Subsequently the results are sorted in a Matrix *sort_angle(distances, azimuth angles)* according to the increasing azimuth direction angle values. Duplicates in the Matrix will be eliminated.

After that the spectrum line can be displayed in the polarization space (like in Figure 1). In case of 3D-coordnates there are three polarization spaces of each perspective (xy, xz, yz). Now our new segmentation-process for defining the spectrum line segments will be done:

- First the value-differences between all sorted azimuth angles are calculated. This happens by subtraction of sorted azimuth angle (i) with sorted azimuth angle (i+1).

  Formula (3):

  Matrix

  $$\mathrm{d\_sort\_angle} = \{|\,\mathrm{sort\_angle(i)} - \mathrm{sort\_angle(i+1)}\,|\}$$

  for all i = 1..n-2   whereas n = number of all points

- Now the spectrum line will be segmented in an iterative process. The spectrum line will be segmented starting with the largest value of the sorted azimuth angle *max(d_sort_angle)* for the threshold $\Delta\alpha$, in other words the largest difference between two neighbor points in the spectrum line. Based on that segmentation all points that follow Qian's requirements for preserving characteristic nodes – like described in the previous chapter – will be kept, all others eliminated. To be more precise if the azimuth angle difference between two neighboring points of the spectrum line is larger than $\Delta\alpha$ then set a threshold.

  Formula (4):

  $$\textit{if}\ \ \Delta\alpha < [|sort\_angle\ (i)\ \text{-}\ sort\_angle\ (i{+}1)/|]\ \ \textit{then set a threshold}$$

- In the iteration that step will be repeated until the number of kept points are equal to (or not more than) the user-defined (in case of a user-defined output scale - the calculated) number of points to be kept (N_T). With each iteration the next smaller value of *d_sort_angle* will be used and with each step the resulting number of kept points will decrease whereas the resulting number of eliminated points increases.

Formula (5):

repeat $\Delta\alpha$ = *d_sort_angle (n-i+1) for i = 1..m whereby m = number of entries of d_sort_angle* ***until*** [*n-local maxima-local minima-threshold points*] <= N_T *whereby n = number of points*

- In case of 3D-point-coordinates we perform these iterative steps of equation (7) until equation (9) for each 2D-perspective (xy, xz, yz) and we have to determine the identical kept points which are common for the three perspectives (N_{Txy}, N_{Txz}, N_{Tyz}). In that case the iteration stops when the number of these identical kept points of all three perspectives reaches the number of the user-defined points to be kept.

The determined kept (kept) points and the points to be eliminated can now be plotted as demonstrated in Fig. 3.

The benefits of our new enhanced Polarization approach are summarized in the following list:

- it allows a scale-dependent selection/generalization of point data
- not only for x,y- point data but also for static and dynamic point data in 2D or 3D (x,y,z,t)
- with an calculation simplicity it is applicable as an Web-application
- through an interactive tool the user can upload any point data set and define either the output scale or the achieved number of points which he wants to be eliminated
- point selection while keeping still the global and local characteristic of the point data distribution and point data densities

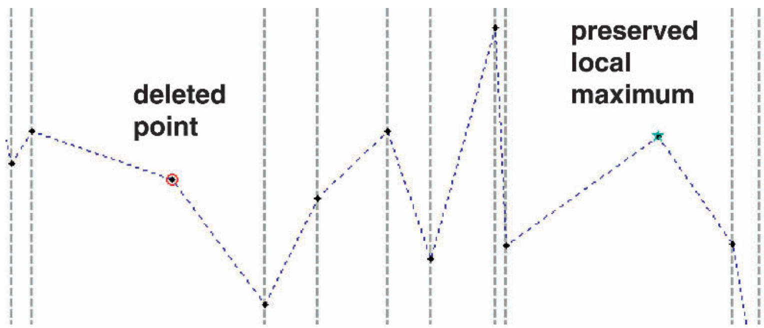

Figure 3

2.2 Evaluation of the enhanced PT generalization

To evaluate a point selection two different methods can be used, both value for 2D- point data sets. The second method we extended to evaluate 3D- point data selection:

2.2.1 Comparison of the density values

The first evaluation method is a comparison of the density- values of the kept points before and after the generalization. Furthermore a visual comparison of the density map with all points with the density maps of the kept points can be done. We used Scotts formula for density calculation (formula 6, Scott 1992). For the search ratio *h* (or Kernel Density bandwidth) the mean distance of all original points was used.

Formula (6): general Kernel density function

$$\widehat{f}_h(x) = \frac{1}{N \cdot h} \sum_{i=1}^{N} K(u) \quad \text{with} \quad u = \frac{x - x_i}{h}$$

whereby we used for K the Gaussian-Kernel:

$$K_G = \frac{1}{\sqrt{2\pi}} \cdot \exp\left(-\frac{1}{2}u^2\right)$$

with K_G = standard Gaussian function
h = smoothing parameter (bandwidth)
$x_1, x_2, \ldots, x_N$ = points, placed within the Kernel Radius h

2.2.2 Comparison using the "Relative Local Densitiy"

Relative local density is used to express the density of an area over the whole study region (Yan and Weibel 2008). The area can be a Voronoi polygon (Fig. 8) and the relative local density of each point can be calculated as follows.

Formula (7):

Relative local density r_i:

$$r_i = \frac{R_i}{\sum_{k=1}^{n} R_k}$$

whereby:

$R_i = 1 / A_i$ (absolute local density of the i-th point)

$R_k = 1 / A_k$ (absolute local density of the k-th point)

A_i = the area of the Voronoi polygon containing the i-th point

A_k = the area of the Voronoi polygon containing the k-th point

n = the number of the points

We assume that R_1 is an array to capture all values of the relative density on the initial map. The i-th element of R_1 is r_i_1. R_2 is an array to capture all values of the relative density on the reduced map. The i-th element of R_2 is r_i_2. The goal is to compare the change of relative local density between the initial map and the reduced map point by point. Therefore the following steps are applied:

1. Test R_1, and eliminate r_i_1 if the i-th point on the initial map had been eliminated.
2. Sort R_1 in increasing order and organize the elements in R_2 according to the sequences of the values of the corresponding points in R_1.
3. Create curves for R_1 and R_2 (see Fig. 9) to provide a clearly comparison of the relative local density change.

With a plot of point numbers (x) and relative local density (y) of both, the points of the initial as well as of the reduced map, the similarity can be compared visually. As more the both curves increase in roughly the same way, as more similarly the relative local densities are.

The relative local density is based on Voronoi areas. For our 3D-point data we extended the method and used Voronoi volumes instead of Voronoi areas in Formula (7) and computed the relative local densities based on Voronoi volumes.

3- Results

3.1 Applying the enhanced PT to a test data set

We used as an original dataset airplane data containing the coordinates (x,y,z) of 405 airplanes. Our sample dataset have been provided by the

Deutsche Flugsicherung GmbH and the EUROCONTROL Information Centre. The dataset contains points representing airplane positions over the area of Germany. We used the positions of 405 airplanes from the 15.05.2009 at 9:26:00 o'clock. We applied this data set to our enhanced PT-approach.

Figure 4 and Figure 5 show screenshots of our interactive selection tool for multidimensional point data using the enhanced PT approach. Fig. 4 shows an example for 2D points and Fig. 3 shows an example for 3D points. The user can load any point data set, 2D-points (x,y), 2½D-points (x,y,t), 3D-points (x,y,z) or 3½D-points (x,y,z,t). In the plot of the original points (top left) the Polarization-centre (P_c) is drawn with a blue colored circle. After defining the original scale (scale1) and either the reduced scale (scale2) or the number of points which have to be eliminated (in number or percentage), the polarization space and the segmented spectrum line will be calculated and displayed. Depending on the original data set (xy- or xyz-coordinates) either 2D plots (Figure 4) or 3D (Figure 5) plots are displayed. Through a time slider the user can change the coordinates for the particular time and will get the regarding selection displays in real time. In the polarization space all points are drawn in black. If points are kept as local maxima they are drawn with cyan colored circles, in case of local minima they are drawn with green colored circles. Points which have to be eliminated are drawn with a red colored circle. For 3D- or 3½D-point data three spectrum-lines are plotted, xy-diagram, xz-diagram and yz-diagram (Figure 6). Thereby the potential to be eliminated points are drawn in purple and in red color. The red points occur in all three spectrum-lines and will be finally eliminated.

The results are drawn in the top middle plot which shows the kept points in black color and in the top right plot the deleted points are shown in red color. The number of the kept and deleted points is displayed in each case in the sub-plot title.

In our example for 2D point selection, shown in Fig. 4, an initial scale of 1:1000 and a reduced scale of 1:2000 were set. All detailed results (deleted points in each perspective, finally deleted points, etc.) after applying the enhanced PT are listed in Table 4.

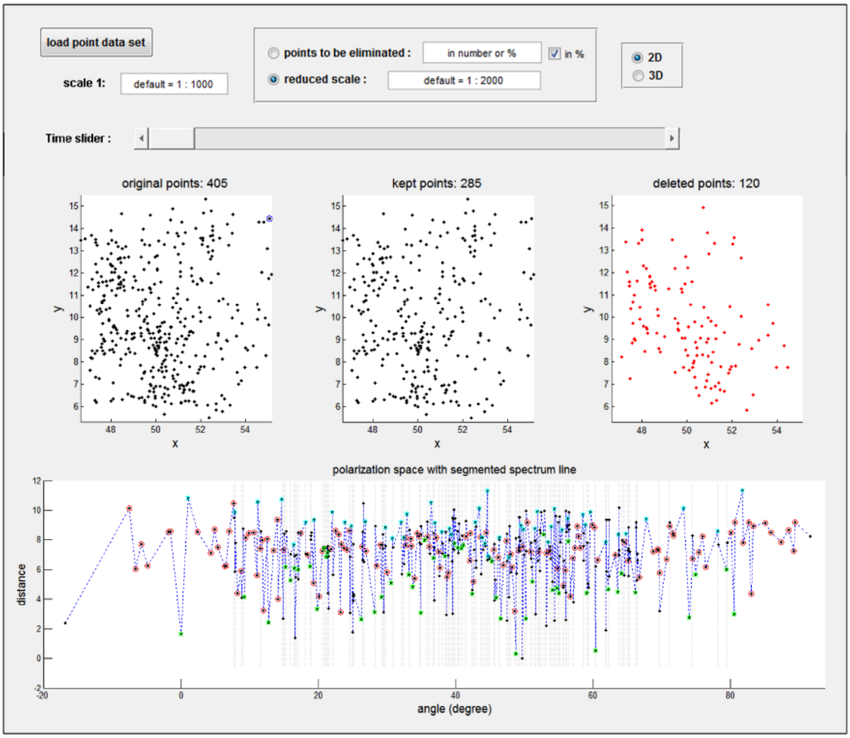

Figure 4: Interactive selection tool – example with 2D point data

initial number of points	405
set initial scale 1:	1000
set reduced scale 1:	2000
kept points	120
eliminated points	285
local maxima	48
local minima	48
number of segments of the spectrum line	187

Table 4: Results of 2D point selection using the new enhanced PT

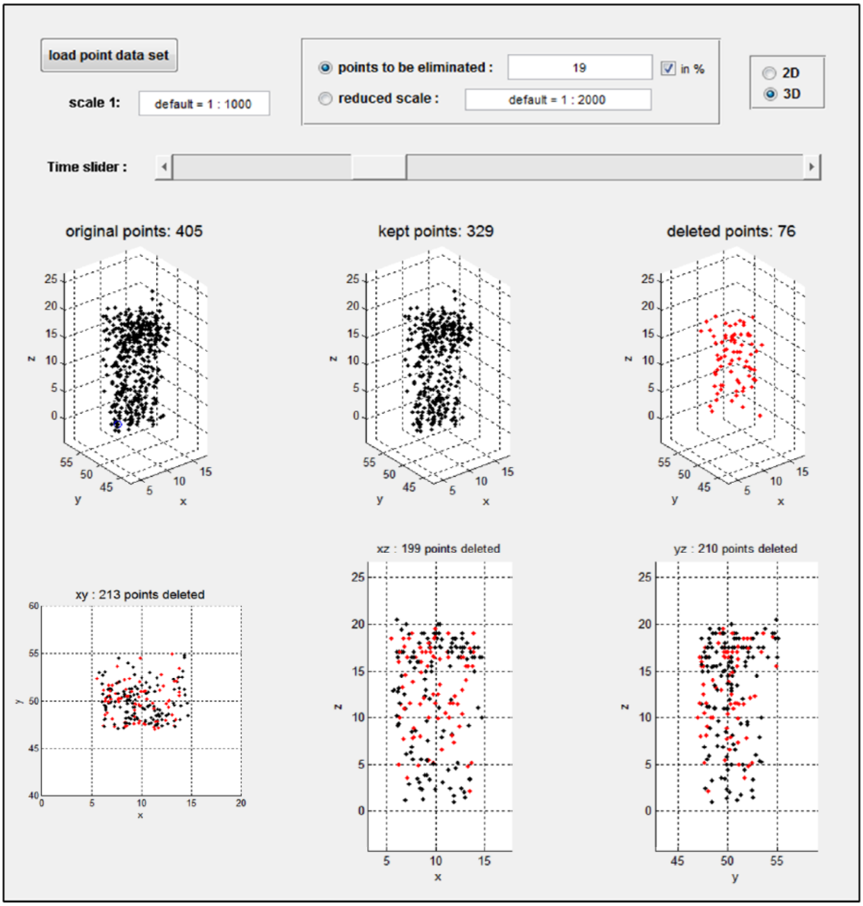

Figure 5: Interactive selection tool – example with 3D point data

In our example for 3D point selection, shown in Fig. 5 an initial scale of 1:1000 and an achieved percentage of 19 % of points to be eliminated were set. Thus all together 76 points have to be eliminated. Using Töpfer's radical law corresponds to a reduced scale of 1:1500. The xy-, xz- and yz-diagrams show the potential to be eliminated points in each perspective. The points in red color are the identical points in all three plots. Fig. 6 illustrates the appropriate three spectrum lines. The finally deleted points are shown in red color circles. All detailed results (deleted points in each perspective, finally deleted points, etc.) are listed in Table 5.

initial number of points	405
set initial scale 1:	1000
set percentage of achieved number of points	19 %
calculated reduced scale 1:	1500
finally kept points	329
finally eliminated points	76
points which are detected to eliminate in xy-perspective	213
points which are detected to eliminate in xz-perspective	199
points which are detected to eliminate in yz-perspective	210

Table 5: Results of 3D point selection using the new enhanced PT

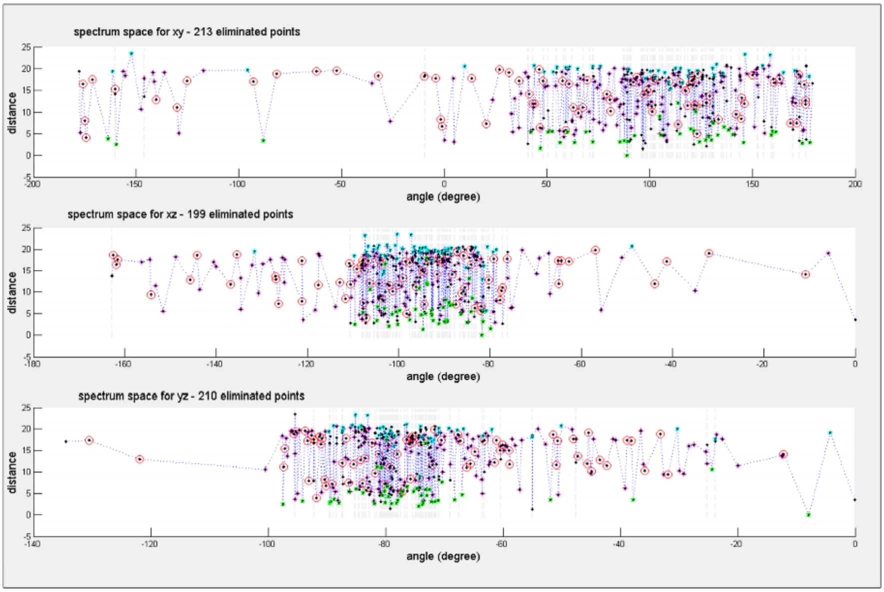

Figure 6: Segmented spectrum lines for 3D point data (for xy-, xz- and yz-perspective)

3.1 Comparison of the density values

We used our sample point data set of 405 points at an initial scale of 1:1000 and a reduced scale of 1:2000 whereby 120 points were deleted and

285 points were kept. The results are shown in Table 6 and in Fig. 7. The density maps (density map of all points: Fig. 7a, density map of kept points: Fig. 7b) as well as the density values at the kept points do only change slightly. The density distribution over the study area remains. In Table 6, 7 and 8 points were taken exemplary from the region displayed in Figure 8.

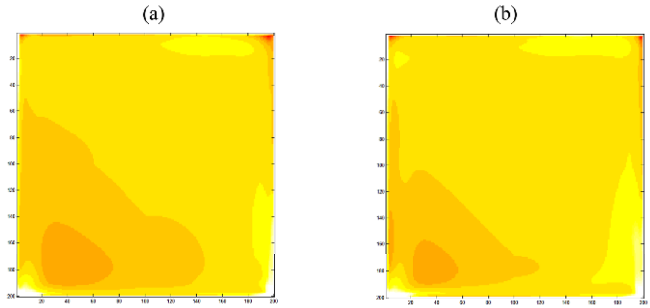

Figure 7: Density map of the original points (a) and of the kept points (b)

Point number	density_Original point	density_selected point	difference
16	0,0609	0,0531	0,0078
29	0,0683	0,0581	0,0102
252	0,0718	0,0584	0,0134
255	0,0700	0,0565	0,0135
266	0,0620	0,0554	0,0066
273	0,0608	0,0544	0,0064
378	0,0737	0,0610	0,0127

Table 6: Results of the density-comparison of the original and the kept points

3.2 Comparison of the Relative Local Densities

The relative local densities were calculated for our test data set of 405 points whereby the initial scale of 1:1000 was reduced to 1:2000. Thereby 120 were deleted and 285 kept.

The arrays *R_1* and *R_2*, which contain all values of the relative density on the initial and the reduced map, were computed.

Fig. 9 clearly shows that the curve for *R_2* monotonically increases in the same order like for *R_1*. This stands for that the relative local densities of the points on the initial and on the reduced map have approximately the same “positions”.

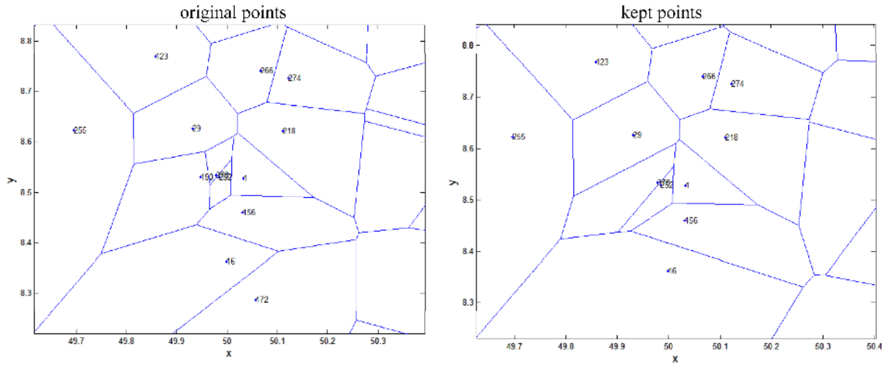

Figure 8: Voronoi diagram of original points (left) and of the kept points (right)

Point number	r_i_1 Original point	r_i_2 Selected point	difference
16	0,0022	0,0183	-0,0161
29	0,0077	0,0053	0,0024
252	0,0735	0,0073	0,0662
255	0,0009	0,0182	-0,0173
266	0,0098	0,0034	0,0064
273	0,0013	0,0009	0,0004
378	0,0621	0,0160	0,0461

Table 7: Relative local density of points before and after generalization for 2D-points

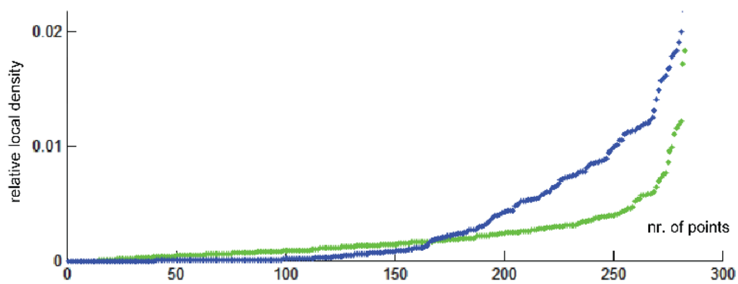

Figure 9: Curve of relative local density change of kept points (2D) before (green) and after (blue) generalization

Table 8 and Fig. 10 show the results of the evaluation of 3D-points using Voronoi-volumes for calculating the relative local density. The curves in Fig. 10 increase very similar like for the 2D-points in Fig. 9.

Point number	ri_1 Original point	r_i_2 Selected point	difference
16	16	0,0046	0,0018
29	29	0,0053	0,0001
252	252	0,0031	0,0191
255	255	0,0059	0,0034
266	266	0,0023	0,0001
273	273	0,0009	0,0004
378	378	0,0058	0,0073

Table 8: Relative local density of points before and after generalization for 3D-points

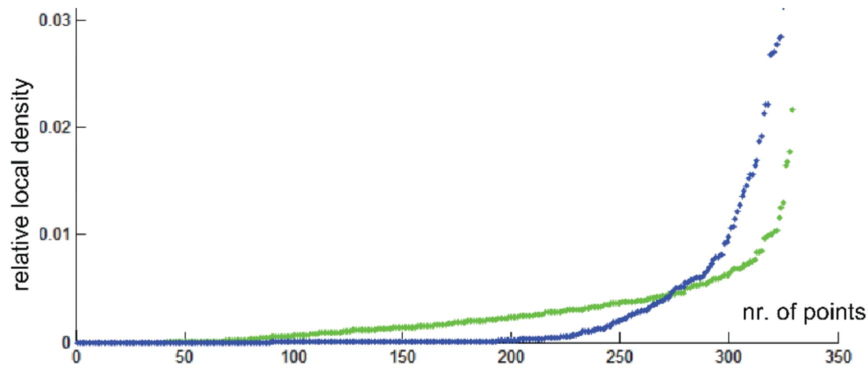

Figure 10: Curve of relative local density change of kept points (3D) before (green) and after (blue) generalization

4- Conclusion and future plans

Diverse fields such as Web mapping, Geo-visualization or topographic and thematic cartography all need to consider a most faithful and recognizable representation of the real world by different map objects at different scales. In our work we developed an interactive scale-dependent generalization tool for selecting/eliminating multidimensional points while preserving global as well as local characteristics of the spatial distributions.

Our enhanced Polarization Transformation (PT) approach works with large point data sets and is suitable for real-time generalization of points in Web maps because of its computing simplicity. Through its interactive use the user can define either the number of points to be kept or the target map scale. The evaluation verified the similarity of point distribution and density before and after the point selection. In this work an existing evaluation method for point selection in 2D based on Voronoi areas was extended for points in 3D using Voronoi volumes.

A next step within point generalization using our enhanced PT-approach should be to apply the adequate point symbol size to the kept points appropriate to the target scale. In further research we will also include semantic attributes in our enhanced PT algorithm. Another planned further investigation will be an interactive combination of point selection and aggregation (clustering) using the PT-method and as well a comparison with other point selection methods.

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Automated Delineation of Stream Centerlines for the USGS National Hydrography Dataset

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Abstract

An algorithm is presented for creating a continuous centerline utilized in base mapping with the National Hydrography Dataset (NHD). This research is part of ongoing efforts to fully automate generalization processing for use on the NHD as part of planned updates to *The National Map* maintained by the USGS. For cartographic purposes, it is necessary to delineate a hydrographic centerline feature which is appropriately continuous and represents the visual main channel of any basin. The algorithm is placed within the context of a generalization routine for a NHD high-resolution subbasin. The solution described here presents a more closely geometric approach to centerline delineation since the NHD does not store centerline attribution explicitly in its database. For validation, the algorithm is tested on several NHD subbasins and evaluated for completeness by creating a flowline network of the delineated centerline. Final results indicate successful centerline extraction with further testing planned on larger datasets.

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1- Introduction

A frequent task for geographers is to distill geographic features and to assemble these data in a map. Given the nature of this distillation process, geographers modify data details for representation at a chosen scale. It is this possibility to focus on a map region as a synopsis of given themes such as hydrography, transportation, or landcover that enables spatial analysis. However, the ability to construe geographic features in any given map design is limited in part by feature extraction. Many in the Geographic Information Science (GIS) and Remote Sensing communities are familiar with the difficulties of extracting features from a raster image such as a satellite scene (Sowmya and Trinder 2000). In vector datasets, the choice of which features provide important characteristic shapes for mapping can be a time-consuming task especially when selecting from a large database (Peter 2001). Unfortunately, few vector databases contain feature attributes which aid the geographer in the selection process. This paper describes a database enrichment process which adds attribution delineating a continuous channel centerline through a set of hydrographic flowlines.

2- Problem Context

One area of GIS research that has historically offered rich insights about the synoptic link between maps and the real world is generalization. Cartographers are frequently faced with the task of manipulating geographic databases for the purpose of generalization, and in many cases feature extraction and/or selection are necessary. Although many tools are currently available through commercial GIS packages to analyze and generalize data (Regnauld and McMaster 2007), the relationship between feature extraction and generalization is still an area with much research potential.

As Steiniger and Weibel (2005) note, feature-oriented generalization offers a useful paradigm, which organizes generalization based on map objects chosen to emulate certain processes, presumably within a certain theme. More explicitly, the chosen theme is in reality a context which determines what common features are expected from a cartographic product (Thomson and Brooks 2007). Touya (2008) argued a similar point, that generalization processes must collaborate based on the underlying geographic distinctions such as urban versus rural, residential versus commercial, etc.

Therefore, generalization is constrained by the topical theme, the map design, the features available for processing, and the target scale. And as Mustière and Moulin (2002) note, generalization decisions ought to be informed by the spatial context of the database such as the relations between objects in a geographic region. The complexity of the generalization in turn is directly related to how clearly the features to be generalized can be separated from their surroundings (Heinzle and Anders 2007).

The context of this research project is situated in relation to an ongoing research effort with the United States Geological Survey (USGS) Center of Excellence for Geographic Information Science (CEGIS). CEGIS has been collaborating with the University of Colorado research team, designing tools for creating reduced scale versions of hydrographic data for *The National* Map (http://nationalmap.gov). Research efforts have been directed towards creating fully automated generalization solutions which preserve differing hydrographic characteristics reflected in specific physiographic landscapes (Buttenfield et al. 2010). Differentiated generalization routines are designed to reflect generic physiographic contexts across the coterminous Unites States, using terrain and climate factors (Stanislawski et al. 2010, forthcoming).

3- Research Objectives

Given the size and extent of the United States, the NHD is a substantially large and varied dataset. The USGS maintains and coordinates the NHD as a vector database containing surface water features of the United States. Several versions of this database include a high resolution compilation, for use at 1:24,000 (24k); and a medium resolution version compiled for use at 1:100,000 (100k) (http://nhd.usgs.gov/data.html). A local resolution version is currently under development for selected parts of the country which densifies the features in the 24k database.

In best cartographic practice, topographic base maps will often delineate a primary water channel or centerline. At present, the NHD schema does not incorporate a centerline attribute. This is due to interrelated factors. First, the 24k NHD is updated on an irregular cycle which can be very short, and based on unexpected events (e.g., storms or floods) or on expected events (e.g. impacts due to urbanization, mining, or human development). Essentially, the database is updated more frequently in regions where changes to stream networks occur (http://nhd.usgs.gov/nhd_faq.html). Second, the sheer volume of NHD stream data precludes computing a new hierarchy of centerlines for all basins and subbasins nationally, for a database undergoing frequent updates. In response to the cartographic demand for centerline inclusion on topographic maps, the CEGIS and CU research teams have designed a tool to identify a centerline automatically during generalization processing, but to do so it is necessary to enrich the high resolution NHD with additional attributes. Once delineated at the largest (compiled) scale, centerlines can be simplified for smaller mapping scales, albeit using tolerance parameters which differ from those applied to other flowlines.

Previous approaches to centerline delineation are also known as methods for finding the “main channel” or the “primary channel”. Central to these many approaches is the idea that the generalization process should preserve enough structural detail to maintain the continuity of all features, and their relative position in a geographical network (Thomson and Brooks 2007). Marr (1982) refers to the natural acuity of humans to see continuation along a network; and Thomson and Richardson (1999) cite visual continuity of geographic phenomena as crucial for the quality of communication and interpretation of maps.

A potential proxy for subbasin centerlines is maintained by the NHD as a feature type named "artificial path”. Artificial paths delineate the flow of water through polygonal features, such as a large river (http://nhd.usgs.gov/nhd_faq.html), and establish continuity of the stream network through lakes, ponds, and other polygonal water features. However, as Figures 1 and 2 show in the humid and hilly Pomme de Terre subbasin in Missouri (NHD subbasin # 10290107), while the set of artificial paths present numerous segments contributing to a centerline feature, the set is often not continuous.

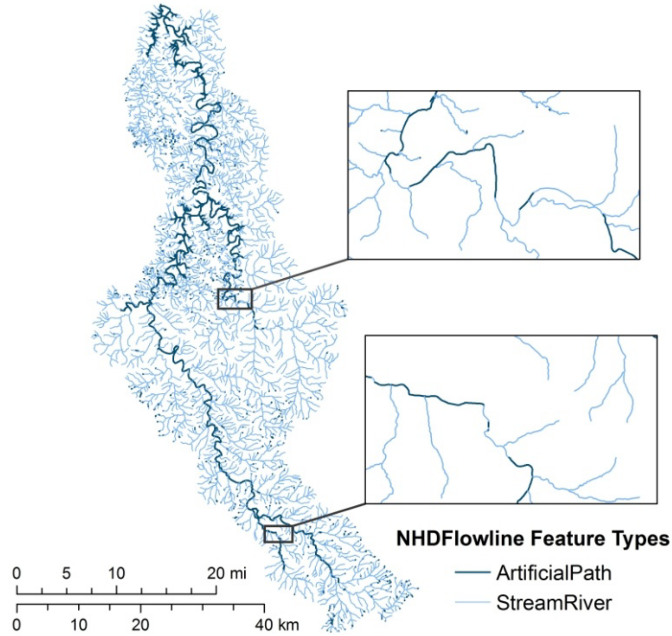

Figure 1: Pomme de Terre Subbasin illustrating (a) artificial paths and (b) breaks within the centerline feature

In addition to artificial paths, the NHD schema stores other attributes associated with the flowline feature class including reaches. A reach is defined as a confluence-to-confluence section of a stream in the NHDFlowline feature class with similar hydrologic characteristics (USGS 2000). Reaches are broken into multiple segments when they cross a topographic mapsheet tile, when a new tributary is added to the subbasin network, or at the boundary of a Digital Update Unit (i.e., a region used for database maintenance and field monitoring), and thus it is common to see multiple records attributed with a single reach code (USGS 2007). A unique reach code identifier is assigned to each reach in the NHDFlowline feature class of the NHD. Reach codes are maintained as a means to permanently distinguish stream tributaries for the entire United States across all resolutions of the NHD database. Reach codes are assigned in chronological sequence as the reach is incorporated into the NHD dataset, thus the ordering of reach codes is temporal and not necessarily spatial. This aspect of the NHD schema will figure prominently in subsequent discussion.

4- Methods: Algorithm Design

Several preprocessing steps extract the backbone of a centerline feature. The first preprocessing step dissolves all flowlines on reach code; this reduces the number of records which must be searched during subsequent steps. The original, non-dissolved version of data is retained, so that (subsequent to centerline delineation) all segments for each reach in the centerline will be individually attributed.

The second preprocessing step merges all polygonal water features contained in the NHDWaterbody and NHDArea feature classes. Once merged, a selection on minimum size is applied to select those polygons considered large enough for the extraction of a centerline. The minimum size criterion of 0.02 km^2 was chosen for this research to delineate a centerline from the 24k source data. The specific value might be expected to vary with source scale and density of flowline channels.

In a third preprocessing step, dissolved reaches are intersected with the merged and selected water polygons to form a "master centerline" list. Comprehensive intersection of all reaches with all polygons is preferable to beginning with the set of artificial paths: as Figure 2 (upper panel) shows. Selection of artificial paths alone misses many stream channels that contribute to a continuous centerline, and includes many artificial paths (flowing through isolated lakes and ponds) which are not viable centerline features. Subsequent processing will identify these channels eventually, but requires a lot of additional searching through the flowlines.

The lower panel shown in Figure 2 demonstrates that a simple intersection is sufficient to capture the majority of centerline features; but some gaps persist that make the centerline non-continuous.

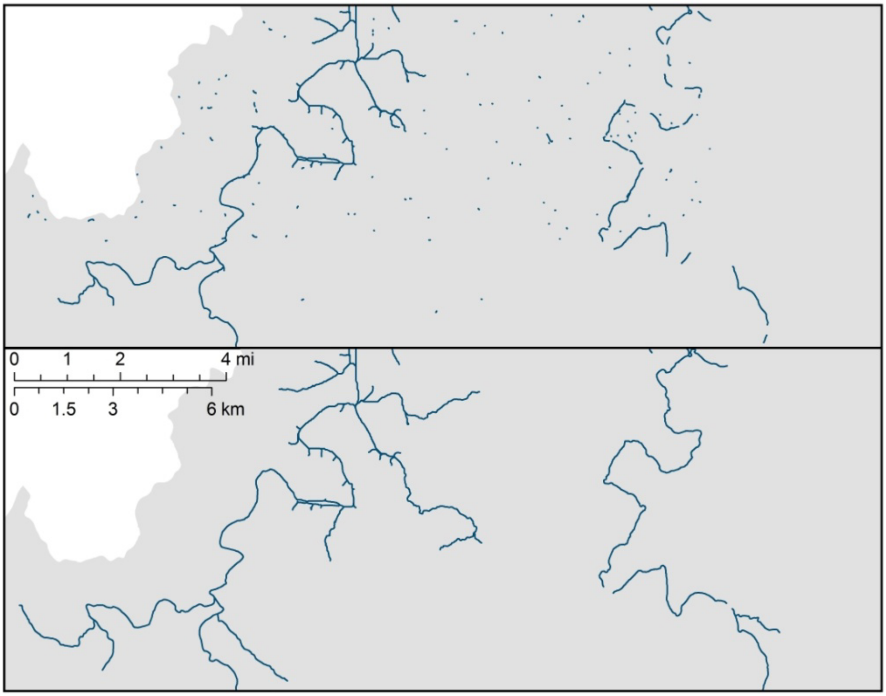

Figure 2: The upper panel shows NHDFlowline artificial paths for a portion of the Pomme de Terre subbasin. The lower panel illustrates the alternative solution created by intersecting flowlines with polygonal waterbodies which have been selected on size. Notice that the lower solution contains fewer gaps in the candidate centerline.

After the intersection, all reaches that are part of the master centerline delineation are selected to form a master centerline list. The rest of the flowlines are relegated to a candidate list to be examined as potential channels to "fill in" centerline gaps. The last preprocessing step creates a master list containing the endnodes of each reach in the derived centerline list and also creates a separate list of endnodes for reaches in the candidate list.

The process of filling in gaps in the centerline is iterative. The candidate reach list is scanned for reaches that contain at least one endnode coincident with an endnode from the centerline master list. The algorithm utilizes a tolerance value to delineate a range of acceptance for coincidence. This tolerance value is dependent on the stated resolution of the database. For instance, the stated resolution for the Pomme de Terre database on download is 0.001 meters, and the algorithm utilizes a slightly larger value of 0.0015 meters to capture node coordinates that are not precisely coincident.

Reaches with one coincident node are further scanned to check if both endnodes are coincident with the master list. Reaches with both nodes coincident are added to the centerline master list and removed from the candidate list. Figure 3 illustrates what this process looks like for a subsection of the Pomme de Terre subbasin where two reaches fulfill the criteria for coincidence.

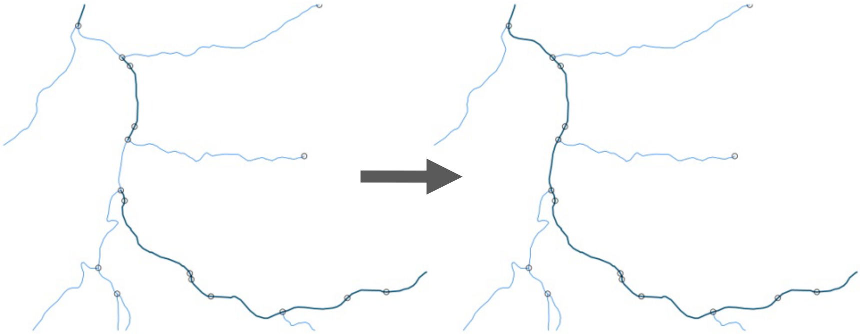

Figure 3: A portion of Pomme de Terre flowline geometry shown at 1:10,000. The circles represent nodes in the stream network. Gaps in the discontinuous centerline in the left panel are filled in the right panel by flagging individual reaches having both nodes coincident with centerlines.

The next step works with reaches in the candidate list sharing at least one node with the centerline and one node with each other. Therefore, this step finds series of two reaches which also connect to nodes bounding remaining gaps in centerlines. These reaches are added to the master centerline list and removed from the list of candidate reaches.

After completing the second scan, some gaps may still remain in the centerline, where a gap spans more than two reaches (Figure 4). The candidate list is once again scanned for reaches that share at least one node with a centerline. Reaches that share nodes will occur at the edge of centerline gaps but also will occur at confluences where minor tributaries connect to the centerline (see circles in Figure 4), creating false candidates. The test to remove false candidates considers two alternatives. In one case, at least one reach will not share its second node with any other flowline, that is, it is a terminal reach (upper red circle in Figure 4). These reaches can be eliminated from consideration. In the other case, one of the reaches will share a node with another reach which does *not* eventually connect to the centerline (lower circle). In this case, an estimate of upstream drainage area computed as part of the enrichment process aids the choice of which reach to add to the master centerline list.

Once false candidates are removed, the correctly identified set of candidate reaches is moved to the master centerline list and removed from the candidate list.

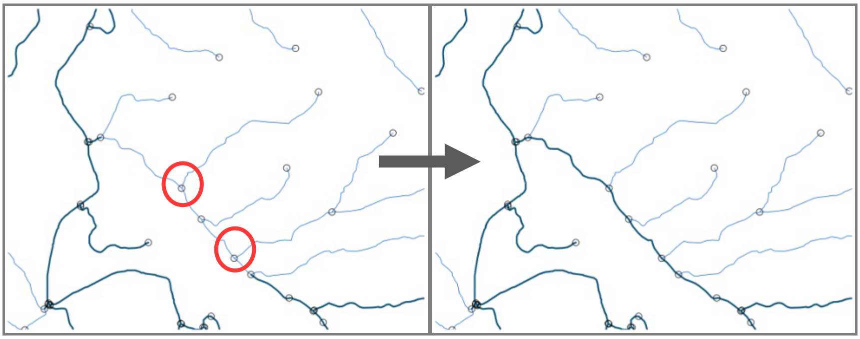

Figure 4: Inset of a portion of Pomme de Terre subbasin geometry shown at 1:15,000. The circles represent nodes in the stream network. The left panel shows a gap of more than two reaches between centerlines. Red circles highlight two confluences where false candidate reaches must be eliminated, as discussed in the text. The panel at right shows the solution of the centerline delineation, eliminating false candidate reaches.

During the algorithm design, it was noticed that in some cases, reach code numbering tends to follow in a spatial sequence. For example, if two extracted centerline segments have reach codes 001 and 005, and the centerline formed by these two contains a gap, the reaches connecting the gap might be numbered 002, 003 and 004. Furthermore, if reaches branch off the centerline in this vicinity, those reach code values tend to be much larger or much smaller. A reduced-search strategy used a range delimiter to assess which of the alternative reach codes would more likely fill in the centerline gap.

And so in cases where a centerline gap was discovered to span more than two reaches, stream channels exhibiting a range of successive reach code values were considered (i.e., a "candidate series"), instead of scanning the full set of remaining candidate reaches. These candidate series were then iteratively dissolved and each group tested to see if the dissolved feature's nodes were coincidental with endnodes of any centerline gap. This shortcut worked for the Missouri subbasin, but was found to operate incorrectly for some other NHD subbasins. This limitation will be discussed in more detail later in the paper.

Following centerline delineation, a post-processing step is required to actually enrich the database with centerline attribution. First a field is added to the original NHDFlowline table to store a flag for every feature which forms a part of the centerline. Post-processing selects all original NHDFlowlines that match part or all of a reach in the master centerline list, and adds a flag for the selected flowlines. This attribute field is not part of the original NHD schema, but enriches the NHD file and can be accessed subsequently for cartographic base mapping, or for generalization.

5- Results

The delineation algorithm was implemented as a tool using Python 2.5 coding and geoprocessing functions available in ArcGIS 9.3.1. Figure 5 shows results for delineating the centerline of the Pomme de Terre subbasin. The total length of all artificial paths (Figure 5, left) is 808 km, comprised of 2,901 reaches. Following the preprocessing steps of the algorithm which intersect all reaches with water polygons, the total length is reduced to 462 km comprised of 1,083 reaches. In comparison to the method of simply selecting artificial paths, the intersection method eliminates more than 1,800 reaches which could not reasonably become a part of the centerline, thus reducing by more than half the set of reaches which the algorithm must search. Following complete delineation (Figure 5, right) the centerline length grows to 488 km with 1,152 reaches. The algorithm fills a total of 26 km of gaps, delineating an additional 69 reaches.

6- Discussion

The algorithm presented in this research presents an automated method for centerline delineation of NHD subbasin data. Development of this algorithm is one tool in an ongoing project to build a geoprocessing toolbox containing routines for data enrichment, pruning, simplification and validation, which will be disseminated for use with *The National Map*.

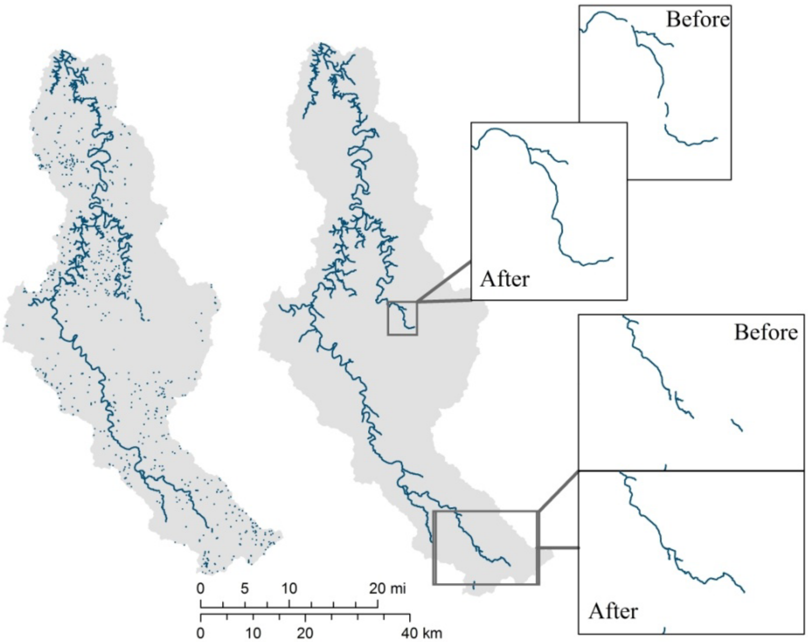

Figure 5: Pomme de Terre subbasin illustrating for the entire subbasin the master centerline selection method using artificial paths (left panel), and (right panel) the solution from the centerline extraction algorithm. In the far right one sees insets of exemplar problem areas before and after processing.

The current solution retains some limitations. The methods presented in the paper have been tested on the Pomme de Terre subbasin. The algorithm was tested against other NHD high-resolution subbasins from the state of New Jersey whose centerline delineations have known discontinuities. Results from these tests indicate that the current version of the algorithm successfully finds and fills gaps which span a single reach and which span two successive reaches. Delineation across gaps which span three or more successive reaches works only for stream networks where the sequencing of reach codes demonstrates close spatial proximity. Where the sequencing does not do so, a fourth scan of the node lists is required to generate a fully continuous centerline. This is much slower computationally, and efforts to speed processing are underway.

A second limitation is that the current algorithm relies on the presence of standing water in the subbasin, that is, the existence of polygonal water features. In dry landscapes, where there are few water polygons, centerline initiation must use an alternative method to the intersection approach applied in this paper, since there are few artificial paths initially.

One solution being explored involves a prerequisite form of database enrichment, wherein upstream drainage areas are estimated (Stanislawski 2009, Stanislawski et al. 2007) prior to centerline delineation. This paper already discussed the use of upstream drainage area values to determine which of several reaches is a better choice for tracing upwards through a drainage network. Upstream drainage area also can be used to locate the mouth (pour point) for the subbasin, which will be characterized as having the highest upstream drainage area value for any reach in the subbasin. From the pour point, one can trace upstream through the beginning and end nodes of reaches to the penultimate confluence. As in the paper's earlier discussion, where multiple reaches share a node, the reach is chosen with a higher upstream drainage area estimate. Specifically, the use of upstream drainage area estimates might accelerate processing times to the extent that it can reduce unnecessary scanning of the node lists; and this forms an area for future research.

Other potential problems include identifying multiple pour points in a subbasin, as for example in processing a coastal hydrographic network. In dry landscapes, the delineation must deal with centerline gaps which are formed by subterranean flows. In these regions, it seems logical to process master and candidate flowline lists using full network topologies, which creates an extra processing step but will ensure that node lists can support searching continuously through the subbasin.

A promising application which is also slated to be explored is the identification of a centerline within a braided stream, as described by Buttenfield et al. (2010). In braided hydrography, multiple channels will share a node, and indeed, may carry equivalent values for upstream drainage area. Delineating a centerline automatically through a stream braid must resolve these ambiguities; and at present, no clear solution is apparent based on the existing NHD schema.

7- Summary

The delineation of a primary channel is important to topographic base mapping for cartographic and analytic reasons. Centerline delineation enriches the NHD database, making additional information available to the cartographer that may be used to generate smaller scale generalized versions of compilation-scale data. It should also reduce processing times for mapping at much smaller scales, since one can anticipate that the centerline will satisfactorily represent a stream network in its most simplified form. A delineated centerline likewise provides a minimum level of prioritization within a data environment wherein it is difficult to maintain a comprehensive and current channel hierarchy.

The work presented here also provides a working example of how various forms of data enrichment can support automated generalization processing, and add to the emerging body of knowledge about its various roles in automated generalization. Early work (Plazanet et al. 1998) argued for enrichment of additional geometric or procedural information. The value of data enrichment within the generalization process has been more recently cited by Neun et al. (2004), who encoded horizontal and vertical relationships to support multiscale thematic and web mapping. Savino et al. (2010) enrich a road data set to inform feature selection during generalization. The work here focuses on enrichment of semantic attributes, establishing which stream reaches mark the primary path of water through a hydrographic basin. Research by the authors is ongoing to further enhance and streamline the processing steps.

As Neun et al. (2008: 133) remark, knowledge exacted by the enrichment process should be "… made available to other generalization operators". In every published example, enrichment is able to facilitate more complete automation of generalization processing which would otherwise be computationally intensive, require domain expertise which is not widely available, or augment existing database information. Further developments and extensions to database enrichment show great promise for continued automation of cartographic generalization.

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Pattern Recognition and Typification of Ditches

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Abstract

This paper will present the algorithms developed for the generalization of ditches in the CARGEN project. Despite the increasing number of algorithms available for cartographic generalization, only few of them address directly the problem of typification; noticeably this has been done in the context of building and road network generalization only. Ditches are man made features used to carry water, they are commonly found in groups in rural environments and in maps they are widely used to describe such a landscape. Groups of ditches usually show a regular pattern of straight lines, hence they lend themselves to be generalized through typification. In this paper a novel algorithm for the typification of ditches will be explained. The algorithm has been developed inside the Italian CARGEN project, aiming at the automatic generalization of 1:25000 data from 1:5000 data. The first section introduces typification, followed by brief review of related work in section two; the third section gives a description of the salient features of ditches; all the consideration of section one and three will be then used to set up a generalization algorithm that is explained in section four. Section five illustrates the results and gives a perspective on the future work.

1- Introduction on typification

During the generalization process the cartographic phenomena present in the original map should be read, interpreted and understood and then given a new representation that should be able to convey the same information of the original one or the most important aspects of it. Many different generalization operators have been identified (Agent 2000) and while each of them has some distinctive features and functions, all of them operate to

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fulfill the purpose stated above; among these generalization operators there is typification.

According to (McMaster and Shea 1989), typification replaces a large number of objects by a smaller number of objects while trying to ensure that the typical spatial structure of the objects is preserved. From this definition the two salient features that distinct typification from other generalization operators stem out clear:

1. it works on patterns
2. it creates new objects

These two abilities, both to identify patterns and to draw new objects, make typification algorithms complex and very difficult to develop.

Working on patterns implies that the typification algorithm should be able to identify in the source data some information -the spatial structures- that are implicitly coded in the characteristics of the geometries like direction, dimension and shape in general. Because of the countless combination of such characteristics, the extraction of patterns from geometries is almost an impossible task if it is not constrained to just some characteristic (e.g. alignment (Christophe and Ruas 2002)) or some type of patterns (e.g. grids (Heinzle et al. 2005)).

The generation of new objects is too a very challenging task for an algorithm, even more than pattern recognition if possible. To create a new object the algorithm should be able to decide autonomously the shape, the dimension, the direction and the position of it. Furthermore a deep understanding of the constraints on the new object should be embedded in the algorithm that should be able to evaluate any topological and geometric constraints imposed both by the semantic and the surrounding environment[1].

In general we can say that the difficulty in developing a good typification algorithm is related to the fact that the task that such an algorithm should pursue, to identify the pattern that characterize a certain cartographic phenomena and replace this phenomena with a new representation that

[1] In this paper we will perform typification creating from scratch new geometries that will replace the original ones. But typification could also be performed by selection and displacement, i.e. deleting some elements and arranging the remaining ones in order to maintain the pattern. Nevertheless, in both cases, the considerations on the complexity of any typification algorithm apply.

preserves the pattern, requires skills as abstraction and creativity that belong more to the human than to the machine.

If developing generalization algorithms could be regarded as teaching the computer how to draw maps, this is particularly true about typification. In their work (McMaster and Shea 1989) state that to generalize we need to know why, when and how to generalize; we can write that to develop a good typification algorithm we need to teach the computer what to draw, how to draw and where to draw it.

Despite the complexity of such a task, developing a typification algorithm is not impossible. The following section of this paper contains a brief review of some works on typification: the algorithms described there are a good example on how constraining the type of patterns to search for and focusing on just some cartographic phenomena it is possible to develop smart and effective typification algorithms.

Typification is very useful -and much used- when the conflicts for space are very high, i.e. when generalizing at small scales, thanks to its ability to replace a group of objects with a smaller group of objects. At large scales there is usually enough space to preserve patterns simply reducing the symbol size or deleting some of the objects in the pattern; in most cases a selection algorithm, maybe driven by a pattern recognition algorithm, could be enough to generalize a pattern: the number of objects left will be sufficient to convey the information about the original distribution. A typical example of this is the typification of buildings in settlements: at large scale buildings inside a city block can be generalized simply deleting the smallest of them; if the spatial structure has to be enforced it is enough to delete the buildings outside the main direction of the pattern (e.g. a building not facing a street). At smaller scales, when the space for the representation of the block is much less, buildings can not be simply selected: the original buildings should be replaced by a new representation counting fewer objects through a typification operation.

The algorithm described in this paper has been developed in the frame of the CARGEN project, a research started in 2006 as a collaboration between the Department of Information Engineering of the University of Padua, the local government Regione Veneto and the Italian NMA, the IGM -Istituto Geografico Militare, with the aim to investigate the automatic generalization of the 1:25000 IGM geodatabase from the regional geodatabase in scale 1:5000. Despite the scale at which the CARGEN project works does not usually require typification, we found a feature class that lends itself to be generalized through this special operator: ditches. A detailed description of ditches and the reasons why they require typification is given in section three. The algorithm will be explained in details in section four. Although the algorithm has been developed for the generalization at such large scale, our guess is that the procedure is general enough to be applied also to other (smaller) scales.

2- Related work on typification

Typification and pattern recognition are closely related, as the first step of typification is to understand the pattern that should be kept.

Pattern recognition techniques have been developed for roads and buildings. (Heinzle et al. 2005) find grid-shaped structures in roads analyzing the nodes of the road graph; (Christophe and Ruas 2002) find alignment in buildings while (Anders and Sester 2000) developed a parameter free cluster recognition algorithm that can be used as a preprocessing step for typification. Due to the simple shape of ditches, the pattern recognition is not as complex as that of roads or of buildings, and thus let us develop a strategy much simpler that those in these works.

Many papers investigating pattern recognition techniques focus also on typification. (Regnauld 1996, 2001), uses a minimum spanning tree to cluster and typify buildings, (Sester and Brenner 2000) developed a typification algorithm based on Kohen maps, (Burghardt and Cecconi 2007) apply mesh simplification to solve the same problem. Most of the work on typification focuses on buildings, but there are also some examples of road typification in (Thom 2005), (Luan and Yang 2010)). Neither the works on the typification of buildings nor those on the typification of roads can be extended to our case: the algorithms cited in fact operate on geometries (e.g. polygons) or pursue objectives (e.g. collapsing dual carriageways) that are quite different from ours. The clustering strategies proposed could find application in our case, but at the moment the implementation relies simply on a fixed maximum distance threshold to group ditches.

3- Characterization of ditches

As the Oxford dictionary defines it, a ditch is "a narrow channel dug at the side of a road or field, to hold or carry away water". Ditches are man made features used to convey water; they are typical of rural environments, where they may run along the roads or inside the fields, eventually dividing different crops. Ditches can be dug singularly, but most often are made in groups, for example as part of an irrigation or drainage system. Being a man made feature, ditches usually show a regular pattern: groups of ditches often run parallel to each other, in straight lines with similar lengths and equally spaced (see Figure 1).

From the cartographic point of view, ditches are represented as single lines that might or might not be connected to other features of the hydrology network; ditches usually do not take part in the hydrology graph and as they are usually not described with a rich semantic they are treated as a different feature class than rivers and canals.

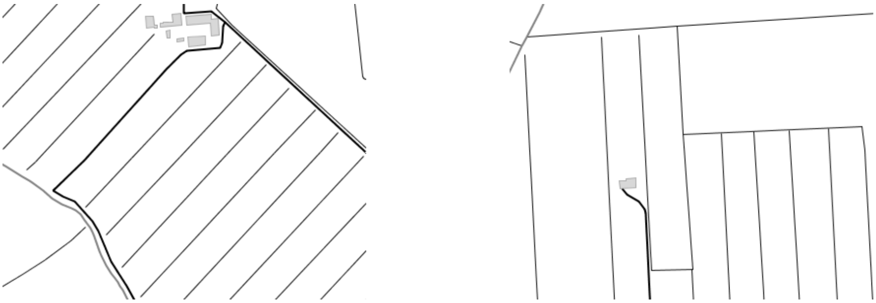

Figure 1: on the left: ditches not connected to any other feature; on the right: ditches are connected to other hydrographic features; in both figures the regularity of the patterns is noticeable.

In rural environments, characterized by the absence of dense road networks or settlements, the straight patterns of ditches are a prominent feature and as such they should be retained during generalization. It is interesting to underline though, that what is important to the description of the rural landscape is not the single straight ditch but the pattern of the group as a whole. Because of this, ditches lend themselves to be typified.

Selection vs. typification

One may wonder whether there really is the need of a typification algorithm to generalize ditches, or a simple selection algorithm could do the deed. From our tests we found out that the generalization of ditches can be accomplished with a simple selection algorithm, but that the results are not always good.

A simple example is the case of a group with an even number of ditches: selecting one ditch every two, the resulting generalized ditches will be equally spaced from each other (if this was true in the original data) but will not be distributed evenly on the space that was covered by the original ditches. In general, a selection algorithm offer less possibility to represent the generalized data as it is constrained to keep the position of the objects that are not deleted. On the other hand, a typification algorithm that creates a completely new representation of the generalized objects could disconnect them.

As we said, though, the odds of a group of ditches being connected to the hydrography network are much less than a group of an even number of ditches (50% of probability in normal distribution) and we evaluated more important a good pattern representation that its connectivity.

For this reason, and in general the ability of a typification operator to perform a better generalization of patterns, our choice was to try to develop a typification algorithm for the generalization of ditches.

Moreover this gave us the chance to approach a more challenging research topic.

Figure 2: from left to right: original data, only one ditch present, only another ditch present, a group of ditches present. No matter which ditch is selected and which are deleted, it is only the presence of a group of ditches that allows to convey the concept of the pattern.

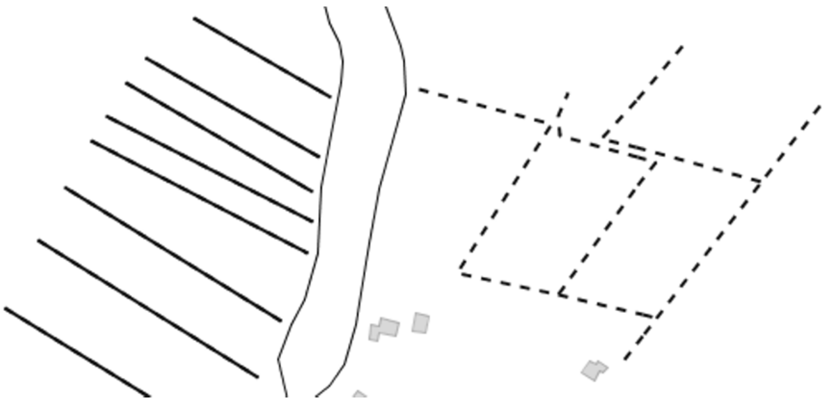

Figure 3: ditches to be typified (on the left, solid lines) and not to be typified (on the right, dashed lines).

As we wrote in section two, not all the ditches of a dataset are part of a group: some ditches run isolated, following the course of a road or surrounding a field.

The first step of our algorithm is then to find which ditches belong to a pattern and which do not: this is done analyzing the direction of each ditch and then clustering them in groups. Depending on the way the data was digitized, it can be hard to recognize a pattern; because of this the ditches are preprocessed to ease the pattern recognition. During preprocessing, every ditch is divided in segments with the same direction. Algorithms performing the segmentation of lines already exist (e.g. (Plazanet 1995), (Balboa 2009)) but the almost straight shape of ditches allowed us to set up a quite simple algorithm that measures the angle between three consecutive vertices and decides whether it is small enough to consider the three vertices almost in-line, or otherwise to split the ditch in the middle vertex.

At the end of the preprocessing all ditches have been divided in almost straight lines, that we will call segments; for each of these segments the centroid and the average direction is computed. For two segments to be in the same pattern they must have a similar average direction and their centroid should not be too far away. The direction similarity and centroid distance threshold are controlled by two parameters of the algorithm: in our tests for the generalization of 1:25000 scale data from 1:5000 scale data we found respectively $\pi/24$ and 50m to be good values for them.

All the segments that are found to be part of the same pattern are then grouped together in what we call a “ditch cluster”. At the end of the process if a ditch cluster contains only one segment this segment will be flagged as “not to be typified” otherwise all the segments in the same ditch cluster will be typified together.

Once we have identified the ditches to generalize and grouped them in ditch clusters, we need to typify them. That is to replace their representation with a new one, that is simpler (i.e. uses less geometries) but still conveys the same information of the former one.

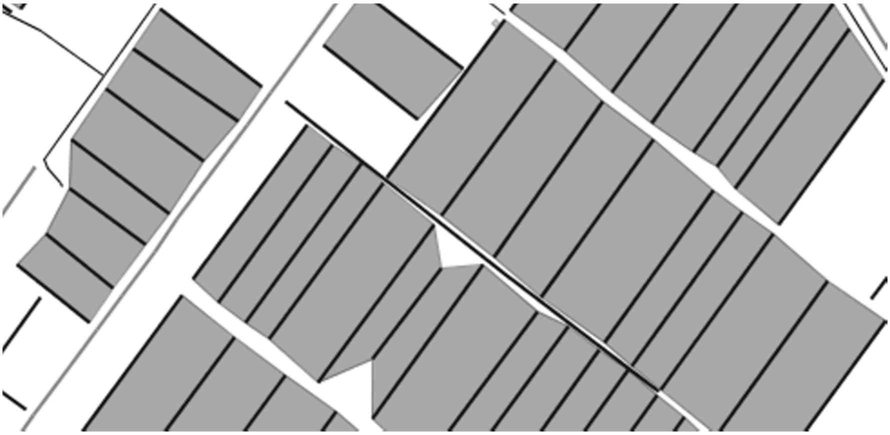

Figure 4: cluster of ditches and their cluster envelope.

The idea behind our algorithm is that the area interested by the presence of ditches should be considered as a “canvas” where we can freely draw the new ditches (as it will be explained later, this is not completely true and this behavior is constrained). The new ditches will run in the same direction of those that are replaced and will be equally spaced, accordingly to a distance parameter SP that is function of the target scale.

It is important to underline that the new ditches that will be drawn are completely new features that are not present in the original dataset: this is what makes this algorithm different from a selection algorithm.

The shape of the “canvas” where to draw the new ditches is obtained calculating a hull or envelope around all the segments of each ditch cluster. To obtain the shape of the “canvas” where to draw the new ditches we chose not to use the convex hull: since the convex hull may not follow closely the shape of the ditches, the resulting canvas could be too broad, enclosing areas that in the original data were not interested by the presence of ditches. Our choice was to be more conservative, in order to minimize the possibility of topological errors while drawing the new ditches: the algorithm that we developed will create a hull connecting all the end points of the ditches in each ditch cluster, thus obtaining a shape that both encloses all the ditches in the ditch cluster and minimizes its area extension. We call this shape “cluster envelope”. Each cluster envelope has its own centroid, boundary and direction - the average direction of the ditch segments it contains.

Once the “canvas” has been set, the new ditches are drawn as following: a line L orthogonal to the envelope direction is traced by its centroid and on that a set of new points P_i, all equally SP spaced, will be created. All the new ditches will be drawn as straight lines, having direction equal to the envelope direction; for every line, only the part inside the envelope will be kept.

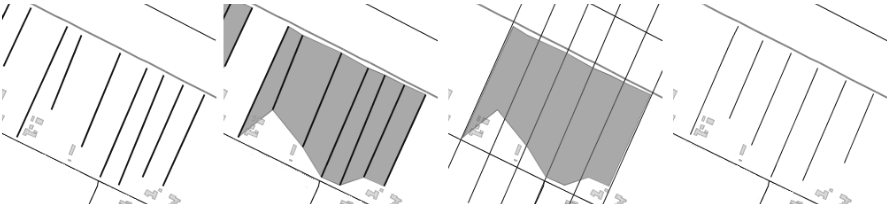

Figure 5: the typification process; from left to right: source data, cluster envelope, the new ditches are drawn, final result.

Every line is drawn by a different point P_i on L. All the original ditches inside the canvas are then replaced by the new pattern of straight lines that are their new typified representation.

Once we know how to draw the new pattern of ditches, the only question left is to find where to draw it. As a first guess, the new pattern of straight lines will be centered on the centroid of the cluster envelope. To distribute evenly the new ditches over the surface of the ditch envelope, the number of points P_i contained in L is counted: if it is an odd number, the new ditches will pass on the centroid, otherwise they will pass at a distance $SP/2$ from it.

To avoid topological errors, this procedure should be extended to take into account eventual objects that are present inside the ditch envelope (e.g. a farm). In this case the center of the new pattern can be shifted along the line L to minimize the occlusion between these objects and the new ditches (see Figure 6).

Also objects surrounding the new pattern can be taken in consideration: the position of the new pattern could be constrained by a buffer of size s on an object surrounding the ditch pattern (e.g. a road); this is equivalent as constraining the new ditches to a minimum distance from these objects.

Once that the presence of constraining objects is found, the algorithm tries to find a better position for the ditches: this is done with a simple iterative procedure that shifts *n* times the pattern along the line *L* of a measure *SP/n*, trying to minimize the intersection between the ditches and the constraining objects. The parameter *n* is set by the user and could be set as *SP/n* being smaller than the map tolerance. If the minimum number of intersections is different from 0, the algorithm uses these objects to crop the new pattern.

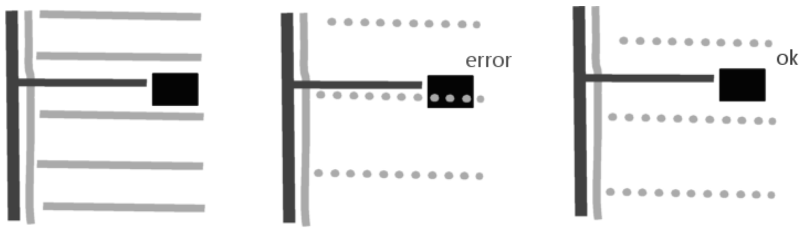

Figure 6: the placement of the new pattern is decided evaluating the position of eventual occluding objects, e.g. buildings; in the figure above, from left to right: original situation, wrong placement of the new pattern (gray dots) as one ditch collides with the building (black), correct placement of the new pattern, obtained moving down the pattern.

To obtain a better result the crop can be done applying a small buffer around the objects, in a similar way to what is done in maps with the application of a halo around names or objects to emphasize.

4- Results and future work

The algorithm was tested on two datasets, one comprising a mountainous territory, the other a plain, the latter being more rich of ditches. In both cases the algorithm produced good results, reducing the number of ditches and creating uniform patterns.

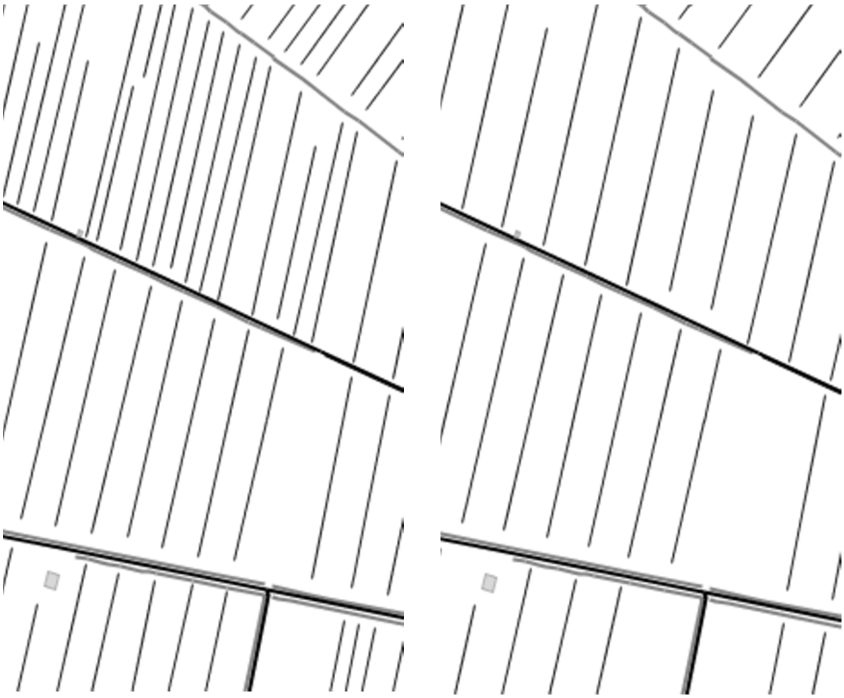

Figure 7: results: on the left source data, on the right generalized data: it is possible to notice a general reduction of the number of ditches and a more regular spacing among them.

The algorithm produced some errors that leave space for future improvements.

A couple of ditches running along the same road might be clustered and typified together, with the new pattern being comprised of only one new ditch, running exactly over the road among the original ditches. Such a situation is not so uncommon and while the present algorithm will crop the new ditch, a better solution should be found.

Another issue arises when the ditches in a group are connected to each other by another ditch or hydrographic element (river, canal): if the shape of the ditch envelope doesn't follow the shape of this connecting element in the new pattern some ditches can be disconnected from it. Furthermore if this element had an end connected to a ditch, this end might become dangling.

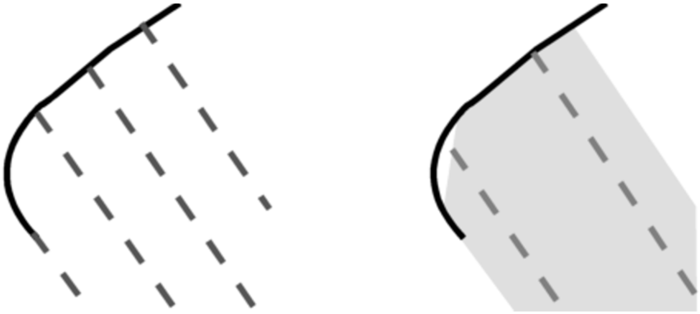

Figure 8: on the left: source data, on the right: generalized data; in black a canal, dashed gray the ditches and light gray the cluster envelope; on the right one of the new ditches has lost the connection with the canal and as a consequence the canal has a dangling edge.

Another feature that can be developed in the future is to aggregate ditch clusters that are spatially close to each other and have similar average direction: once two of such clusters are found, the new patterns will be created as a unique pattern, but using the two cluster envelopes. This would guarantee an even more uniform typification of ditches. The process could also be extended to more than two ditch clusters, working on clusters of ditch clusters.

5- Conclusions

In this paper a novel algorithm for the typification of ditches has been presented. The algorithm is able to identify ditches that are part of a pattern and those that are not, and to create a new representation for the ditches that should be typified. The procedure presented is both simple and effective and is general enough to be applied also to generalization at scale ranges different from the 1:5000 to 1:25000 for which it has been developed.

The concept of canvas, as a constrained area inside which to draw freely new objects, can find application in other contexts.

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Model Generalization of the Hydrography Network in the CARGEN Project

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Abstract

This paper will present a complete process for the generalization of a hydrography network. The process was developed in the Italian CARGEN project, that aims at the generalization of geodatabase data from 1:5000 to 1:25000 scale. The model generalization process relies on the data enrichment of the input model that allowed to re-classify the data according to the output model and to drive the selection assessing the importance of each river. The information gathered is the river width, the Strahler order, the flow direction, the longest path to the furthermost source, the length, the number of branches uphill and the density. The paper will describe how the width of each river was measured, how the classification of the rivers was harmonized, how the flow direction was calculated from the z coordinates, the reconstruction of the river courses and the algorithm for the selection of the rivers both on length and density thresholds.

1- Background and objectives

In 2006 the Department of Information Engineering together with the local government Regione Veneto started a research project to investigate the problem of cartographic generalization. This project, called CARGEN (CARtographic GENeralization), enjoyed the collaboration of the Italian NMA, the IGMI (Istituto Geografico Militare Italiano). The aim of the CARGEN project is to develop algorithms for the cartographic generalization of the IGMI geodatabase DB25 in 1:25000 scale starting from the regional geodatabase GeoDBR in 1:5000 scale.

A. Ruas (ed.), *Advances in Cartography and GIScience. Volume 1: Selection from ICC 2011, Paris*, Lecture Notes in Geoinformation and Cartography, DOI 10.1007/978-3-642-19143-5_25,

The generalization process was set up following a deep analysis of the documentation and the literature; in particular it required a careful manual study of the correspondences between the input and output data models - each of them comprising around 200 feature classes-, and a phase of requirements analysis and a review of all the algorithms developed so far in the field.

With no surprise hydrography is one of the most important feature classes to generalize. Hydrography as a theme comprises many feature classes that describe both man-made and natural features, flowing and still waters, with the network of flowing waters usually represented as a node-edge graph. As one of the most prominent natural themes, hydrography is probably the most complex, for its big number of elements and feature classes, its extension spanning big areas of the dataset and its being in relation with other themes (as transport networks and settlements). The generalization of hydrography is then a complex task, which made it one of the first topics to focus our attention to.

1.1 Input and output data models

The GeoDBR and DB25 data models for hydrography share many similarities: they both distinct watercourses between man-made (canals) and natural (rivers), and classify them on their width. All the flowing waters are represented in a node-edge graph and the broadest of them (both canals and rivers) are also represented as an area.

In the input model there is a 1:1 relation between edges and areas of the broadest watercourses (the area of a broad watercourse is divided into sections, each of them containing one edge of the graph). A node is present at each intersection between two or more edges and also at the intersection with the edges of other graphs, noticeably those of road and railroad networks.

Water bodies like ponds, lakes, swamps and so on are represented in separate feature classes and those of them connected to the hydrography network contain also edges that guarantee their connection to the graph (e.g. edges connecting the inlet and outlet of a lake). Smaller watercourses, as creeks and ditches, are stored in two different feature classes; creeks are part of the hydrography graph while ditches are not.

Both the input and output data models for the feature classes representing flowing waters (rivers and canals) have a simple semantic, comprising only the attributes id, name and hydrography class (a code to differ between the types of rivers or canals based on their width). The flow direction is not present in the data models and this required reconstructing it from other data.

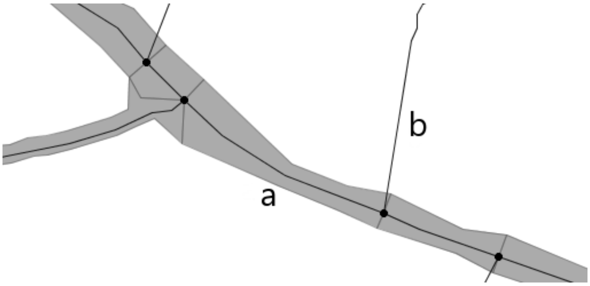

Figure 1: the hydrography network is divided into sections having areal geometry (a) or linear geometry (b).

The differences between the two data models arise comparing the specifications of each feature class. In the input data model (GeoDBR) watercourses are classified only into 2 hydrography class: “narrow” watercourses, represented as a single line, and “broad” watercourses, those wider than 1 meter, represented both with a single line and an area. In the output data model (DB25), they are divided in four hydrography classes: “very small”, “small”, “medium” and “large” watercourses, respectively with width being less than 1 meter, from 1 to 5 meters, from 5 to 20 meters, more than 20 meters; all of them are represented with a line and only the latter class is represented also by an area. As a further specification, the IGMI data model imposes a minimum river and canal length of 250 meters.

1.2 Objectives

Comparing the input and output data models and their specifications, it was clear that the generalization process for the hydrography should pursue two objectives:

- to find a way to classify the watercourses based on their width;

- to apply the 250 meters length threshold to each watercourse, i.e. to prune the network of those branches shorter than this measure.

Furthermore, a third objective was set by the IGMI specifications, requiring that:

- in the regions where the hydrography network is too dense the less important branches should be pruned.

In the following sections we will describe the generalization process of the river network. Water bodies as lakes, ponds, swamps will not be covered; even though the generalization process could be applied also to canals, we will not make explicit reference to them. Also the generalization of ditches is not included in this paper, as they lend themselves to a different generalization approach (i.e. typification)(Savino et al 2011).

1.3 Related work

When we started to develop our process for the hydrography generalization we looked with interest at the experiences done in the past by others. The objective that we pursued was three-folded: first we had to find a way to classify the rivers on their width, second prune the network of the shortest branches and third prune the network of the least important branches in regions where they were too many. A great deal of work on generalization of hydrography can be found in literature, that helped us to set up our generalization process.

(Horton 1945 and Strahler 1952) developed a metric to classify the branches of a river network using a counter that increases when two branches meet. This metric, known as Strahler order, is widely used to enrich the river data models extending the original classification to prune the network (Thomson and Brooks 2002; Touya 2007). To prune the river network many other parameters and thresholds can be used, singularly or in conjunction: density (Stanislawski 2008), water basin (Ai et al. 2006), the upstream drainage area (Stanislawski 2009) or other (Zhang 2007), (Brewer et al. 2009).

As a matter of fact most of the river network generalization algorithms step first through a process of data enrichment and then prune the river network. In the following section we will illustrate the generalization process that we developed: our set up follows some of the ideas and concepts found in literature but also introduces some original ones.

2- Approach and methods

The generalization process that has been implemented can be divided in two parts: the first handles the generalization of the semantic information in order to make it fit the target data model, the second operates on the representation of the data, in order to make it fit the specifications for the target scale.

The semantic generalization requires to measure the width of the rivers in order to re-classify them; this process is followed by an harmonization step that improves the aesthetic quality of the results and corrects some mis-classification errors; the generalization of the representation operates mostly on the geometries, gathering information from the geometric data and using the enriched data to reconstruct the river courses that are then pruned by length and density.

2.1 Width measurement

The width of a river, although being a concept easy to understand, is an ambiguous definition when it has to be transformed in a metric for an algorithm. The width of a river, in fact, is not represented as a single value but it varies along the course of the whole river. Since in our datasets each river is divided in sections, each of them comprising both an area and an edge of the graph passing through it, we decided to measure the width of each section. This task can be accomplished in many ways, more or less precise (e.g. with a perimeter and area ratio): our choice was to develop a simple algorithm, mimicking the manual process of river width measuring. The algorithm to measure the width of each river section area samples the edge in n points equally spaced d meters. For each of these points a line normal to the direction of the edge in the point is drawn and the first couple of intersection points with the boundary of the area are found; the width of the section will be the average of the distances between each couple of intersection points. In our tests, the distance d was set to the value of 15 meters.

Once the width of each section has been calculated, each section can be classified according to the target data model, following the IGMI specifications; if due to model generalization the geometry of a river section has to be collapsed from area to line, the algorithm simply deletes the area and keeps the relative edge.

The choice of averaging the width measures in each section could be questioned: indeed the search for a minimum or maximum value could be a valid alternative too and may provide some more insightful information (e.g. the minimum width is related to the maximum allowed boat size). Anyway our guess was that the average would be a more reliable measure, being robust to eventual local minima or maxima in which our simple algorithm could fall (see Figure 2); furthermore since each river is divided into a new section at every confluence, the size of each section will be more or less constant (the water flowing in or out of it is the same), with the average width then being not too far away from the real minimum and maximum width.

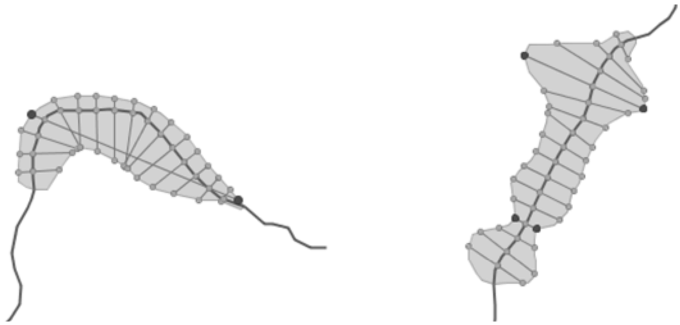

Figure 2: measuring the width of an areal river section may incur in some errors: on the left the normal projected from a point on an "hits" the boundary in two points very far away (dark dots); on the right the intersection points (dark dots) are local minima and maxima; averaging the measures of every section mitigates the influence of these errors on the measured width.

Moreover some errors in our measurement could be tolerated, as our aim was to calculate a reference measure to classify the rivers and not to calculate their exact width.

The simple approach that we set up gives the best approximation of the width of each river section when the shape of its area is mostly regular -i.e. when the river banks run parallel to the graph edge-. Results can be worse for odd shaped sections or sections that are small compared to the parameter *d*. For the former of these issues our guess was that averaging the width measured at each of the n points will mitigate these measurement errors; to solve the latter we set up a harmonization process that will be described next.

2.2 Harmonization

The classification of the river sections, with the consequent collapse from area to line, may lead to unwanted abrupt changes in the representation of the river (see Figure 3c). This may be caused by a wrong evaluation of the width of a river section (e.g. because the section length is similar to the sampling measure *d*) and, as an error, it should be correct; in other cases instead the width assessment is correct but nevertheless the result should be changed as it is aesthetically unpleasant (e.g. see Figure 3d).

The harmonization algorithm is triggered by the following situations:

1. area to line collapse of small sections of braided river;
2. rough appearance of the confluence of an area river section into a line river section,
3. a river represented with a sequence of area, line, area, line sections.

The solution to these problems is to analyze the neighbors of each river section that had been collapsed and to override the new classification or to change the shape of the neighboring areas.

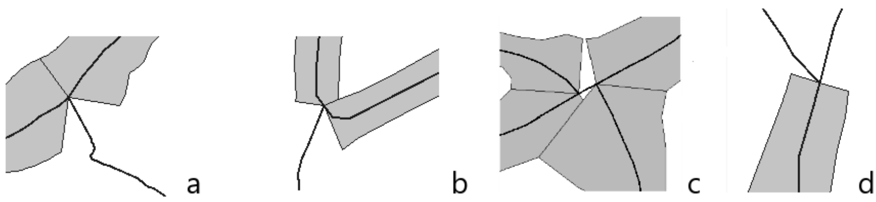

Figure 3: examples of sections that need to be harmonized.

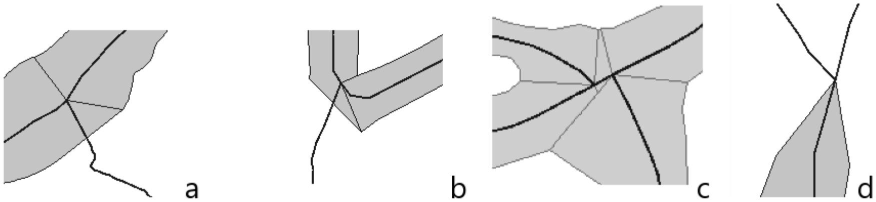

Figure 4: sections after harmonization.

In braided rivers the watercourses are segmented in many sections due to the big number of edge intersections and this results in sections that may be too small to be correctly classified: it might happen then that a small section of a broad river could be classified as a minor river[1], and then collapsed to a line, leaving an empty space (see Figure 3c). In this case the classification of this small section is overridden and the section "upgraded" to "big" river, returning it to its original representation of area river section (see Figure 4c).

Also in normal long streams, the loss of an area due to the collapse to line of an area section could result in a confluence having an "odd" shape: this is the case of a minor river leaving or entering a "big" river or a minor river becoming a "big" river as it flows downhill. In such cases the harmonization algorithm will change the shape of the area river sections touching the minor river in order to assure a smoother representation of the class change (e.g. see Figure 4d).

In some other cases, finally, the generalized river could result in a sequence of line-area-line-area sections; in this case the algorithm iteratively changes the classification of the shortest section to that of the contiguous ones if they are below a length threshold that has been set to 500 meters.

2.3 Pruning

The IGMI specifications for the DB25 require that watercourses shorter than 250 meters should not be acquired. This threshold can not be applied directly to the data because deleting all the edges shorter than 250 meters would disconnect the graph of the river network. This constraint could

[1] We use the term minor river for rivers classified as "very small", "small" or "medium"; i.e. represented only by a line and not also by an area.

neither be translated in deleting all the dangling edges shorter than 250 meters, as this will much probably result in the entire graph to shrink.

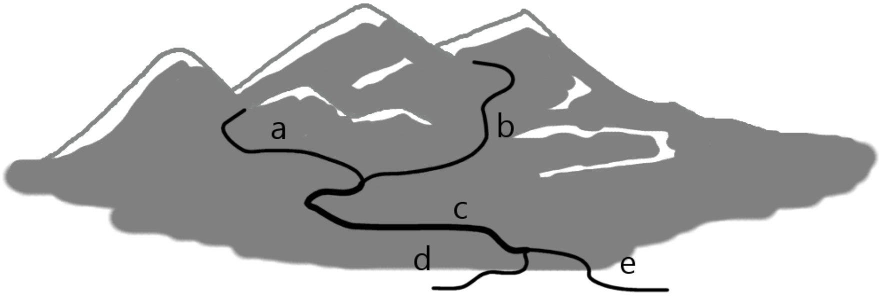

Figure 5: relations between rivers: a and b are siblings, and they are both father of c, that is a child of both a and b; d and e are children of c.

The IGMI specifications also require pruning the network of the least important branches in dense regions. This implies the ability to recognize the importance of each river and compare it. The four different classes of the IGMI data model are not enough for such a task: a new classification is needed, that could take in account other parameters to evaluate the importance of each river.

The solution was to set up a network pruning algorithm able to reconstruct the course of each river, to enrich the data in order to classify the rivers by importance and to prune the network, first applying the length threshold and after removing the least important branches in the densest regions of it.

All these considerations lead us to develop a pruning algorithm that follows these steps:

1. reconstruction of flow direction,
2. data enrichment,
3. river course reconstruction,
4. short rivers pruning,
5. dense rivers pruning.

2.3.1 Reconstruction of flow direction

The first step to reconstruct the course of a river from its sections is to know the direction that water is flowing to.

Without this piece of information it is impossible to say, at a branch, if two sections are converging in one or one is branching in two. Flow direction is usually embedded in the hydrography data models either implicitly (e.g. the flow direction follows the order of the points of each edge) or explicitly (i.e. as an attribute). In the case the flow direction is not known, it can be calculated from the z-coordinate: this was the case with our input data.

The algorithm to evaluate the flow direction in each section of the river network iteratively analyzes every edge and for every current edge tries to classify the edges touching it into fathers, children and siblings, comparing the z-coordinate of the vertices of each edge.

For the current edge the algorithm finds the highest point *cpMax* and the lowest point *cpMin*; the same is done for all the edges connected to it (*pMax* and *pMin* respectively):

- *if an edge has pMax > cpMax and it is connected to c on the point cpMax, it is a father,*
- *if an edge has pMin < cpMin and it is connected to c on the point cpMin, it is a child,*
- *if an edge has pMax > cpMin and it is connected to c on the point cpMin, it is a sibling,*
- *if an edge has pMin < cpMax and it is connected to c on the point cpMax, it is a sibling.*

Furthermore,

- *if c doesn't have any father, it is a source,*
- *if c doesn't have any children, it is a drain,*
- *the flow direction of c is from cpMax to cpMin.*

It is common that in cartographic datasets the values on the *z* plane have a lower precision than the *x, y* data. For this reason the simple model above had to be expanded to include two special cases:

- flat edges
- uphill edges

A flat edge happens when *cpMax* = *cpMin*. This may be caused when a river flows on an almost flat surface (e.g. a big plain) or the edge is an artificial connector inside a water body (e.g. in a lake), or the edge is too short to record a difference in the *z* values of its points. Flat edges are quite common in braided rivers where the slope is not very steep and the length of each section is small.

An uphill edge happens when an error in the z values of an edge turns its flow direction uphill. This error, caused by a high tolerance on the z values accuracy, is troublesome to detect. In an uphill edge, *cpMax* and *cpMin* are inverted and fathers and children edges are classified as siblings, actually disconnecting the graph and preventing the generalization algorithm to work on all the edges down hill from the current edge.

The algorithm tries to detect the uphill edges: if an edge has only siblings, the connected edges are classified again inverting *cpMax* and *cpMin* and if this new classification provides at least one father and one child, the edge is flagged as uphill and the latter classification is kept.

Unfortunately not all the uphill edges can be detected; since flat edges are much easier to treat, it has been chosen to reduce the number of possible uphill edges using a z threshold *zT*: if $cpMax - cpMin < zT$ then the edge is classified as flat. This results in many edges, both uphill and correct, being treated as flat: we somehow traded many good edges and some bad ones for plenty of flat edges, but this is definitely worthy, as flat edges will not usually block the generalization process.

Even though it is not possible to set the flow direction on a flat edge, it is still possible to classify the connected edges following the first six of the rules above. One more rule is used to deal with flat edges:

- if *c* is connected to a flat edge *f*, all the edges connected to *f* should be considered connected also to *c*

This rule virtually collapses each flat edge to a point, connecting together its fathers and children. In a group of connected flat edges like those inside a lake, this rule means that the inlets of the lake are directly connected to its outlet.

With the eight rules listed above and no uphill edges above the z threshold *zT* it is possible to find in the river network sources and drains and to find, for each edge, its fathers and children.

2.3.2 Data enrichment

The data enrichment process collects, for each edge *i*, the following information:

- S_i : the Strahler order of the edge *i*
- L_i : the total distance to the furthest source up hill
- B_i : the total number of branches up hill

The procedure is top-down: starting from one of the sources, the algorithm follows the flow direction down hill, calculating L_i for each edge (S_i and B_i will not change until another edge is met). If the current edge *c* has two fathers *a,b*, the values for *c* will be calculated as follows:

$$S_c = max(S_a, S_b) \qquad if\ S_a\ != S_b$$
$$S_c = S_a +1 \qquad otherwise$$

$$L_c = max\ (L_a,L_b) + length(c)$$
$$B_c = max\ (B_a,B_b) + 1$$

The next current edge will be one of the children of *c*. The algorithm randomly chooses a source edge to start from: as a consequence it may happen that when two edges meet, one of them has not been enriched yet. In such a case the algorithm will pick another source and start the procedure from there. The same happens if the current edge has not any child. The process will end when all the edges have been enriched.

2.3.3 River course reconstruction

The procedure is bottom-up: starting from the drain with the highest Strahler order, the algorithm follows the flow direction up hill choosing as the next current edge one of the fathers edge of the current edge. The next current edge is chosen after assigning a score to each father that depends on the name of the edge, the IGMI hydrography class it belongs to (among "very small", "small", "medium" and "big" river), the number *L*, the number *B* and its width.

The scoring procedure will assign a higher score to a father edge if:

- it has the same name of the current edge,

- it belongs to the highest IGMI hydrography class,
- it has the highest value *L,*
- it has the highest value *B,*
- it has the largest width.

The score will be decreased if the father edge:

- it has a different name from the current edge,
- it has a lower Strahler order than the current edge.

The idea behind this scoring is to try to find, at each fork, the most relevant branch of the river. The scoring mechanism of course is not perfect but our aim is not to reconstruct perfectly the course of a river, but to have a good approximation of it.

If the current edge has not any father edge, the course of this river has been reconstructed to its source: all the edges touched have been flagged and added with a unique id; the procedure is then repeated, starting from the edge with the highest Strahler order among those not yet flagged.

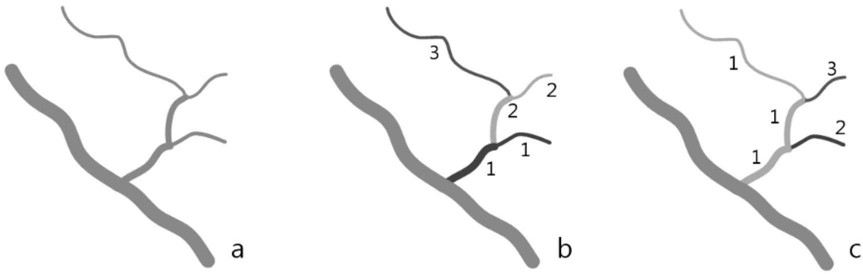

Figure 6: reconstructing the river courses; a) source data, b) a possible reconstruction, c) the one chosen by the algorithm (numbers indicate to which course each section belongs to); the reconstruction tries to create long courses; in c the small courses 2 and 3 are likely to be deleted because they are too short; in b if the course 1 was deleted because too short, also 2 and 3 would be deleted thus pruning the network too much.

2.3.4 Short rivers pruning

Once that the course of each river has been reconstructed it is straight forward to apply the IGMI minimum length threshold: the length of every river course is calculated as the sum of all its sections and if the length is smaller than the threshold all the sections belonging to it are deleted.

Recursively, every river stemming from a river that has been deleted is deleted too. The reconstruction process avoids that a long river course could stem from a short one: the scoring in fact tends to build courses using the longest branches (see Figure 6).

2.3.5 Dense rivers pruning

The last step of the process is to detect the regions where rivers are too dense (rivers are too close to each other) and to delete the less important of them. The algorithm that we developed uses buffers to find which rivers are too close to others and uses the same scoring procedure explained before to assess the importance of a river to decide whether to delete it or not.

A buffer is built around each river course and the percentage *P* of the area of this buffer that is covered by other buffers is calculated and assigned to the river course (the percentage is the ratio between covered area and total area). All the river courses are then decreasingly ordered by the percentage *P*: the higher the value of *P* and the more this river course is close to other rivers courses. Starting from the highest *P*, the importance of every river course is evaluated and, if below certain parameters, it is deemed not important and it is deleted. When a river course is deleted, all the river sections comprising it are deleted, its buffer is deleted, and the values of *P* of the neighboring river courses are updated accordingly; the same happens to every river course stemming from it.

The process continues until the highest value of *P* is below a certain threshold *Pmax* or there are no more river courses to be deleted over that threshold (i.e. all the river courses having *P* bigger than the threshold are deemed too important to be deleted).

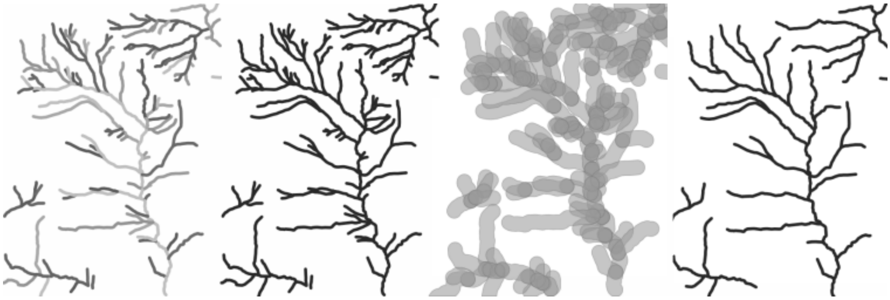

Figure 7: the four steps in the pruning process; from left to right: river course reconstruction (different color means different course), pruning on length, calculation of buffers and overlapping regions, pruning on density.

After some tests, we found that good values for the parameters are: *Pmax* = 50%, buffer size = 120m. A threshold on the values *S*, *L* and *B* of each river that is candidate to be deleted is used to decide whether this river is important or it can be pruned; these thresholds, found empirically for the 1:25000 scale, are: $S < 3$, $L < 1000$ meters, $B < 4$. Table 1 lists all the parameters used in the generalization process.

Parameter	Value
d sampling for width measurement	15 m
Minimum dangling branch length	250 m
Threshold contiguous area-line-area sections	500 m
Buffer size for density pruning	120 m
Pmax percentage of buffer overlap	50%
S max Strahler order	3
L length to furthest source	1000 m
B number of branches uphill	4

Table 1: Parameters used in the generalization process.

3- Results

The overall process has been tested on a sample dataset representing a mountainous area of the Italian Alps, enclosing around 1300 sq km and 10000 river sections. The results have been visually inspected by expert cartographers and found generally good. Table 2 lists the times elapsed by each step of the generalization process.

Algorithm	Time (msec)
River width and re-classification	3053453
River flow	785187
Strahler order	140954
Data enrichment	299218
River course	1054672
Pruning	1427500
Total	6760984

Table 2: Time elapsed by each step of the generalization process in msec on a dual Intel Xeon 2.0 Ghz CPU with 3 Gb RAM; the total time amounts to 1 hour 52 minutes 40 sec.

Figure 8: results of the network pruning: left source data, right generalized data.

The flow direction reconstruction algorithm worked very well but in one of our tests it could not provide a complete reconstruction due to the high number of flat and uphill sections: despite some little improvements that can be made on the algorithm, this proves once again that to have a good generalization it is important to have a good input data; in our case in the absence of a directed graph (i.e. having the flow direction of the streams) the z coordinate of the data must not contain errors. The reconstructed river courses show in some cases sharp bends: it is under investigation the use of "good continuity" as a parameter in the river course reconstruction algorithm (e.g. see (Touya 2007)).

The pruning algorithm was found to perform well, even though the speed of the density pruning could be probably improved. The pruning solved also some braided streams sections removing the shorter branches. The performances of the pruning algorithms are given in Table 3.

The generalization of braided sections of rivers needs further investigation, as the first attempts did not produce satisfactory results. In one of our sample datasets the presence of too many flat edges inside braided sections of rivers caused the river course reconstruction to fail; the only viable solution was then to exclude these sections from the pruning.

	Source	Generalized	Length	Density
River sections	9786	6290	2112	1474
River courses	5674	2530	2053	1091
Total length (meters)	3420245	2720324	299766	400155
Average length per section (meters)	349	432	142	366

Table 3: results of the generalization process; the third and fourth columns indicate respectively the numbers relative to the rivers pruned by length and density thresholds.

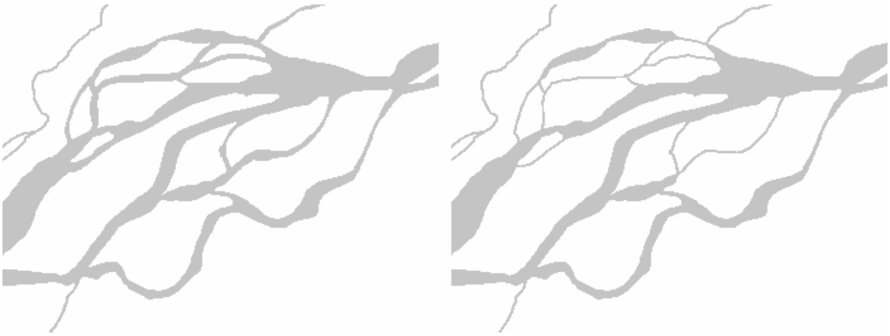

Figure 9: results of the generalization: left source data, right generalized data (only re-classified, not pruned).

This was achieved finding the cycles in the hydrography graph (the edges forming a cycle are part of a braided stream). The braided parts of the rivers then are not pruned but only re-classified. We are currently investigating a generalization strategy that detects the areas enclosed between the branches of a braided river and typifies the clusters of these areas either by collapsing each area to a line, or by merging neighboring ones.

4- Conclusions and future plans

In this paper a complete process for model generalization of a hydrographic network was described.

The algorithms that have been developed are explained in details; in particular the data enrichment process that enabled to perform the generalization, the reconstruction of the river courses and the assessment of their importance; the technique used to reconstruct the flow direction of rivers from the z-coordinate, able to handle flat rivers and also some errors in the z-coordinates; finally the pruning algorithm that removes river courses applying both a length and a density threshold.

The overall process has been applied to the generalization of rivers from 1:5000 to 1:25000 scale and the test results, visually inspected by cartographers, obtained a good evaluation.

Of course our work is not complete, as many topics have not been covered yet.

How to simplify the outline of the area and lines representing the rivers has not been treated; despite the fact that we do not expect that at our scales the geometry simplification would change too much the representation, this topic should be integrated in the process. Also the interaction with other themes (e.g. roads and railroads but also contour lines and banks) should be studied to develop a complete hydrography generalization process.

A big question that is left open is the problem of partitioning; some recent works (Ai et al 2006), (Chaudhry and Mackaness 2008) suggest that this can be done relying on the division in water basins and we will soon investigate this approach.

Another research question is whether this set up, especially the pruning algorithm, is general enough to be applied to generalize data at different (smaller) scales simply changing some parameters: at the moment we are testing the algorithm to prune the network to 1:100000 scale. Also, we believe that the density pruning might be applied to other themes (e.g. roads, railroads).

Another open question is if the performance of the algorithm could change using a directed graph (i.e. having the flowing direction of the streams): it is our guess that in this case the generalization of braided rivers would be different.

Finally it would be interesting to evaluate automatically the results of our approach comparing them to data that has been manually generalized using some metric (e.g. the CLC (Stanislawski et al. 2009)).

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Evaluation of Properties to determine the Importance of individual Roads for Map Generalization

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Abstract

Many researchers have paid much attention to the importance of individual roads for various applications such as traffic flow analysis and road network generalization. This paper gives a comparative analysis of different properties to determine the importance of individual roads for road network generalization purpose. These properties include one geometric property (length); three topological properties (degree, closeness and betweenness) and one thematic property (road class). Two representative selective omission approaches (stroke-based selection and mesh density-based elimination) are implemented to generalize road network. For each approach, different properties are respectively used to determine the importance of individual roads. The road network of Hong Kong Island is used as study area for testing and two measures (similarity and connectivity) are employed to evaluate the selections. Results show that, when the stroke-based selection approach is implemented, using length performs best in determining the importance of individual roads, and using betweenness or closeness performs well in preserving the connectivity of the retained network; when the mesh density-based elimination approach is implemented, all these properties have quite similar selections.

1- Introduction

Road data is a type of infrastructural geographical data and all roads in a given area form a network. Study of road networks has been a topic of

A. Ruas (ed.), *Advances in Cartography and GIScience. Volume 1: Selection from ICC 2011, Paris*, Lecture Notes in Geoinformation and Cartography, DOI 10.1007/978-3-642-19143-5_26,

interest to many groups of people such as transportation engineers, traffic administrators and geographers. In geographical information science, many researchers have paid much attention to the importance of individual roads for various applications such as pedestrians or vehicle movement analysis (Hillier and Hanson 1984; Hillier et al. 1993) and road network generalization (Mackaness and Beard 1993; Mackaness 1995; Thomson and Richardson 1995).

Road network generalization which is caused by scale change aims to abstract the representation of road networks by reducing details. When the map scale is reduced, the available space on map to represent the same amount of information is also reduced. Therefore, it's essential to determine which roads are still needed to be represented on map. A series of operators, such as selective omission, simplification, and displacement (Li 2006) may be involved. Among these operators, selective omission which is defined as a processing of selecting more important roads is one of the most essential ones.

There have been several approaches proposed for the selective omission operator. Due to the fact that a road network in the database is always viewed as consisting of a number of road intersections and road segments, it is natural to implement selective omission by analyzing the importance of road intersections (Mackaness and Machechnie 1999) or road segments (Mackaness and Beard 1993; Mackaness 1995; Thomson and Richardson 1995; Kreveld and Peschier 1998). However, a long road may be represented by many road segments. This may constitute a problem for some spatial analysis because the results obtained from analysis of the whole road could be different from those obtained from segment-based analysis. That is, sometimes, to re-build individual roads in the road database is very desirable. Thomson and Richardson (1999) adopted the concept of "stroke" which was first defined as "a set of one or more arcs in a non-branching, connected chain". This concept makes selective omission based on the importance of individual roads become possible. More importantly, in the road network, the property of an individual road seems more sensible than the one of a road segment. For instance, normally a long road is more important than a short one, but it is hard to say a longer road segment is more important.

The importance of individual road/stroke may be determined according to different properties. Chaudhry and Mackaness (2001) proposed stroke length. All the strokes were ranked based on their lengths. Then the road network could be abstracted by simply selecting long strokes. Zhang

(2004) further adopted the concept of stroke connectivity (i.e. the number of connections of one stroke with other strokes). Jiang and Claramunt (2004) used street name to build strokes and ranked them respectively according to three different topological centralities, i.e. degree, closeness and betweenness. Jiang and Harrie (2004) considered multiple attributes which included topological, geometric and thematic properties of streets by applying a self-organizing map (SOM). Chen and his collaborators (2009) presented another selective omission approach which is based on eliminating unimportant road segments by taking "mesh density" into consideration. However, the importance of each road segment was still based on the importance of its own stroke which was determined in consideration of road class, stroke length and stroke connectivity.

In summary, the properties to determine the importance of each stroke can be classified into three types, geometric properties (e.g. length), topological properties (e.g. centralities) and thematic properties (e.g. road class). Normally, the selections are different by applying different properties. It can be noted that there is not much literature about comparing the differences of applying various properties for road network generalization which is the main concern of our study.

This paper is structured as follows. Section 2 introduces basic concepts of investigated properties to determine the importance of individual roads. Section 3 gives an experimental design to evaluate of various properties. Section 4 presents the experimental results and analyses. Finally, results are discussed in section 5 and conclusions are made in section 6.

2- Properties to determine the importance of individual roads

As reviewed in the previous section, there could be a number of properties which can be classified into three types, geometric, topological and thematic ones. This section will introduce them in detail.

2.1 Geometric properties

"Length and width are two important geometric properties. Common sense tells us that long and wide roads tend to be more important". (Jiang and

Harrie 2004) In practice, a road network in the database is often represented by single lines, especially at middle or small scale dataset. Therefore, length is more widely used than width. Normally the longer the road length, the more important the road is.

2.2 Topological properties

A series of topological properties has been proposed to detect network characteristics. Degree, closeness and betweenness are just three of them and they can be used to determine the important nodes or links within the network such as social network (Freeman 1979), street network (Jiang and Claramunt 2004; Crucitti et al. 2006) and so forth. In the road network, in order to calculate the importance of individual road, it is needed to represent the road network as a dual graph in which individual roads are taken as nodes and road intersections are taken as links (Porta et al. 2006). And the importance of each road can be respectively calculated according to three properties as follows (Jiang and Harrie 2004):

Degree measures the number of roads that interconnect a given road. Normally the higher the degree, the more important the given road is. In a dual graph, degree is the number of nodes that link a given node. Formally, the degree centrality for a given node *i* is defined by:

$$C_i^D = \sum_{j \in N} a_{ij} \tag{1}$$

where N is the total number of nodes in the graph, a_{ij} is 1 if there is a link between node i and node j, and 0 otherwise.

Closeness measures the smallest number of links from a given road to all other roads. Normally the higher the closeness, the more important the given road is. In a dual graph, it is the shortest distance from a given node to all other nodes. It is defined by:

$$C_i^C = \frac{N-1}{\sum_{j \in N, j \neq i} d_{ij}} \tag{2}$$

where d_{ij} is the shortest path length between i and j.

Betweenness measures to what extent a given road is between roads. Normally the higher the betweenness, the more important the given road is. In a dual graph, it reflects to what extent a node is located in between the paths that connect pairs of nodes in a network. It is defined by

$$C_i^B = \frac{1}{(N-1)(N-2)} \sum_{j,k \in N; j \neq k; k \neq i} \frac{n_{jk}(i)}{n_{jk}} \tag{3}$$

where n_{jk} is the number of shortest paths from j to k, and $n_{jk}(i)$ is the number of shortest paths from j to k that pass through i.

2.3 Thematic properties

Thematic properties (or attributes) always exist in the database, if any. A number of thematic properties may be used to determine the importance of individual roads. Li and Choi (2002) investigated six different ones which were road type (or class), length, number of lanes, number of traffic directions, width and connectivity. From our observations, in most cases, road class is often available and other properties may be unavailable.

3- An experimental design for evaluation of various properties

Since a number of properties to determine the importance of individual roads have been introduced, it is nature to follow up with an evaluation of them to see which one(s) may produce better results for road network generalization. This section will give an experimental design for evaluation.

3.1 Properties to be tested

In the experiment, five different properties which include:

- one geometric property: length,
- three topological properties: degree, closeness and betweenness, and
- one thematic property: road class

are used for comparative testing.

3.2 Experimental data

The digitized road network of Hong Kong Island is used as the experimental data (see figure 1). Original road segments represented by double-lines were collapsed into single lines. Road class (including main road and secondary road) and road name were manually added to each road segment according to the available thematic attributes in the database.

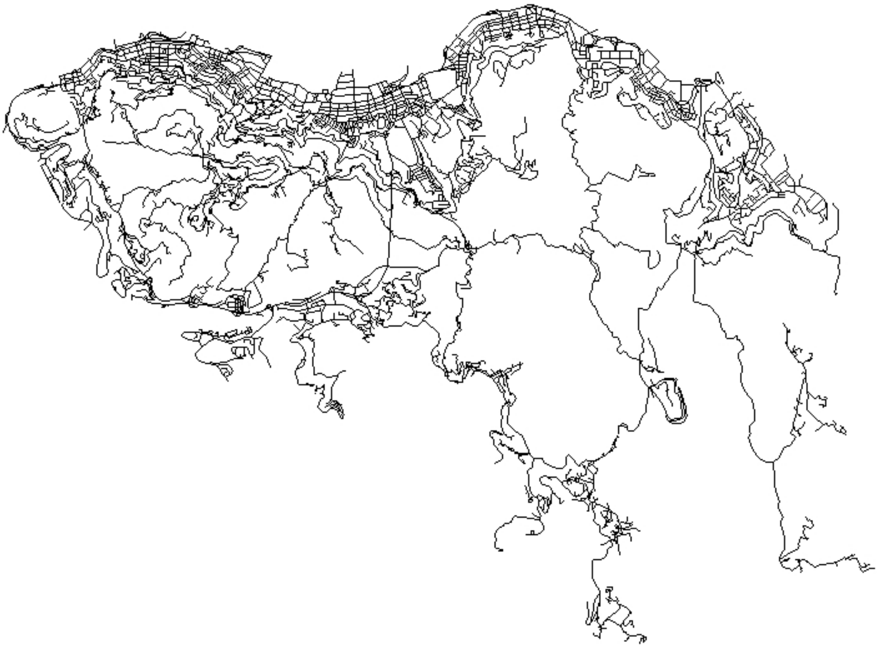

Figure 1: The road network of Hong Kong Island

3.3 Experimental approaches

Selective omission operator is implemented to check whether important individual roads within a road network can be retained. To be specific, in the experiment, two representative selective omission approaches, i.e. stroke-based selection and mesh density-based elimination are used. Following is a brief introduction of these two approaches.

Stroke-based selection: this approach, first proposed by Thomson and Richardson (1999), had two steps, *build stroke* and *order stroke*.

1. *Build stroke:* To concatenate continuous and smooth network arcs as a whole. Several criteria may be used. It was found from our previous research that, when road class, road name and the every-best-fit (a geometric criterion named by Jiang and his collaborators (2008)) are combined together, the built strokes can have a better result. To be specific, road segments with the same road class are first concatenated together. If road segments at an intersection are all with the same class, road names are then used to determine the concatenation. If road segments at an intersection are all with the same road name or all with different road names, every-best-fit is finally employed to determine the concatenation.
2. *Order stroke:* After strokes are built, the importance of each stroke can be calculated according to various properties. And stokes may be ranked in a descending order. Selective omission becomes as simple as selecting a number of strokes ranked ahead. And different rankings result in different selections.

Mesh density-based elimination: this approach was proposed by Chen and his collaborators (2009). In this approach, road network is abstracted by eliminating unimportant road segments rather than selecting important ones. In a road network, the mesh (i.e. a close region surrounded by several road segments) with the maximum density is detected. And bounding road segments of the mesh with the least importance are eliminated. The importance of each road segment is determined according to the importance of its own stroke (each road segment can be belonged to a unique stroke). This processing is repeated until no mesh is left.

3.4 Experimental benchmarks

The aim of this research is for road network generalization, thus the selection results are compared with maps at different scales. The digital map at 1:20,000 scale is used as source data to which selection omission operator is implemented. And other smaller scales (1:50,000, 1:10,000 and 1:200,000 scales) produced by the Hong Kong Land Department are used as benchmarks for evaluation.

3.5 Measures for evaluation

Two measures, *Similarity* and *Connectivity* are used to evaluate each selection.

Similarity: is a critical index which has been used to evaluate the similarity of two graphs or chemical structures (Tversky 1977; Willett 1998). Always the higher the similarity value, the more consistent two graphs are. In the experiment, similarity is used to measure the consistency between the automated selection and the corresponding benchmark (i.e. the map produced by the Hong Kong Land Department at different scales). A value can be calculated according to Formula (4).

$$Similarity = \frac{A \cap B}{A + B - A \cap B} \tag{4}$$

where, A denote the length of retained roads in the selection; B denote the length of retained roads in the benchmark; and $A \cap B$ denote the length of their common retained roads. The maximum similarity is equal to 1.

Connectivity: is one of the basic concepts in graph theory. In a graph, two vertices i and j are connected if they have a path to connect with them. In the experiment, *connectivity* is used to measure how well the connectivity of a retained road network. It can be calculated according to Formula (5).

$$Connectivity = \frac{\sum_{i \in N} \sum_{j \in N; j \neq i} a_{ij}}{N(N-1)} \tag{5}$$

where a_{ij} has two values: 1 and 0. It is equal to 1 only when there are paths from i to j. Otherwise, it is equal to 0; and N is the total number of links. The *connectivity* value is normalized into 0 to 1. The higher the *connectivity* value, the better the connectivity of a network. Only when the *connectivity* value is equal to 1, all roads within the network can be well connected. Figure 4 shows six schematic networks with different *connectivity* values.

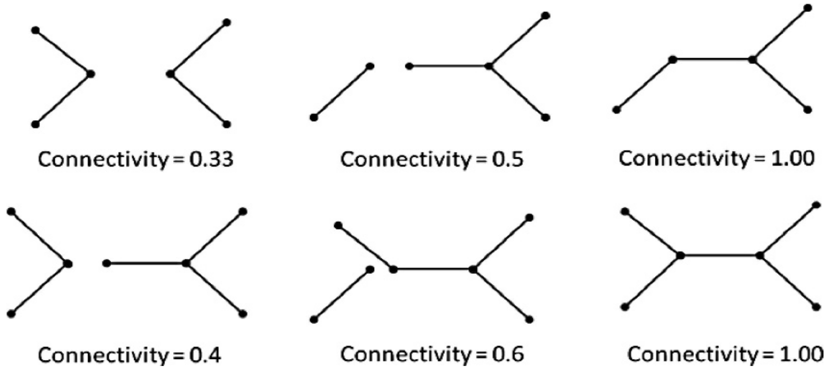

Figure 2: Examples of six schematic networks with different connectivity values

4- Experimental testing of properties

A series of experiments was carried out to evaluate various properties by implementing two selective omission approaches, stroke-based selection and mesh density-based elimination.

4.1 Stroke-based selection to testing properties

Strokes were selected according to their importance from the highest one to the lowest one. Once two or more strokes had the same importance, all of them were selected in the meanwhile. For each selection, *similarity* and *connectivity* were calculated.

4.1.1 Evaluation of similarity

Figure 3 plot a series of relationships between the number of selected strokes and the similarity by using five different properties. Only the similarity compared with the corresponding benchmark at 1:200,000 scale is list here. The distributions for other scales are very similar.

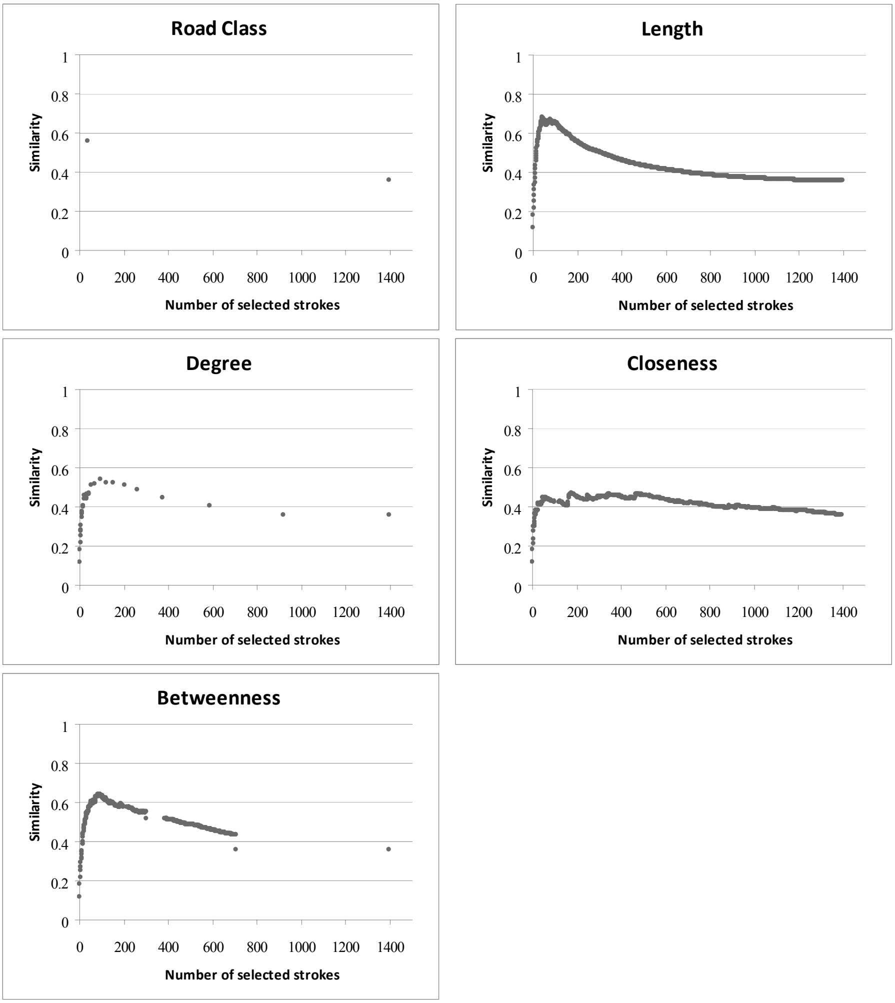

Figure 3: The distributions of similarity by using five properties

These distributions in figure 3 show that, at first, the value of similarity increases quickly along with an increasing of the number of selected strokes. It illustrates that most of the selected strokes are also retained in the corresponding benchmark. Then, the value of similarity begins to decrease after passing a peak (or a maximum value). This means some unretained strokes (in the corresponding benchmark) are also selected.

Further, it is found that there are only two sample points when using road class. It is because that this experimental data only has two different road classes, main road and secondary road. Obviously, it has more sample points by using length. Normally, strokes all have different road lengths. Using topological propetries can also have more sample points than using road class but less than using length. Thus it is possible for two or more strokes with the same topological importance in the road network. For example, the dead end road only has one connection with other roads, and thus its degree is equal to 1; also it is not used as a link inbetween the shortest path of other two roads, its betweenness is equal to 0. However, length is more effective to distinguish the different importance of dead end roads.

In each distribution, the maximum similarity reflects the goodness of using a certain property. Table 1 lists the maximum similarity of using five different properties.

Properties	Maximum similarity		
	1:50K	1:100K	1:200K
Road class	0.808	0.607	0.560
Length	**0.847**	**0.773**	**0.680**
Degree	0.808	0.658	0.539
Closeness	0.808	0.607	0.468
Betweenness	0.808	0.686	0.642

Table 1: The maximum similarity of using five properties

In most cases, the maximum similarity is above 0.6. It seems that all the five properties somehow can be used to determine the importance of individual roads. Obviously, length property performs better than other ones. Among three topological properties, betweenness property performs a little better than the other two.

4.1.2 Evaluation of connectivity

Figure 4: Plot a series of relationships between the number of selected strokes and the connectivity of the retained network.

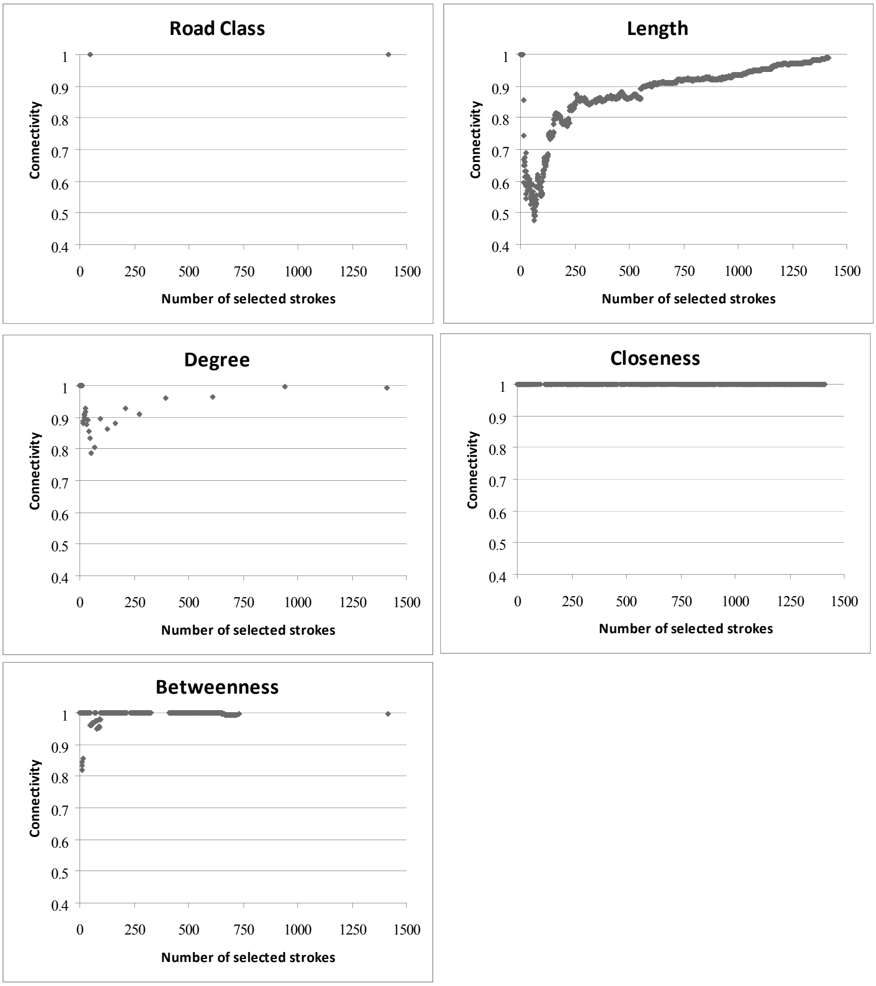

Figure 4: Plot a series of relationships between the number of selected strokes and the connectivity of the retained network. The distributions of connectivity by using five properties

We can see that the retained network is well connected (in most cases, the connectity values are equal to 1) by using road class, closeness or betweenness, but it may be disconnected by using length or degree. It is because that road length is only a geometric property, and no any topological information within the network is considered by calculating the length. The number of connections of a given road is considered by calculating the degree. Thus degree property performs a little better than length. And a more complex topological infromation, the shortest path within the road netowrk, is considered by calculating both closeness and betweenness. Therefore, closeness and betweenness properties perform better.

4.2 Mesh density-based elimination to testing properties

Due to the reason that it's common for a mesh to have bounding road segments all with the same road class, properties except road class were used to determine the importance of each stroke. In each elimination, *similarity* was calculated. Since some road segments (such as dead end roads or tree-like road patterns) did not belong to a boundary of any mesh, their lengths were not taken into consideration in calculation of the similarity.

4.2.1 Evaluation of similarity

Figure 5: plot the relationships between the times to elimination and similarities. The same as before, only the similarity compared with the corresponding benchmark at 1:200,000 scale is list here.

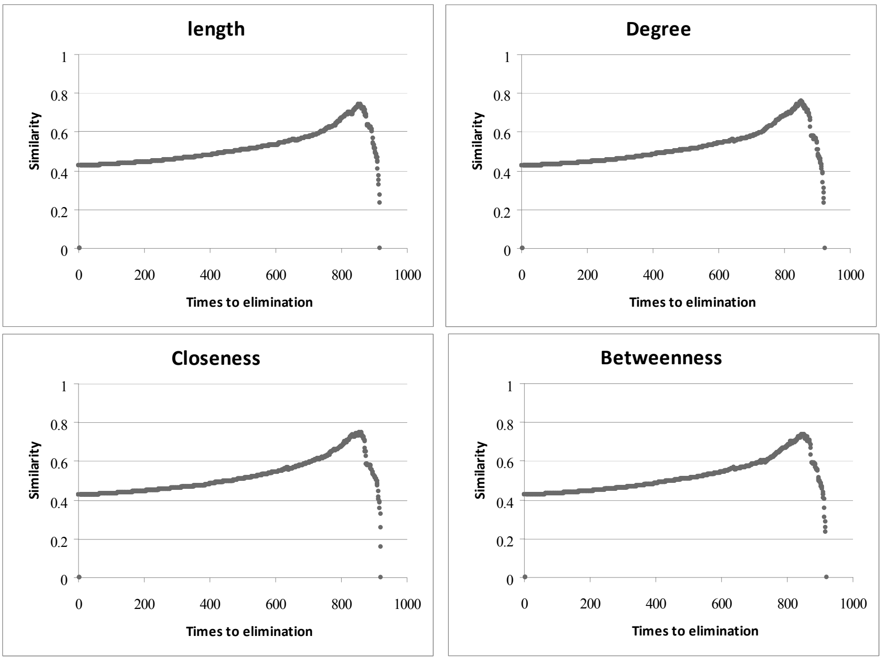

Figure 5: The distributions of similarity by using four properties

The distributions in figure 5 show an opposite tendency with those in figure 3. The value of similarity increases slowly. After passing a peak, the value of similarity begins to decrease sharply. This is because the mesh density-based elimination approach implements an opposite processing compared with the stroke-based selection approach.

Furthermore, the distributions are quite similar in despite of using different properties. It is because that, in each elimination, only several strokes (i.e. those bounding strokes of a mesh) are involved Tto be ranked. Thus it has more probabilities for these strokes to have the same ranking in despite of using different properties. Table 2 lists the maximum similarity of using four properties.

Properties	Maximum similarity		
	1:50K	1:100K	1:200K
Length	0.871	0.779	0.742
Degree	0.870	0.782	0.759
Closeness	0.873	0.767	0.747
Betweenness	0.870	0.780	0.738

Table 2: The maximum similarity of using four properties

Results in Table 2 show that the similarities of using four properties are very similar. Using length does not have obvious advantages any more. It may be because the dead end roads which do not belong to a boundary of any mesh are not involved in calculation of the similarity. And using degree property seems to perform a little better.

4.2.2 Evaluation of connectivity

As stated by Chen and his collaborators (2009), "a mesh is a loop, when one or more of its segments are omitted, the remainder becomes part of a new larger loop formed by one or one originally adjoining meshes". Therefore, when the mesh density-based elimination approach is implemented, the connectivity of the retained network can be preserved in despite of using different properties.

5- Discussion

This paper gave a comparative analysis of using five different properties to determine the importance of individual roads. However, each property was only considered independently. It is also possible to combine several properties together. One problem of this combination is that the appropriate weights are not easy to be determined. More importantly, even using the combination strategy, there is no obvious improvement. Following is an example to illustrate it.

In this example, the road network was generalized by implementing the stroke-based selection approach and the importance of each stroke was determined according to an equal weighted combination of length and betweenness. Results show that the maximum similarity of using an equal weighted combination falls in between the values of using individual properties (see table 3). This characteristic is also validated in calculation of the connectivity.

Properties	Maximum similarity		
	1:50K	1:100K	1:200K
Length	**0.847**	**0.773**	**0.680**
Betweenness	0.808	0.686	0.642
Length & Betweenness	0.840	0.770	0.674

Table 3: The maximum similarity of using an equal weighted combination

6- Conclusion

This paper reported a comparative analysis of various properties to determine the importance of individual roads for road network generalization. These properties include one geometric property, i.e. length; three topological properties, i.e. degree, closeness and betweenness and one thematic property, i.e. road class. Two representative selective omission approaches, stroke-based selection and mesh density-based elimination were implemented to generalize the road network. For each approach, five different properties were respectively used to determine the importance of strokes. The road network of Hong Kong Island was used for testing and two measures, similarity and connectivity were employed to evaluate the selection results. The results show:

- When the stroke-based selection approach is implemented, length property performs best in distinguishing the different importance of all the strokes, but performs worst in preserving the connectivity of the retained network; Both betweenness and closeness perform best in preserving the connectivity of the retained road network, and betweenenss performs better than the other two topological properties in determining the importance of strokes.
- When the mesh density-based elimination approach is implemented, length and three topological properties have similar performances in determining the importance of strokes and degree property seems to perform a little better than others. Also, the connectivity of the retained network can always be preserved by using this approach.

In future work, other possible properties will be investigated and also other measures are needed to give a more reasonable evaluation of these properties.

Acknowledgments

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A multi-agent System Approach for Feature-driven Generalization of isobathymetric Line

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Abstract

Generalization is an important branch in cartography. This process abstracts a map for emphasizing important items and increasing its legibility. On a nautical chart, the purpose is also to emphasize navigational hazards and main navigation routes. Therefore, the cartographer not only adapts the amount of information to the scale of the chart but also selects the information according to the types of features on the seabed and their importance to the navigator. Features are characterized by the isobaths. Methods usually applied on contours for topographic maps cannot be applied on isobaths as they do not take information about features into consideration and a new strategy coordinating different generalization operators must be defined for nautical charts. This paper focuses on isobaths generalization and introduces a new approach based on a multi-agent system. It first introduces the characteristics and constraints of isobath generalization. Then it presents the multi agent model where features and isobaths are represented by agents at different levels. Possible actions performed by each agent are presented with measures for evaluating their results according to generalization constraints.

1- Introduction

A nautical chart is a plane representation of the seabed. It is used by navigators to establish their route and ensure safety of navigation. On the chart, the seabed is described by soundings (depth points) and isobathymetric lines (contour lines of equal depth). In order to present a useful and legible chart, soundings and lines must be generalized with regard to their relevance to the map purpose and scale. Automatic generalization of contour

A. Ruas (ed.), *Advances in Cartography and GIScience. Volume 1: Selection from ICC 2011, Paris*, Lecture Notes in Geoinformation and Cartography, DOI 10.1007/978-3-642-19143-5_27,

lines has been studied for long and several approaches have been developed. Different criteria are used such as the distance between the lines (Gökgöz, 2005, Li and Sui, 2000), the slope gradient (Mackaness and Steven, 2006) or the medial axis transform (Matuk et al., 2006). The objective of these methods is mostly to improve the legibility and aesthetic of the map by selecting or simplifying the contours. Local terrain characteristics can be taken into account but the character of terrain features modeled by contours is not considered and these methods are not applicable for isobath generalization on a nautical chart. On a chart, features representing a risk for navigation such as reefs and shoals must be highlighted while channels representing main routes of navigation should be indicated.

Generalization must be done by considering the types of features modeled by contours in order to consider navigation constraints. Limited work has been done on nautical chart generalization. Papers tackling the overall generalization strategy of nautical charts are (Tsoulos and Stefanakis 1999) and (Sui et al. 2005). In both cases, generalization is performed as a sequence of operations and follows condition-action modeling requiring an exhaustive description of all possible situations. The final result may strongly depend on the order in which the lines are processed and the choice of operations that is made (Harrie and Weibel 2007). Another approach would be to compute an intermediate DTM from the contours and to generalize this DTM to get the generalized representation of the relief. However, the reasoning should be done instead on contours as the user would identify the features based on the sets of contours that appear on the map.

More recently, other generalization models based on constraints have been considered. Instead of imposing rules on what should be done, constraints stress what results should be obtained (Harrie and Weibel 2007). The most generic strategy is based on multi-agent systems (MAS). The system treats elements on the map as agents and allows them to decide their own actions. An important property of multi-agent modeling is that it is generic as it can integrate any kind of generalization operation and deal with any kind of constraint.

The main interest for agent modeling in isobath generalization is that agents can be used to model terrain features so that the process is feature-driven. Relationships are established between the different features and the lines so that they can communicate together in order to take into account constraints expressed at feature level and at line level. Such an approach would allow the generalization of terrain features through contour generalization.

Only isobaths are considered in this paper as they are the main elements characterizing the relief. The constraints will be considered to maintain the shape of isobaths and features. Although other elements such as soundings are not considered, the model can be easily extended so as to include these elements in future work.

The objective of this paper is to present a model for isobath generalization that can deal with constraints specific to nautical charts. A multi agent system model is presented where agents model not only the lines but also the features so that terrain information is considered in the process. In the next section, constraints specific to nautical chart generalization are reviewed together with related works on isobath generalization. Following section discusses related works on multi-agent based generalization. Then, the generalization strategy is presented, including the feature description and the agent model. Finally, conclusions and perspectives for future studies are presented.

2- Generalization constraints on nautical charts

Referring to Ruas and Plazanet (1997) classification, the main constraints in isobath generalization for nautical chart are classified as:

- The legibility constraint: generalized lines must be clearly legible and a minimal distance must be observed between them. Polygonal lines must be of a sufficiently big area to be visible and contain a sounding;
- The functional constraint: it is related to navigation safety and states that the generalized representation of the relief must be higher than the original representation so that the depth interpreted from the chart cannot be deeper than the real depth. A line cannot be deleted if it models an upper section of the relief on the seabed (Figure 1). A deformation can only be done if the isobathymetric line is pushed towards bigger depth. This implies that usual operators for smoothing or displacement cannot be applied and that specific operations are used;
- The structural and shape constraints: morphological details of the seafloor (slope, roughness) must be maintained as much as possible. Characteristic features of the relief must be maintained and emphasized;

- The topological and position constraints: spatial relationships and relative distances between objects must be maintained.

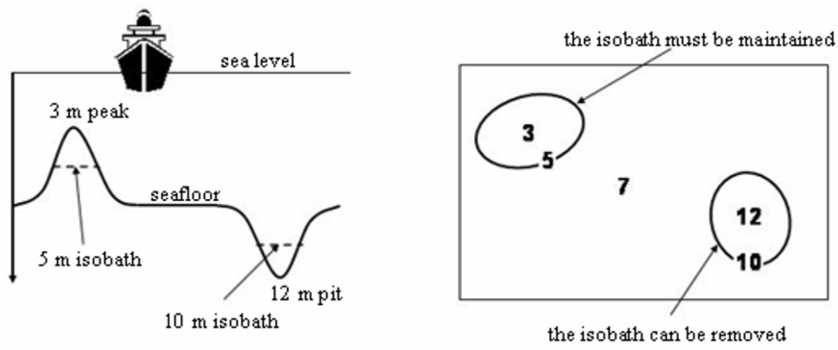

Figure 1: Illustration of the safety constraint

The first two constraints are the most important and must be satisfied for the chart to be valied. The safety constraint imposing rules on the selection and displacement of lines, specific operators must be defined. Guilbert and Saux (2008) defined a smoothing operator which pushes the line in one direction. This method is based on a snake model and takes into account the proximity between neighboring lines. It also prevents the creation of self intersections in the deformation process. The authors applied the method together with other operations (selection, aggregation and contour interruption) however the application of an operation has to be confirmed by the user as the algorithm does not possess enough information about the context to make its own decision. The required information is mostly related to the type of feature the isobath belongs to and its relation with other features.

Other constraints are related to the preservation of terrain features. Morphological information is useful for the navigator to locate his position based on surrounding landmarks and seabed information returned by sonar especially in shallow and coastal areas. They are less important than the first two constraints and are used to evaluate the quality of the chart. They refer to the amount of deformation applied to lines and the preservation of topological relationships between features and lines.

3- Multi agent systems and generalization

Multi agent system (MAS) is a concept of artificial intelligence. The system contains agents which represent different objects. One important characteristic of agent is its autonomy. An agent can choose its own behavior and cannot be imposed its action by other agents or by the environment. The first type of agent is reactive agent, with limited intelligence. It acts in reaction to some stimulation from its environment. The intelligent agent model was then introduced. This kind of agent can remember the action history and compare which combination of actions is better. The intelligent agent model includes perception, control algorithm, state and actions parts (Schumacher 2001).

Schumacher (2001) gives a model of intelligent agent in figure 2. Perception part gives the surrounding environment conditions to agent. State part stores the history of actions to evaluate the situation of agent. Action part is a list of actions including all acceptable behaviors. The intelligent agent can make action plans and evaluates the best one for action.

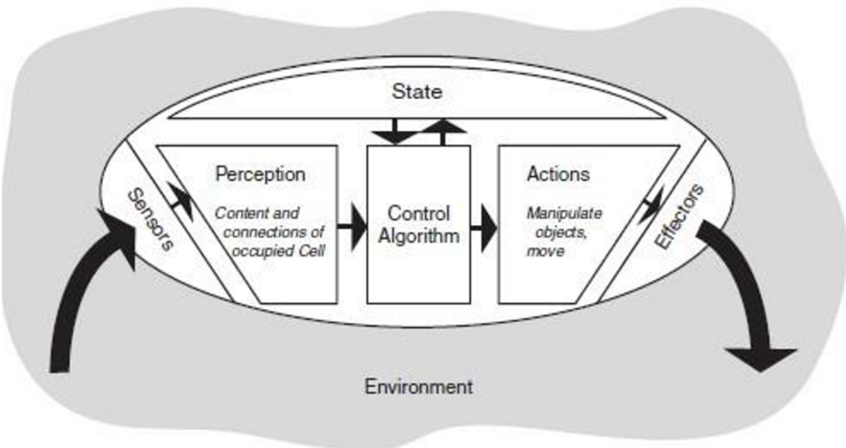

Figure 2: Architecture of intelligent agent (Schumacher 2001)

Agents were introduced in map generalization by Baeijs et al. (1996) with the system SIGMA (SemI automated Generalization using Multi-Agent System). It designs a group of scopes to control agent actions. It used reactive agent. The agents react when the conditions are triggered. It does not contain a state model to evaluate the result of its action. In a problem such as line generalization, line agents would act when some constraints are violated however the choice of actions is based on limited set of rules and does not consider the quality of the result.

Lamy et al (1999) used more intelligent agents which can make an action list and choose actions from it. They decomposed map objects into agents at three different levels, macro agent, meso agent and micro agent (Fig 3). Lower level inherits higher level's attributes. Decomposing objects partitions the map into several parts, making the generalization process more efficient.

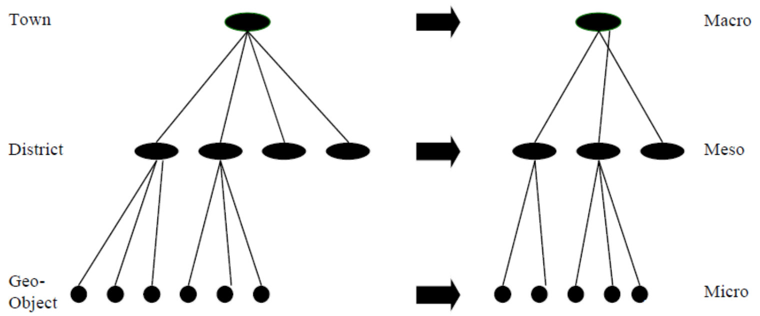

Figure 3: Decompose map into three levels of agent Lamy et al (1999)

The life cycle of a meso-agent when a constraint is violated and action is needed is presented in Figure 4 from Duchene (2001). Communication between meso agents and micro agents are described. Meso agent makes a plan of its actions for generalization. Then it sends a signal to the micro agents it contains to manage their own generalization. Each micro agent makes its plans and evaluates the best one. Then meso agent re-evaluates its situation. Once all evaluations are done, the meso agent chooses the best plan for itself.

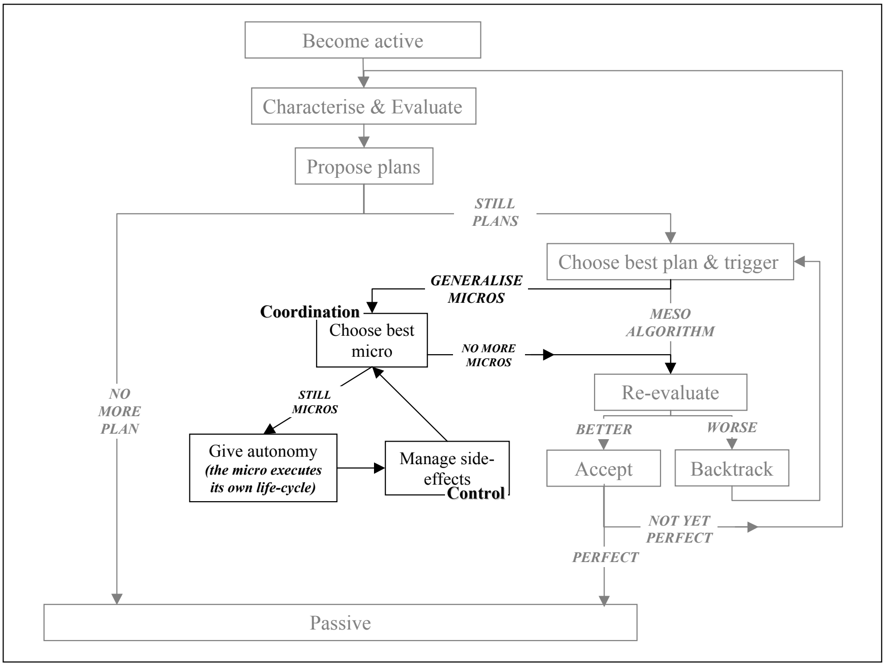

Figure 4: Life cycle of a meso-agent (Duchene 2001).

Galanda (2003) introduced a strategy for evaluation of an agent plan. It evaluates constraint violations based on agent situation. The minimum violation demonstrates that the state of an agent satisfies the constraint. The violation is larger, the situation of agent is worse and it needs another plan for generalization. Then, it calculates the sum of violations of all constraints. The smaller the sum, the better the plan. The agent records the amount of violation for each plan and chooses the one with the minimum violation. The advantage of this method is that it can quantify the effect of each constraint so that the agent can find the balance between different constraints.

4- The MAS-based generalization model

4.1 Definition of terrain features

As it appears through the expressions of cartographic constraints, isobath generalization is driven by the types of morphometric features on the seabed and so their identification is required. Morphometric features from a contour map are usually extracted by building the contour tree based on inclusion relationships between the contours (Cronin 1995). Two kinds of features are extracted: peaks and pits, which correspond to the branches of the contour trees (Figure 5). In Figure 5, branches with white nodes are peaks or pits. However, the description of a landscape also depends on the scale of observation and interpretation from the user. Identifying the branches of the tree only yields a description of features at the highest level of detail. Other features of larger size can be identified by the user depending on his interest (Figure 6). These different features can be identified and stored in a feature tree as, like contours, they can be connected based on their inclusion relation.

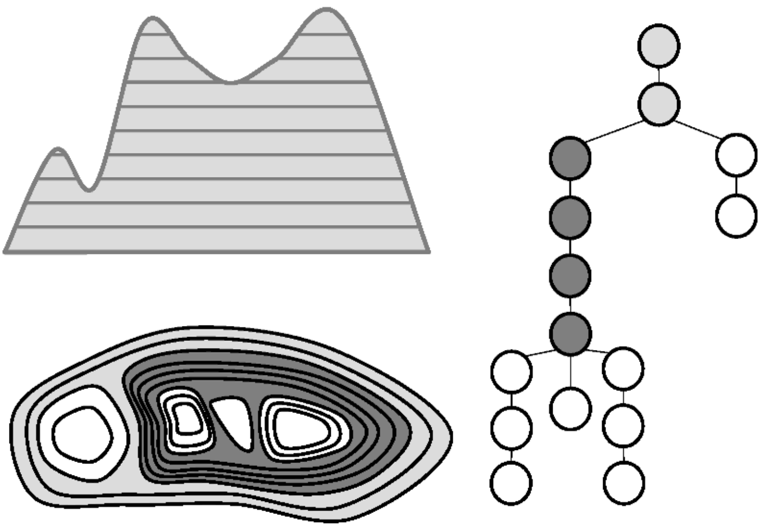

Figure 5: Contour tree corresponding to a contour map

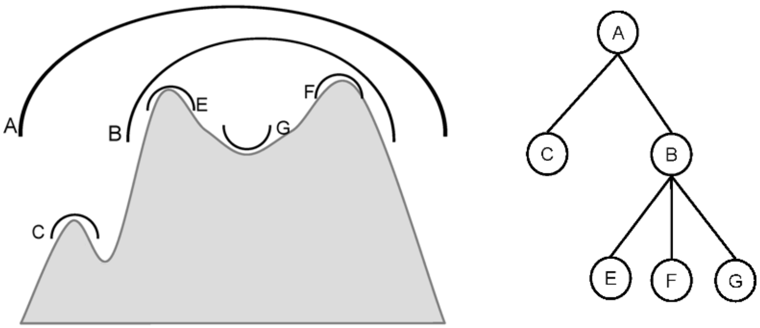

Figure 6: Feature representation and its corresponding feature tree

Two kinds of features are considered in this research: features corresponding to higher areas (peaks) characterized by a set of contours where contours on the boundary are deeper than all inner contours, and features corresponding to deeper areas (pits), characterized by boundary contours shallower than all inner contours. On Figure 6, the peak A contains two peaks B and C and peak B contains two peaks E and F and one pit G. These features are identified from the contour tree on Figure 5, right. A third kind of feature may appear in the feature tree which is a mixed feature, that is, a feature whose boundary contour is neither the highest or the lowest. Such feature always contains some descendants which can be described as peaks and pits.

4.2 The multi-agent model

4.2.1 Agent description

In this project, agents are divided into two levels: macro agent and micro agent. The agents with higher level contain lower level agents. Macro agent can activate daughter features and contours. Macro agents represent terrain features. Micro agents are the contour lines. As the features are organized in a hierarchy based on inclusion, a contour line can belong to different features. Generalizing one feature implies that its children features are also generalized. Therefore, in its life cycle, a feature will activate all its children features in order to generalize common contours. For example, in Figure 7, all contours belong to a large peak A. L3 also belongs to peak

B and L4 also belongs to peak C. When it performs generalization, peak A will ask peak B to generalize which will ask L3 to generalize. During generalization, the macro agent will pass both generalization actions and feature information to micro agent in order to let micro agent choose acceptable actions.

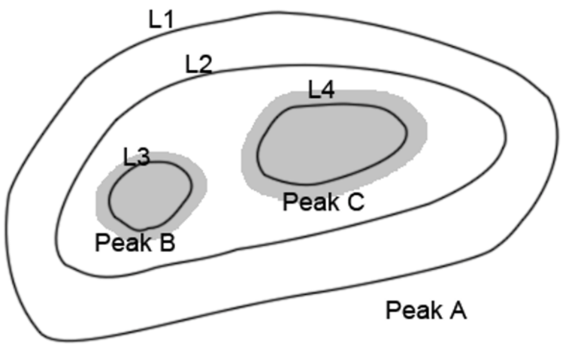

Figure 7: Description of feature agents

4.2.2. Actions for agents

In order to satisfy the constraints, the generalization operations are provided as actions for agent. A set of operations for both features and lines is presented in Table 1. Constraints and characteristics at macro-level are passed to micro-level in order to decide the appropriate action. For example, if a feature characterizing a peak needs to be generalized, it will trigger some actions at its level and coordinate the generalization of lines inside the feature at the micro level. For that purpose, lines will also get constraints such as the type of feature from the macro-agent.

Actions that can be performed by feature agents are selective omission, enlargement, reduction, and aggregation. Micro-agent can perform enlargement, smoothing, reduction, aggregation, selective omission and segment deletion.

Agent	Actions	Definition
Feature agent	Selective omission	Remove a feature
	Enlargement	Enlarge a feature
	Reduction	Shrink a feature
	Aggregation	Merge two features
Line agent	Enlargement	Enlarge an isobath or part of an isobath
	Smoothing	Smooth isobath
	Reduction	Shrink a isobath
	Aggregation	Merge two isobaths into one
	Selective omission	Remove an isobath
	Segment deletion	Delete a line segment from an isobath

Table 1- Actions for agent

4.2.2. Constraints of an agent

This part will introduce the constraints used in the system for different levels of agent. The constraints are generally divided into four types resuming the constraints presented in section 2: legibility constraints, safety constraint, shape preservation constraints and structural constraints.

The most important constraint is the safety constraint which applies to all operations of both features and lines. The depth of any point of a feature cannot be greater than its original depth and a line can only be moved toward greater depth.

Enlargement	Feature is a peak
Reduction	Feature is a pit
Selective omissio	Feature is a pit
Aggregation	Features to aggregate are peaks

Table 2: Safety constraints on line

The legibility constraint is determined by the minimum distance between two lines and by the area of closed isobaths. If the value is smaller than the tolerance, there is a conflict and agents will choose available actions. The constraints of each type of agent are shown in table 3.

Agent	Describe
Line agent	Distance between two segments of a line should not be less than □1
	The distance between two lines should not be less than □1
	The area of a closed isobath should not be less than □2
Feature agent	The distance between two features should not be less than □1
	The area of a feature should not be less than □ 2

Table 3: Legibility constraints, ε is the given tolerance.

The shape preservation constraint maintains the shape of the objects in order to preserve the terrain morphology. For line agent, this constraint preserves its shape and tends to reduce displacements. For feature agent, this constraint evaluates the elevation and distance between the isobaths in order to preserve the shape of the feature.

Agent	Describe
Line	Maintain the shape of line
Feature	Maintain the slope of feature
Feature	Maintain area of feature

Table 4: Shape preservation constraint

Structural constraints preserve topological relationships between lines and features and the data structure consistency by imposing constraints on actions. The detail of this constraint is shown as Table 5.

Action	Structural constraint
Line aggregation	At least one isobath must be closed.
	Both should have the same elevation.
Line segment deletion	Isobaths cannot be the innermost or outermost contour
Feature deletion	All descendant features in the feature tree can also be deleted

Table 5: Structural constraint.

4.2.4. Evaluation method of agent actions

One important characteristic of MAS is that the agent can propose several plans and choose the best one automatically in this system. This means the agent has a method to evaluate its situation. This part will introduce the evaluation method of agent.

In our project, there are four types of constraints and some can be contradictory. The shape constraint opposes the legibility constraint as one tends to retain as much information as possible while the other modifies this information by displacing or deleting objects in order to clarify the map. As a result, it introduced Galanda (2003)'s method for evaluating different constraints. For legibility constraints and shape constraints, agents calculate how much they obey the tolerance. System calculates the amount of violation and chooses a set of actions which has minimum violation.

Constraints do not have the same importance. Safety constraint is the strongest while shape preservation of terrain morphology is the weakest. An action which does not respect safety will be automatically rejected by the evaluation. Second, actions are ranked according to the legibility constraint. An action that ensures legibility is always preferred to one which does not. Violation is defined by a value which represents the amount of displacement to be done on the lines to correct the conflict. Actions which satisfy the first two constraints are ranked according to the amount of information preserved. This is evaluated by measuring the deformation on the lines and the features.

Agent	Constraint	Evaluation
Line agent	(Safety) Isobath has been moved toward greater depth	Reject if violated
	(Legibility) Minimum distance between two segments is ε_1.	Minimum distance >= ε_1 : 0 Minimum distance < ε_1 : ε_1 – Minimum distance
	(Legibility) Minimum distance between two lines is ε_1.	Area >= ε_2 : 0 Area < ε_2 : ε_2 – Area
	(Legibility) Minimum area of closed isobath is ε_2.	Area >= ε_2 : 0 Area < ε_2 : ε_2 – Area
	(Preservation) The distortion of line cannot be changed too much	Σ DistP
	(Preservation) The deletion of line.	Area of deletion
Feature agent	(Safety)	
	(Legibility) Minimum distance between two regions is ε_1.	Minimum distance >= ε_1 : 0 Minimum distance < ε_1 : ε_1 – Minimum distance
	(Legibility) Minimum area of region is ε_3.	Area >= ε_3 : 0 Area < ε_3 : ε_3 – Area
	(Preservation) The slope of region cannot be changed too much	Area between two isobaths – original area between two isobaths

Table 6: Evaluation of constraint

In table 6, ε_1-ε_3 are given tolerances. DistP is the distance between original point and displaced point. Σ DistP is the sum of DistP of all points on line. For line aggregation, the change of line calculates the distortion changing of original line and displaced line. As figure 8 shows, the P1 is original line, P2 is displaced line which needs to merge with Q. It calculates the Σ DistP for all modified points.

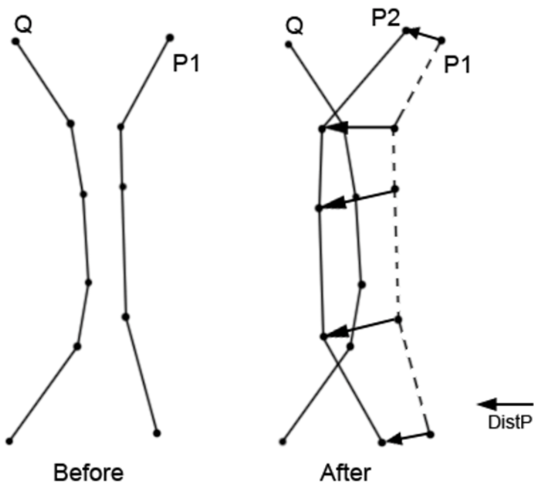

Figure 8: Distortion of line for aggregation

If an agent performs a selective omission, points are removed and no distortion can be calculated. Instead, the preservation value is its area. If a segment is removed from an isobath, no preservation violation can be evaluated for the segment but the violation can be evaluated at the feature level.

In feature level, preservation is evaluated by measuring the area difference between consecutive lines of different elevations in order to estimate if the overall shape and slope is preserved. Figure 9 shows the computation method. For example, the difference between original area from 10m isobath to 30m isobath and area after line modification are calculated.

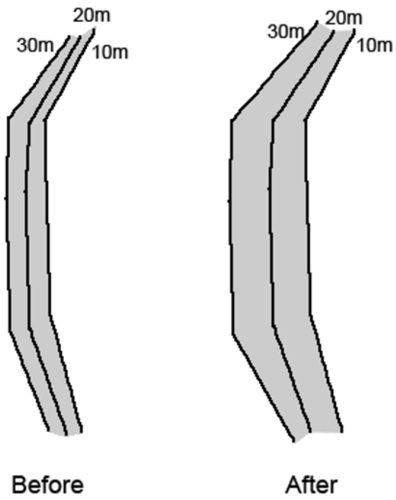

Figure 9: Difference of gray area as slope distortion

When calculating the area, the contours defining the feature boundary must be at the same elevation but other contours can be removed. As shown on Figure 10, if the 20m isobath is eliminated, the area will be calculated from 10m to 30m.

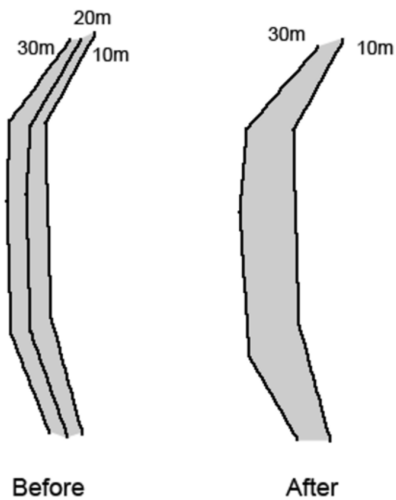

Figure 10: Consistent boundary for calculating slope

4.3 Preliminary results

The data structure has been developed and tested on a set of isobaths from a nautical chart of a coastal area (Figure 11). The map is at scale 1:12500. Isobath depths are -2, 0, 2 meters and every five meters from 5 to 25 meters. The first step of the work consisted in extracting features and building the feature tree (Figure 11).

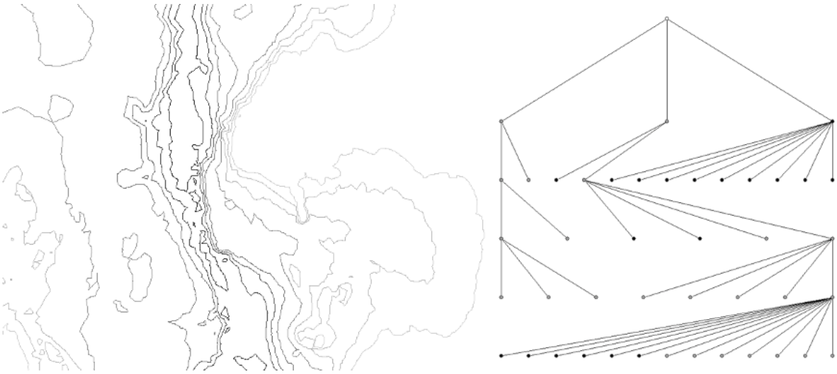

Figure 11: Isobath map with its corresponding feature tree. Grey nodes are peaks, black nodes are pits.

Depending on the type of features, features can be removed if they do not satisfy the legibility constraint. Current result with the simplified map and its feature tree is shown on Figure 12. Small contours located in the channel have been removed by removing the features. The feature tree has been simplified at the same time as the number of levels has been reduced: a peak that contained only one peak has been removed to maintain consistency of the tree structure.

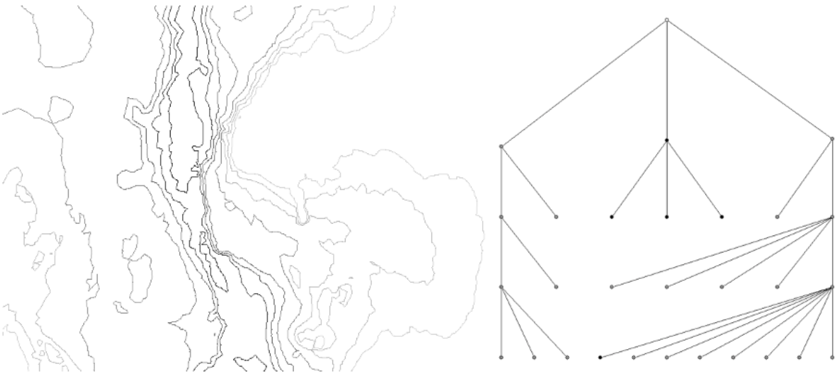

Figure 12: Simplified map with its corresponding feature tree. Grey nodes are peaks, black nodes are pits.

The data set presented here is relatively simple and results are still limited as only selective omission is considered. Line deformation methods for smoothing, aggregation, displacement and enlargement are still yet to be developed according to nautical chart constraints so as to be evaluated.

5- Conclusion and perspectives

This article dealt with the problem of isobath generalization for nautical charts. Due to the safety constraint specific to this kind of maps, traditional contour line generalization methods cannot be used. Lines have to be generalized based on the type of feature they belong to in order to emphasize potential risks for navigation. As a consequence, different types of operations have to be applied and combined together. This paper introduced a novel approach where generalization is feature-driven and operations on features and lines are coordinated by an agent model. First, the definition of terrain features and their representation in a feature tree was presented. Feature tree classifies terrain into peak or pit. The feature tree not only presents the structure of terrain, but also maintains the shape of slope during generalization transformation. Second, the agent model was described. Two kinds of agents are considered: feature agents at macro-level and line agents at micro-level. Feature agents hold the information about the morphology (such as the type of feature and its size) and pass them to lines so that different actions can be performed and evaluated. Constraints considered for evaluation are the safety constraint, the legibility constraint and the shape preservation constraint. Based on these, each operation can be given a score so as to choose the most efficient.

Preliminary results are presented however further work is still required in this direction as specific methods for line deformation are still to be implemented. Line smoothing and displacement methods can be based on (Guilbert and Saux 2008). Enlargement and aggregation operations should also be introduced. The method should be tested on several maps at different scales in order to assess different tolerance values and adjust the evaluation method.

Two directions are identified for future work. First, feature definition is based on the analysis of a contour tree. However, the contour tree relies on inclusion relationships between contours and inconsistencies can appear when dealing with open contours on complex terrains. One objective is therefore to be able to classify accurately the relations between all contours so as to describe features more precisely and extract more information from the contour tree.

Second, work presented here only considers isobaths. On a longer term, other items on nautical chart can be added. For example, soundings can be included in the generalization process as micro-agents belonging to features. Specific constraints would then be added for sounding selection and to generalize both contours and soundings simultaneously.

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Multiscale Hypsometric Mapping

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Abstract

Multiple representations of geographic objects draw one of the main focuses in modern cartographic research. Initial works were concentrated on multiresolution databases and elevation models derivation through generalization process. Development of interactive computer mapping in 90-00's lead to growth of interest in visual representations of multilevel objects. However, the task of multiscale mapping of earth topography has not been paid a due attention. In this work a complete technology of making multiscale hypsometric maps is proposed, beginning from scales and projection definition, walking through database design and DEM generalization with novel algorithm and finally outlining map preparation using hypsometric tints, contours and hill shading.

1- Background and objectives

Multiscale mapping is among the most prominent and problematic areas in modern cartography. Casting away the limits of fixed-scale maps cartographers go into detail of multiresolution databases design, real-time generalization, map layers structure, scale-dependent behavior and symbolization, while trying to keep representation clear and credible. During the 80-00's large amount of work had been done to develop and extend this area of knowledge. Most of results were yielded in digital space, including data generalization for multiresolution databases (Buttenfield 1993, Muller et al. 1995, Li 2007) and optimal database structure (Jones et al. 1996, Frye 2006).

A. Ruas (ed.), *Advances in Cartography and GIScience. Volume 1: Selection from ICC 2011, Paris*, Lecture Notes in Geoinformation and Cartography, DOI 10.1007/978-3-642-19143-5_28,

In recent decade we watched the growing interest in visual, symbolic aspects of multiple representations. Bedard and Bernier (2002) developed a VUEL concept to integrate geometric, semantic, and semiotic presentation of object in multiscale environment. Cecconi et al. (2004) examine limits of LoDs' applicability for display in various scales and accentuate the primary role of symbolization in multiscale maps. Brewer and Buttenfield (2009) analyze data sensitivity for scale variation and propose effective combination of symbology and geometry changes.

Despite variety of existing works in multiple presentations, they have not covered all the geographic phenomena to an equal degree in visual context. Most of them concern discrete objects, which cartographic representation is usually planar (2D): roads, rivers, buildings etc. The task of multiscale mapping of relief have not been paid deserved attention.

Relief concept is used for describing earth topography. It can be logically divided into separate forms, or treated as continuous surface. Both models are useful in their own area and supplement each other in cartographic relief presentation and generalization.

Manual contour drawing is made within neighboring fragments of contour levels, which are topologically related and correspond to the same relief form. Scale reduction and accompanying generalization process lead to representation of higher hierarchical level of topography on the map. Contour interval is increased consecutively. According to Zarutskaya (1958) small-scale hypsometric relief representation should be geographically credible and keeping the most distinct features of great forms which are conditional to their structure and genesis, with respect to scale and purpose of the map.

Careful analysis of guides and instructions for topographic mapping reveals that beginning from scale of 1:200 000 relief forms are extensively exaggerated and contours are deliberately shifted and stylized to save the morphological features typical for relief of certain genesis. Imhof (1982) also singles out scales smaller than 1:100 000. He mentions that simplification of lines at these scales extends more or less over the whole map image and not only in particular places.

Scale dependency is also present in hillshading technique and hypsometric tints selection. As Imhof states, tones and mutual contrasts of small-scale hillshading are dependent primarily on elevations and differences in elevation, and no longer on the angle of slope. Stylized symbols for formations gradually replace individual features (Imhof 1982).

Hypsometric layers height steps and colors obey scale-dependent rules of construction. In small scales steps are usually based on geometric progression while in large and middle scales steps can be equal as contour interval. Colors should be adapted to the steps chosen, thus in small scales contrast between neighboring layers will be more prominent and number of colors will be less. Scale coloring can also change gradually transitioning from spectral in small scales to more naturalistic in large ones.

All these suggestions help us to formulate three *basic principles of multiscale hypsometric mapping*:

1. Every map scale should represent relief forms of corresponding size and hierarchical level with their prominent features and structure lines.
2. At scales smaller than 1:100 000 intensive generalization should be made to maintain most characteristic forms of the earth surface.
3. While changing scales, gradual transition of representation parameters, such as contour intervals, hypsometric colors and hillshading character should be provided.

The problems of multiple relief representations and generalization are closely related to each other. The first studies in automatic relief generalization were based upon filtering (Loon 1978). Since the filtering method does not take structure lines into account, an adaptive technology combining filtering and structural generalization was developed by Weibel (1987). Zaksek and Podobnikar (2005) combine structure lines, characteristic points and cells of smoothed model as source data for interpolation. Fan et al. (2007) developed four-stage method using low-pass, smoothing and threshold filters that are locally combined depending on slope and curvature of the surface. Leonowicz et al. (2009) offer using low and high quartile filters for valleys and watersheds. The same authors developed curvature-based algorithm, which is intended for production of small-scale hillshades (Leonowicz et al. 2010).

Jordan (2007) developed method based upon Strahler ordering of streams. Basins are derivated for streams of certain hierarchical order and then are filled by triangulating watershed borders. Ai and Li (2010) use similar methodology. Process is divided into three stages: stream network generalization using orders, large valleys extension by taking up small ones and smoothing the surface within the areas of removed valleys. Another interesting field of research is generalization based on Fourier analysis (Clarke 1988) and wavelet transformation (Wu 2000).

Careful analysis of direct contours generalization methods reveals that they are harder to implement than indirect methods based on DEM generalization because of necessity to consider topological relationships between lines (Zhang et al. 2007), complexity of structure lines derivation (Ai 2007) and interpolation difficulties when contour interval in resulting DEM should be different (Peled et al. 1989).

There are also advanced techniques for TIN generalization using morphological criteria (Pedrini 2001, Wang et al. 2008). Hierarchical or pyramidal multiresolution models provide generalization mechanism for derivation of intermediate levels of detail (de Floriani et al. 1996). Great attention is paid to global hierarchical models since the amount of detailed information is growing irrepressibly (Bernardin et al. 2010)

Most investigations related to visualization of multiresolution DEMs are oriented on morphometric and hydrologic analysis (Wood 1996, Dragut et al. 2009) and demonstrate results as thematic images in variety of scales. On the whole there is a lack of methods for multiscale relief mapping and visualization, not DEM generalization and analysis. Our methodology is intended to bridge this gap and make relief image the full-fledged element of multiscale maps.

2- Approach and methods

2.1 Scales and projection

As multiscale map can be viewed in a continuous set of scales, there is obvious need in control of map appearance while scale changes. It can be made more consistently if scale range and scale series of map are defined.

Scale range defines space between largest and smallest map scales in which generalization take place. It should cover suitable scales for relief forms that will be studied and allow wide field of vision to study neighboring relationships between forms. Below and above scale range map image will be simply reduced or enlarged.

Scale series defines a discrete set of scales within scale range in which map compilation and design is made. In topography scales are usually reduced by 2-2,5 times. This rule allows gradual transition and sufficient degree of control over the map look and can be used for providing scale series (Figure 1).

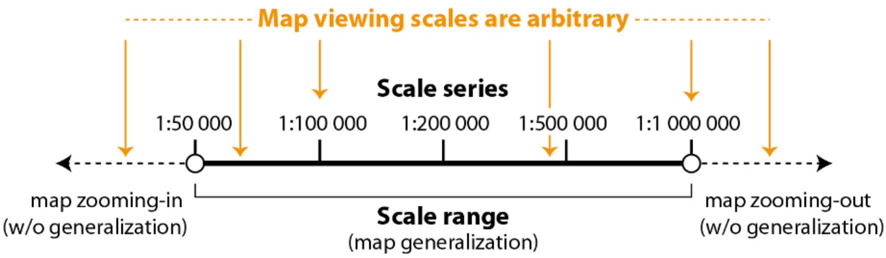

Figure 1: Scale range and scale series

Map projection should be constant or gradually changing to provide cross-scale coherence.

2.2 Database design: structure and content

Database content for hypsometric mapping consists of relief and additionally hydrographic data. All other layers, such as settlements, borders, and transportation are optional and their inclusion depends on the purpose of the map. We can divide data into three functional groups: base, auxiliary and analytical (Table 1).

	Relief	**Hydrography**
Base layers are necessary and sufficient for hypsometric mapping	Elevation raster	–
	Spot heights	Water levels
	Polygons (glaciers, cliffs etc.)	Polygons (lakes, seas, reservoirs, etc.)
	Lines (gully edges, steep slopes, dry channels etc.)	Lines (rivers, brooks, channels etc.)
	Points (volcanoes, holes, mounds etc.)	Points (mineral springs etc.)
Auxiliary layers are used for relief representation, can be derived from base ones, but are maintained in database for visualizeation efficiency	Contours, intermediate contours, hatches, hillshading etc.	
Analytical layers are not used for relief representation, but are needed for generaliszation and analysis	Slope, aspect, curvature (profile, plan etc.), flow direction, flow accumulation etc.	

Table 1: Database content for multiscale hypsometric mapping

Logical structure of the database should be designed to support the full scale range and keeping scale series in mind. To implement multiple representations, database is usually divided into several levels of detail (Figure 2).

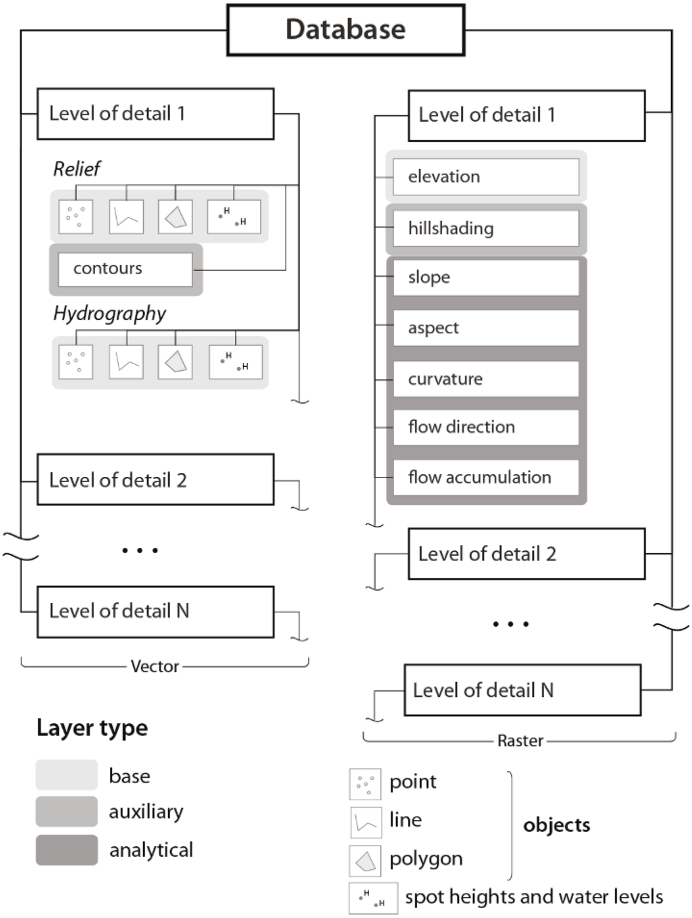

Figure 2: Multiresolution database logical structure for multiscale hypsometric mapping

In general case the number of LoDs can be less than that of scale series. For example, city points are often displayed in many scales using different SQL queries from the same database layer. Desirable number of LoDs depends on the sensitivity of the data geometry to scale reduction. Brewer and Buttenfield (2009) investigated this problem and demonstrated the difference between various geographic phenomena. Among them, relief and streams are the most sensitive: scale reduction in 2 times or greater require extensive generalization. So if scales in our series differ in 2-2.5 times, database for hypsometric mapping should provide LoD for every scale. Otherwise relief representation would be cluttered in some scales.

Data sources for MRDB generation are collected to fit into predefined LoDs as far as possible. Every LoD without suitable data source has to be generated from more detailed LoDs through generalization (Figure 3).

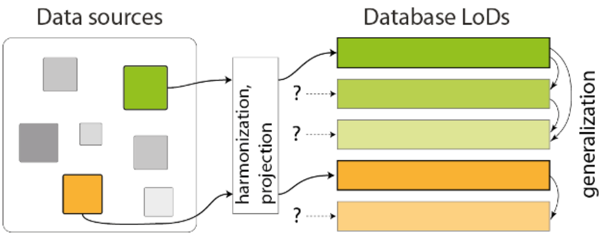

Figure 3: Data integration scheme for multiscale mapping

While data for vector database layers is usually got from digital topographic maps, the sources for DEM generation excel in variety. Careful analysis of existing data and results of related investigations (Doytsher and Daliot 2009) reveal the difference in possible spatial resolutions of DEMs from various data sources and therefore mapping scales (Figure 4).

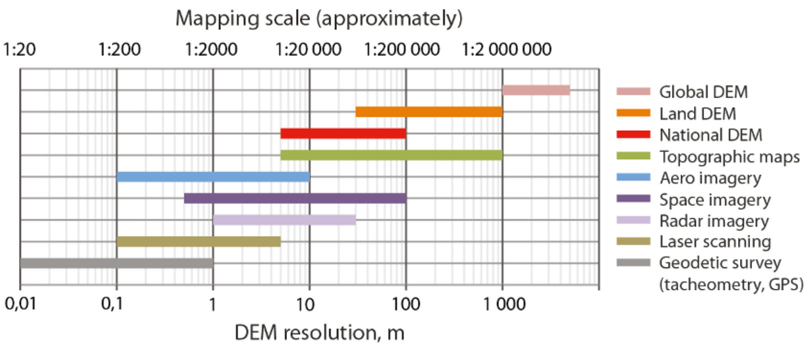

Figure 4: Various sources for DEM generation

However, the situation when every database LoD is supplied by fitting source data is pretty rare. The problem becomes vital in small scales, where no data with proper detailisation is usually available. Thus the task of generalization remains the central issue of multiresolution database preparation. Let's consider DEM generalization as most urgent for our study.

2.3 Algorithm for DEM generalization

The task of choosing the most appropriate algorithm for multiscale DEM generalization entails running into some drawbacks. The initial one is that most of existing algorithms need comparative testing on terrains of different morphology and in different scales. The second issue is that most of advanced generalization techniques are implemented by authors as inaccessible customized software.

To overcome these difficulties, a compromising strategy was taken. First, careful analysis of existing algorithms was made and some useful ideas that can be implemented using standard GIS functions were chosen to combine. Then a new algorithm partially adopting selected ideas was developed and tested on various DEMs and in several scales for multiscale hypsometric mapping purposes.

The concise scheme of the algorithm is presented in Figure 5. It consists of the following steps:

1. Streams generation from flow accumulation (O'Callaghan and Mark, 1984) with density corresponding to source DEM detailization (S1).
2. Streams generation with density corresponding to target DEM detailisation needed (S2). Here we implemented algorithm by Leonowicz et al. (2009) based upon least negative flow accumulation difference as Python script for ArcGIS.
3. Selection of the streams from S1 which are the direct tributaries of S2 streams (S3). Valleys of these streams will be filled by triangulation.
4. Watersheds generation for S2 (W2).
5. Watersheds generation for S3 (W3).
6. Triangulation of S2, W2 and W3 data (Figure 6).
7. Conversion from TIN to raster.
8. Raster postprocessing by low and high quartile filters for slight extension of resulting valleys and watersheds. Here we adopted method by Leonowicz et al. (2009).

We should note similar algorithms, which were developed previously by Jordan (2007) and Li and Ai (2010). The main difference of our methodology is that it does not rely upon stream ordering but uses stream length for generalization instead, as proposed by Leonowicz et al. (2009). We believe that this principle gives more credible generalization results because order-based stream selection can lead to removal of short riverheads and removal of significant streams with low order.

Algorithm was tested for DEM production in 1:500 000 and 1:1 000 000 (from 1:100 000 and 1:200 000) and 1:10 000 000 (from 1:1 000 000) scales. For every scale several source DEMs with morphologically different terrains were selected to estimate algorithm's ability to preserve distinct morphological features such as slope profiles and structure lines sharpness. Some results are presented in Figures 7–9.

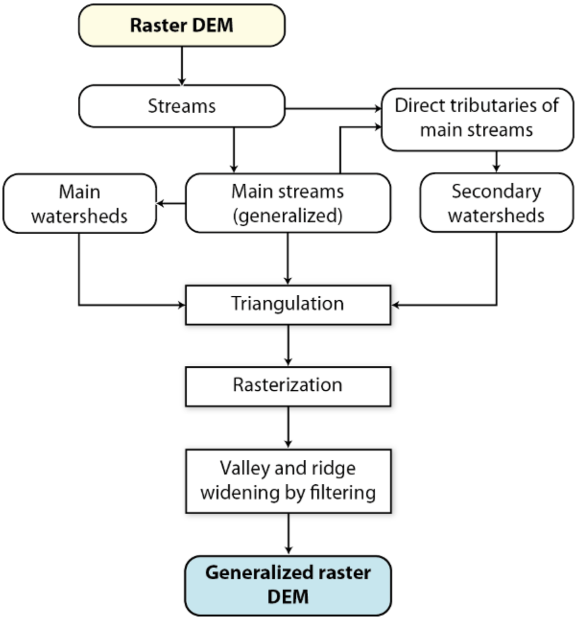

Figure 5: New algorithm for DEM generalization

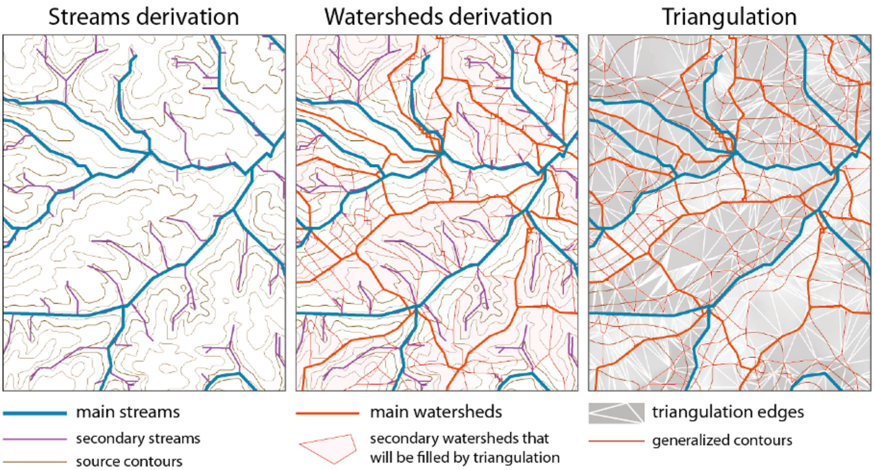

Figure 6: Triangulation of streams and watersheds for DEM generalization

Algorithm proved to be generally preserving main forms, characteristic heights, slope bends and structure lines. However, testing of it revealed some shortcomings, that need further developments:

- Algorithm does not encounter horizontal distance between valleys. This criteria should be used along with length during stream generalization to avoid excessive number of negative forms and preserve correct balance of positive and negative from areas.
- Not everywhere a correct shape of contour bends in upper reaches is preserved which indicates the morphology and genesis of relief.
- Some profile smoothing and distortion takes place during low/high quartile filter postprocessing (Figure 10). We believe that this process should be adaptive to local topography and with respect to hypsometric scale chosen: a certain balance of filters should be found.

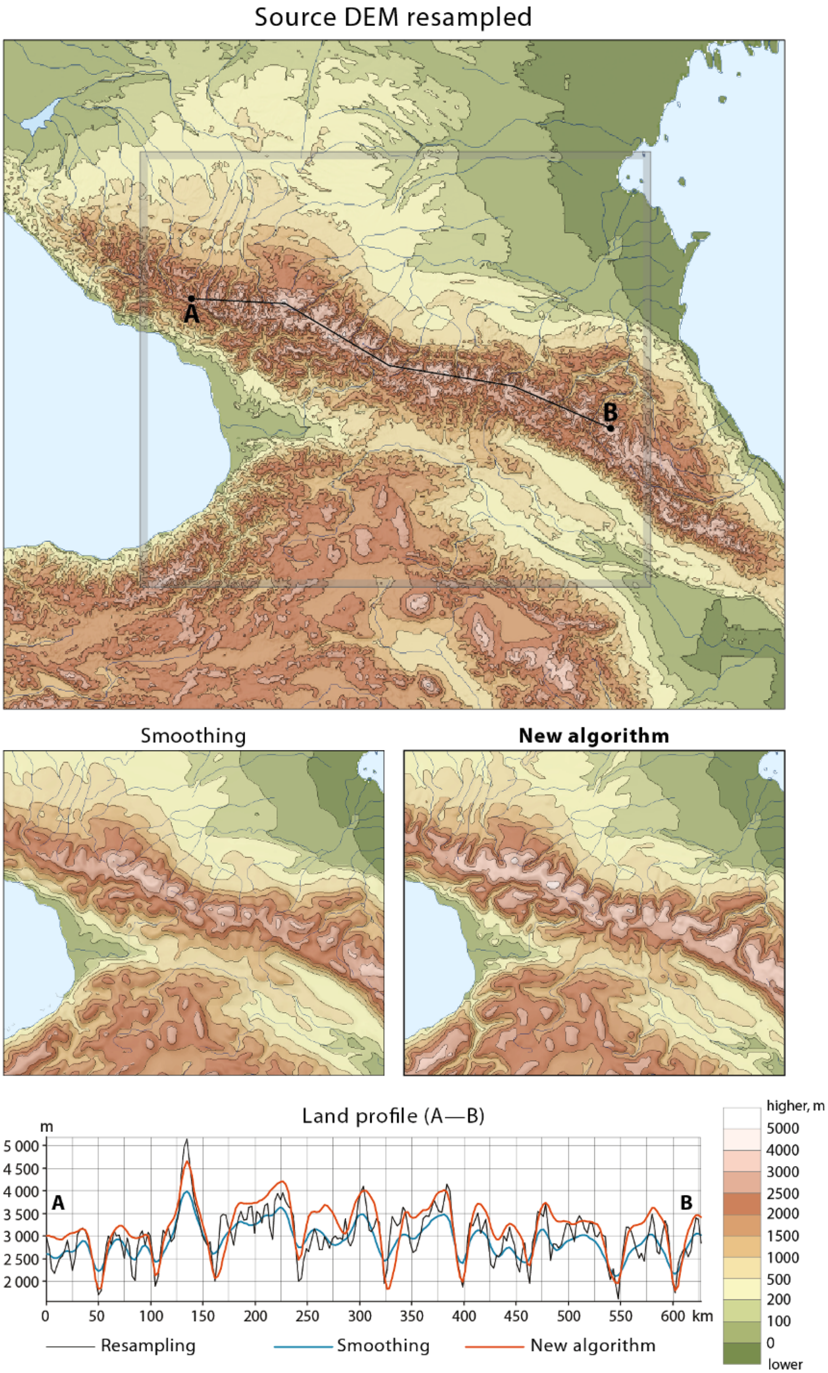

Figure7: Generalization of high mountains (from 1:1 000 000 to 1:10 000 000)

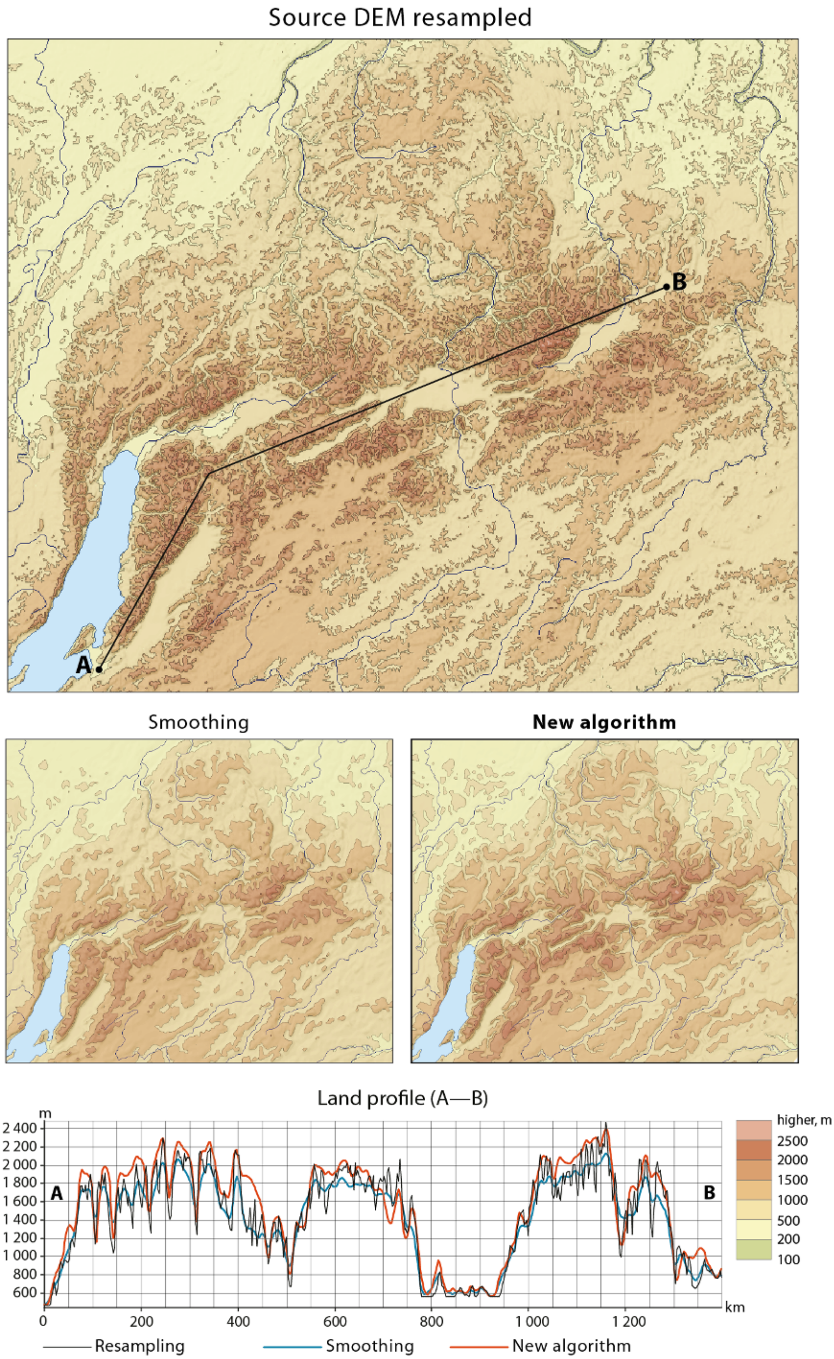

Figure 8: Generalization of upland (from 1:1 000 000 to 1:10 000 000)

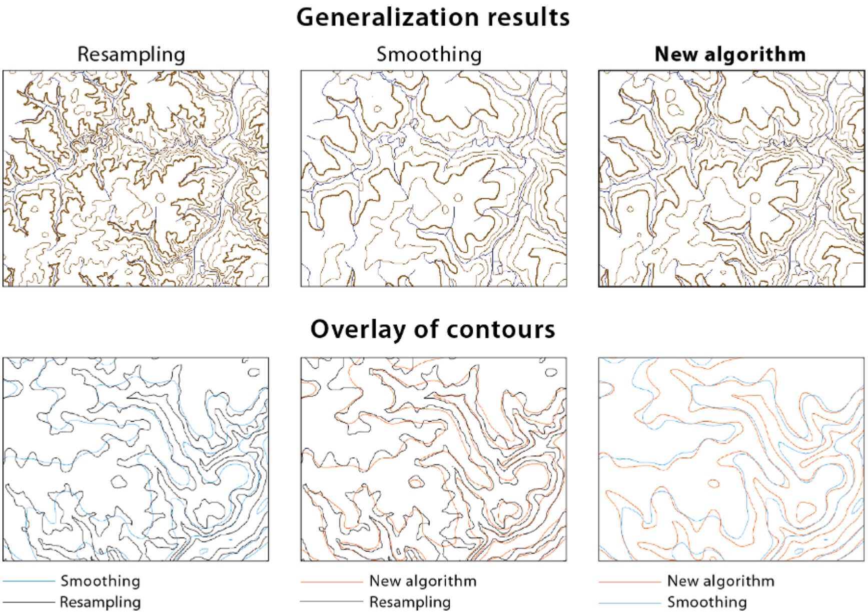

Figure 9: Generalization of gullies (from 1:200 000 to 1:1 000 000)

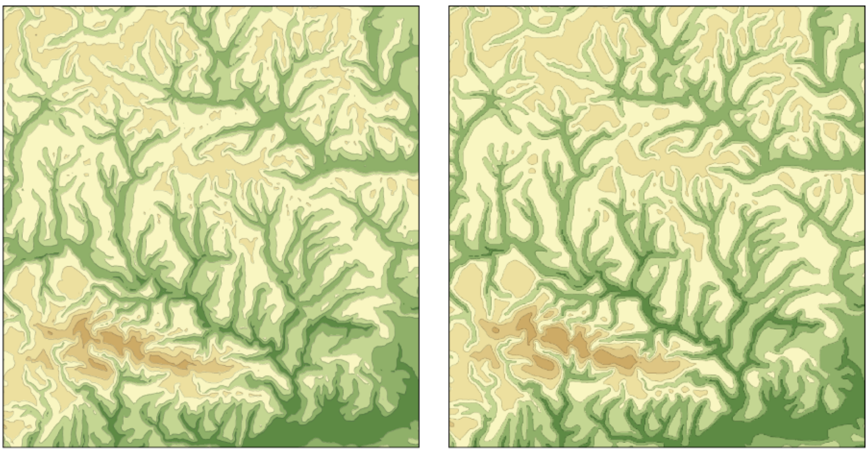

Figure 10: Widening valleys and watersheds: left – before, right – after widening.

2.4 Multiscale mapping and visualization

2.4.1 Layers structure and scale ranges

One general thing to be made when designing any multiscale map is to define logical structure of the layers and their limits of applicability (scale ranges). These questions are deeply considered by Cecconi et al. (2004) and Brewer and Buttenfield (2009). For clear structure layers can be united in thematic and scale groups. What should be the highest level of grouping: scale or theme? We find that in case of scale series with 2-2.5-times difference scale grouping on top level is more suitable. The scale ranges can be set to allow scale decrease in 1.5 times for 2-times interval and in 1.75 times for 2.5-times interval between neighboring scales (Table 2).

Database LoD	Scale Group	Scale range	*$k^{\uparrow}$	$k_{\downarrow}$
1	1:25 000	… — 1:37 500	1,5	—
2	1:50 000	1:37 501 — 1:75 000	1,5	0,25
3	1:100 000	1:75 001 — 1:150 000	1,5	0,25
4	1:200 000	1:150 001 — 1:350 000	1,75	0,25
5	1:500 000	1:350 001 — 1:750 000	1,5	0,3
6	1:1 000 000	1:750 001 — 1:1 750 000	1,75	0,25
7	1:2 500 000	1:1 750 000 — 1:3 750 000	1,5	0,3
8	1:5 000 000	1:3 750 001 — 1:7 500 000	1,5	0,25
9	1:10 000 000	1:7 500 001 — 1:17 500 000	1,5	0,25
10	1:20 000 000	1:17 500 001 — 1:35 000 000	1,75	0,25
11	1:50 000 000	1:35 000 001 — …	—	0,3

* $k^{\uparrow}$ — zoom out ratio, $k_{\downarrow}$ — zoom in ratio

Table 2: Scale ranges (limits of applicability)

These rules prevent LoD to be decreased 2 times (keep in mind that relief is sensible for scale reduction) and allow some zooming in without change of detailization for examining areas of complex relief representation.

2.4.2 Contour levels

The most verisimilar contour system is based upon equal intervals, as stated by Imhof (1982). But it's only scales greater than 1:1 000 000 that allow equal intervals. Beginning from 1:1 000 000 it's almost impossible to prevent equal interval everywhere. Here the geometric progression proved to be most useful.

Despite the fact that lots of great contour systems have been developed, they need adaptation for screen visualization. The smallest recommended distance between contours on paper maps is 0.25 mm. At the same time, the smallest clearly visible distance between lines on screen is 1.5 pixels or 0.375 mm (for 0.25 mm screen cell) when using antialiasing, as was ascertained by Jenny et al. (2008). If antialiasing is not used, the distance would be even greater — 2 pixels or 0.5 mm. This means that contour interval has to be extended in some mountainous areas where contours are very close to each other.

While mapping relief in large and middle scales for great territory contour system should inevitably be more flexible than on paper maps and interval would increase up to even 4 times in mountainous areas and decrease by 2 times in flat regions (Table 3).

Scale	**Main interval**	**Additional interval**	
		Plains	Mountains
1:10 000	2,5	1	5/10
1:25 000	5	2,5	10/20
1:50 000	10	5	20/40
1:100 000	20	10	40/80
1:200 000	20	10	40/80
1:500 000	50	25	100/200

Table 3: Example contour intervals for large and middle scales (in meters)

The problem of changing interval is easy in topographic maps, where every map sheet has fixed interval. At the same time, multiscale maps have no sheets and intervals should be changed within whole terrain forms and height levels. Traditional intervals offered by Imhof (1982) for small scales usually need no adaptation and can be used directly.

2.4.3 Hypsometric tints

Hypsometric scale should be developed for every map scale of the defined series. Consecutive scales of multiscale map will be coherent if tint colors are similar and successive without sudden tone changes. The more scale increases the more difficult is the task of creating distinctive layers of color. Imhof (1982) argues that number of colors should not exceed 6-10, otherwise they will be hard to distinguish. Therefore in large scales, where contour interval is small but terrain forms are relatively large in size, a transition from layered to gradient color shading would be effective.

2.4.5 Hillshading

Hillshading of already generalized DEM is rather simple using standard GIS instruments. We also recommend combining oblique and vertical hill-shading in any scales, as this kind of shading reveals ridges and valley bottoms clearly. In smaller scales there usually more need in exaggeration of DEM to give hillshading more contrast (up to 10 times). In large and middle scales exaggeration factor can usually be set to 1-5 when combining with hypsometric tints and contours.

3- Results

The proposed methodology was applied in preparation of multiscale hypsometric map of the European part of Russia. Esri ArcGIS Desktop 10 software was used as it allows implementing of all stages of proposed methodology. The scale range of the map extends from 1:25 000 to 1:50 000 000 and the series includes 11 scales differing in 2-2.5 times from each other. Data sources used in this project include public Russian topographic maps of scales 1:25 000—1:1 000 000, and free digital elevation models ASTER GDEM and USGS GTOPO30. In large and middle scale the coverage of the map is fragmented, which is caused by availability of suitable source data. The scale of 1:25 000 is available on the Black sea coast of the Northern Caucasus, and the largest scale for Central Russian Upland is 1:200 000.

The LoDs of vector data were filled by topography in scale range 1:25 000 — 1:1 000 000 and generalized by simplifying, merging geometry and query selection for coarser LoDs. Raster DEMs were derived for scales 1:25 000 — 1:200 000 using contours and hydrography from topographic maps and GDEM. Rasters for scales 1:500 000 and 1:1 000 000 were derived by generalization of 1:200 000 models, and for smaller scales by generalizing GTOPO30. Auxiliary and analytical rasters were calculated for each LoD. The resulting database structure is presented on Figure 11.

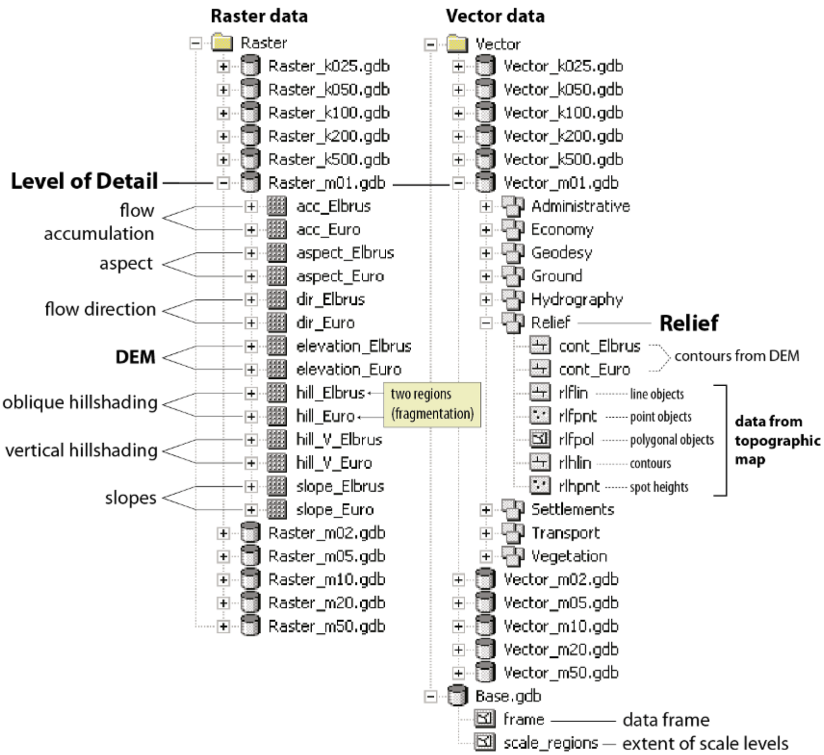

Figure 11: Resulting database structure

As can be seen database content is suitable not only for hypsometric mapping but for more common topographic. Map layer structure was implemented using thematic and scale grouping with the last being the highest level (Figure 12).

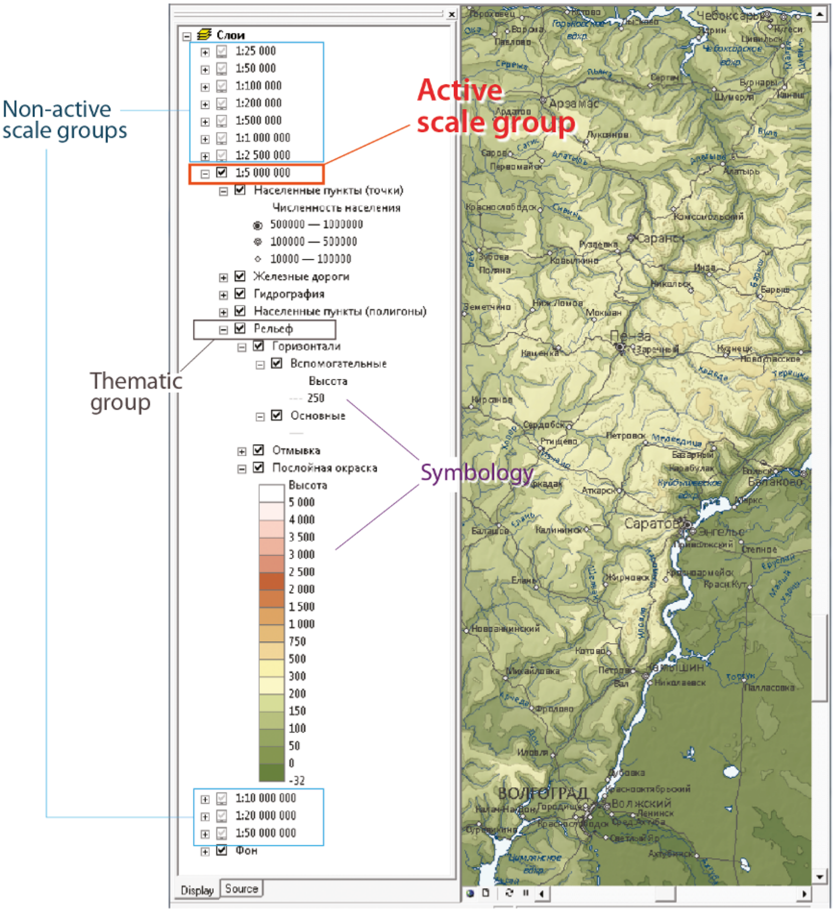

Figure 12: Map layers structure

Every scale group has its own scale range. Group switching is made automatically when scale changes.

We used combination of hypsometric tints, contours and hillshading generated from the same DEM LoD. Hypsometric tints are successive between scales, and free of bright and saturated colors that can tire eyes while looking at computer screen. At the same time they are oriented on combination with hillshades, thus they are lightening (Figure 13). Gradient color shading is used in scales 1:1 000 000 and greater based on colors from 1:2 500 000 hypsometric scale.

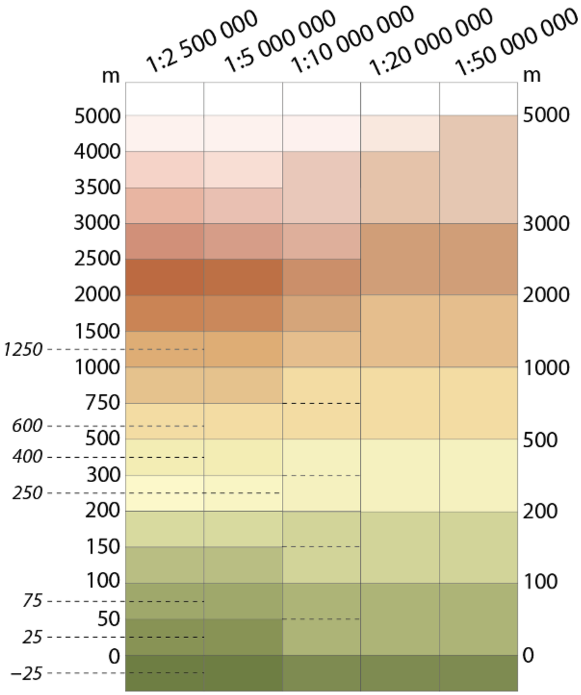

Figure 13: Hypsometric «multiscale»

Selected contour interval is the same as in hypsometric layers height for scales smaller than 1:1 000 000, but somewhere it's supplemented by intermediate contour levels, that favour the representation of morphological features not seen in standard interval. These levels are shown by dashed line in Figure 13. Contour interval for scales 1:1 000 000 and greater is constant and follows those prescribed in Table 3. Examples of map images in scales of 1:10 000 000, 1:5 000 000 and 1:2 500 000 are shown on Figure 14.

Figure 14: Map fragment (Great Caucasus). Scales: A – 1:10 000 000; B – 1:5 000 000; C – 1:2 500 000.

4- Conclusion and future plans

Multiscale mapping has got a lot of attention during the last years, thanks to the growing interest in visual aspects of multiple representations. However surprisingly few works can be found that investigate relief representation as an element of multiscale maps. In this paper we presented methodology that provides representation and generalization of relief on multiscale hypsometric maps. Proposed database structure takes mapping scales into account. Developed algorithm for DEM generalization proved to be efficient in middle and small scales of mapping. It preserves major relief forms, slope profiles and structure lines although not being free of shortcomings. We also pointed out some rules of relief graphical representation in multiscale mapping environment.

We believe that the most promising area to improve our methodology is the development and incorporation of real-time methods to control relief representation not only in fixed set of scales but in any scale within map scale range. This would lead to reduction of number of database LoDs, truly scale-correspondent and continuously changing image detailisation, and ability to interpolate symbology between scales.

Acknowledgments

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Best Pratices for Polygon Generalisation from medium to small Scale in a GIS Framework

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Abstract

The paper presents a best practice approach for the generalisation of polygon data in a GIS environment. Two main issues are addressed: the topological integrity between different themes with inter-theme constraints and the management of themes that are stored in the database with dual geometries such as polygonal units and their linear borders. The use of an auxiliary dataset that results from the application of the map overlay method "union" to a number of polygon themes is introduced. It can be used to solve inconsistency problems of the original datasets and to successfully handle generalisation by supplying structural knowledge. The modelling of polygonal units and their linear borders in a spatial database is discussed and the use of topological relationships for generalisation is proposed. These best practices have been successfully tested in the rule - based generalisation performed in the framework of the ESDIN program in order to produce a pan – European small scale dataset from medium scale one.

1- Introduction

National Mapping and Cartographic Agencies (NMCAs) invest on an annual basis considerable time and effort to provide updated data at medium (1:250 000) and small scale (1:1000 000) in order to contribute to a pan-European dataset handled by Eurogeographics. Since the majority of the themes such as Administrative Units, Populated Areas etc. are common to the two spatial datasets, the updating process is repeated. The automatic derivation of small scale data from medium scale data through generalisation is a strategic goal for NMCAs. In this way the update activity will be

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limited, more time will be spent on the improvement of the quality of the medium scale, the content of both scales will be harmonized and the sustainability of the products will be ensured.

Many medium scale spatial databases contain a number of themes that are encoded with polygon entities such as Administrative Units, settlements, land use etc.The goal of this paper is to present a best practice approach for the generalisation of polygon data from medium to small scale in a GIS environment. Best practice is a technique or methodology that, through experience and research, has proven to reliably lead to the desired result. Best practices for generalisation refer to operators, methods, algorithms, models and auxiliary structures that are offered from industry-standard GIS software and thus can be used by NMCAs. If such best practices are adopted by NMCAs, generalisation will be performed based on the most efficient and effective way.

2- Approach & methods

2.1 Generalisation

Generalisation methods and processes have been improved alongside developments in science and art of cartography and have been strongly influenced by progress in computer science. The application of generalisation to a medium scale database to produce a small scale dataset can be divided into two sub-tasks: model generalisation and cartographic generalisation (Sarjakoski 2007; Weibel 1997). Three different models have been proposed for the overall process of generalisation (Harrie and Weibel 2007): condition-action modelling, human interaction modelling and constraint based modelling. Since an interactive generalisation system is inadequate for working with national spatial data due to their volume, one of the other two models should be considered. The automated generalisation process can be divided into several sub-processes (McMaster and Shea 1992; Brassel and Weibel 1988), often called generalisation operators, which are performed by generalisation algorithms. A generalisation algorithm is a formal mathematical construct that solves a generalisation problem by changing an object’s geometry or attribute (Bader et al. 1999).

2.2 Generalisation of Polygon Data

2.2.1 Operators for polygon data generalisation

Generalisation of polygon themes is carried out utilizing a number of generalisation operators that perform semantic and spatial transformations. The most common of these operators are (Figure 1): selection, simplification, amalgamation, reclassification, collapse, elimination etc.

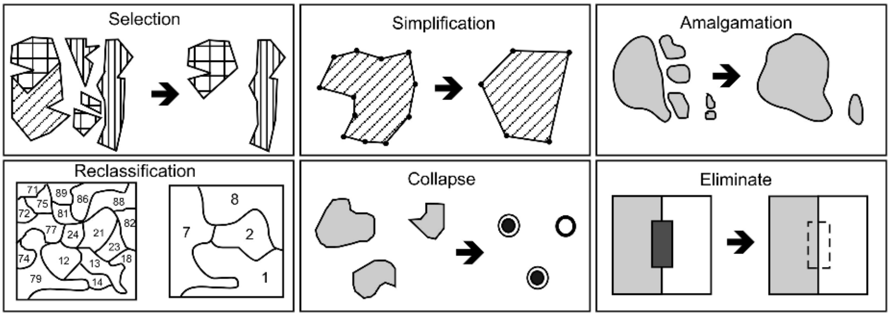

Figure 1: Operators used in polygon generalisation (based on McMaster and Shea 1992; Galanda 2003).

2.2.2 Map overlay operations as auxiliary tools for consistency testing and polygon generalisation

Many spatial databases exhibit inconsistency problems between their themes that should be solved before generalisation. Map overlay operations such as clip, erase, identity, union etc. which allow association of different themes (Laurini and Thompson 1992), can be used to correct inconsistency problems. Erase can be used to assure that one polygon theme does not overlap with another polygon theme, by deleting the common area from the first theme. Clip can be used to assure that a polygon dataset is completely inside the area described by another polygon dataset, by deleting everything that is outside.

One of the basic requirements of polygon generalisation is the topological integrity of the generalised data. Polygon borders should not self-intersect or intersect with other objects. A time and effort consuming task is to detect and correct topological inconsistencies independently of the generalisation process (Edwardes et al. 1998). Topological errors due to simplification can be avoided by generalising an auxiliary dataset. The auxiliary dataset is a combined polygon theme that is created from the application of the map overlay method "union" to a number of independent polygon themes with inter-theme constraints. If it is used for the simultaneous simplification of the geometry of these themes, inconsistency problems that would result from more than one independent simplification procedures are avoided. Most commercial GIS software, provide simplification tools that can assure topological consistency in a single dataset.

In addition to the above, the auxiliary dataset can be used to address inconsistency problems of the original themes. By the application of the "union" operation, a number of polygons are created. If the original themes are fully compatible, a "one to one" relationship exists between the polygons in the original themes and the polygons of the combined dataset. When inconsistency problems exist, new polygons are created in the combined dataset that correspond to each one of the problems. The polygons of the combined dataset carry all the attributes of the themes that are used. The difference in the values of these attributes makes it possible to identify each polygon. The identification and the appropriate handling of these polygons result in a consistent dataset.

Moreover, the auxiliary dataset can be used to better handle other cartographic generalisation issues such as minimum area, imposed by the limits of visual perception. Minimum area limits are applied to independent polygons, enclaves and small polygons between different themes.

The auxiliary dataset is introduced as a structure that can assure consistency to original and generalised data. It is created only for processing issues and does not change the original data schema. Afterwards the original themes can be reconstructed.

Example: Establishing consistency between Administrative units, Built-up areas and Watercourse Areas

The application of the above concepts will now be presented with a concrete example. Most medium class spatial databases contain themes such as Administrative Units, Built-up areas and Watercourse areas that are represented as polygons and have obvious inter-theme relationships. Each theme (Table 1) has at least one attribute that describes one important characteristic of this theme.

Theme	Theme short name	Characteristic field
Administrative units	AU	AUCODE: code
Built-up areas	BA	NAME: name
		AUCODE1: the code of the Administrative units that the Built-up area belongs to (calculated by spatial operation)
Watercourse Areas	WA	HYC: type
Built-up areas without enclaves	BAnoe	NAME1: name
Watercourse Areas without enclaves	WAnoe	HYC1: type

Table 1: Polygon themes in a medium scale database.

In Table 2, a number of rules that satisfy the inter-theme consistency constraints are presented along with proposed actions. The rules application requires the use of the auxiliary structure and map overlay operators. A logical condition based on the attributes of the themes permits the selection of the polygons. Selected polygons are handled as the action dictates. Administrative units are considered of higher accuracy and their geometry is not affected by the rules. After the successful management of the polygon issues (Figure 2 and Figure 3.), the original themes are reconstructed. The above procedure creates consistent themes and can therefore be considered as a best practice for similar problems of polygon themes.

Themes	Consistency Rule	Polygon selection condition based on attribute values	Actions
AU, BA	R1.Build-up areas should not fall in the sea or outside the international boundaries.		Clip
BA, WA	R2.Watercourse areas should not overlap with build-up areas.		Erase
AU, BA	R3.A part of a Built-up area (Clipped polygon) that falls to a different Administrative Unit than the main part of the Built-up area should be large enough to assure that this area exists and is not a geometric error.	The value of the Administrative Unit code differs from the Administrative Unit code that the Built-up area belongs to The polygons are parts of the original Built-up Areas: the “NAME” attribute that holds the name of the Built-up Areas has a value	Union Select Delete
BA, BAnoe/ WA, WAnoe	R4.Enclaves in Build-up areas (Build-up areas enclaves) or Watercourse areas (Watercourse enclaves) should be greater than the minimum area threshold for enclaves.	The polygons are parts of the Built-up Areas / Watercourse areas without enclaves: the “NAME1” / “HYC1”attribute is not empty The polygons are not part of the Built-up Areas/ Watercourse areas as they are holes: the “NAME”/ “HYC” attribute is empty The value of the “Area” attribute is below the minimum area threshold for enclaves	Union Select Eliminate
AU, BA / BA, WA	R5.Small areas between the borders of the Build-up areas and the Administrative Units (In between) or the borders of the Build-up areas and the Watercourse (In between), should be incorporated to the Build-up areas	The polygons are not part of the Built-up Areas: the “NAME” attribute is empty, The polygons are not part the Built-up Areas without enclaves: the “NAME1” attribute is empty Or The polygons are part of the Administrative Units: the “AUCODE” attribute is not empty , The polygons are not part of the Watercourse Areas: the “HYC” attribute is empty The value of the “Area” attribute is below the minimum area threshold	Union Select Eliminate
AU, WA	R6.Small areas between the coastline and the Watercourse Areas (In Between Water Areas) that are not inside the Administrative Units should be incorporated to the Watercourse areas.	The polygons are not part of the Administrative Units: the “AUCODE” attribute is empty. The polygons are not part of the Watercourse Areas: the “HYC” attribute is empty.	Union Select Eliminate

Table 2: Consistency rules, polygon identification based on logical conditions and actions.

Figure 2: Example 1 of the rules application to ERM data: a. Initial Data b. Identification of different kind of polygons c. Final Data.

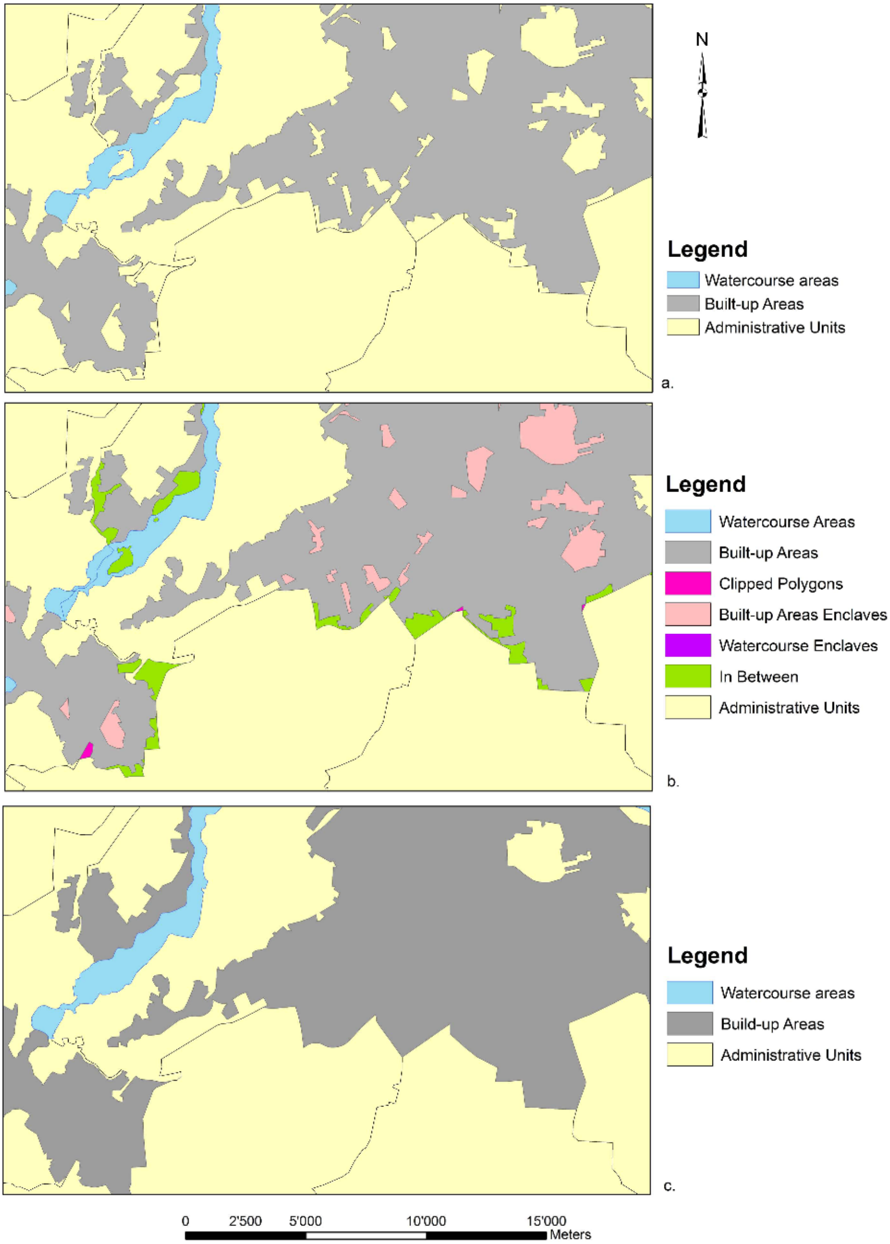

Figure 3: Example 2 of the rules application to ERM data: a. Initial Data b. Identification of different kind of polygons c. Final Data.

2.3 Generalising themes with dual geometric primitives – A generic modelling issue

Nowadays spatial databases, that follow the OGC (Open Geospatial Consortium) simple features standard, store separately different types of geometric entities e.g. polygons from lines. This makes it difficult to manipulate objects comprised of different data types efficiently (Mustiere and Van Smaalen 2007). Themes such as Administrative Units are represented in a spatial database utilising polygons, which store the geometry and the attributes that refer to the areas such as code, area etc, and lines, which store the attributes and the geometry that refer to the borders such as hierarchical level, length, statue etc. The existence of two objects that store the same thematic information in one database creates an important consistency issue, since any changes in the geometry of the polygons must be reflected to the lines and vice versa. However such a mechanism is not automatically supported in any spatial database. Only topological relationships could assist in solving this problem. The current trend in GIS is towards calculating topological relationships when needed, not storing them permanently. Thus data schemas may be different for storage and processing, the topological schema only being used during the generalisation process (Mustiere and Van Smaalen 2007).

For the generalisation of themes with dual geometric primitives, it is proposed to calculate the topological relationships. As generalisation changes the geometry of the objects, a question arises about the sequence of processing in the case of themes with dual geometries. Should one generalise the lines and then update the polygons or vice versa. Two different scenarios are considered.

Scenario 1: Apply generalisation to the linear dataset and then recreate the polygon dataset (ESDIN D10.5). It can be implemented in the following steps:

- Select the Administrative borders and reclassify the Administrative Units areas according to the small scale specifications with respect to country
- Convert the Administrative Units areas to points in order to create a point dataset with the polygons attributes
- Simplify the medium scale Administrative borders dataset.

- Create the small scale Administrative Units polygon datasets from the simplified Administrative borders dataset utilizing the point dataset with the areas' attributes.

The last procedure can sometimes create several attribute errors (e.g. wrong code, no data etc). Since the geometry of the Administrative borders has changed due to simplification, the point that holds the attributes of the original polygon will not always fall inside the new generalised polygon. For example, if the point falls outside the polygon in the case of an island, a "null" attribute value is created (Figure 4a.) or if two points fall in the same generalised polygon the wrong attributes may be attached to this polygon whereas "null" attribute values are attached to the adjacent polygon (Figure 4b.).

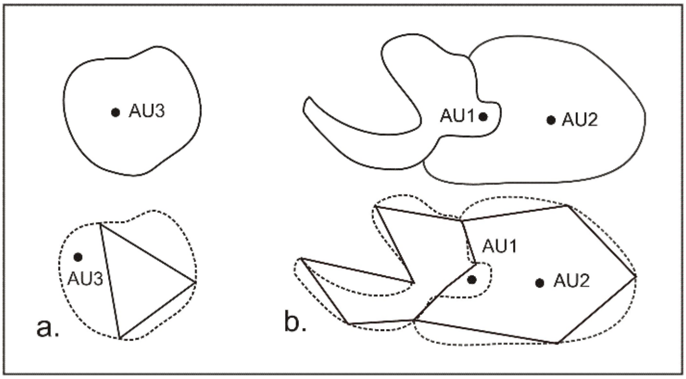

Figure 4: Possible errors caused by Scenario 1

Scenario 2: Apply generalisation to the polygon dataset and then recreate the linear dataset. The geographic objects to be modeled and generalised are the Administrative Units. One of the main constraints in the generalisation of a polygon dataset is the minimum area in relation to scale. Such a requirement cannot be applied when the generalisation is performed at the borders level. In case that the minimum area requirement is applied to the polygons that are created from the generalised lines and a polygon is deleted, this change in geometry cannot be transferred to the borders dataset because the linear and the polygon datasets are independent. As a result the two datasets will be inconsistent. In contrast to this when generalisation is performed at the polygon level, minimum area requirements can be applied along with other generalisation requirements related to the borders such as level of detail, which can be handled by simplification. Afterwards, linear data consistent with the polygons can be created.

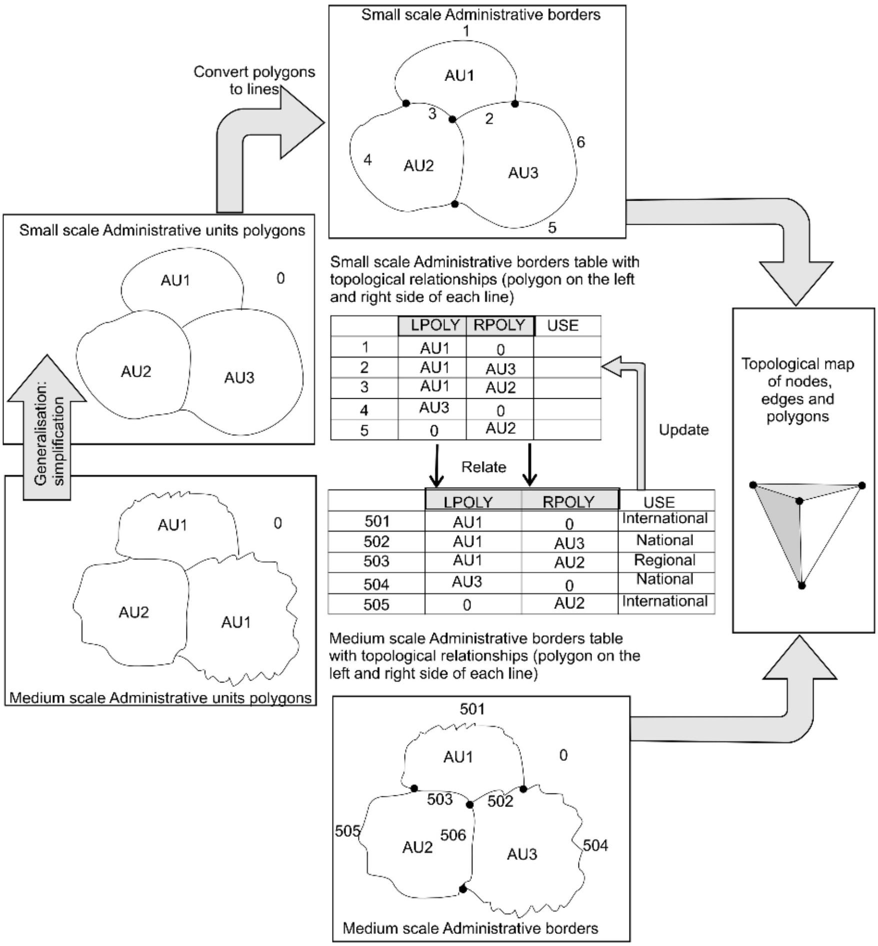

Figure 5: Due to the fact that the topological map of nodes, edges and polygons of the Administrative Units at the medium scale and the topological map of the generalised Administrative Units at the same hierarchy level are isomorphic graphs, attributes of Administrative Borders are transferred from the medium scale to the small scale dataset

Based on the above analysis and the problems in Scenario1, it is considered preferable to generalise the polygons and then recreate from them the borders. An issue that needs to be addressed in this case, is that the small scale borders, which are created by the generalised polygons, do not have any attributes. The retrieval of the attributes from the medium scale borders can be succeeded by the use of topology to the initial and the generalised data. A field is calculated for each border that records the Administrative Unit codes of the adjacent polygons: that is the polygon on the left side and the right side of the border. Based the values of this field, medium scale borders can be linked to the generalised small scale borders. This is accomplished based on the fact that the topological map of nodes, edges and polygons of the Administrative Units at the medium scale and those of the generalised Administrative Units at the same hierarchy level are isomorphic graphs (Figure 5). Two graphs are considered isomorphic if there is a one-to-one correspondence between their nodes and their edges. In other words, the conditions of connectedness and adjacency correspond, even though shapes may be quite different (Laurini and Thomson 1992). The application of the "simplification" generalisation operator does not change the topological map, since the nodes of the lines remain in the same position. In addition to this, it is the hierarchical level of the codes of the adjacent Administrative Units that determines the hierarchy level of the border.

3- Case study and results

3.1 The ESDIN project

The European Commission's ambition to build a European Spatial Data Infrastructure (ESDI) based on the National Spatial Data Infrastructures in Member States, for which INSPIRE (Infrastructure for Spatial Information in Europe) is the legal instrument, is currently in development. ESDIN (European Spatial Data Infrastructure with a Best Practice Network) (http://www.esdin.eu/) is EuroGeographics most recent project that furthers this by focusing on helping NMCAs prepare their data for INSPIRE Annex I themes and improve access to them. One of ESDIN's goal (ESDIN DOW 2008) is the generalisation of the EuroRegionalMap (ERM) medium scale (1:250 000) data in order to create the EuroGlobalMap (EGM) small scale data (1:1000 000) based on rules. Feasibility testing of the ruled-based generalisation is carried out in a GIS environment.

3.2 Generalisation in the ESDIN framework

A condition-action modeling will be used for the ruled-based generalisation process in the ESDIN framework. Rules are the result of the comparison of the specifications of ERM and EGM and a concrete comparison of the data themselves (ESDIN D10.5 2010). An additional point is that these pan-European products are created from national datasets that have different characteristics. The goal of these rules is to respect these characteristics when they are related to independent causes as is the case of the different hierarchical level of Administrative Units for each country. However when these discrepancies are the result of particularities created by the subjective nature of generalisation, they are not followed. The goal is the creation of a good quality harmonised small scale dataset and not the recreation of the existing EGM with its disadvantages.

During the implementation of the generalisation, it has been observed that for some data cases, generalisation rules do not exist or are proved insufficient. In these cases additional constraints have been proposed taking into account the data specifications, generalisation procedural knowledge and common cartographic practice. Rules that guide generalisation describe the selection of a subset of the original data utilising their properties. These properties may be their descriptive characteristics (attributes), their spatial properties or their topological relationships. These selections cannot be made unless the data and the data schema used can support their retrieval. Structural knowledge needed by some rules is created by the auxiliary tools presented earlier in this paper. According to the rules generalisation operators such as aggregation, simplification and collapse are used. The consistency rules presented in Table 2 and the generalisation rules presented in the list below have been applied in the ESDIN framework for Built-up areas, Administrative units and Hydrography:

1. If the number of inhabitants is greater than or equal to 50 000, medium scale Built-up Areas (polygon) are transformed to small scale Built-up Areas (polygon).
2. Built-up Areas polygons that belong to the same Built-up area and the distance between them is less than 500m are aggregated.
3. If the number of inhabitants is smaller than 50 000, medium scale Built-up Areas (polygon) are transformed to small scale Built-up Areas (points). The collapse generalisation operator is performed by using the centroids of the surfaces. If a Built-up area consists of more that one polygon, the centroid of the larger one is used.
4. If the number of inhabitants is greater than 1 000, medium scale Built-up Areas (points) are transformed to small scale Built-up Areas (points).
5. The lowest level for the small scale in the administrative hierarchy is the NUTS3 subdivision.

6. If the width of Watercourse areas in the medium scale is greater than 50m, they become part of the small scale dataset.
7. Administrative units and Administrative borders must share the same geometry.
8. Built-up Areas, Administrative unit and Watercourse Areas must be simplified.
9. If polygons of multi-part entities are smaller than 1 km^2, they are deleted.
10. Administrative areas should be consistent with Built-up Areas and Watercourse.

3.3 Generalisation plan

In order to apply the rules, a general plan for the generalisation of Built-up areas, Administrative units and Watercourse Areas is formed (Figure 6). This plan consists of seven independent generalisation processes (GP).

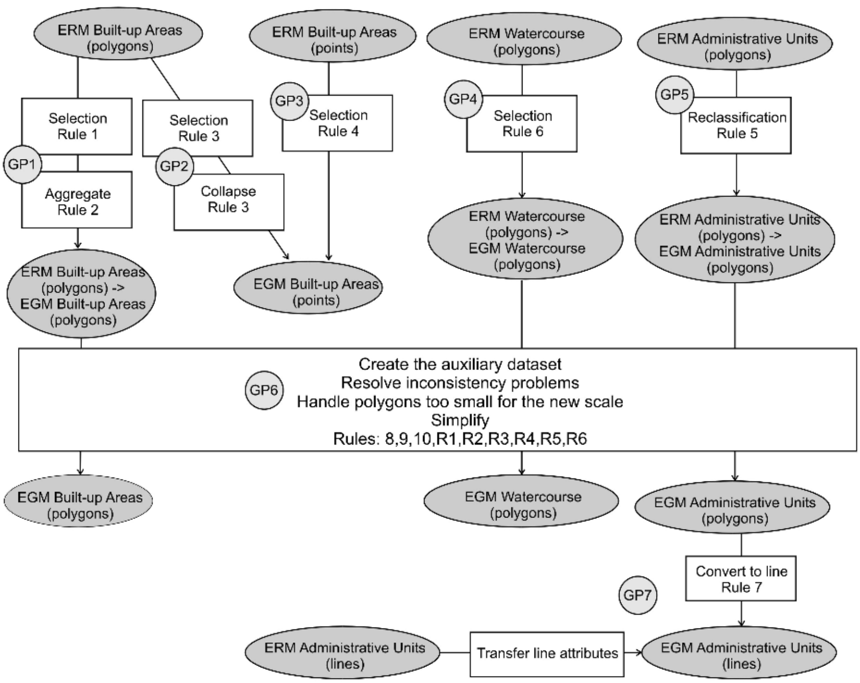

Figure 6: Based on the general plan, the generalisation procedure is analyzed into seven generalisation processes (GP)

Additional information is given for the Built-up area generalisation in Figure 7. A Built-up area may consist of a number of polygons that can be grouped based on the name. However, more than one Built-up area in Europe may have the same name. In order to select the correct polygons, additional information regarding their relative spatial position is needed. This information is provided by the Administrative unit code of the lower hierarchical level that each Built-up area belongs to. A special field is created that holds the Administrative unit code and the name of the build-up area. This field works as an identifier and is used in any Built-up Area selection statement (Figure 7).

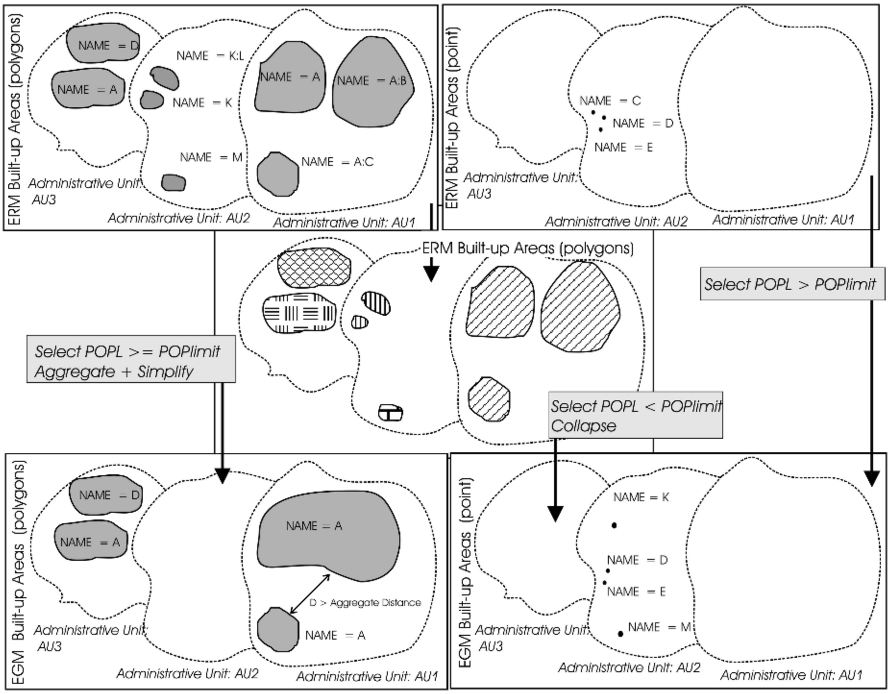

Figure 7: ERM Built-up area (polygon) dataset generalisation results to EGM Built-up area (polygon) dataset and Built-up area (point) dataset. ERM Built-up area (point) dataset generalisation results to EGM Built-up area (point) dataset

3.4 Implementation

The above described generalisation plan has been implemented in the ESRI ArcGIS environment. ERM data are stored in a file geodatabase. The generalisation process is implemented with ArcGIS tools that have been combined and customized utilizing the ModelBuilder environment and the Python programming language. The result is a tool that establishes a fully automated generalisation environment which produces the final datasets. No user interaction is required except from the identification of the datasets.

3.5 Results

The above rules and methods have been successfully applied to a subset of the ERM dataset that covers the region of Germany. Figure 8 presents a comparison of the generalised EGM Built-up areas (polygons) to the existing EGM Built-up areas (polygons). A comparison of the new EGM Built-up areas (points) to the existing EGM Built-up areas (points) can be found in Figure 9. In terms of objects the compliance is 100% for Administrative Units, 100% for Built-up Areas (polygons) and 93% for Built-up Areas (points). This difference is due to the initial ERM dataset. A considerable number of Built-up Areas in the point and the polygon dataset have "no data" population values and thus cannot be selected in order to be present to the new EGM dataset. Differences in the geometry are expected since the EGM dataset has not been produced by the generalisation of the ERM dataset. It has been independently created by the NMCAs utilizing small scale datasets.

In the future, the rules will be applied to a multi-national dataset, in order to adjust any parameters used, and eventually to a pan-European dataset. All the rules stated in the framework of ESDIN project covering all INSPIRE Annex I themes will be later incorporated in the above GIS tool. As a result a powerful platform for the automated production of a small scale pan-European spatial dataset from a medium scale one based on generalisation will be available to NMCAs and Eurogeographics.

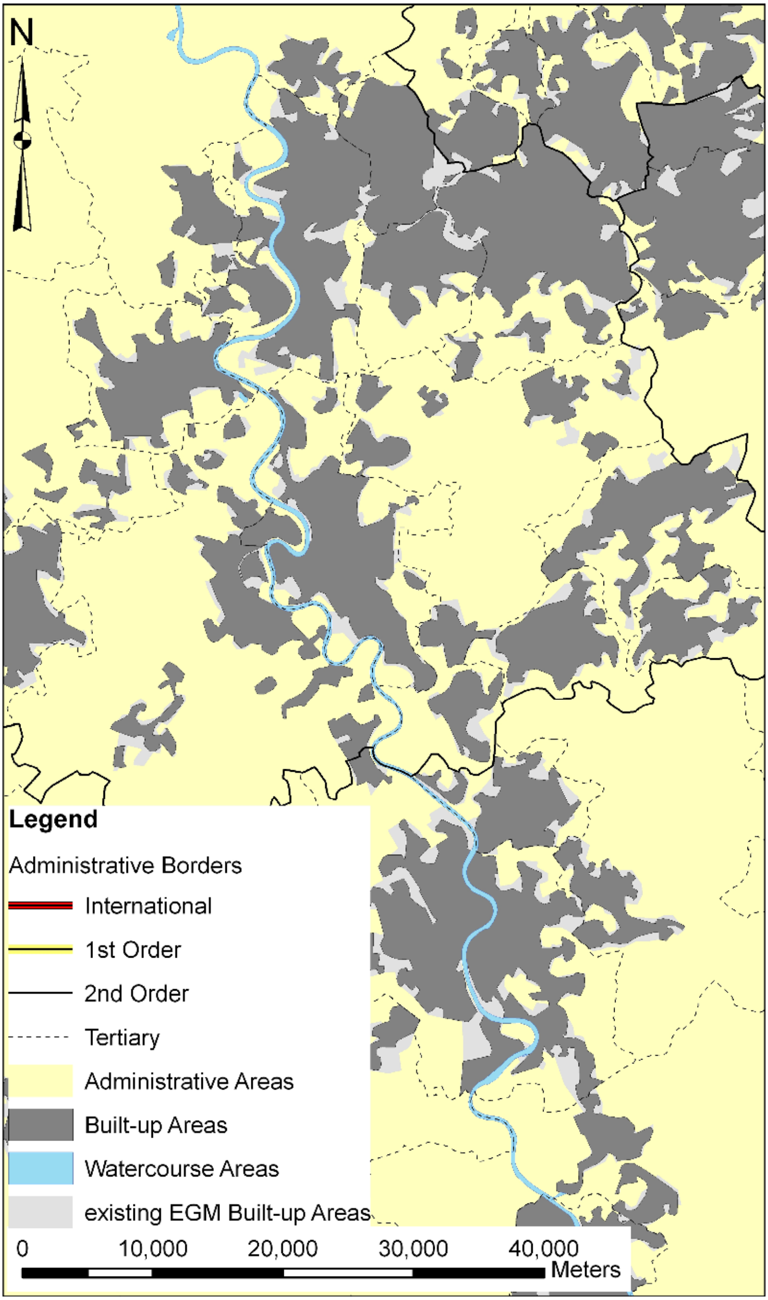

Figure 8: Generalised EGM datasets: Administrative Units, Built-up Areas and Watercourse Areas.

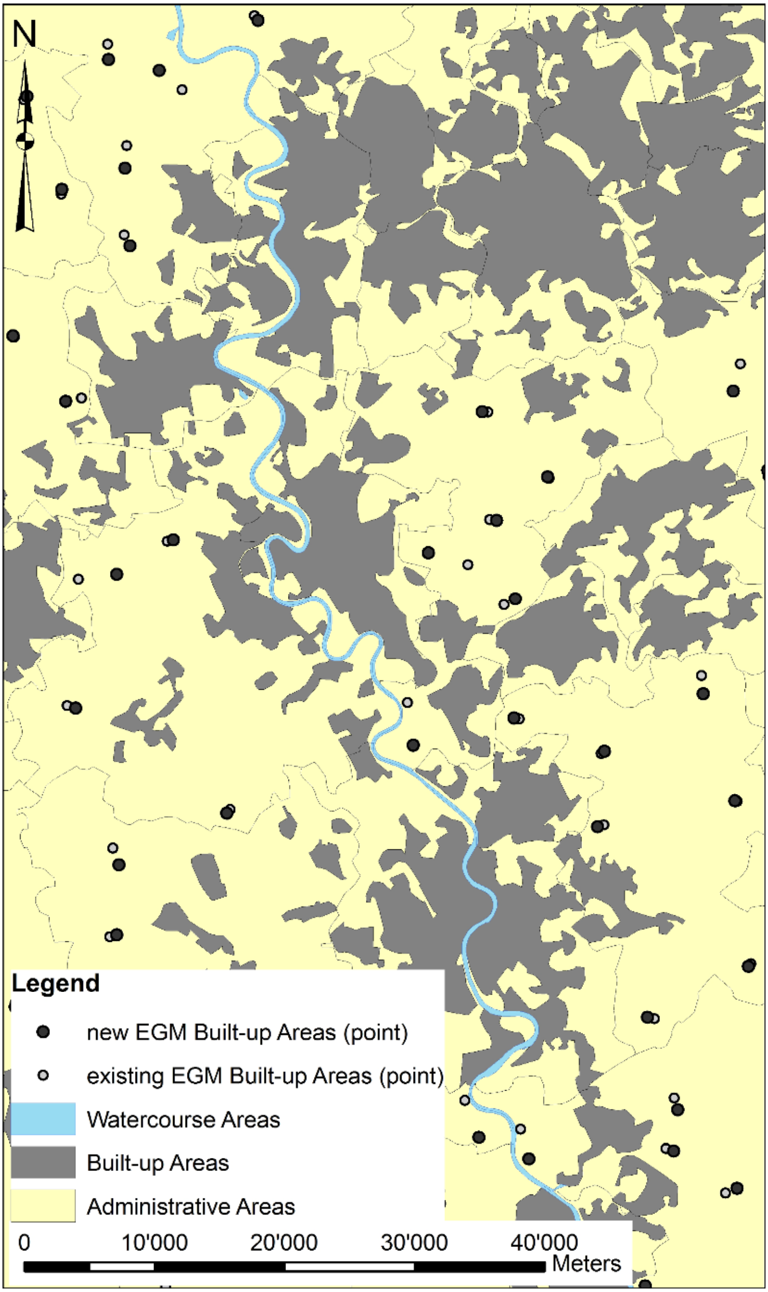

Figure 9: Generalised EGM datasets: Built-up area (points)

4- Conclusion and future plans

The aim of this paper is to present a best practice approach for the generalisation of polygon data from medium to small scale in a GIS environment taking into account inter-theme consistency. The use of the map overlay operations as a tool to solve integrity problems of the original data and to create structural knowledge supportive for generalisation is proposed. An auxiliary dataset is used to solve the integrity problems of the original datasets, to simultaneously simplify the geometry ensuring no inconsistency problems and to better handle other cartographic generalisation issues such as minimum area imposed by the limits of visual perception. In addition to this a generic modeling issue is discussed that addresses the duality between the polygonal units and their linear borders. An appropriate data model to link units and borders is proposed based on topological relationships. Generalisation of themes that are represented with polygons and lines in the spatial database is successfully handled based on topological relations.

The above-described best practice approach has been applied and tested in the framework of the ESDIN project. A number of rules developed in the framework of the ESDIN project for the generalisation of Administrative Units, Built-up Areas and Watercourse areas have been successfully utilized. A tool has been created in a standard based GIS, that implements the generalisation rules with the help of the proposed methods. The case study has proved that EGM can be extracted from ERM based on rules, although these datasets are created in different environments and are based on different national products. In addition to this, the value of the introduced best practices for the generalisation of polygon data has been verified.

Acknowledgments

This work has been done in the framework of the ESDIN project (European Spatial Data Infrastructure with a Best Practice Network - http://www.esdin.eu/). ESDIN is supported by eContent+ programme and is coordinated by Eurogeographics.

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CollaGen: Collaboration between automatic cartographic Generalisation Processes

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Abstract

Cartographic generalisation seeks to summarise geographical information to produce legible maps at smaller scales. Past research led to the development of many automated cartographic generalisation processes, each one being more or less specialised to a particular problem: a landscape like urban areas, a data theme like land use, a cartographic conflict like linear symbol overlap or most of the time of mix of the three. This paper deals with the development of a model allowing collaborative generalisation i.e. the collaboration between automatic processes like these in order to tackle the generalisation of a complete map. CollaGen, our proposed model, allows to partition data in geographic spaces and to find to best suited process to generalise each space. The applications of a process on a space are automatically orchestrated. Interoperability between processes is managed thanks to formal constraints and side effects are monitored after each process application. Results from CollaGen prototype are shown and discussed.

1- Background and Objectives

Cartographic generalisation seeks to summarise geographic data to produce legible maps at smaller scales. The automation of cartographic generalisation would make the production of map series easier as well as it would allow quality on-demand mapping. The past twenty years of research in the generalisation domain have lead to the development of many different and complementary automatic models and processes. (Barrault et al. 2001, Harrie and Sarjakoski 2002, Duchêne 2004, Bader et al. 2005,

A. Ruas (ed.), *Advances in Cartography and GIScience. Volume 1: Selection from ICC 2011, Paris*, Lecture Notes in Geoinformation and Cartography, DOI 10.1007/978-3-642-19143-5_30,

Haunert 2007) are a small sample of the available cartographic generalisation processes.

If so many processes have been developed over the years, it is due to the impossibility to solve the complex problem of generalisation with a single process. Indeed, every process is only completely relevant for a limited part of the generalisation problem. Some processes are well adapted to particular *landscapes*: AGENT (Ruas 1999, Barrault et al. 2001) is designed for urban generalisation while GAEL (Gaffuri 2007) may be specialised to deal with high relief landscapes. Moreover, some are only relevant for the generalisation of a specific data *theme*: (Haunert 2007) is dedicated to land use generalisation for instance. Added to that, some are relevant for solving a limited part of the cartographic *conflicts* resulting from scale change: for instance, the simulated annealing process of (Ware et al. 2003) is designed for solving proximity conflicts. Finally, some mix the three previous cases: the Elastic Beams (Bader et al. 2005) are relevant for road overlap conflicts (*theme* and *conflict*).

Either automatically producing map series or on-demand mapping requires to be able to generalise any landscape, data theme or solve any necessary kind of conflict, which is not possible using a single existing process. Rather than developing a new complete generalisation process, which seems a bit rash, the objectives of our research is to benefit from the existing processes and make them work together. We propose a new framework, *Collaborative Generalisation* (CG), to make processes collaborate to correctly generalise a entire map.

The second part of the paper describes the CG approach and the CollaGen model. The third part focuses on the results obtained with CollaGen. The fourth part draws some conclusions and proposes future plans.

2- Approach and Methods

2.1 The Collaborative Generalisation Framework

Automatic generalisation research first tried to answer to the questions “why, when and how to generalise?” (McMaster and Shea 1988, Brassel and Weibel 1988). Inspired from (Regnauld 2007) and (Duchêne and Gaffuri 2008), the CG framework we define aims at allowing an answer to the question *why*, *when* and *how* to apply *which* automatic process? Within this framework, automatic generalisation processes are applied on parts of space where they are expected to be efficient while side effects are likely managed at generalisation neighbourhood (Figure 1).

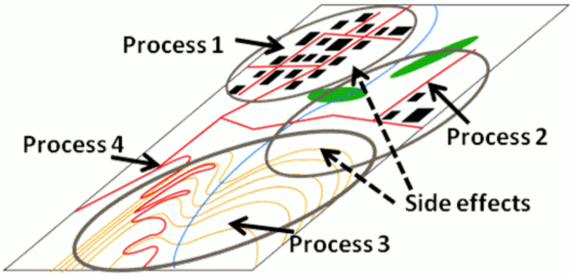

Figure 1: The collaboration principle between generalisation processes. A process 1 is carried out on the town area, a process 2 on the rural area, and then a process 3 on the mountain area and finally a process 4 is carried out on the road network. Side effects are corrected at the neighbourhood (dashed arrows) of application spaces.

2.2 Overview of CG Framework Components

Generalising data within the CG framework brings about specific problems like process interoperability, treatment heterogeneity or side effects (Touya 2008). The framework function analysis lead to a six main components and three resources groups structure (***Figure 1***). *Partitioning* builds the *geographic spaces* where the *available generalisation processes* can be applied. The *Translator* parameterises the processes. The *Registry* chooses the process to generalise a given space. The *Observation* provides online evaluation. *Side effects* are managed by the eponymous component. Finally, the *Scheduling Component* orchestrates the whole process.

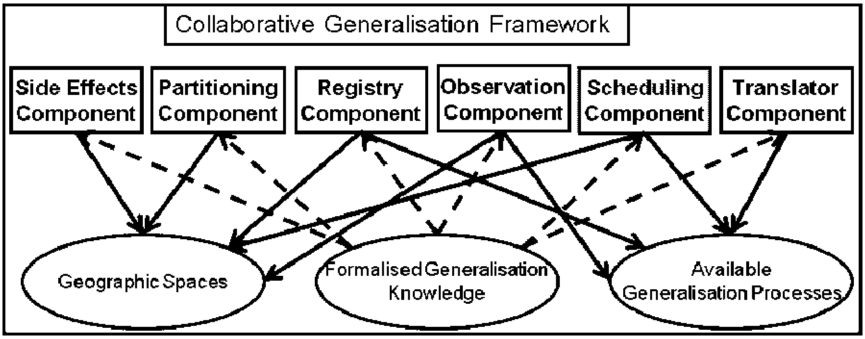

Figure 1: The main Components (rectangles) and Resources (ellipses) of a Collaborative Generalisation framework and how the components act on the resources (plain arrows). Dashed arrows show that formal knowledge is used by each component.

Within the CG framework, we developed the CollaGen model that implements all the aspects of collaborative generalisation defined in Figure 1. The next parts describe how each aspect is managed in CollaGen.

3- The CollaGen Model

3.1 Automatic Generalisation Processes

CG consists in making several available automatic processes collaborate to optimise the entire map generalisation. Thus, we consider as an available automatic generalisation process, any process that can be triggered on geographic data from the software platform the CG framework is developed on. A process is a computer program that automatically triggers generalisation operator (e.g. simplification, displacement...) sequences on geographic objects. For instance, in CollaGen, developed on a research platform (Renard et al. 2010), AGENT (Ruas 1999), CartACom (Duchêne 2004), GAEL (Gaffuri 2007), Least Squares (Harrie and Sarjakoski 2002) or road selection processes are implemented and thus available for collaboration. Processes published as web services (Regnauld 2007, Neun et al. 2008) could also be considered as available processes.

Geographic Spaces

We define a geographic space as a geographically meaningful extract of the data that can be a relevant input for a given generalisation process (Touya 2010). The use of geographic spaces in CollaGen is useful for both optimising the use of the existing generalisation processes and partitioning the data to avoid the processing of very large datasets. The geographic spaces (Figure 2) can be areal (e.g. urban or rural area), thematic (e.g. road network or vegetation) or both areal and thematic (e.g. mountain roads).

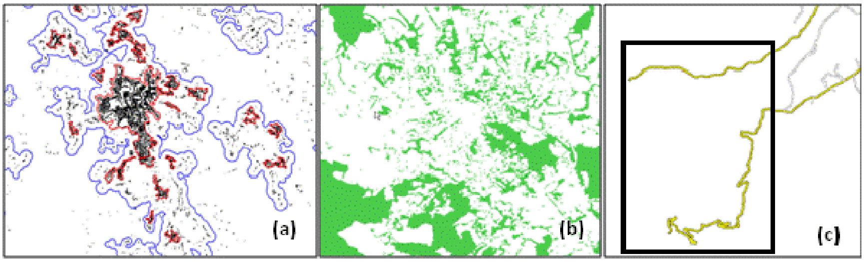

Figure 2: (a) buildings in black, urban areas in red and rurban areas in blue. (b) vegetation thematic space on the same area. (c) mountains roads space (in the rectangle).

It can be noticed that with such a definition, the geographic spaces do not form a mathematical partition as metric spaces can overlap and thematic spaces cross metric spaces. Spaces can be cut in several portions in order to keep small spaces and minimise processing time.

Moreover, some emerging spaces can be managed by CollaGen: they are sub-spaces where conflicts remain unsolved. During the generalisation of a space by a given process, the observation component can identify conflict clusters (close conflicting objects) that emerge as sub-spaces to be generalised by another process than the one processing the whole space (§0).

Formalised Knowledge in CollaGen

Formalised cartographic generalisation knowledge is necessary to allow process collaboration. The model designer (e.g. we are the CollaGen model designer) has to provide a *generalisation ontology* and *sequencing rules*; a process developer (the one that makes a new generalisation process available for collaboration) has to provide a *process description*; the user (the one that generalises data) has to provide *generalisation constraints* and *operation rules* (Figure 3).

- The *generalisation ontology* is the support for sharing a common vocabulary in the collaboration model. It helps to express that map specification ("buildings smaller than 50 m² must be deleted"), a data type ("BATIMENT" class) or a process requirement ("agent_building" in AGENT process) deal with the same concept of 'building' for instance.
- The *sequencing rules* are guidelines for sequencing applications of processes on geographic spaces. As in the Global Master Plan of (Ruas and Plazanet 1996), it allows to formalise that 'road selection' should be triggered before 'urban generalisation' for instance, or that 'urban areas' should be generalised before 'rural areas'.
- The *generalisation constraints* and the *operation rules* formalise the map specifications. The formal model summarises past research (Beard 1991, Stöter et al. 2007, Duchêne and Gaffuri 2008) and allows to express different constraints like 'building area > 0.2 map mm²', 'building block density should be preserved' or 'very concave buildings should maintain initial concavity with 10% margin'.
- A *process description* formalises the capabilities of a generalisation process. As for web services composition, capabilities are described with pre and post conditions (Lutz 2007). In CollaGen, pre conditions are adapted spaces for the process and post conditions are a priori satisfied generalisations constraints and operation rules (after the process has been applied).

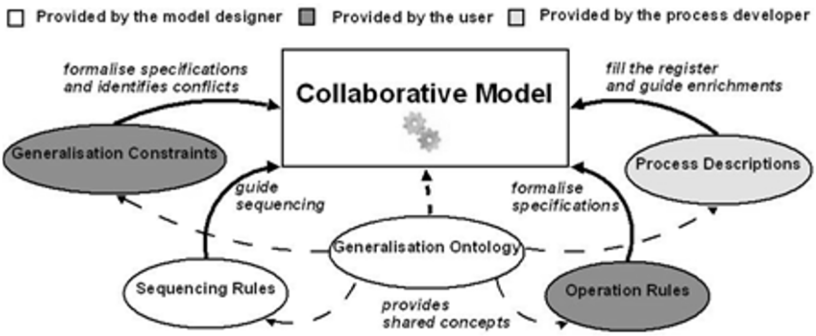

Figure 3: A diagram of the 5 parts of formalised knowledge and their use in the collaborative model. The dashed arrows show that the Ontology provides shared concepts to every part.

(Touya et al. 2010) describes how each piece of formalised knowledge is modelled in CollaGen and how it can be acquired by a user, a process developer or the model designer.

The CollaGen Workflow

CollaGen proposes a workflow for CG to chain the components actions (***Figure 4***).

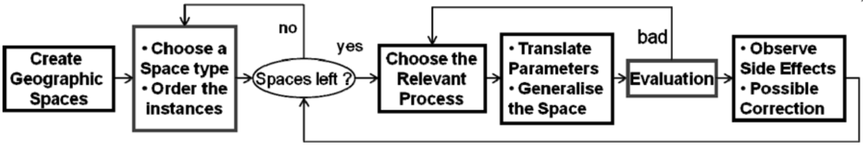

Figure 4: Simplified view of the sequence of CollaGen generalisation (emergence mechanism is not included). Each box is the action of one component.

As a simplified example, let us imagine an area that is firstly partitioned (into two rural spaces, an urban space and the road network), and three processes (AGENT, CartACom and Beams). Then, the urban space is chosen and the registry chooses AGENT. The process is parameterised according to the constraints and generalised. Generalisation is evaluated as good and there is no side effect. Then, the next chosen space type is rural and the two instances are ordered. CartACom is chosen and generalises the two instances correctly without side effects. Finally, the Beams generalise the remaining space (road network) but generates side effects by overlapping buildings. Then, the side effects are corrected by a specific process (Least Squares here) and the CollaGen workflow is finished. An implemented version of this example is illustrated in Figure 14.

Partitioning Component

The *partitioning component* is responsible for the creation of the geographic spaces as additional data (Touya 2010). Thus, the component has to be fed with spatial analysis algorithms able to outline the required spaces. For instance, algorithms to identify urban, suburban, rural, costal, mountain areas were implemented, among others.

Translator Component

The *translator component* provides three kinds of services to translate inputs and outputs of the processes in the language used to convey interoperability: the formal constraints and the ontology (Touya et al. 2010). First, the translator allows process interoperability making the constraints the only input and output of every process (Figure 5). A translating function is provided for every process and transforms the constraints and operation rules into the specific parameters of the process (e.g. numeric thresholds for a river selection, specific constraints for AGENT or CartACom, equations on coordinates for Least Squares or additional attributes for the Elastic Beams).

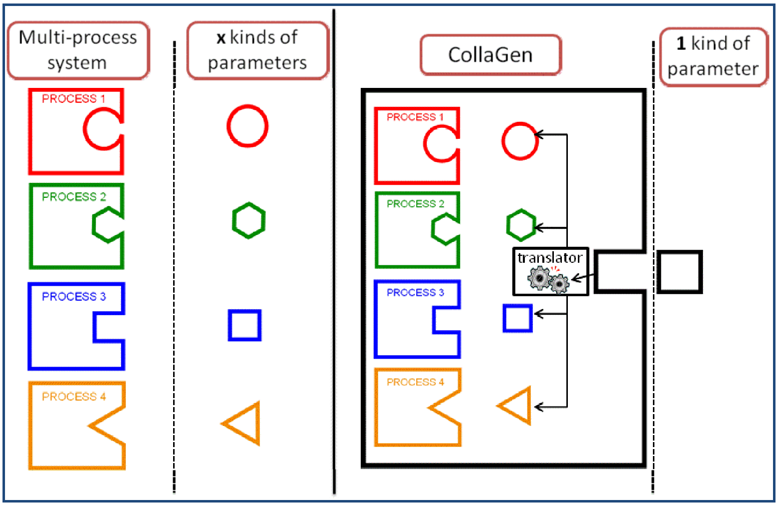

Figure 5: CollaGen allows interoperability with the use of a single output, constraints and the translator.

The translator also serves as a *registration mapping* (Lemmens 2008) to tag the geographic data with the corresponding ontology concept: it makes the mapping between the “IGN_BUILDING” data class and the “building” ontology concept for instance (Touya et al. 2010). Finally, the translator allows to map the formal constraints with measurement algorithms that compute the constraint current value and satisfaction for a given object as in AGENT (Barrault et al. 2001). The use of such mechanism is detailed in §0.

Registry Component

The *registry* serves as yellow pages service to choose a relevant process to generalise a given space at a given time. To a request like ‘what are the best available processes to generalise rural space n°x?’ the registry responds with a list of applicable processes sorted by relevance (e.g. ‘Cart-ACom, Least Squares, AGENT’).

To build the list, the registry first selects the relevant processes according to their description pre-condition: if the pre-condition, a list of space types with relevance rate (e.g. 'urban area 4/5') contains the request space type, the process is selected; then it is rated according to relevance rate.

In a second step, the processes are reordered according to the description post-condition, the list of a priori satisfied constraints after generalisation: a ratio is computed between the post-condition and the occurrences of constraints inside the space (Figure 6). The ratio weights the relevance rate, reordering the processes.

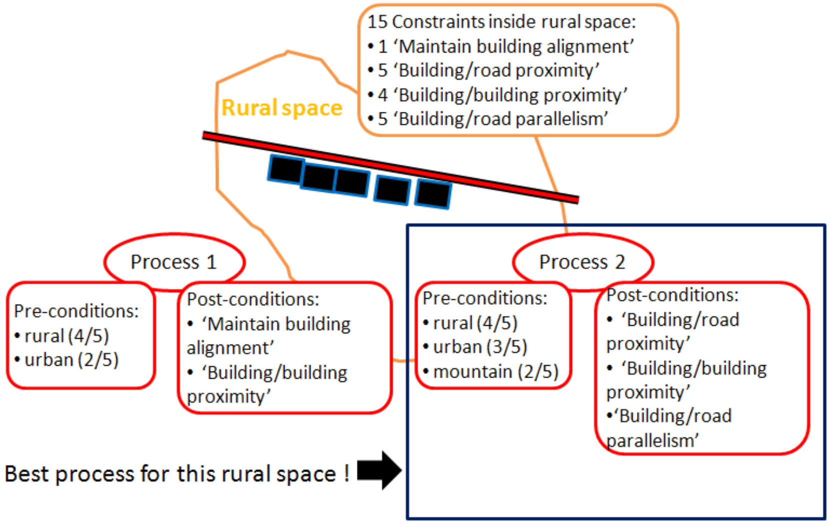

Figure 6: Illustration of the registry response according to the constraints inside a given space: process 2 matches 14/15 constraints against 5/15 for process 1.

Scheduling Component

The *scheduling component* orchestrates the generalisation of spaces by processes. After every generalisation, it decides what to do next: it chooses the next type of geographic space to generalise and then orders the instances of this type. As in a *Global Master Plan* (Ruas and Plazanet 1996) but here rule-based, the space type (urban, rural...) is chosen according to the active *sequencing rules*. If it is not enough to choose, the space type whose instances have the highest conflict mean is selected first. Once the type chosen, the instances are ordered by conflict importance: the most conflicting ones are peeked (Figure 7).

Generalisation is considered in CollaGen as a four step operation: geometry changes (e.g. area-to-point collapses), selection, cartographic and graphic generalisation (Harrie and Sarjakoski 2002). The processes are described as contributing to one or more of these steps and can be used only during the right steps. The scheduling component chains these steps according to the rules.

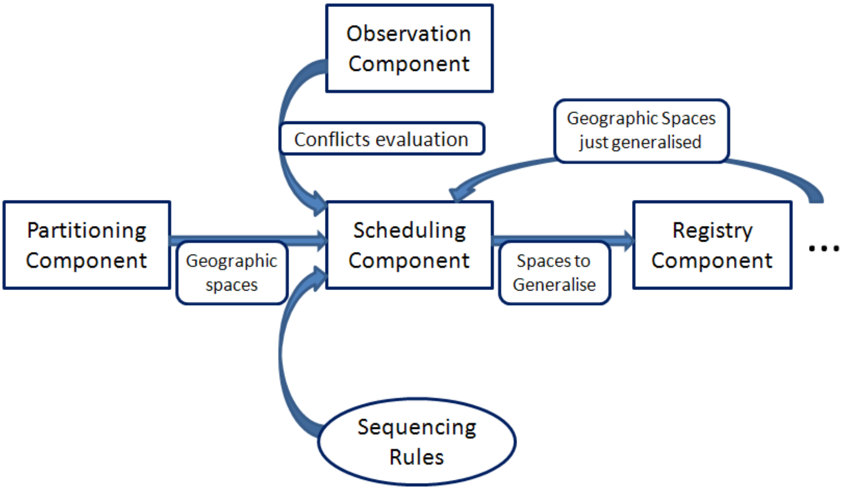

Figure 7: Interactions of the scheduling component with other components and resources.

Moreover, the scheduling component provides state management to allow local and global corrections (Figure 8). When a generalisation is badly evaluated, the scheduling may cancel it and go back to previous states of data. To allow this try/error mechanism, as in (Zhou et al. 2008), the initial state stores the attribute data while all the geometry states are kept linked to the generalisation pair (space/process) that led to the following step.

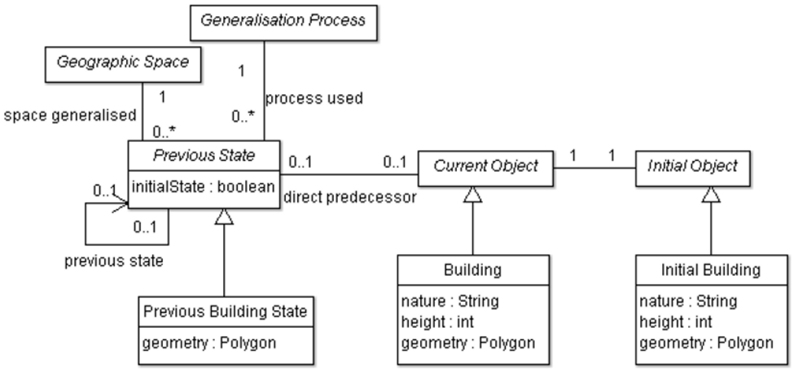

Figure 8: UM=L class diagram of the state management system of the scheduling component.

Observation Component

Generalising a space with the best available process does not guarantee a complete success. Conflicts clusters may emerge during generalisation and the observation component allows to detect them as *conflicting areas* (Duchêne and Touya 2010). Therefore, the component observes the generalisations online and evaluates the progress. The observation component analyses the conflict areas, pauses the process when some are too big, extends the areas to subserve solving, triggers the registry component to propose a local solution and once the local conflicts are solved, resumes to the interrupted generalisation.

The online evaluation embedded in the emergence mechanism, as well as the global evaluation performed on a geographic space after generalisation rely on the constraints to guarantee homogeneous evaluation for every process. To enable this monitoring of the constraints against the data, *located constraints monitors* (LCM) are added on each object concerned by constraints as in (Barrault et al. 2001): if "granularity" and "size" constraints are defined on buildings, granularity and size LCMs are added for every building. LCMs are able to give the satisfaction of the constraint for the given building.

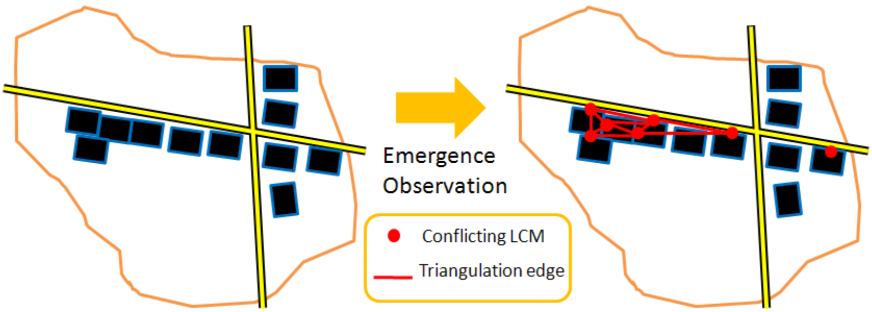

Figure 9: Conflicting LCM are clustered by triangulation to observe 'conflicting area' emergence.

The located constraints are provided with a geometry (Figure 9) that allows the spatial clustering necessary for the emergence mechanism. The geometry also allows to quantify the LCMs *inside* a geographic space so as to evaluate globally the space generalisation from the distribution of individual evaluation. Progress means less unsatisfied LCMs in the distribution while good generalisation means few very unsatisfied LCMs and lots of very satisfied LCMs.

Side Effects Component

Within the CG Framework, generalising a space may cause additional conflicts just outside the space: for instance, a building is moved too close to a building that was just outside (thus not managed by generalisation). We call such additional conflicts side effects. In order to detect and correct side effects, the neighbourhood of each space is defined depending on the topological relation shared by two spaces (adjacency or overlap) (Touya 2010).

Following the principle of the LCM evaluation, the side effects management is based on *consistency* constraints located in each space's neighbourhood. Consistency constraints are kind of integrity constraints that guarantee the consistency of data before and after the generalisation of a space. Three types of consistency constraints can be identified: the *inter-space* relational constraints, the *non-existence* relational constraints and the *operation consistency* constraints.

The *inter-space* relational constraints are relational LCMs (LCM on a geographic relation between two objects) concerning an object inside the space and an object outside the space (Figure 10). The figure "relative position relation" has a building in rural space 1 and the other in rural space 2. The "relative orientation relation" is an inter-space relation in the road network space point of view (building outside the space) but not in the rural space 2 point of view as the road is inside the space.

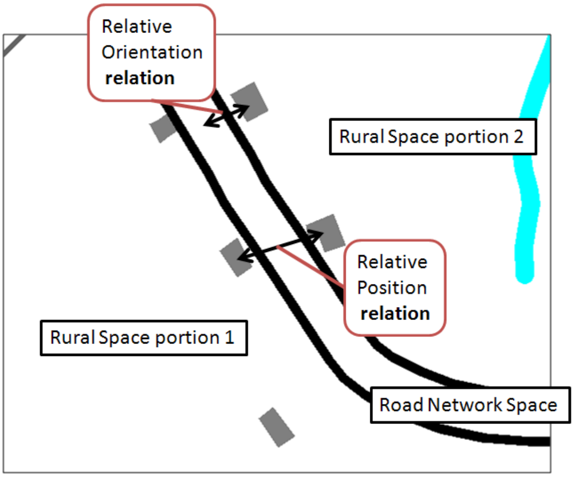

Figure 10: Two examples of inter-space relations with two rural space portions separated by a road: a relative position relation that should be preserved after each rural space is generalised and relative orientation relation (shared by rural space 2 and the road network space) that should be preserved if the road network is generalised

Then, *non-existence* relational constraints check that no additional *inter-space* relation has been created by generalisation.

The *operation consistency* constraints affect the intersection neighbourhood. If the intersecting space has already been generalised, these constraints check that the second generalisation is not inconsistent with the first one. For instance, if a building has been moved one way, it should not be moved the other way round. The operation consistency constraints are based on the previous states of the objects stored by the scheduling component.

Finally, if consistency constraints are violated, side effects correcting processes are triggered. Side effects correctors are monitored by consistency constraints as processes are monitored by constraints. GAEL (Gaffuri 2007), Elastic Beams (Bader et al. 2005) or Least Squares (Harrie and Sarjakoski 2002) can be used to correct side effects (Figure 11) as well as diffusion processes (Legrand et al. 2005). If no balanced solution can be found, the component can arbitrate by choosing a solution (before or after 2nd generalisation) like a legislator (Ruas 2000) or by relaxing some less important constraints like a controller (Ruas 2000).

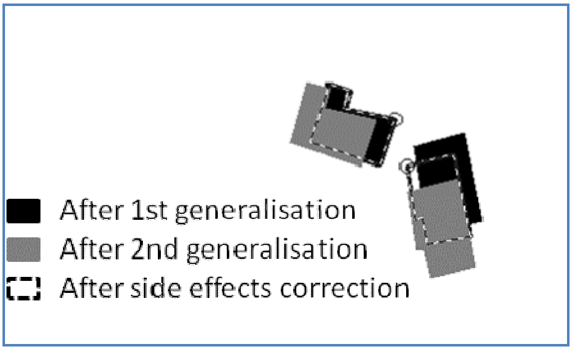

Figure 11: Example of side effect correction by least squares adjustment : a balance between both generalisations.

5- Results

The CollaGen model is not fully implemented but some experiments were carried out on French topographic data (1:15k reference scale) to produce a 1:50k map on a large area containing heterogeneous landscapes (shore, city, country, mountain). A standard set of constraints and rules, extracted from NMA experience, is used as specification (80 constraints and rules). The available processes are the ones implemented on CartAGen platform (Renard et al. 2010): AGENT, CartACom, GAEL, Least Squares, Elastic Beams and network selection processes. Figure 12 shows the steps of a rural area generalisation: the rural space is generalised by CartACom and the road network by the Beams generating a side effect conflict.

Figure 12: (a) initial rural area. (b) rural space generalised by CartACom. (c) Roads generalised by the Beams with a side effect on the circled building.

13 shows the registry answer to a rurban space request: three processes match the pre-condition but CartACom is ranked first as it better matches the constraints (a 10 constraints caricatural sample is used) a priori (97% against 59 for Agent and 6% for the Least Squares).

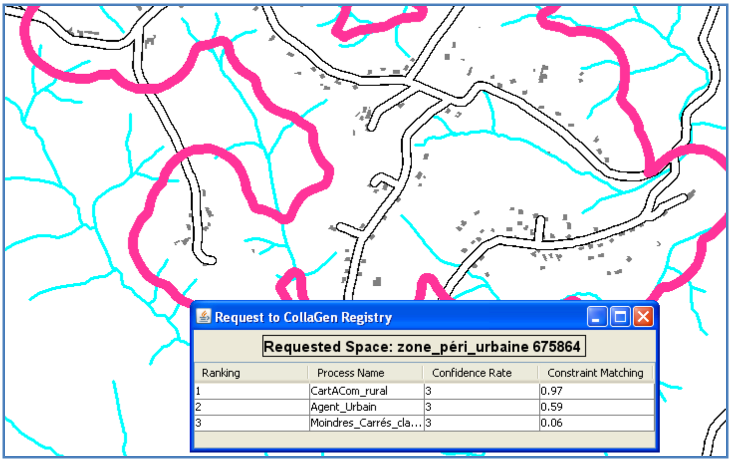

Figure 13: The registry answer to a request from the delineated rurban space. CartACom is ranked first as it better suits the constraints than Agent or the Least Squares processes.

Figure 14 shows a CollaGen result (without side effect correction) on a small area with urban, suburban and rural spaces.

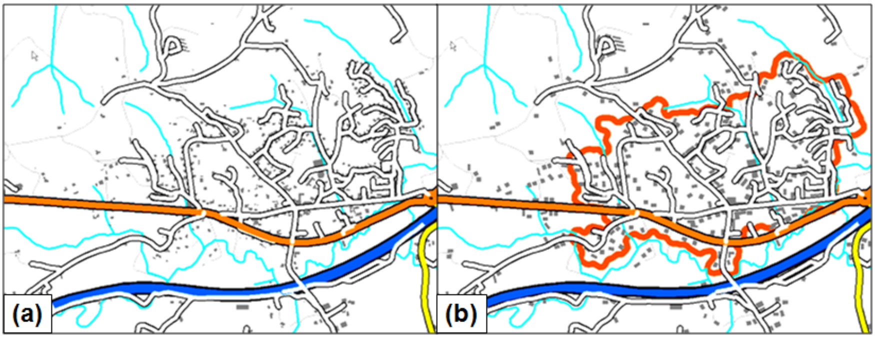

Figure 14:. (a) initial data. (b) urban space generalised by AGENT, then rurban and rural spaces by CartACom and roads by the Beams (urban space is delineated with the thick outline).

Figure 16 illustrates the importance of choosing the best process and the best order. The remaining conflicts in picture (2) show that the choices are not as good as pictures (3) and (4) ones. Moreover, the order of picture (4) is better than in picture (3) as it did not result in side effects. Thus, the sequencing component has to be careful in choosing the order!

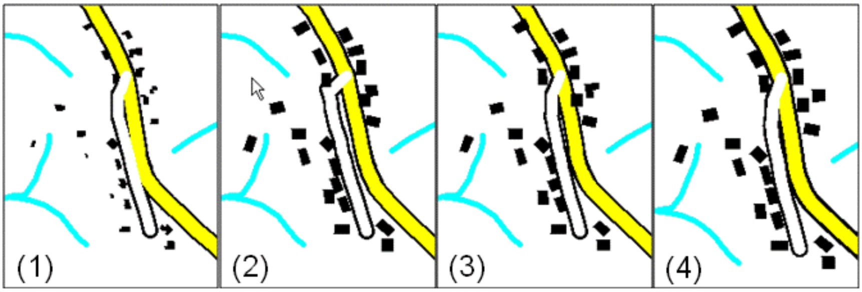

Figure 16: Illustration of order and registry importance: (1) before generalisation. (2) generalisation with AGENT then Least Squares process. (3) generalisation with CartA-Com then the Beams. (4) generalisation with the beams then CartACom.

Finally, Figure 17 shows observed emerging conflicting areas in a space too dense for CartACom and the conflict correction using Least Squares.

Figure 17: Conflict emergence from CartACom generalisation. (a) ungeneralised data. (b) emerging conflict areas are detected after generalization. (c) zoom on a conflict area extended to better solve the conflict. (d) conflicts solved by least squares generalization.

In order to evaluate CollaGen contribution, we used it to generalise the benchmark dataset from EuroSDR generalisation state-of-the-art project (Stoter et al. 2009) and compared the results to the best ones obtained during the tests with CPT and Clarity™ software (Figure 18). Although the seven processes used could be tuned to improve individual results, the comparison shows the pros of CG and CollaGen, particularly in the south-west suburban part that has to be generalised differently from the town area.

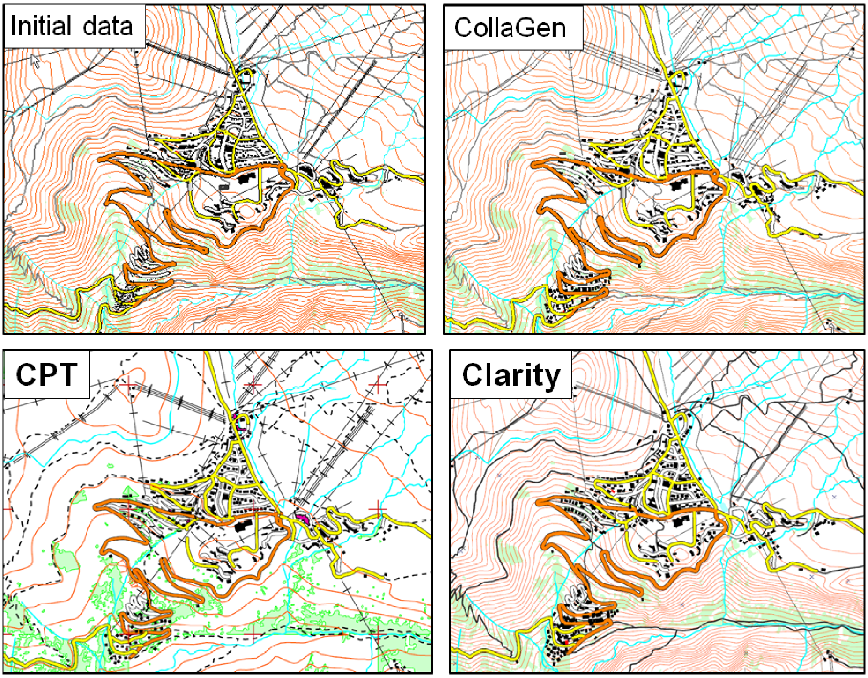

Figure 18: A mountainous French dataset from EuroSDR tests (Stoter et al. 2009) generalized with CollaGen compared to the best results from the tests.

6- Conclusion and Future Plans

This paper introduced a new framework to perform automatic cartographic generalisation by making optimised use of past research processes: Collaborative Generalisation. Within this framework, the CollaGen model allows to sequence interoperable generalisations of geographic spaces by the relevant available process. Among CollaGen contributions, a formal constraints model, a generalisation domain ontology, online evaluation and side effects detection mechanisms can be noticed.

A lot can still be made to improve both CollaGen and the Collaborative Generalisation Framework. The side effects correction really need to be more investigated to know how far corrections can be made without undoing what was previously generalised. In-depth testing (different data and scale change) of CollaGen and each component is also necessary to identify remaining issues. Moreover, rather than being implemented on a platform, the available processes could be called as web services as proposed by (Regnauld 2007).

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