ICA Symposium on Cartography for Central and Eastern Europe
Vienna, 16–17 February 2009

LECTURE NOTES IN GEOINFORMATION AND CARTOGRAPHY

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Georg Gartner · Felix Ortag (Eds.)

Cartography in Central and Eastern Europe

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Georg Gartner · Felix Ortag
Editors

Cartography in Central and Eastern Europe

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Editors
Prof. Georg Gartner
Vienna University of Technology
Institute of Geoinformation
and Cartography
Erzherzog-Johann-Platz 1
A-1040 Vienna
Austria
georg.gartner@tuwien.ac.at

DI Felix Ortag
Vienna University of Technology
Institute of Geoinformation
and Cartography
Erzherzog-Johann-Platz 1
A-1040 Vienna
Austria
felix.ortag@tuwien.ac.at

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Preface

ICA Symposium on Cartography for Central and Eastern Europe
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The region of Central and Eastern Europe has a rich and long history in cartography. Many important improvements in mapping and cartography have been proposed and performed by cartographers and researchers of that region. The long and outstanding history has led to a lively and vivid presence. Now contemporary methods for depicting the earth and its cultural and natural attributes are used. This book focuses on the contemporary activities in all major realms of cartography in Central and Eastern Europe. It covers aspects of theoretical, topographical, thematic and multimedia cartography, which have been presented at the first Symposium on Cartography for Central and Eastern Europe, which took place from February 16th to 17th, 2009 in Vienna, Austria and was organized by the International Cartographic Association (ICA) and the Vienna University of Technology.

The symposium's aim was to bring together cartographers, GI scientists and those working in related disciplines from CEE with the goal of offering a platform for discussion and exchange and stimulation of joined projects. About 130 scientists from 19 countries followed the invitation and visited Vienna, Austria. A selection of fully reviewed contributions is edited in this book and is meant as a mirror of the wide range of activities in the realm of cartography in this region. The innovative and contemporary character of these topics has lead to a great variety of interdisciplinary contributions. Topics cover an enormous range with heterogenous relationships to the main book issues.

The production of this book would not have been possible without the professional and formidable work of Manuela Schmidt. The editors are grateful for her help.

Georg Gartner and Felix Ortag
August 2009 in Vienna, Austria

Table of Contents

List of Reviewers

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Ferjan Ormeling, Utrecht University, The Netherlands
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Chapter 1

From Ortelius to OpenStreetMap – Transformation of the Map into a Multifunctional Signpost[1]

Ferjan Ormeling

Faculty of Geographical Sciences, Utrecht University, The Netherlands
f.ormeling@geog.uu.nl

1.1 Introduction

My first job, in 1970, when I started my university career, was to help prepare an exhibition on the 400th anniversary of Ortelius' first atlas. If I compare the practice of Ortelius with the general cartographic practice in the 1970s and the situation now, it would appear that more things changed in cartography after this exposition than before it. One exponent of those changes is the recent *OpenStreetMap* project, in which volunteers collect topographical information on their own. This is an exponent of the current goal of achieving a "well-mapped society", whereby everyone has access to the spatial information that she needs. It is such changes, and their consequences with respect to the future of cartography, that I wish to discuss with you.

1.2 Ubiquitous Cartography

Just imagine a world in which up-to-the-minute spatial information is always available to everyone who needs it, anytime and anywhere – this is referred to as *ubiquitous cartography.* Imagine you can request and receive information about your environment anywhere you want it, using a mobile computer. Where is the nearest hospital, or theatre, and what is the telephone number you can ring to find

[1] abbreviated, translated version of Ferjan Ormeling's valedictory address, held in the Aula of Utrecht University, April 23, 2008

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out whether there are still tickets available for tonight's show? What type of soil am I standing on, and how do people vote around here? Through the evolution of GPS systems, mobile computers and wireless networks, the realisation of this fantasy is coming more and more within our reach (see *Figure 1.1*). Over the course of time, we will all get to a point where we can combine dynamic information from satellite images with static digital topographic files, so that we can indeed see on our TomTom whether we will run directly into a rain shower if we turn left, or on Google whether the car belonging to the person we want to visit is standing in front of his house or not – so far we still receive the image that was recorded a year ago.

In my country, with the exception of the Topographical Survey, all of the geospatial data-oriented services have now for some time been switched over from paper maps to the establishment and maintenance of information systems from which their employees can obtain the information they need for their own use. However, if these files have indeed been made accessible at all to people who are not employees of specific agencies, their use now does require a high level of technical knowledge

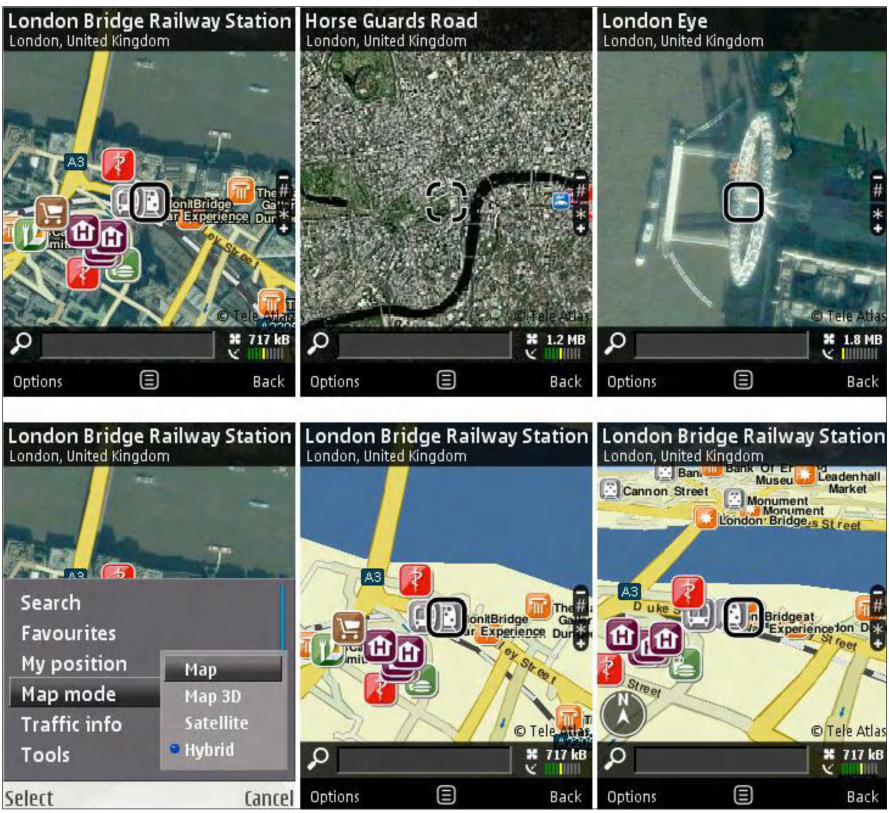

Fig. 1.1. Various use modes of the Nokia with the Maps 2.0 system (http://www.allaboutsymbian.com/news/item/6704_Nokia_Maps_20_hits_beta.php)

and a well-filled wallet: it is usually only engineering firms that can afford to acquire the files they need in order to carry out their projects. And thus has the provision of spatial information to the greater public been compromised considerably. The same has taken place outside our country, and there it has led to the development of Public Participation GIS, or Participatory GIS (Sieber 2006), an attempt to make GIS techniques and government data files clear and accessible to a broader public, which is to result in the actual establishment of realistic possibilities to share in decision-making as the transparency of government decisions based on GIS activities becomes greater.

On the other hand, some government departments at different levels have developed websites where the non-professional can obtain information about a number of environmentally-related topics free of charge. In addition, the commercial sector has taken over a number of tasks from the government. Our city maps used to be based on cadastral maps, but now they are more frequently based on information obtained by commercial map production companies themselves. Such companies as TeleAtlas and NavTeq, who specialize in car navigation systems, as well as Google and Microsoft, have recording vehicles driving around that collect geographical information and convert that information to files from which they can also make road maps. Google (Earth), Microsoft (Virtual Earth), and Terravision produce files based on satellite or aerial photographic recordings with which we can zoom in on Internet, at the expense of advertisers, on any area down to such a level that we can even see our own houses . We can navigate through a city on our own and see the city in three dimensions at any point, in the direction of our choice. The quantity of maps in the media has increased tremendously, as has the quality of that visualisation. Government departments produce map images or even atlases for the web. An example is the National Atlas of Public Health of the National Institute for Public Health and the Environment (RIVM) *(Figure 1.2)*. In addition to the increased range of maps that are available, the interest in these maps has increased as well.

Therefore, in addition to there being a wider range of spatial information from the commercial sector, it has become in some ways more difficult and in other ways easier to acquire specific spatial information from the government. How is the public reacting to this?

1.3 Geotagging, OpenStreetMap and Web 2.0

Well, map production has been democratized. Maps can be adapted more and more to the interests of the user, not only with a bit of reality chosen by that user, given form with the symbols of his preference, in the desired perspective, and also with his own notations, but also – more generally – equipped with information that he adds. At

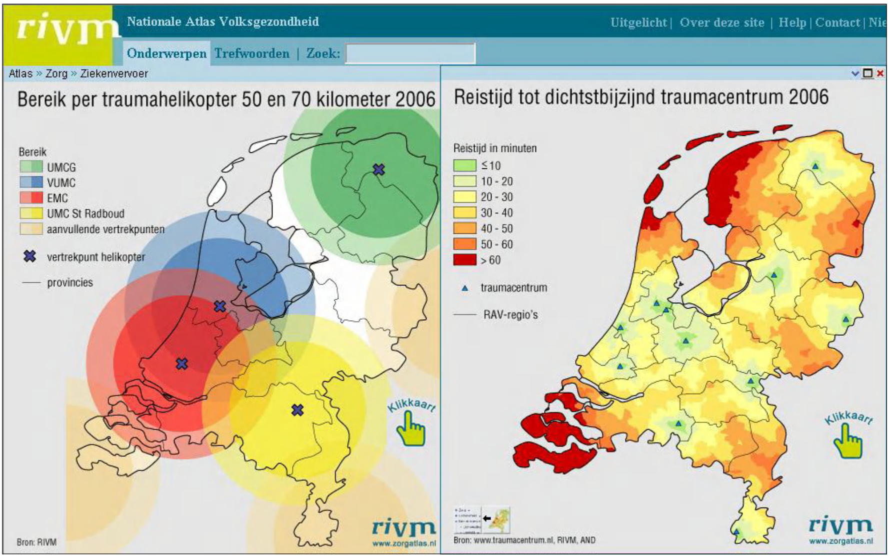

Fig. 1.2. Two maps from the National Atlas of Public Health of the RIVM (http://www.rivm.nl/vtv/object_document/o4235n21143.html)

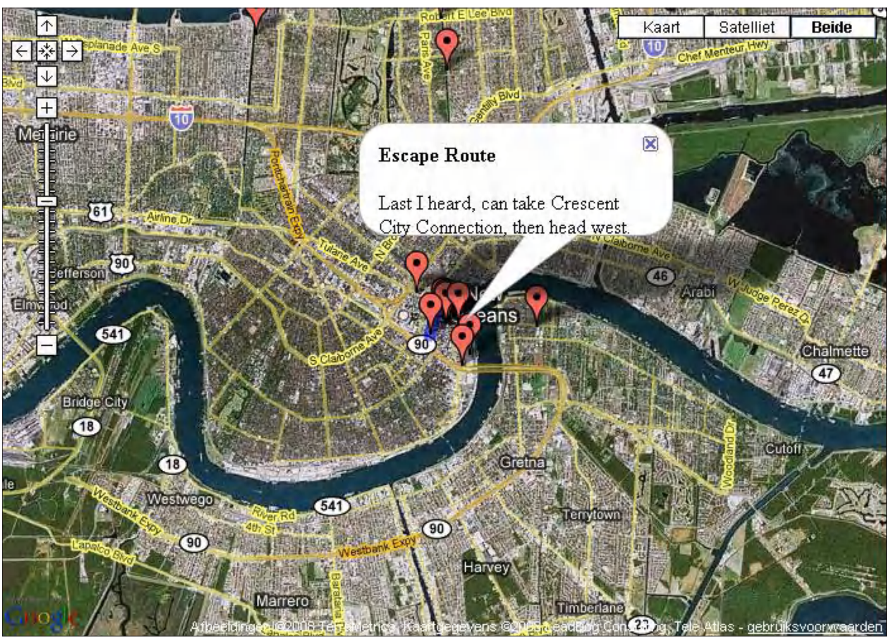

Fig. 1.3. View of a Katrina map, where residents or refugees could paste information to their families or neighbours on their former homes.

the time of the hurricane Katrina in 2005, the widespread use of *mash-ups* was made clear on a broad scale for the first time: Due to the suboptimal provision of information by the American government, victims themselves were forced to seek ways to find their lost relatives: by referring to a map of the city on Internet, and linking their houses on that map with information about, for example, their temporary address or information about the condition of their house (see *Figure 1.3)*.

Geotagging, or assigning geographic coordinates, for example to holiday photos, is the latest manifestation of our desire to pinpoint our position. Flickr.com is a website where you can upload your photos so that you can show them to everyone. Last month, some 2 million geotagged photos were added to the site. This has led to a gigantic reservoir of photos of which it is known precisely where they were taken, and if you search at a certain location you will find many photos of that location. By means of geotagging with photos, it is possible to determine more than an exact location; you can also find out about the altitude, time, date and compass direction of the view, so that the photo is almost reproducible, given the right weather conditions and camera. Therefore, because it is now possible to carry out searches in terms of coordinates, geotagging uses the organising power of mapping. So mapping something also means organizing spatial information! A comparable initiative is *Wikimapia*, where a person can attach sub-maps or remarks to objects on a map.

Another application of the 'mapping urge' is the already mentioned *OpenStreetMap* initiative of making maps oneself; it is a project focused on generating freely available geographic data, such as for road maps and city maps, for anyone who wishes to do this. These are all cartographic applications of Web 2.0, the platform on which people join forces to create their own information, of which Wikipedia is also a manifestation. It is participants who determine and control their own data; not data suppliers.

Therefore, a great deal of spatial information has become available, from the government, from companies and from private parties, because people are making maps more than ever before. But to what extent does this information reach its users? Let us look again at cartography, in order to answer this question.

1.4 Paradigm Changes in Cartography

The definition of the term *cartography* has gone through quite a few changes during the period that the term has been in use. In approximately 1820, when the term was first introduced in Germany, it encompassed the *production of maps*. When I started my university studies cartography was regarded as *projection theory*, a multiple of ways in which one could depict the earth on a flat surface. Only in the 1960s it started to be defined as the *visualization of spatial information*. This was a process subject to clear-cut rules, as was demonstrated by Jacques Bertin (1967), who in 1967 elaborated a grammar of the language of graphics. By following his rules, when designing maps, one could be assured of the proper presentation of geographic information. That term, *geographic information,* in 1967 had just been introduced in a model by the Czech cartographer Kolačny (1969), and that provided the impetus for a scientific approach to the transfer of information. This was based upon empirical research: by comparing what map readers read off a map (A', see *Figure 1.4)* with what cartographers placed on it, (A), one could measure the effectiveness of a map design. The model of this information transfer is no longer used, but it did once play a key role in the development of cartography, because it opened the door for psycho-physical research (that is the comparison of such physical stimuli as map symbols with the perceptual-psychological reactions to those stimuli). It also led to a new definition of the term *cartography*: that definition had then become, in the 1980s, *the production and use of maps* (Ormeling & Kraak 1987).

We did not have enough time to elaborate its research possibilities sufficiently, as this was followed rather too closely by the development of automation. In my university we carried out research into automatic line generalisation and experimented with a digitalization unit. We experimented with the production of line printer maps; these are maps on which we simulated the various shades of grey by printing letters in various combinations over one another. We learned to work with plotters that could draw borders of areas and also shade those areas. After 20 years of automation, then, we had reached a point where we could use the computer to make maps that were almost as good as the ones that used to be made by hand.

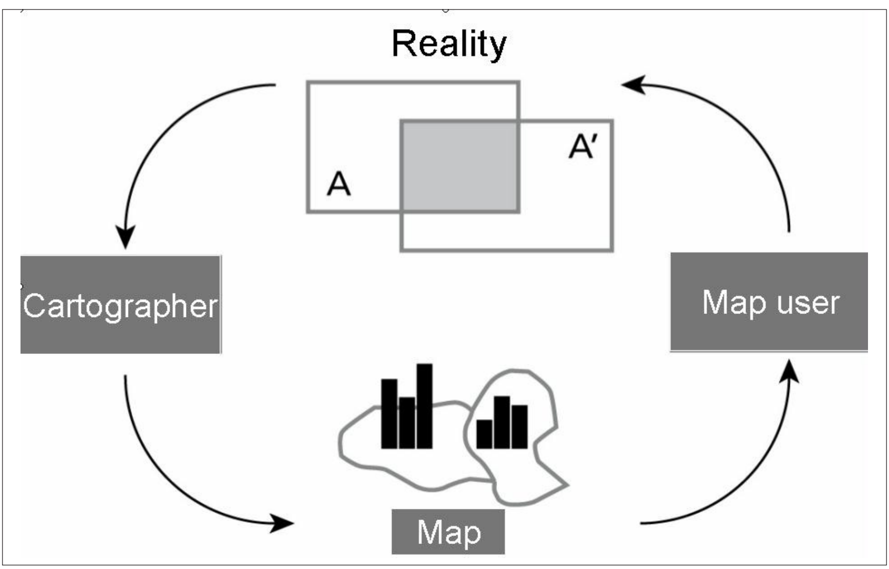

Fig. 1.4. The cartographic communication model by Kolačny (1970)

Simultaneously, however, it became clear that the computer could do more than only produce maps: once one had stored the spatial information needed to draw maps in the computer, one could also begin doing some calculations: determining surface area, measuring distances, and carrying out visibility analyses. The part of the field that encompassed this work was called *analytical cartography* or, in more modern words, geo-visualisation. With the new methods of analysis, we had opened the door to geographic information systems.

The arrival of digital geographic files led to a revolution in map production – not so much because we were able to work faster (because if you include all the preparation time, it was certainly not faster!), but because now the map image could be flexibly adapted for various purposes. Once the information was digitally stored in a file, one could easily visualise that which was needed for a certain purpose from that file. In the past, we produced nautical charts that contained all the information that helmsmen might need somewhere at any given time: now all we need on a monitor is the information we require for our own ship: we only need to see the depth contours that are crucial to the draught of our own vessel, making the image considerably clearer (see *Figure 1.5).*

The fact that we were able to use the computer meant that we were able to separate the *storage function* of the map or, in digital form, the geographic file (which describes all the measured aspects of the surface of the earth), from the *communication function* (with which the only objective is to pass on whatever knowledge is required). This breakthrough changes the content of the term cartography once again: now cartography stands for *passing on spatial information to support decision making*.[2] Sometimes this involves maps indirectly, such as in a navigation system in which one listens only to oral instructions, but usually this still takes place based on maps, where we use their unique quality of being able to predict spatial reality as it applies at any given time.

[2] In the Mission of the NVK it was stated in 1996: "Cartography is making accessible and transferring spatial information with a view of solving spatial issues, emphasizing visualisation and interaction" (Kartografie is het toegankelijk en hanteerbaar maken en overdragen van ruimtelijke informatie met nadruk op de visualisatie en interactie, afgestemd op het oplossen van ruimtelijke problemen." (NVK adresboek 1996/97, The Hague: Netherlands Cartographic Society, p. 6). In 2003 cartography was described in the Strategic Plan of the International Cartographic Association as: "the unique facility for the creation and manipulation of visual or virtual representations of geospace – maps – to permit the exploration, analysis, understanding and communication of information about that space." http://www.icaci.org/documents/reference_docs/ICA_Strategic_Plan_2003-08-16.pdf

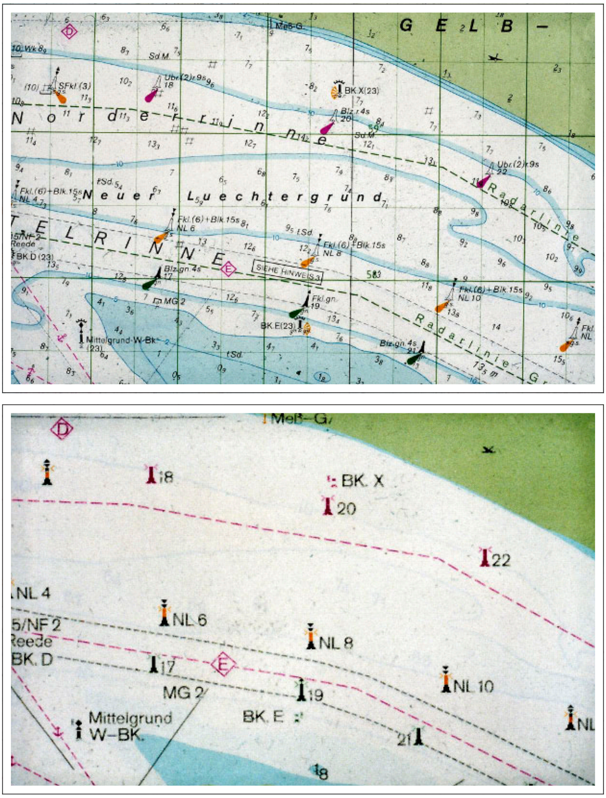

Fig. 1.5. Complete nautical chart and digital version for individual use

1.5 Maps as Predictive Tools

We view maps as models of reality. The map of *Treasure Island*[3] is a model of a renowned Caribbean location. While searching for the treasure, we replace reality by the model, imagining ourselves in that model as in a sort of immersion *(Figure 1.6)*. However, when the story ends and the treasure has been found, that process nonetheless confronts us with the most important characteristic of the map, namely that it displays what is in store for us in a spatial sense. If we identify our position in reality, our orientation and destination, on the map, we can determine how we get from one point to the other, and what we will encounter on the way. This is true, in any case, assuming that the map is an accurate model of reality and we obtain the correct impression of reality from that map. Because, after all, this is what it is all about, not that the map is correct but that what we expect in terms of reality from that map is correct. Then we can take relevant and correct decisions.

[3] Robert Louis Stevenson (1883).

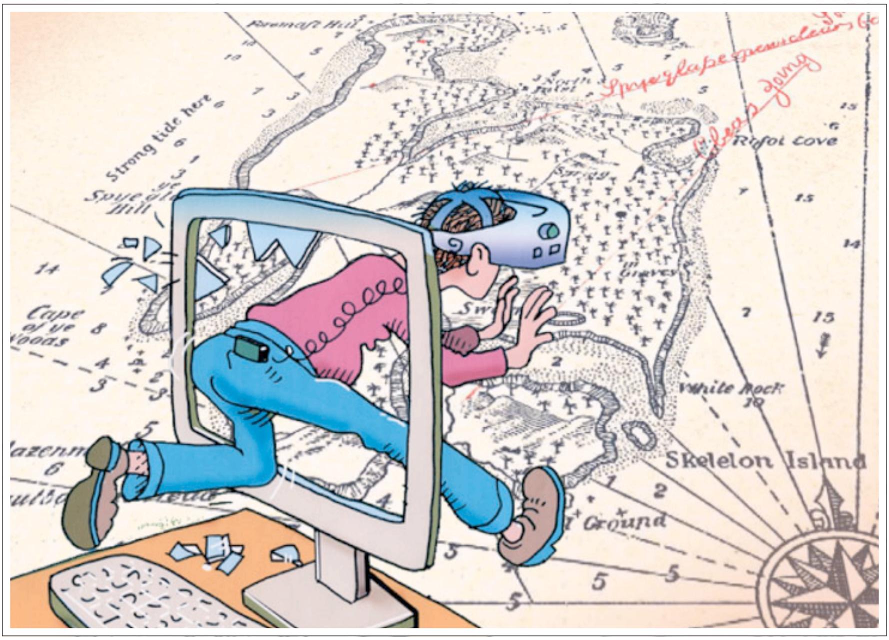

Fig. 1.6. Immersion in the map (drawing A. Lurvink)

These days, searching for a treasure has become a sport: it is called *geocaching*. With their GPS units set at specified coordinates, the innumerable aficionados of this sport *(Figure 1.7)* search for a treasure in a box hidden somewhere that contains a logbook or camera with which they can confirm that they have found the *cache*.

It is not only cartographers who make such a GPS application possible – the task also requires specialists in information technology, photogrammetry, remote sensing and geodetics. But it is indeed cartographers that ensure the transfer of spatial information. Cartographers know how to draw information and generalise it correctly if it is to appear without distortion, and how to adapt images to a limited bandwidth and our small mobile screens. We call this *context-specific design* of spatial information.

So we use maps in order to predict a situation at a certain place and at a certain time. Or we use them to determine by which route we can best reach a faraway place. Of course, maps also have other applications, such as analysis, the storage of information, education and advertising. However, being able to make a statement concerning expectations of a situation in some other place is, after all, the most important application. The success of every prediction depends upon the quality of maps – their suitability for an envisaged use – answering the questions of whether they are indeed up to date and complete, whether they contain the right amount of detail, whether their area has been effectively measured, and whether reality

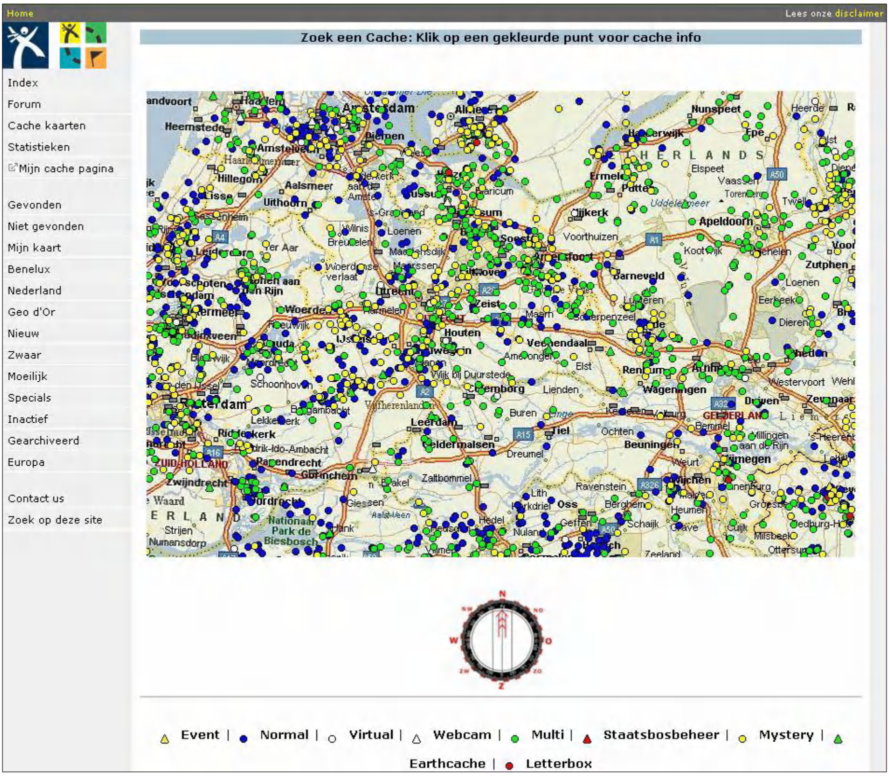

Fig. 1.7. Modern treasure hunting: geo-caches in part of the Netherlands (http://www.geocaching.nl/maps/DisplayCachemaps.php?action=nederland)

has been modelled and categorized in a relevant manner. Together with Menno-Jan Kraak I recently studied which trends can limit the role of the map as a predictor of space (Ormeling & Kraak 2007).

The most important trend is the democratization of cartography: more and more map users are generating their own maps from statistical files that are at their disposal, using software packages. They often do this without sufficient cartographic knowledge, so that while the results indeed appear technically attractive they can also give readers an entirely incorrect impression of spatial reality. After all, if one is not aware of the characteristics and possibilities of the data to be shown and of mapping techniques, one cannot adjust maps for those areas.

A second limiting factor for the predictive capacity of maps is the increasingly larger gap that is growing between theory and practice. It is the easiest thing in the world for us to combine a wide range of data sets, to carry out overlay operations, or manipulate with buffers, but we do not know how accurate map images resulting from that work will be, even though we are indeed aware of the degree of accuracy of the original maps and files.

We do not even know to what extent, if at all, we may combine various types of sets of data with one another. In addition, we are still too unfamiliar with the degree of accuracy map images must have in order to guarantee sufficient support for spatial policy, nor are we aware of the likelihood of map users interpreting maps correctly. We do not know whether users read relationships between mapped objects as they are meant to be read, and this is made even more difficult because the range of digital analysis techniques continues to expand daily. Therefore, our field requires research inorder to answer those questions.

1.6 Cartographic Research / Research Agenda

Here I would like to ask your attention for the research agenda of the International Cartographic Association (Virrantaus & Fairbairn 2007). This is a programme that we have developed over the last eight years, the goal of which is to steer research efforts in the commissions of the ICA. This focuses partially on analysing large files in order to be able to identify changes based on *data mining* or *change detection* techniques. The development of spatial analysis techniques, the establishment of the quality of our geographic files, and the assessment of the uncertainty inherent to analyses of combinations of files are points that are high on the agenda.

In my opinion, the most fertile topic for cartographic research on this agenda, in addition to data quality and generalisation, are the psycho-physical studies already mentioned above, which now plays a role in *usability* studies[4] (here, that is research regarding the effectiveness and efficiency with which certain map users reach a specified goal in specific circumstances). We still know too little about how to use the information on maps and insert this into our current knowledge. During the last five PhD studies that I monitored, the thinking-aloud laboratory *(Figure 1.8)* was used during this type of study, a laboratory set up for usability studies at the

[4] "To date, virtually nothing is known about the usability of geospatial technologies. Even less is understood about the extent to which those technologies can be matched to human conceptualizations of geographic phenomena or about the use to which the information will be put. It will be necessary to develop new tools to track how individuals and groups work with geospatial technologies, to assess which approaches are most fruitful, and to identify the usability impediments imposed by the technologies. Such understanding will be vital for tailoring user-centered design and other usability engineering methods to the needs of general audiences working with geoinformation.
In particular, it will be important to establish which techniques can measurably improve how effectively and productively geo-information is used by the general public, students, and other non-specialist audiences. As noted previously, current HCI research methodologies look at people's interaction with technology rather than at how technology is applied to support people's interaction with information. Cognitive and usability assessment techniques do not address visually enabled technologies or ones intended for application to ill-structured problems." (National Research Council 2003, p. 93).

Fig. 1.8. Laboratory setup for thinking-aloud research on the usability of maps at the ITC (from Elzakker 2004)

International Institute for Geo-information Science and Earth Observation (ITC), where the test persons describes orally what task she is performing and why, and where both her comments, the image of the monitor and of auxiliary material used are registered.

This research listing of the ICA also contains the history of cartography, because it is necessary for those practicing the profession to know how spatial information was collected, visualised and used in the past. If one would look at an old map *(Figure 1.9),* one would usually just see an attractive graphic image. Historians of cartography, however, would see more: they would see a landscape as perceived through the eyes of a cartographer, containing the information that the client of that time considered important and which the cartographer gave form in his own specific way. So a map is both a source of knowledge of the landscape of a given time, of the society that had it mapped and a representation of the ideas and expertise of a cartographer.

Standardisation is a factor that is also part of the applied research that is vital to the many plans we have with regard to the exchange of information in the future. One aspect that we have actually neglected in cartography is the standardization of geographical names. These names are essential to maps; they form the most important interface for users who wish to know more about their environment. The

Fig. 1.9. Old map as a source of knowledge of the early landscape, but also of the cartographer and his patron (drawing A. Lurvink)

standardisation of geographic names is also important when it comes to searching for information based on those names. In that context I mention the eContent-project *EuroGeoNames*[5] financed by the European Commission, a predecessor of Inspire. Its objective is to create a virtual European database of geographic names by combining various different existing national databases. The use of unequivocal geographic names optimizes the search function of maps…and this brings me to the portal function of maps and atlases.

1.7 The Map as Data Portal

In the field of cartography, atlases are viewed as the ultimate challenge, because the information they contain must be coordinated not only within one map but also between various different maps. The best atlas is then a national one, the most detailed presentation of the spatial knowledge about a country. By way of Internet we can give the national atlas an extra dimension by geocollaboration, whereby different institutions collaborate in order to supply spatial information, via a central

[5] See for a description of the project http://www.eurogeographics.org/eng/03_projects_EuroGeoNames.asp

point or data portal. A website has been developed for this purpose in the United States, called (http://www.geodata.gov/gos), "your one stop for federal, state and local geographic data" (that is to say, the geo-spatial one-stop) (Goodchild et al. 2007) . An atlas structures our view of the earth, familiarises us with geographic concepts, and is therefore eminently suited to function as an interface with the GDI, the spatial data infrastructure. This makes an atlas more than just a costly cage in which one captures the earth. In the Netherlands we are working on creating such an interface in the context of a Geo-Information.

Drive research project[6], based on the national atlas of the Netherlands (Kraak et al. 2007). With that atlas as a metaphor, we are developing an alternative, sustainable map-oriented access to the geodata infrastructure, via user-friendly solutions, in order to make geo-information accessible to the greater public. This requires responsible, systematic visualization, because it is essential that the maps can also be compared with one another. See also *Figure 1.10.* Improving access to spatial information is also consistent with the objectives on a European level (European Umbrella Organization for Geographic Information 2000).

In order to keep up with the latest developments, atlases must also keep up with the possibility of including data from their users. The Canadian cartographer Fraser Taylor speaks, in this context, of *Cyber cartographic atlases*[7], atlases that form contexts within which user-generated data as well as such social digital networks as Web 2.0 and Wiki can be easily integrated. This sounds fantastic, because in this way we enable people to provide information that they consider to be relevant. But is this consistent with the concept of the atlas? Ortelius collected information from the world's best cartographers, whose approved map material (the best available at that time) he used, and this is what made his atlas such a success. So are we going in the right direction with Taylor's cyber-atlases? Is active civilian participation enough? The American movement of Critical Cartography (see Crampton & Krygier 2006) thinks that it is. But in my opinion we are running the risk, with such atlases to which anyone and everyone can contribute her own information, that – without exercising professional control over the contents to be added – we are replacing quality by consensus, so that in the long run no one will any longer be able to truly depend on the data. The cartographers of the future will have to monitor the processes of the collection, design and use of information (such as in the OpenStreetMap), in order to inform the public about what is already available in terms of spatial information, so as to ensure that the relevant information is collected and properly given form for each specific application, and they will also have to contribute to the professional use of visualised spatial information. There certainly are challenges enough in our profession!

[6] Ruimte voor Geo-Informatie (RGI)-project no 111, National atlas as portal to the Geodata-infrastructure.

[7] Challenge for the industry is brainware. Interview with Fraser Taylor, GIS Development, December 2007. http://www.gisdevelopment.net/interview/previous/ev0123tayler.htm

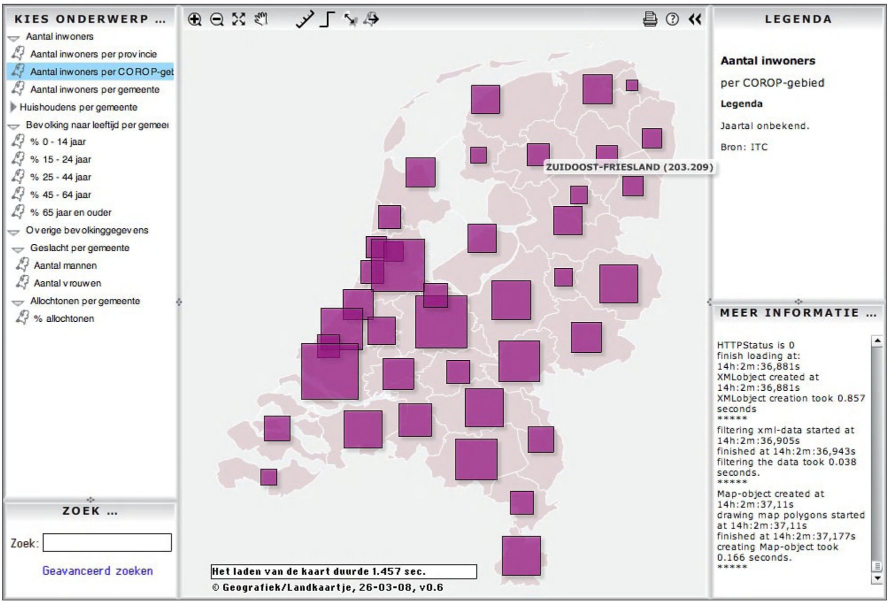

Fig. 1.10. Screen layout of the new Atlas of the Netherlands. Design by Geografiek and Landkaartje.

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Section I: Topographic Mapping

Chapter 2

EuroRegionalMap – How to Succeed in Overcoming National Borders

Andreas Pammer[1], Anja Hopfstock[2], Anita Ipša[3], Jarmila Váňová[4], Igor Vilus[5] and Nathalie Delattre[6]

[1] Bundesamt für Eich- und Vermessungswesen, Vienna, Austria
andreas.pammer@bev.gv.at

[2] Bundesamt für Kartographie und Geodäsie, Frankfurt am Main, Germany
anja.hopfstock@bkg.bund.de

[3] Geodetski inštitut Slovenije, Ljubljana, Slovenia
anita.ipsa@gis.si

[4] Cesky urad zememericky a katastralni, Sedlcany, Czech Republic
jarmila.vanova@cuzk.cz

[5] Državna Geodetska Uprava, Zagreb, Croatia
igor.vilus@dgu.hr

[6] Institut Géographique National, Brussels, Belgium
e-mail: nde@ngi.be

Abstract

EuroRegionalMap (ERM) is a pan-European multifunctional topographic reference dataset at scale 1:250 000 based on national contributions from EuroGeographics member organisations. In one of its regional production groups data providers of eight Central European countries faced the challenges of harmonizing their national medium-scale databases in matters of content, geometry and quality standards.

This paper presents a progress report about the chosen approach and the realization of this multinational co-production. In this context the used project organisation and the given ERM specifications and guidelines are introduced. Thereafter the different national ways and means of deriving an ERM dataset by converting national data to ERM are exemplarily shown. Furthermore, to demonstrate a best practice approach the edge-matching of data at the cross-border area of countries to reach a seamless dataset is presented in more detail. The last focus is set on how

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quality assurance is achieved. In a validation phase all data is checked by several validation procedures to identify errors in the data's logical structure as well as to insure feature/attribute compliance with the current ERM specifications. On-going changes and future developments complete the paper.

Keywords: EuroRegionalMap, topographic dataset, harmonisation, edge-matching, pan-European

2.1 Introduction

EuroGeographics with its 52 members from 43 countries represents nearly all European National Mapping and Cadastral Agencies (NMCAs). Currently, four pan-European geographic datasets are available as products that were produced in project cooperation by the NMCAs (EuroGeographics 2009). Among them EuroRegionalMap (ERM) is the multi-functional topographic reference dataset at scale 1:250 000. ERM data is intended to meet two objectives. At the one hand the data should be fit for geospatial analysis in GIS applications, on the other hand their usage as topographic map backdrop for thematic mapping is envisioned. In *Figures 2.1* and *2.2* ERM data is visualized in different scales to give an impression of the topographic content.

Looking back in the history of ERM the first product distributed on the market as release 1.0 in June 2004 was only covering seven countries (France, Germany, Belgium, Luxemburg, Denmark, Ireland and Northern-Ireland), but demonstrated the feasibility of harmonising the medium scale topographic databases owned by the NMCAs at a European level. In a next step a new project phase called the "extension phase" of ERM was established aiming to extend the coverage to at least the European Union and the EFTA countries. During that phase the organisational bases as well as the management and production workflow for an enlarged production of EuroRegionalMap over Europe were set up. The harmonisation approach, the data model and specifications were adapted and enlarged to include the contributions of the new project members. Furthermore a new management and production organisation was established setting up regional groups of production and quality assessment. As a result of these efforts, release 2.1 was published in March 2007.

Currently, the project is facing the "consolidation phase" that will end in December 2010. There are two main objectives: to provide regular updates and to enhance data quality and improve the level of harmonisation (Hopfstock 2008). The detailed update plan as well as further changes in the specifications are agreed and prioritised with the main customers, the European Commission with its sub-organisation Eurostat and the European Environment Agency.

Fig. 2.1. ERM data visualised in the cross-border region between Austria, Czech Republic and Germany at scale 1:250 000

Fig. 2.2. ERM data visualised in the cross-border region between Austria and Slovenia at scale 1:100 000

In the following the organisational and technical framework is introduced in more detail and a progress report about the chosen approach and the realization of this multinational co-production is presented from the perspective of producers in the Central-European regional group.

2.2 Organisational Framework

In the first place the project management structure which is working at four different levels with different organisations involved has to be mentioned.

- The **EuroGeographics Head Office** (EUROHO): This central permanent unit of the association of the European NMCAs acts as the contracting party and contract manager for the EC (Eurostat).
- The **Project Manager** at the National Geographic Institute of Belgium (IGNB): IGNB works as the project coordinator and is responsible for the overall project management and tasks like project awareness, product exploitation and the maintenance of EuroRegionalMap data. IGNB is also responsible for the final data collection of the ERM national data components and for the integration of the data into a seamless dataset, which is delivered to customers and data providers. IGNB is supported by the Project Management Team.
- The **Project Management Team** (PMT): The PMT is subdivided into
  - The **Technical Team**: It is composed of staff members of the National Geographic Institute of France (IGNF), the National Geographic Institute of Belgium (IGNB), the Bundesamt für Kartographie und Geodäsie of Germany (BKG) and the Bundesamt für Landestopografie of Switzerland (swisstopo) acting as technical experts. They are responsible for the technical development of the ERM production workflow and for the technical support to the producers by developing production tools, providing technical guidance for the producers, updating specifications and the data model and addressing any issues in production and data maintenance reported by the regional co-ordinators.
  - The **Regional Coordinators**: Owing to the amount of producing countries (32), the supervision of the production has been shared between four regional coordinators, which are the National Geographic Institute of Belgium (IGNB), the National Geographic Institute of France (IGNF), the National Centre of Geoinformatics and Remote Sensing of Lithuania (GIS-Centras) and the Federal Office of Metrology and Surveying of Austria (BEV). The Regional Co-ordinators are responsible for the regional co-ordination including the supervision of the production done by a group of partners and the final data

validation and data assembly at regional level. The area of responsibility for each regional co-ordinator is presented in *Figure 2.3*.

– The **Business Manager**: The Business Manager from the EuroGeographics Head Office is responsible for all issues related to communication and marketing on behalf of the project partners.

- The **ERM data Producers** (NMCAs): Producing NMCAs are responsible for providing the EuroRegionalMap data of the national territory and of other territories that might be under their production responsibility.

The members of the different management levels have to play their roles according to the general **production workflow** described below (The different steps mentioned in this overview are described in more detail in the following chapters):

NMCAs harmonise their data by re-engineering their existing national data collections according to the ERM specifications and data model and update the ERM data model according to the agreed update plan. Each national producer is responsible for the conversion and upgrade of the national database of its national territory into ERM and for the update and maintenance of this national part of the ERM dataset. The production limits between produced areas are represented by international boundaries, which have been commonly agreed and fixed between both

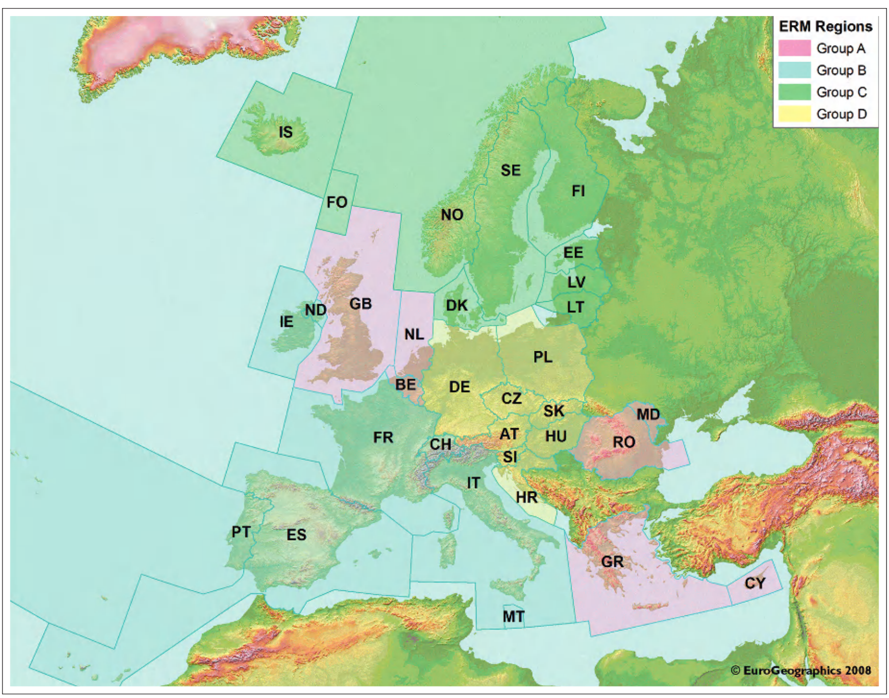

Fig. 2.3. Production area and the division in regional groups

neighbouring producers and approved by the project co-ordinator. Project partners of neighbouring countries should collaborate to get cross-border consistency of the data at both sides of the international boundaries. National producers have to check the quality of the dataset according to the Validation Specifications before delivery to regional co-ordinators. After the validation and correction phase the national datasets including delivery report and metadata are sent to regional co-ordinators who provide the final validation and data assembly at regional level. Finally the project manager integrates all regional results into a seamless pan-European dataset.

The used **communication tools** complete the organisational framework. As the project is still developing, the producers need to be informed about changes as soon as possible. ERM producers get information about news, events and updates in documentation via e-mails and they are available at the EuroGeographics web site, too.

An important communication tool is the ERM Discussion Forum. Its main function is to notify any technical issue or question raised for open discussion or comments. This system allows getting a quick answer from the technical team in a way transparent for every member. All information related to the project, i.e. contacts, news, events, production plans, agreements, templates, data, documentation, tools, metadata, are stored in ERM Repository on IGNB web server.

In the Central-European regional group (group D) data exchange during the edge-matching and validation phase is realized by means of Projectplace, a web based project management tool for downloading and uploading data and documents (Projectplace, 2009).

Meetings and workshops represent another way to support co-ordination between data producers or inform about substantial changes in specifications. They are organised either by the project manager (for all producers) or by the regional co-ordinators (for producers within one production group).

2.3 Technical Framework

The ERM specifications and data model, technical guidelines, and database templates build the technical framework of the multinational ERM co-production to ensure the harmonisation of the existing national data collections (Hopfstock et al. 2007a, Hopfstock et al. 2007b).

The ERM specifications define the data model, the spatial reference, the positional accuracy, and the data content. The feature and attribute catalogue includes portrayal and quality criteria. *Table 2.1* states the basic parameters of the specifications.

Table 2.1. Basic Parameters of the ERM Specifications

Data Type	Vector
Resolution	1:250 000
Data Model	Georelational based on DIGEST
Geodetic Datum	ETRS89 (~WGS84)
Coordinate System	Geographic Coordinates in Decimal Degree
Positional Accuracy	125m
Themes	Administrative Boundaries, Hydrography, Transportation, Settlements, Vegetation, Miscellaneous, Named Locations
Delivery formats	ArcGIS Geodatabase, Shapefiles

The ERM conceptual model is a geo-relational data model based on the DIGEST[1] vector data model. The basic topological relationships are set up at the level of geometric primitives (node, edge, face), and can be described as edge-to-node, face-to-edge, and node-to-face.

The ERM data is made available in geographic coordinates (latitude and longitude) with a decimal fraction based on the European ETRS89 spatial reference system. At scale 1:250 000 this corresponds to the world reference of WGS84. The spatial reference is chosen to support both transformations from national coordinate systems to ERM as well as from ERM into European coordinate systems for cross-border applications.

In general, the quality of a dataset is defined by the positional accuracy and the completeness of the data. According to the ERM specifications, national contributions shall be consistent with topographic maps at scale 1:250 000 in terms of positional accuracy and completeness. Features shall be provided with a positional accuracy at least of 125m and a horizontal geometric resolution of 5m. The minimum length of a line feature shall be more than 50m. Area features less than 0.06km^2 shall be merged or omitted. These definitions are guidelines for data collection and generalisation of ERM data, but do not overwrite national production rules. Thus, differences in positional accuracy and completeness of ERM occur.

The ERM data is organised into seven data layers (themes, see *Table 2.1)* containing several feature classes. A feature class shares the same geometrical type and a set of attributes. A feature class may hold one or more feature codes representing different geographic entities. Besides, the ERM database contains a number of related tables:

- EBM_NAM is related to the administrative areas holding the names of the administrative units;

[1] DIGEST: Digital Geographical Information Exchange Standard is a NATO standard developed by the Digital Geographic Information Working Group (DGWIG) to support efficient exchange of digital geographic information among nations, data producers, and data users.

- EBM_ISN is related with EBM_NAM string the national hierarchical level of the administrative units;
- SYMBOL_RAT is related to the Named Locations providing information for a classified symbolization of cartographic text for representation on hardcopy output at scale 1:250 000;
- FERRY_LINK is a cross-link table connecting the ferry stations with the ferry lines;
- ERM_CHR is a general table holding the information which ISO character sets were used to encode names attributes. This is important to display the national characters of the names attributes in a system that does not support Unicode encoding.

Figure 2.4 shows an extract of the ERM data schema.

The ERM feature catalogue contains mandatory and optional features and attributes. This concept on the one hand leverages the provision of a consistent core dataset by the producers, and on the other hand takes into account the geographical diversity and the particularities of the national data production within Europe (Hopfstock et al. 2007a).

The demand for a multilingual international dataset is met by providing two attributes for geographical names per feature. Geographical names of a feature can be populated in the first and – if applicable – second national/regional official languages. Additionally, the language code is stored according to ISO639-2/B for each name, and the names are transliterated into the ASCII-7bit format. This ensures displaying the names in a non-Unicode environment for all countries.

The ERM technical guide contains guidelines to support the re-engineering of the national databases according to facilitate geometric and semantic harmonisation. It provides guidelines and examples from best-practice for data capture, generalisation, and attribution.

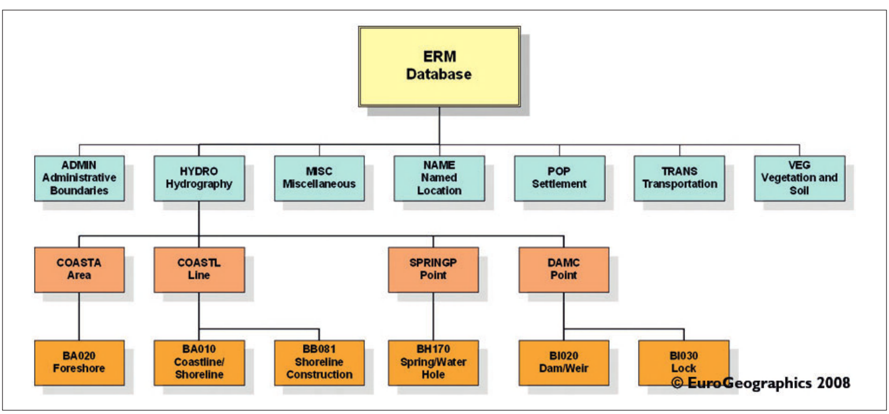

Fig. 2.4. EuroRegionalMap Data Schema (Hopfstock et al. 2007b)

The ERM edge-matching rules provide guidelines for handling features crossing or consistent with international boundaries to ensure the final pan-European dataset is seamless across borders. Meaning, there are no gaps or overlaps between country datasets, and the hydrographic and transportation network are continuous. For more information refer to *Section 2.5*.

The ERM specifications and data model describe the conceptual data model of the pan-European dataset. Into which physical data model the producers would like to implement the conceptual model depends on their national production system. However, the implementation may lead to differences in data structure and topology. Therefore The ERM PMT provides a physical implementation of the conceptual data model for the preferred data production and exchange formats (see Delivery formats of *Table 2.1)*. Pre-defined empty datasets (i.e. ArcGIS Geodatabase Templates) are maintained to accommodate the ERM production and to support data quality, a hassle-free internal and external data exchange, and the final data assembly of the pan-European dataset from national contributions.

2.4 National Data Production

On the basis of the technical framework requirements different ways to produce the national ERM data can be located at the contributing NMCAs. The production workflows are determined by

- Resources and organisational constraints: Can production be performed in house or must it be outsourced?
- Data sources: Are there proper national databases in scale 1:250 000 or must data be generalized based on data sources in bigger scales?
- Data maintenance method: Is data maintained at the national database level or is the ERM data directly updated?

Below the national data production of five countries are described in more detail in order to give quite good samples for used strategies that represent the entire European approach.

2.4.1 National Data Production of Austria

2.4.1.1 Data Source

The main data source of the Austrian ERM contribution is the cartographic model 1:250 000 of Austria (KM250) that has been established and is maintained by the federal office of metrology and surveying (Bundesamt für Eich- und Vermessungswesen, BEV). This multi-purpose database is focused mainly on the production of the Austrian Military Map in scale 1:250 000 (ÖMK250). For providing certain attributes accessory data sources are needed:

- Digital Landscape Model of Austria (BEV),
- Population census (Statistics Austria),
- Information about motorways and expressways (ASFINAG),
- Information about hydrography (Hydrographisches Zentralbüro).

2.4.1.2 Hardware, Software and Human Resources

ERM production is performed on standard PCs (Intel Pentium 4 CPU 3GHz, RAM 1GB, Windows XP) using ArcGIS 9.2 and the extension PLTS 9.2. For conversion tasks FME 2008 is also in use. Two people, one technical coordinator and one cartographer are actually producing the Austrian contribution to ERM.

2.4.1.3 Production Workflow

In principle the ERM dataset is automatically derived from KM250, which is regularly updated. For this purpose the structure of KM250 was adapted to the ERM specifications. If there are any changes in the ERM specifications corresponding adjustments in KM250 are always implemented. As a result KM250 contains some features and even feature classes that are only used for the ERM delivery.

Generating the ERM dataset is actually a transformation from the edited national database KM250 done with FME. Only edge-matching needs to be performed in an interactive way afterwards. Of course, quality checks attend all procedures.

2.4.2 National Data Production of Croatia

2.4.2.1 Data Source

Due to the lack of recent data in smaller scale, the main source for production of the ERM dataset is the large scale (1:10 000) topographic database (TTB) as the only up to date source of topologically correct and attributed vector data.

Data in TTB covers approx. 60% of the territory of Republic of Croatia, so the ERM dataset covers only that area where the data is currently available.

Another relevant data source used for ERM production is the Registry of spatial units which contains inner and outer administrative boundaries of Republic of Croatia.

2.4.2.2 Hardware, Software and Human Resources

For production of the ERM dataset a standard PC (Intel Core 2 CPU 2.13 GHz, RAM 2 GB, Windows XP) is used. Software used is ArcGIS 9.2, FME, AutoCad Map and GeoMedia (due to specific input data formats). The work on ERM production was shared in a three men team (1 technician, 2 experts).

2.4.2.3 Production Workflow

As described above, the main source of ERM data is the large scale topographic database. So the main work that has to be done is the generalisation of this primary dataset. After transforming from national coordinate system to reference coordinate system of ERM using FME software by applying a 7 parameters transformation, the generalisation is adopted to get in conformance with the ERM specification.

Generalisation is conducted in a step by step fashion keeping in mind the 1:5 rule, meaning that from the original data set in 1:10 000 scale, we have to generalise to 1:50 000 scale and then once more to 1:250 000 scale.

The resulting data set does not include cartographic generalisation (repositioning of objects) but only the generalisation based on the simplifying of the data model and of the individual objects. Other tasks related to ERM dataset production consist of remapping of the original dataset and edge matching – where required.

2.4.3 National Data Production of Czech Republic

2.4.3.1 Data Source

The main data sources are:

- Digital Landscape Model 1:250 000 (DLM250) – produced by the Military Mapping Service
- Fundamental Base of Geographic Data 1:10 000 – produced by the Land Survey Office

Ancillary data sources are:

- Register of Administrative Units (The Czech Statistical Office)
- Base Dataset of Administrative Boundaries (Land Survey Office)
- Database of Roads (The Headquarters of Roads and Motorways of the Czech Republic)
- Data of Agency for Nature Conservation and Landscape Protection of the Czech Republic
- Aeronautical Information Publication (Air Navigation Services of the Czech Republic)

2.4.3.2 Hardware, Software and Human Resources

The ERM project is running on standard PCs (Intel Core 2 Duo E8400 3GHz, RAM 2 GB, GPU NVIDIA Quadro FX 370 256 MB, Windows XP). ArcGIS 9.2 and PLTS 9.2 are available since 2008. There are 2 persons (1 expert, 1 technician) engaged in ERM project in the Land Survey Office of the Czech Republic.

2.4.3.3 Production Workflow

The DLM250 was transformed from WGS84 to the national coordinate system using a 7-parameter transformation. The data was modified with regard to the ERM Specifications and updated according to the national database at 1:10 000 scale and other ancillary sources. A positional accuracy was improved to satisfy 1:200 000 scale. After an editing and validation process the database was transformed to WGS84 and submitted to an edge-matching process. However the edge-matching had to be performed both in WGS84 (ERM) and in national coordinate system (national database).

The first final database became source for a new official national database at 1:200 000 scale. In future all topographic databases at a corresponding scale (including ERM updated versions) will be derived from this national database based on ERM data model and specifications.

2.4.4 National Data Production of Germany

2.4.4.1 Data Source

The German contribution to the ERM database is mainly derived from the most up-to-date version of the Production Database 250 (PD250), a topologically structured vector dataset at resolution 1:250 000. Additionally, the following ancillary data sources are used to enhance the geometry and attribution:

- VG250, a vector dataset with related tables containing all administrative units of all hierarchical administrative levels starting from state to the municipalities. The geometry of the borders follows the scale 1:200 000 concerning accuracy and resolution.
- GN250, the geographical names book.

2.4.4.2 Hardware, Software and Human Resources

The ERM production is performed with standard PCs (Intel Core 2 CPU 2.66 GHz, RAM 3.6 GB, Windows XP) equipped with ArcGIS 9.2, PLTS 9.2 and FME 2008. There are two persons (1 expert, 1 technician) involved in the production of the German ERM contribution. The maintenance of the national topographic data is continuously executed by the production group of the department of geoinformation.

2.4.4.3 Production Workflow

The German ERM dataset is derived by converting the national data to ERM using extraction and conversion rules which are determined by the ERM specifications. A cross-reference documentation between PD250 and ERM is maintained to record the production, facilitate the maintenance and future update process of ERM contribution, and as a source for compilation of the ERM metadata. The national data is derived and transformed using FME. The resulting ERM database is validated and if necessary corrected using ArcGIS and the PLTS extension.

2.4.5 National Data Production of Slovenia

2.4.5.1 Data Source

The main data source is the National General Map of Republic of Slovenia at scale 1:250 000 (last updated in August 2008).

Additional ancillary data sources:

- Register of spatial units (The Surveying and Mapping Authority of the Republic of Slovenia),

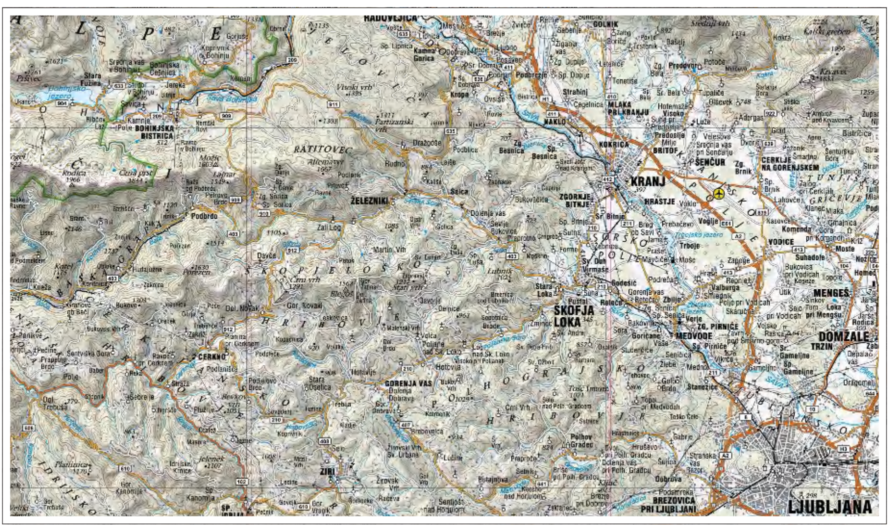

Fig. 2.5. Part of the National General Map of Republic of Slovenia at scale 1:250 000 (© Geodetska uprava Republike Slovenije)

- Register of public roads (Slovenian Roads Agency, Ministry of Transport),
- Statistical databank (Statistical Office of the Republic of Slovenia).

2.4.5.2 Hardware, Software and Human Resources

For the ERM production standard PCs (Intel Core 2 CPU 2.13 GHz, RAM 2 GB, Windows XP) are in use. ArcGIS is the main program for loading the data into the ERM template geodatabase. Additionally other software for preparing the data was used.

Mainly three persons are involved in ERM production. One is the national coordinator form The Surveying and Mapping Authority of the Republic of Slovenia, which is the ERM contractor. ERM production was outsourced to the Geodetic Institute of Slovenia where two persons (1 technician, 1 expert) share the work.

2.4.5.3 Production Workflow

After collecting all the source data, it is generalized according to the ERM specifications and some basic topology editing is done. In the next step the data is transformed from national coordinate system to reference coordinate system of ERM. Then additional attributes are filled in and geometry is edited regarding the topology constraints. Finally data quality control and edge-matching with all the neighbouring countries is performed as described in *Sections 2.5* and *2.6.*

Two country specific advantages of the ERM production are worth mentioning. First, the main source, the National General Map of the Republic of Slovenia at scale 1:250 000, was generated in vector format completely new in 2005 (updated in 2008) and was at the same time harmonized with ERM specifications. Thereby almost all layers can be derived directly from this main data source; additional sources are needed mostly for some attribution and for the administrative units. Second, because Slovenia is a small country it is easier to handle the data volume and less automation is needed (some editing and corrections can be made manually).

Production deficiencies are mainly related to software restrictions. For instance in ArcGIS it is hard to define the 7 parametric transformation, that would be necessary to perform correctly the transformation between the national coordinate system and the ERM reference coordinate system. In the end this problem is solved by performing this transformation with other software. The second deficiency is that some validation checks cannot be executed, because some checking tools would only be available in PLTS. Therefore these checks can only be carried out by the regional coordinator.

2.5 The Edge-Matching Procedure

The objective of the edge-matching procedure is to get continuous and seamless data at cross-border zone implying a consistent selection of features at both sides of the international boundary.

2.5.1 Edge-Matching Rules

The edge-matching process intends to ensure a coherent spatial and attribute continuity between features at both sides of the international boundaries. It is necessary to fit together both the geometrical representation of the features and their attribute values or just significant attributes. The producers have to follow the "Edge Matching Rules" and respect the topological relationships between features. Obviously the new matched features must be in conformance with ERM Specifications.

The matching process is performed on the line features and on the area features crossing or overlapping the international boundary and on the point features located on the boundary. All producers follow the directives containing a set of rules for edge-matching the geometry and a list of attributes that need to be consistent at both sides of the boundary. The guidelines document gives specific examples how to match the geometry and attributes.

Exemplary rules for matching the geometry and attributes are:

- When a feature is stopped at the international boundary with no counterpart at the other side, the decision whether to erase it or to extend it should be decided in common agreement between neighbour countries (see *Figure 2.6a)*.
- Two line features are automatically (without discussion) moved to match each other if they are of the same feature type and if the gap is no greater than approximately 125 meters.
- When a line segment (usually a watercourse) is consistent with the international boundary, the segment should have exactly the same geometry in both national components.
- The matching distance between borderlines of area feature is a maximum of 125m. If bigger distance is noticed, it is not needed to do the edge-matching except for the water bodies and islands.
- When the extended part to be added to the feature is less than 20ha (for area feature), this can be ignored and not added (see *Figure 2.6b)*.
- When country A portrays a watercourse located on the international boundary as a line, while country B portrays the same watercourse segment as an area with a fictitious axis, then the watercourse segment should be commonly portrayed as a line feature (see *Figure 2.6c)*.

• Features overlapping the international boundary must have the same attributes in both country datasets (see *Figure 2.6d)*.

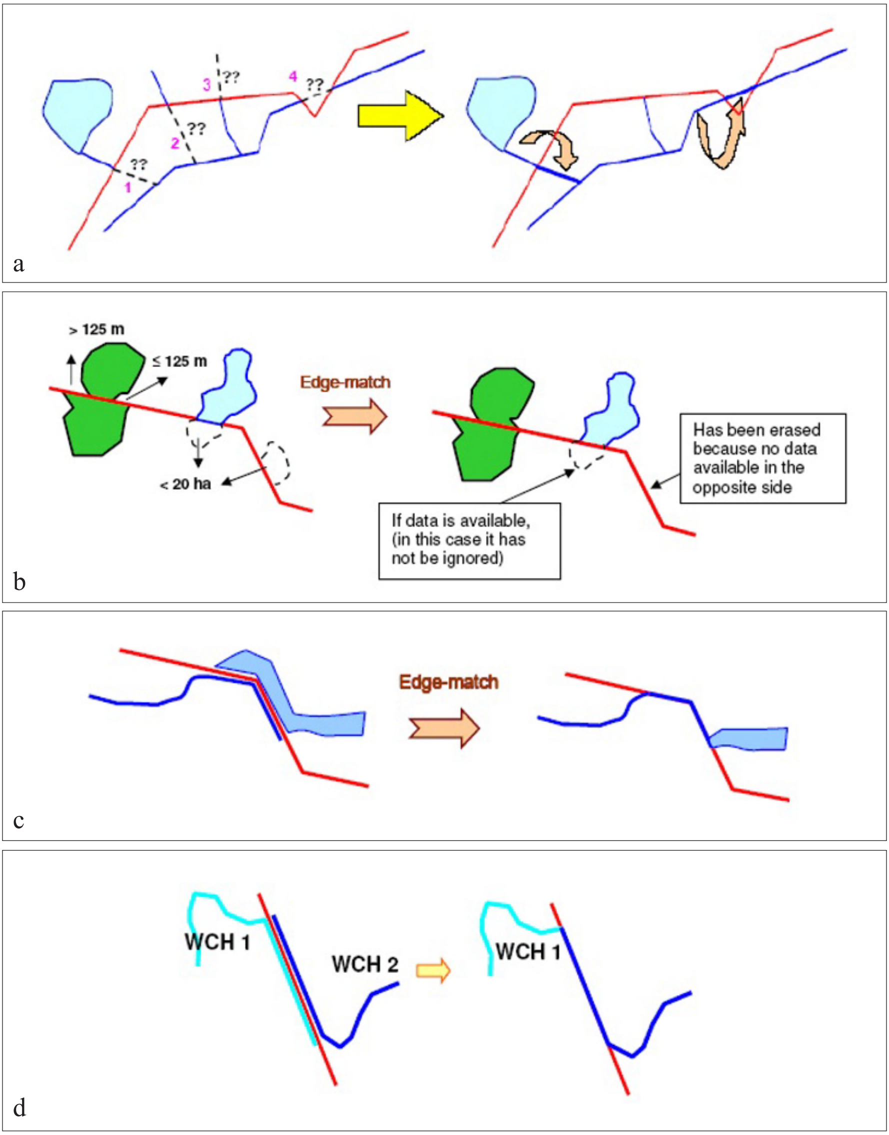

Fig. 2.6. Edge-matching rules

2.5.2 Edge-Matching Workflow

The edge-matching phase is performed at the end of the production workflow. The preferred approach is to perform an accurate edge-matching when both neighbouring datasets have already been submitted to a first checking phase by the regional co-ordinator. When the edge-matching is done, the data can be delivered again to the regional co-ordinator for a quality control of the edge-matching.

Preliminary the responsible persons of neighbouring countries contact each other and decide how to share the work to avoid duplicate efforts (see examples in *Table 2.2)*. Most edge-matching work is in themes "Hydro" and "Transportation", less in other themes. The sharing is done so that the amount of work is shared approximately equally between two neighbouring countries.

Table 2.2. Sharing the edge-matching work along international borders

Border between		Who is going to perform edge matching along border for specified theme				
Country A	Country B	Hydro	Transportation	Vegetation	Settlement	Miscellaneous
Austria	Slovenia	Austria	Slovenia	Austria	Austria	Austria
Czech R.	Germany	Germany	Czech R.	Germany	Germany	Czech R.

The actual edge-matching workflow is presented in *Figure 2.7*. The country responsible for edge-matching gets the latest data from the neighbour to perform edge-matching according to the directives. The country performing the edge-matching may only displace the features within its national territory. This can be systematically done when the matching distance is stated within the limits of the indicated parameters. If the edge-matching between features has to be done within a bigger distance, which requires the displacement of a feature belonging to the neighbouring country, the issue has to be notified in a report to the neighbouring country in order to discuss and negotiate the displacement of features.

After edge-matching by editing only national data, the responsible country provides a report with all remaining discrepancies to the neighbour. The discrepancies are divided in two types, changes and issues. Changes refer to necessary modifications of the neighbour dataset; issues represent unsolved edge-matching problems. The report should contain suggestions for a solution and a picture identifying the problem. Based on this report, discussion and negotiation can start between countries. The neighbour country sends back the report indicating the discrepancies that have been approved and/or corrected with a new version of corrected data or the discrepancies not approved and commented (see *Figure 2.8)*. The responsible country will check again the data and restarts the procedure with reporting until all discrepancies will be solved and all changes approved.

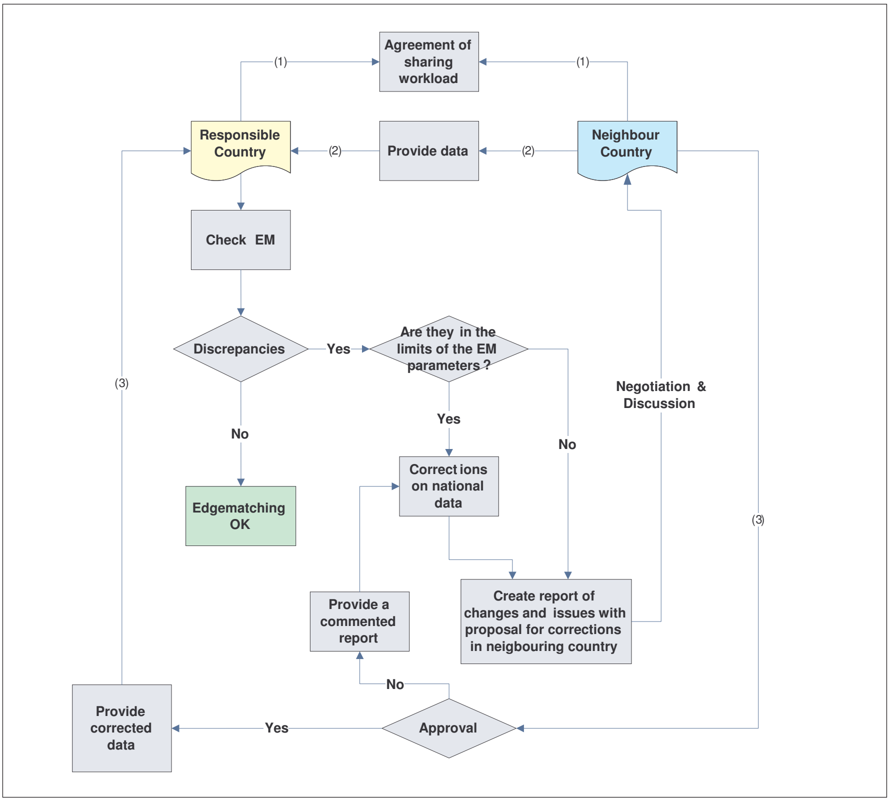

Fig. 2.7. Workflow of edge-matching procedure

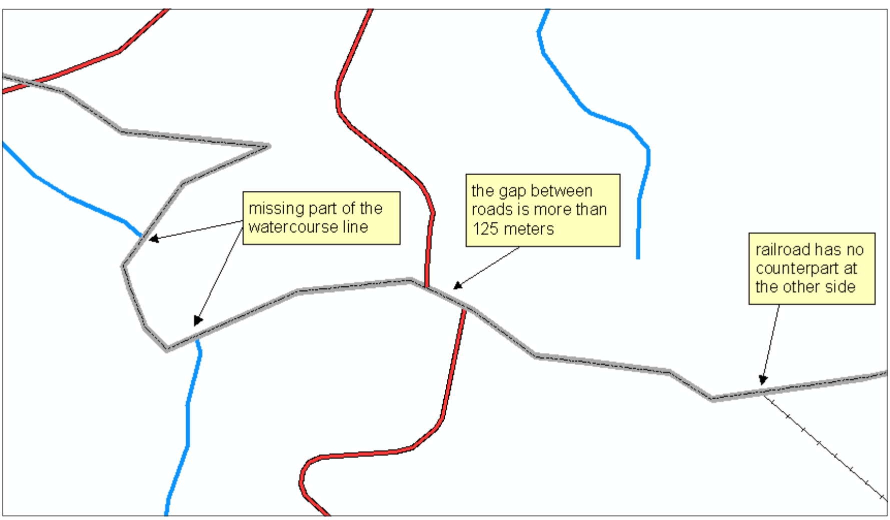

Fig. 2.8. Example of reported discrepancies at international boundaries

ERM producers can use automatic validation tools for checking points and lines. The ERM technical team has developed two Python scripts for checking line edge-matching and point edge-matching. Areas have to be checked visually. The principle of the automatic tool is to locate features within a very small distance from the international boundary and look if they have a companion feature in the neighbour country dataset. The scripts generate a list of suspect features, which have to be reviewed visually because not all findings are errors. The list contains the attribute values of matching features, too. When the edge-matching is done, the data can be delivered again to the regional coordinator for a quality control of the edge-matching.

2.6 Quality Assurance

For the purpose to ensure good data quality the ERM production process includes two independent validation controls. On one hand producers have to perform a comprehensive check after data production themselves in order to deliver clean data to the regional coordinator. On the other hand the regional coordinator validates the received data and reports about the results. If any severe errors have been found data has to be corrected by the producer and delivered to the regional coordinator again. Data may pass this cycle presented in *Figure 2.9* several times till an acceptable result is reached.

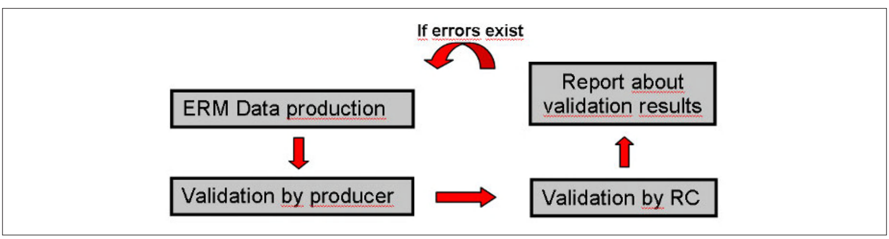

Fig. 2.9. Validation process at ERM production

The validation procedures (Hopfstock et al 2007a, Hopfstock et al. 2007b) consist of a series of checks against the following criteria:

- Compliance with the ERM Specifications regarding topology, data model, allowed attribute values, selection criteria and the geometrical resolution
- Coherence and consistency of feature and attributes
- Homogeneity of attribute values in a feature network
- Consistency between themes
- Cross-border continuity between neighbouring countries

The completeness of data collection is in the only responsibility of the producers, because the review by the regional coordinator is done without maps and ancillary sources.

Because producers work with different GIS and mapping software and additionally with different versions there is no directive for using certain validation tools to perform the checks. In contrast, the regional coordinators use the same validation tools for the specified checks to achieve a comparable quality standard for the whole ERM dataset. These validation tools can be classified in four groups:

- Standard tools of ArcGIS: checking i.e. topological rules or connectivities
- Automated checks with PLTS GIS Data ReViewer: checking i.e. allowed attribute values, attribute combinations, geometrical resolution or spatial relationships
- Non standard tools of ArcGIS: additional extensions of ArcGIS that must be installed separately and self-developed programs, i.e. Python Scripts for checking edge-matching
- Visual quality checks: for all those criteria which can't be checked automatically i.e. generalization and selection rates

The regional coordinator reports the validation results both by means of an Excel-sheet stating the number of errors relating to the validation criteria (see *Table 2.3)* and additionally sending a ReViewer table.

Table 2.3. Example of validation report (Excel sheet)

Qualita criteria	Validation results of RC
Attributes structure	
allowed attribute values for FERRYL (DETN, DETA, DNLN, USE, RSU, FerryID)	ok
allowed attribute values for RAILRDL (EXS, FCO, GAW, LLE, NAMxx, RCO, RGC, RRA, RRC, RSU)	62 errors (LLE)
allowed attribute values for ROADL (EXS, LLE, LTN, MED, NAMxx, RST, RSU, RTE, RTN, RTT, TOL, TUC)	3 errors (TUC)
Topology	
AIRFLDA must not overlap with HARBORA	ok
FERRYL, HARBORL, RAILRDL, ROADL, RUNWAYL: Must not intersect or touch interior	RoadL: 14 errors

The ReViewer table is a database table written by PLTS that contains the features that have been found using automated checks and visual review. This table contains a link (ObjectID) to the found feature and therefore, when using ArcGIS, errors can easily be corrected and evaluated as needed. In addition the ReViewer table contains several columns that provide information on the records such as the feature class, the used check and an error description (see *Figure 2.10)*.

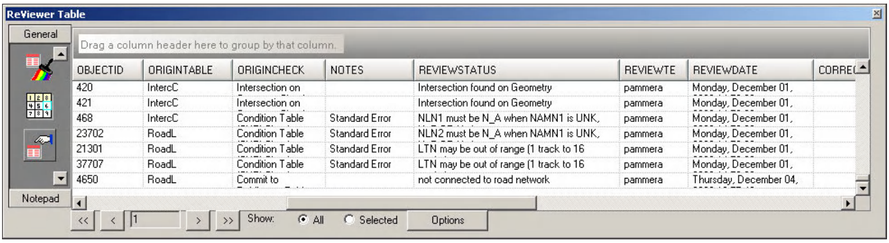

Fig. 2.10. ReViewer Table

2.7 Conclusion and Outlook

This paper presented a progress report about the best-practice approach of the multinational ERM co-production for the central-European region.

A new release ERM v3.0 providing a regular update will be published in the first quarter of 2009. The ongoing consolidation phase aims at improving the data quality and, therefore, increasing the level of geometric and semantic harmonisation to meet the user requirements in spatial analysis and visualisation. Further on, the ERM specifications are reviewed in the context of the ESDIN project.

ESDIN – **E**uropean **S**patial **D**ata **I**nfrastructure with a Best Practice **N**etwork – aims to develop, test, and implement services providing transformations to European data specifications, support for multi-lingual aspects, transformation of coordinates to common spatial reference systems, generalisation from 'large' to 'small' scales, and edge-matching to address inconsistencies at national borders (ESDIN 2009). Besides achieving technical interoperability, the project also addresses business interoperability seeking for simple data licensing, digital geo-Rights Management providing fast and easy user access to the data. Finally, data quality is a prime concern of users and ESDIN is looking into establishing a standard approach to reporting data quality.

In a long-term vision the ESDIN developments could lead to a distributed European Network running services that automatically join proper national databases in scale 1:250 000 at a European level and generate the EuroGeographics' products, amongst others ERM, meeting the requirements of INSPIRE.

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Chapter 3

Methods of Portraying Spatial Data Used in Official Geoinformation Services in Poland – A Comparative Study

Marek Baranowski, Elżbieta Bielecka and Dariusz Dukaczewski

Institute of Geodesy and Cartography, Warsaw, Poland
{marek.baranowski, elzbieta.bielecka, dariusz.dukaczewski}@igik.edu.pl

Abstract

The appropriate selection of means of cartographic portrayal of geodata is one of the factors vital for proper understanding of the essence of presented geographic features, especially when dealing with public data, which are available via official public geoinformation services. The last 19 years have brought rapid growth in official Web-based geoinformation services in Poland. The authors analysed the thematic scope of the geodata published by Polish official Web-based geoinformation services, the functionality of these services, the methods of portrayal used, and their correctness. This paper then goes on to propose a typology of official geoinformation services in Poland. The analysis has allowed the authors to formulate certain generalizations concerning combination of methods, by which the effectiveness of information transfer might be increased.

Keywords: geoinformation services, spatial data, thematic maps

3.1 Introduction

In the last few years, rapid growth in the availability of digital spatial data has been coupled with a growing need for this to be used in all kinds of GIS applications supporting the decision-making process. With the development of communications technology, it has become possible to use Internet services to search, view, and download queried geodata. Even though forms of display of geodata differ consid-

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erably (tables, graphs, charts, thematic maps, pictures, outline maps, 3D visualisation), it is widely assumed that geodata will gain portrayal in thematic maps.

The main objective of this paper has been to present an analysis of the thematic scope of the spatial data published by thee official Web-based geoinformation services in Poland, the functionality of these services, and the methods used in data portrayal and their correctness.

As we analysed use of spatial data, we paid particular attention to:

- the diversity of methods used in portraying qualitative and quantitative data,
- the correctness of the selected methods and map design,
- the effectiveness of communication,
- the use of non-conventional forms of data visualisation.

An appropriate selection of means of cartographic portrayal of geodata is of decisive importance if the essence of presented geographical features and phenomena is to be understood properly. It is especially vital where public data available via official public geoinformation services are being dealt with.

Many current research works on maps on the Internet have been focused on city and road maps, mush-up maps, multiple representation, data format and the technology of data visualisation. There are also papers presenting the state of the art of the geoportals from the international level (Crompvoets et al. 2005, Giff et al. 2008, Dukaczewski & Bielecka 2009, Craglia & Campagna 2009), and the national and regional level (Beaumont et al. 2005, Tegtmeier & Hack 2007, Dukaczewski 2007b, Craglia 2008, Mercadante & Salvemini 2008) down to the local level (Opach 2007, Siekierska 2007). Many current research work on maps on the Internet are focused on city and road maps, mush-up maps, multiple representation, data format, and technology of data visualisation. The analysis presented here has a broader context, dealing with cartographic Web-based services in a more comprehensive way, through the inclusion of both an analysis of methods used in spatial data portrayal and an attempt to formulate statements on methods by which to increase effectiveness of information transfer.

3.2 The Analysed Public Administration Services

As of December 2008, it was possible to identify 2876 official governmental and local government administration portals in Poland, these being:

- 1 national geoportal (geoportal.gov.pl);
- 18 regional portals of the 16 voivodships[1];

[1] province-regions into which Poland is divided

- 379 local/county-level portals;
- 2478 local gmina (commune)-level portals.

The authors have analysed the portals falling within the first three groups and 379 local level county capital city portals, as well as selected thematic geoinformation services like:

- the portals of 23 National Parks;
- the *Natura 2000* portal;
- 6 geological portals of the Polish Geological Institute (Central Geological Database, MIDAS, Mineral Resources of Poland, Hydro Bank, Underground Water Monitoring, Geotopes of the Polish–Lithuanian border region);
- 6 meteorological portals (1 official one – of the Institute of Meteorology and Water Management) and 5 commercial: *Onet, Interia, Wirtualna Polska, Meteo Group* and *Twoja Pogoda*);
- National forests portals (of the State Forests organisation *Lasy Państwowe* and the *Leśny Przewodnik Turystyczny*).

In total, 815 portals were analysed.

3.3 The Thematic Scope of Geodata Published by Official Web-based Geoinformation Services

3.3.1 The National Geoportal

The national geoportal.gov.pl of the Head Office of Geodesy and Cartography (GUGiK) is a WMS solution, which is used to publish information from the State Register of Borders, cadastre, aerial and satellite ortophotomaps, a TBD topographic database (1: 10 000), VMap2, BDO database (1: 200 000 – 1 000 000), DTM, and raster topographic maps. The thematic scope of this geoportal is concerning 18 of the INSPIRE thematic groups. It is planned to extend this scope with data on soils and geology. In 2008, geoportal.gov.pl was also providing metadata *(Figure 3.1)*.

3.3.2 Regional Level Portals of Voivodships

The regional portals represent various different solutions, ranging from the usual advanced Web Maps (Świętokrzyskie Voivodship), through WebGIS-es, to WMS (Pomorskie, Zachodniopomorskie and Mazowieckie Voivodships). The thematic scope of the geodata published by the voivodship portals varies from 6 to 46 layers *(Table 3.1),* which corresponds to 3–26 of the 34 INSPIRE thematic groups.

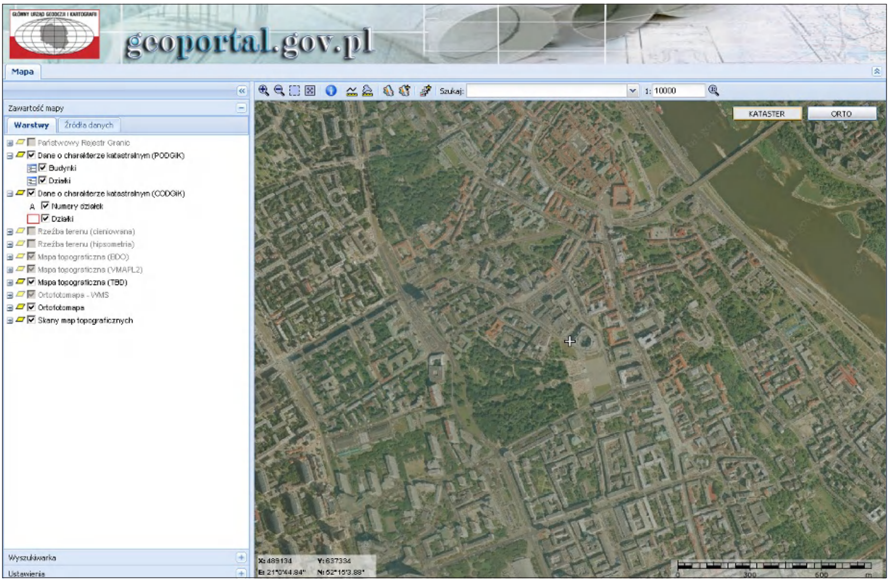

Fig. 3.1. Geoportal.gov.pl

Table 3.1. Number of thematic groups of maps and interactive functions of voivodeship portals

Voivodeship portal adress	Number of thematic groups	Number of interactive functions
http://www.wrotapomorza.pl/	46	20
http://www.malopolska.pl/	43	11
http://www.um-zachodniopomorskie.pl/	38	35
http://www.lodzkie.pl/	37	24
http://www.wrotaopolszczyzny.pl/pl	34	14
http://www.silesia-region.pl/	30	2
http://www.mazovia.pl/	26	19
http://www.kujawsko-pomorskie.mw.gov.pl/	22	24
http://www.wrota-swietokrzyskie.pl/	18	14
http://www.podkarpackie.pl/	17	2
http://www.wrotapodlasia.pl/	16	19
http://www.dolnyslask.pl/	15	under construction
http://www.lubelskie.pl/	12	13
http://www.wm.24.pl/index.php	11	2
http://www.wielkopolska.mw.gov.pl/	11	2
http://www.lubuskie.pl/	6	2

Using as a criterion the number of layers and number of related INSPIRE groups, it is possible to distinguish 5 groups of voivodship portal:

1. Pomorskie and Małopolskie voivodships (comparable with the Rhine-Westphalia portal);
2. Zachodniopomorskie, Mazowieckie, Łódzkie, Opolskie and Śląskie voivodships (similar to the Rhine-Pfaltz portal);
3. Podlaskie, Dolnośląskie, Kujawsko–Pomorskie, Podkarpackie and Świętokrzyskie voivodships (comparable with the portal of Wales);
4. Lubelskie, Wielkopolskie and Warmińsko–Mazurskie voivodships (similar to the portal of Olomoucky Kraj);
5. Lubuskie voivodship (similar to the portals of Galicia and Bourgogne).

In the case of all the portals it was possible to access information on coordinate systems, spatial planning and map indexes. Through 15 portals (83.3 %), layers and/or maps of protected areas were available, while the administrative division layers were presented on 14 portals (77.7 %), transport networks and wastewater management policy – on 12 portals (66.6 %), hydrography – on 11 portals (61 %). The layers concerning other themes were more scarcely presented. This was the case with tourist paths (10), habitats (9), health environmental risks, public services, limited access zones (8), land use (7), education, heritage, monitoring installations, morphogenetic regions (6), soils (5), parcels, power lines, watersheds, buildings (4). The raster topographic and thematic maps were available through 7 portals, DTM – through 4. As in the case of many portals in Europe, a tendency to avoid the 'fragile' social themes like unemployment and health & welfare was visible. The metadata were available through 6 portals (33.3 %).

3.3.3 Local County-Level Portals

Only 83% of local level county portals (317 of 379) offer access to maps. 75% (238) of them are simple WebMaps solutions. In 2009 only 5 cases (Chojnice, Krapkowice, Łęczna, Polkowice and Żyrardów) were WebGIS-es portals. The thematic scope of the geodata published by county portals ranges from 1 to 43 layers, corresponding to 2–24 INSPIRE thematic groups.

Using as a criterion the number of layers and corresponding INSPIRE thematic groups, it is possible to distinguish 6 groups of county portals:

1. Krapkowice (0.3%, 43 layers, 24 INSPIRE thematic Groups);
2. Brodnica, Mińsk Mazowiecki, Chojnice (0.94%, 20–16 layers, 23–22 INSPIRE groups);

3. Piotrków Trybunalski, Gorzów Wielkopolski, Kościan, Łobez, Grodzisk Wielkopolski, Strzelce Opolskie, Gryfino, Strzyżów, Łęczna (3.15%, 15–14 layers, 20–18 INSPIRE groups);
4. Opole Lubelskie, Olkusz, Grodzisk Mazowiecki, Białobrzegi (1.26%, 13–10 layers, 16–15 INSPIRE groups);
5. Chrzanów, Żyrardów, Żary, Aleksandrów Kujawski, Bolesławiec, Głogów, Jasło, Jędrzejów, Nakło, Skarżysko–Kamienna, Wieruszów, Żuromin, Łosice, Kielce, Milicz, Ostróda, Śrem, Łęczyca (5.67 %, 9–5 layers, 12–8 INSPIRE groups);
6. other counties (88.68 %, 4–1 layers, 3–2 INSPIRE groups).

All portals published information on geographical names and administrative units. In 90 cases (28.39%) the coordinate systems, transport networks, hydrography, protected sites, land cover, buildings, land use, utility and governmental services, production and industrial facilities, agricultural and aquaculture facilities, habitats and biotope information were all available. In the case of 16 portals (5.04 %), information on a strategic plan of development was available, while physical planning documents were accessible through 7 portals (2.2 %). The information on tourist trails was available on 9 portals (2.83%). Data on species distribution, energy resources, and mineral resources was available via 4 portals (1.26 %). Ortophoto was accessible on 11 portals (3.47 %), information about parcels through just 1.

3.3.4 The Local-Level Portals of County Capitals

98.41 % of county capitals official portals (373 out of 379) allow access to maps. 136 of these (36.46%) are simple Web Maps, while 225 (60.32 %) are advanced Web Maps and WebGIS, and 23 (6%) WMS solutions. The thematic scope of geodata published by county portals varies from 1 to 254 layers, corresponding to 2–31 INSPIRE thematic groups.

Using as criteria the number of layers and the INSPIRE thematic groups, it has been possible to distinguish 6 groups of county-capital portals:

- Rybnik (0.26 %, 254 layers, 31 INSPIRE groups);
- Świnoujście and Łódź (0.53 %, 65–56 layers, 28 INSPIRE groups);
- Warszawa (Warsaw), Bartoszyce, Bytom, Gdańsk, Konin, Kościan, Szczecin, Wrocław, Chorzów, Kędzierzyn-Koźle, Żory and Chrzanów (3.21 %, 46–32 layers, 26–24 INSPIRE groups);
- Starogard Gdański, Bochnia, Kielce, Kwidzyn, Białogard, Będzin, Biała Podlaska, Krotoszyn, Leszno, Ostrów Wielkopolski, Zgierz, Przemyśl, Białystok, Cieszyn, Kluczbork, Olsztyn, Iława, Poznań, Końskie, Gołdap, Gorlice and Strzelce Krajeńskie (5.89 %, 28–20 layers, 22–20 INSPIRE groups);
- Inowrocław, Lubartów, Bełchatów, Lublin, Tomaszów Mazowiecki, Wałbrzych, Bielsko-Biała, Jasło, Ryki, Strzelce Opolskie, Kutno, Sławno, Wodzisław Śląski,

Olkusz, Opole, Gniezno, Grodzisk Wielkopolski, Łęczyca, Nowy Tomyśl, Krapkowice, Lubin, Lubliniec, Łańcut, Zielona Góra, Bieruń, Kraków, Nowy Dwór Mazowiecki, Opole Lubelskie, Jastrzębie, Jaworzno, Grodzisk Mazowiecki, Piotrków Trybunalski, Elbląg, Łomża, Słubice, Września, Żary, Skarżysko–Kamienna, Stalowa Wola, Zielona Góra, Krasnystaw and Siemianowice Śląskie (11.26 %, 19–10 layers, 17–12 INSPIRE groups);

- other county capital cities (78.85 %, 9–2 layers, 10–2 INSPIRE groups).

373 portals provide information on geographical names, administrative units, transport networks, hydrography, land use, buildings, utilities and governmental services. In the case of 344 (92.22%), there was access to information about production and industrial facilities, agricultural and aquaculture facilities, and protected sites. Addresses were available on 54 portals (14.47%). Information on cadastral parcels was accessible though 28 portals (7.5%), orthophotomaps in the case of 20 portals (7.5 %). In a few cases, historical orthophotomaps were also available (e.g. Warsaw of 1935, 1945). The habitats and biotopes information and species distributions were accessible via 24 portals (6.43%). Digital elevation models, statistical units, and environmental monitoring facilities information was available via 4 (1.07 %) portals (Warszawa, Bydgoszcz, Białystok and Bytom). Other rare information concerned demography (Białystok), energy and mineral resources (Bytom), geology and soils (Chrzanów), historic maps layers (Szczecin and Olecko), public safety (Suwałki and Stalowa Wola), and noise (Warszawa, Wrocław, Bydgoszcz *(Figure 3.2)*, Białystok and Bytom).

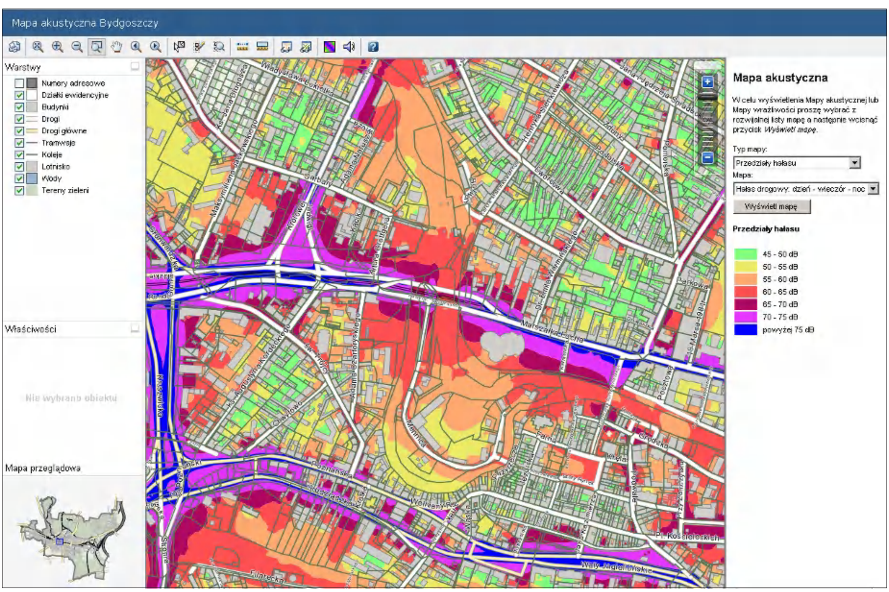

Fig. 3.2. Bydgoszcz. Map of noise

3.3.5 National Park portals

In December 2008, 19 (79%) of Polish National Park portals were Web Map solutions, while 5 (21 %) (i.e. Bieszczadzki, Kampinoski, Karkonoski, Tatrzański and Wielkopolski NPs) wers WebGIS solutions. The number of thematic layers published by National Park portals ranges from 5 to 39 *(Table 3.2),* and the number of corresponding INSPIRE themes ranges from 5 to 18.

Table 3.2. Number of thematic groups of maps and interactive functions of national parks portals

National park portal adress	Number of thematic groups	Number of interactive functions
Tatrzański: www.tpn.pl; www.gis.tpn.pl	39	33
Babiogórski: www.bgpn.pl	23	3
Bory Tucholskie: park.borytucholskie.info	23	1
Wielkopolski: www.wielkopolskipn.pl	23	10
Magurski: www.magurskipn.pl	19	5
Karkonoski: kpnmab.pl	18	28
Kampinoski: kampinoski-pn.gov.pl	16	30
Poleski: www.poleskipn.pl	16	2
Białowieski: www.bpn.com.pl	14	3
Gorczański: www.gorczanskipark.pl	14	6
Słowiński: www.slowinskipn.pl	14	7
Biebrzański: www.biebrza.org.pl	12	3
Ojcowski: www.opn.pan.krakow.pl	12	3
Narwiański: www.npn.pl	12	2
Bieszczadzki: www.bdpn.pl	11	20
Gór Stołowych: www.pngs.pulsar.net.pl	11	3
Wigierski: www.wigry.win.pl	10	3
Drawieński: www.dpn.pl	8	1
Świętokrzyski: www.swietokrzyskipn.org.pl	8	4
Ujścia Warty: www.pnujsciewarty.gov.pl	8	3
Woliński: www.wolinpn.pl	8	3
Pieniński: www.pieninypn.pl	5	4
Roztoczański: www.roztoczanskipn.pl	5	2

Using as a criterion the number of thematic layers and INSPIRE groups, it is possible to distinguish 4 groups of these portals:

1. Tatrzański (4.16 %, 39 layers, 18 INSPIRE groups);
2. Babiogórski, Bory Tucholskie, Wielkopolski, Magurski, Karkonoski, Kampinoski and Poleski (29.16 %, 23–16 layers, 15–12 INSPIRE groups);

3. Białowiecki, Gorczański, Słowiński, Biebrzański, Gór Stołowych, Ojcowski, Narwiański, Bieszczadzki and Wigierski (37.5 %, 14–10 layers, 9–8 INSPIRE groups);
4. Świętokrzyski, Ujścia Warty, Roztoczański, Woliński and Pieniński (29.18 %, 8–5 layers, 5 INSPIRE groups).

All portals provide information on geographical names, transport networks, hydrography, protected sites and land cover, while 10 (41.6%) cover digital elevation models. Orthophotomaps are available in 7 cases (36%). Other thematic groups are less frequently represented – administrative units (6 cases – 29%), environmental monitoring facilities (5 cases – 20.8%), coordinate reference systems, utilities and government services, buildings, habitats and biotopes (4 cases – 16.6%), human health and safety, natural risk zones (3 cases – 12.5%), geology, species distribution (2), cadastral parcels, area management, soils and atmospheric conditions (1).

3.3.6 The *Natura 2000* Portal

The Polish *Natura 2000* portal publishes a wide range of information corresponding to INSPIRE themes of protected sites, habitats and biotopes, and species distributions. The themes of coordinate reference systems, geographical names, administrative units, transport networks, hydrography, DTM, land cover/use are presented as well. This portal also provides metadata.

3.3.7 Geological Portals

- The *Central Geological Database portal* is a WMS solution publishing information corresponding to INSPIRE themes of mineral & energy resources (boreholes; gravimetric, magnetic, seismic and geoelectric measurement points; maritime profiles; deposits; concession borders), DTM, geological map indexes and reference elements (administrative division, hydrology, roads, built-up areas, *Natura 2000* areas), and metadata.
- *The MIDAS system* portal publishes information on mineral deposits and concessions. It can also be used to consult mineral-deposit documentation metadata.
- *The Mineral Resources of Poland* is a portal dedicated to the dissemination of metadata on geological mapping in Poland.
- *The Hydro Bank* portal can be used to carry out queries on hydrogeological maps and documentation.
- *The Underground Water Monitoring* portal contains information on water monitoring points and underground water basins, also including data on administrative divisions.

- The *Geotopes of the Polish–Lithuanian border region* portal is a WebGIS solution which provides information on the locations and characteristics of geotopes, including also data on borders, transport networks, hydrography and land use.

3.3.8 Meteorological Portals

The *Pogodynka.pl* is an official meteorological geoservice of the Institute of Meteorology and Water Management. This service provides maps of temperature, wind, cloudiness, meteorological phenomena, the states of rivers and underground waters and storms, as well as radar maps of clouds and precipitation, maps of biometeorological conditions, satellite images, forecast and warning maps. The *Onet.pl Pogoda* in turn provides maps of temperature, cloudiness, precipitation, wind and snow, as well as satellite images and forecast maps. A similar scope of geoinformation is published by the *Interia* portal. The *Wirtualna Polska* portal is in turn a source of general information on temperature, cloudiness, rainfall and snow, as well as forecast maps. The *Meteo Group* portal provides simplified maps of weather, satellite images and forecast data, while the *Twoja Pogoda* portal offers maps of temperature, winds and precipitation, as well as radar and IR satellite images, plus warning and forecast maps.

3.3.9 The State Forests Portals

The *Lasy Państwowe* is a national forests portal publishing information on the administrative divisions of forests and Promotional Forest Complexes, areas of fire risk, and restricted-access areas. For visualization purposes, it also employs information on state administrative divisions, hydrography, parks, built-up areas, and communications networks.

The *Leśny Przewodnik Turystyczny* portal is a forest tourist geoservice, providing information about forest education paths and centers, tourist accommodation, car parks, camps and bonfire sites, and it also includes data on the transport network, land use and hydrography.

3.4 Functionality

It was possible to identify 48 main interactive functions of the portals analysed. The maximal number of these functions was 35 (the Zachodniopomorskie voivodship portal). There is found to be considerable diversity to the levels of interactivity of map functions. Following Asche & Herrman (1994), three main levels might be distinguished: a first related to viewing and displaying (choice of extent, scale, pan); a second allowing for interaction with a database (choice of layers); and a third relating to analytical functions and a superimposition of layers. In turn, Crompton (2002) proposed five levels of complexity to interactive functions: publishing (1), comparison (2), modification (3), extraction/combination/deletion (4) and detection of reasons or results (5). For his part, Dukaczewski (2007b) proposed 7 levels of complexity of interactive functions of cartographic animation, relating to: navigation (1), data gathering (2), conceptual programming of visualisation (3), query and selection of information, (4), choice of method of data processing (5), choice of form of visualization (6), analysis of spatio-temporal processes (7), which can also be employed in the case of static visualisation.

3.4.1 The National Geoportal

The national geoportal employs 22 interactive functions (legend/layers, configure, zoom in/zoom out, fit in center, full extent, new window, line measure, area measure, coordinates, fit to visualised layer, fit to selected layer, add layer, scale selection, show cadastre, show orthoimagery, layer query, find, show at map, sort by category, object parameters and metadata viewer). This choice seems to appropriate to its functions. Regarding the existence of many coordinate systems in Poland it could be a good idea to add a function for their selection.

3.4.2 Regional-Level Portals of the Voivodships

The number of interactive functions of regional-level portals is very diversified *(Table 3.1).* Using the criterion of level of complexity of interactive functions it is possible to distinguish 5 types of portal, equipped with:

1. a partial navigational interface (Lubuskie, Podkarpackie, Śląskie, Wielkopolskie);
2. a full navigational interface (Dolnośląskie, Kujawsko–Pomorskie, Lubelskie, Łódzkie, Małopolskie, Mazowieckie, Opolskie, Podlaskie, Pomorskie, Świętokrzyskie, Zachodniopomorskie);
3. functions of data gathering (Dolnośląskie, Kujawsko–Pomorskie, Lubelskie, Łódzkie, Mazowieckie, Opolskie, Podlaskie, Pomorskie, Świętokrzyskie, Zachodniopomorskie);
4. functions of conceptual programming of visualisation (Dolnośląskie, Kujawsko–Pomorskie, Łódzkie, Mazowieckie, Pomorskie, Zachodniopomorskie);
5. functions of query and selection of information (Dolnośląskie, Kujawsko–Pomorskie, Łódzkie, Mazowieckie, Zachodniopomorskie).

It is worth mentioning that it is still not possible in any of these portals to make a choice of method of data processing, to make a choice of form of visualization, or to carry out an analysis of spatio-temporal processes.

3.4.3 Local County-Level Portals

Only 21.1 % (80 out of 379) of local county-level portals have cartographic modules equipped with an interactive interface. The number of functions varies from 24 to 1. In 12 cases, only a link to a gmina-level portal was provided. A full navigational interface was present in only 26 cases (Polkowice, Strzelce Opolskie, Płońsk, Chojnice, Ryki, Skierniewice, Żyrardów, Grodzisk Mazowiecki, Kościan, Łowicz, Milicz, Krapkowice, Legionowo, Ostrołęka, Trzebnia, Żywiec, Grodzisk Wielkopolski, Opole, Prudnik, Szamotuły, Brodnica, Olecko, Ostróda, Poznań, Zawiercie and Żary), while the functions of data gathering were only there in the case of the first 13 counties.

3.4.4 Local-Level Portals of County Seats

63.53% (237 out of 373) of local-level portals of the capitals of counties were equipped with an interactive interface. The number of functions varies from 1 to 27 (Białystok, Bydgoszcz, Chorzów and Siemianowice Śląskie). A full navigational interface was only present in 154 cases (41%), the functions of data gathering – only in the case of 47 portals (12.6%), while visualisation programming functions – in 24 portals (6.43%) (Białystok, Bydgoszcz, Chorzów, Siemianowice Śląskie, Kraków, Jasło, Piotrków Trybunalski, Puławy Ruda Śląska, Zielona Góra, Wrocław, Stargard Szczeciński, Strzelce Opolskie, Szczecin, Gdańsk, Kołobrzeg, Mysłowice, Nisko, Piła, Łęczyca, Sosnowiec, Stalowa Wola, Starogard Gdański, Suwałki, Zawiercie, Żory and Rybnik).

3.4.5 National Park Portals

All National Park portals are equipped with interactive interfaces. The number of functions varies from 1 to 33 *(Table 3.2)*. A partial navigational interface was available in the case of Słowiński, Gorczański, Magurski, Poleski, Pieniński, Świętokrzyski, Ojcowski, Ujścia Warty, Wigierski and Woliński National Parks), while a full navigational interface was present in only 5 cases (the Tatrzański, Kampinoski, Karkonowski, Bieszczadzki and Wielkopolski NPs). The functions of data gathering were available in only the first 3 portals.

3.4.6 The *Natura 2000* Portal

This portal employs 15 interactive functions (zoom in/zoom out, fit in center, full extent, legend/layers, configure, select layer, refresh, HTML mode, select scale, select selected areas, logical selection of sites, selection of sites by administrative unit, selection of areas using species, logical selection of areas using complexes of species). This choice seems to appropriate in line with the stated objectives.

3.4.7 Geological Portals

- The *Central Geological Database* portal is equipped with an interface of 25 functions (hide/show preview, legend/layers, configure, zoom in/zoom out, pan, full extent, fit to selected layer, select units, find, query, line measure, selection with: point, rectangle, circle, polygon, buffer, remove selection, print, help, buy map, refresh, select layers, object parameters and show).
- *The MIDAS system* portal employs an interface with logical selection of mineral deposits and metadata queries.
- *The Mineral Resources of Poland* portal is equipped with an interface allowing for the logical selection of maps (with type, name, and number of sheet), and the information on the metadata.
- *The Hydro Bank portal* employs 14 interactive functions (hide/show of preview, legend/layers, configure, pan, find, query, parametrical query, help, refresh, select layers, select scale).
- *The Underground Water Monitoring* portal has an interface of 14 functions (zoom in/zoom out, full extent, fit to map, line measurement, area measurement, coordinate measurement, add layer, query, find, configure, select layers, apply and select scale).
- *The Geotopes of the Polish – Lithuanian border region* portal is equipped with 21 interactive functions (hide/show of preview, legend/layers, zoom in/zoom out, pan, back, selection with: point, line, polygon, buffer, remove selection, configure, full extent, find, query, line measure, print, refresh, select: layers, rectangle and show at map).

3.4.8 Meteorological Portals

The Pogodynka.pl portal is equipped with an interface for time selection and city selection, as well as links to the maps, satellite images and warnings. The animation interface allows for the starting, stopping, and configuring of the speed of animation, as well as for the adding of additional information (cities, coordinate systems, and DTM). The interface of the *Onet.pl Pogoda* portal allows for the selection of the layer or thematic weather map. *The Interia* portal employs an interface allowing for selection of date, time, and type of weather map. *The Wirtualna Polska* portal interface in turn allows the day and the type of map for visualization to be selected, while the *Meteo Group* portal employs an interface with selection of name of city, layers, and links to yesterday weather, IR and radar satellite images. The animation interface allows for starting, stopping and configuring the speed of animation, the creation of a loop, and zooming in/out. Finally, the *Twoja Pogoda* portal interface allows for selection of the day of the weather forecast, as well as for visualization of the map of warnings.

3.4.9 The State Forests Portals

The Lasy Państwowe portal is equipped with an interface of 21 functions (back to the first map, hide/show preview, legend/layers, configure, zoom in/zoom out, pan, full extend, go forward/go back, query, find, scale selection, percentage zoom, selection with point, select units, line measure, calculate coordinates, select layers, add layer, remove layer).

The Leśny Przewodnik Turystyczny portal in turn employs an interface of 10 functions (zoom in/zoom out, pan, go forward, go back, back to the first map, print, query, select layers, display info).

The majority of the analysed portals are equipped with an interface that allows viewing, displaying, and (more rarely) querying of geoinformation. Only in a few cases it is allowed to save (legally) the result of a query, and in only one case (of the *Central Geological Database* portal) it is possible to order a map. Even though the number of interfaces which allow the user to generate an interaction between layers of the database(s) has grown significantly over the last few years, these constitute right now only approximately 20 % of all interfaces. In order to avoid errors, these kinds of functions need solutions of locking layers of an inappropriate level of detail, which are recently becoming more widespread. Only a very small number of portals is equipped with analytical functions and superimposition of layers. Thus, most of the analysed portals can be used rather for publishing, comparison, modification, and combination of geoinformation, than for the detection of reasons, or presentation of results as regards geographical phenomena.

3.5 Methods used in the Portrayal of Data and their Correctness

The appropriate selection of a cartographic method of presentation (or combination of methods), as well as a semiologically correct choice of visual variables at a relevant level of measurement is a *sine qua non* condition if there is to be effectiveness of communication. The choice must be a very careful one in the case of public datathat are available via official public geoinformation services.

3.5.1 The National Geoportal

At geoportal.gov.pl the sole employed cartographic methods are qualitative line symbols (Sβa), qualitative point signatures (Sαa), the chorochromatic method (MCa), and range maps (MZa). This choice is correct, due to the character of the visualized data. The scale-oriented mechanism of lock of layers allows problems with visualization of data to be avoided, the sole remaining problem being too large a size of parcel number labels.

3.5.2 The Regional-Level Portals of the Voivodships

The portals of the voivodships employ only 9 of the 24 main types of cartographic method. The most frequently used methods are quantitative area symbols (Sγa) and the chorochromatic method (MCa) (both in 122 cases). The first method is used for the creation of simple administrative maps with links. Other frequently-used methods are qualitative line symbols (Sβa) (105 cases), range maps (MZa) (75) and quantitative line symbols (Sβc) (73 cases). The methods of ordinary point symbols (Sαb) and ordinary line symbols (Sβb) were employed more scarcely (62 and 38 applications). The most rarely used were quantitative area choropleth maps (Kγc(cs)) and ordinary area choropleth maps (Kγb) (3 and 1 cases respectively). Quantitative cartodiagrams were not employed at all. The application of absolute values in quantitative area choropleth maps (e.g. on the Małopolskie Voivodship portal) was a more frequent error. The analysis reveals that most correct portals methodologically are those of Zachodniopomorskie and Mazowieckie voivodships.

3.5.3 Local County-Level Portals

In the case of these portals the most frequently used methods are chorochromatic maps (MCa), qualitative point symbols (Sαa), qualitative line symbols (Sβa) and quantitative area symbols (Sγa). Most of the products are tourist or general maps. Cartodiagrams are totally absent from the cartographic part of the portals. However, it is possible to identify one quantitative area choropleth map (Kγc(cs)) of unemployment in Mazowieckie voivodship. As in the case of voivodship portals, a large proportion of the maps wwere prepared by non-cartographers, the results sometimes being erroneous usage of colour and value and the application of non-scaled symbols (e.g. on the portal of Ostrołęka poviat). Good examples of local web cartography are provided by maps of Krapkowice and Ryki powiat (good usage of visual variables, well-scaled symbols, and layers locked according to the scale of visualization).

3.5.4 Local-Level Portals of County Seats

A large part of the geoinformation product of these portals consists of tourist or general maps. The 136 products available though these portals were scanned, professionaly made city maps. Such maps also offered the base layer for 53 interactive city maps. The most frequently employed methods were chorochromatic maps (MCa), qualitative point symbols (Sαa), qualitative line symbols (Sβa) and quantitative area symbols (Sγa). Cartodiagrams were used in the presentation of election results in Białystok. The quantitative area choropleth method (Kγc(cs)) was used only rarely, e.g. for the presentation of density of population in Białystok, noise immision in Warszawa (Warsaw), Wrocław, Bydgoszcz and Bytom. For presentation of noise acoustical variables were also used (in Bydgoszcz and Warsaw). Via this last portal it is also possible to visualize a 3D animation employing sound effects. The 27 city portals include the virtual visit module. A very interesting solution is a multi-temporal comparison of city space (semi-transparent historical layers on the Szczecin portal). The most frequent errors were: too small a legend on a scanned city plans, legends conflicting with the frames of plans (e.g. Leszno), an inadequate relationship between level of detail and possible scale of visualization (e.g. 1:500 scale maps of Świnoujście), problems with overlap of symbols (e.g. Bytom, Tychy), choice of colours incompatible with semiotic rules (map of Sosnowiec). A large part of the maps available though the city portals are methodologically correct, however.

3.5.5 National Park Portals

In the case of these portals the most frequently used methods were qualitative point symbols (Sαa), qualitative line symbols (Sβa), chorochromatic maps (MCa), and range maps (MZa). The ordinary and quantitative methods were not used at all. The qualitative methods are simple and easy to comprehend, and can guarantee a reletively high level of effectiveness of communication. In the case of the portals of the Słowiński, Gorczański, Magurski, Poleski, Pieniński, Świętokrzyski, Ojcowski, Ujścia Warty, Wigierski and Woliński National Parks most problems relating to the portrayal of spatial data were related to characteristics of the source material used (different scales and coordinate systems, lack of uniformity of thematic scope and used methods, legends of scanned maps that are too small and only partially legible). In the case of the Tatrzański, Kampinoski, Karkonowski, Bieszczadzki and Wielkopolski National Park portals, the problem was related to logical and geometric errors of layers (e.g. streams inside the Morskie Oko tarn, wrong positioning of geographical names, point symbols that are too large and not scaled [2], a lack of 'bring to front' function[3]), as well as to incoherence of legends[4] and lack of interoperability of cross-border data[5]. In the case of all these portals there is no function 'lock the map against the overload'.

3.5.6 The *Natura 2000* Portal

This portal is employing a combination of only 4 types of cartographic method of presentation: the chorochromatic method (MCa), range maps (MZa), qualitative line symbols (Sβa) and qualitative point symbols (Sαa). This choice is correct, due to the character of visualized data. All layers and its legends are strictly harmonized, what can guarantee the lack of uncontrolled overlap and no loss of parts of geospatial information.

3.5.7 Geological Portals

All geological portals are employing combination of chorochromatic method (MCa), range maps (MZa), qualitative line symbols (Sβa) and qualitative point symbols (Sαa). This choice is correct, due to the character of the visualized data. Hovever, it needs to be mentioned that a part of the point symbols of the Central Geological Database portal can overlap during the visualization, and that the point symbols of the Geotops of the Polish–Lithuanian border region portal are not scalable. All layers and their graphical legends are harmonized.

3.5.8 Meteorological Portals

Due to the specificity of geospatial information (e.g. ordinary scale of measurement), the meteorological portals use very individual groups of methods. *Pogodynka.*

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[2] Portal of Tatrzański Park Narodowy

[3] ibid and portal of Kampinoski Park Narodowy

[4] portal of Bieszczadzki Park Narodowy

[5] e.g. between the Czech Republic and Poland in the case of the portal of Karkonoski Park Narodowy

pl employs qualitative point symbols (Sαa), qualitative line symbols (Sβa), the chorochromatic method (MCa) and isoline maps (Ic), but also quantitative line symbols (Sβc), ordinary area choropleth maps (Kγb), ordinary line cartodiagrams (Kdβb), as well as a combination of quantitative area choropleth maps (Kγc(cs)) and quantitative line symbols (Sβc)[6]. This choice of methods can guarantee semiologically correct presentation of meteorological information. The *Onet* portal uses ordinary point symbols (Sαb), qualitative point symbols (Sαa), the chorochromatic method (MCa), qualitative line symbols (Sβa), and ordinary area choropleth maps (Kγb). *Interia*, due to its reduced scope of published information, uses ordinary point symbols (Sαb), ordinary area choropleth maps (Kγb), and quantitative area choropleth maps (Kγc(cs)). *Wirtualna Polska* uses only qualitative point symbols (Sαa), ordinary point symbols (Sαb), and qualitative line symbols (Sβa), while the Meteo Group employing the chorochromatic method (MCa) and ordinary point symbols (Sαb). *Twoja Pogoda* in turn uses qualitative point symbols (Sαa), ordinary point symbols (Sαb), the chorochromatic method (MCa), and qualitative line symbols (Sβa).

3.5.9 The State Forests Portals

Both State Forests portals employ only three cartographic methods of presentation – the chorochromatic method (MCa), qualitative point symbols (Sαa) and qualitative line symbols (Sβa). These are in line with the thematic scope of published maps.

This analysis of spatial data portrayal in official geoinformation services in Poland has demonstrated that, despite the technical and methodological possibilities available, most official Polish portals use a reduced number of presentation methods. Only meteorological portals employ combinations of qualitative, quantitative and ordinary-level methods. This kind of solution is limited by properties of visualized entities, their level of measurement, employed visualisation variables, as well as properties of cartographic presentation methods. According to Dukaczewski (2007a), despite these limitations it is possible to distinguish at least 191 correct combinations of methods *(Appendix 3.1)*.

3.6 Conclusion

The comparative analysis of the methods of spatial data portrayal used in official geoinformation services in Poland brings us to the conclusion that the level and intensity of its development are very diversified. The fastest and most innovative development is visible in the national cartographic geoportal, State Forests portals,

[6] e.g. for the velocity and direction of the wind

Natura 2000 portal, some regional-level portals (e.g. those of Mazowieckie, Zachodniopomorskie, Pomorskie and Podlaskie voivodships), and some geological portals (especially the Central Geological Database) and only a few city portals. Its comparison with other solutions applied across Europe reveals many similarities (concerning e.g. the thematic scope and scope of functions). However, it is still necessary to stimulate its development, especially when it comes to the employment of advanced spatial and spatio-temporal analyses.

Most of the layers published through the official geoinformation services are methodologically correct and characterised by satisfactory effectiveness of communication. However the list of employed methods, especially advanced solutions, is relatively short. In this situation, the appropriate solution is to intensify research on visualization, to make fuller use of the achievements of cartographic methodology and semiotics, and to stimulate research on 'use and use issues in cartography'.

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Tegtmeier W, Hack R (2007), The use of Geoportals in the Netherlands – the example of infrastructural developments, Proceedings of the New Engineering Geology Sources of Information Conference, Namur, October 9, 2007

Addresses of Quoted Portals

Polish National Geoportal http://geoportal.gov.pl/
Natura 2000 portal http://natura2000.mos.gov.pl/natura2000/

Geological portals
Central Geological Database http://baza.pgi.gov.pl/
MIDAS http://geoportal.pgi.gov.pl/portal/page/portal/MIDASGIS
Mineral Resources of Poland http://www.pgi.gov.pl/mineral_resources/
Hydro Bank http://www.pgi.gov.pl/hydro/
Underground Water Monitoring http://baza.pgi.gov.pl/psh/MapPage.aspx?language=
Geotops of Polish–Lithuanian border region http://baza.pgi.gov.pl/geotopy/

Meteorological portals
IMiGW Pogodynka Portal http://www.imgw.pl/index.php
http://pogoda.onet.pl/
http://pogoda.interia.pl/
http://pogoda.wp.pl/.?ticaid=174ca
http://www.meteogroup.pl/pl/home/pogoda/polska/pogoda_lokalna.html
http://www.twojapogoda.pl/

National Forests portals
Lasy Państwowe http://www.lp.gov.pl
Leśny Przewodnik Turystyczny http://lesnyprzewodnik.pl
Polish regional Voivodeship portals:
http://www.wrotapomorza.pl/
http://www.wrotamalopolski.pl/
http://www.um-zachodniopomorskie.pl/
http://www.lodzkie.pl/
http://www.wrotaopolszczyzny.pl/pl
http://www.silesia-region.pl/

http://www.mazovia.pl/
http://www.kujawsko-pomorskie.mw.gov.pl/
http://www.wrota-swietokrzyskie.pl/
http://www.podkarpackie.pl/
http://www.wrotapodlasia.pl/
http://www.dolnyslask.pl/
http://www.lubelskie.pl/
http;//wrota.warmia.mazury.pl/
http://www.wielkopolska.mw.gov.pl/
http://www.lubuskie.pl/

Foreign Regional portals
Rhine-Westfalen portal http://www.nrw.de
Rhine-Pfaltz portal http://www.rlp.de
Portal of Wales http://www.wales.gov.uk
Portal of Olomoucky Kraj http://www.kr-olomoucky.cz
Portal of Galicia http://www.xunta.es
Portal of Bourgogne http://www.bourgogne.fr

National park portals
Tatrzański www.tpn.pl; www.gis.tpn.pl
Babiogórski www.bgpn.pl
Bory Tucholskie park.borytucholskie.info
Wielkopolski www.wielkopolskipn.pl
Magurski www.magurskipn.pl
Karkonoski kpnmab.pl
Kampinoski kampinoski-pn.gov.pl
Poleski www.poleskipn.pl
Białowieski www.bpn.com.pl
Gorczański www.gorczanskipark.pl
Słowiński www.slowinskipn.pl
Biebrzański www.biebrza.org.pl
Ojcowski www.opn.pan.krakow.pl
Narwiański www.npn.pl
Bieszczadzki www.bdpn.pl
Gór Stołowych www.pngs.pulsar.net.pl
Wigierski www.wigry.win.pl
Drawieński www.dpn.pl
Świętokrzyski www.swietokrzyskipn.org.pl
Ujścia Warty www.pnujsciewarty.gov.pl
Woliński www.wolinpn.pl
Pieniński www.pieninypn.pl
Roztoczański www.roztoczanskipn.pl

Appendix 3.1

Evaluation of the combinations of cartographic presentation methods.

	Evaluation of the combination																						
Sαb	X																						
Kαb	ns	N																					
Kdαb	N	ns	C																				
Kc	X	N	X	X																			
Sαc	X	ns	N	X	X																		
Kαc (cs)	ns	N	C*	N	C*	N																	
Kdαc (cs)	N	ns	N	X	X	C*	X																
Sβb	X	C*	X	X	X	C*	X	X															
Kβb	X	N	X	N	ns	N	X	ns	X														
Kdβb	X	ns	X	X	X	C*	X	C	C***	X													
Ic	X	X	X	X	X	X	X	X	C***	X	X												
Sβa	X	X	X	X	X	C*	X	X	X	X	X	X											
Sβc	X	C*	X	X	X	C*	X	C	C***	X	X	X	X										
Kβc (cs)	X	N	X	N	ns	N	X	N	R?	C***	ns	X	C***	X									
Kdβc (cs)	X	C*	X	X	X	C*	X	C	C***	X	X	X	X	X	X								
KαBb	N	N	ns	N	N	N	N	N	N	N	C***	X	C***	N	C***	N							
Kγb	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	N	X****						
Kdγb	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	N	N	X****					
KαBc	ns	N	ns	N	N	N	N	N	N	N	C***	X	C***	N	C***	N	N	R?	N				
Kγc(cs)	X	C**	X	X	X	C*	X	X	X	X	X	X	X	X	X	N	N	N	R?	X****			
KDγc(cs)	X	C**	X	X	X	C*	X	X	X	X	X	X	X	X	X	N	N	N	?S	N	X****		
Sαa	X	C*	X	X	X	C*	X	X	X	X	X	X	X	C***	X	N	X	X	N	X	X	X	
MCa	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	?S	N	N	N	N	N	X	N	
MZa	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X***	X***	X***	X***	X	X	X	X	X
Methods	Sαb	Kαb	Kdαb	Kc	Sαc	Kαc (cs)	Kdαc (cs)	Sβb	Kβb	Kdβb	Ic	Sβa	Sβc	Kβc (cs)	Kdβc (cs)	KαBb	Kγb	KDγb	KαBc	Kγc(cs)	Kdγc(cs)	Sαa	MCa	MZa

Cartographic methods

Sαb – Ordinary point signatures,
Kαb – Ordinary point choropleth maps,
Kdαb – Ordinary point cartodiagrams
Kc – Dot method,
Sαc – Quantitative point signatures,
Kαc (cs) – Quantitative point choropleth maps,
Kdαc (cs) - Quantitative point cartodiagrams,
Sβb – Ordinary line signatures,
Kβb – Ordinary line choropleth maps,
Kdβb - Ordinary line cartodiagrams
Ic – isoline maps,
Sβa – Qualitative line signatures,
Sβc – Quantitative line signatures,
Kβc (cs) - Quantitative line choropleth maps,
Kdβc (cs) - Quantitative line cartodiagrams
KαBb – Ordinary Bertin's choropleth map,
Kγb – Ordinary area choropleth maps,
Kdγb – Ordinary dasimetric choropleth maps,
KαBc - Quantitative Bertin's choropleth map,
Kγc(cs) - Quantitative area choropleth maps,
Kdγc(cs) - Quantitative dasimetric choropleth maps,
Sαa – Qualitative point signatures
MCa – Chorochromatic method maps,
MZa – Range maps

Solutions

X	correct
ns	not practiced, or sporadically practiced
C	conditional
R?	sporadicaly practiced, but doubtful
?S	practiced, but doubtful
N	incorrect

* In the case of geometric dot choropleth maps

** Only in the case of non continuus choropleth maps

*** Only when one of the method is used like a element of base map

**** Only in the case of cross choropleth maps and chorochromatic maps

Chapter 4

Compilation of Digital Elevation Model for Turkey in 3-Arc-Second Resolution by Using SRTM Data Supported with Local Elevation Data

I. Oztug Bildirici[1], Aydin Ustun[1], Necla Ulugtekin[2], H. Zahit Selvi[1], R. Alpay Abbak[1], Ilkay Bugdayci[1] and A. Ozgur Dogru[2]

[1] Dept. of Geodesy & Photogrammetry, Selcuk University, Turkey
iobildirici@yahoo.com, {austun, hzselvi, aabbak, iatasoy}@selcuk.edu.tr

[2] Dept. of Geodesy & Photogrammetry, Istanbul Technical University, Turkey
{ulugtek, ozgur.dogru}@itu.edu.tr

Abstract

In February 2000, the Space Shuttle Endeavour of the “Shuttle Radar Topography Mission” (SRTM) launched by NASA collected elevation data by scanning the earth landmasses between ~60º north and south parallels. After this 11 days mission, the collected data were processed, and a Digital Elevation Model (DEM) at 1-arc-second – and also 3-arc-second – resolution was created. SRTM DEM contains data voids because of several disturbing effects. The proportion of data voids in Turkey (0.17% for second corrected version) is approximately same as the global proportion (0.15%). The data voids are the most important obstacles for efficient use of the data. DEMs with high resolution are important data sources for all disciplines in geosciences. Since collecting such data and creating DEM are both time consuming and expensive processes, many scientists have been studied on filling these voids in a reliable way. The aim of this paper is to present the results of a project, which aims to validate the SRTM within Turkish territory, and to create a DEM based on the SRTM data covering the same area without data voids. The validation of SRTM was performed using following ground truth data sets: topographic maps (25K maps) and DGPS tracks. The executed statistical analysis for accuracy assessment of SRTM within Turkish territory gives the results consistent with those of global analyses performed by several researchers. The voids are visually classified as the clustering and the scattered voids. The clustering voids were filled with a local

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data source. For this purpose the 1:25000 scaled national topographic map set (25K maps) was used. The scattered voids were filled with interpolation. As a result of the project, which was completed in September 2008, a complete DEM of Turkey at 3-arc-second resolution has been created and published via Internet for the use of researchers and professionals in geosciences.

Keywords: Digital Elevation Model, SRTM, Turkey, Topographic Maps, Topography, Accuracy Assessment

4.1 Introduction

The topographic models of the Earth land masses have been considered essential in a variety of geospatial applications such as mapping, hydrology, geology, navigation, Geographic Information Systems (GIS), mission planning, simulation, etc. To capture such data, especially for large-scale mapping applications, imaging techniques based on air- or space-borne methods are required. A Digital Elevation Model (as a form of the Digital Terrain Model) is such a model commonly obtained from raster images. In 2000, the Shuttle Radar Topography Mission (SRTM), spearheaded by the U.S. National Geospatial-Intelligence Agency (NGA) and the U.S. National Aeronautics and Space Administration (NASA), produced the most complete high-resolution digital topographic database of the majority of the landmasses of the Earth to date (NASA 2007a, Farr et al. 2007). The radar images were acquired by the Space Shuttle Endeavour equipped with two radar antennas at the end points of a baseline 60 meters in length. This technique is known as Interferometric Synthetic Aperture Radar (IfSAR or InSAR) that produces topographic (elevation) data derived from the phase difference of the radar images (Burgmann et al. 2000). The horizontal datum of the SRTM data is the WGS84, while the topographic heights are referred to the EGM96 geoid, which approximately coincides with mean sea level.

SRTM data sets at 3 and 30 arc-second resolution for all land portions between the latitudes of ~60° in the northern and southern hemispheres are freely distributed via the Seamless Data Distribution System (SDDS) of the USGS (USGS, 2007) and the Land Processes Distributed Active Archive Center (LP-DAAC) of the NASA (NASA 2007a and b). The original data set at 1 arc-second resolution has only been released for the US territory. The 3 arc-second data have been generated from 1 arc-second data by sub-sampling and averaging. The data set available at SDDS is sub-sampled where each 3 arc-second data point is generated by selecting the center sample of the 3x3 array of one arc-second points surrounding the post location. The data set available at LP-DAAC is averaged where each point is the average of the nine 1 arc-second samples surrounding the post. This data set, which was used in this study, is distributed in tiles sizes of 1x1°, the file format is SRTM or "hgt". *Table 4.1* gives a summary about publicly available SRTM data sets (NASA, 2007b).

Although some areas with missing height data (voids) are still present, the second version, also known as the "finished" version, has been available since 2006. This version is the result of a substantial editing effort by the NGA, and exhibits well-defined water bodies and coastlines and the absence of spikes and wells, i.e. single pixel errors (NASA, 2007b).

A project supported by the Scientific & Technological Research Council of Turkey (TUBITAK) was initiated in 2006 that aims to validate the SRTM data, and to compile a complete digital elevation model of Turkey based on this data at 3 arc-second resolution (Bildirici et al. 2007a). To date, comparisons were performed to validate the accuracy of SRTM heights – within Turkish territory – using GPS tracks collected by cars and 25K maps. Thereafter, the SRTM data was checked against data voids, and clustering and scattered ones were distinguished. The former were filled with help of 25K topographic maps and the latter by interpolation techniques (Bildirici et al. 2007b).

Table 4.1. SRTM data availability

	SDDS	LP DAAC
Version 1		1" U.S. 3" world – averaged 30" world – averaged Format: SRTM
Version 2	1" U.S. 3" world – sub-sampled Formats: ArcGrid, Bil, TIFF, GridFloat	1" U.S. 3" world – averaged 30" world – averaged Format: SRTM

4.2 The Status of the SRTM Data Covering Turkish Territory

4.2.1 Data Voids

The Turkish territory covers or intersects 112 tiles size of 1º×1º in the SRTM data. Ustun et al. (2006) analyzed the SRTM version 1 data and determined that the proportion of the void data was much higher than the global proportion. In version 1, the void data is mostly clustered around water bodies, and mountainous areas. The voids around water bodies were mostly edited and corrected in the SRTM version 2. Bildirici et al. (2007b) examined this version in a similar manner. They found that the quantity of void data was about 0.17%, which is near the global level. In version 2, it is also observed that the points with void heights remain in the mountainous

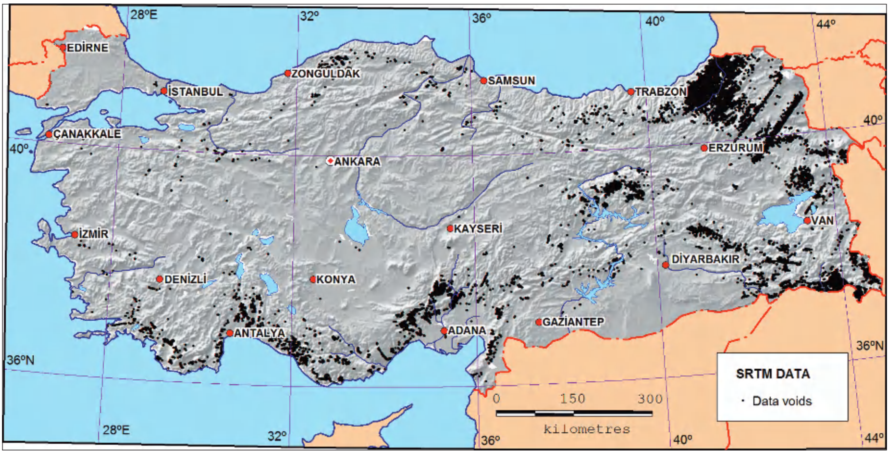

Fig. 4.1. Distribution of data voids

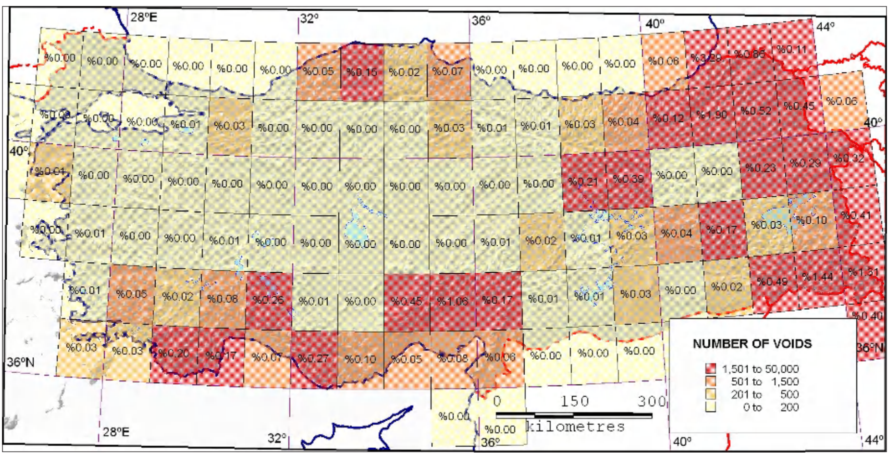

Fig. 4.2. Data voids per tile

regions in the northeast and southeast of the country, which can be seen in *Figure 4.2*. Another analysis of the data voids, at the global level, can be found in Hall et al. (2005), and Rodriguez et al. (2005). Reuter et al (2007) analyzed and classified data voids in order to determine the most appropriate interpolation method.

4.2.2 SRTM Validation

SRTM data products were validated on the continental scale by using long tracks of GPS, at an accuracy under 1 m (Farr et al 2007, Rodriguez et al 2005). Rodriguez et al (2005) attained 90th percentage of errors under 10 m, which is less than 16m, the targeted error of the SRTM *(Table 4.2)*.

Table 4.2. Summary of SRTM validation. All quantities represent 90% errors in meters (Rodriguez et al., 2005)

Error Type	Africa	Australia	Eurasia	Islands	N. America	S. America
Absolute Geolocation Error	11.9	7.2	8.8	9.0	12.6	9.0
Absolute Height Error	5.6	6.0	6.2	8.0	9.0	6.2
Relative Height Error	9.8	4.7	8.7	6.2	7.0	5.5
Long Wavelength Height Error	3.1	6.0	2.6	3.7	4.0	4.9

In this study, the validation of the SRTM within Turkish territory was performed against two types of data as ground truth: DGPS tracks and topographic maps scale of 1:25000 (25K maps). The tracks along roads crisscrossing the country were collected with the DGPS receiver CSI Wireless Minimax, positional accuracy being less than 1 m. According to the mapping agency, General Command of Mapping (HGK), the vertical error of 25K maps has been given as 2.5 m, the horizontal error as 5 m (HGK, 2008). Since both data sets are more accurate than the SRTM data, they can be used as ground truth for the SRTM validation.

The DGPS tracks and test areas (25K map data) are shown in *Figure 4.3*. The tracks crisscross the territory; while the 25K test areas are so distributed that many topographic features of the country will be represented. In the test areas of 25K maps, there is no void data.

4.2.2.1 Methodology

For the SRTM validation following methodology was used. For every point of the ground truth data set, the SRTM height should be calculated, which can be estimated by interpolation. The height differences are calculated,

$$dH = H_{SRTM} - H_{GT} \tag{4.1}$$

where H_{SRTM} denotes the SRTM height, H_{GT} the ground truth height. The root mean square error (RMSE) between the SRTM DEM and the ground truth heights is used to measure the accuracy of the SRTM DEM:

$$RMSE = \sqrt{\frac{\sum dH^2}{N}} \tag{4.2}$$

Alternatively, in order to show the variability of the measurements from the mean, the standard deviation that implies the index of precision of the model,

$$\sigma = \sqrt{\frac{\sum (d - \overline{dH})^2}{N}} \tag{4.3}$$

is calculated, where the mean

$$\overline{dH} = \frac{\sum dH}{N} \tag{4.4}$$

is a residual mean that describes the bias between the reference surfaces of the SRTM-DEM and the 25K-DEM. Since the differences are signed (negative and positive values), the bias – the possible shift in height between the ground truth data and the SRTM data – can be determined. Another meaningful measure is the 90th percentile of absolute errors (absolute height differences), denoted with *AE*, showing that the 90% of the absolute errors do not exceed this value. *AE* is commonly used in similar studies, e.g. Rodriguez et al (2005). Additionally the median of the height differences is also computed, which is – in terms of blunders – more reliable than the mean.

For these comparisons, a computer program was developed in C running under the LINUX environment. The program uses the "hgt" files (native SRTM format) directly. The ground truth data are taken from text files.

4.2.2.2 Validation with DGPS Data

For the validation of SRTM data DGPS data along roads by car were collected. For this purpose NMEA messages from the receiver were recorded and analyzed. Only valid DGPS points with acceptable positional accuracy were extracted from NMEA messages. Acceptable accuracy was determined by using several parameters, such as number of satellites in use, current DGPS accuracy, PDOP, HDOP, VDOP, etc.

The DGPS device used here is tested in a small area. With respect to the bench-marks with known coordinates, the horizontal and vertical accuracy are below 1m, and 1.5m respectively.

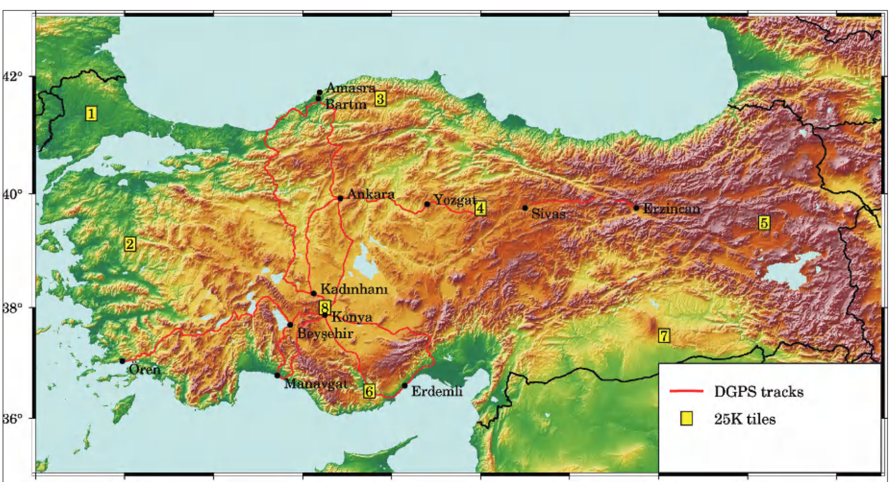

Fig. 4.3. Ground truth data for SRTM validation: DGPS tracks and test areas of 25K maps

For every valid point on the tracks, four surrounding grid points in the SRTM data were found, and the SRTM height for this point was computed by IDW (Inverse Distance Weighting) Interpolation. Doing so, all height differences (*dH*) were computed for statistical evaluation. The test points that depart from the SRTM surface more than 35 m were considered to be over or under the natural topographic surface (e.g. points on the bridges, viaducts etc.), and excluded from the statistical evaluation.

Starting from Konya, 9 tracks crisscrossing the country were measured. Total length is 3670 km. The tracks are distributed in north-south and east-west directions, and cover areas with different topographic characters. The location of the tracks can be seen in *Figure 4.3.* A summary of track characteristics is given in *Table 4.3.* In *Table 4.4,* the results of the statistical evaluation can be seen.

Considering the mean and median values, there are differences between them about 1 m. So it can be concluded that the SRTM DEM surface is about 2–3 m higher than the actual topographic surface. The possible reason is the vegetation of the area.

With the other measures in *Table 4.4* the possible accuracy of heights that are taken from the SRTM DEM can be judged. The RMSE and standard deviation values are about 5 m. The AE is a meaningful measure for validation of SRTM, which vary from 3.7 m to 13.1 m; the value for the whole tracks is 9.2 m. All are under the target error of the SRTM project, 16 m.

One of the results of the statistical evaluation is the dependence of accuracy on the topography. In the rough and rugged areas the statistical measures increase whereas they decrease in flat areas. In this context the tracks 9 and 4 (from Pozanti to Amasra) were analyzed, and a diagram was created *(Figure 4.4)*. From the diagram the correlation between topography and height differences (*dH*) can easily be recognized.

4.2.2.3 Validation with 25K Topographic Maps

Since the DGPS tracks are linear in character and collected along roads, they can depart from the actual topographic surface significantly. Another way to validate the SRTM data is to use topographical maps – the areal data. For this purpose, eight test areas distributed in the territory of Turkey were selected. Each test area consists of four 25K map sheets, being 15x15 arc-minutes in size. The standard contour interval in these sheets is 10 m.

The digitized contour lines of these maps are available at GCM. These data have been delivered in common CAD file formats in the desired datum and coordinate system. Before the comparison, a point thinning algorithm should be applied to 25K-data vectors, because the point density on the digitized contour lines is too high (approximately 10 m of intervals on the contour lines). In this research, those

Table 4.3. Characteristics of DGPS tracks

Track Number	Track	Length (km)	Number of point	Terrain slope
1	Bartin-Kadinhani	680	16390	2.6
2	Beyşehir-Ören	530	12357	3.0
3	Erzincan-Sivas	230	5447	2.2
4	Konya-Amasra	600	13130	2.2
5	Konya-Erdemli	320	7297	2.0
6	Konya-Manavgat	270	6400	3.0
7	Konya-Yozgat	580	14534	1.5
8	Manavgat-Konya	220	5028	3.2
9	Pozanti-Konya	240	6434	0.7
Total		3670	87017	2.3

Table 4.4. The results of the comparison of SRTM with DGPS data (units: m)

Track number	Median	Mean	RMSE	Std. dev.	AE (90%)
1	1.6	2.8	6.4	5.8	9.7
2	1.6	2.4	5.8	5.2	8.9
3	4.8	6.3	8.1	5.2	13.1
4	1.9	2.7	5.6	4.9	8.8
5	1.5	2.5	4.8	4.1	7.7
6	2.4	3.8	7.3	6.3	11.9
7	3.2	3.4	5.5	4.3	8.4
8	2.3	2.9	6.7	6.1	10.6
9	-0.9	-0.6	2.8	2.7	3.7
Total	2.0	2.8	5.9	5.2	9.2

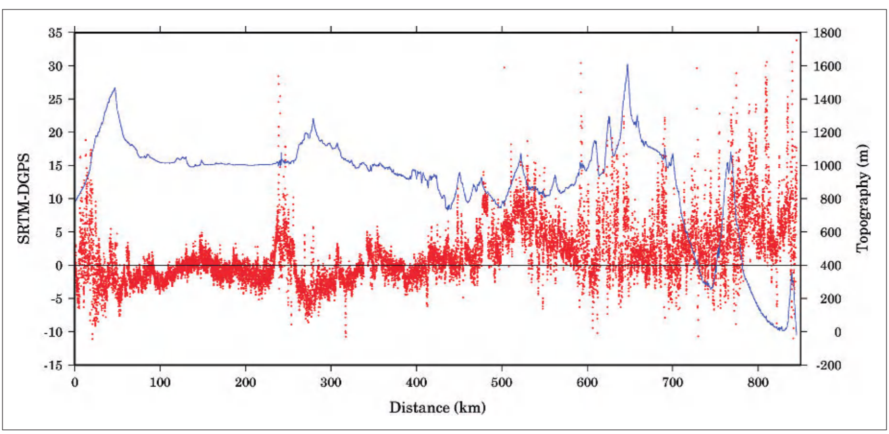

Fig. 4.4. The relationship between topography and SRTM accuracy

points that are closer than 25 m (1 mm on the map sheet) to the next point were eliminated.

The comparison can be undertaken in two ways:

Method A: For each point on the contours of the 25K data set, the SRTM height is calculated. In this method four surrounding SRTM grid points are found, the SRTM height is interpolated using the surrounding points (H_{SRTM}). Similar to the comparison with DGPS data the IDW method (Inverse Distance Weighting) is used. The original height (ground truth) is denoted with H_{GT}.

Method B: Another way to make the comparison is to create a grid file (25K DEM) having the same structure as the SRTM (3 arc-second resolution). The 25K DEM files were created with the GMT software package (Generic Mapping Tools, 2007). The algorithm implemented in this software is "gridding with continuous curvature splines in tension" (Smith and Wessel 1990). Since the structure is the same for every grid point, the SRTM height (H_{SRTM}) and the height from 25K DEM (H_{GT}) can be compared directly.

Regardless of which method is used, there are two data sets available for the comparison: The heights from the 25K maps-considered as ground truth- and the SRTM heights. The statistical evaluation explained above was applied for both of the methods.

The results of the statistical evaluation with method A are shown on *Table 4.5.* These are the results of the comparison of approximately 1 850 000 test points. The point density changes with the topography, because test points were the points on the contour lines. Since the blunders are not expected in this data set, all points were taken into consideration. In the test areas 3 and 4, the departure of the mean and the median values from zero was significant. This is the evidence of a height shift about 5 m between the SRTM DEM and 25K DEM. The possible reason is the vegetation, because these areas are partially forested. In the other test areas the mean and median values are converging to zero. The values of RMSE and standard deviation were less than 10 m. All the AE values were less than 15 m. So, it can be said that the SRTM performance in the territory of Turkey was as good as expected.

The results with the method B are similar to those of the method A. In this test approximately 725 000 test points were used, and all points were taken into statistical evaluation. The height shift in the test areas 3 and 4 was recognized again. The RMSE, standard deviation and AE values are similar.

The dependence of the SRTM accuracy on the topography can also be recognized in these tests. The authors give a more detailed analysis in previous works (Bildirici et al. 2008a, Bildirici et al. 2008b). Bildirici et al. (2008b) deals with the method B and gives maps of the spatial distribution of the height differences (*dH*) for all test areas. They also performed a correlation analysis and found a strong correlation between the accuracy and the topography.

Table 4.5. The results of the comparison of SRTM with 25K map data (Method A)

Test area	# of point	min	max	Median	Mean	RMSE	Std. dev.	AE (90%)
1	92463	-23.1	15.9	-0.8	-0.7	3.1	3.0	4.8
2	361911	-67.0	68.1	1.1	1.4	8.8	8.7	14.1
3	196392	-32.4	45.3	5.0	5.4	8.7	6.9	14.1
4	315530	-33.1	48.6	4.4	5.2	9.4	7.9	15.5
5	229205	-41.6	34.6	0.3	0.3	6.4	6.4	10.2
6	344009	-60.7	67.3	1.4	1.7	9.2	9.1	15.0
7	152355	-34.1	36.6	-0.1	-0.2	5.8	5.8	9.3
8	155344	-54.2	33.9	0.8	0.5	7.4	7.4	12.0
Total	1847209	-67.0	68.1	1.6	2.1	8.2	7.9	13.3

Table 4.6. The results of the comparison of SRTM with 25K map data (Method B)

Test area	# of point	min	max	Median	Mean	RMSE	Std. dev.	AE (90%)
1	90601	-22.6	17.6	-0.7	-0.7	3.0	2.9	4.7
2	90601	-67.3	74.4	0.3	0.5	9.7	9.7	15.6
3	90601	-40.6	48.1	5.0	5.4	8.5	6.6	13.4
4	90601	-37.8	48.6	3.4	4.1	10.5	9.6	17.2
5	90601	-62.2	41.0	0.8	0.7	6.5	6.5	9.7
6	90601	-63.6	57.5	1.1	1.0	10.1	10.1	16.4
7	90601	-50.7	44.9	0.7	0.3	6.4	6.4	9.1
8	90601	-51.0	41.0	2.4	2.4	6.4	5.9	10.0
Total	724808	-67.3	74.4	1.4	1.7	8.0	7.8	12.9

4.3 Compilation of the Turkish Digital Elevation Model with 3 Arc-Second Resolution

The second goal of the project is to compile a DEM at 3 arc-second resolution for the whole country without any void heights. The basis for such a DEM is the SRTM DEM. If the voids are properly filled, such a DEM will be available. For void filling two approaches were used. By visual inspection, the void data was divided into clustering and scattered voids. The clustering voids were filled by using 25K topographic maps. The scattered voids were filled with interpolation.

4.3.1 Analysis of Voids

In order to determine which voids are clustering and which are scattered, all 25K map frames containing more than 100 voids (1244 sheets) were visually inspected.

340 sheets containing clusters of voids were decided to be used for void filling. The remaining voids were considered scattered in character, which were decided to be filled by means of interpolation. The void filling with 25K maps precedes the void filling with interpolation. Doing so, the heights that are captured from 25K maps can be used in the interpolation.

4.3.2 Void Filling with 25K Topographic Maps

The 25K map sheets selected for void filling were scanned and registered. The void data were extracted from the SRTM data and overlaid on maps. Then, the contour lines covering the clusters of void points were digitized and partial DEMs based on the contour lines were formed. The heights of void points were interpolated from these partial DEMs. Finally these heights were added to the first version of Turkish DEM at 3 arc-seconds (TDEM3).

4.3.3 Void Filling by Means of Interpolation

After the clustering voids had been filled with help of 25K maps, the remaining ones were filled by interpolation. For the interpolation multiquadric interpolation technique (MQ) is selected, in which a surface passing through known points are used to interpolate the heights of unknown points; void data (for more details see Amidror 2002). Since all valid points in the SRTM DEM cannot be used for the determination of MQ surface, moving windows are defined. In this approach, there are two windows; an internal window size of 60x60 arc-second and an external window size of 90x90 arc-second around the other. The points with heights within the external window are the control points for interpolation, while the heights of void points within the internal window are to be interpolated. These windows were moved within the territory of Turkey. The external windows are overlapping the others around, the internal windows not *(Figure 4.5)*.

For this purpose a computer program was developed, which processes one window. With help of a GIS system (MapInfo), the centers of all windows being within the Turkish territory were determined and listed in a file. With help of a script the interpolation program processed every window listed in this file. After this long process the second and the final version of the TDEM 3 was completed.

4.3.4 The Resulting DEM

After the void filling process the heights of approximately 250 000 points were determined, and a DEM covering the Turkish territory –TDEM 3- and contains no

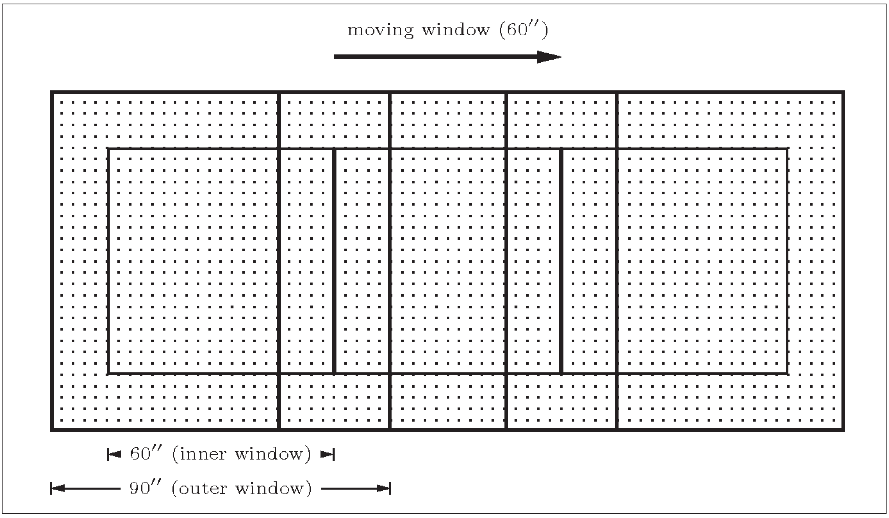

Fig. 4.5. The moving window approach for the interpolation.

void data was compiled. This DEM has been published via Internet (www.tsym3.selcuk.edu.tr).

4.4 Conclusion

SRTM, an international research project to create “the most complete DEM of the Earth”, was a starting point in mapping the Earth surface at the global level. The project was conducted by the NGA, NASA, and the German and Italian Space Agencies. Digital elevation data on a near-global scale was obtained by processing interferometric radar images taken by two radar antennas. This study presented the results of a project that aims to validate the SRTM data within Turkish territory and to compile a DEM without voids. Void data are filled with help of 25K topographic maps and by means of interpolation.

The analysis for validation of SRTM shows that the values for the 90^{th} percentile of errors are less than the targeted project error of 16 m. Some height shifts in forested areas were observed. This is not surprising because the SRTM data are influenced by vegetation.

After void filling a complete DEM called TDEM 3 model was compiled. The TDEM 3 is in the SRTM file format, organized in the same tile structure. The void filling is performed within the territory, so there are remaining voids located outside the territory in some tiles of the TDEM 3. The TDEM 3 has been shared with interested users in such a DEM via Internet (www.tsym3.selcuk.edu.tr).

Based on our experiences, the methodology proposed here can be used in any part of the earth, where percentage of the voids are under 1% per tile; and a complete SRTM DEM can be created.

Acknowledgement

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Chapter 5

Mapping Land Cover with Commercial and Freeware Image Classification Software – An Example from Bavaria, Germany

Lucia Ďurisová and Hartmut Asche

Department of Geography, University of Potsdam, Germany
{durisova, gislab}@uni-potsdam.de

Abstract

This paper deals with mapping object-oriented land cover classification of digital remote sensing imagery. It is a new method of automated interpretation of remote sensing imagery. In its time the EU land cover project CORINE targeted the generation and dissemination of quality information about land cover in Europe. By now the existing data sets require updating and revision. Visual interpretation of the landscape is time-consuming. That is why fresh efforts are required to automate the interpretation process. To perform the necessary update of the land cover data set, it is important that image classification does not exceed a tolerable amount of time. Computer-based object-oriented classification is faster than visual interpretation of a human operator. Object-oriented classification is an automated process, interactive correction is, however, required to yield results comparable to visual image interpretation. Land cover maps created using this method present geo objects close to reality on the ground. In the research presented, the mapping of land cover has been performed based on high resolution digital orthophotos of the German HRSC sensor. The area of interest is located in Bavaria, in the south of Germany, on the northern fringes of the Alps in the Murnau-Staffelsee area. The method applied is compared in a commercial and a freeware environment: eCognition/Definiens vs. Spring. The classifications have been evaluated for accuracy both visually and statistically. This paper presents a cutout of the land cover map produced including legend and discusses the potentials and limitations of the software systems used.

Keywords: land cover, remote sensing imagery, object-oriented classification, mapping

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5.1 Introduction

Interpretation is one of the primary objectives of remote sensing, besides creating and processing image records. One of the oldest interpretation methods is visual interpretation of the landscape picture. This method is time-consuming because the interpretation is carried out by a human interpreter. Hence, new methods are developed seeking to automate and standardise the interpretation process. Because of the bulk of data to be processed it is essential to reduce processing time which occupies the time of the interpreter. The rapid spread of digital technology, in part, already led to the replacement of a human interpreter by (micro) computer systems. To complement visual interpretation a number of pixel-based image processing methods have been developed – collectively known as classifications. While classification have successfully reduced image processing time and standarised image interpretation they have, however, not been able to eliminate one major disadvantage of software-based classification. Computer-based classification does not reach the quality of results achieved by human visual interpretation. The reason is simple: the human eye and brain sense the landscape as a system of objects, not pixels.

As a consequence, numerous efforts have been made both in a scientific community and the remote sensing software industry to partially automate object-oriented classification in order to arrive at automated interpretation results matching the quality of visual interpretation in a fraction of time. In particular, pixel-based methods of image processing known as classification have been developed to supplement visual interpretation. All of these methods share a basic principle: substitution of the human interpreter by a computer-based software system. Among them object-oriented classification methods prove to be specifically suitable to process high-resolution remote sensing data.

Segmentation and classification can be considered the essence of an object-oriented classification. Multi-stage segmentation results in objects, or segments, which contain information about their neighbours and also about so called superobjects and subobjects. Every segment provides information on relations with other objects and specifies such properties as shape and texture of an object and other properties depending on the respective thematic layer. Segmentation, the results of which highly depend on an operator and the settings of various parameters, is followed by the creation of a hierarchical class system. This system can be generated according to various criteria, such as nearest neighbour classificator, standard nearest neighbour classificator or texture properties of an image. Classification of an image essentially connects classes generated with image objects. It is dependent on previous segmentation. The aim of this paper is to evaluate object-oriented classification of a high-resolution digital orthophoto acquired by a digital camera sensor (HRSC).[1]

[1] The High Resolution Stereo Camera (HRSC) is a digital sensor developed by the German

5.2 Mapping Land Cover with Commercial and Freeware Image Classification Software

Many authors have dealt with interpretation and classification, therefore various definitions can be found in various academic publications. Well known is definition by Laurini & Thompson (1994) who describe classification as a process of arranging single occurrences of monitored phenomenon into categories, which are created pursuant to chosen attributes or functions. Likewise Brown (1998) defines classification as a mode of attribute generalization or a process of combination of various features into classes and types.

5.2.1 Image Interpretation

Interpretation is one of the fundamental analytical tools for implementation of a ranked system into quantitative geographical data. However, one should not forget that arranging initial data into classes significantly reduces their information content. That is why the natural structure of data has to be considered in order not to corrupt them further. Instead classification should clarify the internal set-up of data we evaluate (Hlásny 2007). According to Žihlavník, image interpretation is divided to visual, half-automated and automated interpretation (Žihlavník & Scheer 2001).

Visual interpretation uses such interpreting characteristics as colour, tone, resolution, structure, texture of an image, size and shape of an object. It is objective only to a certain degree. Because of his/her predisposition each interpreter will arrive at different results although using identical object categories, and interpreting the same area. It is important therefore to establish and adhere to rules of interpretation, so that the results are comparable. Output data are related to a system of classification categories defined prior to interpretation. It is essential to define to categories that are related to as many geo objects as possible in order to facilitate the generation of proper land use maps.

Semi-automated interpretation, as can be inferred from the name, is an interpretation method where some phases are automatically executed and others, necessarily, by an interpreter. For example, data needed are entered into a computer, the process selected is executed and the results are evaluated by an expert human eye. In comparison, automated interpretation is, in fact, image classification. Classification can either be pixel-oriented (pixel: the minimum image element) or object-oriented. Subtypes of pixel-oriented classifications are the so called supervised and unsupervised classification. Hybrid classification is a combination of the two subtypes.

Aerospace Center (DLR) for planertary and terrestrial imaging (cf. 5.2.2). The authors gratefully acknowledge the provision of the HRSC Murnau-Staffelsee image used here by DLR.

In this paper standard techniques of image interpretation will not be elaborated because the focus is on object-oriented classification of a digital image.

5.2.2 Material and Methods

The investigation area, which was used for verification of applied methods, is situated in the pre-alpine region of Germany, specifically in the south of Bavaria, in the surroundings of Murnau am Staffelsee towns and villages *(Figure 5.1)*. An Area of 27x6 km was sensed on the 12th and 13th of August 2003 from an altitude of 3500 m by the HRSC sensor. Sensing was recorded in 3 channels of the visible spectrum – red, green and blue (RGB).

Final digital orthophotos had 12 bit radiometric resolution and 0.20 m spatial resolution. Simultaneously HRSC created a digital surface model of 16 bit radiometric resolution and 0.20 m spatial resolution. Area of 420 km^2 was subject to classification in both environments. A small section was selected as an object-lesson. For the purpose of research presented in this paper a test area of 3,780 x 6,000 km was chosen which represented predominantly agricultural territory. The section is situated in the surroundings of Großweil village and depicts meanders of Loisach river in the neighborhood of A95 motorway *(Figures 5.1* and *5.3)*.

The High Resolution Digital Stereo camera (HRSC) was developed in 1996 in the Institute for planetary research of the German Aerospace Center (DLR) at Berlin-Adlershof for a European space mission to map the Mars surface. When this mission failed the surviving camera was adjusted to acquire terrestrial remote sensing data from an airplane. Mounting the HRSC sensor in an airplane like a stan-

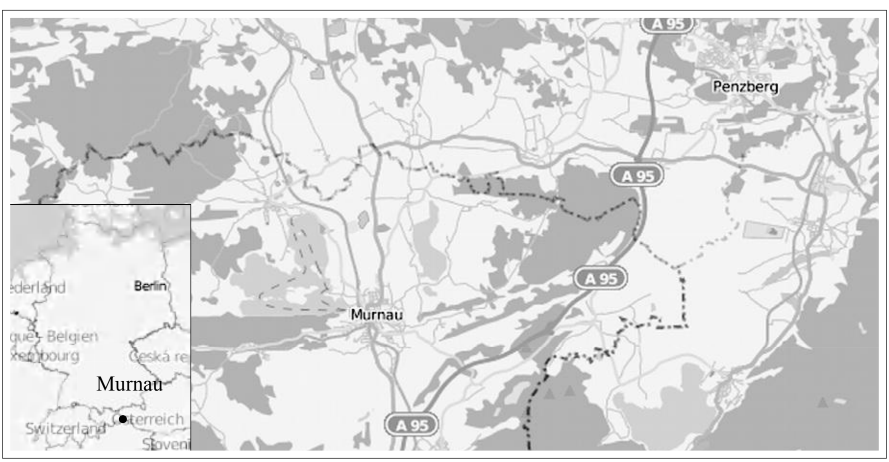

Fig. 5.1. Location of analyzed region: Murnau-Staffelsee area, Germany. Source: OpenStreetMap, http://www.openstreetmap.com/

dard analog aerial camera yields digital imagery with stereoscopic overlap that is utilized in photogrammetry. From this imagery orthophotos are generated using additional geographic information from the DGPS and INS sensors (location and rotation of projecting center) implemented in a digital camera as well as from a digital surface model simultaneously acquired. Automated processing is used as much as possible during the interpretation (Centrum DLR 2007).

The study area selected from the Murnau-Staffelsee orthophoto has been processed by selecting an object-oriented classification method in the eCognition/ Definiens software environment. The (object-oriented) classification consists of a number of steps detailed in the following. First it is essential to create a project and import raster data (i.e. in our case a digital orthophoto). Second comes the most important step – multi-level segmentation. In this process, objects or segments, respectively, are created which carry information on their neighbours, superobjects and subobjects *(Figure 5.4)*. Each segment incorporates information about its relation to other objects, a description of properties, such as shape and texture of an object, and others which depend on thematic layer. Segmentation heavily depends on the operator and settings of several parameters *(Figure 5.2)*. The third step is the definition of a ranked classification system. Its hierarchy can be created to various criteria. In this project we used the standard nearest neighbour classifier (SNN). To do so a set of well-defined, representative training segments are selected from the data set by the human interpreter (UGE 2000, UGD 2006). To address the textural properties of the digital image the "Texture after Haralick" procedure has been implemented. Once data have been input into the system the classification automatically assigns classified objects to reference objects of the training segments. This method allows for better arrangement of categories in multispectral space of RGB channels.

The system of classification categories defined can only be applied to data sets after it underwent an interactive process of defining and discarding training sets, creating, editing and revising categories. Following is the classification of an image by which classifying categories are linked with image objects. On the one hand

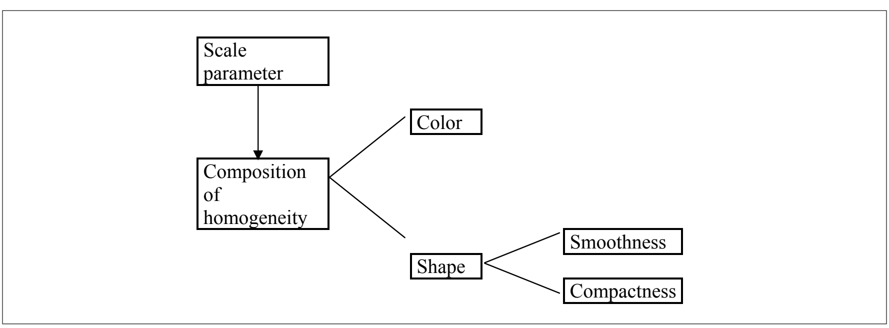

Fig. 5.2. Input parameters for segmentation (UGD 2006)

using the SNN classifier including texture properties greatly improves classification results; on the other hand it considerably extends computing time. Classification thus heavily depends on previous segmentation that has to be performed very precisely and carefully. The final step is the export of raster and vector layers created that represent classified categories of objects.

Spring is a product of Brazil's National Institute for Space Research (INPE/DPI) (Image Processing Division). Spring is a GIS and remote sensing image processing system with an object-oriented data model which provides for the integration of raster and vector data representations in a single environment (UGS 2008). In this freeware is first step defining the project. This consists of creating a database in DBase format, creating a project, setting a coordination system, projection and name of a project, and defining data model. In a data model we have to define the types of data, i.e. digital terrain model, orthophotos or thematic layers. Thematic layers are important to create a classification hierarchy for a supervised classification. Segmentation depends on settings of Similarity parameter (corresponds with scale parameter in eCognition) and Area parameter. During the classification a context file was created, which contains informations which orthophoto will be classified and whether the classification will be pixel or area-based. Since we were dealing with object-oriented classification, we chose area-based classification.

While performing an unsupervised classification with Spring freeware it emerged that an inadequate maximal number of categories were created. Forest areas (woods), e.g., were classified as water bodies in most cases. Areas of arable soil prior to harvest were classified as grassland. This is caused by the fact that the Spring classification only uses spectral information (data). It is not possible to distill information about texture, superobjects and subobjects into both types of classification. As a result the final image is less corresponding to reality.

5.2.3 Results and Discussion

In our project we classified data based on natural hierarchical categories. We used the hierarchical structure of CORINE Land Cover which had been designed to map a land cover from remote sensing records and was adjusted according to specifics of our processed area for the purpose of our project *(Figures 5.5 and 5.6).*

When compared to conventional pixel-oriented methods, the advantages of object-oriented classification can be highlighted: First, the complete process is a much better approximation to that of human interpretation and perception by the human brain. A second important fact is that we can use object attributes, for example shape. The result of our experiment is in line with Neubert's statement (Neubert 2004) that the so called salt-pepper effect (an effect of scattered pixels) is suppressed by using object-oriented classification. Pixel-oriented classification

Fig. 5.3. Detail of HRSC orthophoto before classification

Fig. 5.4. Detail of HRSC orthophoto after segmentation

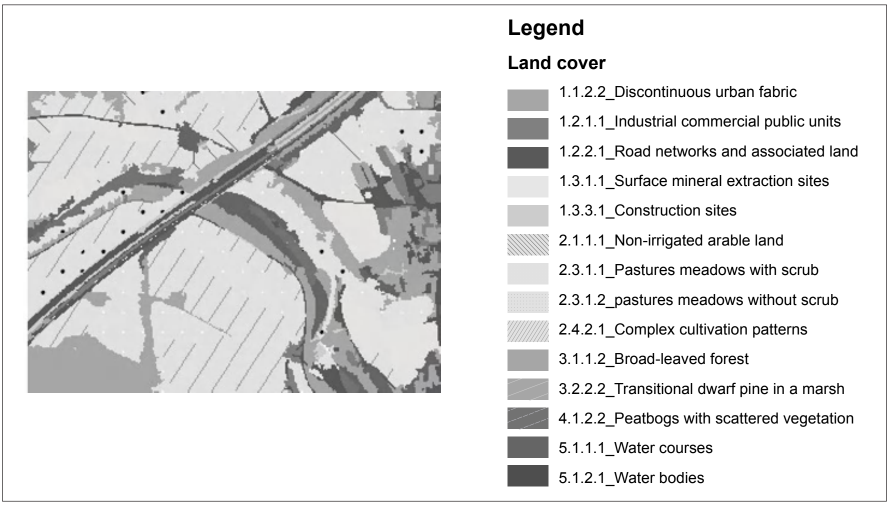

Fig. 5.5. Map-like presentation of classified Corine land cover areas in investigantion area

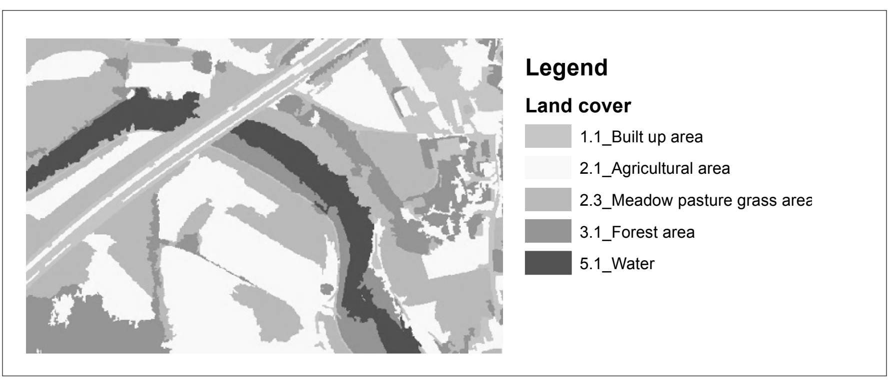

Fig. 5.6. Map-like presentation of classified land cover areas in investigation area in the first level (after manual modification)

produces more unclassified pixels scattered throughout the image. Hierarchical segmentation enables monitoring of land image in “n“ different levels. Another significant advantage is that an image classified by using an object-oriented method is easier to comprehend and understand as the results are closer to those of visual interpretation (Stanková & Čerňanský 2004).

One disadvantage of the segmentation process is that a human interpreter is reliant on the method of trial and error. To achieve practical results the interpreter has to set parameters entering the segmentation so that the classified image is neither oversegmented (an image that consists of abundant number of segments) nor undersegmented (an image that consists of insufficient number of segments). Our investigation indicates that shadow of land objects (classified as water bodies) are most problematic. As a consequence, all water bodies cannot be classified as a single object without additional interactive modification. Moreover, the presence of water flora caused some water bodies to be classified as a forest because of close spectral resemblance *(Figures 5.5 and 5.6).*

For GIS it has been shown that the resulting graphic presentations of geodata do not have the cartographic quality to qualify as a proper map (Buckley et al. 2005). The graphic presentation of image classification does not count as a professional map either. Rapid changes in our dynamic environment require maps to be periodically updated to present a correct picture. Maps should adapt to users‘needs and facilitate intuitive visual perception as well as unambiguous and associative comprehension. Viewing the maplike presentation it becomes apparent that the Colouring scheme used in the CORINE Land Cover project is not associative enough and thus exhibit low information quality only. That is why we suggest a different colour representation *(Figure 5.5).* This land cover nomenclature which is included in the Legend of *Figure 5.5* is modified land cover nomenclature for the Phare countries (Feranec & Otahel 1991). In *Figure 5.6* we see a map-like presentation of classified land cover areas in the hierarchical first level of classification after manual modification *(Figure 5.6).*

The investigation presented here has discussed potentials and limitations of the commercial as well as the freeware software systems used. One major disadvantage of the eCognition/Definiens software is laborious segmentation and time-consuming configuration of categories and rules for connection with objects in an image as mentioned above. The higher the resolution data of an image, the larger the volume and longer the time of classification. In addition, hardware efficiency is important.

Another software limitation of eCognition/Defieniens is its one-sided focus on image analysis. This requires data preprocessing and post-processing in a separate software system. This deficit is partially compensated by export options into vector format, shape file or raster format/Tiff). We agree with Neubert’s statement (2004) that eCognition/Definiens has multiple functions for input and output. In addition, eCognition/Definiens is rather costly. This limits its wider distribution and application.[2] An advantage of the eCognition/Definiens software is that it is able to segment and classify data files of bigger size, unlike the Spring freeware.

An advantage of Spring environment is that it enables using both supervised and unsupervised classification. In eCognition/Definiens only supervised classification is possible). A notable advantage of the Spring software is its compatibility with both Windows and Linux operations system, contrary to the present version of eCongnition/Definiens which runs under the Windows operating system only. A disadvantage of the used version of Spring (4.3.3.) is the limited maximal size of input raster data (2000 x 2000 pixel). As in our case it is necessary to select a smaller section out of the orthophoto. When a user wants to classify the complete image record, he will have to partition the image and the merge it again after the classification. Peripheral areas of each section are the most problematic, because the categories classified can be different in the neighbouring section, although it depicts an identical unit type. One of possible solutions to this is to mosaic the image. In the new version Spring 5.0.4. this problem is already solved and also larger images can be imported. The software is slightly instable, it did crash several times. Lower values for segmentation parameters were set, the application stopped responding and the system had to be restarted.

Many bugs of the software can be eliminated by limiting the area or amount of input data to be processed, respectively. However, the actual problem is the limited number of classifying categories. Classification systems of more than 5 classifying categories resulted in higher inaccuracy of the unsupervised classification. But sufficient number of classifying categories cannot be created for supervised classification either. Objects don't have information about object on higher or lower hierarchical levels. As a consequence, each hierarchical level has to be classified independently. Nevertheless Spring software seems to have a good perspective if it continues to evolve. We recommend this software for data with spatial resolutions lower than the resolution of our area of focus, which is more than 5 m. It is also expedient for classifications of monofunctional, less diverse areas.

The best results for investigation area in Spring environment were achieved by segmentation with Similarity parameter set to 10 and Area parameter set to 150. In eCognition/Definiens environment the best segmentation results were achieved with Scale parameter set to 50, Color set to 0.7, Shape set to 0.3, Smoothness set to 0.7, Compactness set to 0.3.

In statistical evaluation, we often use Kappa coefficient, a ratio of an actual match to a probable match of reference and classified data. The Kappa coefficient of our orthophoto equals 0.69 in eCognition/Definiens environment. This value implies that resultant categories are (almost) a strong match with reference categories. In

[2] That is why the work described here was performed at Zvolen Technical University (Slovakia). The authors gratefully acknowledge the opportunity granted by Zvolen Technical University to carry out the research in their labs.

Spring freeware the Kappa coefficient of the same orthophoto equals 0.58. This value is insufficient. Hence we did not create map and map-like presentation from the classified orthophoto in Spring environment. The value would be higher if additional information on thematic layers of the area had been available.

5.3 Conclusion

Automatic object-oriented classification of a remotely sensed image can not fully replace visual interpretation. Following the classification in the eCognition/Definiens environment, manual modification of created objects is necessary. Only then the results of object-oriented classifications are comparable to those of visual interpretation. At the same time, the processing time for land object interpretation is considerably reduced.

Based on our experience with Spring freeware, we would recommend it for the classification of a monofunctional landscape, especially when a project has a low budget. Its use is suitable also if thematic informations of the landscape are available. Polyfunctional landscapes or high-resolution data should be classified in eCognition/Definiens environment.

“The future use of land cover maps resulting from an interpretation project should determine the degree of sophistication of the cartography of these maps” (Rasch 1994)

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Chapter 6

New Approach to Multi Scale Cartographic Modelling of Reference and Thematic Databases in Poland

Andrzej Głażewski[1], Paweł J. Kowalski[1], Robert Olszewski[1] and Joanna Bac-Bronowicz[2]

[1] Department of Cartography, Warsaw University of Technology, Poland
{a.glazewski, p.kowalski, r.olszewski}@gik.pw.edu.pl
[2] Institute of Geodesy and Geoinformatics, Wroclaw University of Environmental and Life Sciences, Poland
bac-bronowicz@kgf.ar.wroc.pl

Abstract

The primary goal of the elaboration of new visualisation methods of spatial data in Poland was to obtain a readable and understandable cartographic composition for any scope of the state topographic and thematic databases. Within the framework of the Project „Methodology and procedures of integration, visualisation, generalisation and standardisation of reference databases, which are accessible in state geodetic and cartographic resources, as well as their utilisation for development of thematic databases" the concept of Multiresolution Topographic Database (WTBD) and new visualisation concepts were established.

Several preliminary assumptions were made, aiming at the universality and functionality of proposed solutions. The final cartographic presentation should fulfil the condition of readability, unequivocality and measurability both on the screen and in printed forms. Many variants of the visualisation of reference data and technology of producing the topographic map sheets at the scale of 1:50 000 as a product of WTBD have been worked out.

Second task performed within the frames of the Project was to develop a prototype of WTBD webservice which would make state reference data accessible for any client. It was also reasonably to amend visualisation of vector data with satellite images, for example distributed by Google Maps webservices. This solution, which

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is known from mashup services, allows for attractive and useful presentation of selected areas.

Keywords: MRDB, reference database, cartographic visualisation, topographic map, webservice

6.1 Introduction

Development of modern teleinformation techniques and – on the other hand – increasing user demands, result in the situation when reference databases, which mostly occur in the form of multiresolution and multirepresentation information systems, have become the basic source of spatial data. Such a system has been designed within the frames of the granted Project No. 6 T 12 2005C/06552 „Methodology and procedures of integration, visualisation, generalisation and standardisation of reference databases, which are accessible in state geodetic and cartographic resources, as well as their utilisation for development of thematic databases". The System has been called the Multiresolution Topographic Database (WTDB). The proposed concept of the WTBD is based on two basic assumptions:

1) the maximum utilisation of existing databases,
2) the maintenance of certain autonomy of particular databases and the possibility of their gradual development, synchronised with other databases.

The following databases, which are included in the state resources of geodetic and cartographic data, have been utilised for implementation of the task related to cartographic visualisation and presentation:

- The Topographic Database (TBD) and its simplified version, the TBD2,
- The VMap Level 2 database and its useful version, known as the VMapL2u database,
- The new edition of the VMapL2+ database,
- Thematic databases: sozological (SOZO) and hydrological (HYDRO) databases,
- The General Geographic Database (BDO).

Ordination of symbols have been developed for each of the above databases; those symbols are used for cartographic presentation. However, works aiming at development of the complex representation of those data files, have not been undertaken in the past. Issues which appear, concern various conceptual models, lack of mechanisms of their topological and attribute harmonisation, as well as diversified levels of the content timeliness. Therefore, the development of the concept of harmonisation of databases, within the Multiresolution Topographic Database

(WTBD) has become the leading task within the discussed Project (Gotlib et al. 2005; Bac-Bronowicz et al. 2007c). This also concerned specification of the basic, reference data set for Poland.

It has been assumed that the TBD, developed from the very beginning, which implements possibly the best conceptual model of topographic databases in Poland, will be the basic resources of spatial data (Gotlib et al. 2006). The TBD database (or the TBD2) is to be the basic source of data for the WTBD; for areas, which have not been covered by that database – the VMap L2 or the VMap L2+ should play that role. Other databases which are accessible in the state resources of geodetic and cartographic data, and, first of all, the state Register of Geographic Names, the State Register of Borders and cadastral databases should be considered as auxiliary data.

This paper presents issues related to visualisation of the WTBD, which have been developed in accordance with the rules of symbol separability, unequivocality and logics of transfer, which exist in cartography. This required that algorithms of selection, generalisation and symbolisation were developed, which would enable to utilise the WTBD data resources at various level of details: starting from the base scale of 1:10 000, through the scale of 1:50 000, to smaller scales. The basic objective of the discussed task was to implement examples of visualisation and presentation of databases with respect to the content corresponding to the 1:50 000 scale.

6.2 The New Concept of Reference Data Visualisation

At the initial phase of elaboration of the new concept of 1:50 000 reference data visualisation, the assumption of the maximum utilisation of national databases, as the source data for the WTBD was made; economic aspects, which focused the concept towards the possibly high automation of works were also considered. The best GIS solutions, known in the world were utilised, both, Geomedia and ArcGIS environments were applied, with the maintenance of connection of visual content with the content of the source databases.

The following components of the WTBD, which may be utilised in the process of development of the 1:50 000 topographic map in the discussed version, are: the TBD, VMap Level 2, with its usable version, the VMapL2u (Bac-Bronowicz et al. 2007a) and the updated and new edition of the VMapL2+ database. The source materials for the new version of the map are also: the State Register of Geographic Names, the State Register of Borders, the Bank of Control Networks and other, official registers, which contain spatial data. The basic materials for the elaboration were: the TOPO component of the TBD and the VmapL2 database, while the State Register of Borders and The State Register of Geographic Names played the role of auxiliary materials.

In order to achieve standardisation of editing, as well as to meet the existing substantial and economic requirements, and, in the future, in order to prepare technical guidelines concerning the map development, the following assumptions were approved.

In the map content, the image of the terrain, generalised to the scale level of 1:50 000 was presented. It included the most characteristic features, represented by topographic objects and basic relations, which occur between them. This presentation is performed by means of distinguishing using the so-called, leading colours, superior categories of topographic objects, following the TBD standards (GUGiK, 2007) and by presenting them on a map as certain features, which represent particular components of the natural environment and man-made elements of the space.

Two stages of data processing were distinguished:

1) the stage of screen *visualisation* at the scale of 1:50 000 (WTBD50)
2) the stage of the final *presentation* in the form of a printed map sheet (MTP50TBD).

In the first stage, the result is the digital *visualisation,* which may serve as the momentary, screen image, which may be easily modified, with respect to its content and its graphical form. This visualisation is the result of utilisation of automatic data generalisation rules and data symbolisation, without utilisation of the manual editing. Its utilisation is limited to electronic visualisation of the WTBD content at the scale level of 1:50 000 (or close to this level), with the use of classification of objects and graphical forms of symbols, which are obligatory for a map *(Figure 6.1).* The second stage of development comprises the manual graphical editing of the map content and achieving the level of the full cartographic *presentation* in the form of a map sheet, which contains descriptions, names of objects and map frames, graticules and marginal data, required by the technical instruction.

6.3 The Development of the 1:50 000 Topographic Map

During both stages: visualisation and presentation the map contents is connected with the content of the source data files, providing that the stage of visualisation maintains this connection directly, while the final form of the map is based on the KARTO50 data files, which are referenced to data files by formal selection and generalisation queries, and which contain data transformed to the cartographic model of reality (DCM).

Desktop GIS software was used for the needs of the discussed task; this software, together with additional applications, allows for implementation of the stages of data generalisation, symbolisation and editing of the content. Two supporting applications were applied, which serve for: data generalisation with respect to topological

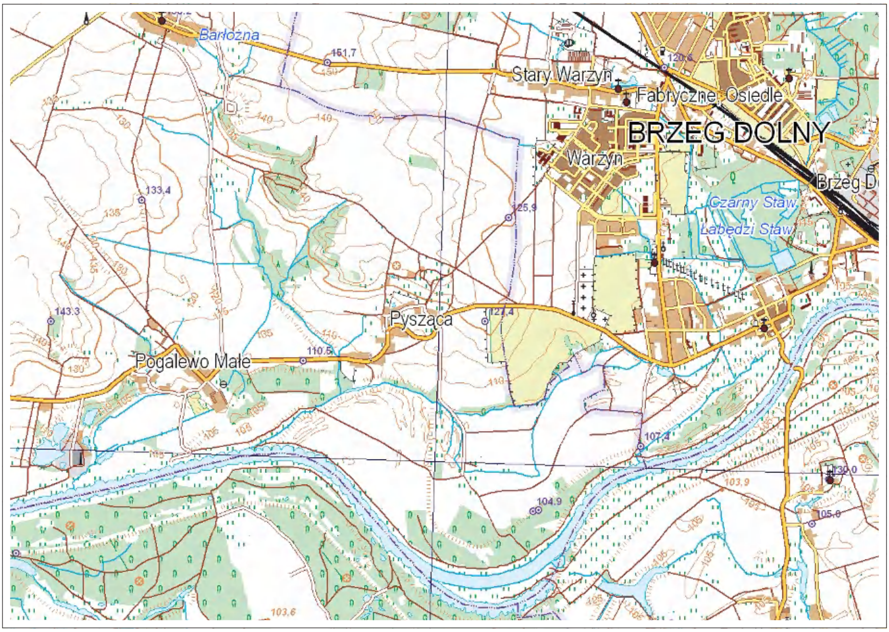

Fig. 6.1. Cartographic visualisation of the WTBD at the scale of 1:50 000 (ArcMap document – MXD)

relations between objects and generation of the map frame, including the elements of marginal data, the 1’ map frame and the cartographic graticule.

Libraries of cartographic symbols and graphic styles were developed as well as the sets of fonts and colour palettes. Data from the source databases were imported to the GIS application environment. The map was developed in stages, starting from the above discussed data import to plotting the map sheet.

The first stage of elaboration was utilisation of criteria of the qualitative generalisation, which comprised selection of data – i.e. selection of such objects from the database, which meet the assumed conditions, formulated in the SQL notation. The spatial extension of those data files was limited to the borders of the work (for example, corresponding to the selected map sheet). Besides automatic selection, data generalisation was performed by means of generalisation of shapes of area objects and location of line elements (with maintenance of mutual topological relations).

Then the stage of the map content composition is performed, which starts from the appropriate ordering of visibility of particular layers of objects, including symbolisation of the map content elements, according to the library of symbols, graphical styles and colour palettes. Then names of objects are introduced, according to the assumed concept, by means of the tools for dynamic labelling. Thus the GIS application map file is generated (its format depends on the environment: .GWS, .MXD or .WOR), which contains the complete cartographic visualisation, adapted to the screen presentation in the assumed scale interval.

During the next stage, as a result of spatial and attribute SQL queries, the new attribute KARTO50 was assigned to generalised objects, which allows for generation of new data files, which undergo the final graphical presentation at the scale of 1:50 000. Those files become the basis for the manual editing, which result will be the topographic map. The stage of the manual editing contains generalisation corrections of the map content elements, such as: dislocation of symbols, quantitative generalisation of objects which create local densification, or elimination of conflicts between symbols. This stage includes also editing of names and descriptions, which were earlier converted from dynamic labels onto static graphical descriptions.

The process of map development is finalised with introduction of elements of mathematical construction, adding map frames, as well as inner- and marginal descriptions, together with explanations of symbols and preparation of a map sheet for plotting, including vector to raster transformation of the graphical data file. The rasterised graphical file, containing the map sheet, undergoes the procedure of test plotting and correcting; then it may be finally plotted with resolution of at least 1100 dpi on an appropriate map paper *(Figure 6.2)*.

6.4 Data Generalisation

The data files of the graphical database, KARTO50, which was created basing on selected and generalised elements of the content of the source database (the WTBD) are the subject of cartographic presentation in the form of a topographic map. Those data files, recorded in the geodatabase format, contain the generalised geometry of objects, spatially referenced to the scale of presentation 1:50 000. The generalisation operations may include: selection of the map content from the source files, aggregation of classes and subclasses of objects, selection of elements of data files with respect to quantitative criteria. All generalisation of the map content finishes the stage of the editing generalisation, connected with graphical corrections.

Therefore, the first stage of generalisation is selection of the content from the WTBD, basing on detailed attribute and topological criteria. This selection concerns, first of all, entire classes of objects, which may be successively aggregated or undergo other generalisation procedures. In general, only such objects, for which the special attribute X_KAT_ISTN = 1 (exploited), are the subject of generalisation, excluding destroyed objects, such as *unexploited railway line,* or *monumental ruins* or *motorway under construction*, as well as objects of the HIPSO_RZEZBA_TERENU_L class, which origin from the VMapL2u vector database (Bac-Bronowicz i in. 2007b). The scope of the content of visualisation includes 140 elements of the KARTO50 database, which have their sources of

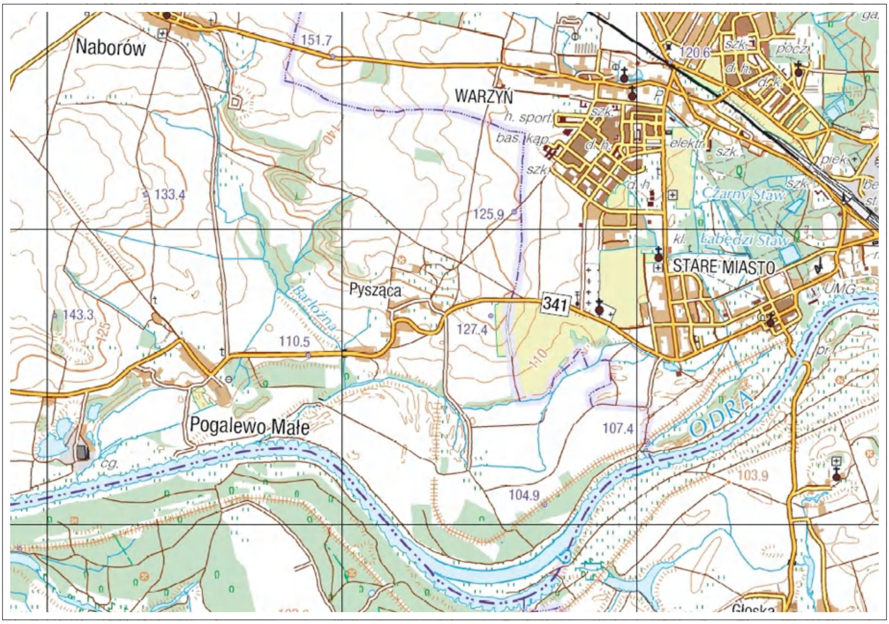

Fig. 6.2. A fragment of MTP50TBD topographic map sheet at the scale of 1:50 000

origin in the WTBD database, as well as more than 40 types of descriptions of own names. Development of appropriate rules of selection, reclassification, including data aggregation and cartographic generalisation, performed, first of all, for *data* and for the *graphical* image at the final, editing, is of the basic importance. Each element of the map content, which is created as the subclass of the KARTO50 files by means of attribute selection of the WTBD objects, is assigned to an identifier and becomes the graphical representation of the given subclass, independently from the source geometry. Thus some objects of the source database are not the subject of presentation at all, some of them are directly visualised and the basic group of objects undergo both, reclassification – re-grouping or combination of classes, as well as aggregation of classes, and then the process of editing generalisation.

Both, aggregation of objects within a class, and combination of classes of objects, i.e. creation of super classes corresponding to the higher level classes, were applied. Such aggregation is performed for the selected database content and, together with selection of objects within particular classes, results in the content of the created KARTO50 database *(Table 6.1).*

The successive generalisation task is limitation of data files to objects which are the elements of the map content – selection within classes of objects. The stage of selection of objects according to the minimum size criteria were fully automatised. This concerns the length of line objects, as well as the size of area objects. For example, forests bigger than 2500 sq.m. are presented on a map and enclaves within a forest, smaller than 1 hectare (10 000 sq.m.) are neglected in the presentation. In the case of woods and areas covered with trees, only objects bigger than 5000 sq.m. are presented, and in the case of dense bushes, mountain pine, plantations, orchards and parcels, meadows and pastures – only object bigger than 10 000 sq.m. are presented *(Table 6.2)*.

Table 6.1. Aggregation of object classes using the example of *a tower* and *a chimney*

No.	Visualization element	Source feature class	Attribute selection *(SQL)*	Code and sign
62	tower (wieża)	BBWT_P	RODZAJ In (‘2’,’3’,’9’)	070
		OIOR_P	RODZAJ=10	
		BBWT_A	RODZAJ In (‘2’,’3’,’9’)	
63	chimney (komin)	BBWT_P	RODZAJ=1	071
		BBWT_A		

Table 6.2. An example of attribute selection, comprising the selection of objects, which meet the assumed size criteria (the minimum size)

No.	Visualization element	Source feature class	Attribute selection *(SQL)*	Code and sign
110	orchard or allotments (sad, ogródki działkowe)	PKUT_A	[SHAPE_Area] >=10000 And RODZAJ_ UPRAWY= Sad, Odz	431
111	plantation (plantacja)	PKUT_A	[SHAPE_Area] >=10000 and RODZAJ_ UPRAWY= Pln	432
112	forest (las)	PKLA_A	[Shape_Area] >=2500	433
113	coppice (zagajnik, teren zadrzewiony)	PKLA_A	[RODZAJ] in ('Zag') AND [Shape_Area] >=5000	434
114	przesieka leśna	OIPR_L	[RODZAJ] = '10' and [SHAPE_Length] >= 250	435

6.5 Graphical Simplification and Map Editing

The above discussed preparatory works, comprising development of the library of cartographic symbols or cartographic styles, fonts and colour palettes, are the substantial basis for map editing and they are the practical outcome of development of the new concept of the map.

Three main types of applied editing generalisation operations may be listed: reduction of a symbol size to a point (this concerns both, line and area object), exaggeration of symbols, together with utilisation of equi-distance lines, generated around objects – as the basis for visualisation and elimination of conflicts between symbols, by means of their displacement and possible deletion.

Reduction of symbol size occurred in all places where the line or area class of database objects is presented by a point symbol. Geometric representation of objects of those classes in the KARTO50 data file are their centroids, which were assigned specially located graphical symbols. In the case of presentation of (road and railway) bridges shorter than 50m, which are recorded in the source database in line class of objects, reduction of an object to a point (and utilisation of point cartographic symbols) is connected with assigning the symbol to orientation following the location of a road or a railway line, the course of which the bridge is located *(Figure 6.3)*.

The most expressive examples of reduction of area to a point symbol are individual premises, which are not the components of built-up areas. They were assigned symbols, which also may be oriented, according to the longer side of the premises area and thus they amend the area presentation of built-up areas *(Figure 6.4)*.

Presentation of built-up areas fully utilises experiences concerning delineation of built-up areas, which are diversified with respect to functional, as well as physionomic features (Ostrowski, 2008). Those areas are the content of the source database; however the new approach to classification of buildings is also applied *(Table 6.3)*. In general, housing areas are distinguished (dense, multi-family and one-family areas are distinguished), as well as industrial and storage areas are delineated (basing on the class of objects from the land use group), which correspond to industrial built-up areas, if they include industrial buildings. Besides, premises, which are not included in the areas of dense, single-family housing areas, are presented by point symbols, what was already discussed above. Buildings are divided into 5 categories, depending on their functions: dwelling houses, municipal buildings, sacral buildings, industrial, farm and other buildings. Dwelling houses are presented (with the exception for single-family areas) according to the division into area presentation (objects bigger than 600 sq.m.) and point presentation (a symbol for objects smaller than 600 sq.m.). Municipal and industrial buildings are presented when they are bigger than 300 sq.m. However, this limitation does not concern sacral buildings.

Sacral buildings (Christian and other churches, chapels) are presented by means of point symbols, independently on their size. It should be added that the full presentation of built-up areas is achieved only after introduction of names and descriptions on a map; this concerns, in particular, abbreviations concerning functions of municipal buildings and farm buildings.

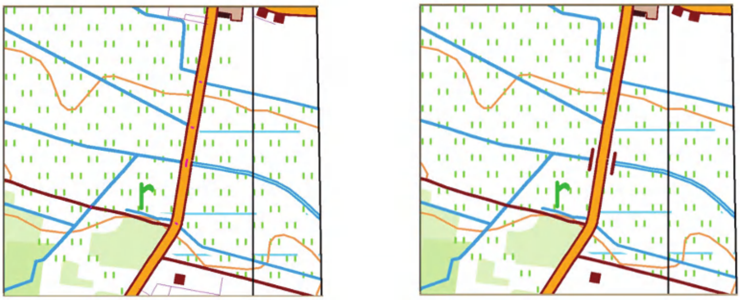

Fig. 6.3. Presentation of a bridge using the line reduction to the point and orientation of a symbol along the road axis (source data, which cover also culverts – located on the left)

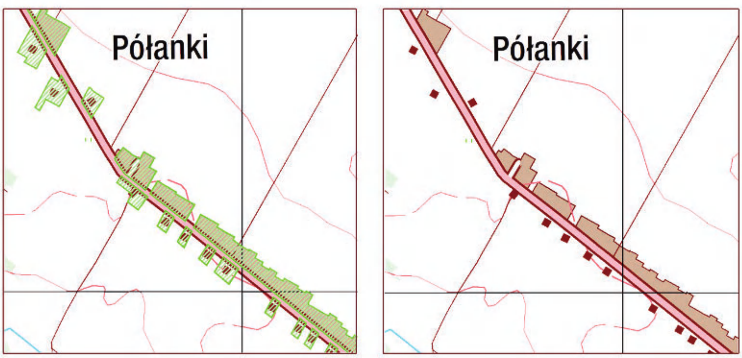

Fig. 6.4. Presentation of premises – visible reduction to the point and orientation of symbols according to the longer side of presented objects (source data in green – located on the left)

Table 6.3. Classification of buildings as map content elements (objects reduced to a point)

No.	Visualization element	Source feature class	Attribute selection *(SQL)*	Code and sign
45	dwelling-house area > 600 m² (budynek mieszkalny o powierzchni większej od 600 m²)	BBBD_A	[FUNKCJA_OGOLNA] = 'm' and [SHAPE_Area] >= 600	352_2
46	dwelling-house area < 600 m² (budynek mieszkalny o powierzchni mniejszej od 600 m²)	BBBD_A	[FUNKCJA_OGOLNA] = 'm' and [SHAPE_Area] < 600	352_1
47	public service building area > 600 m² (budynek użyteczności publicznej o pow. większej od 600 m²)	BBBD_A	FUNKCJA_OGOLNA in ('b' , 'h' , 'k' , 't') and FUNKCJA_SZCZEGOLOWA not in ('Tg' , 'Th' , 'To' , 'Tr') AND [Shape_Area] >=600	354_2
48	public service building area < 600 m² (budynek użyteczności publicznej o pow. od 300 do 600 m²)	BBBD_A	FUNKCJA_OGOLNA in ('b' , 'h' , 'k' , 't') and FUNKCJA_SZCZEGOLOWA not in ('Tg' , 'Th' , 'To' , 'Tr') AND [Shape_Area] >300 AND [Shape_Area] <600	354_1
49	Christian church (świątynia chrześcijańska)	BBBD_A	(FUNKCJA_SZCZEGOLOWA= 'Rc' and X_ID_KOD_K in ('061', '061_1', '061_2')) or [FUNKCJA_SZCZEGOLOWA] = 'Rs'	355
50	non-Christian church (świątynia niechrześcijańska)	BBBD_A	FUNKCJA_SZCZEGOLOWA= 'Rq'	356
51	chapel (kaplica)	BBBD_A	(FUNKCJA_SZCZEGOLOWA= 'Rc' and X_ID_KOD_K in ('062' , '062_1' , '062_2')) OR [FUNKCJA_SZCZEGOLOWA] = 'Rk'	357
52	industrial building area > 600 m² (budynek przemysłowy o powierzchni większej od 600 m²)	BBBD_A	[FUNKCJA_OGOLNA] = 'p' AND [Shape_Area] >=600	358_2
53	industrial building area < 600 m² (budynek przemysłowy o powierzchni od 300 do 600 m²)	BBBD_A	[FUNKCJA_OGOLNA] = 'p' AND [Shape_Area] >300 AND [Shape_Area] <600	358_1
54	other building area > 600 m² (budynek gospodarczy)	BBBD_A	[FUNKCJA_SZCZEGOLOWA] in ('Tg' , 'Th' , 'To', 'Tr', 'Sl' , 'Sm' , 'Gw' , 'Gp') and [SHAPE_Area] >= 600	359

Table 6.4. Classification and symbols of roads of higher categories

No.	Visualization element	Source feature class	Attribute selection *(SQL)*	Code and sign
17	autoroute (autostrada)	SKJZ_L	[KLASA_DR] = 'A' and [X_KAT_ISTNIENIA]=1 and [ID_JEZDNI].INT_JEZDNIE_SZ LAKI=1	321_2
18	carriageway of autoroute (jezdnia autostrady)	SKJZ_L	[KLASA_DR] in ('A') and [X_KAT_ISTNIENIA]=1 and L_JEZ_DR=2	321_1
19	dual expressway (droga ekspresowa lub ruchu przyspieszonego dwujezdniowa)	SKJZ_L	[KLASA_DR] in ('S' , 'GP') and [X_KAT_ISTNIENIA]=1 and L_JEZ_DR=2 and [ID_JEZDNI].INT_JEZDNIE_SZ LAKI=1	322_2
20	single expressway (droga ekspresowa lub ruchu przyspieszonego jednojezdniowa)	SKJZ_L	[KLASA_DR] in ('S' , 'GP') and [X_KAT_ISTNIENIA]=1 and L_JEZ_DR=1	322_1
21	carriageway of expressway (jezdnia drogi ekspresowej lub ruchu przyspieszonego)	SKJZ_L	[KLASA_DR] in ('S' , 'GP') and [X_KAT_ISTNIENIA]=1 and L_JEZ_DR=2	322_3
22	dual main road (droga główna dwujezdniowa)	SKJZ_L	[KLASA_DR] = 'G' AND [NAWIERZCHNIA] in ('Br' , 'Bt' , 'Kk' , 'Kl' , 'Kp' , 'Mb') and L_JEZ_DR=2 and [ID_JEZDNI].INT_JEZDNIE_SZ LAKI=1	323_2
23	single main road droga główna jednojezdniowa	SKJZ_L	[KLASA_DR] = 'G' AND [NAWIERZCHNIA] in ('Br' , 'Bt' , 'Kk' , 'Kl' , 'Kp' , 'Mb') and L_JEZ_DR=1	323_1
24	dual paved road (droga zbiorcza dwujezdniowa)	SKJZ_L	[KLASA_DR] = 'Z' and [NAWIERZCHNIA] in ('Br' , 'Bt', 'Kk' ,'Kl' , 'Kp' , 'Mb') and L_JEZ_DR=2 and [ID_JEZDNI].INT_JEZDNIE_SZ LAKI=1	324_2
25	single paved road (droga zbiorcza jednojezdniowa)	SKJZ_L	[KLASA_DR] = 'Z' and [NAWIERZCHNIA] in ('Br' , 'Bt', 'Kk' ,'Kl' , 'Kp' , 'Mb') and L_JEZ_DR=1	324_1
26	dual local road (droga lokalna lub inna o nawierzchni twardej dwujezdniowa)	SKJZ_L	[KLASA_DR] in ('L' , 'I') and [NAWIERZCHNIA] in ('Br' , 'Bt', 'Kk' ,'Kl' , 'Kp' , 'Mb') and L_JEZ_DR=2 and [ID_JEZDNI].INT_JEZDNIE_SZ LAKI=1	324_3
27	single local road (droga lokalna lub inna o nawierzchni twardej jednojezdniowa)	SKJZ_L	[KLASA_DR] in ('L' , 'I') and [NAWIERZCHNIA] in ('Br' , 'Bt', 'Kk' ,'Kl' , 'Kp' , 'Mb') and L_JEZ_DR=1	324_4

Details of presentation of buildings highly differ from the signs used on the Topographic Map of Poland (GUGiK 1998), let us mention colours of symbols of churches and municipal buildings, or diversification of sizes of symbols of dwelling houses and premises, which may be thus differentiated on a map.

Roads were classified according the attribute, which was not previously considered on a map, i.e. the *class of a road*. It is the sectoral diversification, which considers both the importance of a road (including the road management unit), as well as its technical parameters, including the width and number of lanes. Additional attributes, which contain more details of road classification, is the number of pavements and – in the case of the lowest classes of roads – the type of pavement. Roads (for vehicles) were presented by means of brown contouring lines and filled the symbols in shades from red to yellow (hard pavements) and without filling (hardened pavement). *(Table 6.4)* Roads for pedestrians (alleys and paths) were presented in grey without colour fillings.

In the case of wetlands, their areas were exaggerated by using equidistance lines. Those areas are mostly the clusters of small areas of location which corresponds to real occurrence of wetlands. Their cartographic presentation might be performed by means of reduction to a point symbol, distributed with the excessive density; however another way of presentation is also possible. The equidistance line (buffer), 70m around those areas, was applied; resulting areas were symbolised with the use of well known pattern of irregularly located horizontal dashes. Stagnant and flowing water bodies were excluded from those areas and required distances between the symbol of wetlands and the symbol of waters were maintained *(Figure 6.5)*.

Vegetation was presented according to the general division into 4 groups: forests, other high vegetation (trees, woods, orchards and allotment gardens), lower vegetation (bushes, mountain pines, plantations) and herbal vegetation (grasses, reeds and bulrush). Those groups are diversified on a map by intensification of the green colour used as the colour background of area symbols of the mentioned objects (or lack of such background in the case of the lowest vegetation). Particular crops (plantations), grasses and scrubs were diversified in shapes of elements of applied patterns. Within the areas of woods and other tree-covered areas the types of stands were not diversified; however they were diversified within forests. In the group of remaining high vegetation various shades (colour) were used to diversify bushes and mountain trees from orchards and allotment gardens. Narrow belts of forests and tree-covered

Fig. 6.5. Presentation of wet areas, marked in dark blue, by means of equi-distance lines (buffers), which delineate the final linear pattern

areas were not distinguished in the map content. One common symbol was assumed for the objects "dense bushes and mountain pines" and another common symbol for the objects „orchards and allotment gardens" was assumed. Single trees and rows of trees, as well as belts of bushes, hedges as well as groups of bushes, were not presented.

The possibility to change the content of the cartographic symbol was applied, depending on the context – mutual relations of objects. It takes place in the case of presentation of administrative borders, which symbols consist of two components: the basic line and the streamer. The streamer is used when the border follows another (line) element of the map content (such as a road or a stream); the symbol basic line is not applied then. However, if the border overlaps the axis of a water stream, which is presented by means of an area symbol, only the streamer is not applied. In other cases the full symbol is used. *(Figure 6.6)*

The basic sources of data for presentation of descriptions on a map are the State Register of Geographic Names and attributes of objects of the TOPO TBD and VMapL2 databases. At the stage of screen visualisation those descriptions are presented as dynamic labels, which are directly connected with the database content. At the stage of the final presentation, they are changed into descriptions (text type graphical objects), which features are connected with the scale of presentation and which are not the subjects of dynamic modifications, depending on the zoom of the map drawing. The size and location of those descriptions do not change; they are settled at the stage of editing, according to the rules if introduction of names and descriptions.

Issues related to data generalisation, as well as graphical editing works, are the new experiences in the field of development of topographic data presentation by means of GIS tools. Those experiences lead to creation of a new product, i.e. the topographic map at the scale of 1:50 000, in the WTBD version.

Fig. 6.6. Change of the number of components of a border symbol, depending on relations between presented objects

6.6 Results

The proposed scope of presentation content of the WTBD database and cartographic generalisation procedures consider the standards of the Polish topographic cartography; however the modified ordering of several classes of objects, as well as new symbols used for cartographic visualisation, have been proposed. This was required in order to unify presentation which uses various data sources (mainly the TBD and the VMap L2, with its different structure and content). At the same time, analysis of possibilities of utilisation of automated processes of generation of maps basing on the WTBD in the GIS environment, was performed.

Practical results of performed works include:

- Ordination of symbols used for presentation at the scale of 1:50 000, modified with respect to the WTBD, as well as the test map sheets,
- Cartographic visualisation of the WTBD at the same scale,
- Libraries of symbols: a set of point symbols in the open form (bitmap files) and the complete library of styles (STYLE file) for ArcMap (in the ArcGIS) and for GeoMedia software tools,
- MXD map documents of the ArcMap software tool and GWS map document of GeoMedia, containing the complete digital visualisation of the TBD50 database (basing on the TBD10) and the VMapL2u database in the usable structure,
- The list of object classes and visualisation parameters XLS.

A series of applications, information systems and technological lines, which ready for implementation at voivodship and central data centres have been developed within the discussed task. They are:

- Graphical libraries, applications, parametric files and descriptions of procedures, which allow for visualisation of the WTBD data, as well as VMapL2 data, stored in the usable structure in ESRI, Intergraph and MapInfo tool environment,
- The technological line, developed in Intergraph tool environment, allowing for 1:50 000 topographic map editing, generated basing on the TBD database,
- The technological line developed in ESRI environment, which allows for 1:50 000 topographic map editing, generated basing on the TBD database,
- Distribution of the VMap L2u database and SOZO i HYDRO database, basing on WMS and WFS standards – description of configuration of open source tools (Geoserver and OpenLayers) and supply with data, development of the prototype technological line.

At the final stage of Project geoinformation website have been launched. Works performed in this area aimed both, at popularisation of valuable topographic and thematic data from the state resources, as well as at verification of the possibility to apply the open source or free software, which allows inexpensive and effective publication of geographic data via Internet. In the complete version of the system (Bac-Bronowicz et al. 2008), successive components are: VMap L2u, DTED2 elevation data, data from SOZO and HYDRO thematic databases and geographical names from the State Register of Geographic Names. Efficient integration and visualisation of those data resources in one service is possible due to the same spatial reference – military topographic maps at the scale of 1:50 000 are the sources for the majority of data. The content scope and the functionality of geoservices allow for simple reviewing and searching for georeference data for a voivodship. Besides the standard access, performed by means of a web browser, the service may be accessed by means of an arbitrary GIS tool or a geo-browser, such as ArcGIS Explorer, which reads WMS or WFS services (Kowalski 2008).

6.7 Conclusions

In Poland the key issues related to distribution of geodetic and cartographic data are connected, first of all, with integration of large, however non-uniform databases, as well as with their coherent visualisation and presentation. The discussed examples of cartographic visualisation served both, for publication of the 1:50 000 topographic map according to the new concept, as well as for establishing geoinformation services, which distribute reference and thematic data stored in the state resources of geodetic and cartographic data.

The basic conclusion which may be drawn from performed works confirms the possibility of automated and direct visualisation of various data sources at the scale of 1:50 000; this will be also possible in derivative scales in the future. The possibility of full automation is important due to elimination of all manual works, as well as immediate and direct utilisation of databases, which already exist in the resources of geodetic and cartographic data. The developed libraries of cartographic symbols are the platform of multirepresentation graphical libraries for many scale levels of topographic presentations – which are required for automation of editing processes of derivative maps. The high flexibility of the structure and the content of the TBD was also confirmed; this allows for the arbitrary cartographic presentation at the scales of 1:10 000 and 1:50 000 – of both, the topographic and thematic natures.

The assumed, stage implementation of the task related to the WTDB content presentation at the scale of 1:50 000, leading through the screen (digital) presentation to the sheet (printed) presentation ensures the uniformity of editing rules and the maximum coherence and the content and the form of the map accessible in geoinformation services (eg. in geoportals), or in desktop cartographic visualisation and the conventional, printed map. It may be assumed that the importance of the digital form of information transfer related to the reference data will systematically grow, however conventional forms of publications are still required for many applications.

The new proposal concerns the possibility of utilisation of the common, integrated visualisation of a vector database and raster images, such as orthophotomaps. Thus a *hybrid visualisation* may be developed, which – assuming the appropriate data integration and selection of visual variables, may ensure the satisfactory results of perception and widens the topographic map content (Głażewski A. 2007).

Within the Project, the prototype geoinformation webservices will distribute the content of reference and thematic databases, which are included in the state resources of geodetic and cartographic data. The assumed scope of the content, as well as its functionality allow for simple reviewing and searching for VMap L2, DTED2, SOZO and HYDRO, as well as State Register of Geographic Names data for a specified voivodship.

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Chapter 7

Implementation of the INSPIRE-Directive in Germany and Poland – Legal Point of View[1]

Mateusz Badowski

Faculty of Law, University of Osnabrück, Germany
mateusz.badowski@uni-osnabrueck.de

Abstract

The aim of the Directive 2007/2/EC of the European Parliament and of the Council of Ministers dated 14 March 2007, establishing an Infrastructure for Spatial Information in the European Community (INSPIRE), which came into force on 15th May 2007, is to set up a spatial data infrastructure (SDI) and to simplify access to spatial data and spatial data services in Europe. Because of the transnational aspects and the general need to coordinate the conditions of access to, exchange and sharing of spatial information within the Community, it can only be sufficiently achieved at the Community level. Each Member State is obliged to implement the INSPIRE-Directive. In Germany the implementation procedure has to take place both on the federal and the Federal States level. Thus, good coordination of work and cooperation between the federation, Federal States and municipalities is essential. The federation and each of the federal states are together responsible for the implementation of the INSPIRE with regards to its own public authorities. In Poland, as in other non-federal states, this directive has to be implemented only by passing a new law for the whole country. But the oft amended geodesy and cartography Act passed in the People's Republic of Poland, which is in force till now, does not make that process easier. This paper presents the works on the implementation of the INSPIRE-Directive in the Federal Republic of Germany, on the federal and the Federal States level and compare them with regulations contained in a proposal of polish implementing Act.

Keywords: geoinformation, directive, INSPIRE, implementation, Spatial Data Information, Spatial Data Infrastructure, Germany, Poland

[1] Effective: 15 March 2009.

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7.1 INSPIRE

Value and importance of information grow constantly (Püschel 2006). Spatial data (SD), which mean data with a direct or indirect reference to a specific location or geographical area, provide the best illustration of this process.

Approximately SD are used in about 80 % of all decisions taken by public authorities. This shows the need for easy access to this kind of data and its interoperability, which means the possibility for spatial data (sets) to be combined, and for services to interact, without repetitive manual intervention, in such a way that the result is coherent and the added value of the data (sets) and services is enhanced.[2] This will simplify and make the process of taking decisions more effective. Public authorities, as well as individuals and business, require this easy access because of the fact that spatial data are used by these entities. Choosing a place of residence, head office or holiday destination is a good example of how the spatial data could be used in everyday normal life. SD can be also applied in navigation systems, traffic planning, advertising campaigns, by planning geothermic facilities or pipelines, saving the rare species or generally in environmental protection, by extracting natural resources or managing in crisis situations e.g. floods. (IMAGI 2005, KSt. GDI-DE 2007, Bernard et al. 2004, Tappert 2007). The benefits resulting from using spatial data in a field of managing crisis situations can be illustrated by the Flood Hazard Mapping Program, started in 2001 by the Federal Emergency Management Agency (FEMA) in the United States of America. After the estimation of benefits, the cost of the modernization plan was $847.6 million and the total discounted benefits of the plan amounted to $175 billion. Finally, the benefit to cost ratio was over 200 to 1. (Commision 2004a)

According to the assessments of the German Federal Ministry of Economics and Technology (Bundesministerium für Wirtschaft und Technologie), German geoinformation has a value of about €2 Billion and its full exploitation could create 14.000 new workplaces. Globally, the service sector alone, which uses knowledge about the certain location, will have probably in 2020 a value of about €180 Billion. (Ryzenko et al. 2007)

Because of this potential, the European Parliament and the Council decided to pass the Directive 2007/2/EC of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community – INSPIRE.[3] The implementation of the directive should bring potential savings and revenue. It should also help protect the environment in a more efficient manner. That is why the directive

[2] According to art. 3 p. 7 INSPIRE.
[3] EUR-LEX (2007): Official Journal of the European Union, L 108, 25/04/2007, 0001 – 0014.

was enacted on the basis of Article 175 (1) of the Treaty establishing the European Community[4], which refers to environmental protection.[5]

However, the sorts of spatial data, which will be accessible according to the INSPIRE regulations, can also be used for other purposes.

The benefits envisioned by the passage of the directive can only be achieved by establishing an Infrastructure for Spatial Information in the European Community, because the main obstacle to the full exploitation of the data is the loss of time and resources in searching for existing spatial data or establishing whether they may be used for a particular purpose.[6] The establishment of the INSPIRE-Directive cannot be sufficiently achieved by the Member States alone, because of the transnational aspects and the general need within the Community to coordinate the conditions of access, exchange and sharing of spatial information. As a consequence it should be established at the Community level. That is why the spatial infrastructure is needed throughout the entire European Community. It will be based on the infrastructures for spatial information that are created by the Member States and that are made compatible with common implementing rules and are supplemented with measures at the Community level. These measures should ensure that the infrastructures for spatial information created by the Member States are compatible and usable in a Community and in cross-boundary context.[7]

The INSPIRE-Directive applies to spatial data held by or on behalf of public authorities and to the use of spatial data by public authorities in the performance of their public tasks but does not set requirements for the collection of new data.[8]

The details of the regulations of the directive will be contained in the implementing rules, which are designed to amend non-essential elements of the Directive by means of supplementing it. They set forth technical arrangements for the interoperability and, where practicable, harmonisation of spatial data sets and services.[9]

The average annual benefits per Member State (EU25) after the implementation should amount to €27–42 million. The total costs of implementation are not fully quantified because the implementing rules have not yet been passed, but according to the plans the cost rate will be fundamentally lower. Moreover, some additional benefits, which cannot be assessed at this stage, should appear. The required investment is estimated at an average of €3.6–5.4 million per annum per EU Member State (EU25), what would represent only 1% of the total expenditure on spatial information (Commision 2004b).

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[4] EUR-LEX (2002): Official Journal C 325 of 24/12/2002, P. 0001 – 0184.

[5] About the importance of spatial data for German environment you can read in: e.g. Deutscher Bundestag Drucksache 16/7082, 07. 11. 2007.

[6] P. 15 of Preamble of the INSPIRE.

[7] P. 5 of Preamble of INSPIRE.

[8] Art. 4 p. 4 INSPIRE.

[9] http://www.ec-gis.org/inspire/. Accessed 15 March 2009

7.2 INSPIRE in Germany and in Poland

INSPIRE, like all directives, has to be implemented into the national legal order[10], according to the time schedule[11]. In the Federal Republic of Germany the INSPIRE-Directive (as was the case with the Directive 2003/4/EC of the European Parliament and of the Council of 28 January 2003 on public access to environmental information) has to be implemented on federal and Federal States level (Afflerbach, Lenk 2008). In Poland, as a central state, the implementation process will be made through passing a new law for the entire country.

The building of the German Spatial Data Infrastructure was begun in 1998 (Bundesregierung 1998) and has not been finished till now (GDI-DE 2007, Badowski 2008).The geoinformation (spatial data) in Germany is collected on the federal, Federal States and municipal level, which is why the consultation between federal and federal states authorities as well as the communal associations was necessary to assure the good cooperation both in building German Spatial Data Infrastructure (which is classified as very important for the German authorities[12]) and in the implementation process of the INSPIRE-Directive.

These undertakings are closely related with each other. In Poland only regional spatial data infrastructures exist (SDI), which were built according to the multilateral agreements. There is no special Act to regulate this matter. According to art. 1 p. 2 INSPIRE, the Directive shall build upon infrastructures for spatial information established and operated by the Member States. This means that in different countries either the new spatial data infrastructure must be built or the existing one will be rebuilt or just adapted to the INSPIRE requirements, and it is a function of the implementation act to adapt the existing or planned infrastructure to the aforementioned requirements.

In Poland, as well as in Germany on the federal level, authorities decided to implement the INSPIRE-Directive 1:1 and to pass a new law. The Federal States themselves may choose the implementation method.

This paper presents the regulations of the German federal Act concerning access to digital spatial data – Gesetz über den Zugang zu digitalen Geodaten (Geodatenzugangsgesetz – GeoZG)[13] which implements the INSPIRE-Directive to the German federal legal system and provides an example of an Act imple-

[10] Art. 249 of the Treaty establishing the European Community.

[11] http://www.gdi-de.de/de/inspire/f_inspire.html. Accessed 15 March 2009

[12] See documents Germans' Government and Parliament (e.g. Deutscher Bundestag: Drucksache 14/4139, 27. 09. 2000; Drucksache 14/5323, 15.02.2001; Drucksache 15/809, 08. 04. 2003; Drucksache 15/1209, 25.06.2003; Drucksache 15/5834, 27.06.2005; Drucksache 16/2959, 17. 10. 2006; Drucksache 16/3975, 28. 12. 2006; Drucksache 16/6218, 10. 08. 2007; Drucksache 16/10080, 30.07.2008).

[13] The GeoZG came into force on 14th February 2009 (BGBl. I S. 278).

menting this directive on the Federal States level: the Bavarian Act about Spatial Data Infrastructure (Bayerisches Geodateninfrastrukturgesetz – BayGDIG)[14] and compares these Acts with the proposal of the Polish Act on Spatial Data Infrastructure (UIIP)[15]. Both German Acts are very similar because all the work on the INSPIRE-implementation-process and building the German Spatial Data Infrastructure takes place in a close cooperation on federal, Federal States and communal associations level. They are also more similar to the directive itself than the Polish proposal, which duplicate most of definitions, but not the structure in the way the German Acts do it.

To present an overview of these regulations, the following points should be considered: the aim of the regulation; its subjective, objective and territorial scope; definitions; requirements which the data must fulfill and conditions of access to the data.

In all three Acts (GeoZG, BayGDIG and UIIG) the 1:1 method of implementation has been chosen. As a consequence, in Poland and at the German federal level, as well as in Bavaria, one new act will implement this directive.

The aim of all the Acts covered in this paper is to implement the INSPIRE-Directive and create the appropriate spatial data infrastructure. However the Bavarian SDI is a part of the national (German) Spatial Data Infrastructure.[16] In the GeoZG it is expressly set forth that the Act creates a legal framework to access spatial data, spatial data services and metadata from the geodata holders (geodatenhaltende Stellen – this term will be explained further in this paper). The use of these data and services should be primarily aimed at environmental protection.[17] Additionally the UIIP aims to create consistent development of national and environmental protections.[18] The spatial data will be accessible for everybody and for every permissible lawful use. Environmental protection is not treated in a special manner like in the GeoZG. These differences do not change the fact that the aim of all three of them is in line with the INSPIRE-Directive.

The field of application of discussed Acts is also different – BayGDIG affects the public authorities – each office which provides the functions of public administration.[19] These authorities are the public authorities of the Free State of Bavaria, municipalities and communal associations, which carry out administrative tasks of the various entities. These are also legal persons of public law being under the control of the Free State of Bavaria. In the sense of the BayGDIG, the notion of

[14] That is the first INSPIRE implementation Act which came into force (on 1.8.2008) in Germany (GVBl. Nr. 15 vom 28.07.2008 S. 453).
[15] The last version of the proposal is dated 10 February 2009.
[16] See: art. 1 BayGDIG.
[17] See §1 GeoZG.
[18] See: art. 1 p. 1 UIIP.
[19] See : Art. 1 p. 2 Bayerisches Verwaltungsverfahrensgesetz, BayRS II, S. 213.

public authorities includes also natural or legal person providing public services relating to the environment.[20] The GeoZG uses the term of federal geodata holders. These are the "information liable offices" (informationspflichtige Stellen)[21]. The GeoZG is in effect also applicable to the persons of public law under the control of the federation. The UIIP relates to administrative authorities (organy administracji). These are governmental administrative authorities as well as self-administration authorities and other subjects when they are appointed on legal basis or on basis of agreements entitled to exercise public tasks related to the environment.

All the Acts apply to spatial data, spatial data services, metadata, and their aim is to ensure their interoperability. The definitions of spatial data and metadata are identical (or nearly identical) with the language of provisions in the INSPIRE-Directive as well as in mentioned implementing Acts. Spatial data means any data with a direct or indirect reference to a specific location or geographical area,[22] and metadata are information describing spatial data sets and spatial data services and making it possible to discover, inventory and use them.[23] Also definitions of interoperability are very similar in all three Acts and in line with the directive. They do not have to be identical because the most important thing in implementing a directive is to achieve a given result.[24] The definitions of infrastructure for spatial information and of Geoportal are also only based on these contained in the INSPIRE-Directive.

The GeoZG consolidates other concepts and definitions as well, for example by binding the definition of spatial data services with the catalogue of network services from art. 11 INSPIRE (the INSPIRE does not define them only lists), which lists and describes discovery services, view services, download services and transformation services (but without services allowing spatial data services to be invoked). §3 p.7 GeoZG defines network services as the means used for the purposes of communication, transaction and interaction using the electronic networks (e.g. E-Payment-Services). The BayGDIG contains all 5 kinds of network services from art. 11 INSPIRE in a definition of spatial data services.[25] The UIIG does not use the term of network services, but all these mentioned in art. 11 INSPIRE, are contained in the spatial data services defined throughout the UIIG. It uses a definition of spatial data sets (means an identifiable collection of spatial data) copied from art. 3 p. 3

[20] See: art. 2 BayGDIG.
[21] Mentioned in §2 p. 1 Environmental information Act (Umweltinformationsgesetz) from 22. December 2004 (BGBl. I S. 3704).
[22] See: art. 3 p. 6 INSPIRE, §3 p. 1 GeoZG, art. 3 p. 1 BayGDIG, art. 3 p.1 UIIP.
[23] See: art. 3 p. 6 INSPIRE, §3 p. 2 GeoZG, art. 3 p. 2 BayGDIG, art. 3 p. 5 UIIP.
[24] See: Judgment of the Court of 9 April 1987. Commission of the European Communities vs. Italian Republic. Failure of a Member State to fulfill its obligations – Feedingstuffs. Case 363/85; Judgment of the Court of 23 May 1985. Commission of the European Communities v Federal Republic of Germany. Right of establishment and freedom to provide services – Nurses – Implementation of directives. Case 29/84.
[25] See: §3 p. 3 BayGDIG.

INSPIRE, both German implementation Acts resign of this term. Despite mentioned differences to the INSPIRE regulation, all three Acts implement the directive in a proper way.

None of the aforementioned discussed Acts create an obligation to collect new spatial data. The GeoZG applies to data related to an area of the Federal Republic of Germany or to exclusive economic zones situated on the territory of the Federal Republic of Germany. The BayGDIG refers, somewhat obviously, only to Bavarian territory. The UIIP affects the territory of the Republic of Poland. According to all three Acts, the data have to exist in electronic format and be held by or on behalf of any of either geo-data holders (when falling within the scope of their public tasks and when the geo-data holder has produced these data, or the data were received by the geodata holder, or the data are being managed or updated by that geodata holder) or a third party to whom the network has been made available (in accordance with §2 p. 2 GeoZG or art. 8 p. 3 BayGDIG or art. 10 p. 1 UIIP), who will commit to prepare the data according to the regulations and to observe the technical requirements. The UIIP provides that permission be given only when it corresponds with a public interest.

The data must also be related to one or more of 34 themes (which are a duplicate of the themes contained in Annex I-III of INSPIRE): coordinate reference systems, geographical grid systems, geographical names, administrative units, addresses, cadastral parcels, transport networks, hydrography, protected sites, elevation, land cover, ortho-imagery, geology, statistical units, buildings, soil, land, human health and safety, utility and governmental services, environmental monitoring facilities, production and industrial facilities, agricultural and aquaculture facilities, population distribution — demography, area management/ restriction/ regulation zones and reporting units, natural risk zones, atmospheric conditions, meteorological features, oceanographic features, sea regions, bio-geographical regions, habitats and biotopes, species distribution, energy resources and mineral resources. The detailed specification of these themes will be decided in implementing rules and when it will be necessary transpose to each legal order in form of regulation.

§§ 5–7 of GeoZG, art. 5–7 BayGDIG and art. 5–9 UIIP regulate the provisions of spatial data, spatial data services network services (except UIIP which resigned of this term) and metadata. The regulations are similar to those found in the INSPIRE-Directive. It is very general because the details are to be provided in the implementation rules, such as the details of interoperability.

According to the GeoZG metadata, spatial data, spatial data services and network services will be components of the national Spatial Data Infrastructure and will be connected into an electronic network. Access to this network will be possible throughout a Geoportal. The UIIP provide also access to spatial data services and thereby to spatial data sets as well as metadata throughout Geoportal, which will be created and funded by the Polish Chief National Geodesist.

Generally the spatial data and spatial data services are available for use by both the public and public authorities. But not always and not all the information may be accessible for everyone because of, for example, data protection issues. The clear rules have to exist and be known. The SD provides the possibility of treating people differently based upon where they live. For instance, it will likely be possible to process spatial data, like addresses, with the other spatial data, like the area where people are more likely to have cancer, thereby allowing insurance companies to treat people differently based upon where they live in the country. This could result in people being unable to insure themselves. In such situations the consumer would be the injured party because of the free access to SD. Therefore, the SD aims to protect against such misuse of spatial data.

One could also imagine a bank combining spatial data to determine credit ratings without looking at the actual financial situation of a potential customer. Or one could envision poachers using publicly accessible spatial data to allow them to more easily gather information on rare species in order to illegally catch or kill them.

These basic examples illustrate only a few of dangers which are related to the public and unlimited access to spatial data and spatial data services. That is the reason why in some cases the access has to be limited. The restrictions are contained in all three Acts[26] and they are also regulated similar to the rules contained in art. 13 INSPIRE. Generally the public access to spatial data and services through the discovery services may be limited where such access would adversely affect international relations, public security or national defense.

In case of other services (view services, download services, transformation services, and services allowing spatial data services to be invoked) the GeoZG uses the restrictions contained in Environmental information Act, and access may be also limited where it could have a potentially adverse impact, for example:

a) international relations, public security or national defense,
b) the confidentiality of the proceedings of public authorities,
c) how a court case is conducted with regards to the ability of one to obtain a fair trial or the ability of a public authority to conduct an enquiry of a criminal or a disciplinary nature,
d) condition of the environment to which such information relates,
e)but all of this exceptions must have a prevailing value as a public interest than a right from individual to have an access to this data. As far as
f) the confidentiality of personal data,
g) confidentiality of commercial or industrial information and
h) the interests or protection of any person who supplied the information requested on a voluntary basis without being under, or capable of being put under, a legal

[26] See: §12 GeoZG, art. 11 BayGDIG, and art. 11 UIIP.

obligation to do so, unless that person has consented to the release of the information concerned

are not in danger.

According to UIIP its regulations do not offend the rules of the Polish Act of 3rd October 2008 on access to information about the environment and its protection, involvement of society in environmental protection and estimate an influence on the environment.[27] The restriction to the access to view services, download services, transformation services, and services allowing spatial data services to be invoked are similar to these contained in the GeoZG.

With regards to public authorities it is possible to restrict the access to spatial data and services when following would be exposed:

1) the running trial,
2) the request of any person to receive a fair trial,
3) the ability of a public authority to conduct an enquiry of a criminal or disciplinary nature,
4) public security,
5) national defense or
6) international relations.

The public authorities in Germany and Poland which provide the access to the spatial data and services are allowed to implement licenses and payments, but generally access to the discovery and view services should be available without cost.

Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with the INSPIRE-Directive by 15 May 2009. The consequences of delayed or incomplete implementation can result in extreme financial penalties for the Member States.

7.3 Conclusions

The aim of passing the Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE), was to provide the possibility to use the added value which common access to spatial data may bring. The only way this aim will be achievable is through the digitalizing of the SD and making them accessible throughout the Infrastructure for Spatial Information in the Internet. The more countries, the bigger area is included in such infrastructure, the better are the benefits of establishing such Infrastructure (synergy effect). But it shall be functional only when the SD will be interoperable throughout the entire system.

[27] Dz.U. Nr 199, poz. 1227.

To use these benefits, all the subjects in the infrastructure (all the Member States) have to implement the INSPIRE-Directive with the same result. That is the reason why full implementation is so important.

Federal states where the SD are collected on the municipal, federal states and federal level, have a more difficult task. For example in the Federal Republic of Germany the implementation of INSPIRE-Directive needs to be passed in or added to existing law in at least 17 separate and individual government entities (1 federal and 16 on the federal states level). In the process of establishing a German Spatial Data Infrastructure, all actors in all levels have to cooperate.. Only a well planned and organized cooperative effort will result in success in connecting the European and German Spatial Data Infrastructure. The situation with central states, such as the Republic of Poland, seems to be easier because only one new Act must be passed. But this Act has to adjust the new information techniques to the law passed in the People's Republic of Poland which is currently in force and change it in a proper way, making this process complicated.

The implementation of the INSPIRE-Directive is also difficult because all (or nearly all) the ministries in each Member State have to participate in this task.

Further complications relate to the unlimited access to all gathered information and the problems with thereunder also an enormous data collection effort, such as the protection of personal data or intellectual property rights. The implementation Acts constitute a general framework which will be made more concrete by passing implementation rules according to art. 22 p. 3 of INSPIRE or throughout the national regulations.

The main aim and structure of SDI, which is to be established, results from the Directive itself and the national acts in Germany and in Poland generally duplicate its regulations. The most important issue is to assure the interoperability of spatial data, protection of personal data and copyrights. Further research should clarify how these regulations will assure its proper protection.

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Section II: Cartographic Modelling

Chapter 8

Automated Building Simplification Using a Recursive Approach

Tomas Bayer

Department of Applied Geoinformatics and Cartography, Faculty of Science, Charles University in Prague, Czech Republic
bayertom@natur.cuni.cz

Abstract

This article presents a new generalization algorithm for automated or semi automated buildings simplification based on the recursive approach. From the data set with a higher level of detail another data set that containing a lower level of detail can be derived. The proposed algorithm has an ability to detect and simplify buildings rotated in random position and does not depend on ordering of points. To determine the angle of rotation ϕ of the building, a smallest area enclosing rectangle is constructed. The splitting procedure is performed on the basis of splitting criterion σ calculated for each edge of the building. The simplified edges are replaced with regression lines, whose parameters are determined using the least squares method. The algorithm was implemented in C++. With the use of ArcObjects libraries, a new DLL application designed for ArcGIS 9.x was created. This tool is applicable to the polygonal shape files.

Keywords: digital cartography, automated simplification, buildings generalization, recursive algorithm.

8.1 Introduction

A geometric generalization carries out a controlled reduction of the map content based on the analysis of the geometric properties of elements. It tries to remove those elements that are not significant in the map context. The generalization is a

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subjective process with an accent to knowledge and experience of the cartographer. The computational geometry makes a process of the simplification less dependent on a subjective view of the cartographer. But the algoritmization of the simplification process is ambiguous. It is not an easy task to find and set a geometric criterion that should be satisfied by a simplified element.

Automated or semi automated generalization is currently being solved in many ways. Commonly used simplifying algorithms can not be applied, they do not maintain internal angles ($\pm\frac{\pi}{2}$) formed by the adjacent polygon edges representing the building and parallelism. Thus, the building simplification has some constrains that make this process more difficult.

8.2 Related Work

The cartographic generalization represents a process of deriving a cartographic product with a lower level of detail from a source (and more detailed) cartographic product. The resulting map should be easy readable, clearly decodable with aesthetic pleasing (Weibel et al. 1998). The simplification represents a process of more interdependent elementary geometric and graphic operations, an implementation of one step conditionally causes the next step. This idea was mentioned by McMaster (1987) and further developed. A decomposition of the generalization process into sub-processes using generalization operators was introduced by McMaster & Shea (1992), Weibel (1997), Weibel & Dutton (1999). The concept of Elementary Generalization Operations (EGO) described by Sester & Brenner (2004) defines a set of Simple Operations (SO) and rules that can be applied to the geometric structures. Some of these elementary operations (i.e. insert/remove vertex) and concepts are used by the proposed algorithm.

A simplification of the polygon boundary represents one of the generalization operators used in categorical generalization (Galanda 2003). Douglas-Peucker Algorithm (Douglas & Peucker 1973), one of the most frequently used methods for line generalization, has been repeatedly modified: non self intersect version (Wu et al. 2003) or polygon version (Guibas et al. 1993).

A concept of the automatic building generalization based on removing or resolving short edges was published by Staufenbiel (1973). Kanani (2000) presented modified Douglas-Peucker algorithm for buildings. Sester (2000) published a building simplification method based on the least squares adjustment. A recursive algorithm for the building approximation was developed by Gross et al. (2005), a recursive algorithm based on modified Douglas-Peucker algorithm using the least squares adjustment was implemented by Dutter (2008). The proposed algorithm tries to improve the ability to simplify rectangular buildings of complex geometric forms.

The process of the simplification will be significantly modified due to a request for the recursive solution of the problem. From the cartographic perspective it provides relatively good results, see *Chapter 8.6.* Haunert & Wolf (2008) brought an interesting solution using graph algorithms, their implementation is based on the heuristic solution. Yan et al. (2008) introduced an approach to automated building grouping and generalization based on Voronoi diagram and topological adjacency.

8.3 Basic Concept

A map represents an abstract expression of the reality. To maintain the basic characteristics of the cartographic outputs, a controlled reduction of information must be performed. This process results in a simplification of the map content. The generalization takes an important role not only in cartography but also in computer graphics. It allows to reduce the amount of information and to shorten the visualization process. Some basic concepts can be defined as follows.

Building definition. Let us consider a non convex rectangular polygon in the plane to be a building. This polygon is bounded by a finite collection of n line segments. Each segment e_i has two vertices $P_i, P_{i+1}, i \in \langle 1, n-1 \rangle$. Let $P_1, P_2, ..., P_n$ be n points representing vertices of the polygon and e_i, e_{i+1} two adjacent and perpendicular line segments. The building usually does not have to be oriented in the "basic position", when all edges are parallel to axis x, y of the coordinate system. In general, the position of the building is rotated. The angle of rotation ϕ must be detected as a first step of the simplification algorithm. An initial boundary edge consists of all points of the building.

Building simplification. The aim of the simplification process is to find another building representation based on a rectangular polygon of the simpler geometric form (in general non convex). The geometric form of the resulted polygon will be affected by the location of set of vertices of the simplified. During the simplification process such edges, that are not significant in the map context, are removed. Simplified edges are replaced with the set of new edges of a simpler form, whose parameters are determined using the least squares method.

Splitting criterion σ. For an assessment of the geometric complexity of the edge a criterion based on the standard deviation σ is used. This criterion is calculated repeatedly for each detected edge of the building. It is compared with a maximum value of the criterion σ_{max}. Value of the criterion depends on the geometric complexity of the edge, for more complex forms becomes of greater values. Until $\sigma > \sigma_{max}$, each edge is recursively decomposed to the sets of new edges. However σ_{max} represents a simplification criterion regulated by a user.

8.3.1 Scheme of the Simplification Process

Proposing an algorithm with a reasonable time complexity (quadratic or sub-quadratic time complexity), providing appropriate cartographic results and minimizing the needs of manual corrections seems to be a hard problem. In addition, we have the following requirements for the simplification algorithm:

- the ability to simplify a rotated building,
- self intersections removing,
- the ability to keep an area of the building,
- the regulation of the simplification factor by a user,
- ability to simplify non-convex shapes with more complex geometry.

In terms of computational geometry these points will be explained in more detail.

Scheme of the algorithm. The simplification process can be shortly described using the following steps:

Algorithm 1: Scheme of the simplification process.

1: Detection of points orientation, see *Chapter 8.4.1.*
2: Detection of the angle of rotation ϕ of the building:
3: Construction of the convex hull of the set of points, see *Chapter 8.4.2.1.*
4: Construction of the global smallest area enclosing rectangle of the set of points, see *Chapter 8.4.2.2.*
5: Counterclockwise rotation of the building (the angle of rotation $-\phi$), see *Chapter 8.4.3.*
6: Detection of the vertices and edges of the "no-rotated" building using the recursion:
7: Insert initial boundary edge into stack S, see *Chapter 8.4.4.*
8: Processing all edges, see *Chapter 8.4.4.*
9: Reconstruction of the simplified building, see *Chapter 8.4.5.*
10: Clockwise rotation of the building (the angle of rotation ϕ), see *Chapter 8.4.6.*

In order to simplify mathematical calculations, a generalized building is firstly rotated by the angle of $-\phi$ (the building is rotated so that its edges are parallel to the axes of x and y). In this position, all steps of the simplification process are carried out. Finally, the simplified building is rotated to the starting position by the angle of ϕ.

8.3.2 Hierarchical Detection of Vertices

The presented algorithm is based on the idea of hierarchical detection of vertices. Vertices are detected on the basis of their geometric significance. New vertices are gradually added to the building, among them edges of the building are geometrically reconstructed. The similar approach uses Douglas & Peucker algorithm and for buildings also algorithm presented by Dutter (2008).

The idea of the algorithm is based on repeated search for such pairs or two pairs of points, that are located *closest* to the vertices of the smallest area enclosing rectangle, constructed over every edge. Those points will represent new vertices of the building in the next step. All points P_i, which are located "between" two adjacent vertices, are matched all in all to the new edge. This step is similar to Duter (2008), but the process of the detection and results are different.

A replacement of detected edges. Each detected edge of the buildings will be replaced by the set of new edges of simpler geometric forms. Edges of such simple geometric forms, that can not be further split, will replaced by regression lines. Neighboring detected edges are perpendicular to each other. Splitting edges will be processed using recursive approach in the same way.

Detection of the vertices. As mentioned above, we will consider a non convex rectangular polygon in the plane to be a building. The process of detection of the vertices is based on repeated searching for such pair or two pairs of vertices N_j, $j \in \langle 1,4 \rangle$, $N \subset P$, that are closest to one pair or two pairs of vertices M_j of the smallest area enclosing box. Let M_1 represents a point with coordinates $[\min(x_i), \max(y_i)]$. We suppose, that vertices M_1, M_2, M_3, M_4 of the smallest area enclosing rectangle (and thus edges e_1, e_2, e_3, e_4) are clockwise oriented. The process of detection over each edge represents analogy to the situation over the first edge rotated by the angle of $\frac{\pi}{2}, \pi, \frac{3}{2}\pi$, see *Figure 8.1.* This problem is, instead of the rotation of the constructed smallest area enclosing box, also easily solvable by changing an ordering of formal parameters (eg vertices). Let us use this idea for a further development of the algorithm.

Change ordering of formal parameters. If some detected edge of the building is parallel and has the same direction (e.g. it is same orientation) to other edge of the smallest area enclosing rectangle than the first edge (formed by vertices M_1, M_2), we formally rearrange ordering of the smallest area enclosing box vertices (and thus detected vertices of the building).

Depending on the orientation of the detected edge of the building to the orientation of the edge of the smallest area enclosing box constructed over the whole building (i.e. global enclosing rectangle) a set of the vertices $\{M_1, M_2, M_3, M_4\}$ of the smallest area enclosing rectangle over the detected edge (i.e. local enclosing rectangle) is rearranged to another set, see *Table 8.1.*

Table 8.1. An rearrangement of vertices of the local enclosing rectangle depending on the orientation of the detected edge *e* to the global enclosing box

Detected edge *e*, orientation same as	$g^{(1)}(e)$	Rotation	Set of vertices	Vertices of the building
1. edge	1	0	$\{M_1, M_2, M_3, M_4\}$	$\{N_1, N_2, N_3, N_4\}$
2. edge	2	$\frac{\pi}{2}$	$\{M_4, M_1, M_2, M_3\}$	$\{N_4, N_1, N_2, N_3\}$
3. edge	3	π	$\{M_3, M_4, M_1, M_2\}$	$\{N_3, N_4, N_1, N_2\}$
4. edge	4	$\frac{3}{2}\pi$	$\{M_2, M_3, M_4, M_1\}$	$\{N_2, N_3, N_4, N_1\}$

So, we are working with a local enclosing rectangle and rearranging its vertices in accordance with the orientation of the corresponding edge of the global enclosing rectangle.

Vertices of the buildings. Let N_j, $N_j \subset P$, represent four (possible) vertices of the building closest to points M_j. Then point N_1 is the closest to the point M_1, etc., see *Table 8.1.* For the global enclosing rectangle all four vertices (2 pairs) will be searched, for the local enclosing rectangle only one vertex or 2 vertices will be searched.

Remark: For Euclidean distance d and index k $k = 1,2,3,4$, where $k \neq j$, we suppose $d(M_j, N_j) < d(M_j, N_k)$ and $d(M_j, N_j) < d(M_k, N_j)$. In some cases the conditions may not be satisfied. Case one, $d(M_j, N_j) = d(M_k, N_j)$, represents one point N_j closest to the two different vertices M_j, M_k of the enclosing box. Case two, $d(M_j, N_j) = d(M_j, N_k)$, represents two vertices N_j, N_k closest to one point M_j of the enclosing box.

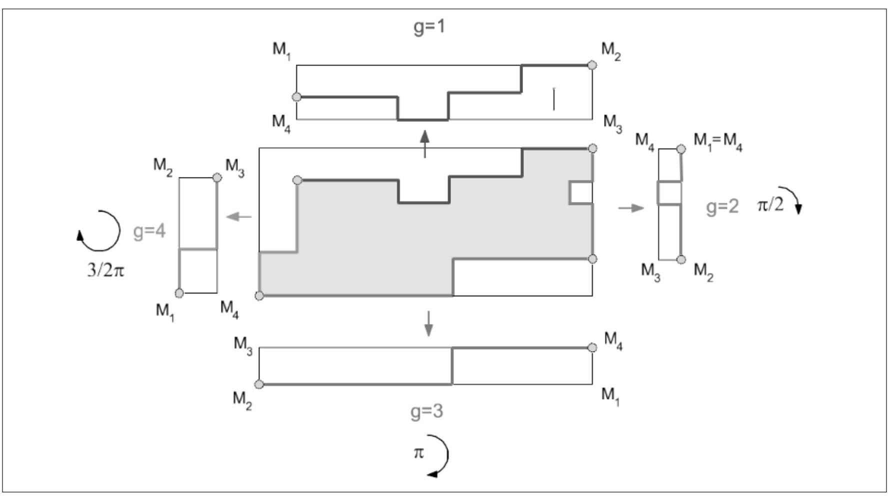

Fig. 8.1. The global and four local smallest area enclosing rectangles with the rearrangement of the vertices

8.3.3 Orientation of Vertices and Edges

This algorithm keeps information about the orientation of the each edge of the building to the edge of the global smallest area enclosing rectangle at any moment. Let g, $g = 1,2,3,4$, represents an orientation of the building segment e to corresponding edge of the enclosing rectangle. As mentioned above, edges of the enclosing rectangle are clockwise arranged. Orientation g of the segment e depends on the orientation of its first point N denoted as $g(N)$. This orientation is subsequently set for all points P_i lying within the segment e. After finding four vertices M_j of the smallest area enclosing rectangle and four closest vertices N_j of the building the simplified building is split into four segments e_1, e_2, e_3, e_4. We set, $g(e_2) = 2$, $g(e_3) = 3$, $g(e_4) = 4$. For details see *Chapter 8.3.3.1.*

Depth of recursion. Let us denote r the depth of the recursion. For any depth of recursion, we are able to determine an orientation of the segment of the building e to corresponding edge of the smallest area enclosing rectangle constructed in this recursion depth.

The relationship $g^{(r)}(N)$ to $g^{(r-1)}(N)$. Let $g^{(r-1)}$ represents a cumulated orientation of the "parent" edge in the last recursion depth $r-1$, let $g^{(r)}$ represents a cumulated orientation of any "child" edge (i.e. actual edge resulting from a split of the parent edge) in the actual depth of recursion r, and let g^{act} represents an orientation of the actual edge in the actual depth of recursion r to the corresponding edge of the local smallest area enclosing rectangle. The relationship $g^{(r)}(N)$ to $g^{(r-1)}(N)$

$$g^{(r)}(N) = g^{(r-1)}(N) + g^{(act)}. \tag{8.1}$$

How to determine orientation of the segment in any recursion depth to corresponding edge of the (global) smallest area enclosing rectangle, constructed over all points P of the building (it means in the first recursion depth, $r = 1$)? We can write

$$g^{(1)}(N) = g^{(r)}(N) mod(4) - (r-1) mod(4). \tag{8.2}$$

If

$$g^{(1)}(N) \begin{cases} = 0, & g^{(1)}(N) = 4, \\ \neq 0, & g^{(1)}(N) = g^{(1)}(N) \end{cases}.$$

Formula (8.2) is calculated repeatedly for each detected edge. For the sample of values $g^{(r)}$ in recursion depths $r = 1,2,3,4$, see *Table 8.2.*

Table 8.2. Values $g^{(r)}$ for recursion depths $r = 1, 2, 3, 4$

$g^{(1)}(N)$	$g^{(2)}(N)$		$g^{(3)}(N)$			$g^{(4)}(N)$			
1	2	6	3	7	11	4	8	12	16
2	3	7	4	8	12	5	9	13	
3	4	8	5	9		6	10	14	
4	5		6	10		7	11	15	

Remark: If two orientations $g_1^{(r)}$ and $g_2^{(r)}$ satisfy the following condition $g_1^{(r)} = g_2^{(r)}$, values $g_1^{(1)}$ and $g_2^{(1)}$ may not be equal, providing the condition $r_1 \neq r_2$. This feature shows the need and importance of maintaining the depth of recursion r as a separate variable. During the process of the proposal of the class structure, it is necessary to take this fact into account.

8.3.4 Splitting Criterion σ

The proposed algorithm performs recursive splitting of the edge depending on its geometric complexity. The splitting criterion σ is calculated for each detected edge of the building. It is based on the calculation of standard deviation σ, that minimizes the sum of the squares of the points distances from the regression line; the variance of the residuals is the minimum possible. The regression line is oriented in accordance with one edge of the smallest area enclosing rectangle, it is parallel to this edge (and depends on the value of $g^{(1)}$ of this edge). In this case, there is no need to determine the angle of the regression line. The regression line also passes through the center of gravity of the set of points. For a construction of the regression line, it is necessary to know the value of $g^{(1)}$ given by (8.2). Depending on the value of $g^{(1)}$ the splitting criterion could be rewritten as

$$g^{(1)} = \begin{cases} 1,3: & \sigma = \sqrt{\dfrac{\sum_{i=1}^{n}(y-y_T)^2}{n}}, \\ 2,4: & \sigma = \sqrt{\dfrac{\sum_{i=1}^{n}(x-x_T)^2}{n}}, \end{cases} \tag{8.3}$$

where n represents number of points of the simplified segment e and $T = [x_T, y_T]$ is the center of gravity of this edge. In the first case, σ is only a function of the variable y, in the second case only a function of the variable x. For each edge the coordinates x_T, y_T of the center of gravity usable to its further reconstruction are stored. An interesting opportunity for further research brings adding the dependency of σ on the map scale.

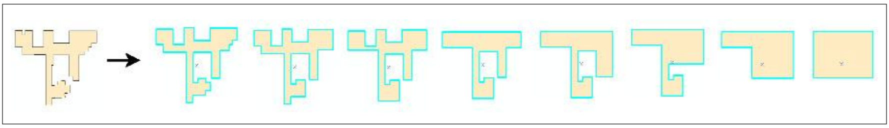

Fig. 8.2. A building with complex geometric form, results of the building simplification depending on σ: source building, $\sigma = 4m$, $\sigma = 6m$, $\sigma = 8m$, $\sigma = 12m$, $\sigma = 16m$, $\sigma = 20m$, $\sigma = 24m$, $\sigma = 28m$

Because of the reduction of the time complexity, a procedure with linear time complexity $O(N)$ is used. Coordinates $[x_T^{(i)}, y_T^{(i)}]$ of the center of gravity for i points can be determined using coordinates $[x_T^{(i-1)}, y_T^{(i-1)}]$ of the center of gravity for $i-1$ points using

$$x_T^{(i)} = \frac{1}{i}[(i-1)x_T^{(i-1)} + x_i], \tag{8.4}$$

$$y_T^{(i)} = \frac{1}{i}[(i-1)y_T^{(i-1)} + y_i]. \tag{8.5}$$

Rearranging (8.3) with respect to (8.4) brings

$$\sigma = \sqrt{\frac{k_1 + k_2 + k_3}{n}}. \tag{8.6}$$

For the orientation $g^{(1)} = 2,4$

$$\begin{aligned} k_1 &= n(x_t^{(n)})^2, \\ k_2 &= -2(x_T^{(n)})\sum_{i=1}^{n} x_i, \\ k_3 &= \sum_{i=1}^{n} x_i x_i. \end{aligned} \tag{8.7}$$

Coefficients for y coordinates could be derived analogously using a substitution of x for y. Coefficient k_1 is determined only once after entering the last point. From coefficient k_2 we calculate repeatedly only the sum, coefficient k_3 must be determined continuously.

Results of the simplification process depending on splitting criterion σ are given in *Figure 8.2.*

8.4 Simplification Algorithm

In this chapter some important steps of the simplification process will be described.

8.4.1 Points Orientation

We assume clockwise and cycling ordering of the points P_i representing vertices of the polygon. The first step of the algorithm represents an ordering test, based on the formula calculating the area A of the polygon

$$A = \frac{1}{2}\sum_{i=1}^{n} x_i (y_{i+1} - y_{i-1}). \tag{8.8}$$

If

$$A \begin{cases} > 0, & \text{points are sorted clockwise,} \\ < 0, & \text{points are sorted counterclockwise.} \end{cases}$$

Ordering of points affects the way, in which points are added to the initial edge. If points are sorted clockwise, they are added at the end of the list using the `push_back()` method. Otherwise they are added to the top of the list using the `push_front()` method. An estimation of the time complexity is $O(N)$.

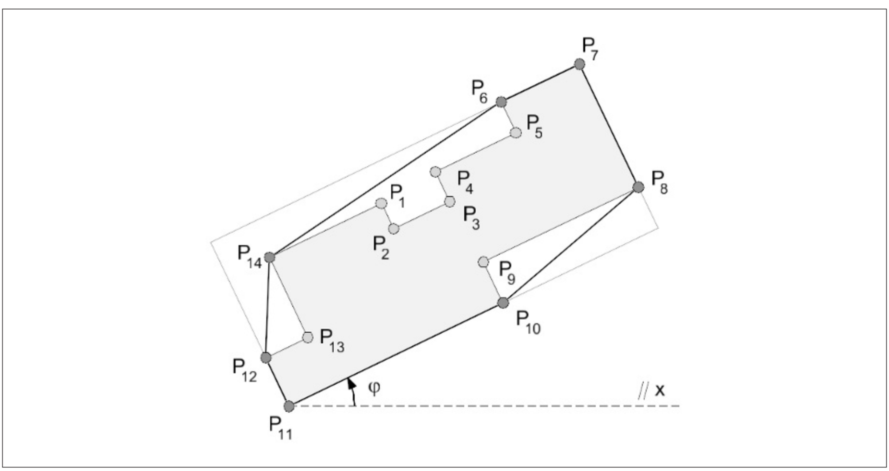

Fig. 8.3. A determination of the building rotation using the smallest area enclosing rectangle

8.4.2 Building Rotation

An accuracy of determining the angle of rotation ϕ significantly affects an effectiveness of the algorithm. The most common method of detecting the angle of rotation ϕ formed by x axis and the longer edge of the rectangle, is based on construction of the minimum bounding box (rectangle enclosing all points with the minimum area), see *Figure 8.3.* An approach based on statistical weighting introduced Bader (2000), a solution using the wall average presented Duchene et al. (2003). Whereas, the calculation is carried out over a large set of points, it is necessary to choose the procedure with low time complexity.

The procedure runs in general over a non-convex polygon and makes the process more difficult. Commonly available algorithms achieve quadratic time complexity $O(N^2)$ for this operation. Using rotating calipers published in Toussand (1983) we can perform this step in sub quadratic time. However this procedure is usable only for convex polygons, it will use a convex hull of the building.

8.4.2.1 Convex Hull

Graham scan enables the construction of the convex hull in sub quadratic time of $O(N\lg(N))$. It assumes, there are no three collinear points in the set. This algorithm is based on the idea of the "right turn". For each triplet $P_i, P_{i+1,} P_{i+2}$, $i \in 1,..,n-2$, we analyze relative position of the point P_{i+2} and the segment formed by points P_i, P_{i+1} (left or right turn). Let us denote $\vec{u} = P_i - P_{i+1}$ and $\vec{v} = P_{i+1} - P_{i+2}$. The right turn criterion we can write as follows

$$\begin{vmatrix} u_x & u_y \\ v_x & v_y \end{vmatrix} < 0. \tag{8.9}$$

A collinearity problem negatively affects the process of construction of the convex hull. This problem is discussed in detail in Rourke (2005, pp. 75–85). However a problem of coincident points (a special case of collinearity) is not significant for GIS data, they are in general topologically valid (without duplicated or coincident points).

8.4.2.2 Smallest Area Enclosing Rectangle

The presented solution described in Toussand (1983) solves the problem using two calipers orthogonal to each other in linear time. An idea of the construction is based on the repeated rotation of the rectangle. This rectangle is gradually improved and becomes an approximation of the smallest area enclosing rectangle in the next step. At least one edge of the smallest area enclosing rectangle must be collinear with at least one segment of the convex hull. Let us denote ϕ_j, $j \in \langle 1,4 \rangle$, four angles formed by the four smallest area enclosing box edges and four edges of the convex hull in points of contact V_j. Each point of contact V_j lies on edge formed by points M_j, M_{j+1}. Let $P_j^s = suc(V_j)$ represents a point, that is a successor of the point V_j, and M_j represents a vertex of the smallest area enclosing box.

A modified version of the rotated calipers algorithm can be formally described as follows:

Algorithm 2: RotatingCalipers (input: points of contact V_j and vertices M_j).

Initialize $\phi = 0$, $A_{min} = \infty, W_j = M_j$.
Find 4 successors P_j^s of points V_j, $P_j^s = suc(V_j)$.
while $(\phi < \frac{\pi}{2})$:
    Calculate 4 angles ϕ_j between line (W_j, W_{j+1}) and line (V_j, P_j^s).
    Find $\phi_{min} = \min(\phi_j)$ and remeber corresponding point of contact and its successor as V_i, P_i^s.
    Using V_i, P_i^s and other three V_j, P_j^s calculate vector equations of edges of the new enclosing rectangle.
    Using vector equations of edges calculate 4 new vertices W_j (i.e. intersections) of the enclosing rectangle.
    If $(\phi_j = 0)$ or $(\phi_j = \phi_{min})$ find new point/points of contact and successor/successors. Repeat:
        increment: $V_j = P_j^s$, $P_j^s = suc(P_j^s)$,
    until line (M_j, M_{j+1}) and line (V_j, P_j^s) are colinear.
    Area A of the enclosing rectangle formed by 4 vertices V_j.
    Increment angle: $\phi = \phi + \phi_{min}$.
    if $(A < A_{min})$:
        Assign: new vertices of the enclosing box $M_j = W_j$, $A_{min} = A$.
        Remeber building rotation $\phi_{res} = \phi$.

We find the minimum angle $\phi_{min} = \min(\phi_j)$ and rotate the rectangle by an angle ϕ_{min}. Another edge of the rectangle becomes collinear with some segment of the convex hull. Three points of contacts will not change. However one point V_j, represented by the start point of the collinear segments, changes to its successor P_j^s. We calculate an area A of the rectangle, compare it with a minimum area A_{min} initialized during the first step to ∞. If $A < A_{min}$, we store $A_{min} = A$. Repeat those steps until $\sum \phi_{min} < \frac{\pi}{2}$ leads to result $\phi = \sum \phi_{min}$, see *Figure 8.4*.

Due to the fact, that buildings are represented by rectangular polygons, in general more than one edge of the rectangle is collinear with more segments of the convex hull. Angles ϕ_j formed by those segments are equal to zero. In this case more than one point of contact V_j changes to its successor V_j^s. It implies the following conclusion: if a tested segment of the convex hull is collinear with some edge of the rectangle, we assign $V_j = P_j^s$ and continue to the first non collinear segment. We repeat this step for all collinear segments (see points 8–10). However there may be such situation, when all four segments are collinear.

Due to the knowledge of points M_j for the last rectangle and points of contact V_j for the new rectangle, we are able to determine coordinates M_j of the new rectangle using analytical geometry. Because of cumulative errors cumulation a problem of the presented algorithm is the numerical inaccuracy.

8.4.3 Rotation of the Building to the Basic Position

The building is rotated by the angle of -ϕ so that its edges are parallel to the axes of x and y (counterclockwise rotation about the origin). Let the point P has coordinates $[x, y]$ in the unrotated coordinate system and coordinates $[x', y']$ in the rotated coordinate system. Then

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} \cos\phi & \sin\phi \\ -\sin\phi & \cos\phi \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}. \tag{8.10}$$

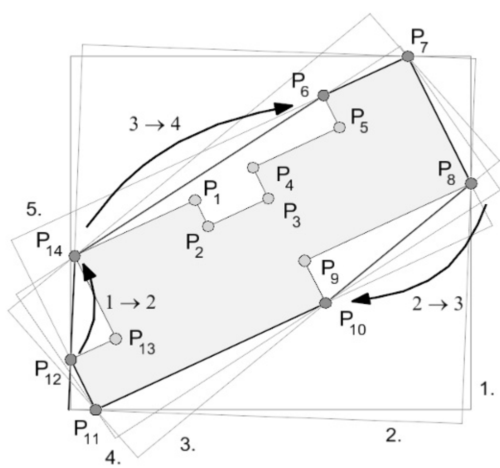

Fig. 8.4. A construction of the smallest area enclosing rectangle using rotating calipers (phases are numbered). Changes of the point V_j to its successor V_j are marked with arrows.

8.4.4 Processing Edges

The proposed algorithm has the ability to simplify buildings of any geometric form with the order of hundreds of vertices, while the algorithm presented by Dutter (2008) some buildings with more complex geometry leaves unprocessed (see p. 58).

The simplification process represents an application of the recursive approach, a recursive processing is realised using the stack S. The first step of the splitting procedure represents insertion of an initial edge e containing all points of the building into stack S. The splitting procedure can be described as follows:

Algorithm 3: Processing edges.

1: Set a depth of recursion: $r = 1$.
2: while the stack S not empty:
3: Pop an edge e from the stack S.
4: Get orientation $g^{(r)}(N)$ of an edge e and a recursion depth r.
5: Calculate orientation $g^{(1)}(N)$ of an edge e, see *Chapter 8.3.3.*
6: Calculate σ for the edge e, see *Chapter 8.3.4.*
7: If e represents initial edge:
8: Split e into four new edges e_1, e_2, e_3, e_4, see *Chapter 8.4.4.1.*
9: Else if $\sigma > \sigma_{max}$ and e has at least 3 vertices:
10: Recursive splitting of the edge e, see *Chapter 8.4.4.2.*
11: Else:
12: Send edge e to the output data structure (list L).

The recursive splitting runs until the stack is empty. It consists of several steps that are repeated while edge e satisfies the following condition: $\sigma > \sigma_{max}$ and has at least 3 vertices. So the procedure performing the recursive splitting of each edge has two parameters. The first one, σ_{max}, represents the simplification sensitivity and could be set by a user. The second one enables or disables splitting of the edge formed by two points.

This step can be formally described as follows: An edge on the top is removed from the stack and split into several new edges if its geometric form is considered as too complex. So, one edge is replaced by more new edges perpendicular to each other. However edges of the simple form are not split but sent to the output. Due to the recursion it is quite difficult to determine a time complexity of the proposed algorithm but having regard to divide and conquer algorithm it can be estimated as $O(N \cdot \log(N))$.

8.4.4.1 Recursive Splitting of the Initial Edge

The first step of the simplification algorithm replaces the polygon with the rectangle formed by four edges. These four edges are subsequently pushed into a stack S. Splitting of the initial edge e formed by the polygon, into four new edges e_j (i.e. e_1, e_2, e_3, e_4) could be described as follows:

Algorithm 4: Recursive splitting of the initial edge e.

1: Find 4 vertices N_j closest to 4 vertices M_j of the global smallest area enclosing rectangle over e, see *Chapter 8.3.2.*

2: If vertices N_j clockwise ordered in edge e:

3: Set orientation $g^{(r)}(N) = g^{(r-1)}(N) + j$ for all 4 detected vertices N_j of the edge e.

4: Split e into four new edges e_j, each edge e_j contains all points between vertices N_j and N_{j+1}.

5: Set orientation $g^{(r)}(N)$ from 3) for all points P_i lying between detected vertices N_j and N_{j+1} of the edge e and for vertex N_{j+1}.

6: Store r for each edge e_j.

7: Push edges e_j into stack S.

8: Else replace a building by the smallest area enclosing rectangle:

9: Create edges e_j from detected vertices N_j.

10: Send edges e_j to the output data structure (list L).

11: Increment $r = r + 1$.

During this step four points N_j closest to four vertices M_j of the global smallest area enclosed rectangle, constructed over this edge, are found. Each point N_j (i.e. new vertex of the building) corresponds with some point P_i, so N_j represents a pointer to P_i. The algorithm also tests, if all points $N_j \Rightarrow P_i$ are clockwise ordered in the polygon. If there is no such ordered set of points, the splitting procedure is stopped and the building is replaced by the enclosing rectangle. Such polygons do not often appear (except of some modern buildings), however the algorithm must be prepared for their occurrence and stops the splitting procedure.

Orientation of new vertices and new edges.

The algorithm keeps information about the orientation of the vertices $g^{(r)}$ in each recursion depth r calculated from (8.2). As mentioned above, an orientation $g^{(r)}$ of the first vertex of the split edge is subsequently set for all points P_i lying within the split edge e. Thus all points belonging to one edge have the same orientation (i.e. we set an orientation $g^{(r)}(N)$ for this edge).

During this step it is not necessary to determine the criterion σ, an initial edge is divided into four new edges in any case. Presented method has the advantage, that orientation of each edge can be determined from the orientation of its first point. Each vertex of an initial edge becomes a start point of one new edge, and at the

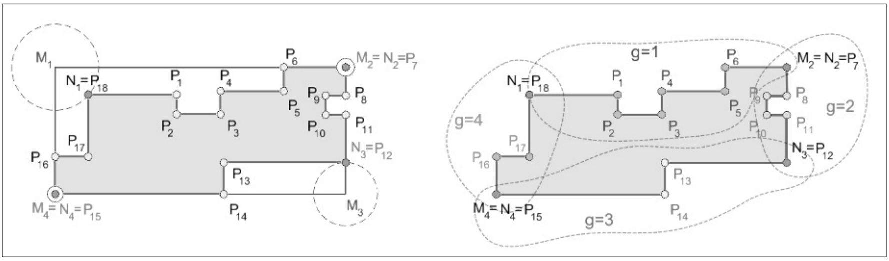

Fig. 8.5. Recursive splitting of the initial edge: finding closest vertices N_j. All points between each pair of vertices are assigned to a new edge

same time an end point of one new edge adjacent to previous edge. Four new edges e_1, e_2, e_3, e_4 are subsequently added to the stack.

It should be noted, that the first point P_1 of the edge *e* may not be at the same time a vertex of the new edge. When setting an orientation, it is necessary to go through some parts of the points list repeatedly.

Orientations of four new edges e_1, e_2, e_3, e_4, generated as a result of the splitting process for initial edge *e* representing by the building in *Figure 8.5,* the recursion depth $r = 1$, are shown in *Table 8.3*.

8.4.4.2 Recursive Splitting of Other Edges

The splitting procedure for other edges of the building is based on the same idea as the splitting procedure for an initial edge. However, it is accompanied by several steps. Recursive splitting of such edge is not always done but only in cases when the geometric form of the edge is more complex. For an assessment of the geometric complexity a criterion based on a standard deviation σ is used. This criterion is called as *"splitting criterion"*. The splitting criterion σ is calculated repeatedly for each edge of the building, and assessing distances of the points to the regression line. As mentioned above, until $\sigma > \sigma_{max}$, such edge is recursively split into sets of new edges. Having regard to the brevity, only the most important steps and options of the splitting procedure will be presented.

Temporary edges. A split edge is intersected by the regression line at least in one point (except the case of collinearity). Such edge is decomposed to several new edges, whose end points are intersections of this simplified edge and the regression line. Those edges are called *temporary edges.* An idea of the splitting procedure is very simple. Each temporary edge is processed separately. All temporary edges are recursively split and replaced by several edges of the simpler form.

Table 8.3. Orientation of four new edges e_1, e_2, e_3, e_4 for $r = 1$

e_1	P_{18}	P_1	P_2	P_3	P_4	P_5	P_6	P_7
$g^{(1)}(P_i)$	1	1	1	1	1	1	1	1
e_2	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}		
$g^{(1)}(P_i)$	2	2						
e_3	P_{12}	P_{13}	P_{14}	P_{15}				
$g^{(1)}(P_i)$	3	3	3	3				
e_4	P_{15}	P_{16}	P_{17}	P_{18}				
$g^{(1)}(P_i)$	4	4	4	4				

Splitting procedure. A splitting procedure for an edge e can be described as follows:

Algorithm 5: Recursive splitting of the edge e.

1: Intersection of the regression line with orientation $g^{(1)}(N)$ and the splitted edge e.

2: Create set of k temporary edges $\{t\}$.

3: For every edge t_k having at least 2 points, orientation $g^{(1)}(N)$ and recursion depth r split t_k:

4: Find a position of the temporary edge t_k to the regression line (left or right).

5: Construct the local smallest area enclosing rectangle over t_k depending on $g^{(1)}(N)$.

6: Find vertices N_j (one or two) closest to vertices M_j (one or two) of the local smallest area enclosing rectangle, see *Chapter 8.8.3.2* and *Chapter 8.4.4.3.*

7: Set orientation $g^{(r)}(N)$ for all detected vertices N_j of the temporary edge t_k, see *Chapter 8.3.2* and *Chapter 8.4.4.3.*

8: Split e into set of new edges $\{e_n\}$, the each new edge contains all points P_i lying between vertices N_j and N_{j+1} detected under each t_k at 6), see *Chapter 8.4.4.3.*

9: For every new edge e_n:

10: Set orientation $g^{(r)}(N)$ (from 7) of the first vertex of the new edge e_n for all points of this edge.

11: Store r for the new edge e_n.

12: Add the new edge e_n to the stack S.

13: Increment $r = r + 1$.

Each edge e is tested whether it intersects the regression line. A list of its intersections is stored for each edge. Intersection can be easily calculated from parametric equations, this step can be done in linear time. Each intersection point stores a pointer to the first point of the edge behind the intersection. A temporary edge t_k is constructed from all points located between two adjacent intersections. However none of the pairs of intersections is added to the temporary edge.

Remark: In some cases (e.g. temporary edge formed by only one point P_i), it is necessary to correct subsequently a form of the temporary edge. For example, such triangle, represented by point P_i, intersection of the segment P_i, P_{i+1} with the regression line and an orthogonal projection of P_i to the regression line, is replaced by the rectangle with the same area.

8.4.4.3 Splitting of Temporary Edges

This procedure represents an important step of the algorithm and significantly affects its effectiveness. One simplified edge may arise at least two new temporary edges. During the recursive subdivision of each temporary edge the local smallest area enclosing rectangle over this edge is constructed. As mentioned above, every split edge of the building has the same orientation $g^{(1)}$ as one edge of the local smallest area enclosing rectangle. Unlike the case of finding the global smallest area enclosing rectangle for an initial edge, only one point or one pair of points closest to one vertex or one pair of vertices, are searched.

First we determine the location of the temporary edge t_k with respect to the regression line passing through the center of gravity $[x_T, y_T]$ of the temporary edge. The temporary edge t_k can be found left or right to the regression line or it may be collinear. In the third case end points of such temporary edge represents new vertices of the building

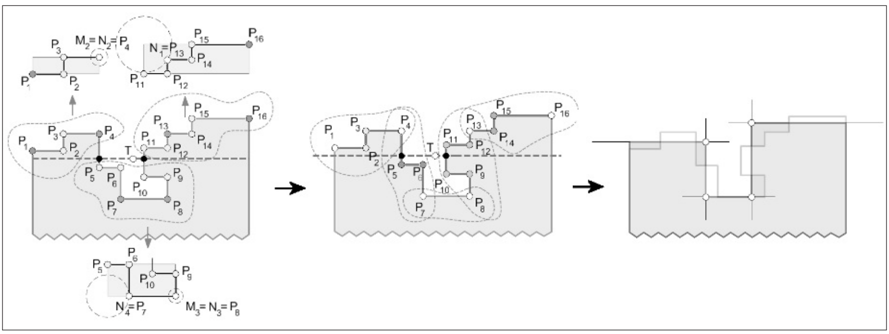

Fig. 8.6. a) Splitting of the simplified edge e, $g^{(1)}(e)=1$, into 3 new temporary edges, detection of the vertices N_j. b) Splitting of 3 temporary edges into 5 new edges, points between each detected adjacent vertices are assigned to new edge. c) The replacement of new edges satisfying the condition $\sigma < \sigma_{max}$ by the regression lines

It is apparent, that a location of the temporary edge to the regression line depends on the location of its first point $P_{(1)} = [x_{(1)}, y_{(1)}]$. The temporary edge t having an orientation $g^{(1)}(N)$ is the left of the split edge e, if

$$g^{(1)}(N) = \begin{cases} 1, & y_{(1)} > y_T, \\ 2, & x_{(1)} > x_T, \\ 3, & y_{(1)} < y_T, \\ 4, & x_{(1)} < x_T. \end{cases}$$

The next temporary edge will be with regard to the regression line in the opposite position than the previous temporary edge, their positions are alternately changing.

Results of the splitting procedure. It should be noted, that points of the building closest to vertices of the smallest area rectangle, represent possible vertices of such building. The first/last temporary edge will be replaced by a pair of new perpendicular edges, the second/penultimate new edge will be shared with the next/previous temporary edge. Other temporary edges will be replaced by a set of three new perpendicular edges. The first new edge will be shared with the previous temporary edge, the third new edge will be shared with the next temporary edge, see *Figure 8.6a.* It is noticeable, that the first and last temporary edges will be split in another way than other temporary edges. Another important variable represents an index of the temporary edge.

New vertices of the building. On the basis of an index of the temporary edge and a position of the temporary edge to the split edge, corresponding points M_j and N_j (vertices) are searched. There are several rules. see *Figure 8.7:*

1. *first temporary edge t on the left of the regression line:* Search for point N_2 closest to point M_2. Point N_2 becomes a new vertex of the building.
2. *first temporary edge t on the right of the regression line*: Search for point N_3 closest to point M_3. Point N_3 becomes a new vertex of the building.
3. *last temporary edge t on the left of the regression line:* Search for point N_1 closest to point M_1. Point N_1 becomes a new vertex of the building.
4. *last temporary edge t on the right of the regression line:* Search point N_4 closest to point N_4. Point N_4 becomes a new vertex of the building.
5. *other temporary edge t on the left of the regression line:* Search two points N_1, N_2 closest to points M_1, M_2. Points N_1, N_2 become new vertices of the building.
6. *other temporary edge t on the right of the regression line:* Search for two points N_3, N_4 closest to points M_3, M_4. Points N_3, N_4 become new vertices of the building.

The splitting process for three temporary edges t_1, t_2, t_3 is shown in *Figure 8.6b.* In some cases the geometric form of the edge may cause problems. As an example the following situation, where one point P_i is the closest point to more than one vertex of the smallest area enclosing rectangle, can be mentioned.

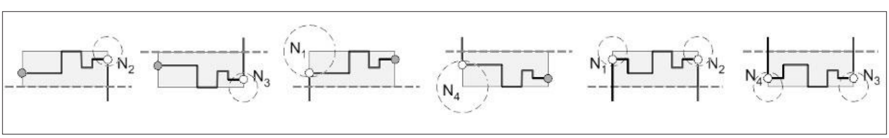

Fig. 8.7. The detection of new vertices of the building using the smallest area enclosing rectangle over temporary edges t_k, $g^{(1)}(t_k) = 1$

Modified splitting rules. If some split edge e has an orientation $g^{(1)}(N) \neq 1$, a set of the vertices $\{M_1, M_2, M_3, M_4\}$ is rearranged to another set in accordance with *Table 8.1.* Let us give an example of some edge with the orientation of $g^{(1)}(N) = 2$. The call of the splitting procedure with rearranged ordering of formal parameters $\{M_4, M_1, M_2, M_3\}$ results in the following assignment: $M_1 = M_4$, $M_2 = M_1$, $M_3 = M_2$, $M_4 = M_3$. All new vertices $\{N_4, N_1, N_2, N_3\}$ will be rearranged the same way: $N_1 = N_4$, $N_2 = N_1$, $N_3 = N_2$, $N_4 = N_3$. For further information about splitting rules see *Table 8.4.*

Table 8.4. Modified splitting rules: an rearrangement of the set new vertices depending on $g^{(1)}(N)$

$g^{(1)}(e)$	R_1	R_2	R_3	R_4	R_5	R_6
1	N_2	N_3	N_1	N_4	N_1, N_2	N_3, N_4
2	N_1	N_2	N_4	N_3	N_4, N_1	N_2, N_3
3	N_4	N_1	N_3	N_2	N_3, N_4	N_1, N_2
4	N_3	N_4	N_2	N_1	N_2, N_3	N_4, N_1

An orientation of new vertices. All found vertices are given an orientation $g^{(r)}(N)$ depending on the position of the temporary edge to the regression line and on an index of the temporary edge. It ensures, that newly created adjacent edges will be perpendicular to each other. Otherwise, it would not be guaranteed, that adjacent edges have any intersection. Look to the following rules $R_1 - R_6$ shown in *Figure 8.7:*

1. For the first point of the temporary edge $P_{(1)}$ we set $g^{(r)}(P_{(1)}) = g^{(r-1)}(P_{(1)}) + 1$, for the point N_2 we set $g^{(r)}(N_2) = g^{(r-1)}(P_{(1)}) + 2$.
2. For the first point of the temporary edge $P_{(1)}$ we set $g^{(r)}(P_{(1)}) = g^{(r-1)}(P_{(1)}) + 1$, for the point N_3 we set $g^{(r)}(N_3) = g^{(r-1)}(P_1) + 4$.
3. For the point N_1 we set $g^{(r)}(N_1) = g^{(r)}(P_{(1)})$.
4. For the point N_4 we set $g^{(r)}(N_4) = g^{(r)}(P_{(1)})$.
5. For the point N_1 we set $g^{(r)}(N_1) = g^{(r)}(P_{(1)})$, for the point N_2 we set $g^{(r)}(N_2) = g^{(r-1)}(P_{(1)}) + 2$.
6. For the point N_4 we set $g^{(r)}(N_4) = g^{(r)}(P_{(1)})$, for the point N_3 we set $g^{(r)}(N_3) = g^{(r-1)}(P_{(1)}) + 4$.

For edges with orientation $g^{(1)}(N) \neq 1$ all vertices (in previous relations) will be rearranged the same way, see *Table 8.4.*

An orientation of new edges. Each detected vertex of the temporary edge becomes a start point of the new edge and an end point of the previous edge. An edge with detected temporary edges is split into a set of new edges. The each new edge contains all points P_i lying between adjacent vertices N_j and N_{j+1}. We set orientation $g^{(r)}(N)$ of the first vertex of new (i.e. split) edge for all points of this edge (i.e. we set an orientation $g^{(r)}(N)$ for this edge). During this step a set of new edges is formed, all edges are subsequently added to the stack. Each edge can be split in the next recursion step equally, if necessary.

Figure 8.6c shows the results of the simplification process for three temporary edges. Split edges satisfying the condition $\sigma < \sigma_{max}$ are replaced by the regression lines. Orientations of newly created edges from the last example are shown in *Table 8.5.*

Table 8.5. The orientation of five new edges e_1, e_2, e_3, e_4, e_5 for $r = 2$

e_1	P_1	P_2	P_3	P_4		
$g^{(2)}(P_i)$	2	2	2	2		
e_2	P_4	P_5	P_6	P_7		
$g^{(2)}(P_i)$	3	3	3	3		
e_3	P_7	P_8				
$g^{(2)}(P_i)$	2	2				
e_4	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}
$g^{(2)}(P_i)$	6	6	6	6	6	5
e_5	P_{13}	P_{14}	P_{15}	P_{16}		
$g^{(2)}(P_i)$	2	2	2	2		

Data structures. For the implementation of the algorithm sequential containers (list) and container adapters (stack) were used. All points are stored along with information about their coordinates x, y and orientation $g^{(1)}$ in the list. All edges of the building are stored with information about points forming the edge in the stack. New edges are pushed into the stack and popped in reversed order. As a result of the use of the list, after the completion of all recursive procedures adjacent edges will be perpendicular to each other.

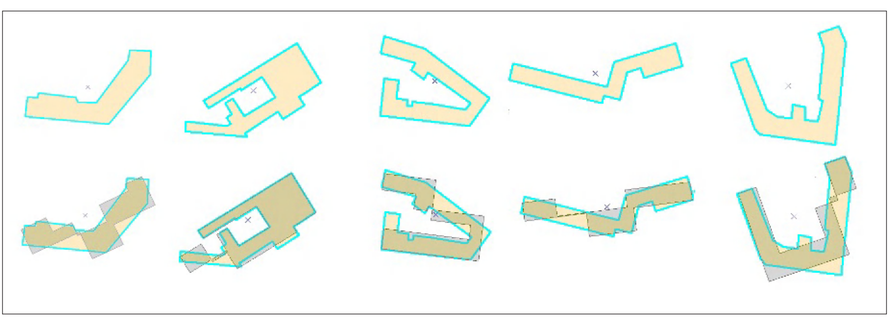

Fig. 8.8. The problem of self intersections for non-rectangular, narrow and long buildings after the splitting procedure, visualization in ArcGIS 9.3

8.4.5 Building Reconstruction

The reconstruction of the simplified building is carried out from parameters of regression lines. Edges are stored in the output data structure represented by the list L, therefore two following edges popped from the list are always perpendicular. The reconstruction process runs in a very simple way.

1. Initialize $i = 1$. Get edge e from the top of the list L.
2. Store coordinates x_T, y_T of the edge e as $x_T^{old} = x_T$, $y_T^{old} = y$.
3. Using (8.2) determine its orientation $g^{(1)}$. Let B_i is a new edge point of the simplified building. If $i > 1$

$$g^{(1)}(N) = \begin{cases} 1,3: & B_i = [x_T^{old}, y_T], \\ 2,4: & B_i = [x_T, y_T^{old}]. \end{cases}$$

4. Add B_i to the building.
5. Go to (1) until we reach end of the list L.

8.4.6 Rotation of the Building to the Starting Position

The reconstructed building is rotated by the angle of ϕ to the starting position (clockwise rotation about the origin). Then

$$\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} \cos\phi & -\sin\phi \\ \sin\phi & \cos\phi \end{pmatrix} \begin{pmatrix} x' \\ y' \end{pmatrix}. \tag{8.11}$$

8.4.7 The Detection of Self Intersections

During the process of cartographic generalization we can be encountered with the problem of self intersections. They represent such situations, in which some undesirable geometric forms (long, narrow and non-rectangular buildings) as results of the generalization process have been created. Due to the topological incorrectness of such data, this error is very dangerous. Closed "pseudo region" is the result of crossing of two or more line segments. In the locus of the intersection there is no vertex inserted. Using GIS software this pseudo region will be considered as topologically incorrect, see *Figure 8.8.*

One of the possible solutions may be a test, which verifies an existence of self intersections. Before an edge removing or edge splitting procedure it is verified, whether actually simplified edge does not intersect any other edge of the building. If so, a procedure for the edge simplification will be canceled. Unfortunately, this step will contribute to a significant slowdown of the algorithm. The fast search (in sub-quadratic time) of possible line segments intersections is a fundamental step of the improved simplification algorithm. One possible solution brings Plane Sweep Algorithm well known as Bentley & Ottman algorithm (Berg et al. 2000, p. 26). Currently a version using Bentley & Ottman algorithm working with the balanced binary tree is being in development. But it shows the need for modification of the concept of the simplification algorithm, first of all some splitting rules.

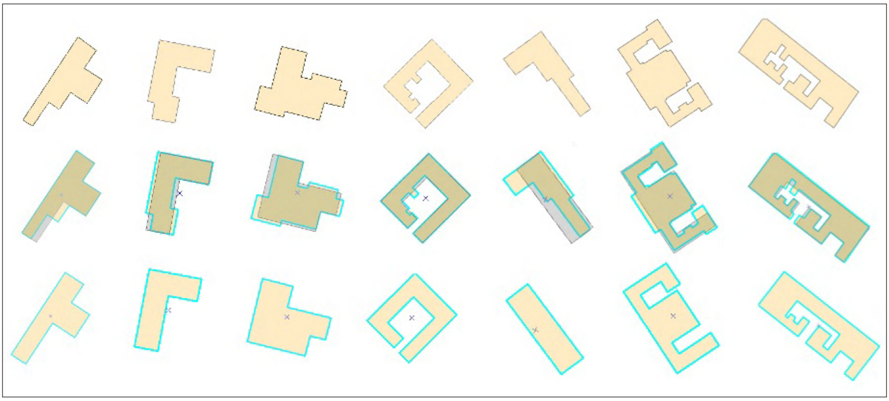

Fig. 8.9. Results of the simplification process for various geometric forms of rectangular buildings, visualization in ArcGIS 9.3

8.5 Results and Implementation

The algorithm was implemented in C++, the graphical user interface was created using WinAPI. With the use of ArcObjects libraries, a new DLL application designed for ArcGIS 9.x was created. This tool is applicable to the polygonal shape files. Author does not use any publicly available library of geometric algorithms.

Table 8.6. Running time (in sec) for the building simplification algorithm depending on the amount of buildings.

Buildings	100	200	500	1000	2000	5000	10 000	20 000	50 000
Running time [sec]	0.8	1.1	2.1	3.6	6.8	17.2	34.3	65.3	163.1

Performance test. Testing was performed on the DLL version of the presented algorithm using a 2.2 GHz CPU, 2 GB RAM, OS Windows Vista and ArcGIS 9.3. Sample data set consists of 51 757 buildings with 357 516 vertices (approx. 7 vertices per building). *Table 8.6* shows the running time depending on the amount of buildings (including redrawing all buildings and saving into feature class). Preliminary results for each set of buildings (100–50000) represent the average of the ten runs of the algorithm under the data set. The performance is significantly affected by the overall slowness, and hardware requirements of the ArcGIS (written in .NET). Nevertheless, the algorithm could be also used for the larger data sets.

Cartographic assessment. The presented algorithm gives cartographic results. It was able to simplify buildings with more complex geometry, sample data contained artificial polygons with hundreds of randomly generated vertices. In most cases, such buildings represent only geometric constructs. However, they generally verify abilities of the simplification algorithm. It also appeared that the need for manual corrections of the simplification process is relatively rare (for rectangular buildings).

This algorithm is suitable for stand-alone rectangular buildings. They represent buildings of "classical" geometric forms, see *Figure 8.9.* Modern architecture is typical of the greater form variability and more complex structures. Due to the fact, that original segments of the buildings are replaced by perpendicular segments, results may look artificially.

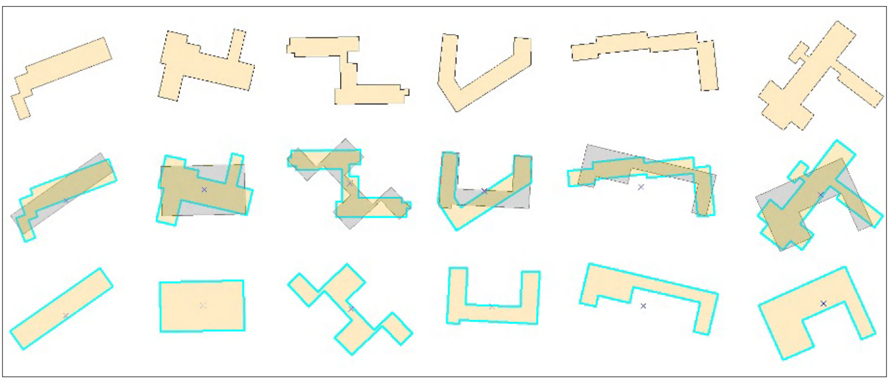

Fig. 8.10. The problem of determining the angle of rotation ϕ for L-shaped and Z-shaped buildings and results of the simplification process, visualization in ArcGIS 9.3

The accuracy of determining the angle of rotation ϕ affects the resulting quality of the simplification algorithm. For U-shaped and L-shaped buildings better results are achieved, L-shaped and Z-shaped buildings bring more problems. For these buildings the smallest area enclosing rectangle may not represent true rotation of the building. As a result of the recursive splitting new vertices in such positions, which are absent in the original building, can be created, see *Figure 8.10.* And so the resulting polygon meets geometric conditions but it is not similar to the building and it has no cartographic relevance (nor aesthetic pleasing). One possible solution of this problem represents the implementation of more reliable methodology for detecting the angle of rotation based on statistical weighting by Bader (2000) or wall average by Duchene et al. (2003) or its combination.

The process of cartographic generalization of the buildings depending on the value of σ_{max} can be considered as quite smooth and natural. Only for buildings, where one of the edges has more complex geometric form than others, the simplification process could be made "in jump". Such edge may be replaced by the regression line during one recursion step, which looks somewhat artificially. Possible solutions may constitute a modification of the splitting criterion or splitting rule.

The presented algorithm nearly keeps an area of the building and therefore it can be categorized in terms of the mathematical cartography as "equal area algorithm" (area distortion less than 5%).

8.6 Conclusion

This paper introduced an algorithm for automated cartographic generalization of buildings based on modified Douglas-Peucker algorithm using the least squares adjustment, that is a redesign of the solution published by Sester (2000), Sester (2004), Dutter (2008). The process of the simplification was significantly modified due to a request for the recursive solution of the problem. As mentioned above, this algorithm is suitable for stand-alone rectangular buildings. Non-rectangular shapes or buildings blocks (in historic urban centers) may cause problems. The proposed algorithm has the ability to simplify buildings of any geometric form, while the algorithm presented by Dutter (2008), some buildings with more complex geometry leaves unprocessed.

For future improvements in functionality, the author is going to modify the algorithm so that it will be suitable for common buildings, prevent self intersections and provide better cartographic results. The aim is to achieve more natural geometric form of simplified buildings and reduce the number of cases, where the algorithm gives cartographic wrong or unaesthetic results. Another possible improvement represents automatic removing of short offsets and extrusions (which may occur as an inappropriate consequence of the automatic simplification algorithm). An interesting opportunity for further research brings adding the dependency of σ on the map scale.

In general, this algorithm provides relatively good cartographic results and minimizes the needs of manual corrections (for rectangular buildings). The presented algorithm was implemented as a stand-alone tool for ArcGIS 9.x and DLL library could be sent freely upon a request.

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Chapter 9

Constraint-Based Evaluation of Automated and Manual Generalised Topographic Maps

Dirk Burghardt and Stefan Schmid

University of Zurich, Department of Geography, Switzerland
{dirk.burghardt, stefan.schmidt}@geo.uzh.ch

Abstract

The paper presents research on constraint-based automated evaluation of manual and automated generalised topographic maps. The research is motivated by a EuroSDR project studying the state-of-the-art of commercially available out-of-the-box generalisation software. At the beginning of the project major effort was spent on defining cartographic requirements in a formal way through cartographic constraints related to four generalisation problems provided by the National Mapping Agencies (ICC, Catalonia; IGN, France; Great Britain; TD Kadaster, Netherlands). After the preparation phase extensive tests are carried out with the generalisation systems ArcGIS (ESRI), Change/Push/Typify (University Hannover), Clarity (1Spatial) and Genesys (Axes Systems AG). The analyses of the generalised maps are based on an expert evaluation, an automated evaluation and a comparative evaluation, which aim to identify and explain the differences between the generalisation solutions

The paper will present in detail the automated evaluation methodology with related research, developed evaluation tools and selected examples of the outcomes. Therefore constraint violation values are calculated and visualised to characterise available generalisation solutions. Major focus will be set also on the comparison of the automated generalised maps in relation to manual, interactive generalised maps. Thus the work published within this paper supports the development of methods for the situation and context dependent application of generalisation functionality and serves on the evaluation of existing generalisation products, to derive future research and development potential.

Keywords: automated generalisation, constraint-based evaluation, topographic mapping, cartographic constraints, characterisation function, reverse engineering

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9.1 Introduction

9.1.1 EuroSDR Project

This paper reports on an on-going work that takes place in the context of the EuroSDR project studying the "state-of-the-art of commercial out-of-the-box generalisation software" (Stoter et al. 2008). The aims of the projects were to show possibilities and limitations of current commercial software for automated map generalisation; as well as to provide insights into commonalities and particularities in the generalisation processes; and finally to identify areas for further research and development. The methodology of the current research builds on the experiences of the former research on the state-of-the-art of generalisation under OEEPE flag (Ruas 2001).

The project started in October 2006 with a project team consisting of National Mapping Agencies (NMAs) and research institutes. In the preparation phase four test cases have been designed based on topographic data sets at larger scales from different NMA. In particular the project team has selected the source and target scales with corresponding symbolisation information and has specified the cartographic requirements on the output maps (Burghardt et al. 2007). These requirements have been defined in formal way as a set of cartographic constraints. Following that the project team has carried out the test with four commercial out-of-the-box software systems: ArcGIS (ESRI), Change/Push/Typify (University Hannover), Clarity (1Spatial) and Genesys (Axes Systems AG). For the evaluation a three step approach is applied as described next.

9.1.2 Evaluation Methods

The evaluation of the topographic maps derived with the different generalisation systems by various testers are carried out manually by cartographic experts and automatically with a constraint-based evaluation prototype (Burghardt et al. 2008). For the expert evaluation, a survey was designed that extends the earlier experts' survey of the AGENT prototype (AGENT 2000). The survey focuses on global indicators which address the overall quality of the output maps, but evaluates also several local, specific situations. The final part of the survey asks the experts to annotate the map with both good and bad examples, by specifically taking into account the interdependencies of several cartographic requirements.

Additionally a comparative evaluation is applied, which aim to identify and explain the differences between the different generalisation outputs as well as the evaluation results. The assessment values for the four systems will be compared to see what software is appropriate to address which kind of problems and to identify cases handled in the same way by all the software and cases that were not handled by any software.

The automated evaluation is based on the calculation of constraint violation values. In S*ection 9.2* of this paper the specification of cartographic requirements with cartographic constraints will be explained. Further an evaluation function will be introduced which describes the main influence factors on the generalisation outputs. In *Section 9.3* experiments with automated evaluation on manual and automated generalised data will be presented. The paper finishes with conclusions on the automated evaluation procedures.

9.2 Theory on Automated Evaluation Based on Cartographic Constraints

9.2.1 Specification of Cartographic Requirements with Constraints

One result of the EuroSDR project was the formal specification of cartographic requirements on the generalisation solutions with help of cartographic constraints. A template has been designed in order to have a uniform way of specification for the four test cases. The template made a distinction between constraints on one object, on two objects and on groups of objects. A further categorisation of constraints was delivered by a constraint typology. The two main categories – the legibility constraints and the constraints for the preservation of appearance – will be introduced in the next subsection. An analysis of the constraint specification showed a heterogeneous distribution with priorities on minimal dimensions for isolated objects, mainly on building, roads and water themes (Burghardt et al. 2007).

Because of the large amount of the initial constraints (250) and because of many constraints were defined for similar situations, the research team decided to harmonise the four NMA specific constraint sets. Further more the harmonisation allowed to simplify the tests and also to ensure consistency between constraints for evaluation so that results on similar constraints could be compared across the test cases. The harmonisation process resulted in a list of 45 generic constraints: 21 generic constraints on one object, 11 constraints on two objects and 13 constraints on group of objects (see Stoter et al. 2008).

9.2.2 Legibility Constraints

Legibility constraints are used to specify cartographic requirements of map readability achieved through the introduction of minimal dimension thresholds. Map objects, parts of them or distances between them should have a minimal size to be clearly legible (Stigmar and Harrie 2008). The limits of visual perception determine threshold values for the minimum size constraints. For example the human eye has a dissolving power of approximately 0.2 mm at a reading of 30 cm (SCC 2005).

Experiments as described later in this paper have shown that threshold values for minimal area and minimal distance are not always preserved during interactive, manual generalisation. Often they are interpreted as recommendations respective guidelines and not as hard threshold values.

9.2.3 Preservation Constraints

Preservation constraints are introduced for the conservation of properties such as shape, pattern, distribution, position, orientation etc. of individual and groups of map objects during the generalisation process. Some of these constraints can be defined by single threshold values such as the allowed change of the absolute position. Other preservation constraints such as shape constraints have to be defined in dependence of the original properties and arrangements. In this case cartographic requirements are described often more general and less formal, e.g. for constraint property "general shape" the constraint to be respected is specified as "target state should be similar to initial state". Cartographic experts might understand the terms *general shape* or *similar to*, but for an automated evaluation more formal specifications are necessary. An overview of formal measures and relations between map objects is given in AGENT (1999), Cheng and Li (2006) or Steiniger and Weibel (2007).

The straightforward approach of one-to-one preservation of the original properties is not always sufficient and it contradicts with the requirement of removing unimportant details. For example a building with a number of small edges will be represented in a generalised map by a square or rectangle, thus the *number of vertices* or *fractal dimension* get reduced. Therefore the constraints have to be specified through functional dependencies.

A model for the description of property evolution during generalisation is the *charaterisation function* proposed by Bard (2004). In his research prototype system, the user has a number of such characterisation functions to choose for the generalisation of building objects mostly. At the moment there are no empirical analysis available which type of characterisation functions are suitable for the different properties as well as how several factors such as scale or context influences the characterisation functions.

Some first experiences are carried out with a reverse engineering approach of manual generalised buildings in topographic maps at 1:50k derived from 1:10k (Schmid 2008). There the characterisation functions were derived by regression analysis for the evolution of building properties such as area size, shape index, concavity, elongation, fractal dimension, perimeter, number of vertices and diameter.

The preservation constraints are calculated from the difference between property values of generalised objects and the property values provided by the characterisation functions. Finally an *interpretation function* is applied to translate the differences in a discrete or continuous way on an interval between zero for no constraint violation and one for maximal constraint violation (Bard and Ruas 2004).

9.2.4 Evaluation Function

In the testing stage of the project, for every defined *generalisation problem*, the four generalisation systems were tested by 2 till 3 testers from the project team. All testers are familiar with generalisation but not necessarily with all the tested generalisation systems. Therefore a distinction was made between *novice* and *expert testers* of the systems. Moreover, the software suppliers were invited to produce outputs in parallel tests where they were allowed to design additional developments to their systems, in contrary to the regular testers who only used out-of-the-box versions of the generalisation systems.

Theoretically there could have been 16 outputs per *generalisation problem* (12 from regular testers and 4 from software suppliers). Because in practice not all the expected tests could be done, there are about 10 different generalised outputs per *generalisation problem*. For the automated evaluation only the vector output layers were used. The provided number of layer varied between 25 and 100 dependent on the applied data schema. In total a number of more than 1’000 data sets (4 generalisation problems x 10 generalisation outputs x 25 layer at least) had to be prepared or inspected for the automated evaluation.

A formal “Evaluation function” was constructed to deal with the huge number of constraint values which could be calculated theoretically under the different conditions.

$E = E$(constraint type, map objects, layer/theme, tester, generalisation problem, system)

A rough estimation leads to 9’600’000 constraint values derived from 20 harmonised constraints, for approximately 1’000 objects per layer/theme, 10 themes, 3 tester, 4 generalisation problems and 4 different generalisation systems.

9.3 Evaluation Experiments

9.3.1 Prototype for Automated Constraint-Based Evaluation

Within the EuroSDR project a prototype was developed for the automated evaluation of generalised data. The evaluation procedure implemented within this prototype follows the typology of Mackaness und Ruas (2007) with three major goals:

a. Calculation of constraint violation values reflecting cartographic conflict situations
b. Derivation of aggregated and average values representing the quality of a part or the overall generalisation result
c. Provision of summary information on modifications resulted from generalisation (e.g. statistical analysis)

The prototype is available as plug-in for the open source GIS “Open Jump” (2009). The user interface (see *Figure 9.1)* consists of three main parts – the presentation frame for the visualisation of generalised and non-generalised data, the application frame for the execution of the evaluation procedures and the output frame which displays the constraint violation values in a tabular structure. Due to the huge number of evaluation results and in order to enable a purposeful control of specific map objects, the presentation and output frame are connected.

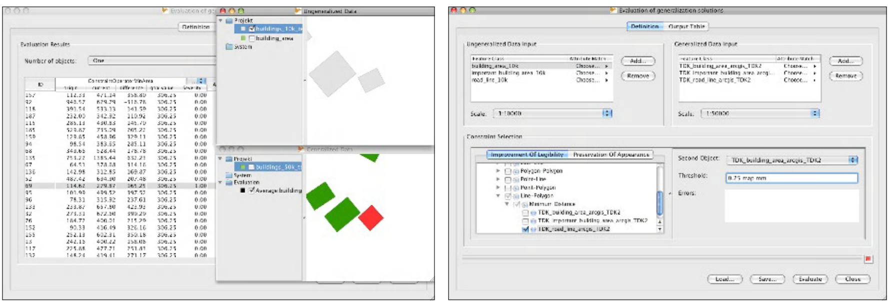
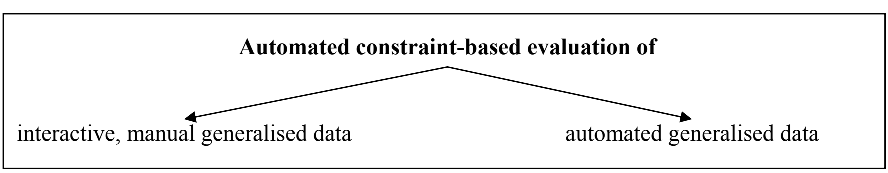


Fig. 9.1. Prototype for automated constraint-based evaluation

9.3.2 Evaluation Experiments on Legibility Constraints

An automated evaluation of legibility constraints is illustrated on the example of building generalisation with two types of constraint a) minimum area and b) minimum distance. The suitability of the automated evaluation method was investigated by applying them first on interactive, manual generalised data. In a second step also the automated generalised data were evaluated through constraint satisfaction values.



9.3.2.1 Evaluation of Interactive, Manual Generalised Data

Manual generalised data of TD Kadaster as currently in production was provided for this case study. *Figure 9.2* shows that 27% of manual buildings falls below the "hard" minimum area threshold value of 400 m^2 and are therefore evaluated as not satisfactory generalisation solution. *Figure 9.3* is an extract of *Figure 9.2* and shows that a large number of objects have only a slightly smaller size than the threshold value. Nevertheless there are buildings, which have an area size far below the threshold

Figure 9.3 shows that many "too small buildings" are just a little below the threshold size. Thus a sensitivity range for the constraint specification might be applied. The difference in minimum area size as mentioned in the specifications and as used in practice can be explained because of two reasons. Firstly the thresholds are meant as guidelines and not as hard values leading to a notion of flexibility around the threshold, i.e. it is not possible for humans to distinguish between the threshold and threshold +/- flexibility (Ruas 1999, Bard 2004). Secondly the interactively generalised objects do not all meet with the requirements because in specific situations the cartographer choose to relax the size constraint in order to meet a more important constraint (for example "keep important buildings"). A comparison

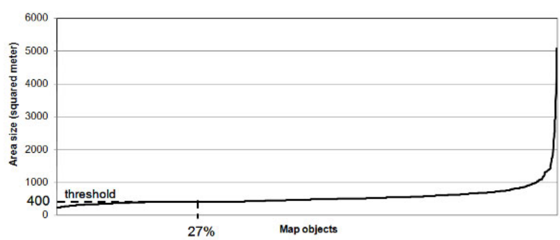


Fig. 9.2. Area size of manual generalised buildings, which shows that 27% of the buildings have a smaller area size than the threshold value of 0.16 map mm^2 (400 m^2 real world)

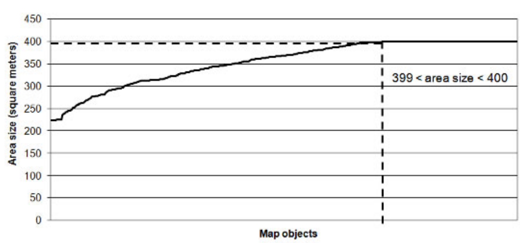


Fig. 9.3. Area size of manual generalised buildings, which shows that a large number of buildings have only a slightly smaller size than the threshold value of 400 m^2. The smallest building has an area size of 224 m^2.

of the area size from buildings at 1:10k and 1:50k in *Figure 9.4* shows the average enlargement of buildings.

The results of the automated evaluation of the minimal distance constraint between buildings (target distance ≥ 0.2 map mm) are shown in *Figure 9.5.* As can be read from this figure, 46% of the buildings are too close to each other (the non violated buildings are not shown in this graph).

Because of the high percentage not meeting the constraint, we examined the violated situations in more detail. We encountered many situations as highlighted in *Figure 9.6a,* which were evaluated as 'bad solution'. If these cases might be acceptable the constraint specification has to be modified or extended. Similar examples are constructed in *Figure 9.6b* and *Figure 9.6c,* which raises the question how specific should the constraint be defined?

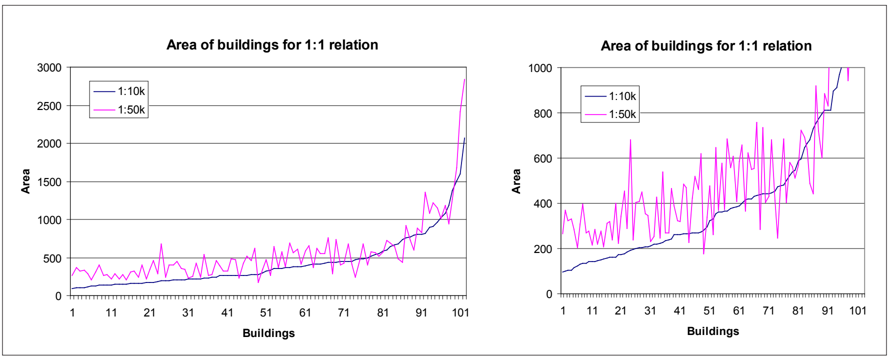


Fig. 9.4. Comparison of building area size at 1:10 k and 1:50 k

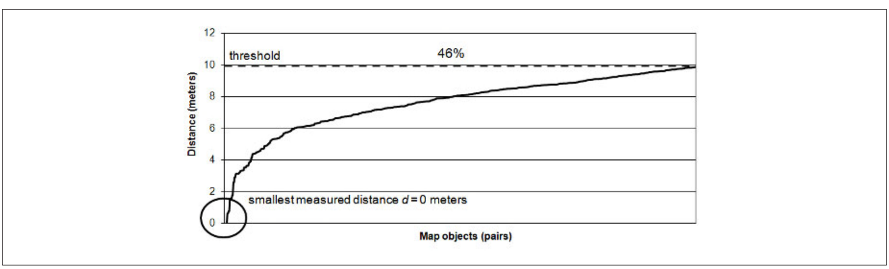


Fig. 9.5. Minimum distance between buildings

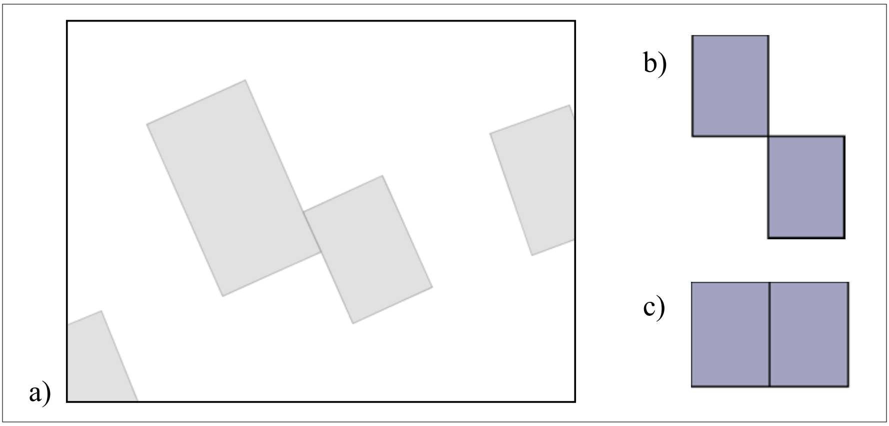


Fig. 9.6. Minimum distance between buildings. a) Extract of original data with minimum distance zero, b) and c) show constructed cases

9.3.2.2 Evaluation of Automated Generalised Data

The automated evaluation within the EuroSDR project was applied on the minimum area constraint of generalised buildings. In *Figure 9.7* three examples of the test case provided by IGN France are selected, which were generalised with the Change-Push-Typify system by three different testers. Thus the evaluation function $E = E$(map objects, tester) contains two variable factors a) the individual map objects and b) the tester. The other factors are constant – constraint type = minimum area; layer/theme = building; generalisation problem = IGN data set; generalisation system = Change-Push-Typify.

The examples show that automated generalisation offers still a lot of flexibility through the selection and parameterisation of generalisation operators. Despite on the fact that the same data set was generalised with the same generalisation system the results varying a lot. In all cases the tester has a huge influence on the generalisation results.

Comparing the different results the reader might guess which result offers the "best" solution. Analysing the violation of minimum area constraint, the results of the third tester are the best *(Figure 9.7 right),* but it is obvious that the overall generalisation carried out was not very successful. In fact a deletion of all objects would satisfy the minimum area constraint perfectly. Thus the example illustrates that an isolated evaluation of constraints needs a careful interpretation.

In *Figure 9.8* the violation of minimum area constraint is compared for the building generalisation of ICC test case achieved with different generalisation systems – $E = E$(map objects, generalisation system, tester). The figures show the variation between the testers as well as the variation between systems.

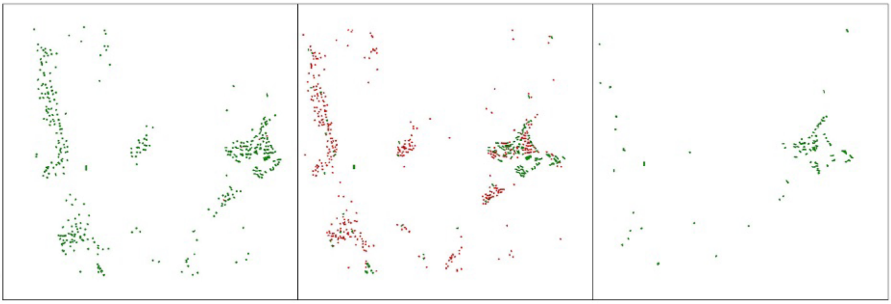
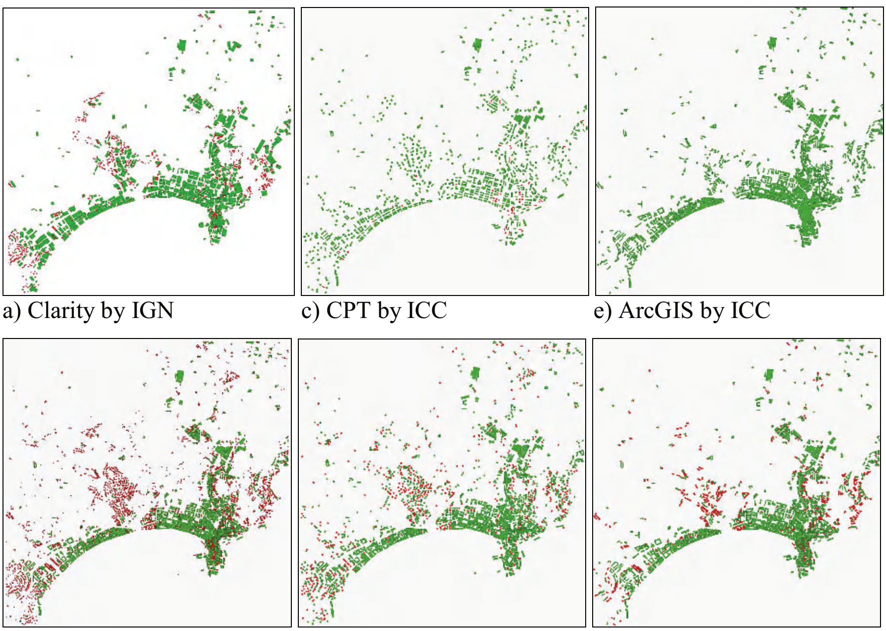


Fig. 9.7. Automated evaluation of minimum area constraint for buildings (IGN data set) derived by automated generalisation. The figures show results of tests carried out by 3 different testers with the same generalisation system (Change-Push-Typify from Uni Hannover).



a) Clarity by IGN c) CPT by ICC e) ArcGIS by ICC

b) Clarity by OSGB d) CPT by ITC f) ArcGIS by TDK

Fig. 9.8. Constraint-based evaluation of automated generalised buildings of ICC data set. Buildings with a violation of minimum area constraint are shown in red. For every system results of at least two different testers could be evaluated.

Figure 9.9 calculates an average value for the violation of minimum area constraint – $E = E$(generalisation system, tester). The ICC tester achieved results with lowest constraint violation of minimum area constraint with two different generalisation systems. Reasons might be that the test case was provided by ICC as well. Thus they had probably more experiences with setting up the generalisation systems for this particular case than the other testers.

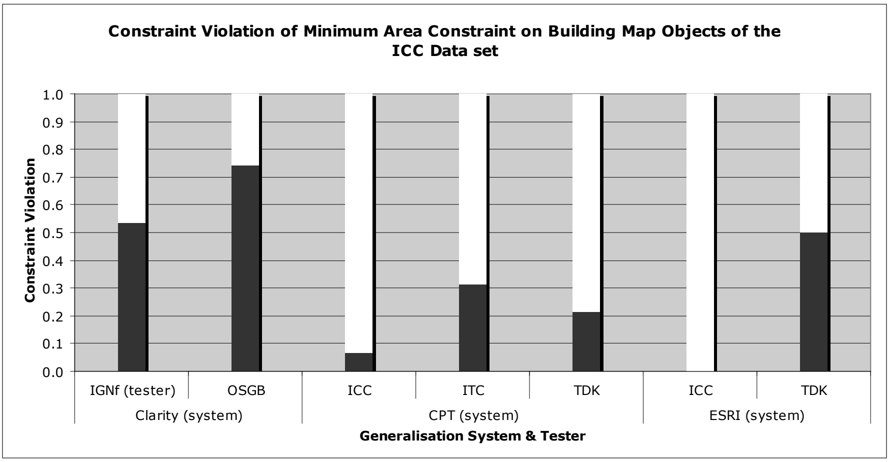


Fig. 9.9. Constraint violation of minimum area constraint on buildings of ICC data set.

9.3.3 Evaluation Experiments on Preservation of Appearance Constraints

First experiments are carried out with an automated evaluation of manual generalised data from TD Kadaster at 1:50k for the absolute positioning constraint. The maximum allowed displacement of building map objects was determined using a threshold value of 0.4 map mm. For the calculation of the constraint violation (CV) a linear interpretation function was applied, thus such buildings removed less than 0.4 map mm (CV = 0.5) are evaluated as nearly good and also less than 0.2 map mm (CV = 0.25) as good and more than 0.4 map mm as nearly bad respective more than 0.6 map mm (CV = 0.75) as bad.

Table 9.1. Summary of evaluation for the absolute position constraint violation (CV) on building map objects

	CV ≤ 0.25 good	0.25 < CV ≤ 0.5 nearly good	0.5 < CV ≤ 0.75 nearly bad	CV ≥ 0.75 bad	Average CV	Quality
Number of objects	273	352	224	114	0.42	Nearly good
Percentage of all obj.	28.3 %	36.6 %	23.3 %	11.8 %		

Further experiments are performed with several shape properties. A reference for the property evolution was derived by reverse engineering from the manual generalised buildings of TD Kadaster at 1:50k and 1:10k (see *Figure 9.4)*. In a first step an assignment of buildings at the 1:10k and the 1:50k were carried out. In the experiments only 1:1 relations between buildings are considered. After that the characterisation functions for the shape properties have been derived by regression

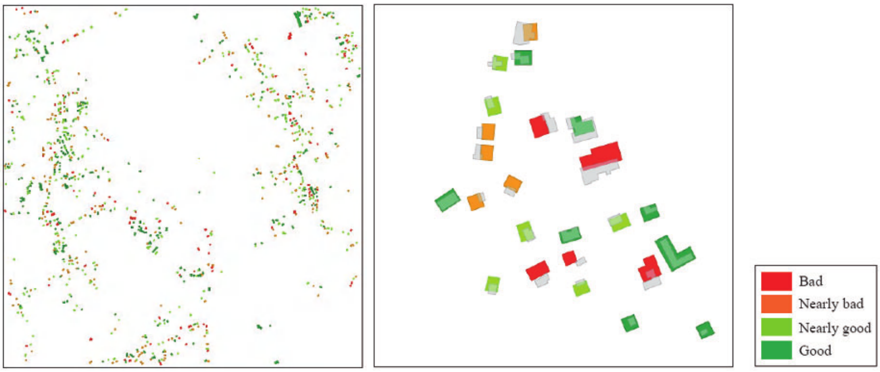


Fig. 9.10. Evaluation of absolute position constraint on manual generalised building map objects from TD Kadaster at 1:50k. Left figure shows an extract of the data set.

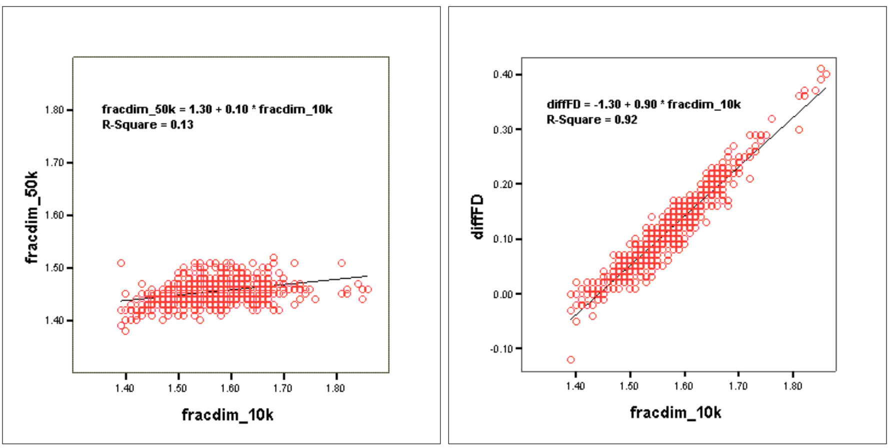


Fig. 9.11. Characterisation function for ***fractal dimension*** property derived by regression analysis of manual generalised buildings from TD Kadaster maps at 1:50k and 1:10k. In the right figure the characterisation function for diffFD = fracdim_50k – fracdim_10k is shown.

analysis as shown in *Figure 9.11* on the example of *fractal dimension (fracdim* = 2 · ln *perimeter* / ln *area* ; with ln – natural logarithm).

The characterisation function determines the average property value at the 1:50k generalised map in dependence of the property value at 1:10k map. The evaluation of the preservation constraints is calculated from the difference between property value of generalised object and the average property value. Therefore an interpretation function with a tolerance range has to be incorporated which models the bandwidth of allowed variations. If the difference between the property value of generalised object and average property value is smaller than the tolerance range, the preservation constraint is good ($CV \le 0.25$) or nearly good ($0.25 < CV \le 0.5$) preserved.

In the first example *(Figure 9.12),* the average fractal dimension value of the final map object amounts to FD = 1.42 which is nearly reached by all three generalised map objects. However, it is obvious that the final value of the manual generalised map object is the closest which is not surprising because the experimentally derivation of the characterisation function arises from this data set. In contrary, the deviation of map objects c) and d) is a wee bit larger which consequently results in a higher constraint violation. Finally, despite of perceptible differences in shape modification, fractal dimension values of all three generalised map objects are very similar.

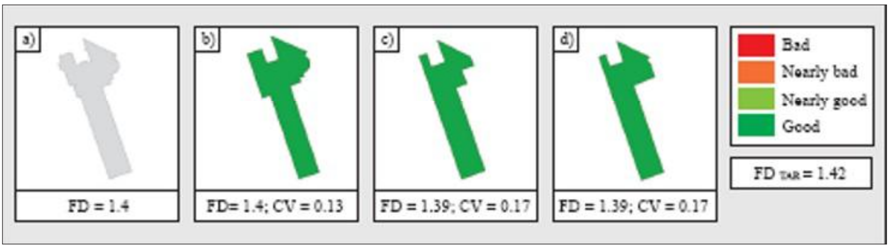


Fig. 9.12. Evaluation results of fractal dimension constraint: a) initial map object; b) manual generalised map object; c) und d) automatically generalised map objects.

The fractal dimension constraint can be used for the evaluation of map object's complexity which generally should be minimised in case of a scale change from 1:10'000 to 1:50'000. In contrary, the elongation which evaluates the width-length-ratio of map object's minimum bounding rectangle (mbr), dictates rather a preservation of the characteristic. In the example of *Figure 9.13* the manual generalised map object has an elongation which is closer to the elongation of the initial map object than the elongation of the automatically generalised map objects. In all three cases, the evaluation results reflect satisfactory solutions.

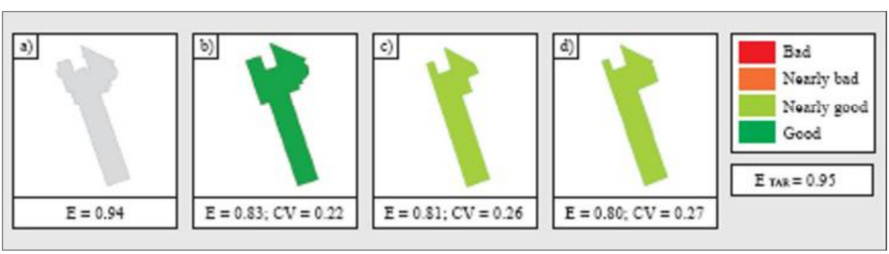


Fig. 9.13. Evaluation results of elongation constraint (ratio of mbr axes): a) initial map object; b) manual generalised map object; c) und d) automatically generalised map objects.

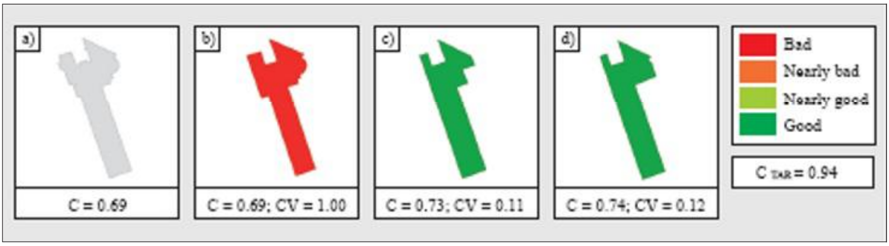


Fig. 9.14. Evaluation results of concavity constraint (ratio between area and convex area): a) initial map object; b) manual generalised map object; c) und d) automatically generalised map objects.

The concavity constraint is based on the ratio between area and convex area, thus it also evaluates map object's complexity. In contrary to the fractal dimension constraint, the evaluation results for the concavity are not satisfactory for all three cases. Map objects c) and d) are minimally violated which seems to be a correct qualification from a visual point of view since there is an adequate simplification at the 1:50'000. By contrast, map object b) is maximal violated and furthermore, it is the only map object whose concavity decreased during generalisation.

9.4 Conclusion

The automated constraint-based evaluation enables the provision of quantitative and qualitative values for different cartographic requirements. The number of constraint values which could theoretically be derived for every object, test case, generalisation system, tester etc. becomes easily very large as shown for the circumstances of the EuroSDR project and therefore difficult to interpret. A reduction of the number is possible through a selective analysis of constraint types and thematic classes, the calculation of average constraint violation values for several objects or a focus on the best testing result per system.

The investigation of interactive, manual generalised topographic maps has shown that minimal dimension thresholds of legibility constraints are interpreted as guidelines and not as hard threshold values. This implicates a more flexible automated evaluation of legibility constraints that takes into account the sensitivity range of threshold values leading to an evaluation result between zero and one, instead of a Boolean outcome. This would have also implications for operators (algorithms) in generalisation systems, which might be able to consider this sensitivity range around the threshold value.

The analysis of automated generalised topographic data has shown a tremendous influence of the tester on the generalisation results. That reflects the flexibility of the generalisation systems, but illustrates also the importance of a thorough adjustment of the out-of-the-box generalisation solutions. Further more the experiments demonstrated that an investigation of isolated constraints requires a careful interpretation. Alternatively a 'constraint by constraint' assessment could be applied in order to get an indicator of the global quality of the map to appropriately address the fact that constraints were violated intentionally to meet more important constraints. This raises questions on weighting and prioritising different constraints as identified also by Bard (2004) and Mackaness and Ruas (2007).

Finally it became obvious that the effort for the determination of preservation constraints is much higher as for the legibility constraints. First the generalised and non-generalised objects has to be assigned (with consideration of m:n-relations). Second the characterisation functions for the property evolution have to be determined. Third an interpretation function is required to transform the difference between property values of generalised objects and the property values provided by the characterisation functions into a constraint violation value.

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Chapter 10

Cross-Border Mapping: Geodata, Geonames, Multilinguality and More

Sabine Witschas

Leibniz Institute of Ecological and Regional Development, Dresden, Germany
s.witschas@ioer.de

Abstract

Recent initiatives and technologies have improved the supply, processing and publishing of geodata, thereby aiding and simplifying the working conditions for the geoanalyses. However, transboundary geoanalyses still have to overcome a number of challenges. A suitable workflow management must be developed for the heterogeneous geodata, various competencies are required to handle multilinguality/multiscriptuality and decisions must be taken concerning the different forms of geonames.

This paper will present recently gained knowledge and skills in the complex and dynamic field of cross-border mapping, highlighting the importance of international coordination as well as appropriate standards, technology and individual skills. The intention is to raise awareness of these difficulties among current or potential "cross-border mappers", encouraging cooperation and the support of specific initiatives in this field.

Keywords: Cross-border Mapping, Geodata, Geonames, Multilingual Maps, Mapping Workflow, Harmonisation, Standardisation

10.1 Introduction

Current EU developments have led to a growth in both the number of transboundary cooperation projects and the need for transboundary geospatial analyses in cross-border regions. At the same time, the recent development of geo-technologies and

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the increased supply of geoinformation should provide the best working conditions for cartographers. So why should cross-border mapping give cause for concern?

Scientists at the Leibniz Institute of Ecological and Regional Development (IOER) in Dresden (Germany) conduct interdisciplinary research on the requirements, concepts and strategies for environmentally-oriented spatial development. Over the past 16 years a significant number of IOER spatial research projects have examined regions of Central and Eastern Europe, including a large number of border areas (Leibenath et al. 2008, Müller et al. 2005, Roch et al. 1995). While IOER cartographers primarily intended to support research by supplying appropriate maps, they soon discovered their own field of cross-border mapping issues (see *Figure 10.1):* A patchwork of heterogeneous geoinformation that has to be mastered at each step of the GIS workflow (see *Chapters 10.2* and *10.4).* The existence of different languages in the study areas greatly affects the workflow, and can be the reason for the creation of multilingual maps (see *Chapter 10.6)*. Moreover, in view of the wide range of consequences, cartographers involved in the creation of cross-border maps must make clear decisions concerning the usage of geographical names (see *Chapter 10.5).*

Experiences gained at the IOER concerning these topics were deepened by an examination of the relevant literature (Afflerbach 2004, Großer & Droth 1996 etc), and condensed into some fundamental principles of cross-border mapping. The following chapters will outline the main problems, advantages and future prospects.

10.2 Cross-Border Mapping

10.2.1 Spatial Types

Spatial environmental phenomena generally ignore political boundaries. In addition, economic and social interdependencies between countries call for transboundary projects, geospatial comparisons and development concepts. Transboundary study areas can correspond to different spatial types, and a review of the IOER cross-border research projects of the past years led to the development of the following proposed spatial typology (see *Figure 10.2):*

SEAM – focussing primarily on one territory, the functional relations of the research subject require the inspection of a zone adjacent to the administrative borders of the study area.

Example: Unfragmented natural areas have a specific importance for nature protection. Large areas can often be found in (cross-) border zones (Walz & Schumacher 2005), and the existing natural units designate the study area better

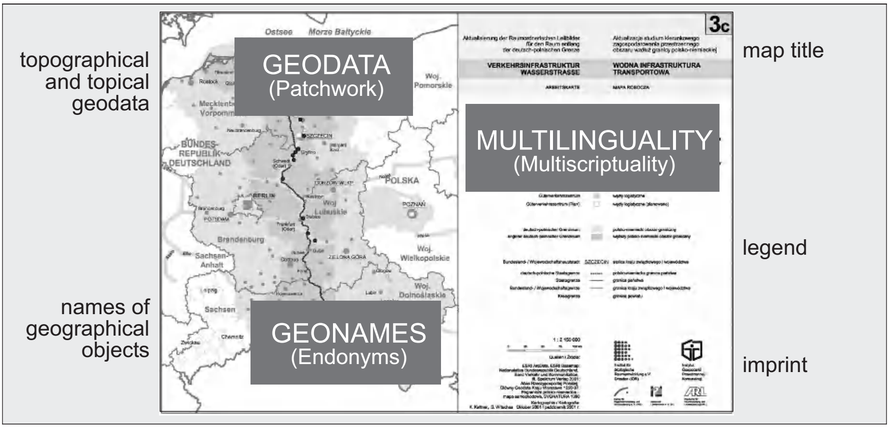

Fig. 10.1. Cross-border mapping issues (Witschas 2005)

than political demarcations. As a result, the project study area includes the territory of Saxony extended by a small seam of additional space.

"CROSS-BORDER" – the study area covers adjacent parts of territories connected/separated by a border. The focus of the investigation is this cross-border area constituted by its internal structures and relationships.

Example: The so-called "Black Triangle" (now renamed to the "Green Triangle") is a region in the southeast of Germany, the southwest of Poland and northern Bohemia. Previously it was notorious for the enormous environmental damages caused by the coalmining industry. A recent IOER research project is trying to evaluate the processes and progress in the region from 1990 until today. The challenge of this geoanalysis is how to handle the multitemporal information describing a multitude of thematical factors in this geographical body (Witschas 2009).

ISOLATED – study areas are chosen for their specific commonalities, even though a common border does not exist or is not of primary interest. The various national affiliations of the study areas cause the heterogeneity of all gathered information.

Example: Former mining regions in several European countries are undergoing dramatic changes. The INTERREG III B READY (Rehabilitation and Development of Mining Regions) connects the stakeholders (Wirth et al. 2006), initiating the gathering of relevant spatial and thematic information necessary to describe and compare the specific situations in the affected regions.

CONGLOMERATE (Europe) – study area is one geographical construct formed by contiguous spatial components. The investigations focus on spatial patterns or distributions within this agglomeration, which is considered to be more or less homogeneous. The intrinsic diversity of the involved territories and resulting heterogeneity of the gathered (geo-) information is usually hidden.

Example: REKULA is another INTERREG III B project of the European Union, supporting the post-mining restructuring of disturbed cultural landscapes (REKULA 2006). A planned comprehensive documentation had to cover all mining regions in the European countries. The collection and processing of information had to resolve the differences concerning languages/scripts, methods/technologies and organisations/responsibility throughout Europe (Witschas & Kettner 2006).

Even the analysis of a single country is not always free from the problem of heterogeneous geodata (Corbin 2009). A recent IOER research project has had to deal with the German Federal geo base data and related issues of harmonisation (Meinel et al. 2008).

Regardless what spatial patterns these study areas present, the problems concerning geo-analysis and mapping prove to be identical.

10.2.2 Workflow

The mere intention to analyse geodata usually initiates a sequence of **work steps** (see *Figure 10.3*). The search for appropriate information, its acquisition and preparation are preconditions for geodata analysis, while visualisation, design and publishing of

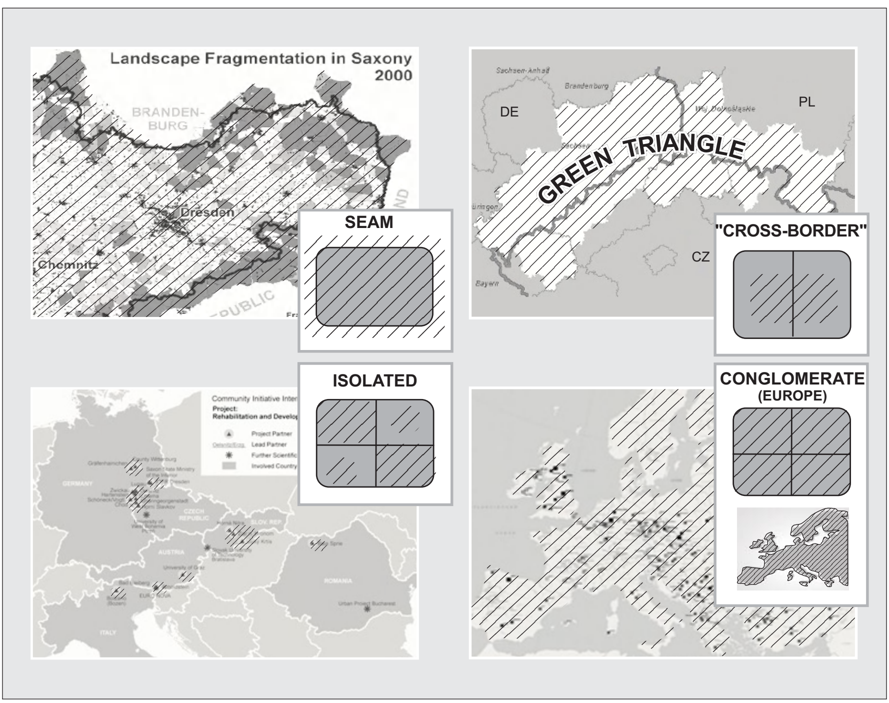

Fig. 10.2. Spatial types of transboundary geoanalyses with examples (Witschas 2009)

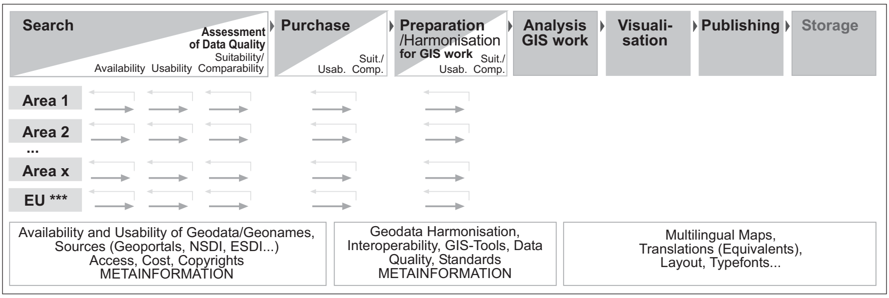

Fig. 10.3. Scheme of a cross-border mapping workflow (Witschas 2009)

maps complete the workflow. The archiving of relevant files and documents should also be considered.

The workflow arising from spatial analyses of transboundary areas is even more complicated, as territorial, departmental, jurisdictional and lingual barriers must first be overcome when gathering all the necessary information (geodata, geonames and other). This cross-border situation can affect and even multiply every step of the map-making process – for instance the search and evaluation of geodata will be **iterative and repetitive** until comparable information for both sides of the border is found.

Accordingly, the **harmonisation** measures performed during the map-making process can be rather complex procedures. GIS can handle varying file formats and support the geodetic or geometric adaptation (e.g. re-projection) of raster and vector data automatically ("on-the-fly") or menu-driven. Attribute data have to be adjusted by the appropriate application of various logical and mathematical operations.

For example, IOER researchers created a tool to harmonise German and Czech spatial base data both geometrically and semantically (Gedrange & Neubert 2008).

Recently, there has been a great deal of discussion and activity in the field of geodata content harmonisation, reflected in numerous publications and projects – including EuroGeographics (Pammer et al. 2009) and GiMoDig (Afflerbach 2004). Ontologies and the integration of schematic, semantic and syntactic data models are generally assumed to have solved these problems. Unfortunately, efforts at the national or supranational level have not yet cleared away all the harmonisation problems in an actual transboundary map-making project.

Thus, "cross-border mapping" can be conceived as the field of cartography which comprises all workflow steps necessary to deal with the transboundary and multilingual situation.

10.3 Characteristics of Cross-Border Maps

Cross-border maps show regions connected or separated by borders which also represent diverse structures, systems and competencies. Depending on the physical dimensions of the transboundary relations, such maps can depict small border regions – whether adjacent or isolated – or larger interregional or transnational spaces.

10.3.1 Content

Cross-border maps are usually the result of transboundary geoanalyses.

Inconsistent or "hybrid" maps merely introduce the geodata without concealing its heterogeneous origin – that is what, for example, OGC (Open Geospatial Consortium) Web Map Services or Web Feature Services provide (Woodsford 2003). When harmonisation is not necessary or feasible, then the differences should be clearly indicated in the graphical visualisation of the map content and in the legend.

However, cross-border maps normally present consistent textual and graphical map content: the thematical layers are homogeneous throughout all territorial units and conceal the previous heterogeneity of technical specifications, geometric/geodetic parameters and semantic aspects.

10.3.2 Function

Transboundary maps have a particular **communicative function**. The non-verbal, graphical language of maps can transmit information about spatial patterns while largely avoiding the semantic problems of spoken language. Also, by representing the material, social and cultural values accepted on both sides of the border, cross-border maps can help strengthen the regional identity of the local population.

Furthermore, cross-border maps can act as **indicators** for successful transboundary coordination. Visualisation of the cross-border issues reveals the degree of professional cooperation and data harmonisation which has been achieved. Conversely, a lack of appropriate cross-border maps and geodata may be one prime cause of poor or non-existent transboundary cooperation (Witschas 2004). In this regard, cross-border maps help to foster the development of cooperation: during the mapmaking phase by connecting specialists in geoinformation or in the phase of map utilisation by supporting users of maps.

10.4 Geodata

10.4.1 Heterogeneous Qualities

The creation of a transboundary map requires the **integration** of diverse geoinformation to provide a sufficiently detailed model of the research subject. The scale and scope of the task may require that supranational, national and regional geodata has to be integrated. Statistical data or special thematic information may be needed for the investigated topic in addition to basic spatial data. All this information is collected by diverse institutions which use various techniques and follow different criteria. Thus, the usual pattern of geodata in a cross-border map resembles a **patchwork.** *Figure 10.4* shows the patchwork, also termed a "zonal fragmentation" in combination with "layer fragmentation/thematic partitioning" (Laurini 1998).

Executing the various steps of the cross-border geodata workflow – search, acquisition, preparation/harmonisation, processing, visualisation and publication – for each of the geodata sets gives some deep insights into the complex nature of **geodata characteristics** (see *Figure 10.5).*

Currently, efforts are being made around the world to define and standardise **geodata quality** parameters such as spatial, temporal and thematic accuracy, resolution, consistency and completeness (Guptill 1995). The **OGC Spatial Data Quality Working Group is continuing** to develop, release and summarise survey results regarding spatial data quality. The ISO 19100 Geographic Information standard series state stipulate data quality elements and measures, quality evaluation procedures, and metainformation issues. These standards are going to be implemented in the European National Mapping and Cadastral Agencies what concerns both topographic and cadastral geoinformation. The relevant guidelines (Jakobsson & Giversen 2006) describe background, strategies and current experiences. Data quality is here defined as a difference between product specification and dataset (Jakobsson & Giversen 2006 p.18). The inclusion of the user requirements is intended. However, the wide-ranging different specific aims of the data use will make this aim difficult to realise (Caprioli & Tarantino 2003).

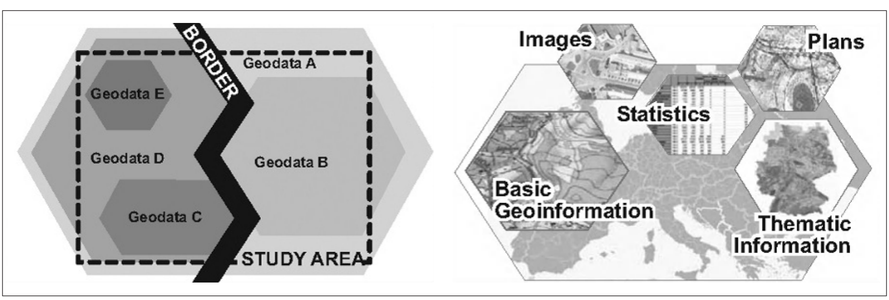

Fig. 10.4. Spatial and thematic patchwork (layout: Witschas 2009)

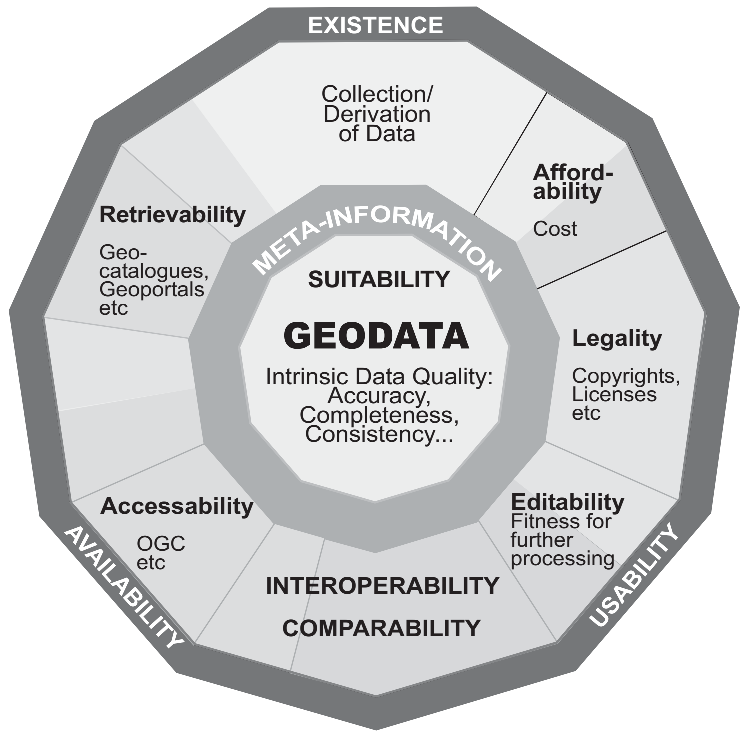

Fig. 10.5. Geodata characteristics relevant for the cross-border mapping workflow (Witschas 2009)

It is the secondary criteria, such as geodata availability (findability and ease of access) and usability (restrictions by price or licenses) which can determine whether specific spatial data is incorporated into a geoanalysis (MICUS 2009).

The quality of analyses is dependent on primary, or intrinsic, geodata quality parameters (see above). In cross-border analyses, comparability of data is essential. This relates to content (general data quality, reliability, criteria of data collection, etc.), geometric/geodetic specifications (scale, projection, etc.) and technical specifications (file format, etc.). **Metainformation** plays a significant role, supplying standards and supporting the scrutinising of data quality and allowing the application of appropriate GIS-tools for geodata harmonisation.

10.4.2 Existence

Geoanalysts can benefit from a wide range of **existing geoinformation**. This comprises primarily the basic spatial data (describing relief, surface waters, settlements, traffic infrastructure and borders) offered by national and federal survey offices. The establishment of NSDI's (National Spatial Data Infrastructures) should enhance the supply of geobase information at low cost and effort (MICUS 2009). Supranational datasets supplied by European or even global data providers (ESRI, EuroGeographics, European Environmental Agency EEA) appear homogeneous. Some of them may have drawbacks in terms of cost, up-to-dateness or poor medium/large-scale accuracy. That may provoke data users to continue their search for geodata or even **create** their **own datasets** by means of a particular data collection or derivation from existing data.

Google Maps and OpenStreetMap are two examples of the current trend towards mapping the world at all scales, and presenting geoinformation at no charge. The final affect of such alternative data sets on cross-border mapping is still vague.

10.4.3 Availability

The internet provides comfortable tools when **searching** for proper sources. The recently developed geocatalogues – often part of geoportals – organise geoinformation according to hierarchies or thesauri. Ontologies generally help to classify the knowledge within a limited subject. However, their usefulness for the broad and dynamically developing geo-sector is disputed (Shirky 2005). An evaluation report on the usability of geoportals (Larson et al., 2006) confirms that they are difficult to locate and inefficient in their search methods. A polish study documents the enormous number of geoportals in one country (Baranowski et al., 2009). Alternatively, search engines can be used to locate geo-information or its supplier. Here, modes and efficiencies vary (Karzauninkat 2007).

Successful search strategies rely on accurate search terms or synonyms, correct translations and notations (e.g. "nature protection" v. "nature conservation" – "ochrana prirody" v. "ochrana přírody").

Language skills or **translation** services help to optimise search procedures and understand foreign web sites. Several transboundary projects have created specific online databases with translated terms – although some of these are now not receiving regular updates (e.g. CEGIS-MDB 2003 – 2005). It is to be hoped that recent developments in the semantic web and spatially aware search engines (SPIRIT (2005), Semantic Web (W3C, 2001)) will indeed prove their worth in practice.

The scrutiny of data quality at an early stage is essential, so that time and money is only spent on geodata which is suitable for the intended purpose (comparability included). **Metainformation** can help by describing the relevant data characteristics. The **INSPIRE** initiative "Infrastructure for Spatial Information in Europe" is developing a legal norm for European and national data infrastructures, beginning with the implementation of metainformation standards in 2009. Thus, metainformation will help assess data quality and support the required harmonisation measures. Some limitations of the data descriptions concerning level of detail and language should be compensated by previews or test files of the particular geodata.

The use of geodata greatly depends on the ease and speed of acquisition. Mapmakers appreciate immediate geodata download or geodata **access** via web services. Here progress has been made with initiatives such as OGC and NSDI (National Spatial Data Infrastructures), INSPIRE and ePSIplus (Public Sector Information in Europe) (Jakobsson & Giversen 2006, MICUS 2009). However, numerous organisational, technical and legal obstacles still have to be overcome before a wide-scale spatial data infrastructure can be developed.

10.4.4 Usability

Geodata **usability** can be constrained by **cost and copyright restrictions**. The feasibility of low-cost or even no-cost geodata supply has been proven e.g. the MICUS studies on geodata infrastructures (MICUS 2006) and public sector information (MICUS 2009). Despites these initiatives in support of free geodata (Corbin 2009), some providers still require their clients to purchase "licenses for use" and "licenses to publish". In view of the potential number of data layers integrated in one cross-border analysis, this practice greatly hampers cartographic work.

Another aspect of geodata usability is the **fitness for further processing** which could be seen as an aspect of extended interoperability (ISO TC 211 "interoperability ... the ability to … employ the discovered information"). Geoinformation web map services now allow the integration of geodata into user's GIS projects but still refuse the editing of either content or visual appearance. This is a handicap for processing and harmonising of geodata.

10.5 Geonames

Spatial entities can have alternative names in different language areas. The local name within the lingual area is termed "endonym", while names in other languages are called "exonyms".

Exonyms can be results of history when explorers/military conquerors were unaware (or dismissive) of original geonames. They can also be introduced to simplify linguistic difficulties where the correct pronunciation in one language exceeds the skills and abilities of non-native speakers. Large geographical objects which extend across national borders can also give rise to exonyms. For example, rivers, mountains or maritime bodies frequently cross a number of language areas, e.g. the Danube river is variously known as the Donau, Duna, Dunaj, Dunav and

Dunarea (Kadmon 2000). *Figure 10.6* shows three online data bases of multilingual and multiscriptual forms of geographical names:

- KNAB, the Place Names Database of EKI (Päll et al. 2006),
- Europe – Forms of Place Names (Wesołowski et al. 2003),
- GeoNames, a community-based name collection offered free of charge under a creative commons attribution license (GeoNames 2009).

Geographical names are usually **standardised** for the sake of better international communication, logistics, planning or disaster management, etc. International boards are dealing with this matter:

- The ***UNGEGN*** (United Nations Group of Experts on Geographical Names) is made up of specialists from the fields of linguistics, cartography and history. The UNGEGN requests national gazetteers (alphabetical lists of names, with coordinates and other data) to promote the use of nationally standardised names on maps and in written documents. This group is also engaged in other measures, such as providing training courses.
- The ***StAGN*** (Ständiger Ausschuss für geographische Namen or Permanent Committee on Geographical Names) works in the German linguistic area and offers, among other things, toponymic guidelines via the internet.

The printed and electronically distributed publications of these bodies recommend the preferred use of endonyms ("Warszawa" in place of "Warschau" or "Warsaw"). Widely used exonyms should be given as additional names.

Fig. 10.6. Multilingual and multiscriptual forms of geographical names (sources: online data bases (1), (2), (3) (see text), layout: Witschas 2009)

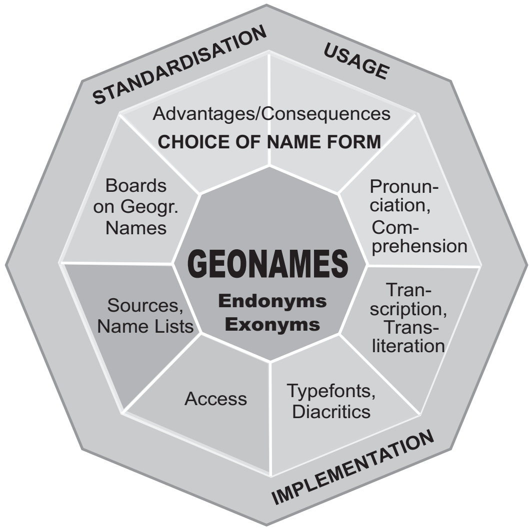

Fig. 10.7. Aspects concerning the diverse forms of geographical names in maps (Witschas 2009)

However, the politically correct application of endonyms has some **consequences** for the map making process (see *Figure 10.7)*.

The use of endonyms requires authoritative **sources** such as official topographic maps or national gazetteers. Access via internet and spatially limited queries to the name bases can improve the usability of these collections. Currently the project “EuroGeoNames” is developing geographical names infrastructure and services basing upon the decentralised national data bases (NSDIs). The multilingual Web Feature Service will start in 2009 (Jakobsson 2008). However, usable lists of multilingual geonames are provided online by teams of scientists and specialists (see *Figure 10.6)*.

The linguistic and script-specific characteristics of human languages may require the adoption of **transliteration** or **transcription** rules. Diacritics and characters which are not part of the Latin alphabet have to be displayed correctly. Appropriate type fonts must be integrated into the workflow and should be kept embedded in the document files. The most recent technical solutions here still lack convenience and reliability.

Endonyms in maps require **pronunciation** skills to ease the wider communication process. UNGEGN and StAGN provide toponym trainings courses and teaching materials, as well as audio files to indicate correct pronunciation of endonyms and their diacritics. The use of endonyms, including correct spelling and pronunciation, is a general problem affecting not just cartographers, but presenting a linguistic challenge to all of society.

The forms of geonames should appear **consistently** in all project documents such as reports, tables and maps. But, in texts endonyms often cause more difficulties than in maps. Besides the already mentioned diacritics and pronunciation problems, name derivations become an issue (Example: a resident of Prague may be called a Praguan, but how to name the resident of Praha?).

The adoption of **anglonyms** (the English forms of geonames) is one solution to this problem as well as to the trouble with diacritics. Projects with international partners usually benefit from English as a lingua franca and use same geographical name forms in maps and texts (see also *Chapter 10.6)*.

10.6 Multilinguality and Multilingual Maps

National borders can also function as linguistic borders. While it is clear that language barriers affect cross-border communication in general, they also hamper team communication at project level as well as research and GIS workflow. The main problems arise in connection with human language abilities such as comprehension, spelling and pronunciation. However, they also involve technical issues such as the handling of foreign scripts and translation tools at the computer.

Linguistic barriers can affect each step of the GIS **workflow** which starts with the search, acquisition and preparation/harmonisation of datasets. Procedures are complicated and slowed down by the necessary expert translation of all relevant information describing the dataset (e.g. internet search terms) as well as the information contained within (attributes and geonames).

Different languages often have their own **forms of geographical names,** requiring appropriate handling in maps (see *Chapter 10.5)*. **Styles** for the placing of exonyms and endonyms have to be defined in order to guarantee the legibility of geonames as well as map contents.

Cross-border maps are often multilingual maps, with **map texts** (title, legend and imprint) translated into all relevant languages (see *Figure 10.1)*. Rather than using several languages, another option is to adopt one commonly accepted **lingua franca** – in the present day, usually English.

In any case, all map texts have to be correctly translated using standard dictionaries (print or online versions), qualified experts or professional **translators**. Great care has to be taken in the case of translated terms which have country-specific professional or legal definitions. For example, although the nature protection area "Nationalpark" in Germany sounds a likely translation for "Národní park" in Czech, in fact the terms have categorically diverse meanings. It takes a degree of expertise to judge the variants and to find acceptable **equivalents**.

Cartographers also have to consider carefully the time needed and possible cost of this translation procedure and the finding of semantic equivalents.

Moreover, they have to compose suitable **layouts** for the double or multiple text entries. The implementation of diacritics and non-Latin characters into the map and the publishing process is always a challenging task.

10.7 Conclusion and Future Prospects

Geodata and geonames are core elements of cross-border mapping. Both are fundamentally determined by heterogeneity, which includes language barriers and lingual specifics. As has been showed, all steps of the **mapping workflow** can be influenced by a cross-border situation. Cartographers have to find practical solutions to meet the particular external factors (availability of information and technological standards) and internal conditions (personnel, time, cost, etc). Cross-border mapping demands knowledge of the specifics of the gathered information (geodata, geographical names), the validity of relevant supranational and national **rules** (standards, laws) and the application of appropriate **tools** (IT technology, GIS features).

This **complex framework** of factors influences the feasibility and efficiency of the mapping process, and careful consideration must be given to their various impacts when planning the project schedule.

Since tasks can change and framework conditions are **dynamic**, the approved workflow of one cross-border project is not necessarily implementable for another one. New geodata, standards and laws, software updates and the dynamics of changing technology may require that procedures have to be adapted (see *Figure 10.8).*

An intensification of cooperation throughout the European Union – and not just in the previously deprived border regions – will increase demands for high-quality and efficient cross-border mapping. Cartographers have to re-examine and increase their expertise in this field. Special training courses or relevant literature may offer the required knowledge and skills, while a system of internet bookmarks and web alerts help to watch the developments in the relevant fields.

An IOER initiated web-portal (see *Figure 10.9)* is one such approach, offering basic knowledge and giving tips as well as helpful links. Experts and interested professionals are invited to contribute or comment on this endeavour, as well as update the contents or suggest fresh ideas. The wide range of topics and organisations involved makes a professional solution seem attractive. Conceivably, a committee of specialists could monitor the various processes and publish relevant results in newsletters, etc.

Cross-border mappers also have some motivation to contribute actively to the respective processes of transnational coordination, as their project experiences can be seen as pioneer work in the field of multilingual geoinformation interoperability. Related European initiatives and large-scale measures such as European Spatial

Data Infrastructure, OGC Web Services and OpenGeoData will have to prove their benefits for cross-border mapping. Discussion among experts can help find a consensus on necessary improvements, as well as helping to develop creative solutions for efficient cross-border mapping.

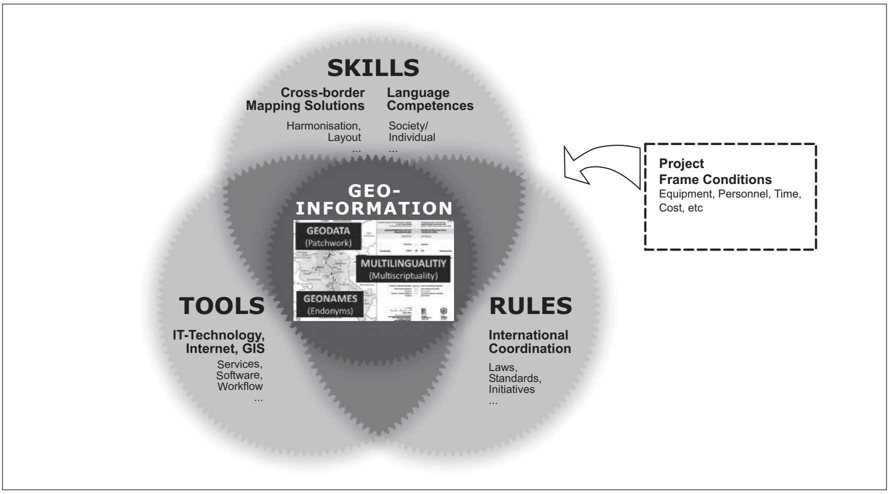

Fig. 10.8. The status of the general frame conditions of cross-border mapping and the limitations of the specific project determine success and efficiency (Witschas 2009)

Fig. 10.9. Cross-border Mapping website – basic information, hints and useful links (www.ioer.de/cbm, Witschas & Kochan 2005)

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Chapter 11

XSLT Templates for Thematic Maps

Otakar Čerba

Department of mathematics, University of West Bohemia, Pilsen, Czech Republic
ota.cerba@seznam.cz

Abstract

Computer technologies are gaining ground in cartography. But support and implementation of the wide range of cartographic interpretation methods ranks among the weak points of most computer systems focused on geospatial data visualisation. This paper tries to fill this gap. It presents XSLT (Extensible Stylesheet Language Transformations) templates and their control file designed for generating some types of thematic maps (e.g. different types of choropleth maps or diagram maps).

The XSLT language was selected for the following reasons:

- Very good compatibility with all XML (Extensible Markup Language) standards, including the GML (Geography Markup Language) format for geospatial data description and the SVG (Scalable Vector Graphics) format for vector graphics description.
- XSLT is standardised by the World Wide Web Consortium (W3C).
- XSLT is strongly supported by many software products, e.g. XSLT processors, XML editors or web browsers.
- Applications created with XSLT can be multiplatform, modular, well-structured, and of course open.

The output of thematic maps can be presented on the Internet, because the maps are generated in SVG format wich is supported by the main web browsers (directly or by plug-in). Some examples of created thematic maps for temporal geospatial data were tested in the VisualHealth project. This project tests different methods of visualisation of geospatial data of healthcare.

Keywords: digital cartography, XML, XSLT, templates, thematic map, SVG, KML

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11.1 Introduction

"I have started to use XSLT 2.0 as my primary programming language (in combination with Python) and I am amazed by its power." (Nic 2005). This sentence was used by Miloslav Nic (the author of the portal ZVON.org – the Guide of the XML Galaxy) in the publication XSLT 2.0 Tutorial (Nic 2005). This sentence characterizes the power and possibilities of style languages, especially the second generation of XSLT (Extensible Stylesheet Language Transformations).

This paper is focused on the implementation of XSLT in digital cartography, especially to generate various types of thematic maps. The main reason for writing about an interconnection of cartography and one or more XML (Extensible Markup Language) technologies is the possibility of extended the usage to a wide range of cartographic interpretation methods. Cartography has many different tools and methods for geospatial data visualisation, but the majority of current software products are unable to exploit the cartographic capabilities, but XML enables creating new and improved styles describing data processing through cartographic methods. The first section of this paper shortly describes XML technologies used in digital cartography in general. After this section the overview of advantages of the proposed approach follows. The last section shows the implementation and results of using XSLT in the VisualHealth project.

11.2 Short Introduction to XML Technologies in Cartography

Before describing the used XML technologies it is necessary to make the term XML clearer. There are many different views on the XML or SGML/XML group (Standard Generalized Markup Language). These languages are called data formats, markup languages, framework for definition of markup languages, meta-languages, metamarkup languages, self-description languages, grammars, technologies or applications. But XML is not itself a markup language. It is a set of rules for building markup languages (Ray 2001). Three main characteristics of XML are described by Eric T. Ray (2001).

1. XML is a protocol for containing and managing information.
2. XML is a family of technologies that can do everything from formatting documents to filtering data.
3. XML is a philosophy for information handling that seeks maximum usefulness and flexibility for data by refining it to its purest and most structured form.

For creating of thematic maps three types of XML technologies are necessary. Regarding geospatial data formats there are two required formats – one for coding and describing source geospatial data and another used for coding and describing thematic maps. At least one language from the group of transformation and style languages (XML Transducers) is intended for the mutual conversion of source and output formats. Cerba (2008a) specifies the large list of markup languages or relative formats suitable for cartography. From this list the following languages from the above-mentioned groups were selected and used:

1. Formats for describing and coding source geospatial data
    1. GML (Geography Markup Language)
    2. JML (JUMP GML)
2. Formats for describing and coding thematic maps
    1. SVG (Scalable Vector Graphics)
    2. KML (formerly Keyhole Markup Language)
3. Transformation and style languages (XML Transducers)
    1. CSS (Cascading Style Sheets)
    2. XSL (Extensible Stylesheet Language) – this language is composed of the languages XSLT and XSL-FO (Extensible Stylesheet Language – Formatting Objects)

GML represents the most widespread "geographic" standard based on XML. This format is managed by the Open Geospatial Consortium (OGC). The Geography Markup Language (GML) is an XML encoding for modeling, transport and storage of geographic information including both the spatial and non-spatial properties of geographic features. This specification defines the XML Schema syntax, mechanisms, and conventions that

- provide an open, vendor-neutral framework for the definition of geospatial application schemas and objects;
- allow profiles that support proper subsets of the GML framework descriptive capabilities;
- support the description of geospatial application schemas for specialized domains and information communities;
- enable the creation and maintenance of linked geographic application schemas and datasets;
- support the storage and transport of application schemas and data sets;
- increase the ability of organizations to share geographic application schemas and the information they describe. (Cox et al. 2002)

JML is the simplification of the GML format, which is used in OpenJUMP, a JUMP software (open-source or free GIS software).

SVG is a language for describing two-dimensional graphics in XML. SVG allows for three types of graphic objects: vector graphic shapes (e.g., paths consisting of straight lines and curves), images and text. Graphical objects can be grouped, styled, transformed and composited into previously rendered objects. The feature set includes nested transformations, clipping paths, alpha masks, filter effects and template objects. SVG drawings can be interactive and dynamic. Animations can be defined and triggered either declaratively (i.e., by embedding SVG animation elements in SVG content) or via scripting (Ferraiolo et al. 2003). SVG is guaranteed by the World Wide Web Consortium (W3C).

KML is an XML grammar used to encode and transport representations of geographic data for display in an earth browser. Put simply: KML encodes what to show in an earth browser, and how to show it. KML uses a tag-based structure with nested elements and attributes and is based on the XML standard. KML documents and their related images (if any) may be compressed using the ZIP format into KMZ archives. KML documents and KMZ archives may be shared by e-mail, hosted locally for sharing within a private network, or hosted on a web server. KML can be used to

- Annotate the Earth
- Specify icons and labels to identify locations on the surface of the planet
- Create different camera positions to define unique views for KML features
- Define image overlays to attach to the ground or screen
- Define styles to specify KML feature appearance
- Write HTML descriptions of KML features, including hyperlinks and embedded images
- Organize KML features into hierarchies
- Locate and update retrieved KML documents from local or remote network locations
- Define the location and orientation of textured 3D objects (Wilson 2008)

Cascading Stylesheets (CSS) are supported and guaranteed by the W3C analogous to the majority of other web formats and languages. CSS is a stylesheet language used to describe the presentation of a document written in a markup language. Its most common application is to style web pages written in HTML (HyperText Markup Language) and XHTML (Extensible HyperText Markup Language), but the language can be applied to any kind of XML document, including SVG and XUL (XML User Interface Language). CSS can be used locally by the readers of web pages to define colors, fonts, layouts, and other aspects of document presentation. It is designed primarily to enable the separation of document content (written in HTML or a similar markup language) from document presentation (written in CSS). This separation can improve content accessibility, provide more flexibility and control in the specification of presentation characteristics, and reduce complexity and repetition in the structural content (such as by allowing for tableless web design). (Wikipedia 2009)

In our application not the complete XSL language is used, because the generated maps are visualised on screen only and they are not printed. Therefore the transformations are provided under XSLT. The language XSLT 2.0 is presently used for a transformation of XML data files. The contemporary version of XSLT along with the query language XPath 2.0 (XML Path Language) constitutes a very powerful tool, which is compared by some experts to programming languages (see the introductory quotation). A XSLT document is composed of one or more templates, which define the transformation of elements and other items of the source XML document to newly created file. XSLT 2.0 was standardized in 2007 by a W3C recommendation. The specification XSLT 2.0 and related languages contains eight documents. (Cerba 2008b)

XSLT represented by an XML file or interconnected files offers many operations with XML documents e.g. querying, selecting, modifying, reclassifying or transforming. XSLT code is processed by an XSLT (transformation) processor, e.g. Saxon, Xalan, etc. The following figure shows the main principle of using XSLT templates in digital cartography.

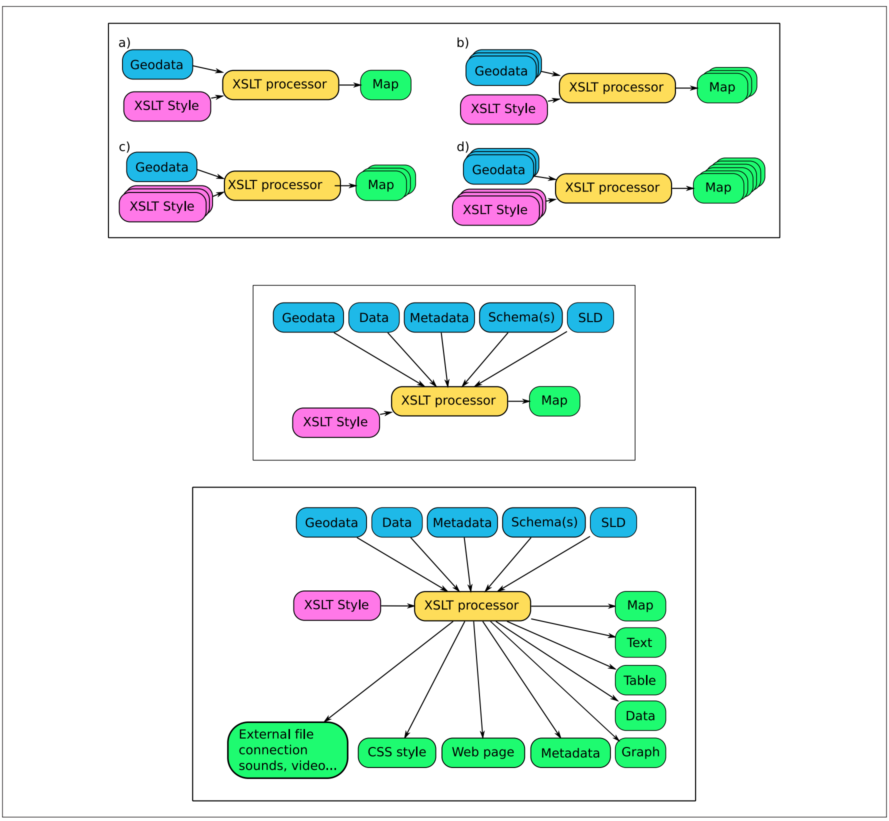

Fig. 11.1. Basic principles of cartographic outputs generating through XML (Cerba 2007)

11.3 Benefits of Using XSLT

Benefits of using XSLT temaplates in digital cartography could be divided into four groups:

1. Benefits of using XML or markup languages,
2. Benefits of using style languages,
3. Benefits of using concrete visualisation formats based on XML,
4. Benefits of the purposed solution.

The first group contains the benefits based on using XML or markup languages in general terms. These benefits result from the characteristics of this language. XML code is written in the form of plain text and the content (data) and meaning or sense of this content (semantics) are separated. The semantics is coded in so-called tags. Due to all attributes of XML and the very simple rules for the application of XML there are the following advantages of using XML:

- Using XML is very simple, because there are about four basic rules for coding XML documents through tags.
- XML files are intelligible to humans (common text files) as well as to computers (strict abidance by rules of coding).
- XML has no predefined tags. Therefore every user can create his own tags and describe any item or structure. XML is very complex, flexible and extensible.
- XML is independent from any software products, software companies, hardware platforms or operating systems.

Style languages benefit from the strict separation of data files and visualisation rules represented by styles. This process is very often used for creating web pages – the HTML file contains only the content of a web page and the meanings of separated parts of the document and the CSS file describe how the tags are presented. The situation in the case of digital cartography is analogous to web pages. The geospatial data is written in a GML file (or in another similar format) and the XSLT and CSS files enable the transformation to the maps or other outputs (tables, texts, graphs, etc.). During the modification of the visualisation rules it is impossible to destroy geospatial data irreversibly by generalisation or converting of the original data model to a cartographic data model. The separation of logical and presentation data enables the application to apply one style to different geospatial data (users can create uniform maps from different source files) and also to use many different styles for one data file (users can create many different maps from one data file without the necessity of copying or modifying this file). Some current GIS products present the separation of data and visualisation form as great news. But markup languages based on the idea of separation of data and its presentation were developed about fifty years ago. The first attempts of this kind in cartography were connected with Styled Layer Descriptor few years ago. But the freedom of XML is still missing.

The selected output formats bring some benefits as well. Both formats (SVG and KML) are based on vector graphics. This could be very useful for some types of maps, especially for all types of thematic maps. SVG offers properties mentioned in the previous section (scalability, support of text and raster graphics etc.). Very important is the interconnection to other XML and web technologies including web browsers. Some web browsers (e.g. Opera, Firefox) have a native support of SVG (in some cases incomplete support – Google Chrome, Safari). The most used web browser, Internet Explorer, needs an external plug-in (e.g. Adobe SVG Viewer – but Adobe discontinued support for Adobe SVG Viewer on January 1, 2009). The KML format is very popular now, because it is designed for Google Earth, a virtual globe, map and geographic information program. But also other software products (e.g. OpenLayers) can work with this format.

The proposed solution is completely formed of XML and related technologies. The benefits of using a uniform type of technologies are above all the interconnection between these technologies and a large number of similar applications. Sufficient experience and a vast bulk of different supporting materials (e.g. tutorials, books, examples, help forums, mailing lists, discussions etc.) result in a large and still rising number of XML users.

The following list summarises some fundamental advantages of the proposed solution:

- Using broadly respected and legitimate standards leads to a higher level of interoperability and accessibility. It is necessary to appreciate that the only way to improve communication between cartographers, data providers, users and technologies is by the support and abidance of standards (technological, cartographic, legislative, etc.), their relationships and interoperability.
- The used software products (web browsers, XSLT processors, SVG viewers or Google Earth) are mostly licensed as freeware or open-source and are offered for free, often together with supporting materials.
- Exploitation of all advantages of styles (e.g. multiple usage, different types of visualisation for one or more data set).
- Use of technologies that make it possible to develop applications that are independent (of platforms, hardware, operation systems etc.).
- Development of a new data model (written in RELAX NG language) describing separated components of the map and their relationships. This model or XML schema may be used for the XSLT transformations and generally for sharing maps, map compositions and all types or cartographic geospatial data visualisations.

11.4 Project VisualHealth & XSLT Templates

The solution based on XML source data and XSLT templates is one of the results of the VisualHealth project (in Czech *Vizualizace zdravotnich dat pro podporu interdisciplinirniho vzdelavani a vztahu s verejnosti,* in English *The Visualisation of Health Data for the Support of Interdisciplinary Education and Relation with Public,* project code 2E08028). This project is developed within the framework of Programme 2E – Human sources (2006–2011) of the Ministry of Education, Youth and Sports in the Czech Republic. In this project three partners from the Czech Republic are cooperating – University of West Bohemia in Pilsen, Masaryk University in Brno (project leader) and Faculty Hospital Brno. The VisualHealth project is mainly focused on cartographic visualisation, on creating different types of thematic maps of public health data for education, their presentation and popularisation. Usage of these easily comprehensible maps of this very complicated data could lead to a higher level of health prevention and protection. Within this project different cartographic methods of geospatial data visualisation on the Internet are processed. For one type of visualisation XML technologies were selected.

For the VisualHealth project three variants of generating thematic maps through XSLT templates were prepared:

Variant	XSLT processor	Version of XSLT	Output format	Presentation tool(s)
1	Saxon 9.x	XSLT 2.0	SVG	Common web browser supporting SVG
2	Processors into web browsers	XSLT 1.0	SVG	Common web browser supporting SVG
3	Saxon 9.x	XSLT 2.0	KML	Google Earth (or any other software supporting KML)

The external Saxon processor (developed by Michael Kay) is safe and very often used (e.g. Tennakoon 2003). The quality of the final maps depends on the level of SVG support in the browser, the programmed control file describing concrete maps and the templates describing the construction of map composition and the interpretation of the cartographic method. The templates create the application which is composed of interconnected separate maps (SVG files). These maps are managed by control items (list of maps, help).

The production of KML maps is very simple as well. The control file and templates are analogous to the previous case. Just one problem may occur with overlapping layers in case of complicated maps.

The second variant of thematic map construction is the most complicated. At first sight it is a very simple method using XSLT processors built into web browsers – users load the data file with the connected XSLT style into a browser and the browser presents the thematic map. But these XSLT processors do not support the newest version of XSLT (for example, version XSLT 1.0 does not contain some mathematical functions or sequences) and the implementation of XSLT 1.0 is often

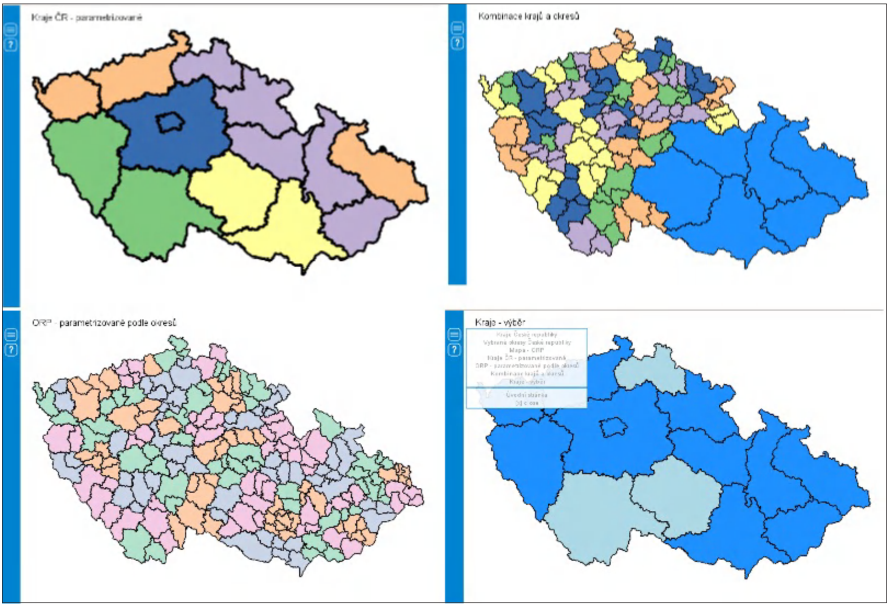

Fig. 11.2. Examples of SVG maps created by XSLT templates.

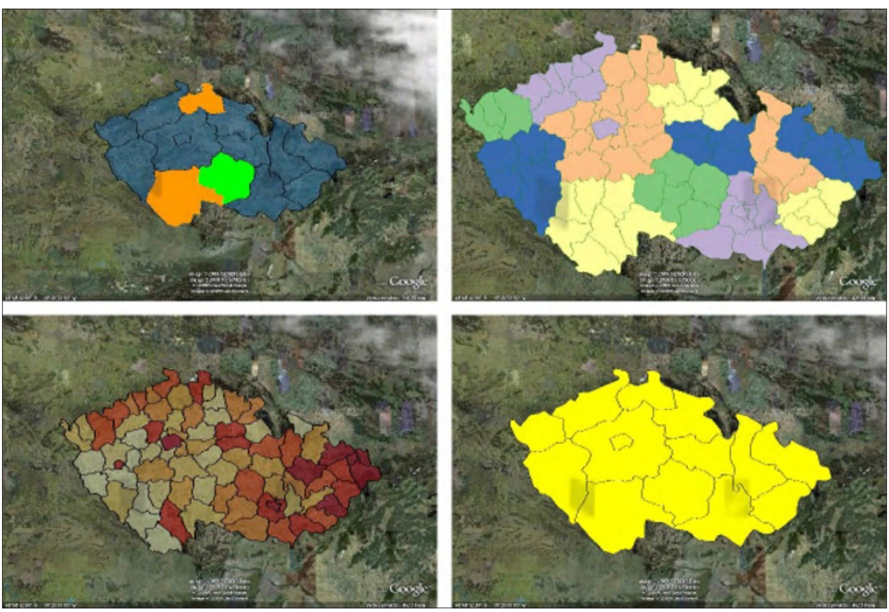

Fig. 11.3. Examples of KML maps created by XSLT templates.

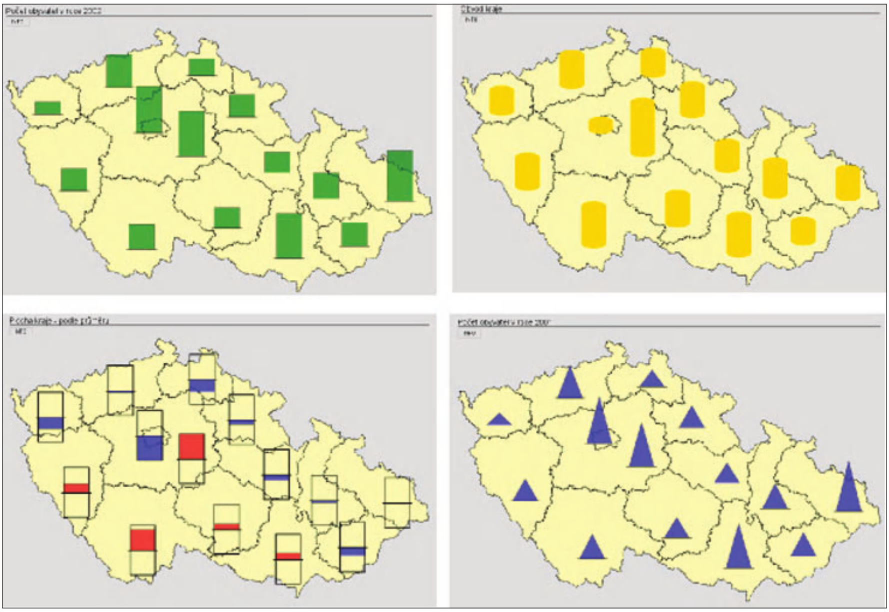

Fig. 11.4. Examples of SVG maps created by Opera web page browser.

very poor. Currently this process works only in the Opera browser. Therefore this variant is not further developed.

XML technologies were used in another project of the University of West Bohemia in Pilsen, Czech Republic. The printed publication *Atlas of International Relationships* (Waisova 2007) was created by external XSLT styles too.

11.5 Conclusion

The application of XML and related technologies in digital cartography or in geoinformatics is common for contemporary map users. Many people use web services (Web Map Service, Web Feature Service, Web Coverage Service etc.) at present. Also the users of ESRI products work with XML – the language ArcXML is important for creating map comopositions. The format KML associated with the very popular Google Earth is mentioned above. XML technologies are connected with the future of information science including geoinformatics. XML technologies represent the fundamental platform of the next evolutionary phases of the web – Web 2.0, Web 3.0 etc. are based on XML and related technologies.

XML is very important in connection with the Research Agenda (Virrantaus & Fairbairn 2007) of the International Cartographic Association (ICA). This document emphasizes terms like interoperability, accessibility, web technologies, cooperation with other branches of science, data harmonisation, semantics, metadata, visualisation models, etc. XML or markup languages are connected with the majority of these terms and in some cases (e.g. web technologies, metadata or semantics) XML represents the fundamental component.

The indirect support of the ICA and direct and very strong support of international standardisation organisations (W3C or OGC) implies a favourable future of XML (including XSLT) in digital cartography. Therefore we want to continue to further development the project of generating maps through XSLT templates. The next steps are:

- Building and designing a user interface that allows the modification of the control files describing the maps.
- Formation of new cartographic interpretation methods.
- Optimization of the XSLT templates.
- Finalization and optimization of the data model written in RELAX NG.
- The conversion of a desktop application to a server application enabling online map generation.

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Chapter 12

Geoinformational Methods in Ecodiagnostical Studies for the Losiny Ostrov National Park Territory

Svetlana N. Arshinova

Institute of Geography, Russian Academy of Sciences, Moscow, Russia
arshinchik@mail.ru

Abstract

Sustainable management of territories of local level appears to be among the topical challenges nowadays. However nature protection areas (traditionally key areas of local econet) are still affected by numerous man-induced factors.

Thereby the results of ecodiagnostical studies (eco-geographical analysis of territory) are of particular importance. Analysis of the quality of environment and its changes under the influence of anthropogenic factors forms a basis for identification of ecological problems, specifying problem-solving methods and elaboration of environmental policy.

In connection with ecodiagnostical research GIS-techniques allow analyzing large amount of miscellaneous information in the most efficient way as well as carrying out timely analysis and synthesis of data.

Keywords: Cartographic support, protected areas, GIS, ecodiagnostics

12.1 Introduction

There are about 250 nature protected areas in the Moscow region. Four of them are the key territories of the regional Econet and have federal level of management. These are the State Complex of Zavidovo (with the National Park status); the Prioksko-Terrasny Biosphere Reserve; the Ivanteevskiy Arboretum; and the Losiny Ostrov National Park.

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The Losiny Ostrov (meaning “Elk Island”) National Park was established in 1983 to preserve the unique ecosystems and valuable natural landmarks of the Moscow region. It also provides habitats for numerous rare species of plants and animals. The Losiny Ostrov National Park occupies the north-west part of Moscow and spreads to the Moscow oblast. This is the largest forest area in the nearest Moscow region occupying 128 sq.km (30 sq.km are within the Moscow city boundaries). Therefore the National Park territory is a link between the Moscow city and the Moscow region Econets as well. Economic development of its territory was rather intensive, but nevertheless it is the least transformed quasi-natural area within the Moscow city. Preservation of the natural ecosystems of the Losiny Ostrov National Park is vitally important for the ecological stability in the region.

12.2 Destabilization Factors

However, the territory of the National Park is permanently affected from outside. The factors of disturbance could be classified into two main groups. First one includes factors of natural origin, such as:

- adverse soil and hydrological conditions;
- natural disasters and unfavorable weather conditions;
- tree ageing;
- decay and canker expansion.
- Second group covers numerous factors of anthropogenic origin, namely:
- road network influence;
- cultivation of lands;
- disturbance of stream conditions;
- withdrawal of forest lands;
- unorganized recreation;
- distress factor of noise discomfort, etc.

Combined effect of the above mentioned factors leads to forest degradation, aggravation of their sanitary state, disturbance of environmental, water-control, recreational and other functions of forests. Further technogenic pressure would result in total degradation of natural ecosystems of the National Park, and the functioning of the Moscow region Econet could be endangered.

One should keep in mind that both direct and indirect technogenic impact on the Losiny Ostrov National Park territory cause damage not only to the particular components of its natural ecosystems, such as soils, water, vegetation or animals. It is people themselves that suffer from the adverse effects of anthropogenic disturbance of the environment. Being users of natural resources humans undergo intellectual and physical discomfort as a result of environment pollution and destruction of landscapes, as well as the decreasing information value of the environment.

12.3 Ecodiagnostics of the Territory

At present the evaluation of the degree of environment comfort for man and other living beings is a point of particular importance. It is based on the analysis of the state of the environment and its changes under the influence of anthropogenic factors. Ecological assessment and mapping of territories provide informational background for the identification of main environmental issues, proposing measures aimed at their solution, as well as for the elaboration of strategies and policies in the sphere of sustainable development of regions.

Eco-geographical analysis of territory (ecodiagnostics) is an interdisciplinary line of research stemming from the complex geography and ecology. It is based on the identification and investigation of features that characterize current and expected state of the environment, ecosystems and landscapes. It also elaborates methods and means for detecting, preventing and liquidating the adverse ecological events and processes. Complex ecological-geographical description of a territory according to the algorithm of eco-geographical analysis could be developed basing on the geosystems analysis and the concept of natural-anthropogenic geosystems. Therefore, the main spatial units under study are the areas of natural geosystems. Various ecological characteristics are attributed to those units in the process of investigation.

12.3.1 Cartography in Ecodiagnostics

Cartographic support is among the main components of ecodiagnostic research. Dealing with spatial data the ecodiagnostics widely apply cartographical methods of investigation and representation of results. Studying ecological problems requires compilation of evaluation maps, both integrated and synthetic. Thus, mapping of environmental situations appears to be a new line of thematic mapping rising from ecodiagnostical studies. This kind of mapping is aimed on the identification and localization of environmental features which have (or could have) negative impact on human well-being or existence.

12.3.2 Algorithm of ecodiagnostic studies

Individual area of environmental situation represents a cartographic synthesis of natural landscapes contours, land use types, population density and the areas with particular ecological problems. This is the fundamental novelty of maps of environmental situations. To compile such map one needs a map of natural landscapes and maps of landscape components (which are already available or should be compiled for the territory under study). Basing on these maps the natural background for environmental problems could be identified as well as regionally specific features of ecosystems response to human impact. The resulting characteristics are indirect factors of ecological landscape potential.

At the second stage contours of environmental situation areals are defined. This could be done by overlaying and subsequent analysis of landscape (geosystems) map, land use map, map of population density, as well as through the synthesis of maps of particular environmental problems. At the same time the correlation between human impact and the natural potential of territory is analyzed. The procedure results in the identification of environmental problems, listing them and evaluating their acuteness according to predefined criteria.

Further on the identified problems are ranked according to the significance of their effects and the scope of their occurrence. It enables to compile a map of spatial combinations of environmental situations providing a realistic picture of their distribution over the territory under study. As a result of complex ranking the legend of the map of environmental situations is produced. It includes integral characteristics of interrelated phenomena which are represented on the map by different cartographic means.

Thus, the most important maps used for the compilation of resulting map are as follows:

- *Integral map of natural landscapes* or *map of natural-landscape zoning of a territory;* it should be accompanied with a series of evaluation maps for ecologically significant natural features.
- *Current land use map.* Land use types are classified by the degree of technical impact on natural landscapes and the basic types of the environment they belong to:

  a) natural environment – unused lands;

  b) slightly industrialized environment – natural farmlands;

  c) industrialized environment – cultivated lands;

  d) urban environment – developed lands.
- *Population density map.* It provides an additional characteristic of population load and is used to evaluate the general human impact on the territory.

The algorithm of eco-geographical analysis has been already applied for a number of Russian regions as well as for the whole territory of the Russian Federation and other countries. The aim of this study is to apply the proposed algorithm at the local level, for the territory of the Losiny Ostrov National Park. It’s important to point out that nature protected areas have a number of specific features that should be taken into account during the ecodiagnostic studies. These are: absence of direct population pressure, clear functional zoning of the territories, particular economic activities related to their functions, etc.

12.3.3 GIS in Ecodiagnostics

The most effective way to integrate information needed for eco-geographical analysis is the application of geographical informational systems (GIS). GIS-tools allow converting the available digital information, which may not yet be in cartographic form, so that it can be recognized and used. Tabular data can also be converted into map-like form to become the layers of thematic information in a GIS, thus a number of analytical maps could be produced just at the first stage of study.

Using GIS for the purpose of ecodiagnostics can make the expert work more efficient. GIS database provides storing and updating of incoming information. A number of GIS-tools allow user to create interactive queries, recognize and analyze the spatial relationships that exist within the spatial data stored in a digital form. Furthermore, score and multiple classifications, which can be also carried out with the help of GIS-tools, are the main means of estimating the acuteness of identified environmental problems.

The main steps of ecodiagnostical research are reflected in the structure of a specialized ecodiagnostical GIS (EdGIS) *(Figure 12.1).* Analytical maps represented in "thematic layers" unit go through several steps of data integration and form a model of the present-day landscape structure of the Losiny Ostrov National Park territory. This model is verified by comparing it with satellite images. After the number of queries to identify correlation between the environmental standards and the current state of the National Park ecosystems the areals of different local environmental problems can be spotted. The materials gained through the modeling and spatial analysis can be involved into the analytical system for more profound investigations.

12.4 Conclusions

Elaboration of EdGIS for a nature protected area has a number of possible applications. First, the results of ecodiagnostical studies could be easily introduced into practice. The EdGIS can become a basis for the development of recommendations on particular nature conservation activities and nature management of the territory, as well as for strategic decision-making at local, regional and federal levels. Moreover, the adoption of EdGIS in the day-to-day activities of the National Park would improve its cartographic support and make possible further efforts to improve the state of its environmental.

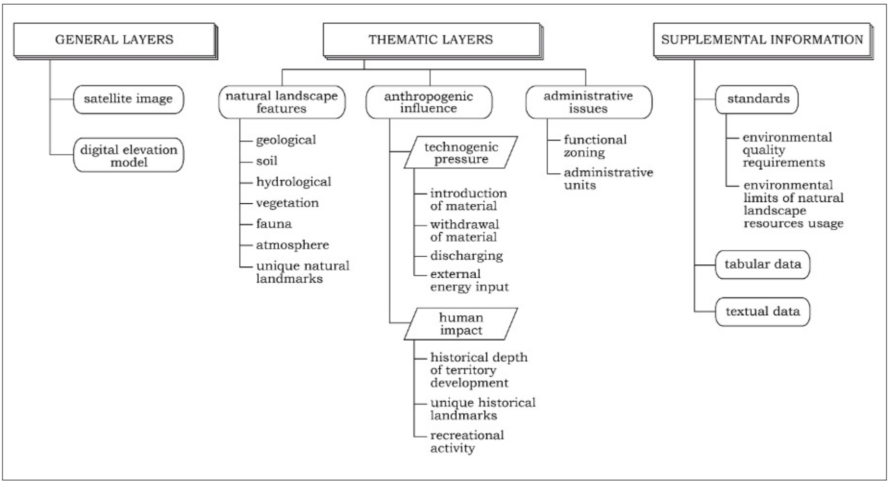

Fig. 12.1. Basic units of the specialized ecodiagnostical GIS

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Chapter 13

Cartography and Graphic Design

Tomasz Opach

The Chair of Cartography, University of Warsaw, Poland
topach@uw.edu.pl

Abstract

Between cartography and graphic design there are some theoretical and practical similarities. Both domains use practically the same techniques and their main goal is to communicate effectively and in a useful way. Methodological principles of graphic design seem to be very interesting for cartographers. For example, the principle “form follows function” known not only in graphic design but also in architecture and in industrial design, may be useful in map-making. Furthermore, there are a lot of graphic designs, which are an excellent inspiration for cartographers. Although it is not always possible in cartography, or at least not in every type of map, there is no reason why cartographers could not use graphic metaphor, unconventional design, techniques or composition manner. Results of cartographers’ work should be also of aesthetic value and engraving in one’s memory. In the article the author discusses the most interesting principles of graphic design and some spectacular case studies in the context of cartography, their beauty and effectiveness of knowledge transfer.

Keywords: cartographic design, graphic design, infographics

13.1 Introduction

The relation between the cartographic methods of presentation and the fine arts’ principles is an important issue in cartographers’ scientific interest. Although some cartographers strongly oppose against the inclusion of the fine arts into cartography (Mościbroda 2001) map makers take advantage of achievements and outputs of artists eagerly – for instance J. S. Keates (1996) tried to indicate similarities and

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differences in generalisation and composition of maps and paintings. Similarly, artists seek inspiration in cartography; an interesting example of cartographic inspiration of artists is a cover of „The New Yorker" (10.12.2001) prepared by M. Kalman and R. Meyerowitz that presents "New Yorkistan" – city divided into Middle Eastern names.

Several theses about the place of fine arts in cartography could be mentioned. Firstly a map designed by a cartographer with artistic skills will probably be more aesthetic and will be characterised by more successful layout than the one prepared by a person without sense of beauty. Moreover, this map will is more likely to be well-balanced, colours' selection will be more harmonious and its composition will be more thorough. Secondly, apart from a strictly visual value, map aesthetics influences the perception of the maps, their legibility; hence map aesthetics affects cartographic communication efficiency.

There were many achievements in various aspects of relationships between cartography and the fine arts. For instance, there was a trend in cartography called "the map graphics theory" (Ostrowski 1984) which E. Imhof was the main representative. According to E. Imhof the mapmakers should pay particular attention to map graphics' improvement and proper composition of maps' development. Furthermore, he held the view that map design is very similar to graphic design in some respects. In one of his speeches he called cartography a „specialised branch of graphics" (Ostrowski 1984, p. 158). J. Bertin, the other cartographer colligated cartography with graphics. He tried to identify the principles in order to prepare graphics and maps properly to make presentations in a way that could render them correct and useful (Bertin 1970). The rules of proper preparation of graphics were presented in his monumental work "Sémiologie graphique". In contemporary cartography, exploration of the art element of cartography is the main research task of Art & Cartography Working Group in the International Cartographic Association, which was established especially for this reason.

The usefulness of theoretical considerations about relationships between cartography and the fine arts could be challenged. However, it seems that such considerations are legitimate when their purpose it to indicate those principles of the fine arts which could be used in cartography in practice.

First and foremost it concerns those sub-disciplines of the fine arts in which the transmitting information is one of the main tasks. Undoubtedly, graphic design is that kind of sub-discipline, because visual communication is one of it main aims. This is a feature that makes it closer to cartography and arouses interest of those cartographers who are active in their profession, as well as scientists and theoreticians.

13.2 Graphic Design and Related Terms

In general, graphic design means a visual representation of information – facts or ideas. The term graphic design derives from the fine arts and refers to posters, postage stamps, graphic symbols, billboards, illustrations for books design, etc. A trend to distinguish between the fine arts and graphic design as a kind of the applied arts appeared in the late 19th century. That separation was noticed especially in Great Britain. The artist who is known as a father of graphic design is Pieter Cornelis Mondriaan. This Dutch painter, born in 1872, used in his works regular grids consisting of black, underscored lines. His graphic grids were the prototype of the modern grid systems used nowadays commonly by graphic designers in page layout, web page design, as well as in advertising layout. The term graphic design was used for the first time by W. A. Dwiggins – an American book and type designer who worked at the beginning of the 20th century.

In one of the contemporary textbooks of graphic design it is possible to read that graphic design explains, decorates and identifies (Newark 2002). Moreover, according to the author of that textbook, graphic design segregates reality, distinguishes, as well as plays with our emotions and helps us to take a seat on the world which surrounds us.

In the literature there are many terms with a similar meaning to graphic design or related to that concept. As a synonym of graphic design a concept *information design,* which is known as the art and science of preparing information, is used very often. Effectiveness of communication is of the greatest importance in that sense. The aesthetic aspect of representation is marginal. The other expression is the *information graphics* or *infographics*. The main purpose of that kind of graphics is the visual presentation of information, messages and knowledge *(Figure 13.1, Figure 13.2).* Infographics is used in situations when a lot of facts and complex data need to be presented quickly and in the eloquent way, i.e. in school cartography or press cartography (Kowalski 1999, 2004). There are also some different fields of *visualisation*. Generally, that term means communication through visual aid – images, animations and diagrams. Scientific visualisation, educational visualisation, information visualisation and knowledge visualisation could be presented as an example of visualisation.

Dual nature is a characteristic feature of graphic design and cartography. Graphic designers struggle with a continuous division into two models: a model of the artist and the craftsman. Similarly, cartographers have been debating for many years what the place of cartography is: is it craft, science or art? (Mościbroda 2001).

According to P. B. Meggs (1983) the main purpose of the graphic design is to give order to information or ideas that document human experience in order to represent facts properly. The hidden thought of this opinion is related to knowledge.

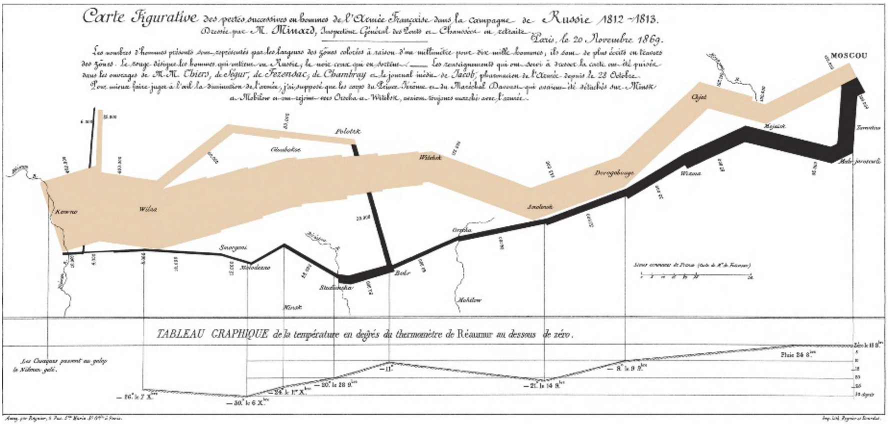


Fig. 13.1. One of the most famous infographics (Ch. J. Minard, 1869) which depicts the losses suffered by Napoleon's army in the Russian campaign 1812–13

Fig. 13.2. Example of contemporary infographics. Visual representation of information concerning military conflict in South Caucasus

It could be said that graphics enhances the transfer of knowledge. That idea is especially important for mapmakers who are looking for theoretical and methodological frameworks of map design in other disciplines. Map design is similar to graphic design. The overriding goal in the mapmaking is to present information, but cartographers should also give that information order – emphasise the facts which are important and reduce information of the minor importance.

One of the problems of contemporary cartography is its products' classification. Cartographers use various expressions, but the proposed terms are usually questionable because the results of mapmakers' works, effects of cartographers' creativity, could be placed very often between traditional cartography and typical graphic design. This fact is caused by lack of clear borders between maps and other graphics.

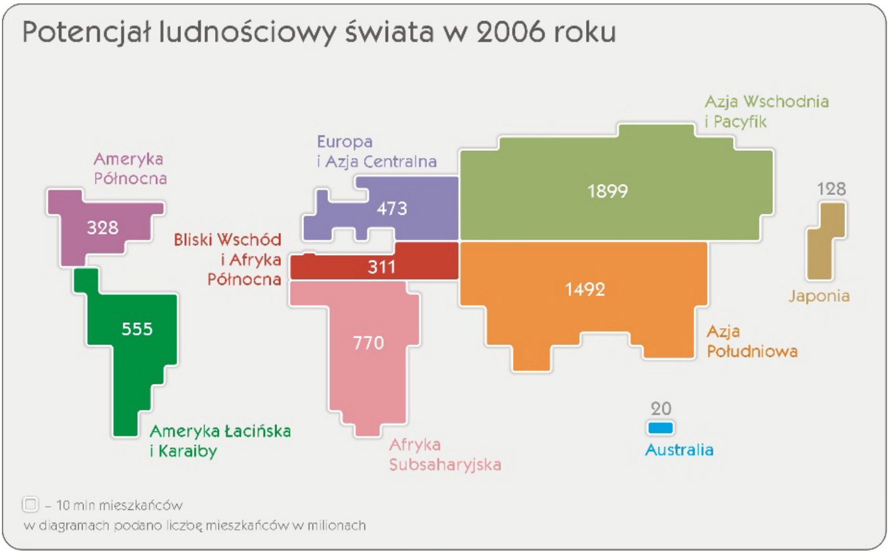


Fig. 13.3. Is it a map or the other kind of graphics? Map presents "population" potential of continents

In some situations it is very difficult to say where the cartography ends and graphic design starts – good examples of that problem are anamorphic maps, also known as value-by-area maps *(Figure 13.3),* and diagrammatic maps of transport network. Survey mentioned by D. Forrest (2003), concerning diagrammatic map of London Tube, gave interesting results: 90 per cent of three hundred first-year university geography students consider Beck's "London Underground Map" as a map and not as a graphic. Furthermore, in the opinion of D. Forrest, percentage of the general public would be probably much higher.

13.3 The Basic Keywords

Undoubtedly studying works of graphic design is of great importance for cartographic practice. It concerns posters, covers of magazines or newspapers, book layouts as well as press infographics. The knowledge of modern tendencies in graphic design could be the excellent source of invention, especially in the Internet cartography: interface design and web-mapping design. On the other hand, the knowledge of works of graphic design is important in acquiring its methodological framework. The following aspects of that theoretical basis seem to be particularly significant:

- informative aspect,
- composition,

- usability,
- graphical hierarchy,
- aesthetic aspect.

These factors could be recognised as crucial elements of the relationship between cartography and graphic design. They will be briefly discussed below.

Information – knowledge

When we talk about relation between graphic design and cartography the first common ground is the transmission of information. This is the basic aim of maps and graphic design as well.

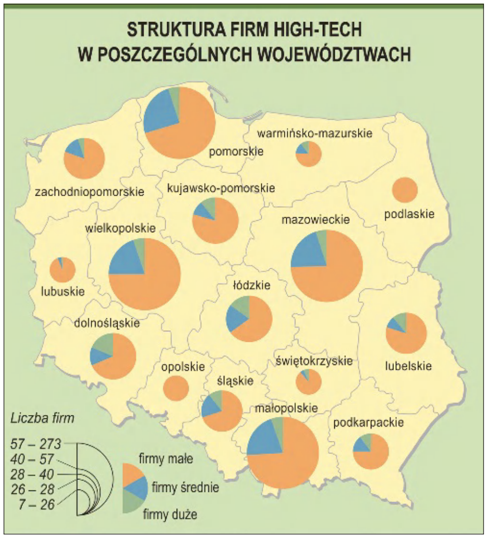
Both maps and graphics need to be designed with reflection on perception of potential users. It means that quantity of presented information and graphic form of these messages must suit users' abilities. In other words, a content and a visual form should be optimised with paying attention to communication efficiency. For example, a way of designing of a press map will be different from the way in which a map for school atlas or analytical map (i.e. which illustrates academic textbook) are designed *(Figure 13.4)*. On the basis of legible map, users could acquire knowledge thanks to the correct interpretation of facts and data presented on maps or graphics.

Composition

Using the most general terms, the composition is a way in which elements/components of maps (i.e. the main map, legend, scale, comments, etc.) and graphics are connected with each other. Cartographers and graphic designers must remember that composition should be ordered and well-thought-out (Quodverte 1997). It means that composition shows the way in which maps should be read and interpreted. Moreover, sometimes various types of composition are distinguished, i.e. "closed composition" where elements of map layout are placed in typical areas (i.e. topographic maps, atlas maps) or "open composition" (free composition) where a map is combined with texts, photos, diagrams (i.e. press maps, maps in travel guides).

In cartography we use such composition schemes which are typical arrangements of map elements. For example, in GIS applications mapmakers can use map templates. These templates enable quick preparation of a map with a small amount of layout work. Usually map templates include popular map composition schemes, but sometimes these compositions are unsuccessful (Depuydt 1999). That is why desktop GIS applications could be used for data visualisation i.e. for cartographic representation of digital elevation model, but next visualisation of that kind should be improved and finished by means of vector or raster graphics editors i.e. Adobe Illustrator, CorelDRAW, Inkscape.

a



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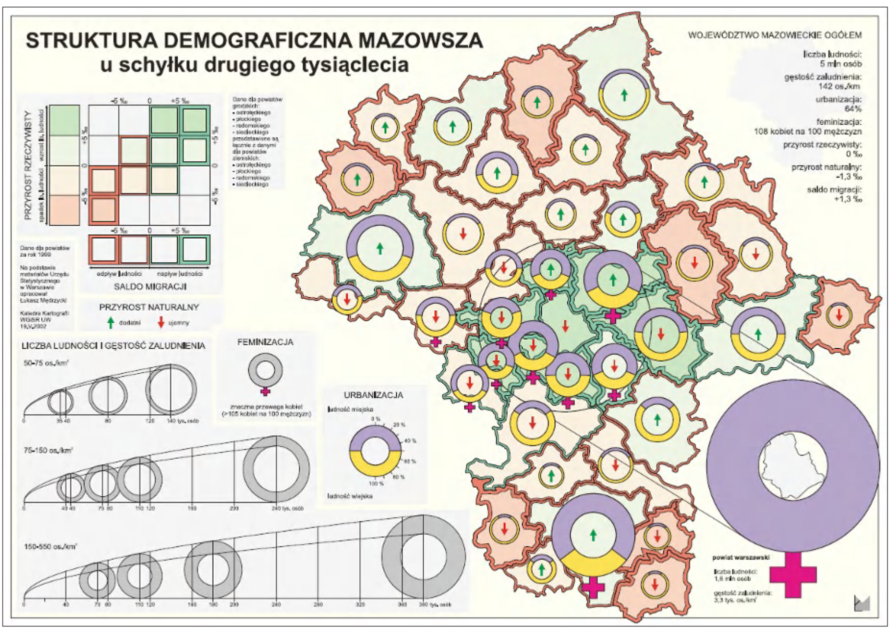

Fig. 13.4. The quantity of information depends on abilities of potential users; maps with different levels of complexity of information: a – press map, b – complex map for specialists

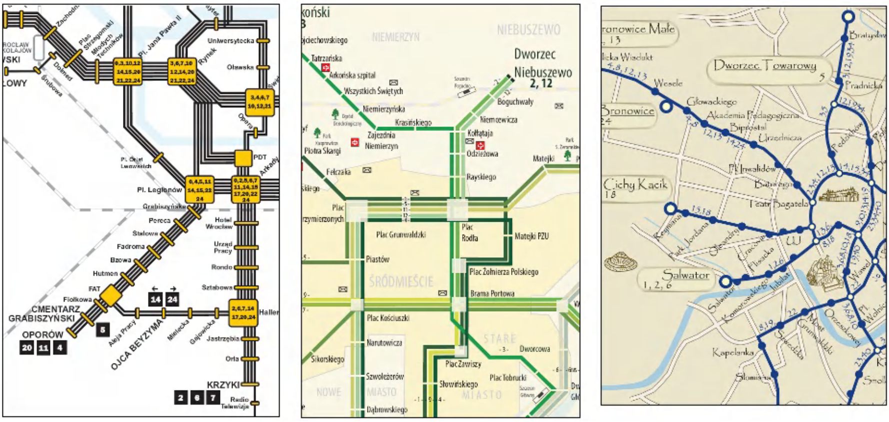

Fig. 13.5. Three examples of city transport maps (tram systems in – from left to right: Wrocław, Szczecin, Kraków; Poland) elaborated as an exercise by students of the Chair of Cartography during "Cartographic design" courses

Usability

Graphic design, as well as cartography, belongs to applied arts (Mościbroda 2001). In that kind of creative activity the important aspect is the pragmatic one, related mainly to the usability issue.

Usability is a feature that lays emphasis on needs, abilities and perception skills of potential users. According to this approach the amount of information should suit intellectual skills of messages' recipients. Graphical form, symbolisation, generalisation and composition of maps or graphics should be also performed in a proper way.

In this context the principle "form follows function" is particularly important, because it states that the design, layout or visual style should be predicated by, or based upon its main goal, or intended function. Admittedly, "form follows function" is a principle which used to be associated with architecture and industrial design, but nowadays is used in others disciplines of applied arts.

The spectacular example of use of that principle are diagrammatic maps of transport networks. In that type of graphics designers dispense with geographical accuracy (Forrest 2003), because clarity of information is more important than a close relationship to directions and geographic locations with real (proper) coordinates (Black 2005). Probably the most famous transport map is the London underground map designed by H. Beck, prepared in 1933 and inspired by electrical circuit diagrams. Beck's underground map has become a model for other transport diagrammatic maps but "first approaches to the London Underground management with the map were unsuccessful" (Forrest 2003, p. 8). Nowadays that solution is commonly used in cartography of transport network and examples of that approach could be found amongst transport maps of cities *(Figure 13.5),* as well as regions and countries.

The interesting case of usability in cartography and the graphic design relationship are propaganda maps. In that kind of presentations cartographic content and cartographic form are conformed to the pragmatic aspect in the extreme way. Transmitting information is very accurate and efficient, and what is important – presented facts and events are usually exaggerated, distorted or counterfeit (Monmonier 1996, Pápay 2006). Cartographic "side" of propaganda maps is often marginal. These presentations have to influence users' emotions and have to be read at glance therefore authors place emphasis on graphic/visual style and not on cartographic correctness.

Graphical hierarchy

During map preparation the cartographers try to think creatively and originally. They deal with novelties and principles known from fine arts, i.e. by using painters' palettes (Friedmannová 2008, Sidonie 2008), but in creative activity they should remember about graphical hierarchy common in graphic design. Visual weights of cartographic signs have to be commensurate with the importance of messages, presented objects or facts. The graphical emphasis should be put on these objects, which are important for the presentation and that information should be weakened which makes geographic background of the map. G. F. Jenks in his article (1975) states that major symbols that present important information and minor symbols should be separated clearly. He called that principle a figure-ground relationship.

Proper use of graphic hierarchy is a quintessence of cartographic design and is a determinant of professionalism in cartographic profession. Amateurs, operators of GIS applications without cartographic knowledge often visualise information directly from databases and the range of their activity is limited by methodological solutions implemented in the GIS applications, i.e. libraries of cartographic signs, methods of symbology, templates (Depuydt 1999). Of course mapmakers do not have to use it, but these tools facilitate and speed up the mapmaking. That is why professional cartographers must think independently, trying to avoid wrong habits and artificial limitations of software.

Aesthetic aspect

Maps and graphics present information not only in a legible and eloquent way, but also attract users attention (eye). Therefore the aesthetic dimension of those kinds of works is important. Apart from the effectiveness of transmitting information, graphical appearance is surely one of the most important factors of the maps' and graphics' success.

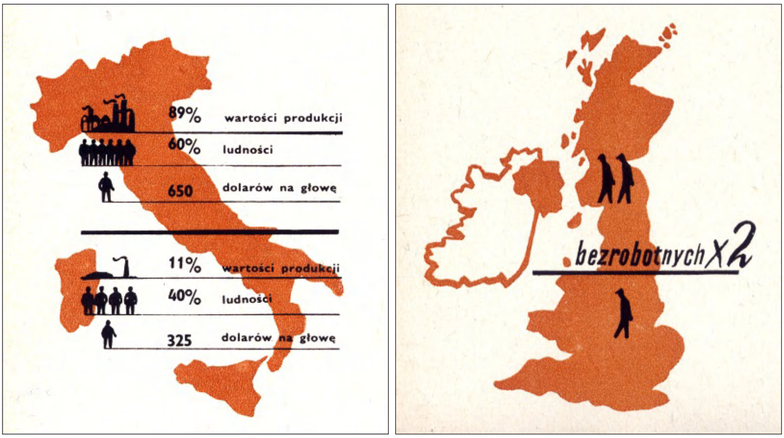

Fig. 13.6. Two examples of cartographic propaganda. These maps was elaborated in Poland in the socialist period and present economic differences between the south and the north of Italy and United Kingdom (in Polish, source: S. Albinowski, 1965)

Map styles, as well as graphic design styles, evolve along with changes of trends in fine arts. For instance graphics of the sixties and the seventies was characterised by simple drawing, simplified shapes. Works of J. Bertin are typical for that period. He used signs and colours in accordance with the principles of his "sémiologie graphique". In that time in Poland combination of maps and graphic was popular in cartographic propaganda *(Figure 13.6)*. In modern cartography we can notice graphical solutions typical for the webpages design. The spectacular example is a map of the World titled: "Patients per doctor" that resembles tag cloud *(Figure 13.7)*.

Among difficulties of combining map with graphic design, getting a high-quality aesthetic result should be mentioned. Common use of GIS applications popularised wrong aesthetic habits (Quodverte 1997). Therefore in cartography didactics interdisciplinary, independent and artistic thinking in performing the didactic tasks is important.

13.4 Conclusions

Maps are similar to graphic design and therefore the principles of their elaboration are partially subordinate to principles of graphic design, first and foremost – principles of information graphics. In many cases it is better to resign from a layout and graphical style of traditional paper maps to achieve the appropriate result (Bláha 2008). In other words, it is more effective to use uncommon graphical solutions from the borderline of cartography and graphic design.

Fig. 13.7. Design of the „Patients per doctor map of the World" resembles tag cloud known from webpage design (source: http://strangemaps.wordpress.com/2007/10/17/185-the-doctorspatients-map-of-the-world/)

Because it is not easy, university students of cartographic specialisation apart from attending geoinformatics and methodological courses should also attend courses related to graphic design or fine arts in general. This is a crucial matter in contemporary cartographic training.

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Chapter 14

Various Ways of Assessment of Cartographic Works

Jan D. Bláha

Department of Applied Geoinformatics and Cartography, Charles University in Prague, Czech Republic
jd@jackdaniel.cz

Abstract

To create valuable output, people must learn from mistakes, learn to evaluate the results of their work and, thus, not to repeat their mistakes. There are many ways of assessing products arising from human activity, i.e. cartographic works as well. Verbal assessment (reviews, references) is the most common one. It usually includes the list of positive and negative aspects of the product, or a multi-criterion assessment containing a system of value parameters of the work, usually numerical. This assessment is usually done by more or less experienced experts. What does the user think, though? It is desirable to find an adequate way of assessment assisted by the user. It is the user who is the ultimate recipient of the product. Apart from standard sociological approach using questionnaires, surveys or managed interviews, there are possibilities with high independence potential in the area of potential semantic differences in the researcher's and the respondent's perception. These are represented by various tasks given to individuals or groups concerning cartographic works or an analysis of user mental maps based on the users' experience with cartographic works.

Keywords: assessment of cartographic works, viewpoints of assessment, methods in assessment, map quality, user-friendliness

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14.1 Introduction

The issue of assessment, in other words the quality, of cartographic works is quite wide-ranging. In the past many experts dedicated their attention to it. The reason for this can be the fact that assessing products arising from human activity has always been the task pursued by various fields of study, including cartography. Especially in this era based on success and successful solution of tasks we make considerable demand on the quality of products. Moreover, thanks to various technologies assessment criteria have to be modified and quality has to be perceived in the context of products such as map portals, interactive and dynamic maps, 3D models, etc.

On the other hand, it is certain that the *presence of the user of cartographic product* remains, i.e. the person who perceives, uses and subconsciously assesses the cartographic work. We have to take into account the user, the user's needs and opinions. Otherwise, cartographic production would become merely an activity pursued for pleasure, or possibly an activity serving self-expression of the author (thus drawing closer to artistic production). At the same time, we have to keep in mind that even users of cartographic works are determined by time, place, social environment, their abilities and knowledge and other variables which more or less influence their needs and opinions.

This paper does not aim to provide answers to most questions concerning cartographic work assessment, neither to offer a complete list of possible ways of assessment of cartographic works. Nor is its aim to provide concrete practical guidelines for assessment of cartographic works for each method. Even though a number of the methods mentioned have been applied to assess concrete cartographic products this paper is not extensive enough to elaborate on detailed procedures and results; such a topic would require a separate publication.

Its aim is to point out various approaches to assessment, both disregarding the cartographic work user, as well as taking the user into account. It focuses primarily on methods with high potential to render objective results, as well as those which make use of knowledge from humanistic fields of study like sociology or psychology. Moreover, we try to keep in mind the context of educating future cartographers.

In the first part of the paper three approaches to assessment are distinguished; from assessment methods, through to discussion of various approaches of cartographic work assessment, to specific characteristics within the assessment. Individual parts of the paper deal with various ways and methods of assessment, and the distribution of results. In the last part possibilities to objectify assessment are suggested.

14.2 Differentiation of Approaches and Methods of Assessment of Cartographic Works

When we said that assessing products of human activity has been one of important tasks, we must also add that each field contributed its own, *specific approach (view)* to the assessment. These approaches may concern the assessment process (procedure) as such, during which specific methods are applied, as well as one's own understanding of the term "quality". In addition to specific approaches in different fields we must perceive the assessment and understanding of quality in the context of the particular product – cartographic work, its author and user.

In contrast, *methods of assessment* are applied within the assessment process and are often *part of a concrete methodology* created as a result of a specific approach to assessment. A joint outcome of these approaches and methods of assessment is then represented by a different character of distribution of results and their use in practice.

14.3 Specific Approaches

14.3.1 Approaches and Understanding of Quality in the Process of Cartographic Work Assessment

Gartner (1998) deals with various approaches to understanding the quality of cartographic works quite in detail. He mentions the needs to conform ourselves to the fact that the meaning of the term "quality of maps" changes in time, space and social context; i.e. that in each period, in different geographic, cultural and social conditions, cartographic works are assessed in a different way. Thus, the rules for measuring quality change. We must respect all the given variables and many others. Nevertheless, even here we can find various approaches to understanding quality, which can be in conflict. On one hand, it is the *idealistic viewpoint* stipulating an absolute value in the form of a theoretical ideal (quality does not change in time...). On the other hand, it is the *realistic viewpoint* which considers the values and quality of a work in the context of (related to) time, space, the work's purpose (added by the author) and those who participate on the whole process of assessment (ibid.) – see three roles of aesthetic subject below.

When defining quality we relatively successfully find base in *philosophy; ethics* and *aesthetics* play an important role in assessment of cartographic works (ibid.). Assessment of cartographic works *from the point of view of aesthetics* is discussed quite in detail in previous papers and articles (Bláha 2005, Bláha 2006a, Bláha 2006b). The main point of this type of assessment is the understanding of the

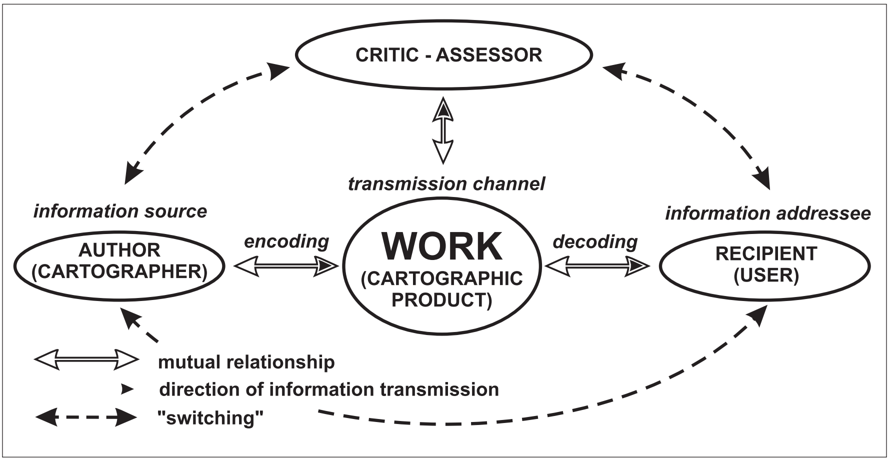

Fig. 14.1. Aesthetic process as a communication process, including three roles of the aesthetic subject (Bláha 2005)

principles of aesthetic situation, where the work (cartographic product) acts as an aesthetic object and the person as an aesthetic subject; at the same time three roles of the aesthetic subject have to be taken into account (role of an author = creative role, role of a user = recipient role, and critical role = evaluation role) – *(Figure 14.1)*. Another important point is distinguishing the aesthetic function of the cartographic work (assessing the aesthetic value) from its utility functions (assessing values of user-friendliness) – (Bláha 2005). Defining the map's function and assessing how they are carried out helps determining what is quality (Gartner 1998); the assessment can be performed using e.g. assessment criteria (Miklošík 2005, Bláha 2005), for more see below.

Economic approach assesses primarily the quality of a product and of the production process, using objective measurable criteria or more or less subjective criteria (Gartner 1998, Miklošík 2005). Of course, even here the user's needs and the purpose of the relevant cartographic product play an important role (ibid.). In case we *perceive* the cartographic work *as a communication device* (see *Figure 14.1)* the simplicity and speed of the process of information (idea) transfer by the map's author via the cartographic work towards the user is measured (Robinson 1952, Robinson & Petchenik 1976 In: Gartner 1998). Measuring the speed can be used for example when assessing the legibility and differentiability of symbols used in the cartographic work. Another viewpoint is represented by the assessment of the cartographic work on the basis of its *connection with knowledge* of the world (in case of maps it is mostly spatial knowledge). In relation to this we can speak of so called *cognitive quality*. The easier the connection with the user's existing knowledge and the higher applicability in the future cognitive process, the better quality is assigned to the map (Peterson 1994 in: Gartner 1998).

The assessment is usually done either by a team of, or by individual experts, or the combination of the two when results by independent experts (independent both in relation to the author of the cartographic work and in relation to mutual contact among the assessors) are collected. Such assessment is called *expert assessment*. The above mentioned facts show that it is essential that the user is *part of the process of assessment* because the user offers a completely original and new viewpoint. However, each subject (assessor, i.e. user) judges quality in a different way, also on the basis of their existing experience, knowledge and personality. Including the user (often a layperson) in the process also gives rise to a number of new problems that have to be solved by the assessor. Nevertheless, the relationship of the experts (authors of maps) with the society (users) is essential (Gartner 1998). It is often claimed that such assessment is subjective. Evidence that such (e.g. aesthetic) judgement does not necessarily have to be purely subjective can be found e.g. in the existence of concordance of opinions concerning the quality elements of the assessed object – the judgement is similar in many cases. In the case of pure subjectivity, there would be no agreement and all would be pure coincidence (Zuska 2003 in: Bláha 2005). Le Bon gives evidence for this in his paper *The Crowd: A Study of the Popular Mind*, in which he states that a person is part of a crowd, society, and must necessarily conform himself, and that pure subjectivity is a myth (in Zuska 2003, Le Bon 1997). Moreover, Bullough (Bullough & Zuska 1998) states in his paper on psychological distance that the terms *subjective* and *objective* were invented for other purposes than aesthetical contemplation (assessment). Below we will suggest how to make use of this "non-subjectivity" in favour of objectivity. It is clear that when the assessment is oriented towards the user the meaning of quality also changes (Gartner 1998).

14.3.2 Specific characteristics of cartographic works and taking them into account during their assessment

The *concepts of assessment respecting new technologies, processes and products* are exceptionally up-to-date and important, and therefore, we will mention them first. With the arrival of something new also new requirements for quality and new definitions of quality appear; it is not possible to use the same criteria to assess analogue and digital works and we have to search for new and fair criteria for quality and its assessment (Gartner 1998). Using the GIS we can for example assess to what extent a model or a cartographic work conforms to the reality, or the quality of transferring the reality into the model, within a visualization concept "the definition of quality is extended to the ability and capacity of a map to lead to more questions" (ibid., p. 43). Nevertheless, we have to add that a number of qualities of cartographic works are universal, which also applies to their assessment. Therefore, some stipulated assessment criteria (e.g. optimum level of generalization, methods of expression in cartography, or expression of aesthetic function) are valid for all types of cartographic works.

Within the group of new products and technologies we can assess primarily *digital maps* which are available as products on various data media or as products that can be uploaded to mobile navigation devices, on-line products, etc. These various forms force us to specify the assessment process and to modify the database of assessment criteria. Common criteria have to be adapted: legibility and differentiability are, on one hand, influenced by monitor size, on the other they can be modified by zooming in (in steps or continuously); the composition is again considerably determined by monitor; the arrangement has a different form and is much more closely related to interactive links and menu, we are aided by so called hotkeys and shortkeys (Karasová 2002).

In addition to common criteria we can also assess the product's software solution, including its relation to hardware possibilities; we can use for example proven methods (see methods and ways of assessment). A relatively good quality indicator is the extent to which custom is applied – standardization and convention – in other (not only) cartographic products. The digital form of a product is also related to various functions and their assessment. These functions substitute e.g. the traditional cartometry – functions of measurement, generating terrain profile; they increase user-friendliness – search function; or they simply supplement further possibilities to the traditional object database, enable GPS connection, etc. (selection of functions according to Karasová 2002).

In *on-line* and *web maps* we must in addition to the above mentioned issues take into account the map type (looking only × interactive maps with editing possibilities), the level of user interface, the possibilities of connection with the user's own database of spatial and non-spatial data; the functionality of the product should be considered in relation to the download speed (Kozáková 2005). Implementation of multimedia into cartography and assessment of the resulting *multimedia cartographic products* represent an independent chapter. Such assessment also has to take into account the specific characteristics of multimedia such as sound or music elements, and video-animation elements which add a fourth dimension to the product, i.e. time. The authors of the publication "Multimedia Cartography" (Cartwright et al. 2007) deal with this topic in more detail.

On the other side of the spectrum of assessed cartographic works we can find *early maps and their analysis*. While some functions of cartographic works are present in all periods (e.g. the spatial-informative or orientation element), other functions are stressed much more in early maps (e.g. the aesthetic-artistic or collection function). The first group of functions was studied as part of cartographic work analyses, the other group was examined within other fields of study. During the analysis the following features are often assessed: similarity of (or difference in) the means of expression used, including the symbol key, mathematical basis for the map (identification of cartographic representation, cartometric analyses, construction of pseudolines of constant scale factor, identification of the map's scale), the map's content, geographical names, all this in comparison with contemporary cartographic works. Historical background and the situation in which the map was produced, including the author's name, present another topic, which however falls under the issue of historical cartography. The availability of maps is also studied and their analyses are performed in order to draw up lists of early maps (Drápela et al. 2005, Veverka et al. 2006, Zimová 2005).

The *assessment of extensive cartographic products* (map convolutes, atlases, map editions and map anthologies, map works of a high number of sheets, multi-layered map portals) requires special procedures and methods. In some of these products at least the same symbol key or topic is maintained (e.g. map editions, map works of a high number of sheets). When assessing cartographic works which contain various maps with different topics and symbol keys (map convolutes, atlases) the situation gets worse. Here we have to *select a representative sample*. On one hand, we must not overlook any of the specific types or topics and we have to take into account all key maps. On the other hand, the sample must not be too extensive, so that we do not hinder comparison with other works, assessment by users, or possibly so that the assessment of the sample does not take extremely long. Except for typical properties the overall concept and the work's structure, unanimity and unification of the means of expression that have been employed, and transparency are also assessed, together with considering the possibilities of using better alternatives, etc.

At the same time thanks to a higher number of assessed maps it is easier to employ *statistical methods and procedures*: frequency graphs, cumulative curves and dependency graphs – unity of scales and topics, number of scales (scale line) and topics, graphs of the topical structure of the works, etc. B. Horodyski in his analysis of atlases used so called degree of polythematicity which represents the relation of various characteristic features (numbers of different areas, topics, scales) to the total number of map in the given atlas (Horodyski In: Beránek 2002).

The *assessment of schematic diagrams or plans* also requires a specific approach. They stand at the border of cartographic representation (using topology and geographical spatial arrangement) and general diagram (taking into account merely relations and links). In addition to common criteria such assessment should reflect the optimum degree of schematization and topological accuracy – e.g. on the basis of lines of constant scale factor (see methods below). Similarly, in digital land models or other products that model the reality the optimum degree e.g. between the time-costly and software-costly realistic form and too simplified and unnatural form should be assessed.

14.3.3 Comparison – On the Border of Approach and Method

It is quite easy to classify comparison as a method of assessment of cartographic works. However, we must realise that comparison brings a new dimension and view to the assessment and also a certain change in the philosophy of assessment. In case of one work its properties and the values for meeting the criteria are analysed, then the quality of the work is assessed in relation to the assessor's experience with similar types of works, sometimes even in relation to a defined ideal. By all this such assessment is performed on a more or less theoretical level. In contrast, comparison of two or more comparable works results in mutual comparison of properties, values and quality of two real objects, thus providing us room for labelling the better, more illustrative, better-arranged… work in practice and room of objectification. On the other hand, the *issue of comparability*, either of cartographic works or map samples (purpose, scale, topic, area …) can present some difficulties.

14.4 Methods and Ways

Methods and ways of assessment should take into account all the issues described above. The methodology of assessment of digital cartographic products is expected to be different from that of assessment of early maps. Similarly, assessment including the user (user-based assessment) will be of a different nature than expert assessment. Usually, the methods used within various methodologies are combined; either using one dominant method and secondary methods only to supplement the acquired results, or comparing results acquired by various methods, and possibly aggregating them to define the overall result.

14.4.1 Verbal Assessment

Verbal assessment takes a relatively traditional place among methodologies because it is based on natural recording of an opinion on what humans have created, done, etc. This way of assessment is subconsciously encoded in humans and is employed by them in relation to everything they get into contact with (partner, family, politics, work, hobbies …). The result of verbal assessment is usually represented by a list of positive and negative properties, values and parameters of the assessed object. The advantage of this way of assessment is that it is natural, easy to reflect details (they play an important role), able to name concrete problems. Its great disadvantage is that it tends to subjectivity and it is easy to neglect some parameters of the assessed object.

To make verbal assessment more transparent *components of assessment* or *qualitative properties of work* are determined. Different authors state different ones, including the following:

a) general facts about the work, basic properties of the work;
b) complementary and constructive (mathematical) elements, composition of map;
c) selection, completeness and substance of the contents, methods of representation of the contents, up-to-dateness of the contents;
d) harmony of the map with the reality in terms of geometry, contents, quality of generalization;
e) technical execution, software, printing;
f) scientific and professional value;
g) user-friendliness (legibility, illustrativeness, clearness, differentiability, balance …);
h) aesthetic effect, creativity, innovation, distinctive features;
i) importance of the area depicted in the map for the user.

14.4.2 Strictly Criterion-Based Assessment Without Adjustment of Criterion Values

Opposite to verbal assessment there is *strictly criterion-based assessment without adjustment of criterion values* which makes use of mathematical representation of properties, values and parameters of the assessed cartographic works in the form of exactly stipulated criteria,[1] i.e. by marking presence / absence of an assessed characteristic or by meeting / not meeting a corresponding criterion (binary scale 1 × 0), or possibly by the extent to which a given criterion is met using various scales (marks, points, percentage…). Moreover, the nature of parameters and properties is such that they are measurable using physical units (time, size, weight, etc.). The advantages and disadvantages of this way of assessment are reverse to those of verbal assessment.

The primary aim of criterion-based assessment is to reach *optimum stipulation of criteria,* i.e. their selection (specification), definition and weight (importance), taking into account the work's purpose (Bláha 2005). The basic principles followed are:

a) adapting the criteria to a particular cartographic work, its purpose, nature, technical possibilities, concretising it in time and space … (see above);

[1] *Criterion* in the meaning of "firstly as a viewpoint or measure for assessment, secondly as a sign of identification or differentiation" (Miklošík 2005).

b) penetrating into the production of the author (while respecting independence at the same time);
c) taking into account interrelations and interdependencies of the criteria;
d) giving preference to criteria that are easy to apply to various types of cartographic works (supporting comparison);
e) detecting significant features of the assessed work;
f) detecting assessed properties or parameters unequivocally;
g) differentiating with enough subtlety between various levels of assessed properties;
h) enabling all expected types of behaviour and approaches to the assessed cartographic work (e.g. from negative to positive). (Bláha 2006a, Břicháček 1978)

In addition, it is necessary to choose assessment scales with consideration (nominal, ordinal, cardinal) and stipulate a reasonable procedure of their conversion to a unified scale when aggregating the results.

14.4.3 Compromise and Combined Solution

A compromise can be reached by a *multi-criterion assessment with the use of weighted criteria*. On one hand, this type of assessment has the character of numerical representation of properties, but on the other, thanks to a considerable number of criteria and their weighing (determining weight using the method of comparison of pairs – *Figure 14.2)* the assessor can apply higher concretisation and adapt the assessment to a particular work. It is in a way a compensation of the two above mentioned procedures. When performing final assessment it is possible to combine verbal and criterion-based assessment and distribute the results synthetically.

14.4.4 Methods Derived from Sociology and Psychology

In case the user is taken into account in connection with assessment it is suitable to apply, in addition to the above mentioned methods which are relatively frequently used for cartographic assessment, methods which respect people's opinions. These are methods described in sociology and psychology. Because there is no possibility to fully cover the set of variables the assessment has at its disposal a *reduced description of reality* (see also the above mentioned components of assessment with described properties or criteria). However, this reduction of reality is much more evident when related to fields of study focusing on human beings (Disman 2005). In addition to the already mentioned reduction of assessment to a system of indicators (assessment criteria), their number (not even multi-criterion assessment can count

Criteria in comparison		Priority	Number of vote	Order weights
1	Illustrativeness		7	1st
2	Differentiability		3	5th
3	Clearness		6	2nd
4	Legibility		4	4th
5	Balance		5	3rd
6	Overall aest.effect		2	6th
7	Weight and volume		0	8th
8	Style and cover		1	7th

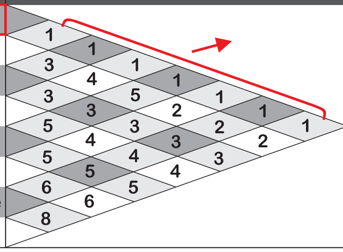

Fig. 14.2. Determining value (weight) of assessment criteria using the method of comparison of pairs (according to Miklošík 2005)

with an infinite number of criteria, for various reasons) and the relationships among them there are the following types of reduction:

a) reduction by the nature of variables (e.g. binary-type criteria);

b) reduction in population[2] of assessors (users) to a given sample (the addressed ones);

c) reduction in cartographic works in case of a higher number of works of similar nature (e.g. from one edition) to one or several representative works;

d) reduction of an extensive piece of work to sample maps (see above);

e) reduction in time continuum – the assessment takes place on a certain date and usually does not include changes of users‘ opinions and the work's development (new editions); this reduction may be eliminated by repeated assessment;

f) reduction by standardisation and norms (e.g. standardised questions in questionnaires);

g) reduction by interpretation of the results (according to Disman 2005).

From the group of sociological methods (direct observation, testing, standard or managed interview, survey, questionnaire) *creating samples and questions* can be considered another problematic issue. Samples and questions determine the assessment results to a certain degree. During *direct observation and testing* the way in which the users handle the cartographic work is observed. The users are assigned various tasks related to the map (finding an object, orientation in the index, etc.) and it is observed, or measured, how the user deals with the given tasks (Bláha 2006b). Using multimedia technology the assessor (and the observed person at the same time) is confronted with tasks like matching a meaning to a cartographic symbol, finding names, independent drawing of symbols on the basis of observed maps, etc.

[2] Population is a term used in sociology for a basic set of units where there is a presupposition that the stipulated conclusions are valid for them (Disman 2005). In case of cartographic assessment these are relevant units (either assessors, users, cartographic works or criteria) that are assessed.

These methods were used for the assessment of Czech school atlases in 2005 and for the yet unpublished multi-year assessment of plans of the city of Prague.

Frequently used methods of *interview* and *questionnaire* both have advantages and disadvantages. These are primarily the cost (lower in questionnaires), number of addressed persons (higher in questionnaires), the possibility to skip a question (higher in questionnaires), successfulness and returnability (lower in questionnaires). This is the reason why the final selection of method depends on the nature of the assessment and the assessed work. The method of interview was used for the assessment of Czech road books – field research in 2008; a combined method was used for the assessment of Czech tourist maps in 2007; the questionnaire method was used for example as part of an extensive research by J. E. Mersey (1990) for the assessment of the role of colour scheme and map complexity in choropleth maps. *Survey* is more suitable for quick and orientational assessment of cartographic works (e.g. on web pages). It is less costly but its main problem is the selection of the sample of users (assessors).

The already stated *method of comparison of pairs* can be applied during the assessment as such. The user is presented with various stimuli and the user's task is to evaluate which one is better, more advantageous, more beautiful, etc. The disadvantage of this method is that the total number of stimuli cannot be high. In case the number of assessors is higher it is possible to perform statistical evaluation and graphical representation of the results *(Figure 14.3)* – (Bláha 2006b).

So called subjective scales can make use of the method of *semantic differential*. It is a technique of associations based on measuring people's (users') attitudes via meaning (connotation) – (Osgood et al. 1964). The basis is the evaluation of the meaning of the given object (word, notion, property …) using 7-point bipolar scales, followed by monitoring the position of the studied stimulus in this space *(Figure 14.4)*. This method was used for the above mentioned assessment of plans of the city of Prague, within assessment by small groups of users. The results represent a compromise between the groups.

The methodology of cartographic work assessment using an *analysis of mental maps* of users acquired during work with the assessed cartographic work is being prepared. The aim is not only to involve the user in the process of assessment but also to eliminate semantic and other discrepancies which arise in connection with the hitherto used methods. The user does not assess the cartographic work directly, and therefore, is not forced to name the values of the work. This is similar to tasks concerning cartographic works, except that with tasks it is sometimes difficult to aggregate and interpret the results while mental maps constitute a basic spatial frame for further interpretation (when the formulation of the task is clear).

When using sociological and psychological methods it is also important to keep in mind the *dramaturgy of assessment* (what to expose to the user and at what time,

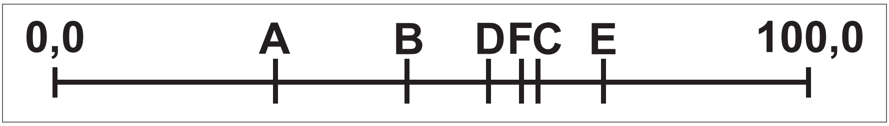

Fig. 14.3. Example of graphical representation of a transformed scale of comparison of pairs with values 0–100 and six stimuli A–F (Bláha 2006b)

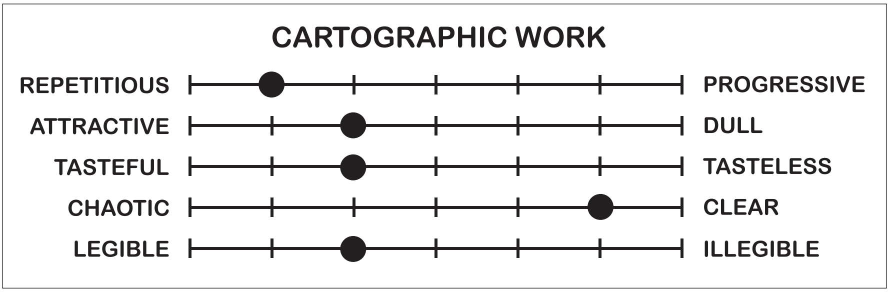

Fig. 14.4. Example of making use of semantic differential for the assessment of cartographic works

what to keep secret, to find the logic of the order of questions asked, tasks given, etc.) – (Bláha 2006b). Some of the methods were applied and tested on students during lessons at the Charles University in Prague.

14.4.5 Methods Using the Eye's Physiology

Methods using the eye's physiology include a number of methods based on legibility and activities of reading a map (especially measuring speed and distance), various methods based on the *eye-movement technique* where pupil movement of a tested person is measured after assigning them various tasks concerning the map. Various modifications of these techniques were used for example by Jenks (1973), Swienty (2008) or Brodersen (2001). While Jensk, later followed by a number of his students, used detection of pupil movement in dot maps showing hog production in North Carolina (Montello 2002), Swienty used this technique in his dissertation thesis on the proposal of suitable geo-visualization enabling effective processing of spatial information, in particular for the assessment of a suitable alternative for data visualization. Brodersen applied this technique when measuring the quality of maps in terms of communication. As he says he combined the technique with the following methods: *questions and answers*, *think aloud protocol*, *video of scenario* and *semi-structured interview* (Brodersen 2001).

14.4.6 Methods of Software Assessment

There is no doubt that assessment of the software solution of a cartographic product is extremely important, may it be various digital maps or geo-information systems used. The method of *Goal-Question-Metric* (GQM) coming from Basili at University of Maryland (Basili et al. 1994) can be considered a well-proved one. This method enables us to assess the properties and functionality of a computer programme and it consists of a system of questions with simple answers. It is defined by three levels:

a) Conceptual level (Goal) – example: "Generating height profile";
b) Operational level (Question) – example: "Is it possible to achieve a fully automated generation of height profile?";
c) Quantitative level (Metric) – example: "0 = no; 1 = yes". (ibid., examples by the author)

14.4.7 Other Assessment Methods

Other methods which make use of the spatial nature of cartographic works are various *measurements of spatial deviations*. These measurements are usually performed on the basis of comparison of the assessed cartographic work with the reality. In case of early maps they are sometimes compared with contemporary maps (pseudolines of constant scale factor), in case of schematic representation with the map base. This method was used for example by Peake & Moore (2004) as part of an analysis of deviations in mental maps, using the GPS and geo-information analysis. There are other *metric methods*, e.g. the measurement of graphical degree of space used and graphical load in the map.

14.4.8 Assessment Procedure and its Performance

After determining the approach and methods we also have to choose the assessment procedure. It can be done for example by gradual integration of the assessed object (cartographic work) into the cognitive structures of the subject (assessor):

a) study of preliminary parameters, analysis of prerequisites, hypotheses;
b) first contact with the work, primary perceptive attractiveness;
c) overall perception of the work, pre-assessment of the work as a whole during aesthetic reception;
d) close study of the non-cartographic contents of the work;
e) close study of cartographic contents of the work;
f) other assessment procedures and complex judgement (comparison, auxiliary examination, etc.). (Bláha 2006a)

The author applies this procedure as part of assessment of cartographic works from aesthetics and user-friendliness point of view. In addition, there are various *forms of performing the assessment*. In addition to assessment using computer technology (including semi-automated methods), desk research and laboratory analyses, there is field research and market research (especially among users), as well as various competitions concerning cartographic works, etc.

14.5 Distribution and Presentation of Results

In addition to various approaches and assessment methods we would like to point out various forms of distribution and outputs of the process of assessment. Unfortunately, these can also lead to different interpretations of the results. Distribution depends to a certain degree on the way in which data are processed and on the nature of data acquired by assessment (e.g. quantitative × qualitative). There can be the following forms of distribution:

a) processing by statistical methods with outputs in the form of tables, graphs *(Figure 14.5)* or maps (results are represented as an inserted thematic contents of the map, or represent a map with specific contents);

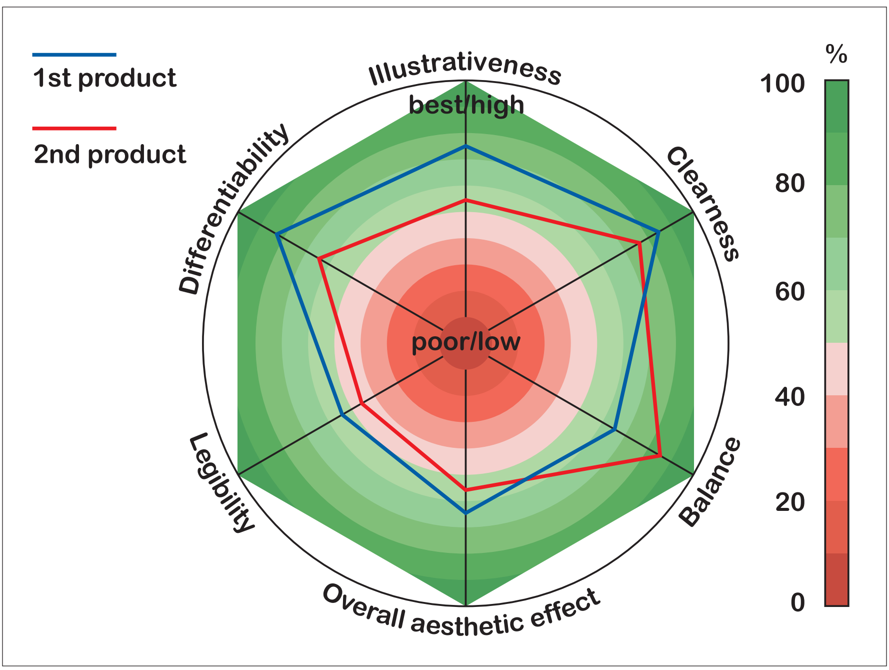

Fig. 14.5. Example of graphical representation of meeting criteria (inspired by A. Riedl in: Cartwright 2007)

b) other graphical and multimedia forms of distribution (pictures, maps and photographs, animations, computer presentations, video- and audio-interviews, reportages and records);
c) textual forms of distribution (abstract/annotation, résumé/summary, lecturer's opinion, corrections, (final) report, published review, extensive expert assessment, paper in a conference, article in a (professional) magazine).

This list is not exhaustive.

We would like to add that approaches, methods, procedures and performance, as well as distribution, depend on the fact whether the assessed object is a hith*erto imagined cartographic product* (finding out about the demand and users' needs), *incomplete cartographic product* (assessed during its creation) or a completed *published cartographic work* provided to users.

14.6 Possibilities to Objectify Assessment Methods and Results

Earlier we said that even seemingly subjective approaches to assessment can be objectified. This can be achieved either by using methods which can be objectified, or by choosing a suitable form of result distribution and finalising. There are several possibilities to objectify assessment:

a) assessment and opinions of a *high number of* (independent) *assessors* (even here weights can be set – see below);
b) assessment by *people with experience* in the reception of similar works (expert analyses);
c) if possible, *use the quantification model of assessment* (e.g. representation in scales) with the possibility of aggregation;
d) attempt to *express* as clearly as possible *the different significance of the criteria – setting the weights* in relation to the fulfilment of user functions and respecting the specific rules;
e) after finishing the individual assessment phases carry out *retrospective assessment* of the logic of the information found out (e.g. if you expect direct or indirect dependence of the criteria, this can be checked retrospectively);
f) *relate* the assessment *to the cartographic work itself*, not to the assessor;
g) *use other methods*, e.g. comparison, survey among users, scaling, if possible. (Miklošík 2005, Bláha 2006b)

An example of point f) can be a different way of describing the value of an aesthetic phenomenon. By saying "I like this map" the assessor states his/her expressly personal opinion and feeling about the given map (the sentence concerns only the aesthetic subject – the assessor). On the other hand, by saying "This map is beautiful" we get a statement about an aesthetic object, i.e. a statement that is related to the map (according to Jůzl & Prokop In: Bláha 2006a). It is clear that the first statement is easier to be made while the second one requires certain evidence. Nevertheless, even the second statement includes part of subjective expression of the assessor. It is interesting to compare this issue with the statement by Gartner (1998): "This map is a quality map." It contains primarily a summary of the fulfilment of utility functions of the map, which can be objectified more easily. Nevertheless, even this statement provides information about the assessor.

14.7 Conclusion

It appears that the process of assessment of cartographic works is not as easy as it might seem at first sight. There is a number of variables that should be reflected by the assessor. It is desirable to distinguish various approaches and methods, which (even though they are interdependent) provide different answers to the question "HOW?". While approaches answer this question with the aim to faithfully explain the nature of the assessed object or take a certain viewpoint of the assessed object, methods rather give evidence of the process of assessment as such.

Within the assessment process it is necessary not only to learn about the *assessment conditions* in detail (nature, type and concretization of the cartographic work, supposed user, time and geographical space in which the work is assessed) but also to select *suitable methods*. When looking for adequate assessment methods a compromise between objective (but sometimes too artificial assessment) and subjective (but natural) way of assessment is chosen. The selection of method determines the nature of the results, and partly also the results as such. Therefore, it is necessary to dedicate special attention to this assessment phase. Moreover, it must be clear at the beginning what way of *presentation and distribution of the results* will be used. And as usual in life, everything is related to everything, and the same applies to procedures, approaches, methods and distribution.

The aim of the process of assessment of cartographic works should be to render a complete message about the quality of the given cartographic product, in a fair, objective, comprehensible and assertive way. Here we need good understanding of the term "quality" and of what "to be better" means in the context of cartographic works, as Gartner mentions. This is the only path which will help cartographers learn from their mistakes and not to repeat them in their future production, even though it is quite difficult to teach old dog new tricks.

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Section III: Multimedia Cartography

Chapter 15

Exploring Space: Applying Interactive Integrated Media for Visualising Geography

William Cartwright

School of Mathematical and Geospatial Sciences, RMIT University,
Melbourne, Australia
william.cartwright@rmit.edu.au

Abstract

This chapter reflects upon the outcomes of the application of multimedia / integrated media for the development and the delivery of geographical information tools. It begins with a reflective description of the progression from analogue media to discrete digital media to distributed media to collaborative distributed media. Each of these stages in the application of new media technologies to cartography is illustrated with examples of prototype products developed by the author for evaluation of their applicability to the representation of geography. It then provides information about the results of evaluations completed on prototype interactive multimedia artefacts.

Keywords: Integrated media, evaluation

15.1 Introduction

In 1985, during an academic exchange at Portsmouth Polytechnic I attended the Association of British Geographers conference. One paper presented outlined the development of an interactive videodisc package that was being built to depict Britain in the mid-1980s and commemorate the 900th anniversary of William the Conquer's 'tallybook' for his newly conquered lands – the *Domesday Book*. Dr Helen Mounsey gave the presentation (and talked about it later in Australia (Mounsey 1988) and during a conversation with her after her formal lecture she invited me to

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Lecture Notes in Geoinformation and Cartography, DOI 10.1007/978-3-642-03294-3_15,

view the real thing at Birkbeck College in London. At Birkbeck the BBC/Philips/Acorn Computers-supported *Domesday Project* (Openshaw & Mounsey 1986) was rolled out and I was able to try-out this new medium for cartography for the first time. By interacting via a trackerball and mouse I was able to view both analogue and digital imagery, read expert and non-expert essays on the country and regions of the country, watch videos, undertake 'surrogate walks' and listen to and audio, all interactively.

I was hooked. I had been experimenting with combinations of audio tape and slides, edited map videos and computer-controlled slide-tape installations that explored how geographical information might be provided differently (Cartwright 1985). Whilst enabling experimentation with different media approaches to the visualization of geography, the systems I built were 'clunky' and not quite what I envisaged a multi-medium to be. Interactive videodiscs had the ability to program how the system would operate offered the potential for doing something using contemporary media that would provide a platform for research and development. This led to what is now a quarter of a century research on the application of interactive media to cartography.

My research with discrete New Media began with the production of an interactive cartographic package using an interactive laservision videodisc (Cartwright 1990). It then moved to CD-ROM (Cartwright 1994) and then the Web (Cartwright 1998). This discrete media era I believe established the very foundations upon which products delivered with distributed media were modelled. The era lasted for a decade – say from around 1985 to 1995 – and I remember it as a time of great innovation in media product development and dissemination and mapping product production in particular. This exciting decade is now past, but the theoretical and practical legacies remain. It is these legacies that I believe provided the very basis for the development of Internet-delivered cartographic products.

This paper outlines the lessons learnt from developing interactive multimedia geographical information artefacts during this decade and it addresses how they might be applied to contemporary cartographic publishing and geographical information provision using the Web. It begins by providing an overview of interactive multimedia, from its foundations with the early innovations with hypermedia and then CD-ROM. It then moves to the Web, 3D, games and hybrid products. In each of these sections examples of prototypes built using each of these mediums are outlined.

15.2 Interactive Multimedia

When interactive multimedia was new innovation was paramount. 'Multi-media' became 'multimedia' and products became integrated, seamless and content-rich.

Users were offered a smorgasbord of media content and applications. Computer displays harnessed to adjunct output and input device were the delivery mechanisms and hyperlinks and interactivity were the ‘glue’ that held them together. For cartography this offered designers the opportunity to move beyond ‘just’ single screen ‘snapshots’ and to be able to assemble products of more generous proportions. These initial products excited users and producers alike. They provided the means for experts and ‘armchair travellers’ alike to explore geography using richly furbished cartographic composite offerings. Initial products were ‘packaged’, with the author/producer deciding the product content, and the user the navigation paths to follow and the type of display to view. Later, products were dynamically ‘built’ ‘on-the-fly’ by users, once generous databases were first cobbled to, and later became integrated with multimedia products. Then, almost as if discrete media had never been the focus of concentrated effort, distributed media using the World Wide Web changed the access method altogether, and along with the strategies for delivering ‘good’ product. Then, once the Web had seemed to stabilize somewhat the phenomena now known as Web 2.0 (O’Reilly 2002) arrived. Collaborative mapping products, or mash-ups became a ubiquitous part of providing geographical information via the Web. And, not just the professional cartographer or cartographic organization now were the sole provider of maps – mapping on the Web became both a resource for foundation mapping products and a medium for self-publishing of mapping products.

15.3 Foundations

As previously noted, the author has undertaken applications development using interactive multimedia – from videodisc to CD-ROM to the Web to Web 2.0. The following sections describe the elements of these products and presents lessons learnt from evaluating these products. However, before delving into the world of interactive multimedia and mapping, the foundation theories that have guided product design in all media applications needs to be explained, so as to provide information about the very foundation theory behind the products developed with various media. These foundation ideas are the *GeoExploratorium* (Cartwright 1998), the *Literate Traveller* (Cartwright et al. 2003) and Engineered Serendipity (Cartwright 2004a).

The *GeoExploratorium* was developed as a hybrid multi-metaphor CD-ROM/Web resource that enabled users to understand geography by exploring geographical space using metaphors that were user-chosen, which ‘drove the way in which information was presented. (The metaphor set has been applied as an on-line / discrete product – the Queenscliff prototype (see *Figure 15.3)* (Cartwright 1999), The Gameplayer (Johnston & Cartwright 2000, Germanchis & Cartwright 2003), The Fact Book (Walker et al. 2000), The Toolbox (Stevenson & Cartwright 2000), The Storyteller (Cartwright 2004b) and The Sage (Cartwright et al. 2003)).

The concept of the *Literate Traveller* were developed as part of the theory for building the *GeoExploratorium*,. The *Literate Traveller* is considered to be a theoretical geographical information user who assembles a range of information resources so as to be fully aware of a geographical area of study, decision-making or travel. The *GeoExploratorium* would provide the *Literate Traveller* with a wide range of geographical information sources before actually beginning their journey. They can select the combination of artifacts that best provides tools for preparing themselves for their voyage of 'geographic discovery'.

Engineered Serendipity (Cartwright 2004a) provides a method for controlling exploration in an interactive multimedia package in a seemingly serendipitous manner. Whilst users might to find geographical information in a package by chance they might become confused and, at worst, lost in an interactive package. Entrances into and exits from interactive processes need to be synchronised and a 'common ground' for exploration should be found. A package needs to be engineered to ensure that appropriate software 'works', but present that information in a seemingly uncontrolled manner. The product is well engineered, but provides the means for users to 'wander' through package interfaces in a seemingly uncontrolled and unplanned manner. Engineered Serendipity might be applied control geographical information provision in a multimedia context.

15.4 Exploring the Application of Interactive Multimedia to Mapping

15.4.1 Videodisc

The analog videodisc was the storage medium used on the first product where the term 'multimedia' was used when describing the *Aspen Movie Map* (Negroponte 1995b). Videodiscs stored analogue video signals and were controlled by programs executed on a computer to which the videodisc was attached. This storage medium provided 36 minutes of PAL or NTSC read-only video from a 12" standard disc or 60 minutes from an extended play disc. Limited as they were, and constrained by underdeveloped user interfaces and interrogation routines, interactive videodisc products heralded the future of the application of hypermedia for the production of geographical visualization tools.

The advantage of the videodisc was that it could be linked to an external computer and then played via computer-instigated commands. Individual frames and sequences of frames could be played as part of an interactive package.

Fig. 15.1. *GeoExplorarorium,* from left to right, from top to bottom: a) initial interface, b) video 'surrogate walk', c) property location map, d) property image

Following this inspiration the author developed the *GeoExploratorium* (*op cit.*), a discrete/distributed interactive multimedia product that included surrogate walks – via still images and videos. Images from this product are provided below *(Figures 15.1a* to *15.1d)*. (Note: these images are photographs from the screen and thus are slightly distorted and show some reflections.)

15.4.2 CD-ROM

CD-ROM, jointly developed by Philips and Sony in 1982, proved to be the most popular medium, and its read only technology that stored a minimum of 540 MB of data made it most attractive to map producers looking for a robust storage medium that could store the large amounts of data associated with map and other geographical visualization artifacts. CD-ROM was overtaken by DVD-ROM during late 1995 and by early 1996 some titles previously published on CD-ROM were re-issued on DVD (Hamit 1996). By around 1998 DVD generally replaced CD-ROMs in most machines that required large storage capacities.

The Queenscliff product, described previously was migrated to CD-ROM and a second prototype developed. At the heart of the discrete unit *(Figure 15.2)* is the

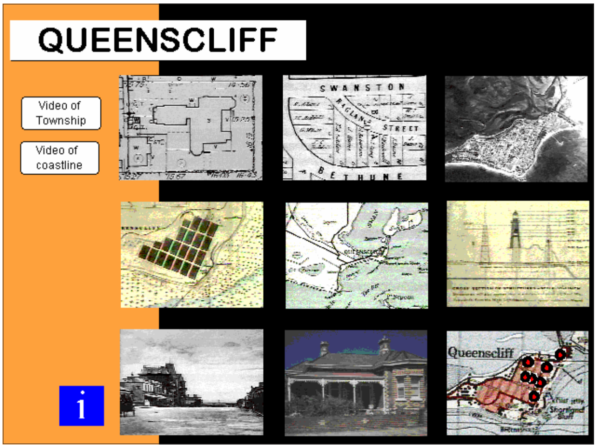

Fig. 15.2. The *Queenscliff* CD-ROM prototype

access matrix. This consists of a page of images that link to specific sections of the discrete package by clicking 'hot spots'. The nine icons lead to information as site plans/house information, cadastral maps, air photographs, historic plans, historic maps, historic artifacts, archival photographs, house photographs and videos of seven township blocks. Videos of both the township and the coastline can also be viewed. Information about the package can be accessed by clicking the information or icon.

By the mid to late 1990s the Internet, and more particularly the use of the World Wide Web, became the focus of interactive multimedia developers. Discrete media was pushed aside somewhat in the move towards the communication system that changed forever how we access information, including geoinformation. The future demise of discrete multimedia was predicted by Louis Rosetto, the founder of Wired, and he called CD-ROMs the 'Beta of the '90s', referring to the quickly-defunct 'Betamax' video format (Negroponte 1995a). Negroponte (1995b p. 68) agreed with him and says that: "It is certainly correct that, in the long term, multimedia will be predominantly an on-line phenomenon."

15.4.3 The Web

The Web, Berners-Lee's communication tool that enabled scientists to collaborate virtually, albeit initially only using text (via HTML-facilitated documents), provided the means to make documents available (almost) instantly. Media that once demanded the movement of voluminous tomes of text or, later CD-ROM-packaged 'rich media' products, were replaced by the Web's 'pull' technology that enabled documents to be found on a computer somewhere else in the network, retrieved, and then used on one's own computer. No paper products to print then post or fax, no CD-ROMs or floppy disks to burn and then mail. This meant that a CD-ROM product could be extended using the World Wide Web. This is shown in *Figure 15.3.*

The Queenscliff product was extended to produce a hybrid CD-ROM / Web product. At the left of the screen are links to Internet-delivered resources that extend the discrete unit.

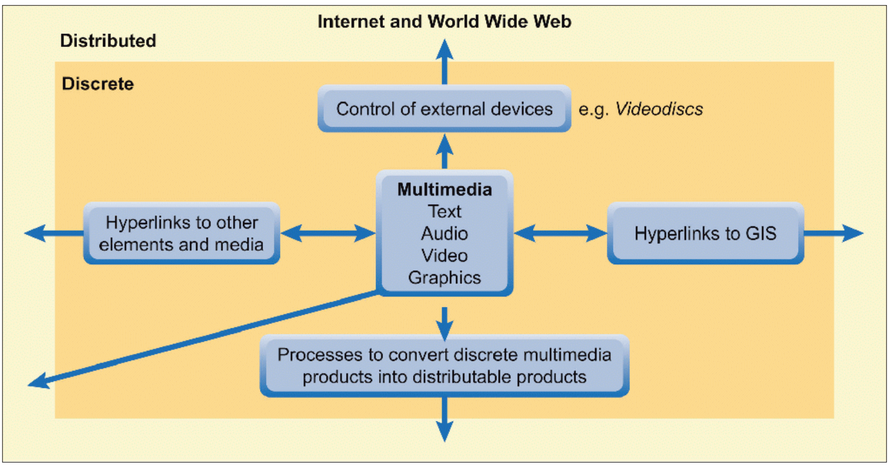

Fig. 15.3. Using discrete and distributed resources

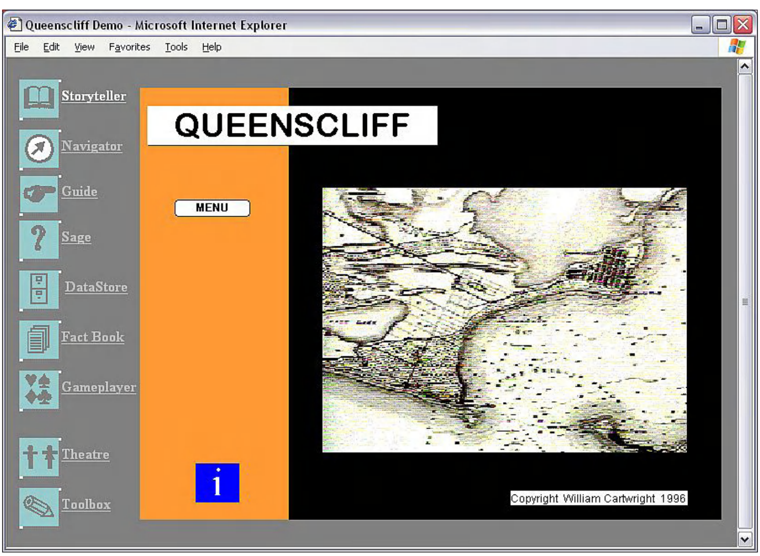

Fig. 15.4. The *Queenscliff* hybrid CD-ROM / Web prototype (Source Cartwright 1998)

15.4.4 Games Applications

A further prototype was developed to evaluate the effectiveness of using an interactive multimedia package using the gaming genre of digital artefact. As games controllers were thought to be the best way to provide access to this age group the use of two approaches were investigated: The *Doom* game engine was investigated as a way in which the 'walls' in the game could be 'rendered' with map images and the 'rooms' used in the various stages of the game would provide thematic rooms to view different areas of topics under consideration. The information from the *GeoExploratorium* was again used, to provide consistency in the information used.

A simple game was built using the *Doom* engine, and populated with maps and other images from the *GeoExploratorium*. Basically, the 'walls' used in the standard *Doom* game were replaced with alternative images. These were photographs, maps and simple house plans. Also, a number of simple graphics were produced. *Figure 15.5* shows a screen shot from the developed game.

Because of the limitations of wad development with the *Doom* engine, and the resultant crude game images that resulted, it was decided not to continue with this strategy. The crude images were a real problem, as the product might be rejected just because it did not compare well to contemporary games with superior imagery, and also 3D imagery. Also, it was thought that the link to a combat game would be a negative aspect when trying to present scientific information.

For testing and evaluation a games-type interface was used developed as a simple HTML application (see *Figure 15.6).*

15.4.5 3D

This was complemented by a 3D interface that was also developed to evaluate the effectiveness of games-line tools. For this product, a simple atlas interface for the State of Victoria, Australia, was developed. A Digital Terrain Model (DTM) was used as the foundation for building this VRML ‹world›. A remotely sensed image was overlaid on the main page *(Figures 15.7a* and *15.7b)* and other purpose-built maps.

15.4.6 Hybrid

Another test prototype, entitled The TOWNSVILLE GEOKNOWLEDGE PROJECT was built as a hybrid product. This component of the research was supported through a research grant from the Department of Defence, Australia, and particularly the Command and Control Division, Defence Science and Technology

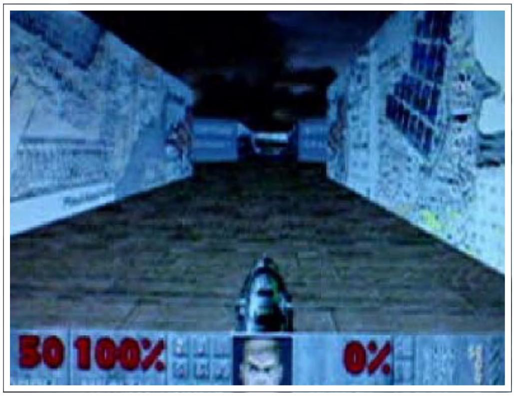

Fig. 15.5. The games interface from the Doom-generated package

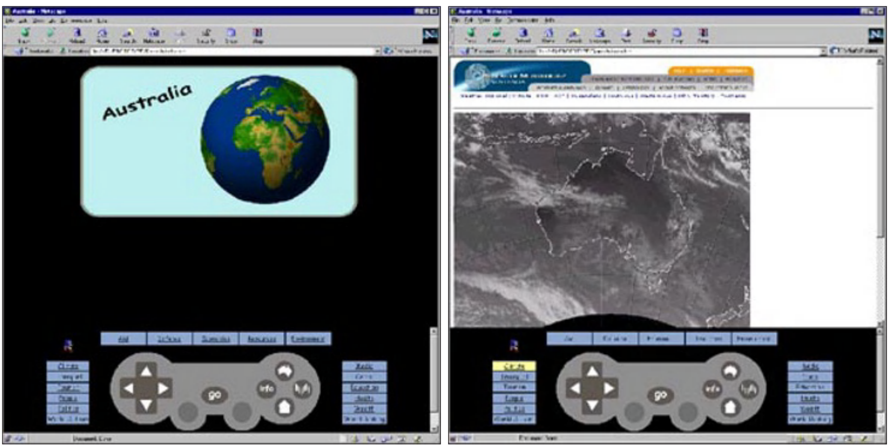

Fig. 15.6. Games interface developed for evaluation

Fig. 15.7. left: a) VRML 3D evaluation prototype, right: b) Map information in 3D

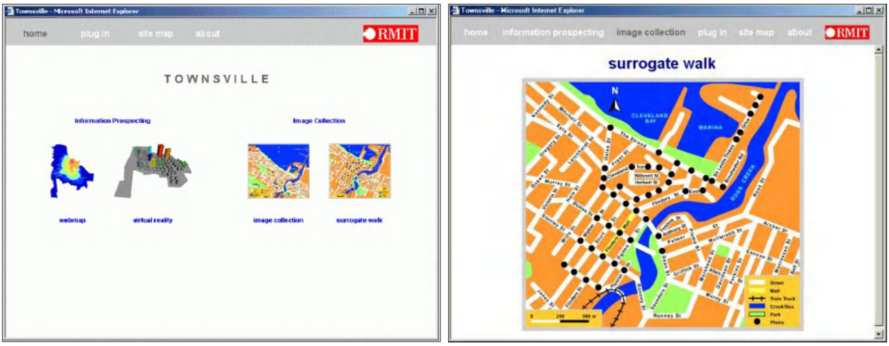

Fig. 15.8. left: a) Townsville prototype, right: b) mages of the city. In this example a panorama image exists and the user is able to choose between an interactive panorama or to view the images that compose that panorama.

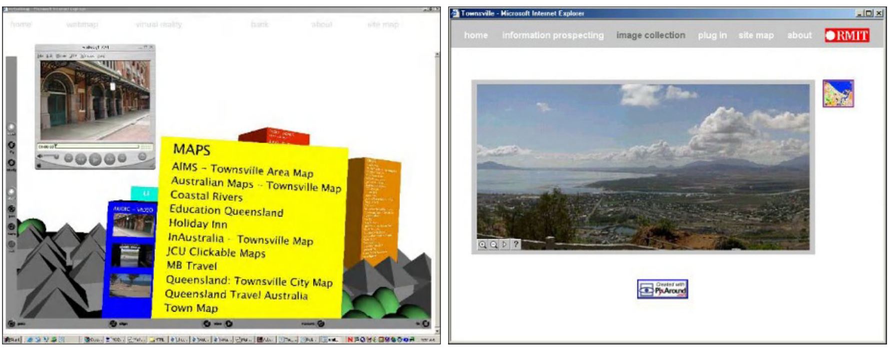

Fig. 15.9. left: a) Access to videos via 'live' video 'walls' on VRML access interface, right: b) Surrogate walk in Townsville. At each street intersection users can choose to move left, right, look backwards, or move forward to the next street intersection and associated photograph set.

Organisation, Edinburgh, South Australia. The prototype was developed for World Wide Web browser delivery, requiring minimal plug-ins – for *Flash* and *QuickTime* movies and *Cortona* for the VRML components. Two access interfaces have been provided as part of the initial interface, a 'map' of information resources and a 3D Information Landscape that the user can move through. The initial access interface and a sample application (surrogate walk) are shown in *Figures 15.8a* and *15.8b* respectively.

The VRML components of the Information Landscape are designed to provide a world where users can browse and 'walk' through the information access 'space', that is a virtual terrain built on information availability, rather that physical or human geographical information. Testing was undertaken to evaluate whether users prefer the traditional 2D map interface or the Information Landscape. The VRML World contains links to information that includes videos and audio that are able to be activated by clicking on the image (which is an active 'running' video) *(Figure 15.9a)* or audio logo that appear on the 'walls' of areas of information availability 'buildings'. The appropriateness of this method and whether users access this information in an intuitive way was evaluated as part of this research program.

Accessing photographs is done via an interactive map produced using Adobe *Flash*. 'Hot Spots" were inserted into the map to facilitate users choice related to location and the type of imagery required – image, interactive image or panorama. Once a point on the map is clicked this leads to a panorama, produced with the software package *PixAround*. One of the panoramas is shown in *Figure 15.9b.* Users can also 'walk' around the city. Once the user 'clicks' on one of the hot spots they are presented with a choice of images of the city, initially through a map interface and then with a more detailed street intersection photograph collection

15.5 Lessons Learnt from Testing the Concepts

Lessons learnt are summarised in three sections, one pre-test and two test routines, viz:

1. Pre-testing the users to gain an understanding of their exposure to maps and other tools for accessing geographical information.
2. Testing how effective the use of other metaphors is when used in place of generally used geographical information interpretation methods.
3. Testing a 'rich media' geographical information product provides a different 'view' of a certain geography compared to the use of paper maps. And, whether different users see different views of the same geography when using the same tool.

15.5.1 5.1 Pre-Test

In the first stage of the evaluation candidates were first asked to complete a simple profile information section and then to answer questions specific to their use of the product. They used the products and then compared this type of product with a conventional map. A pre-test was employed to compile a profile of the candidates. Candidates were 50 first-year tertiary students studying in the geospatial sciences. Their ages ranged from 18 – 25. However, it must be noted that the results are considered to be somewhat biased, as the students were already attuned to using geographical information products.

It was found that all candidates used maps and they considered themselves to be mostly efficient or expert map users. They used a number of maps and map-like artefacts and they had experience in producing products with numerous electronic devices.

15.5.2 Effectiveness of Metaphors

The second stage of the evaluation used a smaller expert user/producer group of 8 candidates, again 18 – 25 years old. As a more focussed group was easier to manage, and the fact that larger groups do not necessarily provide better results when seeking qualitative responses supported the use of a small sample size. Virizi (1992) noted that 80 per cent of usability problems are uncovered with four or five test participants, so the use of a smaller group was deemed to be a sound). A questionnaire asked candidates whether they agreed with statements about metaphor use in interfaces. The games-type interface was used in this part of the evaluation (see *Figure 15.10* in previous section of this paper).

Results showed that candidates thought that metaphors helped them to better understand geography. They did not think that maps alone are best to understand geographical information, and that the metaphor set illustrated was a useful adjunct to simply using maps. They thought that the product could be used with little prior experience and that a games-like interface was easier to use. They felt confident using it. They would choose this type of interface over a conventional one. Finally, they saw this type of interface being appropriate for a first-time user. In general terms, this focus group of expert user/producers supported the concept of metaphor use.

15.5.3 Views of Geography

Subjective methods are typically used to determine the level of media quality required in applications. Therefore this stage of evaluation strived to implement a more formal approach. The evaluation procedure demanded that it be ‘built’ on sound educational theory and implemented through a proven modus operandi. The core educational theories of Bloom’s learning behaviours, developed in his taxonomy of learning objectives (Bloom et al. 1956) were considered to be appropriate for developing tasks for formal evaluation of the prototype product. They were applied to this project to develop specific cartographic applications for testing *(Table 15.1)*.

Candidates were first asked to answer questions using a paper map of the area and then with a 3D/Web information source – the TOWNSVILLE GEOKNOWLEDGE PROJECT interactive multimedia product developed for this part of the evaluation (see earlier description of this prototype). Then they made general comments comparing both mediums. The second feedback required was whether the medium changed their ‘view’ of the geography of Townsville. And, finally general comments related to product improvement were solicited.

At the end of each section candidates were asked to comment on how easy it was to do these tasks with the artefact used – EASY, FAIRLY EASY, MODERATELY

Table 15.1. Formal basis for questionnaire – applying Bloom's Taxonomy to cartographic products.

Application of Bloom's Taxonomy to Geographical Representation artefacts	Task	Question
Knowledge	General undirected map reading.	Name the main streets in the central area of Townsville. Identify the harbours in the town, what are their names? Locate the railway station, the panoramic lookout point, the entrance to the harbour and the way to the airport.
Comprehension	Directed map reading. Users are asked to locate specific items and then to summarise and generalise this information.	Compile a list of points of important to mariners using the port facilities. Summarise the elements that comprise the town. Generalise what constitutes the layout of the town.
Application	Classification of information shown in the product and making general considerations related to the production of a 'second generation' map product that would encapsulate the essential elements of the town.	Considering the information shown on the map, how would you classify the basic elements of the town? If you were asked to produce a map that encapsulated the essential 'things' that comprise the town what would these elements be?
Analysis	Considering different topographical features. Measuring distances. Calculation of travelling times.	Compare the central city area to the surrounding areas. How are they different topographically? Measure the distance from the panoramic lookout to the entrance of the main harbour. Calculate how long it would take you to walk this distance.
Synthesis	Making informed judgements from the geographical information provided. Selecting information deemed to be important.	Differentiate between the main elements of the town. What are they? If you were asked to act as a tourist guide to visitors to the town, which places would you take them to? Select two places that would provide the 'key' points to visit.
Evaluation	Comparing the town to other towns. Evaluating the value of the town's attributes. Projecting possible scenarios.	Comparing this town to where you live, what do you think are the main differences? What do you think is the value of the harbour to the town. Speculate that if there was a flooding related to a tropical cyclone, which areas of the town would be most likely effected?

DIFFICULT, DIFFICULT, HARD, VERY HARD AND IMPOSSIBLE. Once this was completed, candidates answered the same questions using the interactive multimedia package. One of the focus elements of this evaluation was to compare how different perceptions of geographical places are made dependent upon the medium used.

There were definite changes in how the candidates viewed their allocated tasks when using the paper map and then completing the same tasks with the interactive multimedia product. Questions relating to the KNOWLEDGE section were rated, in the worst cases, as impossible/very difficult with the paper map. This changed to fairly easy/easy with the multimedia product. For COMPREHENSION hard/difficult moved to moderately difficult/easy. APPLICATION tasks were rated hard/moderately difficult when the paper map was used, and moderately difficult/fairly easy with the multimedia product. ANALYSIS-related questions were impossible/moderately difficult with the paper map and fairly easy/easy with the multimedia product. There was no change with the SYNTHESIS applications. EVALUATION-specific questions were rated impossible/moderately difficult with the paper map. This perception changed to moderately difficult/easy with the multimedia product. In general terms, five of the 'umbrella' task areas were markedly easier to do with the multimedia product, which indicates the effectiveness of Rich Media products.

Finally candidates were asked to comment on how their perception of what constituted the town had changed once they used the interactive multimedia product. The ability to describe the town improved markedly when the interactive multimedia product was used. Initially, candidates were either unable to adequately describe what constituted the town, or they just provided a general 'location of elements' statement. After using the interactive multimedia product candidates were able to comment about the structure of the town, its location by the sea, the fact that it had a harbour and that it had hills behind. The general structure of the town – city centre with a few historic buildings, with suburban spread beyond was also added to the description. The interactive multimedia product, with enhanced media attributes, enabled a better appreciation of the town to be had.

Users commented that with the interactive multimedia product it was easier to imagine how the town looked, and to get a feeling for the topography. The functions of the various districts in the town were obvious and existing personal experiences could be enhanced. Generally, candidates commented positively on the ability to gain an enhanced appreciation of the town with the interactive multimedia product.

15.6 Where to?

The underlying theory behind the development of the prototypes was to build a product that provided new ways of 'seeing'. If reality is viewed through one viewpoint (one particular media artefact) then a particular view is provided. Development of prototypes and evaluations were undertaken to ascertain whether; if multiple ways of viewing reality were provided, through the use of New Media cartographic products, would there be fewer voids in understanding what constitutes a particular geography? Also, the evaluation needed to ascertain whether the use of New Media products changes how users see geography, and if it is different to the mental image built when conventional materials are used

Results from the evaluation will be used to guide future applications of the *GeoExploratorium*. They will also be used as a starting point for future research focussed on Engineered Serendipity and the application of interactive media tools to geographical information delivery. More extensive subjective testing of the prototypes will complement this research reported here.

A final question: *Do, do we need to develop 'rules' of use, or provide a 'limitations of product' disclaimer?* Rules of use would force users along corridors defined by the package designer, and thus limit their ability to freely explore all elements of the package. A disclaimer about the limitations of the product would discount the product as an accurate scientific document. A balance somewhere both extremes is needed.

15.7 Conclusion

Innovation sometimes means cutting loose the traditional ties that bind the mapping scientist to common presentation-only methods of information communication. The need to use methods that remove the mapping scientist from the delivery component of the package may not be a high priority, as, from the academic perspective, the professional 'packager' of geographical information needs to always be in command of the delivery. Multimedia packages allow the user to select and use the most appropriate 'toolbox' of discovery resources to fully investigate the information provided in the manner with which they feel most comfortable. Innovative packages that empower users to fully exploit the resources being provided offer the means for real discovery and enlightenment.

These different approaches to the provision of geographical artefacts described in this chapter, give access to a different viewpoint to geographical reality and make it possible to see the world differently, leading to a greater understanding of the complexities of the world. This chapter has outlined the direction that research into the provision of a 'different' interactive multimedia package for the exploration of geographical space by the development of a number of packages for evaluation. The concepts applied for underwriting the design of prototypes for evaluation are the *GeoExploratorium,* the *Literate Traveller* and *Engineered Serendipity*. It is believed that the prototypes developed illustrate how enhanced interactive multimedia products can allow users to appreciate and explore geography in the manner that is most appropriate for their particular usage patterns and preferences.

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Chapter 16

The Art of Autostereoscopic Relief Representation in Cartography

Manfred F. Buchroithner and Klaus Habermann

Institute for Cartography, Dresden University of Technology, Germany
{manfred.buchroithner, klaus.habermann}@tu-dresden.de

Abstract

When regarding autostereoscopic cartographic products displaying relief forms, it is not only the art aspect per se which makes these embodiments so appealing but also the aesthetic rendition of landforms. “3D in cartography” is simply attractive, a well-known fact recently corroborated by statistic investigations. The combination of a balanced tinting of elevation zones, a delicate hill-shading and a naturally looking vertical exaggeration is basically a matter of hard skills in software handling. It comprises, however, also a good portion of aesthetic feeling and intuition, which goes beyond the requirements for flat paper maps, to make the depicted landscape relief look attractive. The capability of autostereoscopic lenticular foil maps to let the letterings and map symbols hover above the terrain, even at different height levels, is an additional feature with an artistic whiff. The paper represents state-of-the-art examples and is meant as an invocation to consider maps, also true-3D maps, not only as a piece of hard-or softcopy geo-information but as a piece of art, too.

Keywords: Autostereoscopy, lenticular displays, true-3D, cartographic art, landscape aesthetitics, landscape attractiveness

16.1 Introduction: Landscape Aesthetics and Relief

It goes without saying that art has something to do with aesthetics, and this clearly applies to landscape aesthetics, too. It can further be taken for granted and it has already many times been stated in publications of various disciplines and prov-

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enance that both aesthetics and attractiveness of a landscape and its relief are positively correlated (Carlson 2007).

In this context the term “scenic” has to be mentioned. Scenic landscapes are characterised by a balanced frequency of ups and downs, be they “only” large trees on park-like flat ground or a “real” terrain relief which diversifies a landscape, “with the whole representing a somewhat complex yet comprehensible scene” (Parsons and Daniel 2002) “Scenic landscapes … are … the type most people reportedly enjoy most.” (Mitchell 2002). According to the Online Etymology Dictionary “scenic” stems from Greek *skenikos*, derived from Greek *skene* (i.e. *“scene-building”* or *tent*). In 1842 it has first been recorded for “of or belonging to natural scenery”. Again, according to the aforementioned source, since 1914 we are using this term when e.g. talking of roads etc. “offering fine views”. And these views are certainly only possible if the terrain either rises up (“Matterhorn seen from Zermatt”) or down (“Aletsch Glacier seen from Jungfraujoch”). It will not be possible to obtain an overview over totally plain terrain when “simply standing on the ground”.

This implies 1. that pronounced terrain “pleases us” and 2. that we like – as mentioned below *(Section 16.2,* cf. Weber 2007) – to observe landscapes from raised positions (as it is – in a down-scaled manner – the case with maps, relief models or lenticular geo-displays).

Frequently, also in the context of the term *scenic*, sometimes in connexion with a sort of archetypal reflections, the adjective *Arcadian* is mentioned (cf. Ulrich 1983). Since approximately the 15th century the “Arcadian landscape” type has been considered the “ideal landscape”: besides human beings (only representing a staffage or decoration in the Dutch, French, British, and also German paintings of Romanticism) it comprehends pieces of characteristic architecture, e.g. palaces, castles, ruins, and the following natural constituents: water, trees, rock formations, gorges, and even “lofty” (German “*erhabene*”) mountains (cf. Richter 2007¸ cf. Crofts). The latter ones clearly show the importance of the relief, an aspect which in the present article shall not be further deepened. Rather, we want to refer to the studies by Balling and Falk 1982, Carlson 1993, and in particular Carlson 1977 and Coch 2006 where visual preferences for natural environments and (in the two latter publications) possibilities of quantifying scenic beauty were investigated: There, the relevance and leading importance of the terrestrial relief is clearly demonstrated.

In this context we want to introduce something like *relief aesthetics*, a term which still needs to be defined and investigated in more detail and which stands in close connexion with relief intensity (German *Reliefenergie*, cf. Bill & Zehner 2001), a parameter which might also allow to quantify the aesthetic value of the relief of a landscape. In conjunction with cartographic depictions this is an issue which still waits for more in-depth research, aiming at answering the question to what degree the relief intensity of a landscape determines the possible aesthetics of a map, and – vice versa – how the way of relief representation in a map may bias the aesthetic appearance of the latter. We believe that the level of aesthetics of a cartographic product also facilitates the user's generation of his/her mental ("cognitive") map.

Already in 1975 Roger Crofts proposed the "landscape component approach to landscape evaluation" (Crofts 1975), also considering the relief, and in 1991 Steven Bourassa published his book "The Aesthetics of Landscape" (Bourassa 1991). Both of them stress the importance of the terrestrial relief. It may also be no coincidence that Allen Carlson as one of the leading landscape aesthetes follows in his university lectures the ideas of John Muir whose theoretical considerations are based on his experiences in the high-relief Sierra Nevada of the American cordillera (Carlson 2007).

Russ Parsons who has not only been working as a landscape architect but who is (also) a sociologist, psychologist and environmental psychophysiologist states that the current theory in cognitive science regards emotion as an integral part of cognition (Mitchell 2002; Parsons & Daniel 2002; cf. also Coch 2006). Hence, an optimum visualisation of the relief, e.g. in an autostereoscopic manner, certainly helps to intuitively (and immediately) generate a "mental 3D map". Again, here lenticular displays have to be mentioned with top priority.

For the sake of completeness, however, it has to be mentioned that in a recent study into the psychology of awareness and brain-physiological Thomas Coch points to the fact that a reduction in the aesthetic esteem of both objective or subjective indicators cannot live up to the requirements of the aesthetic experience. Against this background, he seeks to make a case for changing the mechanisms used to evaluate landscape aesthetics (Coch 2006). Albeit, regarding the topic of true-3D geovisualisation these aspects have no real impact. Tveit et al. (2006), however, try to avoid normative values of visual quality, rather than to describe different characteristics of visual landscapes.

The following *Figure 16.1* tries to resume a sort of mental flowchart showing how – in the linguistic sense of semantics – art and true-3D geo-displays are related.

Fig. 16.1. The impact of autostereoscopic lenticular geo-displays on better art experience. A semantic flowchart.

Now the question arises to what extent an aesthetic landscape is also considered attractive. According to the theory of evolutionary psychology the human aesthetic perception is the result of evolutionary adaptation. Basically, anything serving the survival and the reproduction has been considered attractive. Since totally flat landscapes do not (so easily) provide possibilities for shelter (e.g. natural rock roofs, *abris* or caves, or places for cave digging) they have been considered less attractive. Moreover, springs, rivers, are mostly located at lower elevations. Hence, relief always meant water, and water meant survival. Consequently, relief has always, at least to some extent, been attractive (cf. also Balling & Falk 1982).

With reference to the historical, cultural, philosophical and technical contexts of both East and West Jiahua Wu (Wu 1995) and subsequently many other authors studied key issues such as Romanticism of the English School and Tao in Chinese landscape. This systematic study covered landscape art, design and education. Eastern paradigms like the Chinese paintings depicting the mogotes of Guilin (mogotes are karst hills characterized by their rounded, tower-like structure) may in this context be as well mentioned as the Ludwig Richter paintings and drawings of the sandstone-spire landscape of Saxon Switzerland.

Since the 15th century the fine or visual arts have again and again been inspired by cartography and have been playing with topographies. Their experiments with relief models and maps are still continuing today. The terrain relief is being included into the ongoing discussions about aesthetics and the theory of art (cf. Berg & Engler 2003, Bürgi 2007).

16.2 Aesthetic Perception: From Natural to Artificial Stereoscopic Vision

The human capability to visually perceive spatial facts in their three-dimensionality is based on various capabilities. The central element is the synchronous binocular viewing, where two images of different perspectives are formed on the retinas, out of which our brain generates a spatial "map".

Independent of binocular vision one can also receive a certain spatial impression with only one eye. In this case the observer relies on clear visual structures (depth cues):

- Occlusion: one object is partially hidden by another one and, hence, located behind it.
- Previous knowledge regarding proportions and/or scales: that object of two equal-sized ones which is seen as the smaller one is located farther away.
- Motion perception: 1. seen from a moving viewpoint, an object which temporarily hides another one is supposed to be closer than the hidden one. 2. an object which is increasing in size is approaching the observer (assuming that, in reality, it is of physically invariable size).
- "Haze effect": more distant objects are perceived in a less detailed, less textured and less colourful way.

The functionality of the human visual perception and the generation of a spatial impression in our brain condition that one can only see images intuitively and directly but not perceive the geometry as such. That means we are dependent on the observation of differences in intensity, hue, saturation, and illumination effects (e.g. shadow) in order to obtain a spatial impression (cf. *Section 16.3)*.

According to Weber 2007 the wish to view a landscape and its relief from above represents an *archetypal* situation. "The fascination of an overview per se" has to be considered "an element of our biological heritage" (Weber 1993). "The view from a prominent and/or dominant position over the abysmal terrestrial relief causes unconscious feelings of both power and amazement" (Weber 2007).

Aesthetic visual perception only functions if it can be carried out without stress and strain to the eyes, without unpleasant or tiring illumination conditions, without any other significant impediment and objection, i.e. without glasses or other viewing aids, and – this goes without saying – if the scenes per se have an aesthetic radiation or vibrancy. Thus, for their visualisation lenticular foil displays seem to be *the* means of choice. Like panoramic depictions and terrestrial relief models, lenticular geo-displays may represent extremely naturalistic embodiments. All three of them activate the visual sense, the most developed capability of primates, and hence human beings, to orientate themselves in space (Weber 2007). The terms generated in early times "elevation plan" or "plani-stereometric embodiment" (cf. Bürgi 2007) as distinct types of artworks very well hit the nail on the head as far as these aforementioned cartographic relief models and lenticular displays are concerned.

Like for the generation of mountain reliefs, for which no one less but Eduard Imhof introduced *art* as a prominent asset, art also is an issue which has to be assigned to the making of high-quality lenticular geo-displays. Johann Bernoulli even talked about "the art of casting land". Celebrated scientists like Xaver Imfeld, Albert Haim or Fridolin Becker modelled terrain reliefs of extraordinary precision and high aesthetic standards and also succeeded as artists as well as as scientists (Bürgi 2007), a fact that also applies to Eduard Imhof.

16.3 Principles of Artificial Spatial Perception Using the Advantages of Lenticular Geo-Displays

It has to be pointed out that – last not least against the background of portability – solid (i.e. steric) cartographic products like globes (Riedl 2005 cum lit.; Yadlapalli 2006) and solid landscape models (Buchroithner 2005), subject to their primary stationary use, do not possess the versatile application potential of modern portable electronic displays and true-3D hardcopies. This means, that their field of application certainly has to bee seen complementary to a glasses-free "three-dimensional" visualisation by means of "flat" media, e.g. lenticular geo-displays (cf. Buchroithner & Schenkel 2001).

Nevertheless solid terrain models (STMs) can serve as a key to the application of stereoscopic cartographic visualisation techniques possible today. The facts presented in the following paragraphs may not be hundred percent conclusive, they are, however, at least indicative.

According to Buchroithner 2007 (cum lit.; cf. Wastl 1999, 2000) more than 60 percent of 86 interviewed map users were not in the position to spontaneously – this means without a longer reflexion – generate a “mental relief“. In addition to these findings further investigations into the topic of three-dimensionality yielded interesting results.

Studies carried out in the years 1992, 1997 and 2006 in the visitor centres of national parks and national monuments of the western U.S.A. and of Iceland (with a total of more than 900 observed visitors) yielded interesting results: A varying percentage of 67 to 100 percent of the visitors of the information centres spontaneously headed for the solid terrain models as soon as they had “discovered” them: This resulted in an average value of 73 percent without any gender-specific or age-specific trend (Buchroithner 2007).

Hence, regardless of any highly aesthetic and highly instructive static and “flat” geo-displays (colourful maps, colour photographs; movies are here exempted!) in the neighbourhood of STMs, there is much evidence to suggest a high degree of attractiveness and probably also a higher user acceptance of truly three-dimensional geo-embodiments.

Artificial 3D perception is based on the insertion of stereo-images into the human field of view. The common methods either realise an image separation for the eyes or an object reconstruction which makes use of a simultaneous binocular vision. Without going too much into the details of the individual methods or technologies, in the following the mode of functioning and the advantages of the lenticular foil method shall be briefly described.

The lenticular foil technology is an image display method for the generation of multi-image effects like 3D visualisations or animations. In order to spontaneously obtain these effects without additional aids for the viewer (glasses or other means for image separation, “glasses-free stereo-vision”), lenticular displays consist of two components:

1. the lenticular image,
2. the lenticular foil.

The transparent lenticular foil serves the separation of the individual images. For this purpose, on its upper side there are a series of parallel semi-cylindrical micro-lenses (Latin “lenticula”). The lower side is smooth as glass and coincides with the image plain of the lenticular image. The lenticular image comprehends the single stereo-mates (or – in the case of “flat” depictions, e.g. for flipping, – partial images) cut up into small strips and interlaced in an alternating sequence. Consequently, under each of the semi-cylindrical lenses lies one strip of each partial image.

The image separation through the lenticular foil functions according to its optical properties. The semi-cylindrical lenses focus the parallel incident sight rays onto particular strips of the lenticular image. If the viewer changes his perspective by turning or tilting the lenticular display perpendicular to the lenses, the vision rays are focussed onto other strips of the display. This enables the perception of the spatially separated image information out of one lenticular image, because from a particular viewing angle the viewer only sees one strip per semi-cylindrical micro-lens. More comprehensive information about the lenticular technology can be found in Okoshi 1976, Gruendemann 2004a, b, Buchroithner, Gruendemann and Habermann 2004, Buchroithner, Habermann and Gruendemann 2004 and 2005 as well as Buchroithner, Gruendemann, Habermann, Neukum and HRSC-CoI-Team 2005.

A significant strength of the lenticular technology is its versatility concerning displayable effects. They can be divided into two categories: 2D and 3D effects. Each of these major categories comprehends special effects (true-3D, flip, morphing, zoom, and animation; cf. *Table 16.1).*

Table 16.1. Effects of lenticular displays (changed after Micro Lens Technology 2004)

2D Effects	3D Effects	Combined Effects
Flip, Morphing, Zoom, Animation	True-3D	All combinations of 2D and 3D Effects

Displays with 2D effect mostly have micro-lenses running in horizontal direction. Thereby a supply of the same image information to both of the viewer's eyes is achieved. Horizontal tilting of the lenticular display then changes the image content.

For lenticular displays with true-3D effect, however, the semi-cylindrical lenses have by all means to be arranged in a vertical way. This disposition results in the visual perception of different images of the same object(s). Moreover, the displays can be generated as reflectance displays (incident light/"looking at") or transmission displays (transmitting light/"looking through").

As already demonstrated by the lenticular display on the cover of the October 2005 issue of Photogrammetric Engineering and Remote Sensing (Buchroithner, Gruendemann, Kirk and Habermann 2005) combinations of 2D- and true-3D effects can even be combined with multiscale depictions (see below). The semi-cylindrical micro-lenses run vertically in order to permit depth perception. Simultaneously, by tilting the display to the left or to the right different image contents become visible. Thus, in one hardcopy display different scenes can be visualised stereoscopically, and explicatory letterings can, hovering above the relief, be faded in or masked.

However, due to the restricted opening of the viewing angle of the semi-cylindrical lenses, the number of scenarios is mostly limited to two or three. If more than three scenarios shall be displayed, in most cases one has to abstain from the stereoscopic impression (depth perception).

16.4 Generation of Lenticular Displays

If the input data (digital terrain model plus texture, e.g. an ortho-image) are only available in two-dimensional form, for the three-dimensional display they first have to be imported into a 3D modelling- and visualisation software (e.g. 3D Studio MAX) and then spatially modelled. Separate arrangements of the individual objects allows that lenticular flip images may hover in a sort of "flying carpet depiction" above the major scene. The integrated letterings/labels can also be positioned above the relief. In order to make the height relations of the scene spatially visible, in many cases the surface morphology has to be vertically exaggerated by a factor of 3 or even more (e.g. 5). The relief exaggeration should, however, not to exceed the maximum depth range possible. For 75 lenses/inch foils this corresponds to 20 mm.

For the stereo-imaging of the model virtual cameras have to be placed above the "virtual landscapes" consisting of the respective DTMs and the draped hypsometric colour layers or ortho-imagery. Aim of this "photographing" is the generation of image information about the objects from different look-angles, resulting in a series of stereo-images with parallel optical axes, thus emulating a "virtual overflight". When combining the 3D effect with other effects, only some of the virtual cameras record the respective scene. The other part of the cameras records the second, altered scenario. The use of digital data and processing steps opens the possibility for the visualisation of the whole band-width of solid and virtual objects or real and imaginary situations and processes.

For the display in the form of a lenticular hardcopy the individual partial images have to be transformed into a print file and subsequently be printed. This processed print file comprehends the interlaced partial images, i.e. the lenticular image. The printout can be made by direct printing on the verso of the lenticular foil using ultraviolet offset printing technology. This technique offers a high fitting accuracy of the individual interlaced image strips with the micro-lenses and is mainly suitable for high print-runs. Calibration of the printing press and the production of the printing plates are, however, very time-consuming.

The design of a lenticular map display is significantly more demanding than that of a "flat" 2D map. Let us just briefly consider the placement of map symbols, be they linear or punctual, and of the labelling. *Table 16.2* gives a simplified overview of three possible cases how to treat this vector information.

Table 16.2. Inserting vector information into the 3D-model.

Placement of vector information in relation to the relief			
Identical with relief	Identical with relief – merged with image data	Nearly identical with the relief – manual placement	Significantly hovering above the relief
Image data, shading, hypsometric tinting	Elevation contours, boundaries, road network, water bodies	Signatures, elevation figures	Geographic names, lettering in general

The capability of autostereoscopic lenticular foil maps to let the letterings and map symbols hover above the terrain, even at different height levels, is certainly an additional feature with an artistic whiff; something which makes these "3D maps" attractive (cf. "attractiveness" in *Section 16.1).*

It comprises, however, also a good portion of aesthetic feeling and intuition, which goes beyond the requirements for flat paper maps, to make the depicted landscape reliefs look attractive. Here, two assets which also play an essential role in "2D map" generation have to be mentioned: A balanced tinting of elevation zones and a delicate hill-shading have to be combined with a naturally looking vertical exaggeration. The latter is basically a matter of hard skills in software handling.

Hypsometric tinting can certainly to some extent enhance the relief perception. But is a "photorealistic" representation with an ortho-image draped over the DTM,

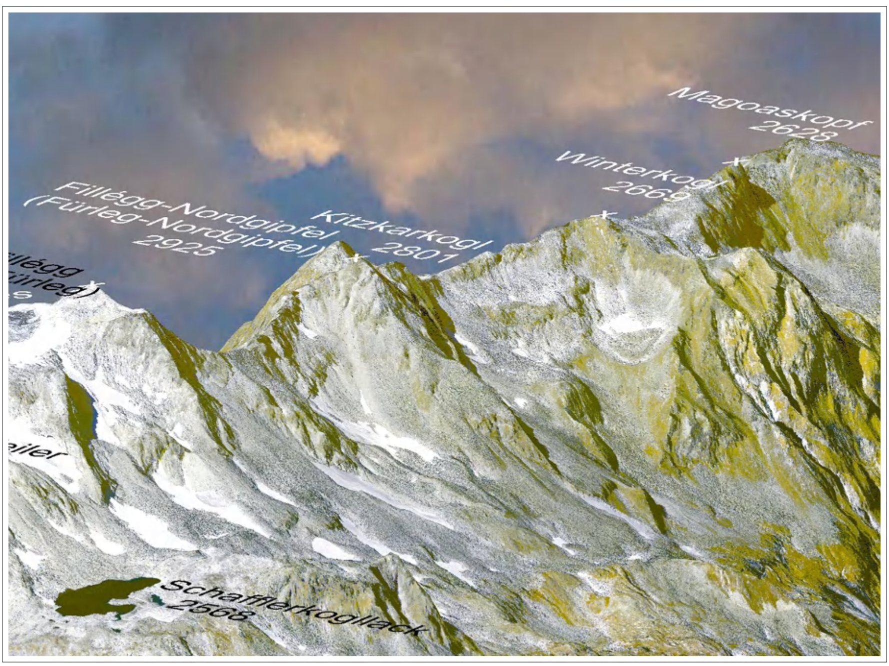

Fig. 16.2. Perspective view of geographic name labels hovering above alpine terrain.

due to the “simulation” of the physical “real” world, equally, if not better, suitable for an autostereoscopic perception? There exits no binary answer: They are two distict types of cartographic depiction, also to a good deal scale-dependent. In any case, an appealing, aesthetic land cover can certainly improve the joy of viewing this type of true-3D landscape depictions.

Remains one final question: Is an autostereoscopic display necessary to convey landscape aesthetics? Based on all the aforementioned evidences related to landscape perception and cognition, both physiological and psychological ones, we dare to give a positive answer.

16.5 Conclusions

Whereas aesthetics, according to an extensive body of literature, has something to do with beauty and is generally characterised by harmony and wellbeing, attractiveness is assigned to something which is appealing, exciting or even thrilling.

The Institute for Cartography of the Dresden University of Technology is dedicated to make their contribution to raise the beauty of maps and, hence depicted landscapes, into the third dimension. In the sense of the famous German cartographer Karl Wenschow the members of the Dresden group consider themselves as a sort of modern “geo-sculptors”. They strongly plead to consider maps, also true-3D maps, not only as a piece of hard- or softcopy geo-information but also as a piece of art, the observation of which is by far more appealing than the viewing of a conventional flat map. Today, modern processing methods and techniques provide highly potential tools to materialise this.

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Chapter 17

Approaches to Image Abstraction for Photorealistic Depictions of Virtual 3D Models

Jürgen Döllner and Jan Eric Kyprianidis

Hasso-Plattner-Institut, University of Potsdam, Germany
{doellner, kyprianidis}@hpi.uni-potsdam.de

Abstract

In our contribution, we present approaches of automatic image abstraction, applied to images and image sequences derived as views of virtual 3D city models and landscape models. We first discuss the requirements of cartography-specific visualization based on the virtual globe metaphor as well as the specific characteristics and deficiencies of visualization based on photorealism. We introduce a concept that extends the classical visualization pipeline by cartography-specific functionality, object-space and image-space abstraction, which also represent the two principle ways for implementing cartographic visualization systems. Abstraction provides the prerequisites to visually communicate uncertainty, to simplify and filter detailed elements, and to clearly encode displayed information of complex geospatial information. In addition, it offers many degrees of freedom for artistic and stylistic design of cartographic products. Furthermore, we outline general working principles and implementation of an automatic image-space abstraction technique we developed that creates high-quality, simplified, stylistic illustrations from color images, videos, and 3D renderings.

Keywords: Non-photorealistic rendering, image abstraction, virtual 3D city models

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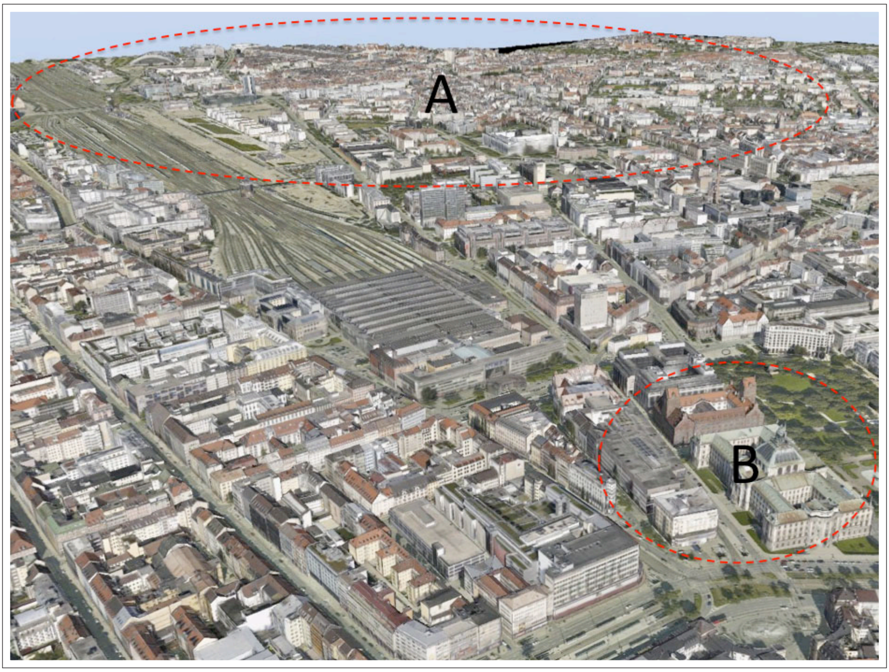

Fig. 17.1. Example depiction with regions of low information value (A) and relatively good visual information value (B)

17.1 Cartographic Visualization Based on the Virtual Globe Metaphor

A growing number of applications and systems use the *Virtual Globe* metaphor as central concept and technology to communicate geospatial information. The base concept is to represent geospatial data as well as georeferenced data by means of virtual 3D models such as virtual globes, virtual city models and virtual landscape models.

These systems already represent key elements in today's information infrastructures and become essential system components in complex workflows in administration and economy (e.g., Google Maps) as well as intuitive, effective user interfaces to geospatial information for the general public (e.g., Microsoft Virtual Earth, Google Earth). As a common characteristic, these systems support naïve geography and thus enhance the specific transmission of geospatial information (Däßler 2002). In addition, communication theories support the assumption that 3D presentation forms establish a naïve information transmission for topographic issues (Egenhofer and Mark 1995).

The ultimate goal, effective communication of geospatial information, has to take into account perceptional, cognitive, and graphical design issues to ensure a clear and efficient understanding of information contents (Jobst 2008). These principles known for 2D depictions also apply to dynamic 3D presentations. In particular, 3D presentations of virtual city models are faced by massive occurrence of occlusion and massive amounts of visual details. Due to that, they demand for specific perceptional, cognitive, and graphic designs compared to well-known, straightforward photorealistic depictions, which often expose large areas of "dead pixels" *(Figure 17.1),* i.e., areas that do not anymore have real information contents. In contrast, illustrative or, more general, non-photorealistic approaches typically achieve better content representation and transmission *(Figure 17.2).*

17.2 City Models and Landscape Models and Their Photorealistic Depiction

Virtual city models and landscape models are based on a multitude of 2D and 3D geospatial information sources such as building and site models, relief models, transportation models, vegetation models, and water models; an overview of principle components has been defined by CityGML, an OGC standard for the exchange of virtual 3D models (Kolbe et al. 2005). The availability of data is not only improved by progress made in remote sensing (e.g., laser scanning and automatic building reconstruction) but also enforced by the increasing compatibility and fusion of data from GIS, CAD/ACE, and BIM (Hagedorn & Döllner 2007). Here, virtual city models and landscape models become general-purpose frameworks for managing, integrating, and using complex, heterogeneous geospatial information.

Image data represents a major part of the data that constitute virtual city models and landscape models – they represent the key elements that enable photorealistic

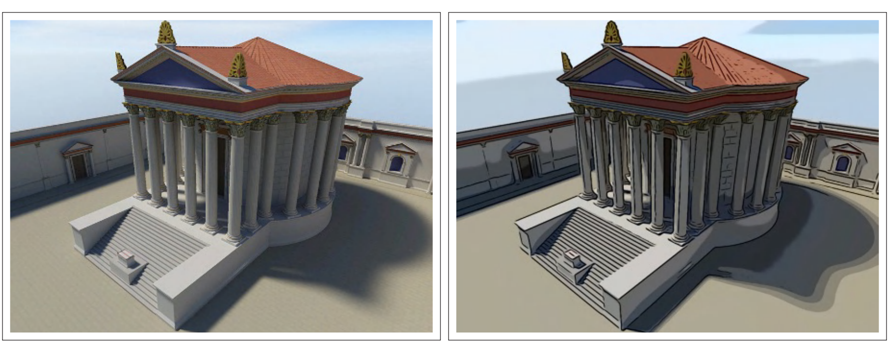

Fig. 17.2. 3D model of a temple of Roman Cologne (Maass et al. 2008): (a) Photorealistic rendering. (b) NPR rendering to communicate missing evidence

depictions. These data sources include, for example, oblique images, orthophotos, and georeferenced photography imagery. In general, in a preprocessing step, the data is filtered, projected, transformed, and assigned to objects of these models, stored frequently in terms of model geometries and textures.

Apart from image data generated by remote sensing, procedurally generated image data represent another important category of photographic data for creating and managing design and appearance of virtual city models and landscape models. The images are generated based on rules that combine pre-defined samples of photographic data (e.g., organized by catalogues for material and surface textures) and synthesize textures for a given object surface (e.g., (Wellmann 2008)).

Photorealistically designed virtual city models and landscape models are generated more and more by automatic processes (Frueh et al. 2004). For example, a collection of oblique images together with a corresponding 3D building model can be automatically processed such that for each visible façade of all building models façade textures are generated. Each façade texture is synthesized by combining parts of the original oblique images according to quality criteria that take into account distance, resolution, occlusion, and error-reducing heuristics about typical façade outfits (Lorenz & Döllner 2006). Insofar we can assume that in the near future the process of creating and updating the geospatial data underlying a virtual city model or landscape model can be automated to a large extend; for base models up to CityGML level-of-detail 2, most likely, this process will be fully automatic.

The photorealistic visualization of virtual city models and landscape models is further enforced by development directions of computer graphics hardware, which concentrate on real-time photorealism. The implementation of systems managing and using massive photorealistic virtual city models and landscape models takes advantage of the texturing capabilities of computer graphics hardware. For example, a number of approaches recently developed allow systems to use an almost unlimited amount of georeferenced texture data within 3D geovirtual environments based on texture atlases (Buchholz 2006).

17.3 Inherent Deficiencies of Photorealistic Visualization

Photorealistic visualization is faced with a number of deficiencies inherent to photorealism. As key characteristic, photorealism wants to represent objects and phenomena by means of the real appearance. In contrast, cartographic visualization relies on abstraction as a fundamental principle to achieve effective communication of complex information. Among the weaknesses of photorealistic visualization we can identify:

- Complex geometry: Models rarely have uniform resolution (e.g., building models derived from cadastral database versus CAD-based models) nor does the resolution correspond in general to the needs and tasks of the user (e.g., detailed CAD models used for an overview of a city).

- Limited texture resolution: The appearance and design of a whole virtual city model suffers from varying and limited resolutions of textures derived by photographic data
- Limited texture quality: The texture contents also expose weaknesses inherent to photorealistic imagery. For example, aerial photography frequently contains non-required objects such as parking cars and pedestrians).
- Fixed lighting and shading: Another inherent weakness of photorealistic imagery represents fixed lighting and shading encoded in photographic imagery. Moreover, they can hardly be removed from the original data.
- Occlusion and perspective distortion: Dependent on the viewpoint, occlusion can strongly impact the visibility of objects. In addition, the perspective projection typically used for 3D viewing leads to distortions and varying scales within a single depiction.

While being attractive in many application areas that benefit from photorealistic visualization (e.g., urban planning, environmental monitoring), photorealism implies strong limitations in the context of cartographic information communication.

17.4 Towards Cartographic Visualization

By *cartographic visualization* we refer to the visualization of geospatial information using concepts and techniques from cartography. Predominantly cartographic visualization relies on abstraction as the most powerful principle to effectively communicate complex geospatial information.

To implement abstraction within the visualization pipeline, two principle approaches can be distinguished: object-space abstraction and image-space abstraction. Both need to be considered independently but have to operate closely at the implementation level. *Figure 17.3* illustrates the corresponding prototypic system architecture.

17.4.1 Object-Space Abstraction

Object-space abstraction refers to an abstraction process that transforms the original 2D and 3D geospatial objects and relations into an intermediate 2D and 3D representation used for rendering. This process typically takes place at the filtering/selection phase of the visualization pipeline.

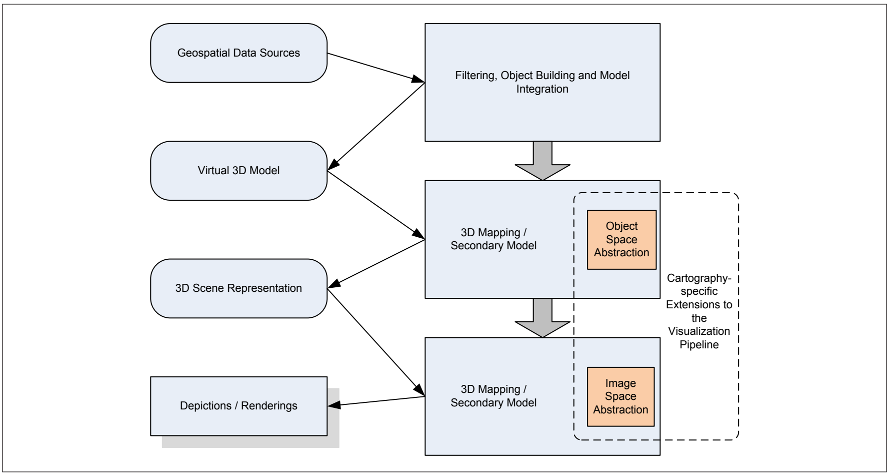

Fig. 17.3. Model of the visualization pipeline extended by cartography-specific components. The data (left column) is transformed through three processing stages (right column) into the final depictions. Object-space abstraction respectively image-space abstraction form part of the corresponding processing stages.

A prominent type of object-space abstraction represents generalization, which in the scope of GI science (Hake et al. 2002) means the process of deriving abstract representations of spatial information subject to a given scale of the communication medium and the intended purpose and tasks to be supported. The process relies on, for example, selecting, combining, reducing, transforming, merging, and enhancing graphical representations; it can also "be understood as a process of representation of the real world by different models" (Cecconi 2003), i.e., derivations of secondary models.

For virtual city models and landscape models, generalization means to derive multi-scale variants. For example, the technique introduced by (Glander & Döllner 2007a) implements the cartographic generalization operators clustering, aggregation, and accentuation. An example of a generalized virtual city model is shown in *Figure 17.4*. It performs the generalization in four steps: 1) City model components are clustered based on the cell structure. 2) For each cell, the weighted average height is calculated, which is also used to automatically identify outliers. 3) Free space is subtracted from the cells such as in the case of outliers or vegetation areas. 4) The modified cells are extruded to building blocks; vegetation areas and outliers are modeled or, respectively, integrated separately. The cell structure can be derived from a given 2D hierarchical network (e.g., hierarchical street and river networks) for which polygonal 2D cells are computed. Each object of the virtual city model is uniquely assigned (and possibly split or re-modeled) to a cluster. The generalized model consists of these representations – that is, abstraction is performed in the scope of the object-space and achieved by generalizing the geospatial data. As key advan-

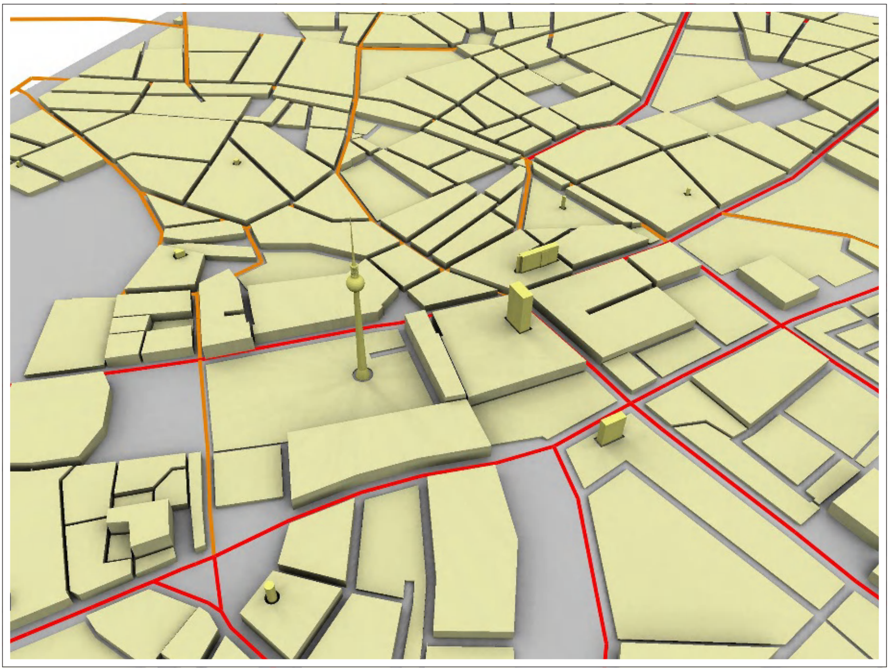

Fig. 17.4. An automatically generalized 3D city model of Berlin, generated by the cell-based method of (Glander & Döllner 2007a)

tage, generalized virtual city models improve the perceptual quality of displayed spatial objects, provide better insights into structure and hierarchy underlying the city model, and facilitate 3D orientation and usability for models with large extend.

Applications and systems based on the Virtual Earth metaphor require object-space abstraction due to manifold reasons such as

- to produce models with homogeneous level-of-detail and, thereby, to integrate heterogeneous geospatial model parts;
- to adapt the level-of-detail of model parts to the current viewpoint;
- to adapt the information density to the needs of users and their tasks.

Object-space abstraction by its nature is non-trivial to implement because it has to automatically analyze, interpret, and synthesize complex 3D geometry, i.e., complete new, consistent secondary models have to be generated. Its automatic implementation in the scope of 3D geospatial data is still in its infancy. Even in the scope of 2D geospatial data the implementation of object-space abstraction techniques represents a major challenge for automation. In particular, techniques must be able to compute results in near real-time to be used in interactive applications and need to define not only discrete levels-of-details but also the transformation in between those levels.

17.4.2 Image-Space Abstraction

Image-space abstraction refers to abstraction applied to the depiction of geospatial representations. It forms part of the rendering process. In contrast to object-space abstraction, it can be implemented by graphics processing, performed in real-time, and applied independently from the underlying geo-objects' representations. Insofar, it is complementary to object-space abstraction and concentrates on the visual design used to render the contents of virtual city models and landscape models.

With respect to cartographic visualization, image-space abstraction demands for dedicated rendering techniques that implement specialized coloring, shading, illumination, and projection techniques. As a simple example of image-space abstraction, consider edge enhancement (Nienhaus & Döllner 2003). It can be implemented by post-processing generated images, applying convolution filtering that enhance color contrasts in the given image. Edge enhancement represents an effective way to improve the perception of the shape of a depicted object.

An example of a more sophisticated image-space abstraction technique is described in *Section 17.5.* It applies complex image analysis and filtering and can be used directly to transform common photorealistic images of virtual city models and landscape models into illustration-like depictions.

17.4.3 Dependencies Between Abstraction Approaches

A cartographic visualization system has to carefully select and co-ordinate object-space and image-space techniques. Object-space abstraction techniques in general will be independently applicable from the 3D rendering system – they operate within the modeling space and, therefore, do not make any assumptions about the rendering technology. Their results may be useful also for analytic computations as well.

There are also hybrid abstraction approaches that require a coordinated implementation. As an example consider an approach that enhances 3D landmarks in perspective views (Glander et al. 2007b). Landmarks represent elements of outstanding importance for user orientation because they facilitate navigation and exploration within large virtual city models and landscape models. The image-space/object-space abstraction technique for enhancing landmarks emphasizes the landmark objects by improving their visibility with respect to their surrounding areas and the current 3D viewing settings; emphasizing is achieved by scaling the landmarks' geometry according to an importance function while simultaneously squeezing their corresponding neighborhood regions *(Figure 17.5).* To reduce visual artifacts caused by this multi-scale presentation, e.g., geometry intersections, the surrounding objects of each landmark are adapted according to a deformation field that encodes the

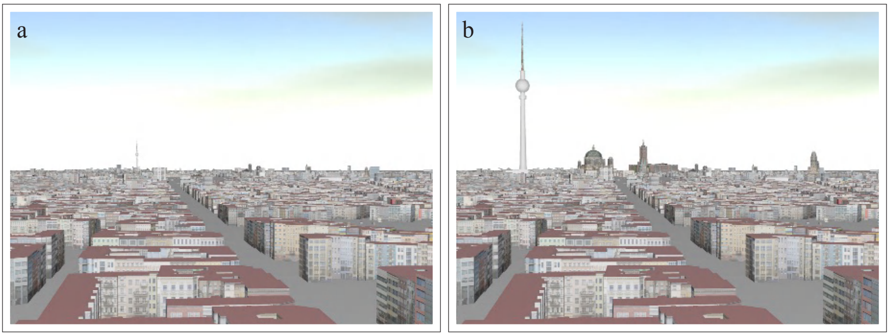

Fig. 17.5. Enhancement of multiple landmarks in a virtual 3D city model (Glander et al. 2007b). Comparison between standard (a) and enhanced rendering (b)

displacement and scaling transformations. An individual weight coefficient can be defined that denotes the landmark's importance. To render a collection of weighted landmarks within a virtual city model or landscape model, the technique accumulates their associated, weighted deformation fields in a view-dependent way. With landmark emphasizing the technique improves the perceptual and cognitive quality of cartographic depictions of 3D models. Coloring and shading of landmarks are emphasized by the image-space part of the technique's implementation.

In an ideal system, both object-space and image-space abstraction techniques would be implemented separately and interchangeably. Still there is a need for concepts and implementations that show how such an interoperable schema could work. OGC as well as all major GIS vendors still do not define dedicated, open standards for these system components – a topic that is at least addressed to a certain degree by the ongoing OGC working group on portrayal services.

17.5 Automatic Image Abstractions for Photorealistic Depictions

We have developed an automatic rendering technique that creates high-quality, simplified, stylistic illustrations from color images, videos, and 3D renderings (Kyprianidis & Döllner 2008). This technique can be added as a general-purpose image-space abstraction technique as post-processing to real-time 3D rendering pipelines and, therefore, is suitable for a variety of interactive 3D applications and systems. It has only minor requirements regarding the contents of virtual city models and their object-space abstractions. For this reasons, it can be used in a straightforward way as a basic building block for cartographic visualization systems and achieves a broad range of illustration styles due to a number of configuration

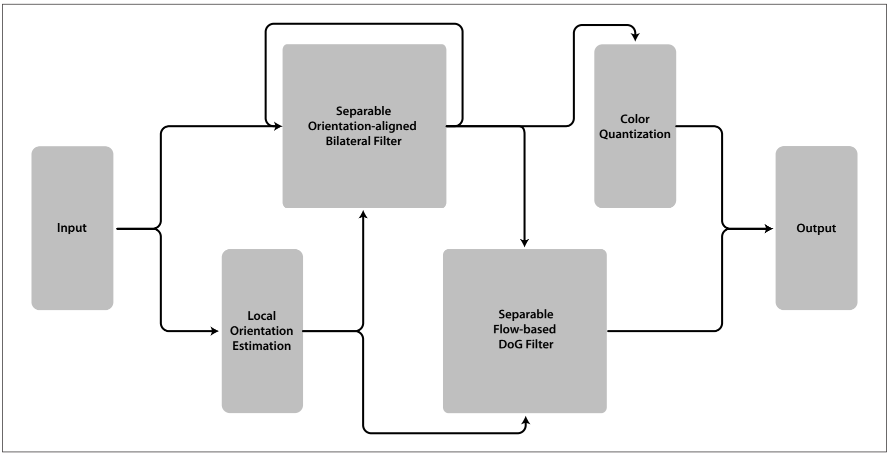

Fig. 17.6. A schematic overview of our image abstraction framework

parameters. Details of the implementation of our technique with focus on recent GPU technology can be found in (Kyprianidis & Döllner 2009).

Our method extends the approach of (Winnemöller et al. 2006) to use iterated bilateral filtering for abstraction and difference-of-Gaussians (DoG) for edge extraction by adapting it to the local orientation of the input. We developed enhancements to these techniques to improve the quality of the output by adapting them to the local orientation of the input. A schematic overview of our framework is shown in *Figure 17.6.* Input is typically an image, a frame of a video, or the output of a 3D rendering. We start with the estimation of the local orientation. Then, the input is iteratively abstracted by using the orientation-aligned bilateral filter. We perform a total of n_a iterations. To the result we apply color quantization. After $n_e < n_a$ iterations, we extract edges from the intermediate result using the separable flow-based DoG filter. In our examples we use $n_e = 1$ and $n_a = 4$. Finally, the extracted edges are superimposed on the output of the color quantization. *Figure 17.7* shows the output of different stages of the algorithm.

17.5.1 Local Orientation Estimation

To represent local orientation we construct a smooth tensor field. From the eigenvectors of this tensor field we derive a vector field that has similar characteristics as the edge tangent flow (ETF) of (Kang et al. 2007), but its computation is much less expensive. Besides gradient calculation, only smoothing with a box or Gaussian filter is necessary. In contrast to that, ETF construction requires several iterations of a nonlinear filter with large filter kernel.

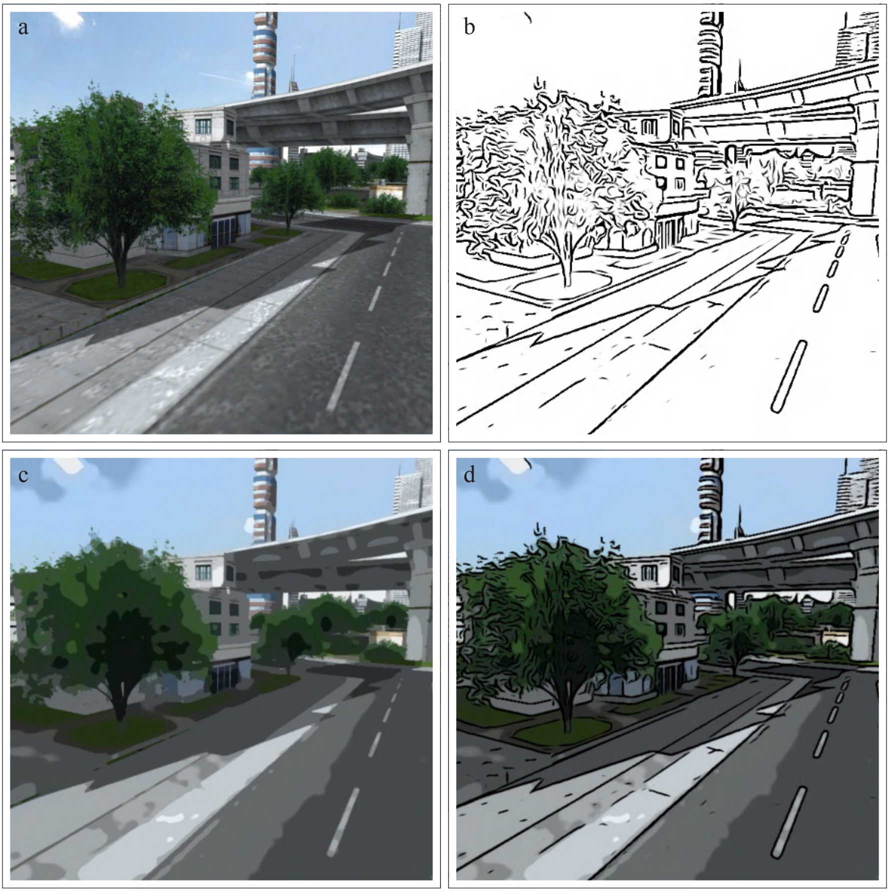

Fig. 17.7. Illustration of immediate results of the algorithm: (a) Original photorealistic rendering. (b) Output of edge detection. (c) Output of bilateral filter with color quantization applied. (4) Abstracted output.

17.5.2 Orientation-Aligned Bilateral Filter

The bilateral filter is a non-linear filter that smoothes images while preserving edges (Paris et al. 2007). It is based on two weighting functions. The first one gives more weight to pixels that are close to the filter center and the second one gives more weight to pixels whose colors are similar to the color at the filter's center. This has the effect that regions of similar color are smoothed, while regions with detail are preserved. For an image *f*, the bilateral filter is defined by:

$$\frac{\sum_{x\in\Omega(x_0)} f(x)\; G_{\sigma_d}\big(\|x-x_0\|\big)\; G_{\sigma_r}\big(\|f(x)-f(x_0)\|\big)}{\sum_{x\in\Omega(x_0)} G_{\sigma_d}\big(\|x-x_0\|\big)\; G_{\sigma_r}\big(\|f(x)-f(x_0)\|\big)}$$

Here, x_0 denotes the center of the filter neighborhood. For the closeness function and the similarity function, we use one-dimensional Gaussian functions:

$$G_\sigma(t) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left(\frac{t^2}{2\sigma^2}\right)$$

To achieve a nonlinear diffusion effect, the bilateral filter must be applied recursively. We are therefore interested in a fast computation of the bilateral filter. Computing the bilateral filter is expensive because it is not separable. A simple implementation requires evaluation of the full kernel. Several acceleration schemes have been presented in the research literature. The *xy*-separable bilateral filter (Pham & van Vliet 2005) used by (Winnemöller et al. 2006) suffers from horizontal and vertical artifacts. These artifacts appear in particular when the filter is applied iteratively. Our approach works by first filtering in direction of the gradient and then filtering the intermediate result in perpendicular direction. When applied iteratively our approach does not suffer from horizontal or vertical artifacts and creates smooth output at curved boundaries.

17.5.3 Separable Flow-Based Difference-of-Gaussians

Edges are extracted from the luminance channel after n_e iterations of the bilateral filter. In our examples we typically use a single iteration. This preprocessing is required to avoid the detection of edges that are due to noise. The (Marr & Hildreth 1980) edge detector works by computing the Laplacian-of-Gaussian and detecting the zero crossings in the result. The Laplacian-of-Gaussian can be approximated as the difference of two Gaussians. This variant is called Difference-of-Gaussians (DoG).

DoG edges often look frayed and don't reassemble straight line and curve segments very well. To work around this limitation, (Kang et al. 2007) recently introduced the concept of flow-based difference-of-Gaussians which, compared to DoG edges, create more coherent lines. They replaced the DoG filter by a flow-guided anisotropic kernel whose shape is defined by the ETF. Comparable high-quality results can be achieved by a separated implementation with corresponding reduced computational complexity. We first apply a one-dimensional difference-of-Gaussian filter in direction of the gradient and then apply smoothing along the vector field that we derive from the smoothed structure tensor.

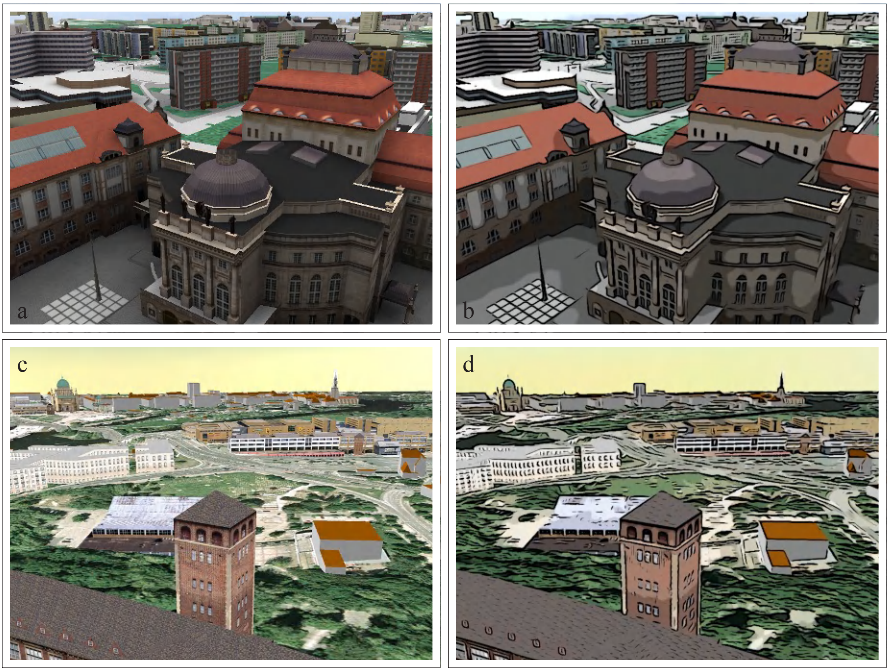

Fig. 17.8. Abstracted depictions produced by our method: (a),(c) Original Images. (b),(d) Abstracted results.

An example set of abstracted depictions produced by our method is illustrated in *Figure 17.8*. The underlying virtual city model is a typical representative of today's frequently found virtual city models with photorealistic design.

17.6 Conclusions

We have discussed essential elements of cartographic visualization, image-space and object-space abstraction as well as a general-purpose technique for image-space abstraction. The presented image-space abstraction helps to achieve a more efficient cartographic display of virtual arbitrary virtual city models and landscape models. Image-space abstraction provides the prerequisites to visually communicate uncertainty, to simplify and filter detailed elements, and to clearly encode the model nature of the displayed information – independently from the degree of generalization of the original underlying models. The technique also shows pragmatic qualities as it can be efficiently implemented on top of today's GPUs and as an add-on to existing rendering pipelines.

In our future work, we would like to investigate object-space abstraction techniques that directly cooperate with the presented image-space abstraction technique. In particular, we would like to separately treat different objects categories (e.g., building models versus vegetation models) and to apply different rendering techniques, respectively.

Acknowledgments

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Chapter 18

Globes on the Web – Technical Background and First Items of the Virtual Globes Museum

Mátyás Gede and Mátyás Márton

Department of Cartography and Geoinformatics, Eötvös Loránd University, Budapest, Hungary
{saman, matyi}@map.elte.hu

Abstract

The "Virtual Globes Museum" project has several aims. It preserves globes for the future and provides an opportunity of examining rare globes without the risk of doing any harm to them. It also can help in globe-restoring as the restoration work can be done on the virtual copy of a globe.

The first part of the paper will present possible solutions to the problem of interactive digital globe publishing on the Internet. It describes the processing method of the two possible source materials: globe prints and photographs. The visualization of results is realized in two different ways. The first one is a 3D virtual world created by using the VRML language. The second one is a special "globe layer" in KML, which can be used in the Google Earth software. The advantages and disadvantages of each solution are also examined.

The second part of the paper will introduce the most interesting items of the museum.

Keywords: virtual globe, 3D visualization, globe museum

18.1 Introduction

Globes are really multipurpose objects. They can be used as educational tools, as ornaments or simply to prevent table-clothes from being swept by the wind. Everybody likes looking at them and spinning them around. The desire of touching

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Lecture Notes in Geoinformation and Cartography, DOI 10.1007/978-3-642-03294-3_18,

the globe is even greater for old ones. The librarians or museologists, however, try to keep their precious spheres untouched in order to lengthen their lifetime as long as they can. The Virtual Globes Museum can be a cure to this conflict as visitors can do anything with the exhibited items without causing any harm to them.

Until the end of the 1980's, when the technical development swept away the traditional globe production technology, the globes of Cartographia (the monopolistic company of Hungarian cartography during the communist time) were very popular not only in the Eastern Block, but throughout Europe. The original aim of the project was only to archive the remaining objects of the Hungarian globe production until they are in good condition.

After examining the possibilities, several new, realizable aims were identified:

- The capacity of an average PC and the usual bandwidth of the Internet connection nowadays make it possible to publish three-dimensional objects on the web. One of the tasks is to develop easily publishable 3D globe models.
- Developing and presenting the method of digital virtual globe restoration on a specified globe in order to free the restoration process of any risks.
- Producing new (thematic) globes (Márton 1975).
- As the authors have found a lot of interesting globes apart from those of Cartographia, it was decided to process all the globes that are somehow related to Hungary (either they were produced or can be found in Hungary).

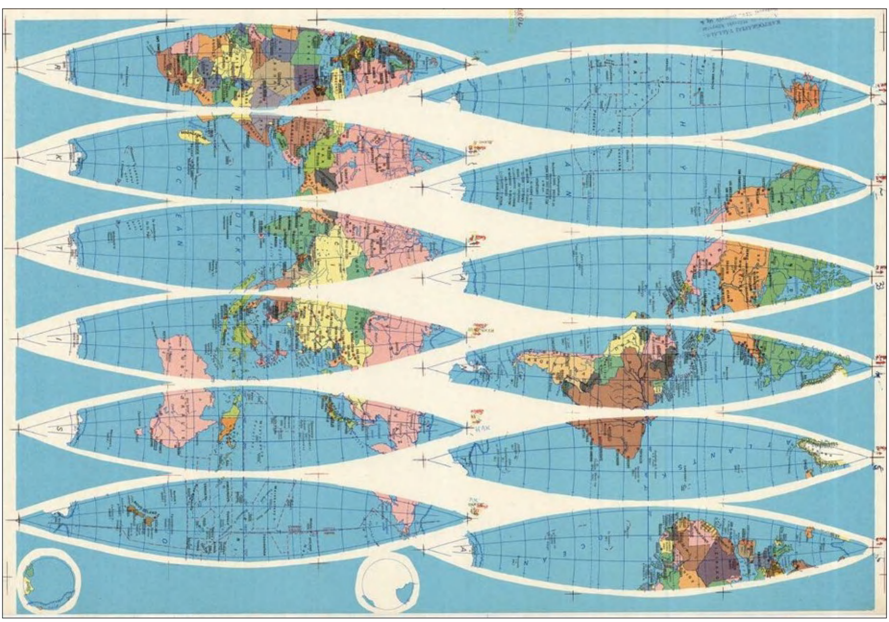

Fig. 18.1. Globe print

There are other virtual globe projects. János Balázs had made a digital version from Waldseemüller's globe (Török and Balázs 2008), but the content is not the original: only the coastlines were redrawn by graphic software and some names were put onto it. The result is an animation, which does not let the user interact.

Another project is Andreas Riedl's "hyperglobe" (Riedl 2000, 2003). This shows several ways of globe visualization. With Florian Hruby and Irmgard Plank he created the digital copy of Mercator's globe by using photographs (Hruby et al 2006). Although the processing method was quite similar to the one described here later, there are some differences: they georeferenced smaller areas and used different software for it. They also examined alternative display technologies for better visualization (Hruby et al 2005).

The largest difference between these projects and that of the present authors is that in the Virtual Globes Museum project several globes are shown in their current, real state. There is a searchable background database, which contains detailed datasheets for each globe. The models are fully interactive, and visitors can spin the globes around, zoom in and out. The museum's web site can be found at: http://vgm.elte.hu

18.2 Source Materials

The first problem when making a digital globe is the question of sources. As three-dimensional scanners are not widespread these days, it is difficult to get a digital image of a globe's surface.

The biggest help here is the unmounted globe prints *(Figure 18.1),* if they are available. In most cases they or at least the pilot prints of globes were found. These sheets can be easily scanned by a traditional scanner.

There are − especially manuscript or illuminated (hand-painted) − globes, however, for which there are no prints. In these cases, several photographs have to be taken of the globes. The photoshots need special conditions *(Figure 18.2).* The position of the camera and the globe has to be fixed, but rotating the globe around its center to any direction must be possible. These restrictions are required in order to assure the same lighting conditions for each photo. There must be specially arranged lamps, and also the exclusion of any outer light. And at last but not least, an expert photographer is needed.

Figure 18.3 shows what happens when the conditions are not perfect. The authors had the opportunity to make a photo series of a globe in a library, but did not have the required equipment as they were just visiting a conference abroad. Without special lighting and a photographer, they managed to take all the photos, but the resulting quality of the digital globe is rather poor.

Fig. 18.2. Photographing a globe needs special equipment and conditions

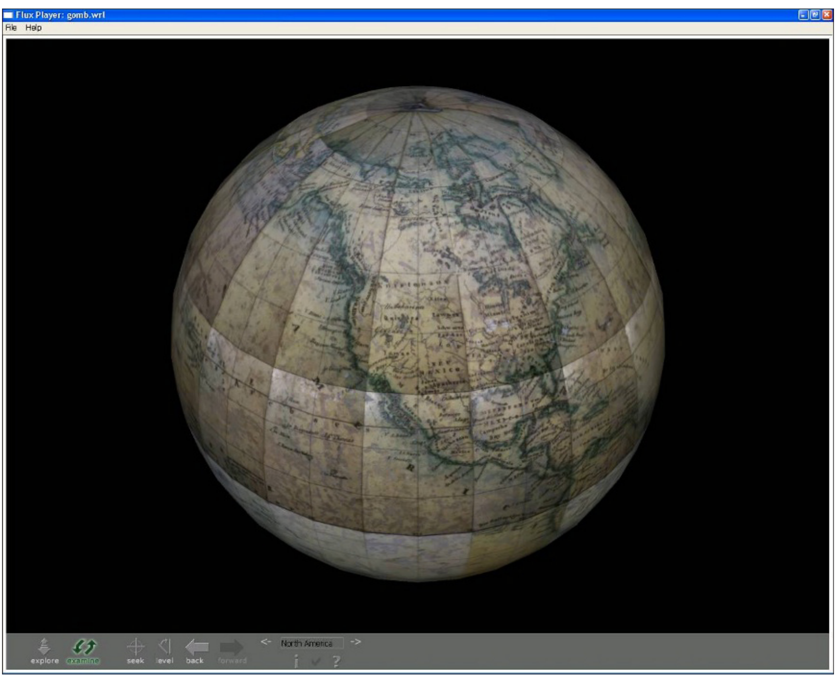

Fig. 18.3. Tone differences caused by insufficient photographing conditions

18.3 Image Processing

Once we have the digital images, we have to georeference them. It is quite easy for the unmounted prints, because their projection is known: Cassini projection (known as Cassini-Soldner by GIS applications) for the segments and Azimuthal Equidistant for the polar caps. The control points of the georeference can be the intersections of the geographic grid.

Georeferencing the photos is slightly more difficult. If the globe photo is treated as a map, its projection is Tilted Perspective (Snyder 1987), which is not known by any GIS program. However, if the centre of the globe is on the optical axis, it is a Vertical Near-Side Perspective projection. Knowing the name of the projection is far not enough as it has several parameters: the longitude and latitude of its central point and the relative height of the perspective point. In order to solve this problem, a program had been developed which uses the Downhill Simplex method (also called Nelder-Mead method) (Nelder & Mead 1965) to find the optimum of these values by using the given control points, which are again the intersections of grid lines; for celestial globes, some stars whose coordinates can be determined can serve as control points.

After georeferencing, a projection transformation of these images to Plate Carrée is applied. The reason is that in this projection the images can be easily assembled into one image. Attention must be paid to the Moiré effects that can appear during resampling the images in the new projection *(Figure 18.4)*. This effect can be prevented by using a Moiré filter.

18.4 Ways of Visualizing the Globes

The first idea to visualize the globes was to use VRML language (Virtual Reality Modeling Language) (Carey & Bell 1997). A spherical object was developed that consists of six surfaces. There are two polar caps and four geographical quadrangles around the equatorial areas *(Figure 18.5)*. Each surface has its own texture. The textures of the polar caps are in Azimuthal Equidistant projection, while the others in Plate Carrée. Some pre-defined viewpoints are also added: one for each continent and for the poles.

The performance of VRML browsers are highly hardware-dependent. The most important factors are the processor's computing speed, the available memory space and the parameters of the graphical card. For example, if the computer's graphical card doesn't have enough memory bigger textures may be simply not rendered.

Another solution is displaying the globe in Google Earth. This software lets us stretch images to geographical quadrangles. If the images are in an equirectan-

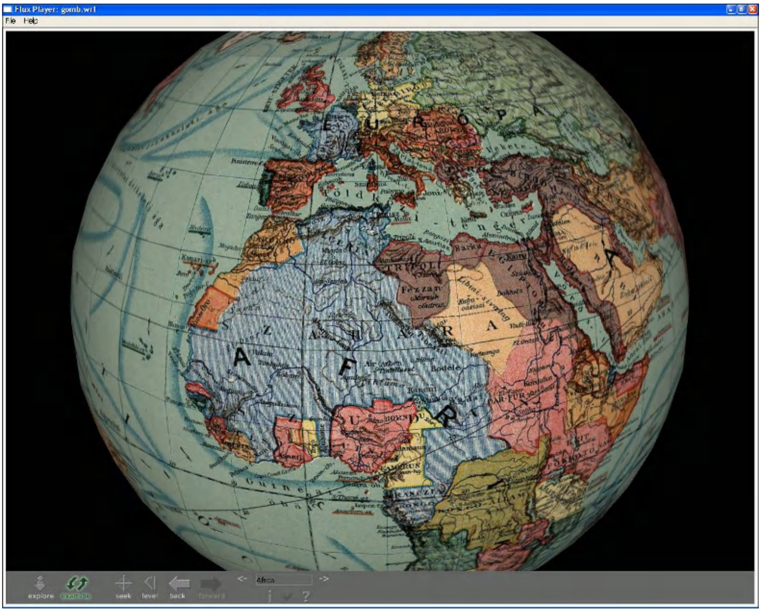

Fig. 18.4. Moire effect appearing due to the interference of the sampling grid and the printing raster

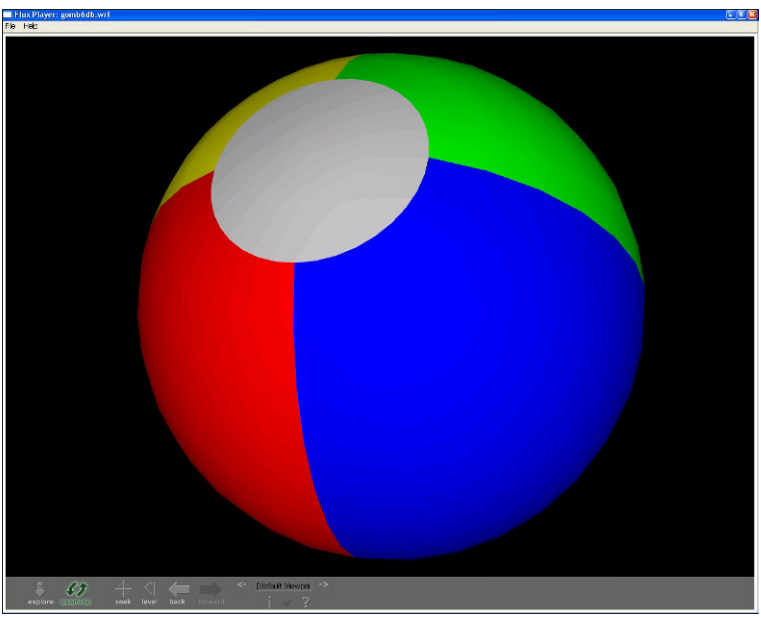

Fig. 18.5. The self-defined sphere built up of six surfaces (here with boundary latitudes of 70°)

gular projection, they will be mapped correctly onto the globe. The only limit is that images larger than 2048*2048 pixels will have their size being reduced. This problem can be solved by using several smaller images instead of a large one. In this case, a KMZ file has to be created. This file is a zipped archive consisting of a KML file describing the position of the images and the image files themselves (Google 2009).

18.5 Samples from the Museum

Willem Jansszon Blaeu's pair of globes *(Figures 18.6* and *18.7)* from the Cistercian Abbey of Zirc were amongst the first items processed by the authors. The globes were recently restored, so now they are in a very good state in spite of their age of more than 350 years. Due to the large size of the globes, the resolution of the on-line versions is limited, but researchers who wish to study them in details can reach the high-resolution models at the authors' Department.

The models of these globes were made by taking a photo series. As the celestial globe does not have a proper geographic grid, the colour tone differences appear sharply on the assembled picture at the adjacent edges of different photos. (If there were a grid line outlining the parts, this difference would not be so much eye-catching.)

A facsimile atlas of Coronelli's globe prints is kept in the National Széchényi Library, and the authors had the opportunity to process it. These prints are monochrome. In Coronelli's time it was possible to order globes with different quality of illumination (hand-painting) or without any (this was the cheapest option). The globes shown in the museum are of course of the latter kind *(Figure 18.8)*.

There are prints of terrestrial and celestial globes of several different sizes in this atlas. The smallest globes have a diameter of less than 10 cm, and the biggest ones are larger than 1 meter.

An interesting item is Alois Höfler's truncated sky globe for students *(Figure 18.9)*. This globe showed only the celestial areas visible from Germany, so its southern pole is missing. Unfortunately, no existing copy of this globe is known to the authors, as only a set of prints is kept in the maproom of the authors' Department.

The shape of VRML globe models is not limited to the sphere only. The 3D versions of the detachable structural morphological Earth model of Cartographia were also created *(Figure 18.10)*. This model consists of two parts, which together build up the whole sphere. The inner surfaces of the parts show different geophysical themes.

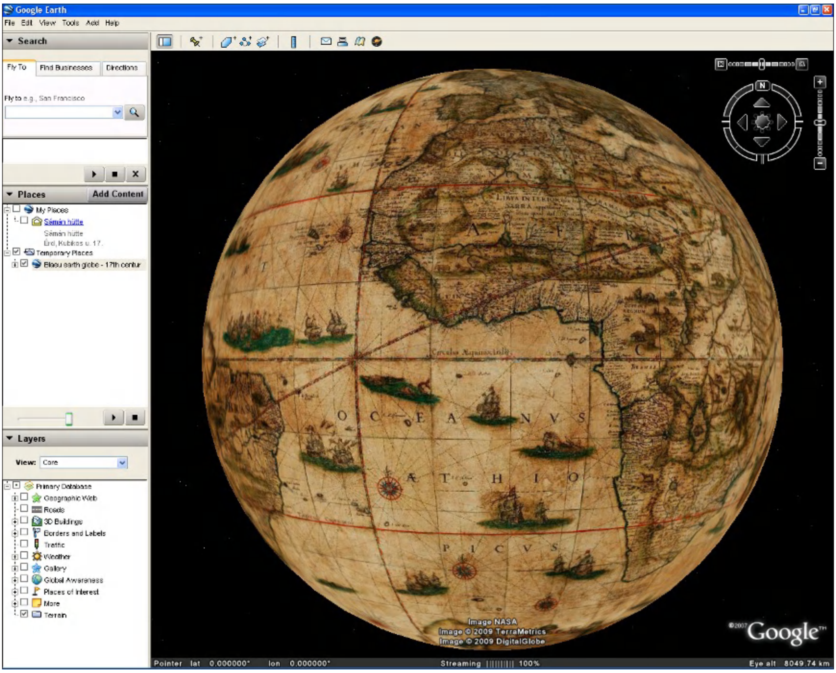

Fig. 18.6. The 68 cm diameter terrestrial globe of Blaeu in Google Earth

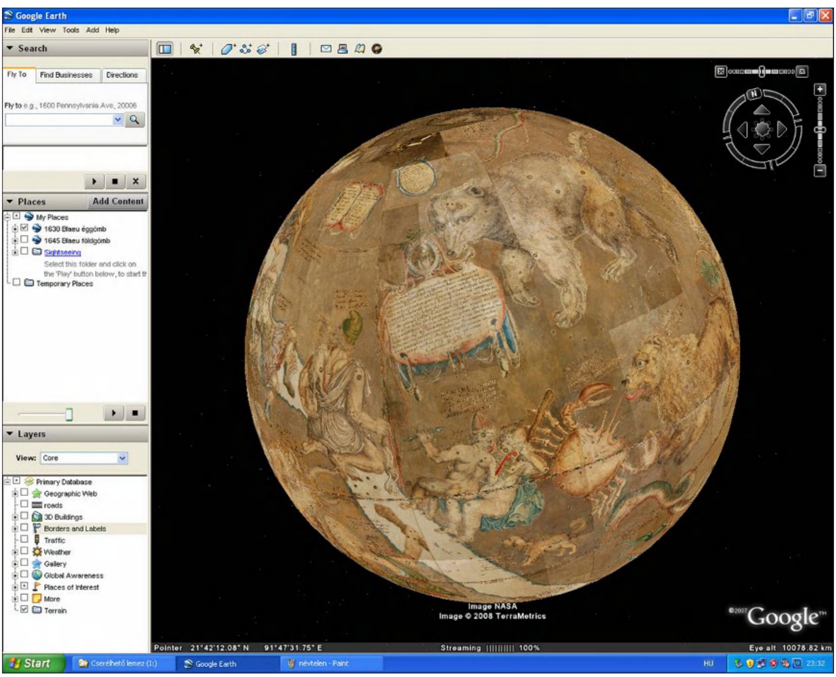

Fig. 18.7. The 68 cm diameter celestial globe of Blaeu in Google Earth

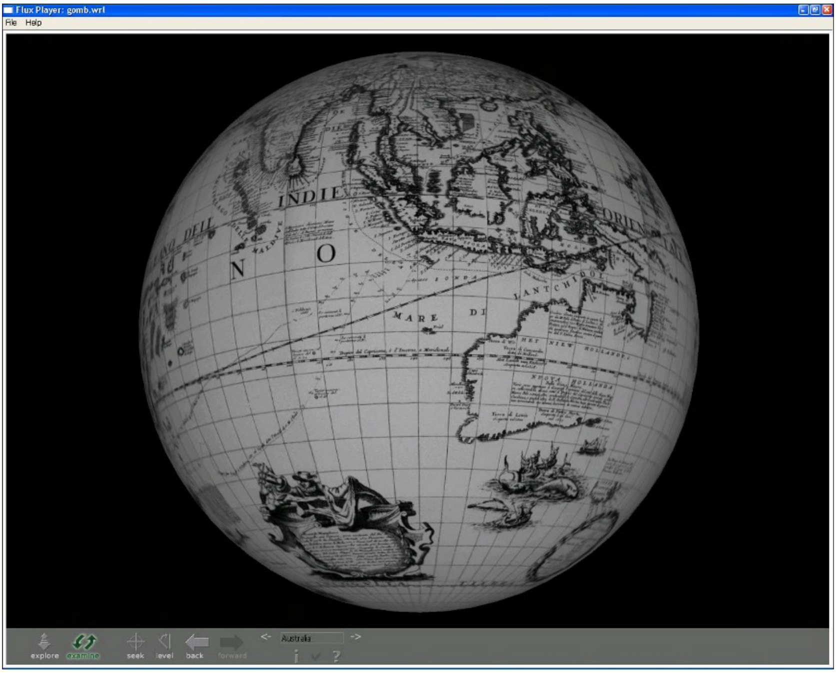

Fig. 18.8. A virtual globe created using a facsimile print of Coronelli

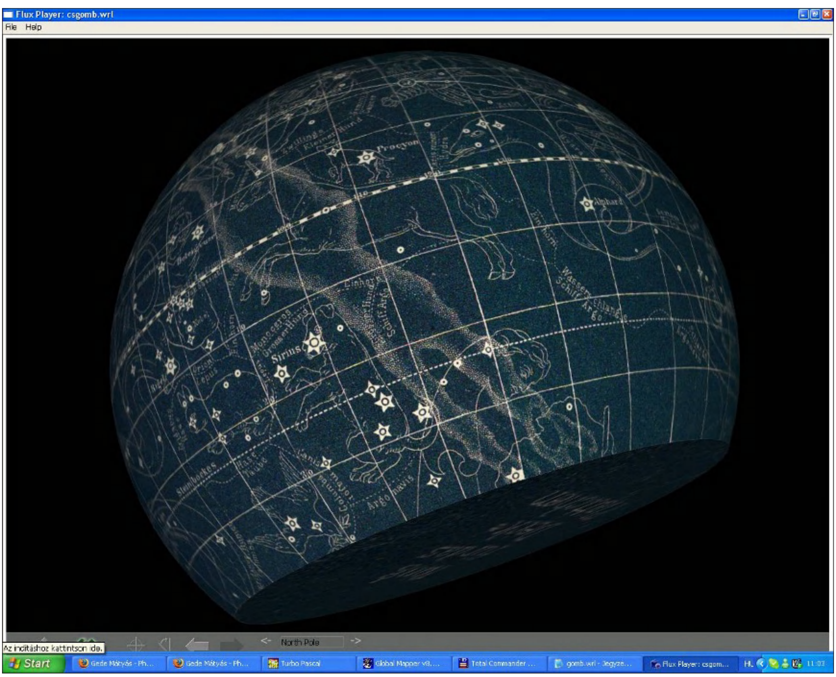

Fig. 18.9. Alois Höfler's truncated sky globe

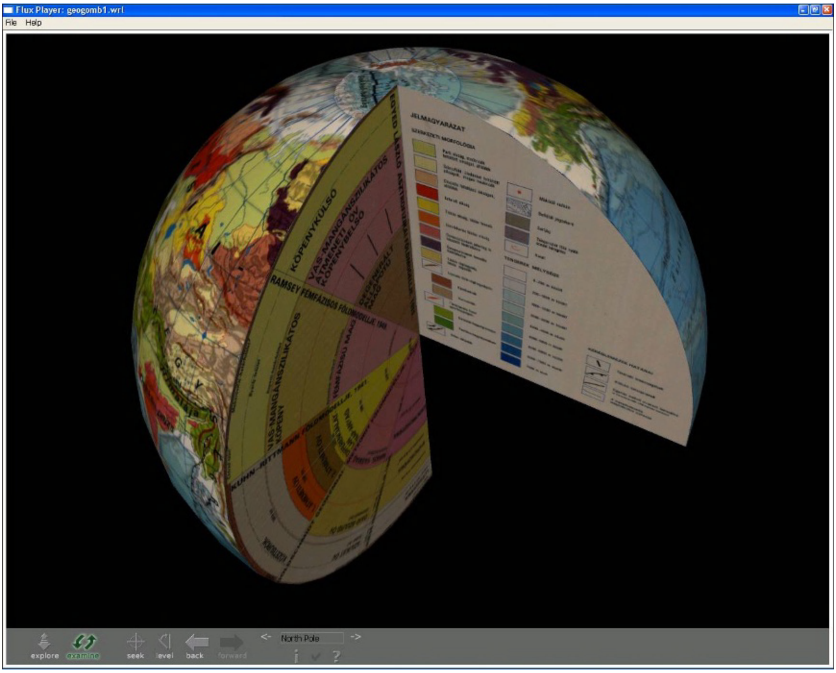

Fig. 18.10. The geophysical Earth-model in the virtual space

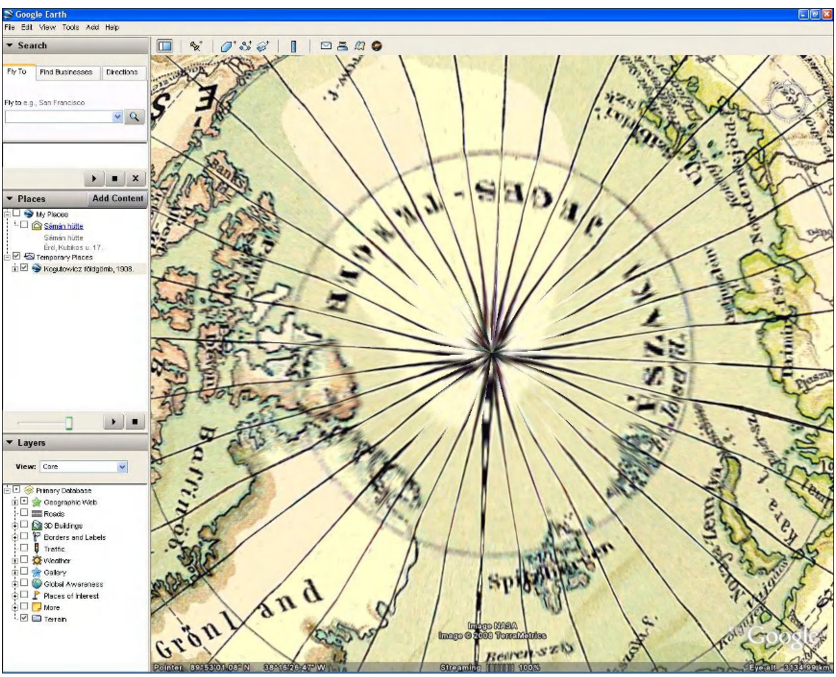

Fig. 18.11. The visualization problem of polar regions in Google Earth

18.6 Feedbacks, Conclusions, Plans

The first feedbacks about the page were mostly positive. The only problem was that many visitors skipped the information page, where the software requirements are mentioned. They complained about the „malfunction" of the page – of course, one cannot watch the VRML model without installing the VRML plug-in. Therefore, the authors placed the notice of installing the appropriate software into the first paragraph of the information text.

In the beginning there were only a few items in the museum. Later, as the number of the globes increased and the whole list exceeded the screen size, a simple search engine had been built in: now it is possible to search by diameter, language, type, date and place of publication etc.

One might ask why it is necessary to publish both models (the VRML and the KMZ). The answer is that each model has advantages and disadvantages, and it depends on the purpose of use which one to choose.

VRML models have a limited resolution. The size of their texture images cannot exceed 2048*2048 pixels. Even images just approaching this limit can cause problems for lower performance computers with insufficient memory resources. A good point for VRML is, however, that the polar regions are viewed correctly, which is a problem in Google Earth *(Figure 18.11).* In other words, if the poles are important, one might choose VRML.

The KMZ models can be easily combined with other contents of Google Earth, which makes it possible to compare the globe's content with the present conditions. For example, the changing borders in Africa or any other former colonial area, or the longitude measurement errors appearing in the coastlines of old globes. Another option is that a higher resolution can be reached with Google Earth than with VRML models on the same hardware.

There are several plans for the future. The most important task is adding as many new items as possible. A huge task is the translation of the existing database entries into English and German, as the detailed data sheet is available only in Hungarian by this time. Luckily, there are two German students spending their practical semester at the Department, and they have started the German translation.

The authors plan to create the digital facsimile copy of Perczel's 132 cm diameter globe. This globe is in a very poor condition. The thick layer of shellac became dark yellowish and the originally red settlement names faded out and became practically illegible. What is more, the globe suffered severe damage during the storms of history. The plan is to create a digital model after taking a complete photo series of the globe and redrawing the whole surface in the virtual space. *Figures 18.12* and *18.13* show the original and the redrawn content on a sample area. As this will be a huge project, the authors have started a course where students who would later join this work can learn the special techniques needed.

Acknowledgements

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Chapter 19

Mapping Crime Using Geovirtual Urban Environments

Markus Wolff

3D Geoinformation Research Group, University of Potsdam, Germany
Markus.Wolff@uni-potsdam.de

Abstract

This contribution explores the potential to apply three-dimensional geovisualization techniques to geospatial crime scene analysis. Because cartographic visualizations can be addressed as fundamental for the communication of spatial phenomena, thematic maps are widely used as a medium to present crime scene analysis results. Predominantly, maps produced by crime analysts are two-dimensional and static. However, according to defined task and analysed crime, these maps vary in subject, purpose, audience and map quality and might be difficult to comprehend – especially for decision makers who are not trained well in map reading. Therefore the main objective of this contribution is to develop a methodical framework that allows decision makers working in security agencies for an instant grasp of complex spatial information. For this purpose the paper explores innovative methods of visualizing the outcomes of geospatial crime scene analysis by combining crime data analysis with three-dimensional geovisualization techniques.

Keywords: crime mapping, geovisualization, geovirtual environments

19.1 Introduction

Within the discipline of crime mapping geographic information systems (GIS) are widely used. Because crime scenes can virtually almost be localised in space a GIS can be considered as an adequate tool for managing and analysing crime data. Both, in academic research and in practical law enforcement GIS is therefore applied for

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the analysis and the mapping of crime data (Murray et al., 2001). Digital analysis and mapping of crime offers a number of benefits, particularly in the following fields of applications: operational policing purposes, crime prevention, change monitoring regarding the distribution of crime over time and evaluation of efficiency regarding crime prevention initiatives (Hirschfield & Bowers 2001).

Subsequent to geospatial analysis of crime scene data, the results have to be communicated to a broader audience. Since thematic maps are used for this purpose, cartographic visualizations can be addressed as fundamental tools to communicate crime scene analysis results. Those crime maps are predominantly presented as two-dimensional static maps, showing, for instance, the spatial variation of crime hotspots related to certain offences. Depending on the topic and advised audience, those maps can be difficult to comprehend. A common issue related to 2D hotspot visualizations, for instance, deals with the issue of how to define adequate threshold values for choropleth maps. Often it is rather ambiguous from what value precisely a certain hotspot can be considered as "hot" (Chainey & Ratcliffe 2005).

The main objective of this contribution is therefore to provide alternative visualization methods that support decision makers to instantly grasp complex geospatial crime-related information. For this purpose the paper explores methods of visualizing the outcomes of geospatial crime scene analysis by combining crime data analysis with three-dimensional geovisualization techniques.

To apply selected methods of 3D geovisualization to crime-related issues the following workflow is applied (cf. *Figure 19.1):* in a first step geocoded crime scene data is processed and analysed with GIS methods. This comprises the application of kernel density estimation (KDE) techniques to discover regional clusters of crime (hotspots). Subsequent to hotspot identification further geospatial analysis is conducted purposing on identifying and typifying hotspot regions using methods of geoinformation science. To visualize the findings of those analyses, a three-

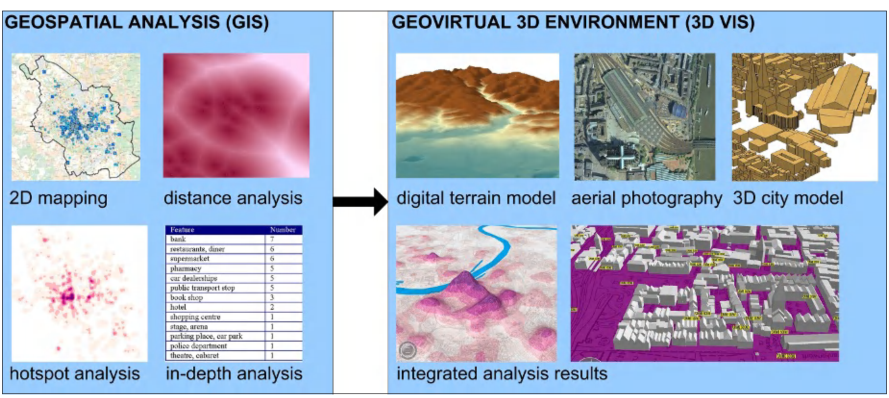

Fig. 19.1. Data processing (GIS and 3D VIS) as applied in this study

dimensional geovirtual environment for the study area is created. This environment includes a 3D city model that is, for visual analysis purposes, combined with the hotspots analysis findings. While GIS is used for all kinds of geospatial analysis, the interactive environment is modelled with a 3D visualization system. This process of linking GIS and 3D-VIS broadens the spectrum of applied geospatial crime scene analysis and mapping while allowing for an intuitive communication of complex geospatial phenomena.

19.2 Related Work

Many published work addresses crime mapping applications in theory and practical application. An introduction into theories, methods and selected software systems used to document, monitor and analyse crime data is given by Chainey and Ratcliffe (2005). An eminent task in crime mapping is to detect and map so-called hotspots of certain offences. According to Ratcliffe (2004), cited in Boba (2005), a hotspot is defined as an “area with high crime intensity”. In addition to Chainey and Ratcliffe (2005), an introduction into the different approaches of detecting and mapping hotspots can be found in McCullagh (2006). An introduction as well as deeper insights into the application of kernel-density-estimation (KDE) is given by Smith et al. (2006), Williamson et al. (2001) and Danese et al. (2008).

In contrast to the abundant literature on crime mapping only little works can be found on the use of three-dimensional geovirtual environments in crime mapping. Lodha and Verma (2000) for instance present some three-dimensional visualization techniques for crime data. Based on VRML (Virtual Reality Modelling Language) the authors present an urban crime mapping application. In this regard they create predominantly 3D bar-charts, where the number of crimes is specified on the z-axis while spatial orientation is given on the x- and y-axis, describing an underlying grid. However, basic 3D visualizations of surfaces calculated on the basis of crime data, as for instance hotspot surfaces, can be found frequently – for instance in Harris (2000).

19.3 3D Geovisualization Techniques for Urban Hotspot Mapping

Though evidence still has to be showed proof by further studies, that 3D map visualisations generally guarantee for a faster comprehension of geospatial phenomena than a 2D map, one can state at this point that interactive visualisations as presented in this paper most likely facilitate an instant and intuitive grasp of spatial information to an untrained map reader. This can be traced back to the fact that the human perception of the real world is basically three-dimensional. Therefore 3D map graphics contributes to reduce the map readers' mental effort since 3D real world features have not to be transformed into 2D map features and vice versa. This leads to an instant grasp of complex geospatial phenomena and thus makes map comprehension more intuitive. Especially decision makers working in security agencies tend to gather information predominantly visually and rather quick. Therefore this paper focuses on visualization of geospatial crime scene results by introducing visually attractive three-dimensional geovirtual urban environments into this discipline. Hence a 3D environment is created for the study area, the German city of Cologne. This geovirtual environment is the basis for urban crime data visualization and consists of a digital terrain model, a 3D city model, aerial photography (25 cm/ pixel), a digital cadastral map and further vector based datasets including rivers, administrative boundaries and many more. *Figure 19.2* shows a screenshot of this 3D environment. Concerning the presented figures, however, it is underlined that this environment is interactive. Using GIS all datasets are processed to prepare them for 3D visualization. Afterwards the datasets are integrated into the LandXplorer software, an appropriate system for interactive three-dimensional visualizations (Doellner et al. 2006).

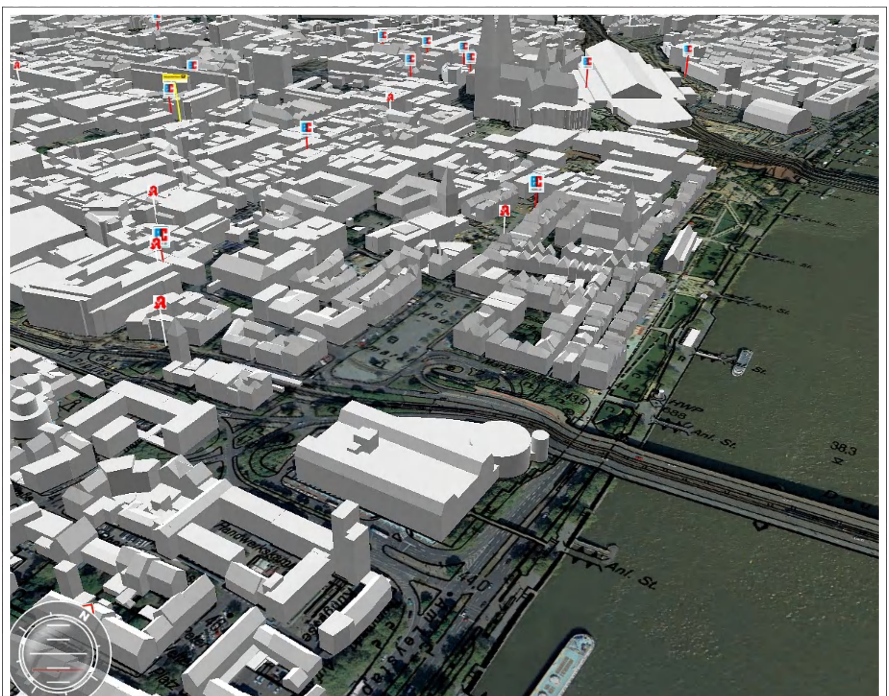

Fig. 19.2. Virtual three-dimensional environment of the city of Cologne

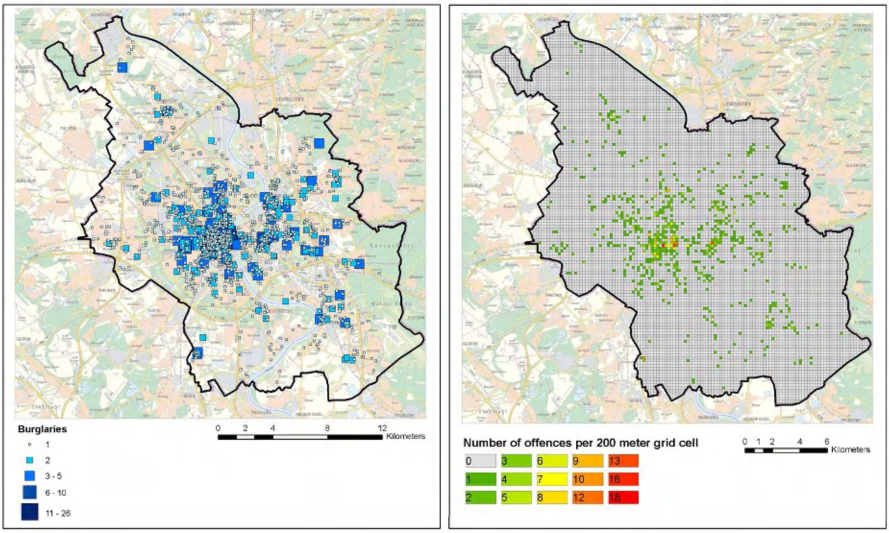

Fig. 19.3. Burglaries in the city of Cologne as represented in a thematic 2D overview map (left hand image) and as displayed on a regular grid (right hand image)

19.3.1 Mapping Crime Scene Distributions

The base dataset for analysis is obtained from the police headquarters of the German city of Cologne. The dataset represents robbery crime scenes for the year 2007 whereas each robbery scene is represented as an individual point, geocoded by x and y co-ordinates. Beyond these co-ordinates each point has further attributes describing the time of the offence.

Creating overview maps (on relative small scales) to visualize the overall distribution of robbery scenes is difficult. One has to consider, that basic positional-based point maps do not show all of the recorded crimes since several robberies can have the same coordinates (several robberies located at the same position at different times). Using graduated symbols those point maps allow for a first overview of overall crime scenes distribution *(Figure 19.3,* left hand image).

Relating the crime scenes to a regular grid is an alternative visualisation for point-related data. In a first step the study area is overlaid with a grid of specific cell size. Regarding the specification of the grids cell size one have to consider that this value should not be too small because this might yield too many cells with no or very few crimes. On the other hand, a too large cell size might produce a map which is too coarse. Taking the spatial distribution of the robbery scenes as an experimental basis, a grid cell size of 200 meters turned out to be adequate to depict the spatial structure of robbery scenes. Subsequent to the definition of cell size the resulting grid values are classified and colour-coded according to their number of crimes calculated per grid cell (cf. *Figure 19.3,* right hand image).

Apart from this overview-mapping spatio-temporal clustering of offences is one of the cardinal purposes of geospatial crime scene analysis. Analysing hotspots is therefore of substantial interest for security agents as well as for decision makers in urban planning. Hotspot analysis is achieved by transforming the discrete point distribution to a continuous surface of crime scene density. For that purpose kernel density estimation (KDE) is a widely used technique. Based on a given point dataset, this technique calculates a grid whose cell values represent density values related to a certain surface measure (for instance number of crimes scenes per square kilometre). For this purpose KDE-algorithms first overlay a study area with a grid of user definable cell size. In a second step, density values for each cell are calculated – depending on the implemented kernel density function (cf. Smith et al. 2006). For the analysis presented in this paper the commercial GIS system ArcGIS, version 9.2, is used. Here KDE is implemented with a quadratic kernel density function:

$$g_j = \frac{3}{4}\left(1 - t^2\right)|t| \leq 1$$

with

$t = d_{ij} / h,$
h as bandwidth,
i as robbery scene position.

The value at each grid location g_j with distance d_{ij} from each robbery scene i is calculated as the sum of all applications of the kernel function over all event points in the crime scene dataset. Therefore two parameters are crucial for every KDE-analysis and have to be specified: cell size and bandwidth. The cell size parameter defines the resolution of the resulting grid, the bandwidth describes the size of the search radius, i.e. how many crime scene locations (points) are used for analysis. A larger bandwidth includes a larger area and more points are used for the calculation. Hence, a too large bandwidth might hamper the chance to identify smaller hotspots, while a too small bandwidth might result in many small clusters. For the KDE-analyses presented in this paper, a cell size of 20 meters and a bandwidth of 400 meters are considered as to be appropriate. However, the lack of rules and standards concerning a reliable hotspot bandwidth parameterisation prompts Smith et al. (2006) to conclude that bandwidth selection "is often more an art than a science". The decision for the 400 meter search radius is taken predominantly as the result of experimental studies: compared with other settings, the 400 meter parametrisation produces the most reasonable output since the resulting hotspot grid reveals very clearly an inner-city hotspot-region while preserves simultaneously the overall representation of crime scenes.

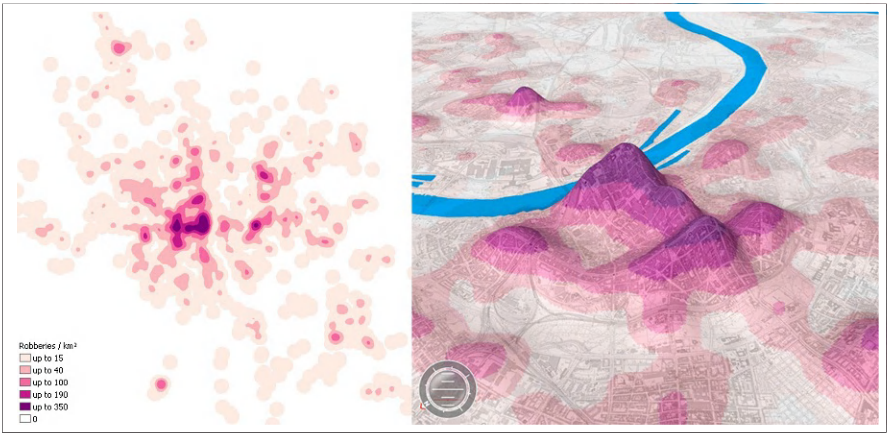

Fig. 19.4. Hotspot grid representing crime scene densities – visualized as a 2D thematic map (left hand image) and as componetnt within the three-dimensional environment (right hand image)

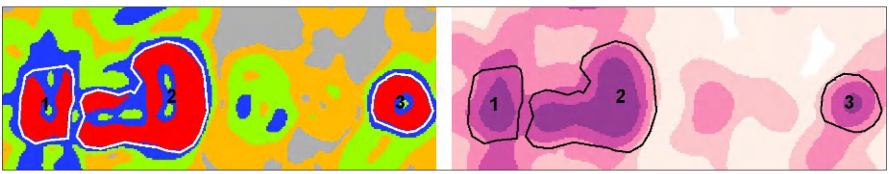

Fig. 19.5. Boundaries of hotspot regions (1, 2 and 3) as derived from focal neighbourhood statistics (left hand image) and as compared with the hotspot grid (right hand image)

Integrated into the 3D environment and overlaid with additional textures – for instance with a (classified) choropleth map of the hotspot grid – this visualization facilitates an intuitive exploration as well as an interactive visual analysis of crime scene densities (cf. *Figure 19.4).*

Subsequent to hotspot identification processes, further analysis of those regions is conducted. Such analysis requires extracting hotspot boundaries from the KDE-grid. Since the grid represents a continuous surface of crime density, the definition of discrete hotspot boundaries is not straightforward. However, to get a rough estimation of the boundary, focal neighbourhood statistic is applied. This method compares each pixel value of the grid to the values of its neighbours: each pixel of the KDE grid is compared to its 7 x 7 neighbourhood and the standard deviation of crime density is calculated. This results in a new grid, whose cell values represent standard deviation values of robbery scene densities. Using this method a gradient of crime scene density is represented. The higher the value, the higher is this gradient of an actual cell to its 7 x 7 neighbours. This value is finally used to detect the hotspot boundaries. Based on visual exploration, standard deviation equal to 15 is defined as to be the threshold value. Finally, the standard deviation grid is reclassified: a third grid is created where all cells with standard deviation < 15 become 0 while all cells > = 15 become 1. After vectorisation of this grid a simplification of the resulting polygons is proceeded manually. The result is polygonal boundaries of the three largest hotspots (cf. *Figure 19.5)*.

19.3.2 Inside the Hotspots: Examining the Urban Environment

This section outlines some methods to characterise the identified hotspot regions by taking the urban environment into account. In a first step the hotspots are typified regarding their location within cityscape. Afterwards a 3D city model is integrated into analysis to calculate minimum distances of each building to the closest crime scene.

To typify particular hotspot regions the distribution of several facilities in the city of Cologne (schools, restaurants, clubs, sights, banks and many more) is analysed for each particular hotspot region (cf. *Table 19.1, 19.2* and *19.3)*.

This analysis reveals distinct differences between the three hotspot regions. Except for restaurants and diners that are frequently found in all three regions, hotspot one with its numerous clubs seems shows evidence for a nightlife district. Similarly characterised is the (adjacent) hotspot region two: here tourism plays a major role due to its high number of hotels, parking places, museums and sights. Unlike hotspot three: Banks, supermarkets, pharmacies and car dealerships point rather to the direction of a housing area.

Subsequently one can conclude that robberies in hotspot regions one and two might be related to pickpocket predominantly, while hotspot regions three seems to be a kind of social hotspot. Overlaying the hotspot boundaries with a city map (cf.

Fig. 19.6. Identified main hotspot regions within the city of Cologne

Table 19.2. Total number of specific facilities in hotspot region one

Feature	Number
restaurant, diner	94
bank	12
club	**9**
public transport stop	8
parking place, car park	7
hotel	7
book shop	7
pharmacy	7
supermarket	4
theatre, cabaret	3
cinema	2
sight	1
school	1
consulate	1
church	1
shopping centre	1

Table 19.3. Total number of specific facilities in hotspot region two

Feature	Number
restaurants, diner	151
hotel	**46**
parking place, car park	**24**
bank	23
public transport stop	21
sight	**16**
pharmacy	14
museum	**12**
church	10
book shop	9
theatre, cabaret	7
shopping centre	6
supermarket	5
car dealership	3
club	3
stage, arena	3
railroad station	2
indoor swimming pool	2
bus terminal	1
tourist information	**1**
consulate	1
post	1
town-hall	1
school	1
petrol station	1

Table 19.4. Total number of specific facilities in hotspot region three

Feature	Number
bank	**7**
restaurants, diner	6
supermarket	**6**
pharmacy	**5**
car dealerships	**5**
public transport stop	5
book shop	3
hotel	2
shopping centre	1
stage, arena	1
parking place, car park	1
police department	1
theatre, cabaret	1

Figure 19.6) reveals that hotspot number one covers an area famous for its nightlife (“Rudolfplatz”, “Friesenplatz”). Hotspot two is located in the very city centre of Cologne – an area that is highly frequented by tourists and for shopping. Hotspot three finally is located in the district of Cologne-Kalk which is a former industrial location with high unemployment rates.

For further hotspot analysis the virtual environment is extended by a 3D city model. The use of a 3D city model facilitates visualizations of spatial relationships at the building level in an easy to comprehend way. This analytical and geovisual potential of 3D city models can be instrumental for decision makers working in security agencies concerning an intuitive communication of spatial phenomena related to urban security issues. In this study a city model that consists of approximately 22,000 buildings is used. To facilitate initial visual analysis of each building the city model is overlaid with the KDE-hotspot grid. *Figure 19.7* shows the central Cologne hotspot area (hotspots number one, left hand image, and number two, right hand image) combined with the corresponding 3D city model.

Fig. 19.7. 3D city model with additional hotspot texture and crime scene positions with hotspot boundary (left hand image) and integrated crime scene positions (right hand image)

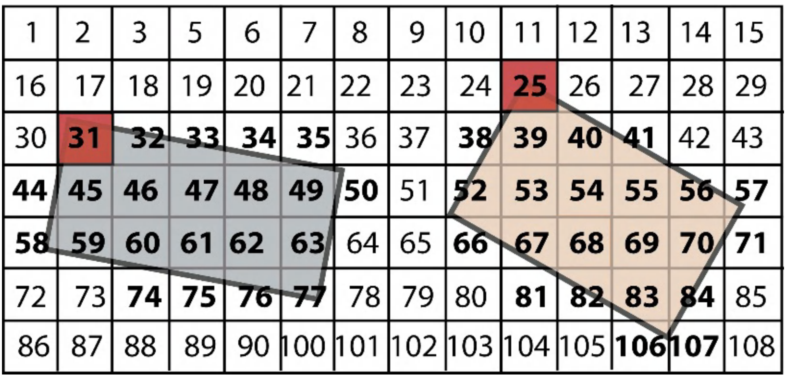

Fig. 19.8. Schematic diagram of the method applied for determining the minimum building distance to the closest crime site: the numbers depict (hypothetical) values of distances from the closest crime scene. For each building (shaded polygons) those pixels are analysed that fall within its boundaries (bold printed distance values). Finally, that pixel with the lowest value is selected (red coloured) and its value is added as a new attribute to the buildings database.

To broaden this visual approach and to facilitate further distance based analysis, the minimum distance of each building to the closest robbery scene is calculated. For this purpose an Euclidean-distances-grid (cell size equal to two meters) is calculated on the basis of robbery scene positions. Each pixel of this grid represents the distance to the closest crime scene. This grid is combined with the city model: for each of the 22,000 buildings those pixels are detected that fall within the respective building footprint. From this set of pixels that one with the lowest value is determined – which is the minimum distance of the building to the closest crime site. This value is added to the building database as a new attribute (cf. *Figure 19.8)*.

In a last step the building dataset is classified and coloured according to these minimum distance values. The subsequent 3D visualization allows for exploring particular buildings of urban districts affected by a high number of robberies (cf. *Figure 19.9)*. Since the distance values are stored in the buildings database further

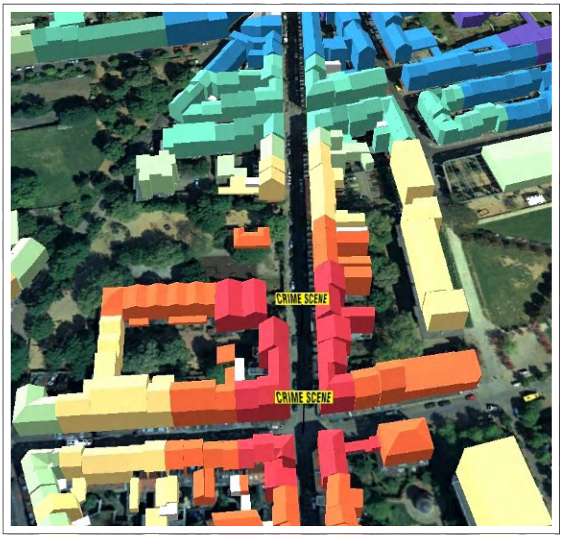

Fig. 19.9. Minimum distances of each building to the closest robbery crime scene

selection tasks are supported. This visualization facilitates an intuitive geo-communication relating the distances of each building from the closets crime scene.

To relate the distribution of robbery scenes to urban population, the positions of crime scenes are correlated with intra-urban pedestrian flows. For this purpose data of the FAW Frequency Atlas of the German Association for Outdoor Advertising (FAW) is integrated into analysis. This atlas contains data of average pedestrian frequencies along road segments within the city of Cologne. These frequencies are represented as average values per hour on a working day basis for the years 1999 to 2005 (Data description FAW-frequency-Atlas 2006). Technically speaking, one FAW point exists with the corresponding frequency values for each road segment. Based on its co-ordinates this point-based FAW information is referred to the corresponding road segments via unique segment IDs. Subsequently each robbery scene is assigned to the closest road segment (cf. *Figure 19.10)*.

To determine whether high pedestrian frequencies are verifiable correlated with a high number of robbery offences, statistical tests are conducted: according to Spearman's rank correlation, a weak but significant positive correlation between the number of offences and the number of pedestrians can be detected (correlation coefficient = 0.202, significant for p=0.01). Analysis shows, that only little robbery is registered near to segments passed by a few pedestrians. However, by far the most robbery scenes are not located close to segments passed by the highest number of pedestrians – instead, most robberies (as analysed for the whole city of Cologne) are committed close to segments passed by up to 45 pedestrians per hour (cf. *Table 19.4)*.

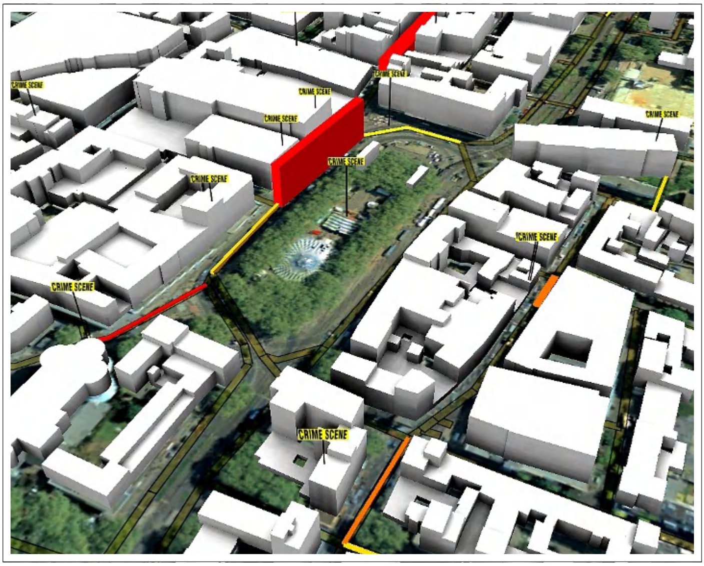

Fig. 19.10. Robbery scenes assigned to closest road segment

Table 19.1. Number of robbery offences compared to average pedestrian frequencies on road segments identified as closest to scene

No. of pedestrians passing road segment per hour	No. of segments	No. of robbery scenes assigned
up to 25	51	60
26 up to 30	45	61
31 up to 45	492	634
46 up to 65	265	351
66 up to 100	164	240
101 up to 200	186	274
201 up to 400	107	200
> 400	121	281

19.4 Conclusion

This paper presented a methodical framework for combining geospatial crime scene analysis with three-dimensional geovisualization techniques. This combined approach allows e.g. decision makers working in security agencies for an instant grasp of complex spatial information. Against this background, hotspots of robbery crimes were identified via kernel-density-estimation techniques and subsequently integrated into a 3D environment of the city of Cologne. In a further step of analysis the boundaries of those hotspot regions were determined by applying focal statistics. To facilitate distance based analysis of single buildings regarding those hotspot areas, a 3D city model was integrated into the environment.

However, for additional studies two further issues are of particular interest: First, since crime scenes are neither static in space nor in time the temporal dimension is going to be included into analysis and (multidimensional) visualisation. Secondly, it is intended to distinguish between the scientifically motivated results of this study on the one hand and the possibilities for an adoption in the day-to-day business of police departments on the other hand. Therefore the usability of the 3D crime maps is intended to be evaluated in a further step.

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Chapter 20

A Survey of Mobile Indoor Navigation Systems

Haosheng Huang and Georg Gartner

Institute of Geoinformation and Cartography, Vienna University of Technology, Austria
huanghaosheng@gmail.com, georg.gartner@tuwien.ac.at

Abstract

With the gradual maturating of ubiquitous computing and the rapid advances in mobile devices and wireless communication, indoor Location Based Services have gained increasing interests as an important application of indoor ubiquitous computing. In this paper, an evaluation framework which combines the key aspects of indoor navigation for investigating mobile indoor navigation systems is proposed. Based on this evaluation framework, we give a comparison and analysis of the current mobile indoor navigation systems, and conclude that "indoor navigation systems are still on an early development stage". We also identify some challenges which require further research and development, such as sensor fusion, context-awareness, route communication, seamless switch between indoor and outdoor navigation, and ubiquitous indoor computing.

Keywords: mobile indoor navigation systems, indoor positioning, context-aware adaptation, route communication

20.1 Introduction

The ubiquity of mobile devices (such as cell phones and PDAs) has led to the introduction of Location Based Services (LBS), or Location-Aware Services. LBS aim at providing information/services relevant to the current location and context of a mobile user.

One of the first several LBS applications, named Active Badge Location System, was introduced in Want et al. (1992). This system employed infrared technology

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for tracking a user's current location and uses this location to forward phone calls to a telephone close to the user. Since then, many researchers have studied this topic and built several LBS applications to demonstrate the usefulness of this new technology. Recent technological advance such as the gradual maturating of ubiquitous computing (Weiser 1991, or pervasive computing) and the evolution of mobile devices (such as PDAs, cell phones, etc.) and wireless communication (3G, Wireless LAN, Wireless Sensor Network, etc.) has further increased the pace of progress (Baus et al. 2005). In order to identify the state of the art in LBS, and then indicate the further challenges, a survey of the current LBS systems is needed.

There are some surveys focusing on LBS systems. Baus et al. (2005) surveyed map-based mobile guides using the dimensions of *Positioning* (either GPS, WiFi, UMTS, or other), *Situational factors* (user or context-related), *Adaptation capabilities*, *Interface/use interaction* (multi-model or others), *Use of maps* (2D vector, 2D bitmap or 3D model), and *Architecture* (client-server, interacting, multi-blackboard or multi-agent system). These dimensions are roughly defined and further subdivision of some of these dimensions is needed. Raper et al. (2007) developed a much more complete classification which used the axes of *Application* (tourism, recreation, transport, and museum), *Positioning*, *Architecture*, *Presentation*, *Context relevance*, *Delivery* (pull or push), *Use case*, and *Adaptivity* (resource adapted, resource adaptive, resource adapting), and then made an investigation on LBS applications in the published literature.

However, these surveys are mainly for outdoor applications. For indoor applications, different positioning technologies are needed to replace GPS. As a result, more detailed dimensions on positioning, such as *signal* (infrared, ultrasonic, radio signals, etc.) and *signal metric* (Cell of Origin, Time of Arrival, Time Difference of Arrival, Angle of Arrival, etc.), are needed to evaluate the various positioning technologies. As context-awareness is very important for LBS systems, there should be some dimensions that evaluate the context-awareness of these indoor applications. Accordingly, further classification dimensions are needed in order to evaluate current various indoor LBS systems.

As the range of LBS applications is vast, it is impossible to do a survey for all of them. Mobile navigation system, which aims at providing wayfinding services to the user, is one of the most important applications of LBS. Therefore, we will focus our survey on indoor navigation systems.

The rest of this paper is structured as follows. *Section 20.2* develops an evaluation framework which combines the key aspects of indoor navigation for investigating mobile indoor navigation systems. The evaluation framework is then applied in *Section 20.3* for an in-depth comparison and analysis of the current indoor navigation systems. Based on this survey, we identify some key challenges that remain to be further investigated in *Section 20.4*. *Section 20.5* draws some concluding remarks.

20.2 An Evaluation Framework for Indoor Navigation Systems

Currently, most of the pedestrian navigation systems are designed to assist outdoor wayfinding. But after arriving at a destination by using outdoor navigation services, a pedestrian always needs to enter the building (indoor) and requires indoor navigation. Also people tend to lose orientation a lot easier within buildings than outdoor (Radoczky 2003, Hohenschuh 2004). Indoor navigation systems are designed to meet this need.

When developing an indoor navigation system, different aspects have to be considered: indoor positioning, context-aware adaptation, route presentation and communication, and other features, such as network access, client platform, etc.

20.2.1 Indoor Positioning

Most of the outdoor navigation systems employ GPS for positioning. Unfortunately, GPS can only be used outside of buildings because the employed radio signals cannot penetrate solid walls. For positioning in indoor environment, additional installations (e.g., WLAN, sensor networks) are required.

There exist numerous different positioning approaches that vary greatly in terms of accuracy, cost and technology. When selecting a positioning approach, several key aspects have to be considered (W. Kolodziej & Hjelm 2006):

Signal: infrared (Infrared Sensors, IrDA), ultrasonic, radio signals (WLAN, Bluetooth, Zigbee, UWB, RFID), or visible light (video)

Signal metrics (Signal properties): Cell of Origin (CoO), Received Signal Strength (RSS), Angle of Arrival (AOA), Time of Arrival (TOA), or Time Difference of Arrival (TDOA)

Positioning algorithms (translate recorded signal metrics into distances and angles, and then derive the actual position): Proximity, Trangulation (Lateration and Angulation), or Location Fingerprinting

20.2.2 Context-Aware Adaptation

Computing has become increasingly mobile and ubiquitous, which implies that services must be capable of *recognizing* and *adapting* to the highly dynamic environments while placing fewer demands on user's attention (Henricksen et al. 2002). It is widely acknowledged that context-awareness can meet these requirements. In order to have a high usability, mobile navigation systems (indoor or outdoor) should be context-aware, and adapt to the dynamic environment (context).

Before comparing various indoor navigation systems, we want to introduce the notion of *context* used in this paper. We adopt the definition provided by Huang & Gartner (2009): "1) Something is context because it is used for adapting the interaction between the human and the current system. 2) Activity is central to context. 3) Context differs in each occasion of the activity."

In order to make an in-depth investigation, we will compare different indoor navigation systems according to the following axes: the *context parameters* it uses, *adaptivity*, and *adaptation object* (which features of the system can be adapted). For the *context parameters* dimension, we will investigate which aspects of the user/context being used when providing adaptation. Some examples are location, time, and device profiles (screen size, color, etc). For the *adaptivity* dimension, we adopt the classification provided by Krueger et al. (2007): *Resource adapted* (optimized in advance for regular patters of usage), *Resource adaptive* (rely on a single strategy for resource usage) and *Resource adapting* (has ability to adapt resource situations using multiple strategies).

According to Downs & Stea (1977), navigation (wayfinding) includes four processes: orientation (determining one's position), planning the route, keeping on the right track, discovering the destination. The last two processes can be combined together as moving from origin to destination. They correspondingly relate to three modules in navigation systems: *positioning*, *route calculation*, and *route communication*. Context-aware adaptation can be applied to these three modules (steps).

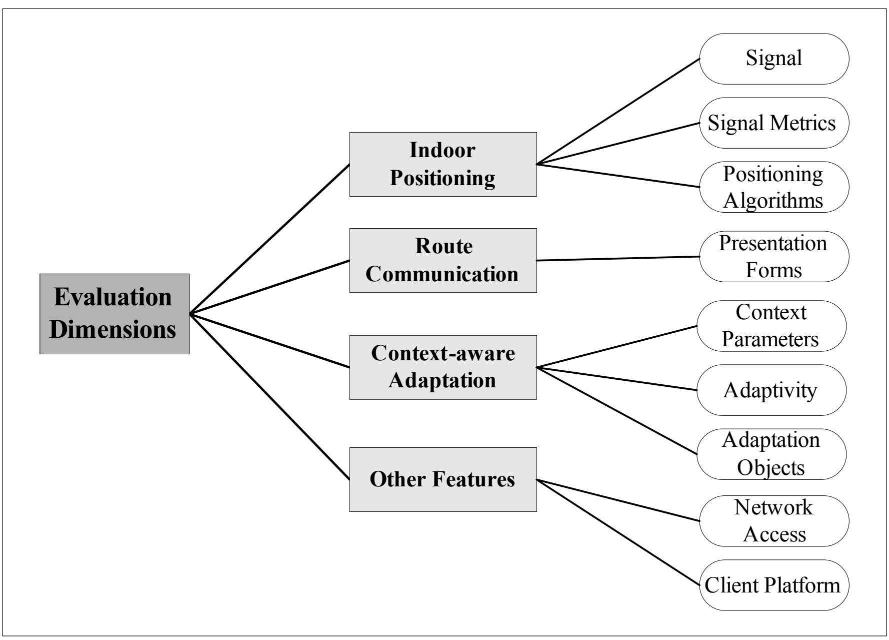

Fig. 20.1. An evaluation framework for indoor navigation systems

As a result, for the *adaptation object* dimension, we will use these three modules to classify current indoor navigation systems.

20.2.3 Route Presentation and Communication

Another important aspect of indoor navigation is how to communicate route information efficiently (Gartner & Uhlirz 2005). A good route presentation form will enable way finders to easily find their way with little cognitive load. We will compare the different indoor navigation systems according to their *presentation forms*: maps, textual or verbal instruction, signs (electronic), images, videos, 3D presentation, etc.

20.2.4 Other Features

Network access and client platform are also very important when designing indoor navigation systems. While not being directly apparent to the user, they have a serious impact on the system's extensibility and adaptability (Baus et al. 2005).

For the *network access* dimension, indoor navigation systems can be classified into server-side (connecting) and client-side (local caching) solutions according to where the application system is executed.

For the *client platform* dimension, compared to outdoor navigation systems which mainly employ cellphones and PDAs, different technological platforms may be used for indoor navigation: cellphones, PDAs, wearable computers, public displays, wrist devices, etc.

20.2.5 Evaluation Framework

Based on the above discussions, an evaluation framework for investigating indoor navigation systems is designed *(Figure 20.1)*. For the indoor positioning, quantitative evaluations on accuracy, costs, and range are also possible. However, in this framework, we evaluate indoor navigation systems qualitatively.

20.3 Comparison and Analysis

Based on the above evaluation framework, this section makes a comparison and analysis of the current mobile indoor navigation systems. Similar to Raper et al. (2007), the comparison only covers systems introduced in the published literature from 1997 to 2008, and doesn't include material from white papers and online

Table 20.1. Comparison of mobile indoor navigation systems (abbreviations used: CoO – Cell of Origin, ToA – Time of Arrival, TDoA – Time Difference of Arrival, AoA – Angle of Arrival, RSS – Received Signal Strength, AR – Augmented Reality, CI – Cognitive Impaired)

System Name	Positioning	Context-Awareness	Route Communication	Network Access	Client Platform	other	Publication
CyberGuide	Infrared/ CoO/ Proximity	No	map, web page	Client	PDA, or pen-based PC	–	Abowd et al. (1997)
IRREAL	Infrared/ CoO/ Proximity	Yes	map/floor plan, text (POI description)	Server	handheld PC	transition between indoor and outdoor navigation	Baus et al. (2002)
CricketNav	Radio, Ultrasound/ TDoA/ Lateration	No	floor plans	Client	PDA	–	Miu (2002)
GentleGuide	/	No	vibration	Server	wearable wrist device	–	Bosman et al. (2003)
BPN	Infrared/ CoO/ Proximity	No	map, 3D, speech	Server	PDA, PC, and in-car device	using predefined itinerary	Krueger et al. (2004)
Drishti	Ultrasound/ TDoA/ Lateration	No	audio	Client	headset, and wearable PC	for blind people, the safest route	Ran et al. (2004)
GAUDI	Configured	No	directional signs (on public displays)	Server	public display	temporary signage and event based navigation (for public)	Kray et al. (2005)
Rotating Compass	Configured	No	signs on public displays, synchronized vibrations alarm on personal devices	Server	public display, and phone	synchronized information displays for navigation	Rukzio et al. (2005)
Open-SPIRIT	Bluetooth/ CoO/ Proximity	No	floor plans, semantic textual instructions	Hybrid	cell phone	the idea of semantic enriched instructions	Rehrl et al. (2005)
Smart Signs	configured	Yes	signs	Server	public display or PDA	group signs and private signs	Lijding et al. 2006)
3DVN	WiFi/ RSS/ Location fingerprinting	No	AR	Client	wearable PC	–	Elmqvist et al. (2006)
Chloe@ University	WiFi, RFID/ RSS, CoO / Location fingerprinting, Proximity	Yes	AR	Client	wearable PC	augmented 3D virtual character	Peternier (2007)
iNav	Compass	No	map, audio, textual	Server	PDA	–	Kargl et al. (2007)
Wayfinding for CI	Bluetooth / CoO / Proximity	No	images, videos	Server	PDA	–	Chang et al. (2008)

presentations. *Table 20.1* summarizes the comparison. For the systems providing context-awareness, the detailed features of context-awareness are investigated in *Table 20.2*.

Table 20.2. Comparison of context-awareness of mobile indoor navigation systems

System Name	Context Parameters	Adaptivity	Adaptation Object
IRREAL	device's resolution, screen size, color capabilities, speed of the user, user's preference, her/his familiarity with the environment, current time pressure	adapting	route calculation, route communication
Smart Signs	user's mobility limitations, user's preference, time, weather, possible emergency situation, transient situation	adapting	route calculation
Chloe@University	user's preference, user access right, security level	adaptive, adapted (positioning)	positioning, route calculation, route communication

20.3.1 Indoor Positioning

As for positioning, the first several systems (CyberGuide, IRREAL, CricketNav, BPN, and Drishti) mainly use *Infrared* and *Ultrasound* as positioning signal, *CoO* as signal metric, *proximity* as positioning algorithms. This is mainly due to the high availability of infrared technologies in mobile phone and the insufficiency of radio-based communication and positioning during 1990s to the beginning of 2000s. These kind of positioning technologies provide rough position information and have some specific restrictions, such as line-of-sight (infrared) and additional hardware requirement (ultrasound).

Recently, due to their broad availability in mobile devices and their continuously decreasing prices, *radio* signals, such as WiFi, Bluetooth, Zigbee, UWB, and RFID, are employed in more and more indoor navigation systems (Open-Spirit, 3DVN, Chloe@University, and iNav) for positioning. Some of the positioning algorithms such as *triangulation (RSS, ToA, TDoA)* and *fingerprinting (RSS)* are also developed to increase the positioning accuracy. Some of the indoor navigation systems (Chloe@University and iNav) combine several positioning technologies to provide reliable and stable positioning, for example, Chloe@University combined sensor network, WiFi and RFID to provide reliable position for the navigation services.

There are also some indoor navigation systems which use *configured* position, such as GAUDI, Rotating Compass and Smart Signs. These systems always employ public displays and signs for route communication. The positions (addresses) of the public displays are configured by administrators in advance. In fact, from the end users' point of view, these public displays are the *positioning (orientation) tools* for their navigation. The drawback of these indoor navigation systems is their high costs: for every decision point, a public display or digital sign is needed.

20.3.2 Context-Awareness and Adaptation

Although context-awareness is very important for mobile applications, surprisingly, most of mobile indoor navigation systems only use location as context parameter and provide location-related services to the users. There are only three systems providing context-aware adaptation: IRREAL, Smart Signs and Chloe@University.

The Chloe@Unversity system provides a very simple context-aware adaptation. In the system, an augmented 3D virtual character in front of a user guides him/her to destination so that he/she can just follow the virtual guide to the desired destination. The most suitable virtual character is selected depending on user's preference. The system also provides adapted (see *resource adapted – optimized in advance for regular patterns of usage)* localization approaches for indoor positioning. In addition, it calculates the route based on user profiles and security level.

For the Smart Signs system, context-awareness is applied to route calculation. User's mobility limitations, preference, time, weather, transient situation are used to calculate the route. It defines *business rules* to determine which and how context parameters are translated into the costs of a route.

The IRREAL system provides context-aware adaptation on route calculation and route communication. Route calculation is based on user's preference, her/his familiarity with the environment and current time pressure, etc. After the optimal route is determined, it is forwarded to the presentation (communication) planning module. This module optimizes the presentation of the route not only according to the resolution, screen size, and color capabilities of the output device, but also to the position, orientation and speed of the user.

20.3.3 Route Presentation and Communication

Compared to outdoor navigation systems which mainly employ map (2D or 3D), textual and verbal instruction for route communication, indoor navigation systems use various presentation forms: *map* (CyberGuide, IRREAL, CricketNav, BPN, Open-SPIRIT, and iNav), *textual or verbal instruction* (Dirshti, Open-SPIRIT, and iNav), *Augmented Reality* (3DVN and Chloe@University), *sign* (GAUDI, Rotating Compass, and Smart Signs), *vibration* (GentelGuide, Rotating Compass), *image and video* (Wayfinding for CI), etc.

For indoor navigation, maps, especially floor plans, are still the most popular presentation form. One reason for this is certainly their pervasive use in physical guides (such as paper maps, You-Are-Here maps installed in the environment) (Baus et al. 2005). Mobile maps can differ in scale, content, and style. As a result, the effectiveness of different types of maps (ranging from sketch or schematic map to topographic map or other detailed map) for indoor route communication should be evaluated. However, little work has been done on that.

Textual or verbal instructions can be also used for route communication. When being used to a mobile device with earphones, verbal guiding instructions can be very useful when users are engaged with other activities during wayfinding because users don't need to refer to the mobile devices (little cognitive load). Textual (written) guidance is the most simple presentation form for navigation (Radoczky 2007). They are easy to create and can be used in almost every mobile phone. Concerning route communication, textual guidance is similar to verbal guidance. The only difference is that when using textual guidance, users have to read the text on the screen.

Some of the systems propose that route communication (such as map, textual instructions, image and video) that requires users to look at the handheld device *"head down"* while walking is not easy to use (Lijding et al. 2006). As a result, other alternatives are proposed: vibration (GentelGuide and Rotating Compass), signs on public displays (Rotating Compass and Smart Signs). The GentelGuide uses two wrist devices on the two arms for route communication: 0.7 seconds on right (left) receiver – go to your right (left), 0.7 seconds on both receivers – destination reached, 1.5 seconds on both receivers – wrong direction. The project concluded that: "pressure haptic output offers significant promise both in improving performance and in reducing the disruptiveness of technology", also "a negative aspect of exclusively relying on a device like GentleGuide is the reduced location and orientation awareness by some participants" (Bosman et al. 2003).

Signs are easy to understand and have always been used for route communication. Signs always have self-explaining meaning. As a result, signs clearly support "computational offloading"': navigating from sign to sign requires virtually low cognitive load and no memorizing of multiple route segments (Hoelscher et al. 2007). Users only need to search for the next sign. Electronic signs can be generated by a navigation system according to the user's context and then displayed on users' mobile devices or public displays mounted on the wall (GAUDI, Rotating Compass, and Smart Signs).

Although several presentation forms have been proposed for route communication, there is little work focusing on evaluating the effectiveness of the above presentation forms for indoor navigation. In order to reduce the cognitive load of the way finders, some user tests should be carried out to find out the optimal presentation styles for indoor navigation.

20.3.4 Network Access

There are several systems using the *server-side solution*: IRREAL, GentleGuide, BPN, GAUDI, Rotating Compass, Smart Signs. iNav and Wayfinding for CI. In this solution, all the calculation (e.g., route calculation) is executed on the server, data is stored in a database which is deployed on the server. The clients (mobile devices) only provide an UI (User Interface) for users' interaction and route communication. Compared to client-side solution, the client devices don't need to have a high process power and big memory, the client devices also *consume less power (battery)* which is crucial for mobile devices. The disadvantage for the server-side solution is that *continual network access* is required during the whole navigation.

In the *client-side solution* (CyberGuide, CricketNav, Drishti, Open-SPIRIT, 3DVN, Chloe@University), sometimes named local caching solution, data and application system are downloaded/copied from the server in advance (for example, when you enter a building at the first time). All the functions (calculation, result visualization) are executed on the client devices. No network access is needed during users' navigation. However, the client devices need to have a *high process power* and *big memory*. And also, *high power (battery) consumption* may become a big problem.

In fact, it is not suitable to simply assign the calculation and data to the server side or the client side. In order to have an extensible and adaptable system, where the calculation is executed should depend on the current context (such as power level of the devices, the requirement of the calculation, the network availability etc.). *Load balancing* between server side and client side is needed.

20.3.5 Client Platform

As for client platform, it is important to note that compared to outdoor navigation systems which mainly use cell phones and PDAs, the client platforms of indoor navigation systems are much more various: *cell phones* (Rotating Compass and Open-SPIRIT), *PDAs* (CyberGuide, CricketNav, BPN, Smart Signs, iNav, and Wayfinding for CI), *wearable computers* (CyberGuide, IRREAL, Drishti, 3DVN, and Chloe@University), *public displays* (GAUDI, Rotating Compass, and Smart Signs), *wrist devices* (GentleGuide), etc. The reason for this is that it is easy and unobtrusive to place/use these kinds of devices (such as public displays) in the indoor environment.

It's also interesting to note that, with the rapid advances in the enabling technologies (wireless communication, mobile devices, and sensor network) for ubiquitous computing, more and more indoor navigation systems integrate mobile devices (PDAs or cell phones) with devices that are installed in the smart environment (e.g. public displays, PCs, printers, or sensors), for example, Rotating Compass displays route guidance (signs) on public displays, and provides a synchronized vibration alarm on mobile devices when users approach public displays. It can be anticipated that a smart environment augmenting with active or passive devices/sensors will enable context-aware route guiding and therefore optimize the wayfinding process.

However, little work has been done on how smart ambient intelligent environment optimizes the wayfinding process.

20.3.6 Others

The project IRREAL addressed the problem of *transition between indoor navigation and outdoor navigation*. It identified several prerequisites (Baus et al. 2002): the coordination of data for indoor and outdoor, and the seamless switch between indoor and outdoor positioning. As indoor navigation and outdoor navigation differ in positioning technologies, data modeling, and spatial cognition basics, more work should be done on the seamless switch between indoor and outdoor navigation.

The project Open-SPIRIT presented a nice idea about semantic enriched instructions. It proposed that simple turn-by-turn instructions that are solely based on geometric information of the form *"walk 9 meters straight and turn left"* should be avoided, instead instructions should be semantic enriched which are more natural sounding and contain references to objects (e.g., landmarks, gateways, and signs) in the scene space in order to improve the interaction of pedestrians and the environment, such as "*Walk to the lower end of the stairs marked with the sign 'Neubaugasse'. Walk up the stairs*" (Rehrl et al. 2005). This idea is continually investigated in their other project named SemWay (Semantic Wayfinding, outdoor pedestrian navigation). The SemWay (SemWay 2009) project carried out several field tests (city touring and skiing touring), and currently is trying to identify *basic concepts* and *image schemas* from the field tests, then will combine basic concepts, image schemas and landmarks into route instructions. The SemWay project focuses on outdoor navigation, some similar work for indoor should be done to provide semantic instructions for indoor navigation.

20.4 Challenges

From the above comparison and analysis, we can draw the conclusion that *indoor navigation systems are still on an early development stage*. With the rapid advances in the enabling technologies, such as wireless communication, mobile devices, and sensors, indoor navigation services will gain increasing interests as an important application of indoor ubiquitous computing. A number of areas obviously require further research and development:

Indoor positioning: Currently, indoor navigation systems always employ radio signal (WiFi, Bluetooth, RFID, etc.) for positioning, which may suffer from the problem of signal impairments, such as Radio Frequency interference and multipath propagation. Further investigation and performance tests of the indoor positioning technologies are especially required. Also how to provide reliable and stable position information in a complex and changing environment is a very challenging task. Sensor fusion may be an option for this question.

Context-awareness: In order to provide high usability, context-awareness should be introduced for indoor navigation. As identified in Brusilovsky (1996), context-aware adaptation has the following dimensions: *Why* (why do we need that a system adapts itself to the particular user/context), *What* (which features of the system can be adapted), *To what* (what aspects of the user/context working with the system can be taken into account when providing adaptation), *When* (timing and triggering of adaptation), *How* (which procedures are needed to adapt the adaptation objects according to the users/context), *How well* (how to evaluate the adaptation processes). Currently, most of the indoor navigation systems only focus on the *To what* and *What* dimensions. More work should be done on the other dimensions. In addition, some field experiments on the relationship between "*To What*" and "*What*" should be done, such as how much detail is needed for wayfinding (*What*) in a specific context (*To what*).

Route communication: Floor plan, textual and verbal instruction, sign are always used for route communication. However, more work should be done to evaluate the *suitability* and *efficiency* of varied presentation forms for indoor navigation in detail. Also, how to provide *landmark-based semantic enriched* presentation/instruction should be considered.

Combination of outdoor and indoor navigation: In daily life, people always have to combine outdoor and indoor navigation, for example outdoor wayfinding from train station to the city hall, and then entering the city hall to find somebody with indoor navigation. The combination of outdoor and indoor navigation should also take place in three modules: positioning (seamless switch between outdoor GPS and indoor positioning), route calculation (seamless switch between the different data models of indoor and outdoor, different context), and route communication (providing a smooth visual switch).

Indoor navigation in a smart ambient intelligent environment: As more and more active or passive devices/sensors are augmented in the indoor environment, indoor environment has become smarter. This abundance of technology has given place to the new notions of "*Smart Environments* (SmE)" and "*Ambient Intelligent* (AmI)". The basic idea behind SmE and AmI is that "by enriching an environment with technology (sensors, processors, actuators, information terminals, and other devices interconnected through a network), a system can be built such that based on the real-time information gathered and the historical data accumulated, decisions can be taken to benefit the users of that environment" (Augusto & Aghajan 2009). With the increasing ubiquity of smart environments, the question of how indoor navigation systems can be benefited by introducing the notions of SmE and AmI should be carefully investigated.

20.5 Conclusions

In this paper, an evaluation framework which combines the key aspects of indoor navigation for investigating mobile indoor navigation systems is proposed. Based on this evaluation framework, we gave a comparison and analysis of the current mobile indoor navigation systems, and then identified some challenges which require further research and development.

From the survey, we can draw the conclusion that *indoor navigation systems are still on an early development stage*. More attention should be paid to sensor fusion, context-awareness, route communication, seamless switch between indoor and outdoor navigation, and ubiquitous indoor computing.

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Section IV: Atlas Cartography

Chapter 21

Mapping Space-Related Transformation Processes in Eastern Europe. Examples from the Atlas of Eastern and Southeastern Europe

Peter Jordan

Institute of Urban and Regional Research, Austrian Academy of Sciences, Vienna, Austria
peter.jordan@oeaw.ac.at

Abstract

The article highlights some principal transformation processes in the post-Communist countries of Central and Southeast Europe as reflected by the Atlas of Eastern and Southeastern Europe, edited as a thematic map series since 1989 by the author. This comprises (1) environmental change, (2) growing spatial disparities, (3) democratic transformation with a focus on administrative decentralisation and (4) the consequences of a rise in national and ethnic consciousness.

Keywords: atlas cartography, transformation processes, Central Europe, Southeast Europe, environment, spatial disparities, administrative decentralisation, national consciousness

21.1 Introduction

The Atlas of Eastern and Southeastern Europe has been published in 26 instalments since 1989 and reflects the spatial dimension of transformation. Major aspects of the transformation process highlighted are (1) environmental change, (2) the problem of growing spatial disparities, (3) democratic transformation and the problems accompanying developing democratic structures as well as (4) the "second national awakening" and conflicts arising from exaggerated national consciousness. Other important aspects like economic transformation, the change of modal split in trans-

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portation or the suburbanisation processes around larger cities are less prominently treated in this Atlas. The paper will focus on transformation aspects prominently represented and treated in the atlas making references to the respective atlas maps and texts. It does not claim to provide for a comprehensive view over transformation in eastern Europe.

21.2 Goals and Concept of the Atlas

The Atlas of Eastern and Southeastern Europe (Jordan 1989-) was first published by the Austrian Institute of East and Southeast European Studies and is now published by the Austrian Academy of Sciences. It succeeds the Atlas of the Danubian Countries (Breu 1970–1989).

It is a scientific thematic map series published in individual numbers and highlighting spatial effects of current transformation processes in the transition countries of Central, East and Southeast Europe. This is done partly by survey maps in smaller scales (1: 1.5 mill., 1: 3 mill., 1: 6 mill.) rendering a topic in a transnational and comparative way and partly by case studies of individual countries or parts of countries in relatively large scales (down to 1:200,000). Survey maps of larger regions like Central and Southeast Europe or Central Europe offer, compared to national cartographic products the added value of comparable presentation across country borders. This is, combined with a rather detailed spatial resolution, for reasons of map scale not achievable by school, hand and world atlases.

So far, 26 issues or instalments have been published. They are composed of at least one map and an accompanying text book in German and English, but include partly several maps. 13 of the instalments are devoted to larger regions enabling comparison across country borders, two more are currently in elaboration. Two instalments are also available as an interactive internet version accessible via www.aos.ac.at.

21.3 Environmental Change

When looking at the main types of environmental changes that occurred from the late 1980s to the late 1990s, the most obvious is the vanishing of the former gradient in environmental pollution from the “Black Triangle,” the former GDR, southern Poland, and the Czech Republic, due to the relatively successful restructuring of industry and agriculture, as well as the application of new production and environmental protection technologies in the most advanced reform countries of East Central Europe. In contrast to Poland, the Czech Republic, Slovakia, Hungary, and Slovenia, environmental pollution in the east and southeast of Europe (mainly Ukraine, Moldavia, Romania, and Bulgaria) has not been reduced significantly since the late 1980s. Apart from this general pattern, the comparison between the two temporal cross-sections as portrayed by two instalments of the Atlas (Nefedova et al. 1992, Hartung et al. 2003) reveals a number of minor and more local developments, which, however, tell a lot about local and national approaches towards economic restructuring and environmental protection.

21.3.1 The Situation in the Late 1980s *(see Figure 21.1)*

21.3.1.1 Large-Scale Air Pollution

The representation of large-scale air pollution on the map (Nefedova et al. 1992) is based on the concentration of sulphur dioxide (SO_2), since comparable data were available across the whole region only for this indicator. Various other indicators such as dust or nitrogenoxide concentration were used additionally to define peaks of pollution more precisely.

The map shows a compact zone of increased air pollution from the south of the former GDR across former Czechoslovakia, southern Poland, and Hungary to the north of former Yugoslavia, western Romania and Bulgaria. Isolated patches of increased, high or very high air pollution can be found in eastern parts of Romania and Bulgaria, as well as in parts of the former Soviet Union.

Within this compact zone some regions stand out by high and very high concentrations: the south of the former GDR, where thermoelectric power production based on local brown coal, and the chemical industry contributed most to pollution; northern Bohemia [Čechy], where similar polluters were also responsible for massive damage to forests in the Ore Mountains [Erzgebirge/Krušné hory]; southwestern Poland and northern Moravia [Morava], especially Lower Silesia [Dolny Śląsk] with its copper smelting plants, and the Upper Silesian Industrial District with its comprehensive heavy industry based on black coal mining; the Horná Nitra basin in Slovakia, where the polluting effect of a thermoelectric power station burning brown coal was multiplied by temperature inversions in winter; the industrial axis through northern Hungary (from Bakony across Budapest to Miskolc and Òzd) with aluminium huts in the west, chemical production concentrated in Budapest, and iron and steel mills in the northeast; the central part of Slovenia, especially from coal mining and thermoelectric power production in Trbovlje and Šoštanj, with impacts reaching as far as southern Austria; some mining and industrial regions in Bosnia [Bosna] and Serbia [Srbija], as well as in Romania, with lignite mining and burning in the Motru basin, steel mills and black coal mining in Hunedoara and Petroşani, respectively, and the industrial agglomerations of Bucharest [Bucureşti] and its surrounding areas, including Piteşti with its oil refinery, and Ploeşti with its

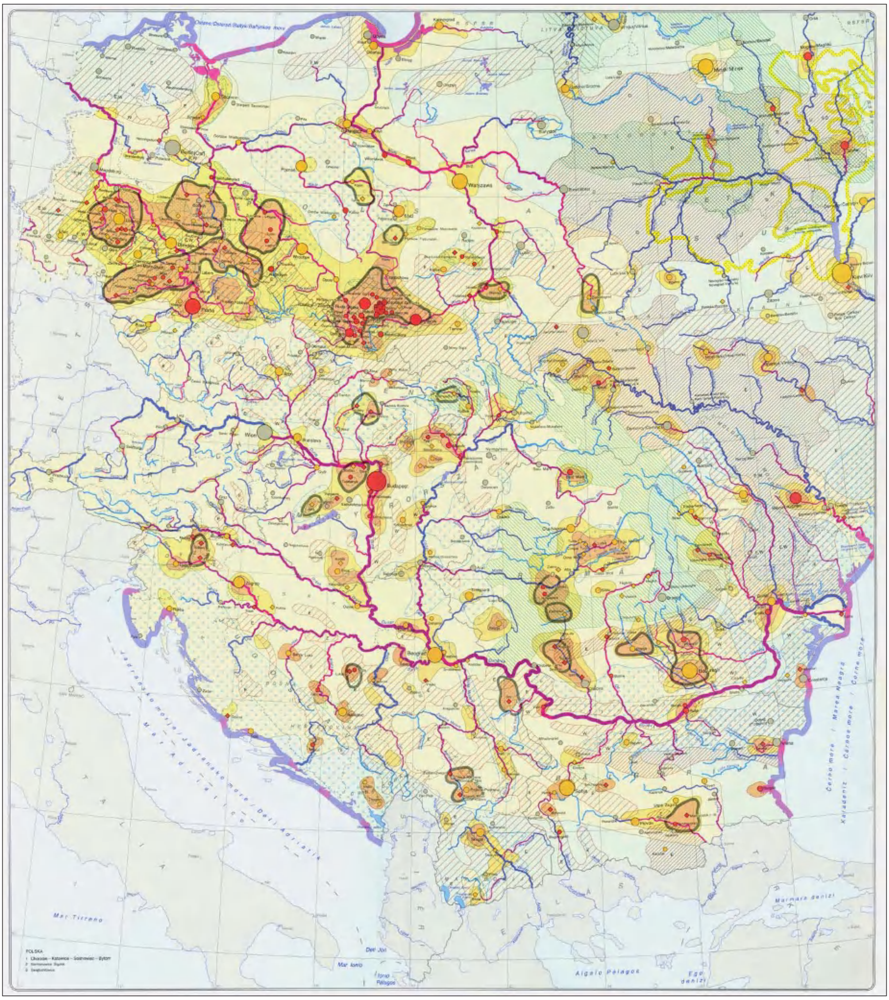

Fig. 21.1. Problems of the environment in the late 1980s, Legend: areal colours indicate large-scale spread of air pollutants (dark orange: very high, yellow-orange: high, pale yellow: increased, pale green: low); coloured circles indicate air pollution in settlements (dark red: very heavy, orange: heavy; grey: minimal, medium); coloured linear symbols indicate pollution of running waters (bright red: very heavy, dark red: heavy, dark blue: medium, bright blue: no, minimal); colour bands along coasts and areal colours on lakes indicate pollution of coastal waters or lakes (bright red: very heavy, dark red: heavy, dark blue: medium, bright blue: no, minimal); brown areal linear patterns indicate soil degradation (dense: critical, wide: near critical); green areal linear patterns indicate damages to forests through industrial use (dense: critical, wide: near critical); green areal dot patterns indicate damages to forests by air pollution; blue areal circular patterns indicate a lack of surface- and groundwater; grey bands confine areas of massive environmental devastation; yellow bands confine areas devastated by radioactive contamination with caesium 137 (dense dot pattern: over 15 Curie/km^2, wide dot pattern: 1–15 Curie/km^2). Grey areas are not treated thematically.

petrochemical industry; finally the lower Marica basin in Bulgaria with its large thermoelectric power stations burning brown coal.

21.3.1.2 Air Pollution in Larger Settlements

Air pollution in larger settlements frequently differs from large-scale air pollution due to local industrial, communal and traffic emissions, as well as specific meteorological situations including location in basins, and prevailing wind directions. Therefore, this indicator is shown separately on the map.

Most polluted in this respect were all the cities of Upper Silesia [Górny Śląsk] including the Czech part, as well as Cracow [Kraków], due to its heavy industry (Nowa Huta) and its location in a basin, which prompts temperature inversions in winter (Trafas 1991). The most polluted capitals were Budapest and Prague [Praha]; Budapest due to its chemical industry and its location in the wind shadow of the Buda Mountains [Budai-hegység], which impedes proper ventilation; Prague due to its diversified industry and its location in the rather narrow valley of the Vltava river. Chişinău, the capital of Moldavia, rounds out the list of the most polluted larger cities in the east.

Relatively better in air quality were Leipzig, Dresden, Ljubljana, Zagreb, Belgrade [Beograd], Bucharest, Sofia [Sofija] and Kiev [Kiïv]. Least polluted capitals in the countries thematically treated were Berlin and Vienna [Wien].

21.3.1.3 Water Pollution

Water quality as it is shown on the map is the result of the harmonisation of divergent national classifications. Some of them were based on chemical, and others on biological indicators.

Generally speaking, in the western parts of the map section river pollution was almost only low in mountain regions, that is, near to the source, while in Belorussia, Ukraine, and Moldavia good water quality was also typical for lowland sections of rivers, due to the overall lower levels of industrial intensity and agricultural land use. Extremely polluted larger rivers include the Elbe, the Oder [Odra], the Vistula [Wisła], the Drava (from the Yugoslavian border), and the Sava.

Water quality among large lakes was poorest in Lake Balaton, especially its western basin, and with some of the Masurian lakes in Poland. Water pollution was relatively low in Lake Ohrid [Ohridkso Ezero/Liqeni i Ohrit], Lake Prespa [Prespansko Ezero/Liqeni i Prespës/Megále Préspa] and Lake Scutari [Skadarsko jezero/Liqeni i Shkodrës].

Comparing water quality along the southern Baltic coast, along the Black Sea coast of Bulgaria, Romania, and the Odessa region of Ukraine, as well as along the eastern Adriatic coast, the Adriatic coast ranked best, while the Baltic coast ranked lowest. The comparatively favourable conditions along the eastern coast of the Adriatic can be explained by rather limited settlement and industrial density, a low intensity of agricultural use, a lack of larger polluted rivers, a system of sea currents providing the eastern coast of the Adriatic with less contaminated water from the eastern Mediterranean basin – water polluted by the large rivers from the Po Plain [Pianura Padana] is exported along the (Italian) west coast – and by the relative deepness of the eastern coast (partly over 100 m), as well as by the occurrence of submarine sources (vrulje) augmenting coastal waters with clean water from the carst hydrologic system. Thus, the water quality along the eastern Adriatic coast is by far superior to that along the western (Italian) coast.

21.3.1.4 Damage to Forests

The map discerns between damage to forests caused by air pollution and damages caused by careless industrial use, neglecting regeneration, age and species structure.

Damage by air pollution was most intensive in the Ore Mountains at the border between the former GDR and Czechoslovakia, in Lusatia [Lausitz] (GDR), in the uplands and mountains around the Upper Silesian industrial district (Beskids [Beskidy], Jeseník), in central Slovenia, in the Romanian Jiu Valley, and in eastern Serbia, as well as in the Balkan Mountains [Stara planina] north of Sofia.

Careless industrial use was most obvious in the Ukrainian and Romanian Carpathians, as well as in Belorussia.

21.3.2 The Situation in the Late 1990s *(Figure 21.2)*

After the collapse of the Communist system, the environmental situation in east central Europe improved remarkably. The main reason for this improvement was what could be called “passive sanitation,” that is, the closing down or conversion of the heaviest industrial polluters, as well as de-industrialisation of agriculture in at least some of the countries. In addition, some active measures against further pollution were taken, such as the application of filters at thermoelectric power stations, or their replacement by nuclear power stations, as was the case in Slovakia and the Czech Republic.

Active sanitation, however, was definitely responsible for only a minor part of the improvement. Shortage in financial capacities, as well as a still less-developed environmental consciousness were the major reasons for the limited use of active sanitation measures. The condition of the environment was still considered a less pressing problem than economic restructuring by the vast majority of the population.

Fig. 21.2. Problems of the environment in the late 1990s, Legend: areal colours indicate large-scale spread of air pollutants (dark orange: very high, yellow-orange: high, pale yellow: increased, pale green: low); coloured circles indicate air pollution in settlements (violet: very dangerous, red: dangerous, dark orange: very heavy, orange: heavy, yellow: increased, light green: low, dark green: very low); coloured linear symbols indicate pollution of running waters (bright red: very heavy, dark red: heavy, dark blue: medium, bright blue: no, minimal); colour bands along coasts and areal colours on lakes indicate pollution of coastal waters or lakes (bright red: very heavy, dark red: heavy, dark blue: medium, bright blue: no, minimal); green areal linear patterns indicate damages to forests (dense: heavy, wide: medium); red areal linear patterns indicate radioactive contamination with caesium 137 (dense: over 15 Curie/km^2, wide: 1–15 Curie/km^2); triangles indicate the impact of mining on the environment (larger: heavy, smaller: medium; black: open-cast mining, grey: underground mining, red: crude oil, natural gas extraction; grey bands indicate road traffic frequency on main traffic arteries in 1995 (from 1,000 to 100,000 motor vehicles per day). Grey areas are not treated thematically.

The opinions that economic restructuring will automatically result in a reduction of environmental problems, and that international support is needed for environmental sanitation were also held by many. Environmental movements and parties had, in general, lost their former vigour.

A new threat to the environment had emerged in the dramatic growth of road traffic, which was increasingly replacing railroad transportation.

21.3.2.1 Large-Scale Air Pollution

What was indicated on the 1980s map as a compact zone of increased air pollution has been dissolved into individual patches on the map showing the state of the late 1990s *(Hartung et al. 2003)*. The "Black Triangle" over the southern GDR, Czechoslovakia, and southern Poland had lost much of its force, but was still the largest contiguous area of at least "increased" air pollution in the whole map area. However, while air pollution in the countries of East Central Europe (Poland, Czech Republic, Slovakia, Hungary, Slovenia) was decisively lower in the late 1990s than in the late 1980s, the situation further to the east (Belorussia, Ukraine, Moldavia) and southeast (Romania, Bulgaria) had not improved very much. The former concentration of pollutants on the western part of the map section had therefore been replaced by a more even distribution.

21.3.2.2 Air Pollution in Larger Settlements

Air pollution in larger settlements had decreased in many cases. In the Czech Republic, only Prague and the industrial towns of Northern Bohemia were still heavily polluted, but their levels of pollution were less than they had been in the late 1980s. In eastern Germany, due to de-industrialisation, the pollution of Leipzig, Chemnitz, and Dresden had been at least slightly reduced, and significantly reduced in Halle. All the larger urban centers of Upper Silesia demonstrated values well below those in the late 1980s; only Katowice and Cracow stood out as still having "high" pollution. Budapest, which has had the heaviest pollution of all capitals in the late 1980s, now had remarkably better values. The reduction of heavy industry also positively affected air pollution in the towns and cities in the rest of Hungary's former industrial belt from Bakony to Miskolc. In Romania, former centers of urban air pollution including Bucharest, Ploeşti, Brăila, Galați, and Giurgiu were much less prominent, while others such as Hunedoara, Baia Mare, and Oneşti remained at the same levels. In contrast to the improvements in at least parts of Romania, the situation in Bulgaria was not better than before; in Sofia and its surrounding areas it had even taken a turn for the worse. Pernik, an industrial town southwest of Sofia, was identified as the nadir of the whole map section in terms of air pollution in larger settlements.

While air pollution in Chişinău had improved from a dangerous situation, the larger cities of the western and central Ukraine, including L'vìv, Kiev, and Žitomir had higher pollution values than before.

21.3.2.3 Water Pollution

In contrast to air pollution, river pollution had not been significantly reduced. Still heavily polluted rivers included the Vistula, the Oder, and the Warta of Poland; the Elbe, the upper course of Spree, the Elster, the Mulde, and the Saale in the southeastern regions of the former GDR; the Dye, the Jihlava, and the Morava in southern Moravia; the Váh and the Nitra in western Slovakia; the Danube, the Tisza, the Rába, and the Körös in Hungary; the Sava and the Drava in lowland Croatia; and the Danube and the lower courses of all its major Danube tributaries, including the Jiu, the Olt, the Vedea, the Argeş, and the Ialomiţa in Valachia. Significant improvements in river water quality were confined to the Sava and Drava rivers in Slovenia, and the Mur, Salzach, Traun, and Inn rivers in Austria.

While the water quality of Lake Balaton had not improved significantly, in spite of the construction of a canalisation network, the formerly heavily polluted Masurian lakes now displayed much lower levels of pollution.

The coastal waters of the southern Baltic Sea were less polluted than before, especially along the Pomeranian coast outside the large bays. The bays also demonstrated a slightly improved water quality. At the Black Sea coast, the former heavy pollution in the vicinity of larger ports had been smoothed. The eastern Adriatic coast had maintained its low pollution level.

21.3.2.4 Damage to Forests

In the map showing the situation in the late 1990s, damage to forests are not differentiated by particular causes. High intensity damage was still present in northern Bohemia from the Ore Mountains to the Sudeten [Sudety], and in eastern Bohemia (Orlické hory), as well as in a wreath around Upper Silesia, including a zone from Częstochowa to Radom.

21.4 Growing Spatial Disparities

Spatial disparities at the sub-national level, i.e. of regions and sub-national administrative units are reflected by several maps of the Atlas, especially by maps on the central place system (Grimm, Friedlein, Müller 1997), population development (Kupiszewski 1992) and migration (Kupiszewski 1993), socio-economic transformation (Jordan & Nefedova et al. 1994) as well as transformation in agriculture (Knappe et al. 2004).

A principal issue to be derived from these maps, but anyway also known from many other sources (e.g., Gorzelak 1996, Fassmann 1997, Heller 1998) is the divide into "winners" and "losers" of socio-economic transformation in the spatial (regional) sense.

Winners of transformation are in the first line **metropolitan cities and large regional centres**.

Due to their favourable infrastructure, easy accessibility, diversified economic structure and rich human capital they succeeded to attract qualified and strategic investment from the very beginning of transformation. Their winner role is reflected also by population growth, mostly, however, directed to the urban fringe and not to the urban core resulting in the very typical effect of suburbanisation. The only major exception in this latter respect is Tirana, which reports a population increase (affecting also the urban core) from about 300,000 in 1990 to currently about 900,000 (qualified estimates, see Doka 2005).

A positive effect on regional centres can best be observed in larger countries, where besides the primate city other centres have space enough to play a major role. This is certainly true for Poland, where besides the capital Warsaw [Warszawa] also Poznań, Wrocław, Cracow [Kraków] and Gdańsk show a very positive development. Another good example is Romania, where apart from the capital Bucharest [Bucureşti], certainly at the very top of the country's socio-economic development, also regional centres like Timişoara, Cluj-Napoca, Braşov, Sibiu, Craiova, Iaşi and Constanța have been rather successful.

In smaller countries or countries with a rather dominant metropolis only one or a few regional centres apart from the capital were more prosperous. In the Czech Republic this can actually only be said of Brno, the "secret capital" of Moravia [Morava]; in Hungary for Pécs and Debrecen; in Serbia for Novi Sad and Niš; and in Bulgaria for Plovdiv, Varna and Burgas. Cities like Košice in Slovakia, Maribor in Slovenia or Rijeka and Split in Croatia suffer already from their rather limited or economically peripheric catchment.

A second type of winners are **western border belts**, when they border a country in a better socio-economic position. They profit from border trade, daily commuting to the neighbouring country with higher wages, shopping and excursion tourism from this other country, the outsourcing of industrial productions due to the gradient in labour costs and other kinds of public and private trans-border co-operation. Typical examples in this respect are the Hungarian and Slovakian border regions towards Austria, the Czech border regions towards Bavaria and Austria, the Romanian border region towards Hungary, the Serbian Vojvodina as the border region towards Hungary, the western Ukraine east of the Polish border.

A next type of winners are **rural regions with tourism**. They profit from (besides agriculture) a second source of income. The effect is stronger, when tourism is not mono-seasonal. Examples for this type are the Tatra Mountains [Tatry] in Poland as well as in Slovakia with both a winter and a summer season; the Masurian Lakes [Pojezerze Mazurkie] in Poland, where rural tourism based on an attractive lakeside scenery flourishes; the Adriatic coast in Slovenia, Croatia and Montenegro, which succeeded to recover after a longer break caused by the post-Yugoslavian wars and crises due to a turn towards quality tourism; the Bulgarian Black Sea coast, which (much in contrast to the Romanian) succeeded in restructuring Socialist welfare tourism; Romanian Transylvania [Ardeal] and Bukovina [Bucovina], where cultural monuments (of the Saxons in Transylvania, the Moldavian monasteries in Bukovina) as well as sentimental and ethnic tourism (mainly in Transylvania) florish.

A last type of winners are **rural regions along communication corridors and economic development axes** between larger centres. They profit from their location and participate in the success of the centres. Most frequently, however, socio-economic development along these corridors is spatially not homogeneous, but confined to pockets or urbanised zoens. It may also happen that human capital is due to selective out-migration already exhausted so that the basis for economic development is missing. Typical cases in point are the corridor between Budapest and Vienna, the Slovenian main transportation axis from Trieste via Ljubljana to Maribor and further to the Hungarian border, the main Croatian transportation corridor between Zagreb and Rijeka, the Morava corridor in Serbia between Belgrade [Beograd] and Niš or the Marica corridor from Sofia via Plovdiv to Edirne in Bulgaria.

Apart from **old industrial regions** with heavy industries, for which it is difficult to be converted and modernised (e.g. Upper Silesian Industrial Region [Górny Śląsk] in Poland, Ostrava-Karvina Region in the Czech Republic) the main loser is the **rural space**, if it is not favoured by the above-mentioned factors, i.e. if it has no potentials for tourism or other tertiary activities. In terms of area, these are large parts of the transformation countries.

As general reasons for the at least relative, but frequently also absolute and accelerated socio-economic decline of the rural space the following may be mentioned:

- Rural space receives less investment than urban and especially metropolitan regions, since investment into urban centres offers higher and faster returns of the invested capital. This means less inovation and modernisation in the rural space.
- Much in contrast especially to Alpine regions, but to rural space in Western Europe in general, rural space in transformation countries receives much less, if any subsidies from European or national sources. Rural economy is therefore almost exclusively determined by market prices and income in agriculture as compared to income in other branches of the economy. Transformation countries,

who are European Union (EU) members, will only in the longer run receive an amount of subsidies from EU Common Agricultural Policy (CAP) comparable to what is received by "old" EU members. Very likely also, the overall amount of CAP subsidies will be reduced after the programme period 2007–2013. Usually this resulted in a decline in agricultural land use and production.

- The agricultural markets of transformation countries were forced to open themselves towards the world market. This resulted in the intrusion of powerful competitors from the EU and from overseas not only in the sector of agricultural production in the narrower sense, but also with foodstuff produced on the basis of agricultural products.
- Due to the fact that restitution to former owners and their heirs has been the main method of post-Communist land reform, the average agricultural enterprise is small and economically weak. Much in contrast to old EU members, also administrative, social and economic supportive structures are missing.
- Migration flows are directed towards better economic prospects. This means in general selective migration from rural to urban space leaving older, less qualified and less active, also politically structure-conservative people behind. This means a decline of market production in favour of subsistence and a further reduction of potentials for innovation.
- Where agriculture had to a high extent been collectivised in the Communist period (all countries to at least 85%, except Poland and Yugoslavia, only 22% and 32% resp., see Taschler 1989), the administrative centres of large state and collective farms had not only acquired economic, but also educational, health care, social and cultural functions for the rural population. Dissolution of these large enterprises meant also the closing down of these extra-economic functions and very often no adequate replacement by central functions of villages and communes. This contributed to a reduction in quality of life in rural space.

21.5 Democratic Transformation

From two maps plus accompanying texts showing the administrative subdivision of Central and Southeast Europe as of 1 January 1989 (Jordan & Slawinski 1989) compared to 1 January 2007 (Jordan 2009) it can be concluded that at the local level (NUTS-5, partly NUTS-4) self-government has been established in all countries. In the successor states of Yugoslavia it had already existed in Communist times (Yugoslavia had developed a specific system of self-administrative Socialism). In Bulgaria it has been established in 1988, in all other countries in 1990 and later.

When it comes to discuss the regional levels (NUTS-2 to NUTS-4), it can be summed up that only Poland has self-government at the NUTS-2 (province) level.

The Czech Republic, Slovakia, Hungary, Croatia and Romania have self-governing units at the NUTS-3 (region) level, Slovakia with a very specific solution: two administrative bodies at the same regional level are responsible for the same territory. Bulgaria has self-government only at the lower regional level (NUTS-4, the level of districts or very large communes). In Estonia and Latvia is no self-government at regional levels, although administrative regions exist. Slovenia has not implemented administrative regions so far.

Major problems accompanying decentralisation in transformation countries are

- the danger that socio-economic disparities grow;
- a lack of qualified and trained personnel especially at the local level;
- a lack of civil participation;
- a lack of coincidence between administrative and cultural regions;
- a lack of coincidence between administrative and functional regions;
- a lack of horizontal networks.

Driving forces for decentralisation in general and administrative regionalisation in particular are quoted below roughly in the sequence of their importance at the average of the countries investigated:

- cities and economically prospering regions;
- political elites ready to comply to the requirements of EU integration and accession;
- regional and local media;
- conservative and liberal political parties;
- other political actors with a regionalized or localized organisational structure of their own or aiming at regionally or locally diversified political goals, e.g. culture associations, farmers' associations, fishermen's associations, chambers of commerce;
- good coincidence between administrative and functional regions;
- good coincidence between administrative and cultural regions;
- ethnic minorities, if they are not regarded (by the central government or by the majority population) as a threat to national integrity.

21.6 Rise of National/Ethnic Awareness and Resulting Problems

Several maps of the atlas are devoted to the representation of national/ethnic structures (Kocsis 1990, Jordan, Schappelwein & Tarhov 1993, Jordan et al. 1995, Wolf & Förster 1999, Jordan & Kocsis et al. 2006). Accompanying texts highlight political and societal backgrounds, characteristics of national/ethnic identities as well as ethnic conflicts, especially minority issues. The most recent map of this series (Jordan & Kocsis et al. 2006) shows ethnic consciousness in Central and Southeast Europe according to the census round of 2000 and by administrative units at the NUTS-4 level *(Figure 21.3)*.

Generally speaking, national/ethnic awareness has gained ground after the fall of Communism. This can partly be explained as a reaction to this a-national and (at least by declaration) internationalist ideology and as filling the ideological vacuum it left behind. It is partly also due to the economic and social transformation crisis, in which governments and political leaders were in the habit of appealing to national/ethnic consciousness in the hope of releasing additional resources.

Other reasons, typical not only for the former Communist countries, but also for Western Europe, are:

- globalisation does strengthen the need to preserve one's own and the group's identity, to find support in a cultural group, to remain special;
- the decentralisation and regionalizing process under way in the EU and beyond its borders (towards a "Europe of regions") favours cultural minorities as the manifestation or representatives of regional identity;
- the European Union and the Council of Europe declared the cultural diversity of the continent an essential trait of the European identity and are prepared to go to considerable expense to maintain it (see the complicated and costly EU official language regulation).

Most obvious and a matter of most tragic results was the resurgence of the national question in former Yugoslavia. Communist Yugoslavia, which was *de facto* a multinational state, but which in the interwar period understood itself also as nation state – namely, of the Yugoslavian nation consisting of the Serbian, Croat and Slovene peoples – went a way different from other Communist countries also in this regard. In a conscious break with the Yugoslavia of the interwar period which was under the hegemony of the Serbs, Tito's Yugoslavia sought a balance between the southern Slavic nations. The non-Slavic Albanians however, were not accorded an equal role.

Achieving this balance involved more than just establishing a federal system. Under the pressure of Tito's partisan movement which had also achieved victory over the Serbian nationalist Chetniks, the Serbs were stripped of their territorial possessions: (1) Regions referred to in Serbia as southern Serbia were upgraded to the Republic of Macedonia, its majority population was provided with all the trappings of a separate Orthodox nation (standard language, autocephalous Orthodox church); (2) Serbia was prevented from direct interference with sections of Serbia that contained large national/ethnic minorities (Kosovo, Vojvodina) because they were autonomous; (3) Bosnia-Hercegovina, whose population up to the 1961

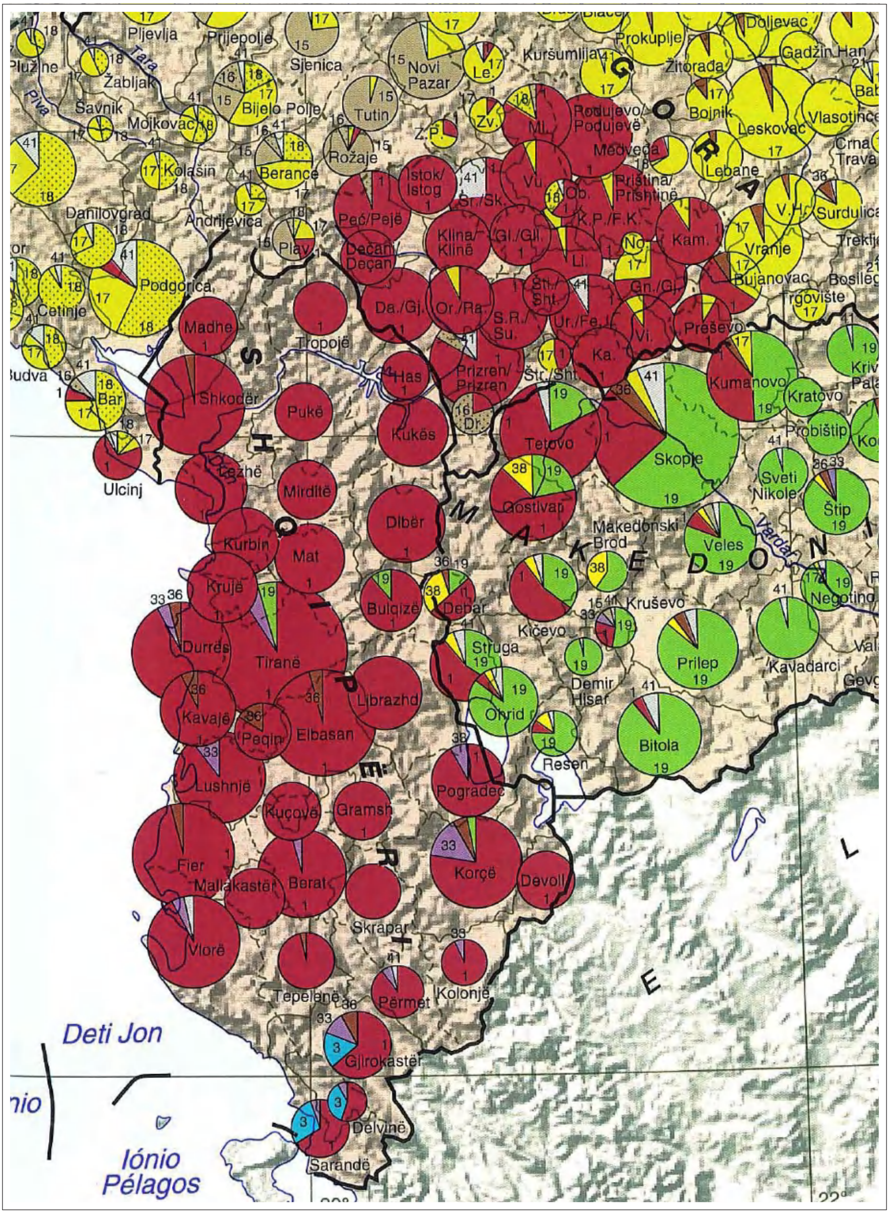

Fig. 21.3. Ethnic consciousness in the southern parts of the West Balkans around 2000, Legend: the size of the circle corresponds to the total population of a reference unit; the share of nations and ethnic groups in the total population is indicated by coloured circle sectors, if it reaches a minimum of 3%; brownish red: Albanians, green: Macedonians, yellow-green: Serbs, yellow-green with dot pattern: Montenegrins, grey: Bosniaks, grey with dot pattern: Muslims, yellow: Turks, violet: Vlachs, Aromunians, blue: Greeks, brown: Roma, Sinti, pale grey: others, if the combined number reaches the minimum share of 3%.

census was predominantly Serbian (The Miroslav Krleža Lexicographical Institute 1993, pp. 123), was granted the status of a republic with no special rights for the Serbs; (4) Montenegro, which had been an independent state prior to the formation of Yugoslavia, but which had integrated itself without reservation into Yugoslavia and whose majority understood itself nationally as Serbs, was also established as an independent republic with "Montenegrins" as the titular nation; (5) 12 compact communes in Croatia bordering each other with Serbian majorities received no special status.

All these measures were tolerated by the Serbs. Flare-ups of Serbian nationalism (such as occurred in the first half of the 1960s when the Serb Aleksander Ranković was the General Secretary of the Communist League) were suppressed under Tito's authority. Nationalist demonstrations by Croats and Slovenes, which were grounded in the feeling that they were disadvantaged within Yugoslavia's disparity equalization system, for which they as the most economically capable always ended up footing the bill, were likewise held back by Tito.

What was lacking to go along with the suppression of national claims and nationalist upsurges through the power of the Communist dictatorship and despite relatively favorable economic conditions, was grappling with the history of the severe conflicts between the Yugoslavian nations (and also with Albanians), especially during the Second World War. They had caused severe mutual injury and continued to fester on as unresolved potential conflicts.

Once the economic situation began to deteriorate in 1980 (bottlenecks with fuel and consumer goods supply at the beginning of the 1980s), following the death of the unanimously popular Tito, the national consciousness of all of these resurfaced. This is also reflected statistically in the decrease in numbers of those who thought of themselves as supranational, in a purely civic sense as "Yugoslavians" – that is, who no longer considered their national/ethnic affiliation essential. Between the all-Yugoslav census of 1981 and that of 1991, this group dropped from 5.4 % to 3.0 % of the population (Savezni zavod za statistiku 1981; Savezni zavod za statistiku 1993).

The resurgence of a national consciousness meant for Serbs that they strengthened their claim to primacy in the whole state and intended to restrict the far-reaching self government of the autonomous Serbian provinces, especially Kosovo. Early in the 1980s, the idea of Greater Serbia was reawakened in the background, which considered all of the Orthodox southern Slavs except for Bulgarians, and all those who spoke the Štokavian dialect to be Serbs, and which held the belief, along the lines of the 1844 published "schemes" of Načertanje, that the Serbian people would only be capable of successful national development once they succeeded in dominating the rest of the southern Slavs. An important representative of the Greater Serbia idea was the Serbian geographer Jovan Cvijić (1865–1927), to whom the Serbian nationalists often made reference.

Among Croats and Slovenes the resurgence of a national consciousness strengthened the conviction that they did not have to share the fruits of their economic achievements with others. They also strove to live out their national cultures even more in their respective republics.

As the majority in Bosnia-Hercegovina, the Bosniaks (at the time called "Ethnic Muslims") strove for political dominance in this republic. The Kosovar Albanians demanded the status of a republic in Kosovo. The ethnic Macedonians increasingly viewed its minority-rich republic as its own nation state. Only Montenegro continued to cooperate closely with Serbia.

With these divergent aims, so at odds with one another, the resurgence of the national question became the driving force behind the collapse of Yugoslavia.

Nationalism and nationalist thinking culminated during the wars following Yugoslavia's collapse, but are still common in the whole of post-Communist Europe, but especially in Southeast Europe today and more deeply rooted than in many other parts of Europe. It is associated with the "youth" of these nations, who first sought to free themselves from the dominance of the superpowers and then to emancipate themselves from nationally different elites. It is associated with the Orthodox churches who, unlike the universal Roman Catholic Church, understand themselves to be national churches and after the fall of Communism regained influence in society. It is also very much associated with the inversion of the political position between these nations, who as Muslim converts backed the authority of the Ottoman Empire, and those other nations, who as Christians were discriminated against at that time and later represented the state nations. The latter accuse the former of betraying the common cause out of opportunism – an accusation that weighs heavily considering the keen historical consciousness in Southeast Europe. This, in fact, was the backdrop to some extent of all the virulent conflicts in the region today between Serbs and Albanians, Bosniaks and Serbs/Croats, Macedonians and Albanians.

The strong national consciousness, based on very different historical views and often antagonistic, makes the relationships between neighboring countries, as well as political and economic cooperation in the region, most significantly in Southeast Europe, difficult. Most of these states have oriented themselves, if at all, to an external reference point (Brussels, USA) rather than trying to seek an intra-regional relationship. That makes it more difficult for Southeast Europe to overcome the status of the European periphery and to gain influence.

21.7 Conclusion

The Atlas of Eastern and Southeastern Europe is a thematic map work with a regional focus on Central and Southeast Europe and a thematic focus on transformation processes in the post-Communist countries. Its editorial concept, its problems with international data collection, its cartographic methods and its electronic version have already been rendered in various publications. (Some of them are quoted in the bibliography). It was therefore the primary intention of this contribution to highlight space-related transformation processes from a geographical angle as far as they are portrayed by this atlas. This was considered to be adequate within a book which focuses right on this region, although it deals otherwise mainly with methodical cartographic issues.

Major space-related transformation processes reflected by at least one, in many cases several instalments of this atlas are environmental change, the growth of spatial disparities, democratic transformation and the rise of national/ethnic awareness.

As regards environmental change a general improvement can be stated. It is, however, more significant in economically prosperous countries and regions and shows a West-East gradient so typical also for economic power and economic transformation.

Spatial disparities grow especially between larger cities and rural space. Other regional winners of transformation are border belts towards economically more prosperous countries and regions with intensive tourism. Rural spaces left behind are characterised a.o. by a lack of young and active population, by insufficient transportation, social, health care and cultural infrastructures as well as by societal and political attitudes inclined to conserve existing structures and to avoid innovations.

Democratic transformation has proceeded differently in individual countries and was partly impeded by violent conflict. When the political landscape as represented by party systems and administrative decentralisation and regionalisation are taken as indicators for democratisation processes, also a West-East or Northwest-Southeast gradient can be observed.

After the rather a-national period of Communism the national idea has significantly grown in force resulting in conflicts between nations and in a recovery of minority problems. Vigour of the national idea as well as the political handling of national and ethnic conflicts may be regarded as indicative for the status of the transformation process.

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Chapter 22

The Demographic Atlas of Croatia – A Web-Based Atlas Information System

Hartmut Asche[1], Aleksandar Toskić[2], Dubravka Spevec[2] and Rita Engemaier[1]

[1] Department of Geography, University of Potsdam, Germany
{gislab, rita.engemaier}@uni-potsdam.de
[2] Department of Geography, University of Zagreb, Croatia
{atoskic, dspevec}@geog.pmf.hr

Abstract

Demographic data are pivotal in the development of any country. In Croatia, a post-socialist reform state about to join the European Union, basic and up-to-date information on the population, economy or environment is often not readily available to the scientific community as well as the wider public. To help bridge this information gap a group of Croatian and German geoscientists in a joint effort are developing the Demographic Atlas of Croatia (DACIS). DACIS is implemented as a web-based demographic atlas information system that provides fundamental information on the structures, composition, distribution, natural and spatial developments and trends of the Croatian population since independence from Yugoslavia in 1991. Targeted at the general public, educators as well as decision makers in politics and the economy, the electronic web atlas will be complemented by a conventional book volume. Through its presentation in easy-to-comprehend maps DACIS seeks to gain the interest of a Croatian as well as international audience in the demographic fundamentals and regional developments of the country.

Keywords: atlas information system, demographic atlas, web maps, web mapping, electronic atlas

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22.1 Introduction

For centuries maps have been a familiar and effective means to document and communicate geographic information, both known and unknown. This fundamental capacity of maps has once again been highlighted in recent research on geovisualisation, e.g. by MacEachren's famous map cube (MacEachren 1994, 1995). Maps and map collections such as atlases are essential to disseminate detailed geographic information on the status and structure of any region or territory. Atlases, in particular, have long been designed and used as cartographic business cards of national states. Their primary objective is to communicate the manifold physical, economic and societal resources of a country or region to a wide audience at home and abroad either in one product or a number of thematic volumes. National atlases like those of Finland (1899), the Soviet Union (1937–40) Sweden (1990–97) or Slovenia (1998), among many others, are prominent examples. Coupled with the dissemination of information is the function of national and regional atlases, in particular, to a lesser extent also of thematic and school atlases, to promote the formation of a national or regional identity, respectively (e.g. Jordan 2002). This is of special importance in the process of nation building of the new national states that emerged from the political turnaround in central, eastern and southeastern Europe in 1989–91.

Croatia is one of those post-socialist reform states rooted in a rich and changeful history. Manifold geographic information on the past and present of its territory is available in maps, atlases and alphanumeric data collections, both analog and digital.[1] Such information, however, is not always readily accessible to a wider public. To help bride the information gap in one pivotal topic, the demographic situation, and provide fundamental information on the structure and dynamics of the Croatian population, a web-based demographic atlas information system (AIS) is developed in a joint project of Croatian and German geoscientists of Zagreb and Potsdam universities. Designed as a systematic collection of easy-to-comprehend interactive quality maps, the Demographic Atlas of Croatia (DACIS) will provide fundamental information on the structures, composition, distribution, natural and spatial developments and trends of the population mainly since independence from Yugoslavia in 1991, complemented by regional case studies. Atlas and map format have purposely been chosen to disseminate demographic information. Maps have long been proven to be a widely familiar, at the same time highly effective means of communicating geographic data (Asche et al. 2005), atlases can be considered the best-known and ultimate cartographic products (Kraak 2001). To achieve the

[1] Recent products include the following atlases: Veliki Atlas Hrvatske (VAH), Zagreb 2002; Središnji registar prostornih jedinica Republike Hrvatske (SRPJ) = [Central register of spatial units of the Republic of Croatia], Zagreb, 2002; Zemljopisni atlas Republike Hrvatske (ZARH) = [Geographic Atlas of the Republic of Croatia], Zagreb, 1992; A Concise Atlas of the Republic of Croatia & of the Republic of Bosnia and Hercegovina (CAC), Zagreb, 1993, etc.

widest possible dissemination of current demographic information via DACIS the electronic web atlas will be complemented by a conventional book volume.

This paper discusses the development and prototype implementation of DACIS. It focuses on the concept, GIS-based software system and selected issues of data processing and quality visualisation to disseminate demographic information to a wide audience both at home and abroad.

22.2 DACIS: Concept and Objectives

DACIS aims at documenting and providing fundamental information on the current structure, composition, distribution, natural and spatial developments and trends of the Croatian population. Using the internet and conventional book form as distribution media the atlas targets a wide national as well as international audience in science and education, politics and economy. More specifically, DACIS seeks to address decision makers, scientists, educators and cartographic laypersons alike. Accordingly the focus of atlas map visualisation is on professional, easy-to-comprehend 2D analytical map types complemented by a selection of innovative 3D map presentations. To facilitate an easy understanding of Croatia's population geography past and present the atlas also includes multi-temporal map visualisation of key demographic features and trends.

For the elaboration of the AIS concept the German partners could draw on expertise acquired during an earlier R&D project with university and academy partners from Albania and Kosovo. One outcome of this project was the development and production of the Demographic Atlas of Albania (AGPS; Bërxholi et al. 2003), a paper atlas based on a GIS software platform. Map construction utilised standard Desktop Mapping software into which GIS data were imported via a dedicated data filter. Unlike DACIS, the Albanian demographic atlas has been conceptualised as a prototype for a multi-volume Albanian national atlas (Asche 2009, Asche et al. 2005, Asche & Engemaier 2006). Its GIS base allows for the subsequent creation of a digital national atlas information system. In the meantime a web-based prototype to complement the print version of the AGPS has also been developed (Engemaier 2005). The experience gained from the AGPS project provided valuable insight into theory and practical application of GIS-based atlas development which has been especially helpful in conceptualising DACIS.

Development of DACIS is based on state-of-the-art science and technology of the geoinformation age. DACIS thus makes extensive use of the internet as the primary and most important platform of disseminating geographic information. The development and implementation is based on commercial GIS software (ArcGIS). This GIS environment provides a powerful and flexible basis data storage and processing.

However, it does not support map visualisation in accordance with the quality standards of thematic cartography. To facilitate professional map construction the GIS is complemented with a visualisation system supporting the full range of graphic composition and design (Wolff & Asche 2008). This combined GIS-VIS environment allows for the development of a web-based information system with interactive maps. The audience is thus offered digital maps which, through a graphical user interface, faciliate further exploration, analysis, manipulation or customisation and even dissemination on the internet. That is why the internet is considered an ideal platform for map-based communication of geographic information (Lechthaler et al. 2005). Due to the global availability of the internet web atlases can be accessed anytime and anywhere. However, on a regional scale it cannot be overlooked that in any country web and sometimes computer access is varied. This might limit the reach of the web atlas. To bypass any potential digital divide a paper atlas is also developed from the DACIS platform complementing the web atlas. The paper atlas will be produced in collaboration with a Croatian publishing house.

The concept of DACIS outlined above can be broken down into a number of objectives both the web and print versions of the atlas will have to meet:

- Development and implementation based on a GIS-VIS software platform linked by adaptive workflow
- Problem-oriented atlas compilation based on narrative
- Thematic focus on current demographic structures and dynamics in a post-socialist transformation context
- Professional, easy-to-comprehend and visually attractive map models
- Short explanatory texts to accompany main atlas topics
- All-embracing graphic design for web and print atlas

Implementation as well as development of DACIS is based on a collaborative approach. That is why the objectives have been operationalised by defining work packages to be executed either in Croatia or Germany. Work progress is assessed in scheduled project workshops with both partners.

22.3 Themes and Database

Demographic data are of crucial importance in the development of any country. This applies, in particular, to the new national states that have emerged from the disintegration of Yugoslavia following the political turnaround of 1989–91 in central, eastern and southeastern Europe. In Croatia, most data on the population geography of that country are available past and prior to independence. Since then the country is subjected to tremendous changes in politics, economy and society. Demographic data, in particular, covering this ongoing transformation phase are frequently not readily accessible to the scientific community as well as a wider public.[2] The continuation of this situation will increase the disproportion between existing data and their unrestricted access as a consequence. By providing fundamental, up-to-date and selected historic information on the following demographic subjects DACIS is contributing to narrow this divide:

- Spatial distribution of population,
- Natural development of population,
- Spatial mobility,
- Population structure,
- Households and dwellings,
- Zagreb population: structure and dynamics,
- Population Projections.

This information is made accessible in informative as well as appealing demographic maps. Additionally DACIS provides information on the country's regional, cultural and ethnic continuity as well as on the political and geographic environment In doing so DACIS is focused on map modeling and quality visualisation as the primary means of communicating geographically related demographic information whether served on the internet or provided in a paper atlas.

In DACIS, maps have been compiled from official data collected by the National Bureau of Statistics and from additional information gathered in the Department of Geography of Zagreb University (e.g. Nejašmić 1996, 2003, Nejašmić & Mišetić 2004, Nejašmić et. al. 2008) All maps show the current demographic situation according to the administrative divisions used in the 2001 census. These data have been supplemented with intracensus data (1991–2001) and older archive data. All demographic source data have carefully been checked for quality and consistency before included in the DACIS database. Depending on the depth of the data available, a number of topics can be traced back to the 19th century, but mostly to the period following the Second World War. These post-war years and the 1990s have seen intensive demographic transformations. Providing retrospective information on the structural and spatial dynamics of the population puts the atlas user in a position to appraise the current status by comparing the data and development. In short, multi-temporal visualisation in animated maps or map sequences will promote a better and deeper understanding of the complexities of the demographic situation in Croatia. Construction of multi-temporal map sequences required all data to be referred to identical administrative divisions. Since the country has seen frequent changes in its administrative divisions historic data have been converted to the administrative units of the 2001 census.

[2] This situation mirrors a frequent and well-known dilemma of the information age: more existing data – less available information.

The definition and implementation of a consistent, up-to-date dataset of the Croatian administrative divisions and their nomenclature is of fundamental importance in the development of DACIS. Such dataset did not exist. What was available was the administrative database and nomenclature from the National Bureau of Statistics. Due to problems encountered in the assignment of ID numbers of administrative units to a strict and logical hierarchical order it was, however, decided to create our own generic administrative unit database and nomenclature. The geometry of the administrative divisions adopted for DACIS is based on the administrative status of the divisions as of the 2001 census. Due to different data sources and changes of administrative boundaries over the past decade the geometry of administrative units had to be corrected from existing datasets, updated and unified. The new administrative units' nomenclature has been defined according to clear geographic criteria: ID numbers assigned for each division level from north to south and west to east, starting from the north-western unit (cf. *Table 22.1)*.

Table 22.1. New administrative division nomenclature – example for Međimurje county

Administrative unit	Name of administrative unit	ID
county	Međimurje	10
municipality	Sveti Martin na Muri	10010
settlement	Marof	100100010
	Žabnik	100100020
	Vrhovljan	100100030
municipality	Mursko Središće	10020
settlement	Hlapičina	100200010
	Mursko Središće	100200020

Such nomenclature allows for transparent identification of the location of each unit and problem-free aggregation of data from lower to higher level administration units. In addition the database facilitates assigning ID numbers to newly established settlements after the 2001 census without violating the newly defined database structure. In the initial phase of DACIS presented here not all demographic data required to document and map the settlement level are available. Hence, for the time being, it is not possible to adapt the data to the newly established administrative level of municipalities. When these data become available the administrative units' nomenclature facilitates easy integration into the database. In the same straightforward manner future changes in the administrative divisions can easily be dealt with. Because of its generic nature the administrative divisions' database implemented in DACIS may also be used for a variety of applications outside the AIS. One will be the incorporation into a modular e-learning system set up by the Department of Geography of Zagreb University used in courses on population geography, urban geography, geoinformation science, etc.

As a necessary complement to the administrative units database a generic attribute database has been set up populated with all relevant demographic and related information. In combination both databases allow for map construction and visual as well as data-oriented exploration and analysis. This GIS database is the core component of the GIS system powering DACIS.

22.4 Visualisation and Map Types

To achieve the objectives explained above clear and appealing map visualisation of demographic data is pivotal for addressing the audience targeted with DACIS. Atlas and map design is aimed at producing attractive, easy-to-comprehend maps to facilitate intuitive visual exploration and analysis. Cartographic visualisation thus includes the full range of classical demographic 2D map types complemented by experimental 3D maps. Visualisation and map design is based on the principles of thematic cartography as compiled in the classic works of European cartographers (e.g. Arnberger 1966, Imhof 1972, Witt 1970) and on current research on geographic visualisation substantially advanced by North American cartographers (e.g. DiBiase 1990, MacEachren 1994, Slocum et al. 2005, Taylor 1994). This approach helps to safeguard that the map models developed fully comply with the professional standards of up-to-date thematic mapping. Quality map visualisations, in turn, facilitate intuitive map reading, exploration and comprehension essential to communicate demographic information and the resulting geographic structures.

Map types have been determined in accordance with the objectives targeted with DACIS and the statistic source data available. The bulk of data refer to administrative divisions of which the county (županije) level is the most important to allow for countrywide comparisons in a single map. In keeping with the aim to provide easy-to-read map models demographic data relating to administrative units have been visualised in analytical 2D choropleth maps or cartograms. Based on the statistical method these single-layer maps are the most common and familiar and at the same time easy-to-comprehend visualisations of demographic phenomena. DACIS includes choropleth maps for topics like population distribution, natural growth of population, mortality, etc. (cf. *Figure 22.1)*.

Whenever quantitative data subdivided into designated groups are available relating to administrative divisions they are visualised in diagram maps. These combine range-graded symbols or diagrams with area information of the cartogram type. On the one hand the resulting double-layer maps raise the explanatory power of the map graphic, facilitating, e.g., comparison of contextually related absolute and relative quantitative data. On the other hand their greater visual complexity might impede intuitive perception of the map content. That is why the use of

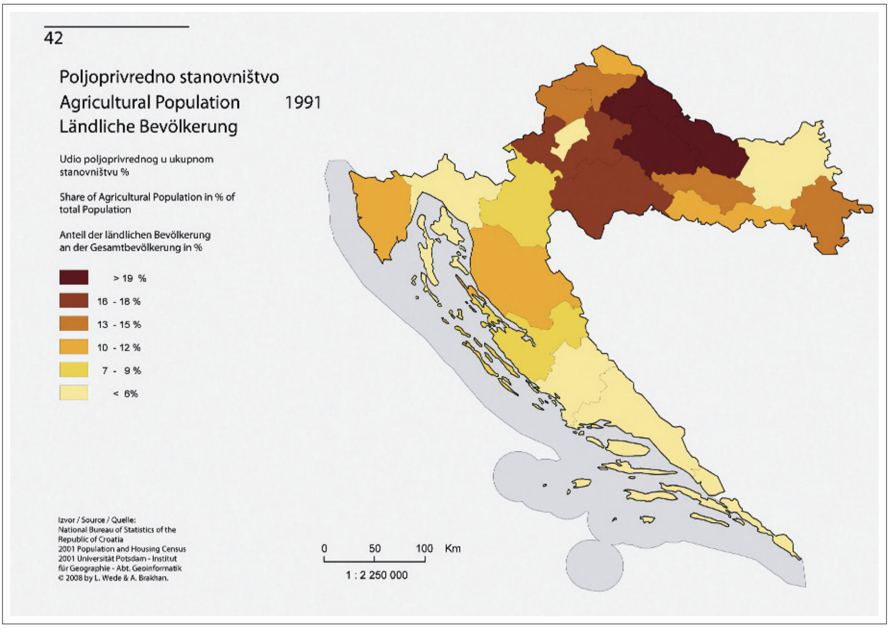

Fig. 22.1. DACIS choropleth map: agricultural population 1991; print atlas map prototype

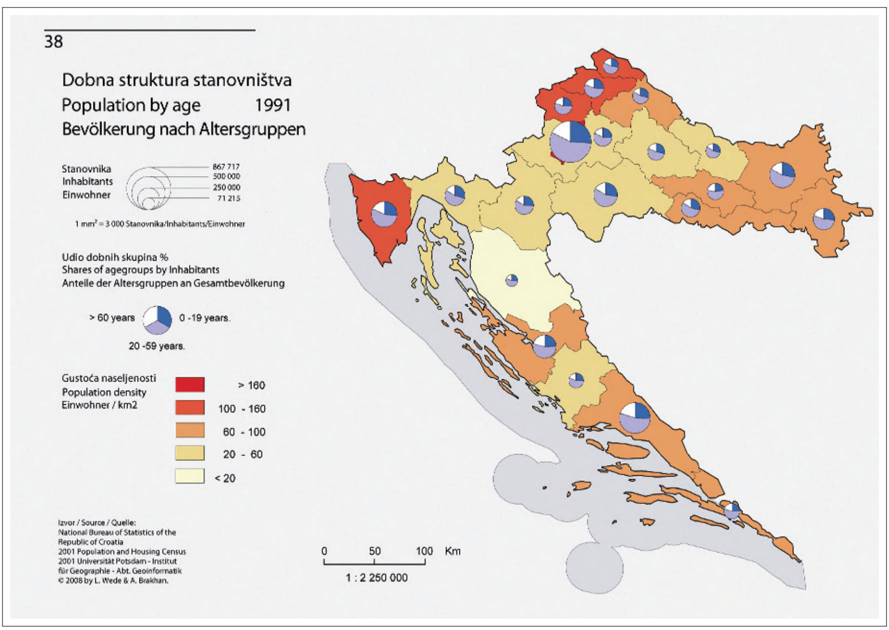

Fig. 22.2. DACIS diagram map: Structure of population by age (1991); print atlas map protoype

diagram maps has been limited to topics like population dynamics, rural and urban population, age structure, etc. (cf. *Figure 22.2)*.

Locational data on population distribution require a map type presenting the geographic position of absolute values. To serve this purpose proportional symbol maps are used to visualise, e.g. settlements and their size or the distribution of population. These analytical maps use range-graded dot symbols to represent the exact locations and values of quantitative information (cf. *Figure 22.3)*.

Map representations of demographic data are supplemented by basic information on Croatia's administrative division and physical environment. While administrative data are essential for the geographic reference of the statistical data, physical data allow for an overall geographic reference. To illustrate spatial interrelation between demographic structures and the physical environment, plastic hill shading models are being developed for DACIS to be added to all country maps.

Professional cartographic visualisation necessitates the generation of a separate graphic data model to complement the data model of any particular map. This process requires cartographic generalisation of the map graphic in accordance with cartographic principles. Since automated generation of a cartographic model is not yet feasible separate graphic models for the map types used or map cartographic model components are constructed in an interactive process. One important aspect of a cartographic model is the topic-oriented generalisation of the geometry data. Choropleth and diagram map types allow for a simplification of boundaries of the spatial units. The resulting map graphic causes less visual clutter and thus concentrates the users' attention on the quantitative (or qualitative) area related features of the respective spatial units and not on irrelevant boundary details (cf. *Figure 22.4)*.

22.5 Implementation

Implementation of DACIS is based on a GIS-VIS software platform adapted to professional requirements of storing, processing, modeling and visualising cartographic information. As has already been pointed out this GIS-VIS link is the fundamental concept behind DACIS. In this concept a GIS is used as the back-end allowing for powerful data storage and graphic-free processing. To facilitate professional visualisation of the map models defined in the GIS database the GIS back-end is complemented by a visualisation platform as a front-end. According to the requirements of map presentation this front-end can either be a 2D vector graphics package or a complex 3D visualisation system (Wolff & Asche 2008). In DACIS the focus is on the construction of quality map models conforming to the principles and standards of thematic cartography. This requires the full range of graphic composition and

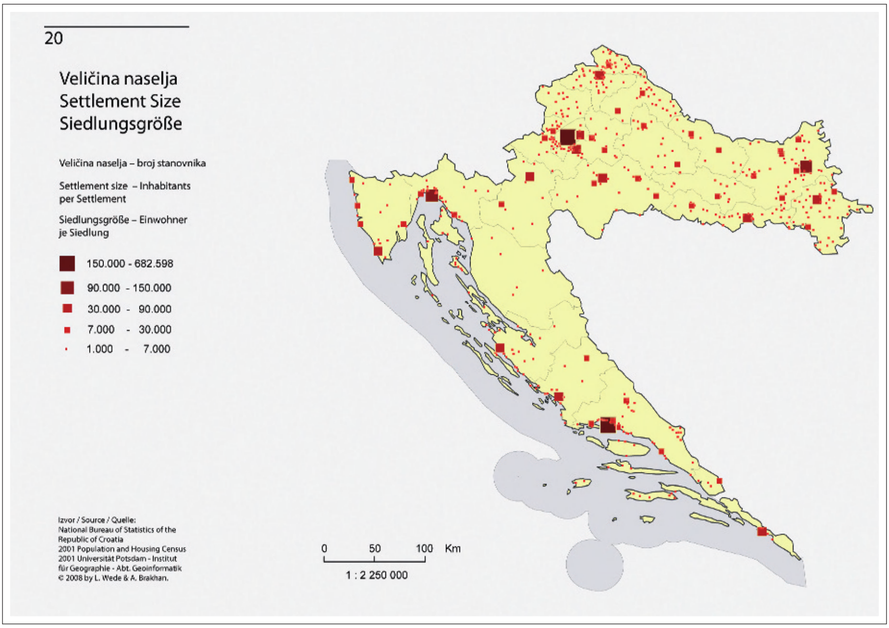

Fig. 22.3. DACIS dot map: distribution of settlements by size; print atlas map prototype

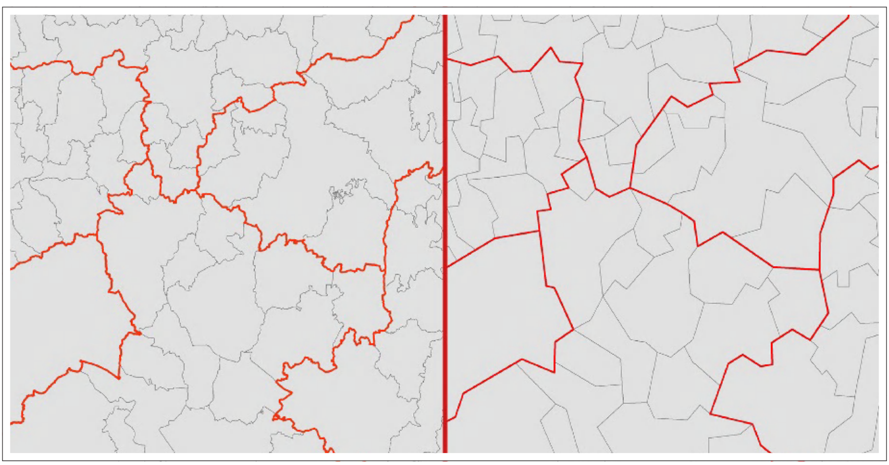

Fig. 22.4. DACIS administrative base map: geometry of data model (left), cartographic model (right)

design functionality provided by standard desktop publishing and desktop mapping software. In the initial phase of DACIS commercial GIS and visualisation software systems (ArcGIS, Illustrator, LandXplorer) have been selected for the atlas production. It is planned to substitute them by open-source software at a later stage.

The GIS back-end and the VIS front-end are connected by a data filter which allows the layer structure of the GIS data to be imported into the visualisation software for subsequent cartographic finalising of each separate layer. Cartographically speaking the graphic-free map data model is transformed into an elaborated graphic map model. This operation cannot be performed in GIS since, for the time being, GIS lack broad professional visualisation capabilities (Monmonier & Johnson 1991, Buckley et al. 2005, Asche 2007, 2009).[3] The combined GIS-VIS environment serves as an offline production base for DACIS database and subsequent map visualisations (cf. *Figure 22.5).* Depending on the complexity of the AIS and the user interaction functions designated the implementation of DACIS in a web environment requires to either import the offline maps directly into the web-based GIS-VIS platform (low interaction) or recreate them as web maps (high interaction). In any case the map visualisations are supplemented by an intuitive graphical user interface that offers adaptive navigation, analysis and visualisation functionality (Elzakker 1993, Siekierska 1996). Map data can be analysed by GIS functions (such as position, area, distance, attributes) on the map or in the respective datasets. External geodata, map or other information (e.g. virtual globes such as Google Earth), may be integrated into DACIS.

A two-tier approach has been decided for the web implementation of DACIS. In the initial phase of prototyping the offline maps are directly transferred into the web atlas prototype. At this stage, the maps provided allow for limited user interaction of the view-only type. In a second extension phase the offline-production platform will be ported to a web-based client-server environment. This facilitates the dissemination of data and client or user-centered map compilation. This transfer necessitates a web-based spatial database (such as commercial ArcIMS or open-source UMN Map Server) as a prerequisite. Such web GIS-VIS platform will permit the use of DACIS map models as templates for vector-based web maps. Interaction with the database is through a graphical user interface (GUI). User interaction with the database via the GUI will be interpreted and performed by an interface script language, such as PHP.

Other prerequisites of a fully functional web-based DACIS are easy accessibility, manifest usability, powerful performance in terms of speed and feedback as well as intuitive interaction. So far a GUI prototype relevant for the web environment has been created that allows for further study and experimentation on the DACIS architecture and workflow. The prototype includes file-based data storage, Java script-based interaction functionality and DHTML/SVG graphic output (*Ernst* 2008).

[3] ESRI, the GIS software giant and developer of ArcGIS offers a solution to this problem based on an extension of the ArcGIS/ArcEditor components called Cartographic Representations. Although they go well beyond the standard GIS functionalities of graphic data presentation their present version, however, does not afford significant progress in professional cartographic visualisation from GIS.

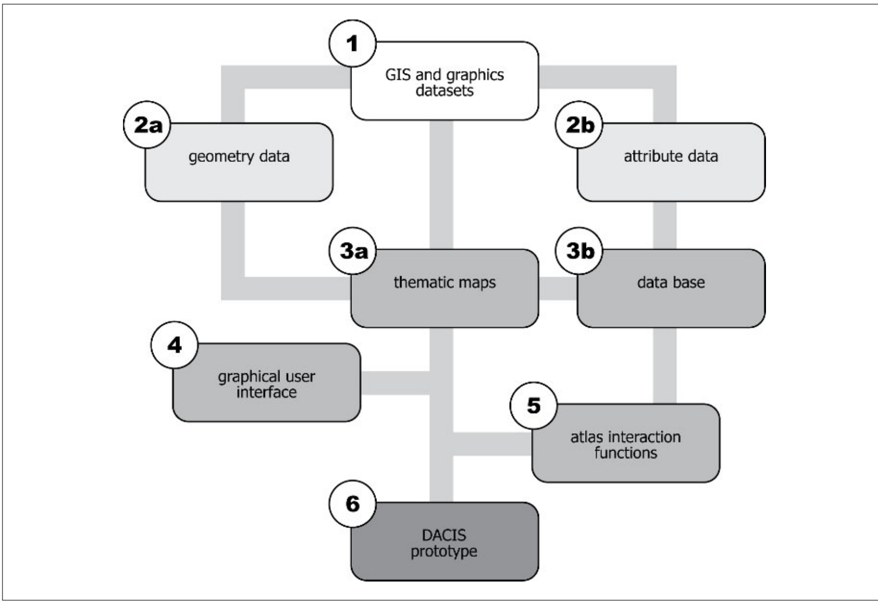

Fig. 22.5. Workflow for DACIS web prototype production

GUI development and design has focused on the integration of basic interaction tools in the initial phase. Priority has been given, however, to screen map design. Although the size of computer screens is steadily increasing the space available for the display of map, legend, menus and toolbars is still limited. As a consequence, efforts are required to provide intelligent solutions for efficient and intuitive use of the navigation and manipulation elements. In the prototype stage of a web-based DACIS user interaction includes selection of

- language (Croatian, English, German),
- map themes,
- base map elements,
- administrative division,
- zoom and pan function within a predefined range of map scale,
- textual information on map theme selected,
- map data and classification,
- map print and export functions.

In addition, help and background information on tools and map themes can be accessed (cf. *Figure 22.6)*. More advanced GUI-based exploration and analysis functions, such as measuring of area and distance, flagging of areas or themes of interest, object selection for comparison of attribute values, manipulation of graphical map appearance by modifying map symbols and data classification, import of personal

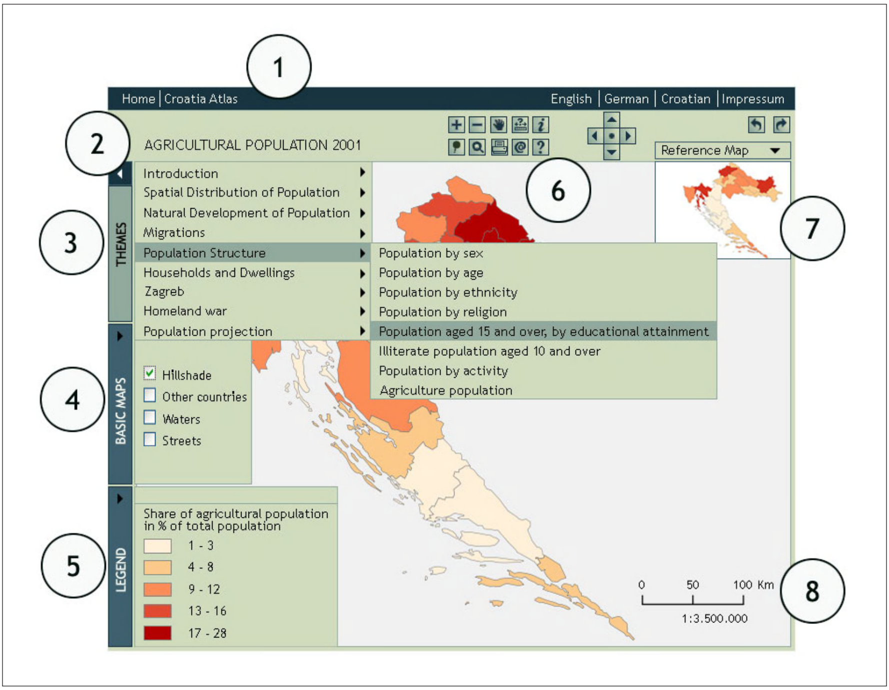

Fig. 22.6. DACIS web atlas prototype – user interface (screenshot). 1: main menu; 2: main toolbar; 3: table of content, 4: base map selection; 5: legend, 6: map view, 7: overview map, 8: scale bar

map symbols, etc. will be implemented in the extension phase. In this upgrading of web AIS architecture and workflow special attention will be given to issues such as methods and functions to update geometry and attribute data, integrate external data, content management, etc.

22.6 Conclusion

This paper presents and discusses the conception, development and implementation of a demographic atlas information system for Croatia (DACIS) in the framework of a bi-national R&D project. First results of the initial phase of prototyping show that the combined GIS-VIS environment has proved to be an adequate, stable and efficient software platform to generate the database as well as the map visualisations relating to the demographic themes selected. The GIS and VIS components are combined in a generic workflow that allows for flexible adaptation to related applications outside DACIS. Maps generated as well as the database created conform to professional standards in current geoinformation science and technology. To date the existing DACIS prototype is available on the intranet only. Web prototype and prototype map products have thoroughly been analysed and discussed with population geographers and geoinformation scientists in Croatia, Germany and abroad. The feedback received has been positive and encouraging stressing the importance of map-based dissemination of demographic information on Croatia on the web and in book form. As collaborative work of the Croatian and German project partners on the AIS commences an executable version will be published. Among the work packages to be executed the porting of DACIS from the present commercial software system to an open-source environment is a major priority. First tests in this future-oriented direction have been promising. Another important task is the revision and improvement of the user interface. For that purpose competent partners have been included in the project.

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Chapter 23

Mapping and Analysing the Local Language Areas for Slovenian Linguistic Atlas

Tomaž Podobnikar[1, 2, 3], Jožica Škofic[1, 4] and Mojca Horvat[1]

[1] Scientific Research Centre of the Slovenian Academy for Sciences and Arts, Ljubljana, Slovenia
{tp, guzej, mojca.horvat}@zrc-sazu.si
[2] Institute of Photogrammetry and Remote Sensing, Vienna University of Technology, Austria
[3] School of Environmental Sciences, University of Nova Gorica, Slovenia
[4] Faculty of Humanities Koper, University of Primorska, Titov trg 5, SI-6000 Koper, Slovenia

Abstract

The aim of our study is a detailed determination of the local speeches areas which are parts of the Slovenian Linguistic Atlas (SLA). The SLA is a geolinguistic project designed in the 1930s with its publishing expected in 2010. One of the goals of this subproject is to analyse the impact areas and to geographically allocate the local speeches for a more precise determination of the isoglosses. This will consequently enable a better understanding of the nature of a particular speech. Various evidences that influenced formation of the particular speech have been analysed with the geographic information system (GIS). The evidences are intra- and extra-linguistic indicators, i.e. geographic and historic. The allocation of the speeches has been generated through the innovative variables, which describe potential delimitations considering geographic criteria with help of the database of settlements in Slovenia. Further study is going to develop twofold: The first is the continuation of the research in dialectometry, and the second is to support these statements with spatial modelling and simulations. The developed methodology could be implemented to the wider areas in Central Europe.

Keywords: geolinguistics, dialectometry, digital terrain model, boundaries modelling, Slovenian Linguistic Atlas

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23.1 Introduction

23.1.1 Introduction to Linguistic Atlases

Tradition of linguistic atlases in Europe originates from beginning of the 20th century in French and German linguistics (Chambers & Trudgill 2002). The first geolinguistic contribution is the *Atlas Linguistique de la France,* which was published by Jules Gilliéron between 1902 and 1910, followed by the *Deutscher Sprachatlas* of Georg Wenker and Ferdinand Wrede, published in years 1926–1956, and the *Sprach- und Sachatlas Italiens und der Südschweiz* of Karl Jaberg and Jakob Jud, published in 1928–1940.

The tradition of linguistic atlases continues also in the Slavic culture space, for example in Polish *(Linguistic atlas of Polish Podkarpatje,* 1934; *Linguistic atlas of Kashubian and nearest dialects,* 1964–1975; *Little atlas of Polish dialects,* 1957), Slovak *(Atlas of Slovak languages,* 1968–1984), Czech *(Czech linguistic atlas,* 1992–2005), Bulgarian *(Bulgarian dialectological atlas,* 1964–1966), Russian *(Dialectological atlas of Russian language,* 1986–1996; *The lexical atlas of Russian national speeches,* 2006), Belarusian *(Dialectological atlas of Belarusian language,* 1963), Ukrainian *(The atlas of Ukraine language,* 1984), etc. These atlases include various methods of surveying and mapping considering symbology, generating of isoglosses, etc.

Two multilinguistic atlases have to be mentioned as the biggest projects in geolinguistics. They are both based on European languages. First one, The Slavic linguistic atlas *(Obščeslavjanskij lingvističeskij* atlas, 1958–) includes all Slavic languages, from Slovenian to Russian and from Polish to Ukrainian. The second one, The Atlas of European languages (Atlas *linguarum Europae),* is the first continental linguistic atlas, whose frontiers are neither political nor linguistic, but rather geographic, due the linguistic situation in Europe is very complex with six families of languages: Altaic, Basque, Indo-European, Caucasian, Semitic and Uralic (Alinei & Viereck 1997).

The basic plan for the *Slovenian linguistic atlas* (SLA) was outlined by Fran Ramovš in 1934 with collection of the material starting in 1946 (Benedik 1999). His work bases on the French geolinguistic tradition begun by Jules Gilliéron and the work of Polish linguistic geographer Kazimierz Nitsch. The project is still awaiting completion, but publishing of the first volume of SLA is expected in 2010. The main reason for its long-term elaboration lies in the large quantity of work based on 406 significant points and an extensive questionnaire. Further reasons are extraordinary diversity of the Slovenian dialects and the complexity of the phonetic and phonological problems involved (Jakop 2008).

The material from the notebooks and index cards, together with edited (newer) audio material have been scanned and imported into the SlovarRed database. This data was prepared for computer cartography based on vector (point) maps (Škofic 2003, 2006). The atlas with the dialect data and linguistic comments will present the gathered lexica in the linguistic maps, which will enable different dialectometric researches and comparisons with ascertainment of other science branches with common analysis with the historic, ethnographic, botanic maps, etc.

23.1.2 Slovenian Linguistic Atlas (SLA) and GIS

The determination of the local speeches areas within the SLA is intended to be supported by modelling in geographic information systems (GIS). The aim of our extended study (partly being described here) is to enhance determination of the influential local speeches areas and to define their boundaries with much greater overall quality. This will additionally enable more precise determination of isoglosses. To achieve these circumstances, the mapping and modelling precision is going to increase to the scale around 1:25,000 (before 1:350,000). For the modelling in GIS we consider the intra- and extra-linguistic indicators that have influenced the forming and comprehension of the particular local speeches and dialects[1], i.e.:

- geographic (considered as natural or bona fide; Smith & Varzi 2000); geomorphology, swamps, large forests, rivers, and
- historic (considered as artificial or fiat); different directions of the Slavic settlement, contacts with aborigines and with neighbouring nations and their languages, political- and church administration borders, colonisations

Our main topic in this paper is to prepare spatial variables which could be useful for precise mapping of boundaries, and at least partly facilitate automation of boundaries determination between the dialects. Variables are going to be generated by performing the analytical capabilities of GIS. Analytically calculated boundaries could be compared with settlement, church administration, and provincial boundaries. With either automatic or manual overlaying of differently derived boundaries we can easier determine the influential areas of individual local speeches. As an important result we expect useful and instructive comparisons between linguistic ascertainment and data given by the GIS-based analysis: to study similarity of the dialectal boundaries with settlement boundaries, geomorphic properties, historic borders, etc. For the study area were chosen the regions of Slovenian dialects in Slovenia, Italy, Austria, Hungary and Croatia *(Figure 23.1)*.

[1] Spoken Slovenian has 37 main *dialects* (regional varieties of Slovenian language) and 12 subdialects. The various dialects are so different from each other that a speaker of one dialect may have a very difficult time understanding a speaker of another, particularly if they belong to different *regional dialect groups* (in which dialects with similar pronunciation/accent/auditory impression are joined). *Subdialect* is a subdivision of a dialect differing mainly in pronunciation and certain local words. *Local speeches* are local varieties of dialects, characteristic for particular localities (one or more villages, which are closely, mainly historically, connected). Semantically and geographically distinguishing between the dialect and subdialect is sometimes uncertain.

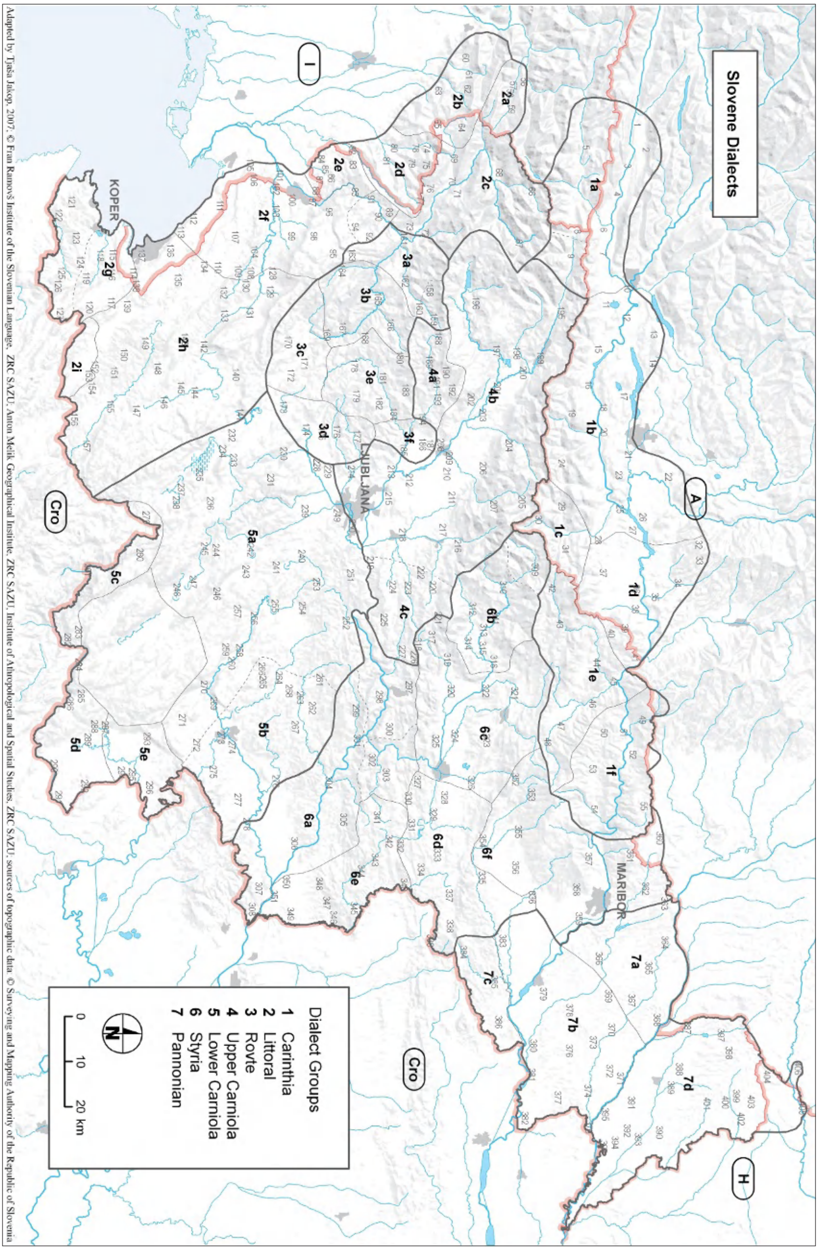

Fig. 23.1. Slovenian dialect groups, dialects and subdialects. Following Logar and Rigler (1983), updated by Škofic and Pehani (2006), seven dialect groups are considered: (1) Carinthia (Koroška), (2) Littoral (Primorska), (3) Rovte, (4) Upper Carniola (Gorenjska), (5) Lower Carniola (Dolenjska), (6) Styria (Štajerska), (7) Pannonian (Panonska). Local speeches, subdialects and dialects are labelled in the paper according to this map (Jakop 2008), e.g. the Gorenjska dialect (4b), the Prekmurje dialect (7d)

23.2 Methodology

Generally looking there are more and more numerically-supported studies in the field of dialectometry, particularly for searching the features and similarities of the dialects[2]. Nowadays, the dialectometry researches may support their studies by modelling in GIS and integrating the precise digital terrain models (DTMs) and other spatial data sources.

We should mention the research of Stančič (1996) who applied the GIS for studying the problems of automatic determination of the selected dialectal lexemes' borders in order to better define the areas of Slovenian dialects. Goebl (2000; 2003) proposed and set up the base for the computer analyses in dialectometry, and tested it on Italian and French dialects. The phases in dialectometry defined by Goebl (2008) are: (1) the manual or automated setting the groups of speeches with regard to fonetical, morpho-syntactical or lexical criteria, (2) the measurement of similarities between particular locations by different measures, (3) the numerical classification or segmentation of linguistic areas with regard to their similarities, (4) and the visualisation of the results. Nerbonne et al. (2007) compared two algorithms for grouping regarding different features of dialects that was performed on German and Bulgarian dialects.

The core for the producing of the thematic maps of local speeches is georeferenced datasets and GIS-tools. The datasets of dialects were provided from Fran Ramovš Institute of the Slovenian language, while topographic datasets from Surveying and Mapping Authority of the Republic of Slovenia (GURS 2008). The GIS-tools were used for acquiring spatial datasets, georeferencing, spatial analysis and enhanced modelling. Besides a multidisciplinary geolinguistic knowledge on understanding of spatial features of the SLA was integrated.

Within the extended project all existing analogue and digital databases were collected, primarily based on SlovarRed database, consisting of 406 significant points of SLA. The main part of this paper is stressed to acquiring the spatial datasets, generate significant spatial variables based on geographic and historic indicators to describe and map the local speeches. Most of the variables were generated with enhanced modelling of the DTM. Additional output is raster-based maps that describe uncertainty of the boundaries. The basic workflow of the project is presented in *Figure 23.2.*

The spatial analyses and modelling are among the most important capabilities in the GIS. Qualitative and quantitative analysis can be distinguished, but GIS-tools are more suited for answering the questions of quantitative analysis where continuous values can describe given problems. The qualitative approach uses nominal or ordinal data. It is based on the classification and identification of problems. As a

[2] Dialectometry means researching the similarity in dialects in metric geographic area.

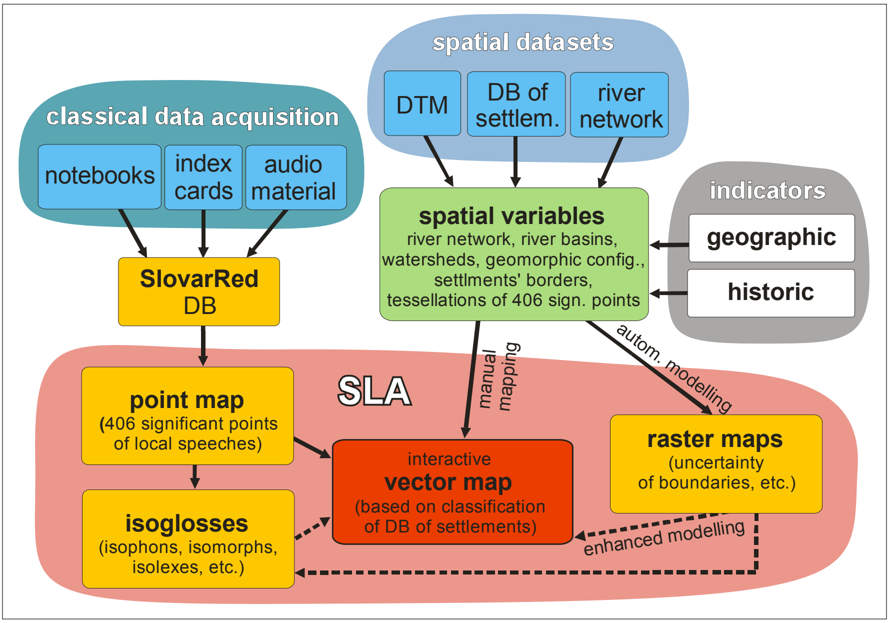

Fig. 23.2. Workflow of the project, from datasets, SlovarRed database, spatial variables considering the indicators, to the SLA

qualitative approach, also different analyses that came from powerful visualizations (thematic mapping) in GIS are considered. Unfortunately, the qualitative spatial analyses tend to subjectivity in evaluation.

The most common quantitative spatial analyses include topologic and cartographic modelling, modelling of networks, automated cartography, map algebra and spatial statistics. Spatial analysis that build the models can be classified as descriptive, explanatory, predictive and normative (Chou 1997), where descriptive analysis evaluates the data and its suitability for explanatory models that are the goal of this study. The other approach to spatial modelling (Anselin 2005) starts with exploratory analysis to find interesting patterns, continues with visualisation for showing the patterns and then with spatial modelling for explaining the patterns which is also a part of the study procedure. As a part of the modelling procedure, other types of models can be involved, e.g. regression, Boolean, empirical. Therefore spatial modelling combines different spatial analyses regarding the decision-making process and even more, the data (variables) and models can be part of environmental decision support system (Kanevski & Maignan 2004) for estimation of selected environmental phenomena or indicators, e.g. erosion, deforestation, disposal dynamics.

In the studied case, the analyses were stressed in descriptive models that answer the basic questions considering spatial patterns. If the patterns are significant (related to borders detection along the certain area), they could answer the hypothesis and other questions. In this case the descriptions can be the basis of the explanatory analysis (Burrough & McDonnell 1998).

23.3 Dialects' Indicators to Generate Spatial Variables

It is well known from the dialectological literature that dialectal differentiation of Slovenian language was influenced by several factors. This section primarily highlights natural (geographic) factors, and additionally touches some uncontested cases confirmed in dialectological researches. For better illustration several indicators have also been compared with similar factors, which have influenced dialectisation of languages in Central Europe.

The first differentiation of Slovenian dialects was already been formed in Proto-Slavic language and might be the consequence of Slavic settlement in eastern Alps which occurred in two different ways – from the north over the Danube into Celovec/Klagenfurt basin and from the south along the rivers Sava, Drava and Mura upwards to the Alps and Karst (even along the ancient Roman ways). After the settlement from the end of the 6th century until the end of the first millennium two Slovenian dialect areas have been formed – south-eastern and north-western one. In the first area Panonnian, Styria, Lower Carniola and Upper Carniola dialects have been formed, and in north/western Carinthia and Littoral dialects.

Similarly, the primary dialectisation of Polish language was influenced by the fact, that Poland was settled by five different tribes (Pomeranian, Vistulans, Polans, Silesians and Masovians), which were the centres of five different cultures and formed five different dialect bases (Kashubian, Great Poland dialect, Little Poland dialect, Mazovian, Silesian). Although these tribes joined in 10th century into the common country of Piast dynasty, they have preserved strong consciousness about regional affiliation (Stieber 1965). Various economical, religious and political reasons have directed also the later (mediaeval) settlements inside the historic Germanic populated areas. I.e. Walserns was settled in the high mountain chain of Vorarlberg and Lichtenstein in the 14th century and have preserved special language features till today (König 2001).

Later on some other geographic and historic factors affected Slovenian dialectal differentiation, which can not be treated separately, because they were often connected with political and/or church administration segmentation that often run upon natural borders and those have also defined the migrations and traffic. For example political and church administration borders, running mostly along the mountain crests, as well as hills and rivers *(Figures 23.3* and *23.4)* have influenced on the extent of Styrian dialects and subdialects. This is why Upper Carniola dialect

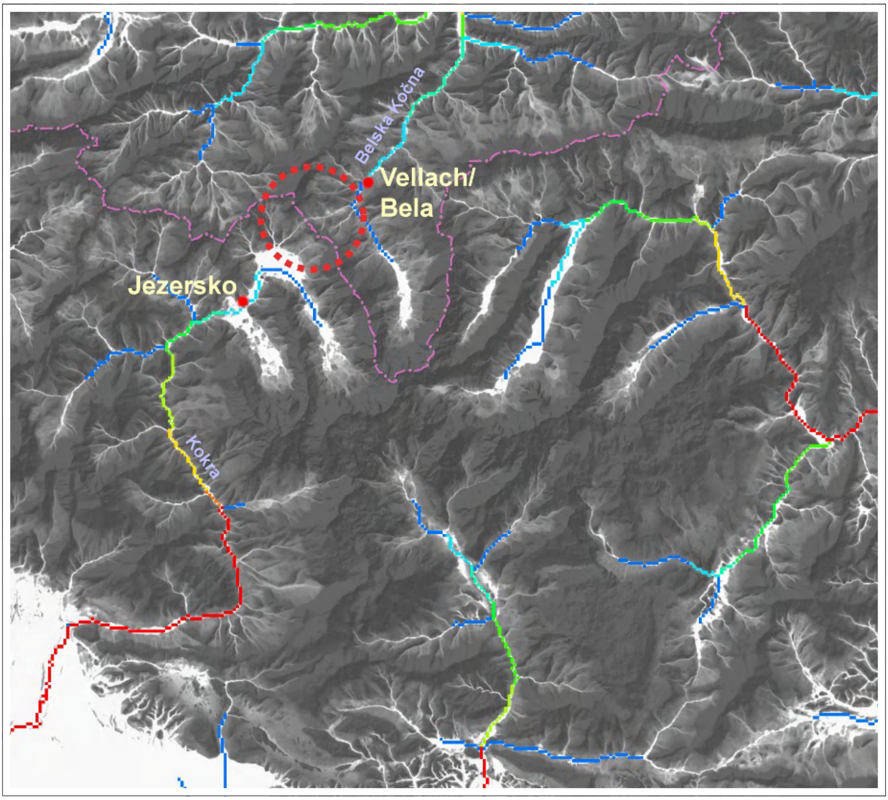

Fig. 23.3. A complex example of visualisation combination of indicators in the Kamnik Alps region (area of 29 by 26 km). Focused is the region of Jezersko (4b in *Figure 23.1)* (in Kamnik-Savinja Alps), where waters accumulate (lower quantity of accumulated areas is in blue, higher quantity in red) through Kokra valley to Upper Carniola (towards south); and Belska Kočna, where waters flow in the direction of Carinthian Železna Kapla/Eisenkappel (1c in *Figure 23.1)* (towards north). In grey casts is with a relative relief presented geographic accessibility, where through more light areas the communication is easier. In the past, Jezersko was more connected with Carinthia over Jezersko sedlo/pass (see a thin white line encircled between Jezersko and Bela/Vellach), because the long, narrow and dangerous Kokra valley has was almost impassable till the beginning of the 20th century. The political border between Slovenia/Yugoslavia and Austria cut off the traditional connection of Jezersko and Carinthia at the beginning of the 20th century. This fact reflects in the Jezersko local speech.

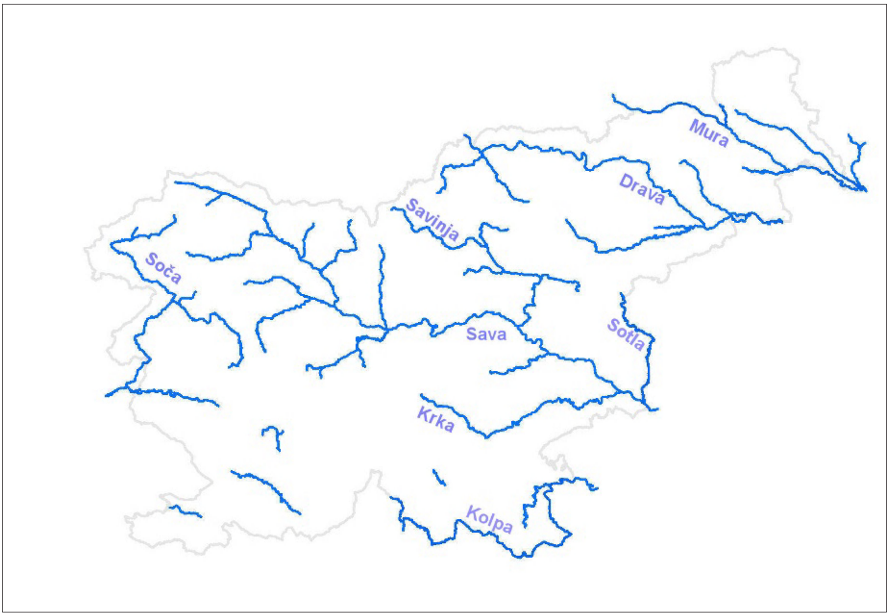

Fig. 23.4. The variable of main river network in Slovenia has been one of the less important factors of the Slovenian dialects' formation. As the rivers haven't presented communication barriers (unless political borders went on them – like between Austria and Hungary on the Mura river) on the contrary, they have presented an economical factor with the function of bounding people from both sides. The comparison with the Map of Slovenian dialects *(Figure 23.1)* suggests the border of the Slovenian-Croatian language along the Kolpa/Kupa and Sotla/Sutla rivers. The newer researches confirm and opposite fact that this border is mostly political, not linguistic, as nearly the same dialects are spoken on the both sides – with interferences/influences from both modern standard languages. Also the Polish-Lower Sorbian border, which runs on Lower Bober, has probably been less important landmark, because Lower Sorbian represents the passable dialect with Polish characteristics (Stieber 1965). In German language space, the rivers more connected than divided people; thus, along the Rhine special passable speeches have been developed (König 2001).

is still separated from Styrian dialect with the old Carniola-Styrian provincial border, running from the Kamnik hills in south-eastern direction on the Zasavje hills.

23.3.1 Geographic Indicators

Geographic diversity of the Slovenian space has proved to be the main factor for the Slovenian language segmentation, because the natural barriers like mountains *(Figure 23.5),* valleys, swamps and forests prevented contacts and consequently communication among people.

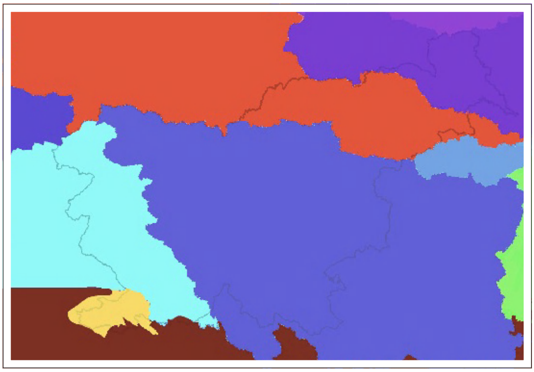

Fig. 23.5. The variable of the main river basins (accumulations) in Slovenia. The comparison with the Map of Slovenian dialects *(Figure 23.1)* does not show any relations. For example the basin of the Mura river extends far into Slovenske Gorice (7a), while the boundary between Prlekija (7b) and Prekmurje (7d) dialects goes by the river Mura, which was the border-river between Austria and Hungary till the end of the WW1.

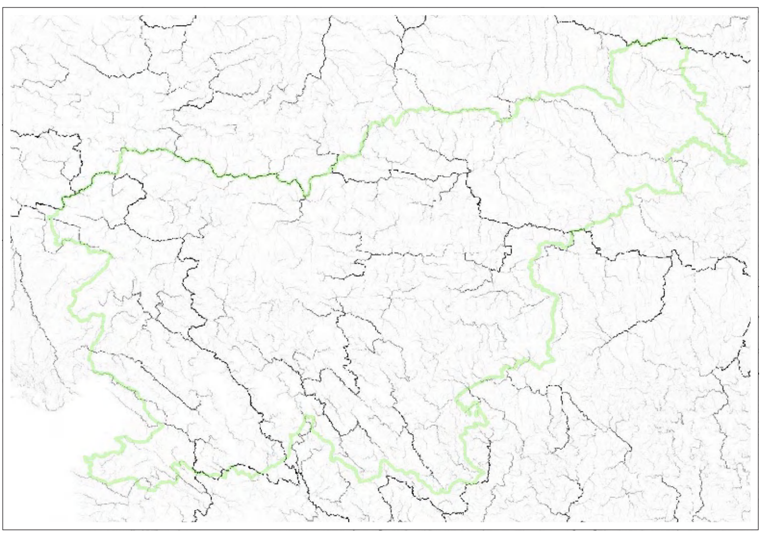

Fig. 23.6. The variable of watersheds (main divides) in Slovenia. Darker lines are longer and therefore more important divides. The comparison with the Map of Slovenian dialects *(Figure 23.1)* shows some interesting relations. The boundary between the Upper Carniola and Carinthian dialects goes by watershed between the Drava and Sava rivers along the Karavanke/Karawanken mountain crest, the boundary between the Upper Carniola and Littoral dialects goes along the watershed between the Sava and Soča rivers in the Julian Alps mountain crest, and also some other dialect borders correspond to watershed borders (like between the Ter/Torre (2b) and Soča dialects (2c), between the Lower Carniola and Notranjska dialects (2h), etc.). Many other dialect borders do not correspond to watersheds (like the watershed between the Raba and Mura rivers, where the Prekmurje dialect (7d) is spoken on both sides).

Some of the dialects are limited to smaller areas as they were formed for speakers who lived in the valleys surrounded by high mountains. Rezija/Resia dialect (2a in the *Figure 23.1)* is spoken in Resia, the Alpine valley in the province of Udine in Italy, which is separated from Soča dialect (2c) in Slovenia in the east by high Kanin/M. Canin mountain chain. From the Ter/Torre dialect (2b) on the south the Rezija/Resia dialect (2a) is separated by the rough and high mountains Muzci/M. Musi and from Zilja/Gailtal dialect (1a) in Carinthia (in Austria) in the north by wide and hilly zone, now populated with Friulians *(Figures 23.6* and *23.7).* So the Rezija/Resia valley has been opened only to the west, to the Friuli.

Extensive swamps and forests were very important for dialectal differentiation of Slovenian language, as well. For example, the border between the Upper and Lower Carniola dialects runs on the ones impassable Ljubljana moors, but on the Sorica field the communication was interrupted by extensive and almost impassable forests, which separated environs of Kranj (4b) and Medvode (4b) from Škofja

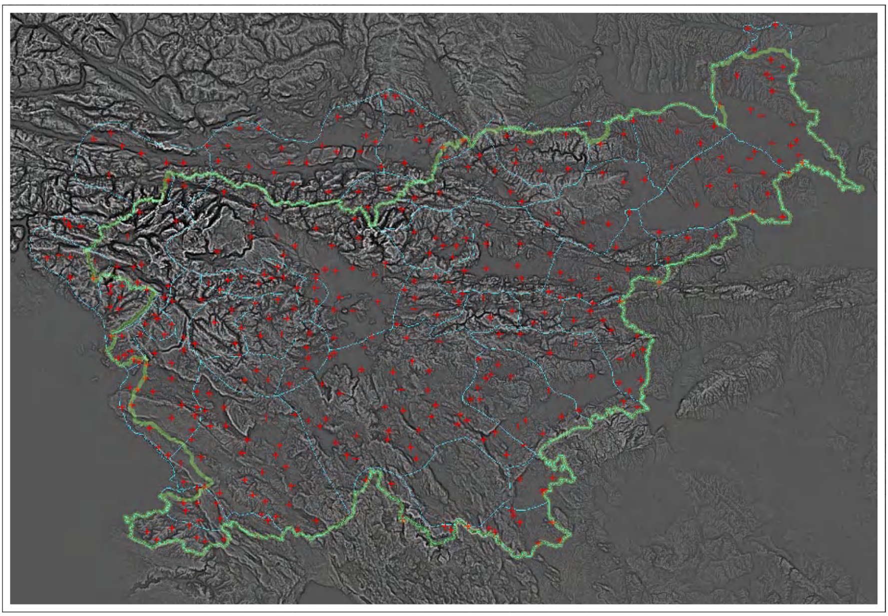

Fig. 23.7. The geomorphic configuration of Slovenia is much related to dialectal boundaries. The rougher areas of relative relief represent natural barriers in lighter grey casts. Currently mapped borders between dialects are presented with blue lines; crosses are 406 significant points of the SLA. One of the most evident is the boundary between the Carinthian and Upper Carniola dialect groups that goes by the Karavanke/Karawanken mountain crest – where in the west the mountains become lower and thus more passable, also the dialectal borders change. Very clear is also the boundary between the Lower Carniola dialect group and Notranjska dialects (2h), that goes on the high Karst hills and the Hrušica–Javorniki–Snežnik mountains. Some other dialects, like the Haloze (7c), Brda (2e) and Bela krajina (5d, 5e), are spoken in special geographic units as well.

Loka (3f) and its environs with the mixed Slovenian-German population in the past, hence the boundary between the Upper Carniola and Rovte dialects was formed. Similarly, the sharp frontier between Polish and Upper Sorbian language represents the area of wide forests between the Upper Lusatian Neisse and Upper Bober rivers (Stieber 1965).

23.3.2 Historic Indicators

Beside natural (geographic) some other (historic) factors have formed a dialectal image of the Slovenian language: church- and political administration partitions, colonisations, Turkish invasion, the economic gravitation, etc.

Normally, individual speeches developed in the areas of old parishes, as in the elder periods they had presented political administration centres, what guided traffic and communication between people, as well. For example, the Upper Savinja dialect (6b in the *Figure 23.1)* was formed in the 12th century within the framework of the Styrian speeches, which were formed on the area of Benediktine's monastery in Gornji Grad (6b).

The former (as well as today's) political administration partition has had a great impact on the Slovenian language and its dialect differentiation *(Figure 23.8).* Thus, the border between the Pannonian Prekmurje (7d) and Prlekija (7b) dialects was established by the political Austrian-Hungarian state border on the Mura river till the end of the WW1 and the Prekmurje annexation to (former) Yugoslavia.

The medieval territory division also greatly influenced the formation of the German language space. This state formation and its borders were stable from the beginning of its origin in late Middle Age till 19th century. Therefore, the dialectisation of Frankish and south-western area is the result of these political divisions (König 2001). Similarly, the environs of Gdansk were repeatedly connected to Poland in the 16th century, before this land dropped under the German hegemony. The consequences are German features in the Gdansk local speech. Also Silesia was under the Czech hegemony for a certain time, which can be proved by the number of Czech characteristics in the Silesian dialect (Stieber 1965).

One of the factors of dialectal differentiations is also colonisation and immigration of non-Slavic colonists. For example, the Bača subdialect of the Tolmin dialect (3a) and the Selška Sora dialect (4a) were formed in the 13th century, when the hilly and woody unpopulated area by the Upper Bača and Sora rivers were colonised by the German farmers from Tyrol, who were later assimilated due to the Slovenian surroundings. Additionally, the Germanisation of the Czech, Moravia and Silesia frontier areas, which was the result of the medieval German colonization of these hilly and rarely populated areas, influenced the dialectisation of the Czech language (Stieber 1965).

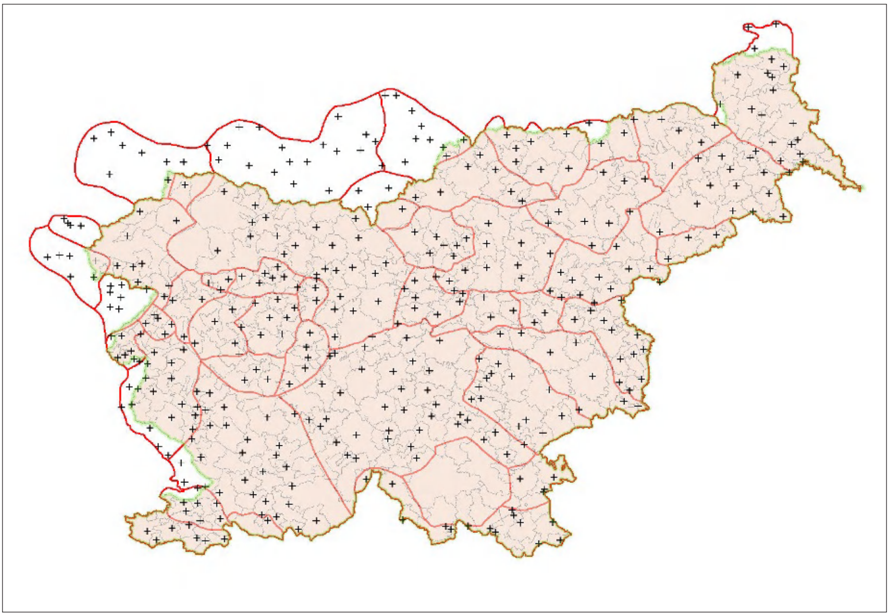

Fig. 23.8. The borders of settlements (grey) (GURS 2008), rough borders between dialects (red) and 406 significant points of the SLA. A very precise settlements' database can be helpful in determination the local speeches' areas in the SLA. However, the relation between them considering only 406 significant points of the SLA proves to be difficult to establish. Actually, the areas of settlements very rarely correspond to the local speeches' areas in relation 1:1. The areas of local speeches for the SLA are mostly much wider, i.e. in Juršinci the local speech of Prlekija dialect (7b in the *Figure 23.1),* where the parish borders correspond to the borders of the local dialect, spoken in several neighbouring villages. They can be even smaller – like in towns, where smaller villages have become parts of bigger towns and thus two or even more significant points for the SLA are set within, i.e. in Ljubljana (4b) with Studenec (5a) and Rudnik (5a).

The Turkish invasions in the 15th and 16th century had great impacts on the Slovenian dialects, for example in Bela krajina (5d, 5e), which was politically, culturally and according to the direction of traffic a Croatian country until the 13th century. Due to the Turkish invasions the autochthon people from lowland and the Kolpa area, who were already Slovenised to a certain degree, started to abandon their old dwellings, and the refugees from the neighbouring lands of Croatia, i.e. Lika, Dalmatia and Bosnia, settled instead. Thus, the modern speeches of Bela krajina (5d, 5e) developed from the mixture of the old settlers' and the refugees' from southern lands languages and also the language of the Slovenian immigrants of newer age.

The cases have proved that the dialectisation of Slovenian language space was accelerated by different factors, which limited or prevented communication between the inhabitants. On the other hand, the economic factor had an expressive connective function with its great impact on the gravitation of population. That's way the Kropa local speech (4b) was formed – Kropa with its iron industry attracted many workers even from the Carinthia and Selška valley between the 16th and the middle of the 19th century and this mixture of inhabitants influenced the formation of the Kropa local speech.

23.4 Determination of Boundaries Between Dialects

The determination of dialectal borders is based on modelling of spatial variables produced according the mentioned indicators. Factors which influence on the actual course of boundaries vary in geographically different areas. The rules for precise border determination are very complicated and they do not allow fully automation procedures. Determination runs in two successive steps: automatic and manual.

The first one, the automatic step includes modelling based on 406 significant points of the SLA that is demonstrated in different ways. Automatic classification enables just a rough assessment as a foundation for the second, manual step. The manual step bases on the attribution of the certain individual groups of settlements to the designated dialect. Additional information is needed: (1) data gathered by the fieldwork, (2) the variables of geographic and historic indicators, and (3) automatic modelled dialectal borders.

23.4.1 Automated Modelling of Dialects' Borders Based on 406 Significant Points of the SLA

The modelling of borders based on tessellations and on calculating of impact areas of 406 significant points of the SLA. The allocated areas were modelled considering Euclidean geometry and with pondered surfaces, based on catchment analysis: (1) tessellation according to regular hexagon-grid, (2) tessellation with Thiessen polygons, (3) generating cost surfaces, and (4) tessellation with pondered Thiessen polygons.

(1) Tessellation of the whole study area to regular hexagons (honeycomb) with 5 km raster was generated. With regard to position of centroids of individual hexagons we have determined them to the certain dialect groups using the data from the Slovenian dialect groups *(Figure 23.1)*. This experiment is important for homogeneous generalization of areas of Slovenian dialectal areas that enables particular spatial analyses bounded to equal regular areas *(Figure 23.9)*.

(2) Tessellation of the 406 significant points of the SLA was performed by Thiessen polygons (Voronoi polygons, Dirichlet's cells) to get borders between dialects

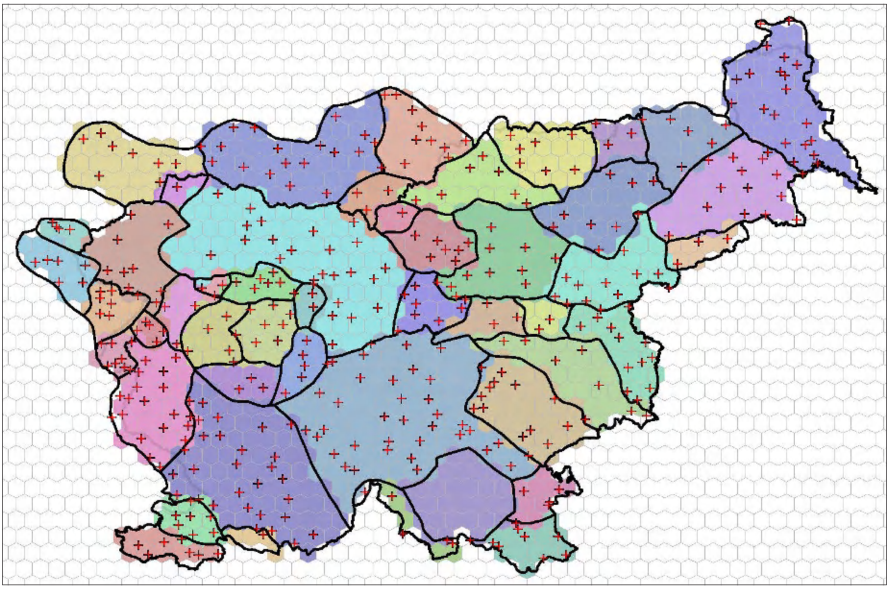

Fig. 23.9. Tessellation of areas of dialectal groups to regular hexagons.

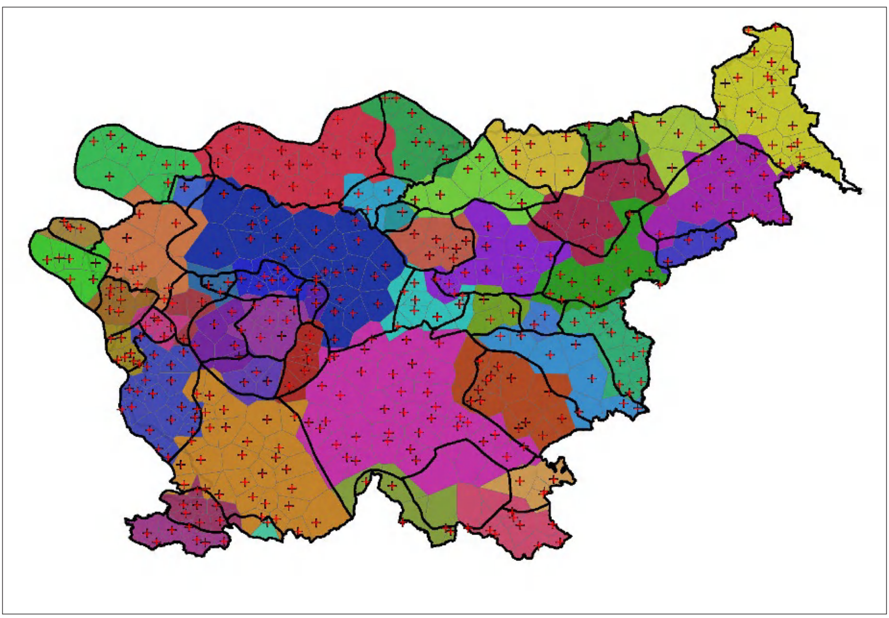

Fig. 23.10. Tessellation the areas of local speeches by Thiessen polygons and reclassifying them to dialects.

(Burrough & McDonnell 1998). The result of tessellation are therefore continuous polygons that separate any point feature (centroid) from the neighbours, on the way that all the interior of polygon is geometrically nearest to polygon's centroid *(Figure 23.10)*. The SLA points, which were Euclidically allocated with borders, were classified to the appropriate dialectal groups (see *Figure 23.1;* Logar & Rigler 1983).

The most problematic part of tessellation by the Thiessen polygons is the area of mixed Kočevje speeches that was automatically divided between the four neighboured dialects (the Dolenjska (5a), the Southern Bela krajina (5d), the Northern Bela krajina (5e), and the Kostel dialect (5c)). Within this area another centroid is obviously missing as there are no research significant points of the SLA. Namely, this area was settled by the German colonists till the WW2, later the abandoned area was resettled by people from different Slovenian regions, so no autochthonous Slovenian dialect are spoken here. In the future the region of mixed Kočevje speeches has to be treated as a special area with adjusted borders (as shown in *Figure 23.1)*.

(3) The cost distances around 406 significant points of the SLA were calculated next, for automatic determination of borders. Quantity that determines the cost like this is also called impendence (Tomlin 1990). It is determined by assignment of different weights. The cost surface was determined according to the energy consumption of moving across the terrain. It was related to relief inclination, calculated by using DTM. The cost distances around the points of the SLA were calculated according to equal energy consumption considering the cost surface (slopes).

Figure 23.11a shows the cost distances from 406 significant points of the SLA. The longer distances in a certain direction signify the less rough (smooth or even flat) relief there. The shorter distances mean more fragmented relief and consequently more local speeches per unit. In the Alpine valleys the areas of cost distances are elongated to the directions of the valleys. All of the cost distances are normalised to flat terrain with classification to classes of 0 to 2 km and 2 to 5 km.

As it can be seen in *Figure 23.11a* some of the areas with longer cost distances are contiguous with the others and with their textures they visually form various patterns that could be visually classified to schematic division of the Slovenian dialects to the dialect groups: the Littoral (with the Istria (2g), the Karst (2f), the Notranjska dialect (2h), and with more crumbled speeches of the Soča (2c) and the Venetian Slovenian dialect), the Carinthia (with more isolated speeches of the Carinthian dialect in Slovenia), the Pannonian (which is much more connected with the area of the Styrian dialectal group), the Upper Carniola and the Lower Carniola; the Rovte dialect obviously originated in regions with difficult access. Also the speeches of the Posavje dialect (6a) and the speeches of the Gorenjska dialect (4b) in the Bohinj and Upper Sava valley indicate big isolations from each other. The *Figures 23.11b* and *23.11c* show the attempts for classifications considering the shape and size of the regions generated by the cost distances shown in *Figure 23.11a.*

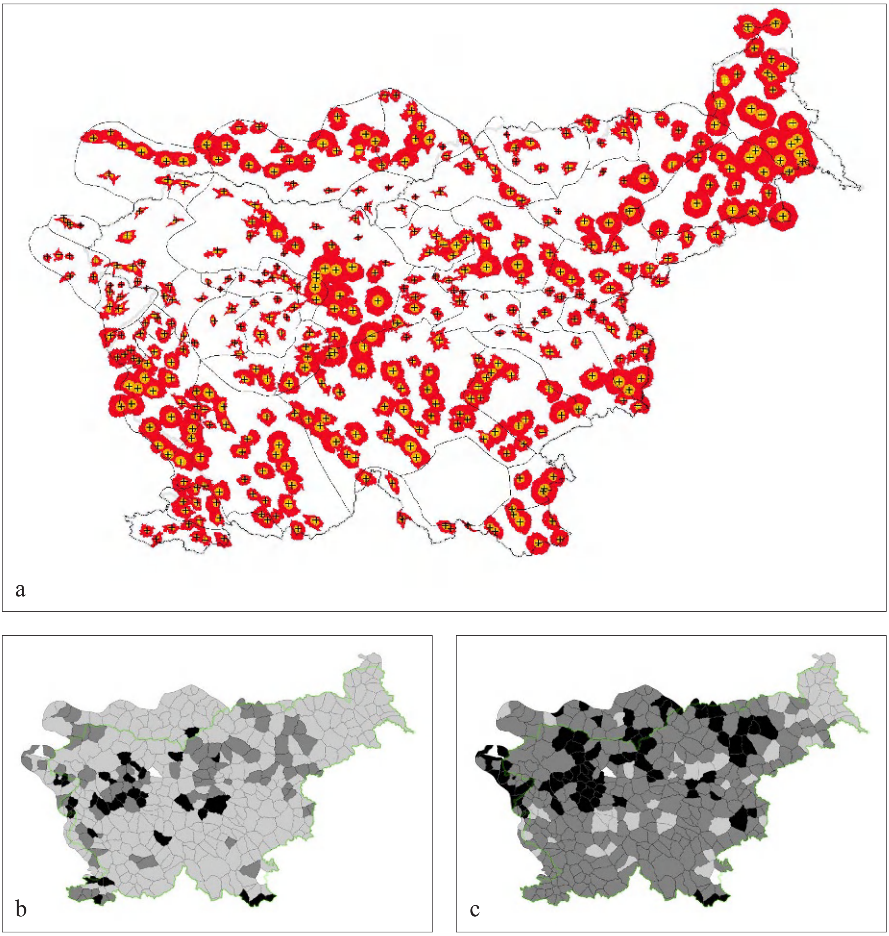

Fig. 23.11. (a) The regions of the cost distances up to 5 km considering the slope of relief, calculated from 406 significant data points of the SLA. Additional attempt with classification of (a): (b) more oblong and (c) smaller regions are darker. In (b) and (c) cases the regions around the 406 points were calculated within the cost distance of 1 km and are presented for areas of pondered Thiessen polygons (see *Figure 23.12)*.

(4) Tessellation of 406 significant points of the SLA with pondered Thiessen polygons is the similar as in case (2). Instead of Euclidean distance, the cost distances were considered for tessellation, as described in case (3). As the result in the *Figure 23.12* we can discover many details on borders of polygons that are much more related to the dialect borders than in previously described models. The examples are the borders of the Obir/Hochobir dialect (1c), the borders of the Upper Savinja dialect (6b) and the Solčava subdialect and the Upper Carniola dialect in Bohinj (4b).

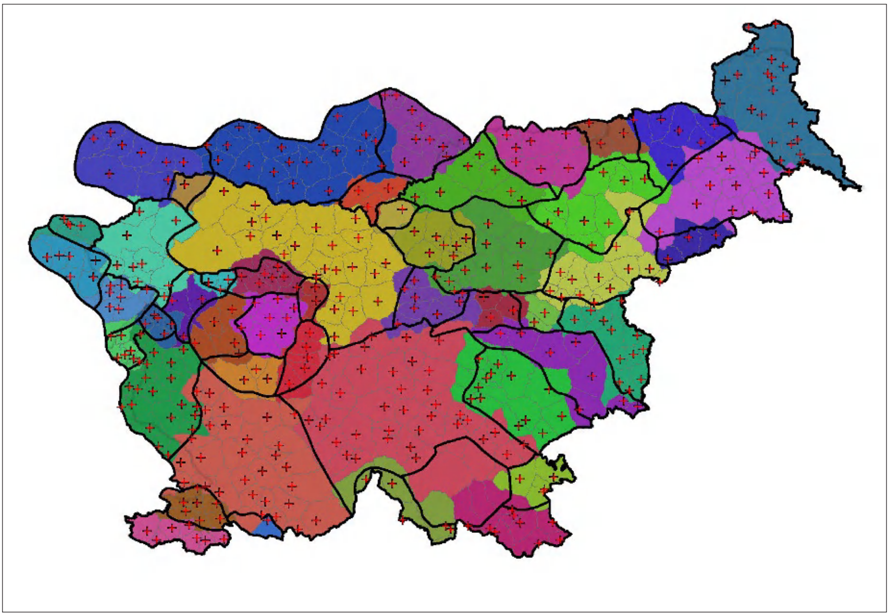

Fig. 23.12. Tessellation of dialects using 406 significant points of the SLA and local speeches with pondered Thiessen polygons

23.4.2 Manual Mapping of Borders

After automated classification of the Slovenian dialect borders to the certain level, based on 406 significant points of the SLA and analysing possible stability and local variability of the results, the manual mapping for SLA vector map (see *Figure 23.2)* is necessary. The major reason is an exceptional complexity in defining the Slovenian dialect borders. The main goals of manual mapping are: adequate definition of areas of local speeches considering the 406 significant points of the SLA, more precise definition of dialect areas, and more precise definition of dialect groups' areas.

The main sources of decision making process for the manual mapping are: Map of Slovenian dialects (Logar & Rigler 1983; see *Figure 23.1),* classically acquired data (gathered by fieldwork) *(Section 23.2),* variables of geographic indicators (3.1), historic indicators (3.2), and maps/datasets of automated preliminary classified borders (4.1). The Map of Slovenian dialects is significant for general assessment of the problem, while the others are important for detailed studies.

Methodology of manual mapping is based on editing the classified database of settlements in Slovenia. Firstly the classification was generated considering the case 4 in *Section 23.4.1* (the automatically classified pondered Thiessen polygons) *(Figure 23.13a).* Secondary the editing of this classification was proceed if necessary – the entire areas of the settlements from database were assigned to appropriate

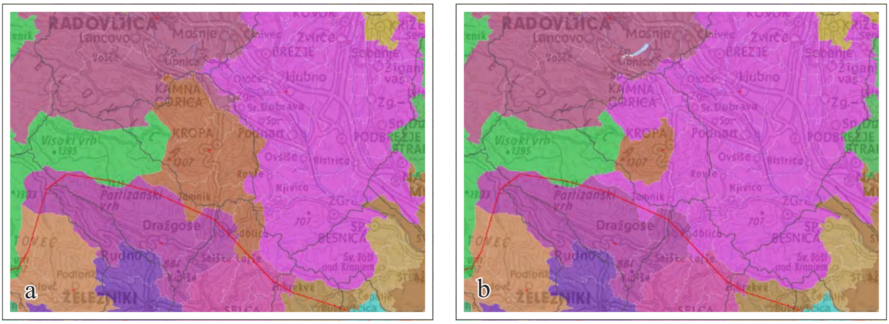

Fig. 23.13. Mapping of the local speeches with 406 significant points of the SLA for the Kropa local speech (4b, *Figure 23.1)* (shown within the area of 8 by 6 km), where in the (a) the results of automated modelling with pondered Thiessen polygons are shown and in (b) the final result achieved by of manual editing is presented.

dialect (and local speech) by means of the listed sources for decision making process and mapping *(Figure 23.13b)*.

The *Figure 23.13a* shows the result of the automatic classification by the pondered Thiessen polygons for the Kropa local speech (SLA p202) attributed to the following settlements: Kropa, Kamna Gorica, Brezovica, Češnjica, Jamnik, Nemilje. The classification of the following settlements has been changed by the manual editing: Jamnik, Nemilje, Češnjica, Kamna Gorica and Brezovica – attributed to Ljubno local speech (SLA p203) – Gorenjska dialect (4b) – *(Figure 23.13b)*. Consequently, only the settlement Kropa in narrow valley of river Kroparica under Jelovica belongs to the Kropa local speech – precisely this geographic fact influenced the formation of the Kropa speech. Also the neighbouring settlements of Srednja Dobrava and Lipnica, by Thiessen polygons attributed to Radovljica local speech (SLA p201), have been manual attributed to Ljubno local speech (SLA p203).

Determination of boundaries between the local speeches demonstrates a power of automated classification and strength of additional manual dialectological verification process. By this the fuzzy transition space between local speeches/dialects is especially important. Attributing of the most problematic settlements that are not included in the SLA will additionally require the increase or densification of data points and determination of the particularly extra-linguistic facts for the formulation of the local speeches and dialects.

23.5 Discussion

The optimised utilisation of the SLA in a high positional and semantic quality was proposed. The procedure integrates various data sources that are accessible, current trends in geolinguistic and enhanced spatial modelling. The automated spatial modelling as it is shown at current state was used for preparation of spatial variables based on the indicators and their visual evaluation with thematic mapping. The manual mapping of the borders should overcome several gaps in datasets that were not solved with the previous automated attribution of settlements area to the certain local speech:

- uninhibited areas and areas of mixed speeches were not considered (e.g. Kočevje)
- several settlements have been expanded to the areas of smaller settlements; the contemporary database of settlements do not include the ancient borders that are important for the dialect borders determination (e.g. city of Ljubljana)
- currently we have no datasets of the settlements for the regions outside of Slovenia (Austria, Italy, Hungary, Croatia)

The current solution uses the most precise data gathered by tessellation with pondered Thiessen polygons and with manual editing the positions of mapped borders.

The discrepancy of dialectical border positions derived by various approaches described in this paper lies in the procedure of dialectal borders determination that is based on different levels abstraction. Actual dialect borders are namely not “sharp”, but gradual and “fuzzy”, and even temporally dynamic. The borders could be presented with band of different width that present a passing zone from one dialect into the other. The dialectal borders within the SLA (currently as the classical Map of Slovenian dialects) are additionally defined according to the density of isoglosses[3] – mostly isophons or isomorphs, rarely isolexes, which allocate appearance of the individual linguistic phenomena. Consequently, the dialectal borders from the map (see *Figure 23.1)* and former local speeches borders from the SLA are just roughly adjusted with the other borders generated by spatial modelling in GIS as described.

Additional analysis, which can describe the border fuzziness between certain speeches bases on modelling in GIS by using automatically and manually gathered data about boundaries (Podobnikar 2008). The analysis includes the calculations of density and dispersion of borders, and possible automatic vector-based interpretation and determination of borders.

Another aspect discrepancy of dialectical border positions lies in quality of the results (especially in uncertainty of boundary). The mapped borders have been visually assessed by expert knowledge. Boundaries of automatic defined borders were overlaid, and compared with the final result of (manual) mapping based on data-

[3] Within the field of linguistics, the term *isogloss* describes a distinctive feature of a language or dialect – it is a geographic boundary or delineation of a certain linguistic feature, e.g. the pronunciation of a phoneme *(isophons),* selection of morphemes *(isomorphs)* or lexemes *(isolexes)* etc. Major dialects are typically demarcated by whole bundles of isoglosses.

base of settlements (Podobnikar 2009). The most precisely the larger discrepancies between the results of various mapping techniques were analysed.

23.6 Conclusions

Our research has demonstrated the results of interdisciplinary connections between linguistic and spatial researches of Slovenian culture space. We have concentrated on determination of the local speeches areas which is the part of the Slovenian Linguistic Atlas (SLA) with help of the Map of Slovenian Dialects, which is based on linguistic features and by using several methods of spatial modelling in GIS.

Determination of the influential local speeches areas is one of the bases for dialectometric analyses of Slovenian dialects (i.e. calculation of similarities and distances of local speeches included in linguistic atlas and also the analyses of similarities on different linguistic fields). This analysis also enables more precise determination of isoglosses (isolexes, isophones, isomorphes) of linguistic maps and also the synthetical maps.

The results of detailed mapping improve importance of good knowledge of dialect indicators on one side, and determination the significant spatial variables on the other. In a high quality boundary determination is important the integrated border analysis, which is gathered with different methods. The manual mapping (after the automated one) is still necessary according to the exceptionally complicated situation with the Slovenian dialects, especially owing to geographic linguistic indicators.

Further researches are going to develop twofold: The first is the continuation of the research in dialectometry, and the second is to support these statements with spatial modelling and simulations in GIS. One of the first steps is going to be consideration of more proposed variables, e.g. watersheds or geomorphic configuration as part of the quantitative automated modelling and not just as part of the qualitative manual mapping. The developed interdisciplinary methodology can be supplementary compared and implemented to the other languages in Central Europe and even to the comparative studies between the dialects of different languages in the geographically same areas.

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Chapter 24

Interactive and Multimedia Atlas Information Systems as a Cartographic Geo-Communication Platform

Mirjanka Lechthaler

Department of Geoinformation und Cartography, Vienna University of Technology, Austria
lechthaler@tuwien.ac.at

Abstract

In modern cartography of the late twentieth century the Internet offers an ideal platform for making communication with maps more feasible – on one hand. But on the other hand there has to be an understanding of the process and the methods of how to generate cartographic models and then how to communicate spatial data, which means geo-information accurately and efficiently. Due to this focus, cartography has to fulfil the obligation to achieve both – the creation of cartographic presentation forms for the new media and to accept the responsibility on understanding the deep relations within the whole cartographic communication process, which includes the user, the models in different cartographic media and the transmission.

In this article, the importance of interactive and multimedia atlas information system as cartographic geo-communication platforms will be presented, where the user expands his knowledge by restrictive but flexible searching for spatial information. An atlas information system subdivides all functionalities into a cartographically conceptional and structured order.

24.1 Introduction

Cartography is an indispensable part of any future for geography and the broader enterprise for geographic information science (Goodchild 2000). The digital map world and the daily increasing number of maps lead to the known paradox between

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Lecture Notes in Geoinformation and Cartography, DOI 10.1007/978-3-642-03294-3_24,

marginalization of cartography and the increasing need for good map products included in cartographic information and communication systems (CICS), based predominantly on visual communication.

Over the last 20 years, the Internet has been a new information transfer medium for cartography and cartographic applications. It offers a variety of ways to communicate geo-information via adequate geo-visualisation of basic geo-data (topographic and thematic).

The communication of geo-information facilitated by CICS is based on maps as user interfaces, which are not only restricted to the visual recognition patterns. The individual user's interest could be satisfied with CICS geo-information only if there is a different content depth and a different scale level – level of details. By means of offered and applied interactive tools the acquisition of spatial information is in principle not static. The user defines, depending on his aims, his own personal form of communication.

The important cartographic web media are regional, national and global atlases in the form of web-based, multimedia and interactive atlas information systems (MI-AIS). There is the need of cartographic principles, good design and skills stronger than ever, with the aim to make the communication of spatial information richer, more efficient, personalized and ubiquitous.

In the next chapter the author will make a short walk through the history of coping with "cartographic communication" and will give the ability to understand the changes over the years caused by new technology.

24.2 Concepts Worth Knowing for Understanding Cartographic Communication

The following map functionalities in a CICS are the author's selection with the aim to give a representative review, which is standing for all characteristics of this process. The pregnant description of each of them will give the possibility to see of what prime importance the maps were and still are in our private and public realm.

24.2.1 Predictions of Cartographic Communication

Information theory and several attempts made at practical application of SHANNON's formulae in determining information capacity of maps (Sukhov 1967, Knöpfli 1980, Lechthaler 1985) as a carrier of geo information influenced the formulation of a "new" approach to the role and tasks of cartography and it set the background for a trend then called "cartographic communication". The model of cartographic communication in the late sixties of the twentieth century inspired further research and discussion till today.

Bocharov (1966) was the first who defined cartography as a science concerning a cartographic form of information transmission.

Kolačny's (1970) main work for cartography was presented in his article "Kartographische Informationen – ein Grundbegriff und Grundterminus der modernen Kartographie" (Kolačny 1970, p. 188). After studying the complex problems of "modern" cartography, he came to the conclusion that cartography can only be understood and the communication problems can only be solved, if the cartographers consider that the creation and utilization of cartographic products are two components of an interrelated process in a "stimulus-response" model. The author called it "communication of cartographic information", where the central element is "cartographic information". His idea has the following fundamental points in the so called communication circle:

- Anticipated monitoring of multi-dimensional universe/reality by the cartographer, with specific objectives in mind,
- Development of a cognitive concept of anticipated reality,
- Mental transformation of this concept into cartographic information,
- Objectification/formalization of cartographic information/map which stands for the reality,
- Effect of objectification of cartographic information in the process of map reading,
- Effect of understanding cartographic information, creation of user's cognitive model of reality and
- Pragmatic behaviour of map user in his world/reality.

In "The science of cartography and its essential processes", Morisson (1976 , p. 86) presents the vision of cartography as a scientific study of the map as a communication channel. There are many essential processes; on one side there are the cartographer's cognitive selections of geo-space data, his data classification and data simplification to form his map conception and map construction though cartographical methods of generalisation and visualisation. On the other side there are the reader's cognitive interpretation and verification of received information in the cartographic communication process. It will only be successful, if the map reader's abilities were taken into account.

The model of cartographical transmission after Ratajski (1978, see also Morrison 1976, p. 75) deals with the map as a model of reality, which is conditioned by two elements: structure (i.e. construction of cartographic expression) and content, which have to be transmitted. So, the map has a transmission capacity where the cartographic language (well established syntactical structure and grammar) has a strong influence.

Board (1978, p. 42) suggests a few ways in which a conceptual model of cartographic communication could be functional. His model is based on cognitive maps included in different relationships between four corners in his communication circle: real world, map maker, physical map and map reader. In order to make maps more efficient, the author develops the theories of cartographic communication.

Grygorenko (1984 , p. 102) explains the map position in the system of cartographic communication through a general theory of (cybernetic) systems with four partial processes: gaining knowledge of reality, producing the cartographic message, interpreting the message and verification of the message. The cognitive map of reality has a central relevance as well as the possibility of representing it by a material model. Without the representation function the cartographic message would have no sense and would never have a practical importance.

24.2.2 Cornerstones of Modern Cartographic Communication

In all mentioned schemes of cartographic communication, independently of terminological differences, the same unchanged arrangement was always preserved: reality → map maker → map → map user → mental image of reality → user's behaviour. This model is typical for any communication system. The information flow through the substantial system channel reaches the recipient more or less correct. In cartographic communication the map i.e. cartographic information is a central element that carries spatial information. This entails, irrespective of the technology of the communication system, various semiotic, modelling and cognitive implications.

MacEachren (1995, p. 5) sees the primary function of cartography as a formal communication system and the maps i.e. cartographic signatures, as a vehicle for transferring spatial information. This cybernetic process (Grygorenko 1984, Taylor 1994) has inputs, transmissions, receptions of information and therefore allows to be analysed as a system in its functionality. The aim is to transport the space simplified, generalised, classified and symbolized without filtering or less information and to expand the user's knowledge.

DiBiase's characterisation of cartographic visualisation matches the view that the interpretation of spatial phenomena depends on visualisation by means of maps (see in: MacEachren 1994, p. 3). Giving a framework for thinking in spatial scientific research, he emphasises the role of all aspects of maps, from initial data exploration in private realm to the final presentation of results in public realm for visual communication. Maps are research and reasoning tools.

After the "stimulus-response" model, Peterson (1995, p. 6) the model includes interactions in the use of maps. The interactive communication is under user control. The interactive mapping environment (provided by the cartographer) allows the user to match the map according to his tasks, needs and abilities. In the author's opinion it is evident that the human mind is well-trained to recognise reality from animated presentations.

MacEachren (1995, p. 358) and Kraak et al. (1996, p. 3) depict cartography as a cubic map-use space in which visualisation and communication stand in opposite corners. For MacEachren the main aim is to make sense of how scientific visualisation links with cartography and not with map making. His space is defined by three map use axes:

- Private (private generating of maps for own needs) – public (access to previously prepared maps)
- Revealing unknowns (looking for something interesting) – presenting knowns (attempting to access particular geo-information)
- High human map interaction (manipulating maps in essential way: changing views, switching among different maps, superimposing map content, merging maps) – low interaction (limited ability to change the presentation).

For Kraak et al. (1996, pp. 41, 49) the starting points of the cartographic communication process are the data/information collected on the part of any third parties. Cartographers have to study and get acquainted with it, as well as with the purposes of the information transfer, applying the necessary data transformation with the aim of their correct presentation in a map format. The cartographic presentation is a cognitive process, which has to get the essence of spatial phenomenon, if it is represented adequately. The authors get maps by a form of scientific visualisation. The objective of cartography from their point of view is to convey spatial information and their spatial relationships, the aims of communication, exploration and analysis.

Cartwright et al. (1999, p. 8) include the concept of interactive multimedia and hypermedia in the cartographic communication process. Multimedia cartography can be presented as sphere of cartographic potential, which moves across and into a space of geographical reality (composed of abstraction-level), allowing the user, depending on his point of contact (POC), to control and to choose the process of presentation according to his needs, abilities and skills. POC is like the geographical window through which reality can be seen. The authors compare multimedia cartography with the metaphor of an atlas information system.

Lechthaler (2000, 2002, 2003, 2005a) has addressed the paradox between the marginalization of cartography and the increasing daily need for efficient cartographic information to be included in CICS. This interest focused on the current major problem related to the value of cartographic information as well as their restrictions, especially in the web environment, and how to deal with geo-communication assisted by maps, especially in MI-AIS.

Nowadays, in many cases the experienced cartographer is not the actual designer of the CICS. The user is invited to form and structure knowledge using the CICS on the web, where he is restricted by the limitations of current hardware, transformation and visualisation tools or the high associated acquisition costs of such. Internet services and newly implemented information and telecommunication technologies allowed a new concept of improvement in geo-communication and support the user's arrangement and designing of geo-space as well as multimedia and interactive exploration of spatial information.

In *Figure 24.1* the characteristics of cartographic information and the changed cartographic geo-communication process are presented respectively. The cartographer, being conscious of the scale and graphic design restrictions in the modelling process of the map space in the MI-AIS, constructs a content level based on different scale retaining and providing the analogies to the geo-space and links the resultant cartographic information with interactive and multi-/hypermedia information environments for display and use in a CICS. In this case the user is directly involved in the interactive geo-communication process that enables restrictivity as well as flexibility in individual and dynamic acquisition and/or generation of spatial information in the MI-AIS.

24.2.3 Cybercartographic Geo-Communication

Furthermore, we live in a new era of cartography – a cybercartography where cartography has developed its own theoretical language frameworks and the communication takes place using more resources including cartographic, linguistic, mathematical, statistical, musical, and visual languages. Maps, virtual space maps, dynamic three-dimensional satellite images, geo-text, videos, photos, sound, computer simulations, statistical graphs, and diagrams can be used in the construction of so called cybercartographic MI-AIS. In this case, the centre of cartographic activity does not lie in the production and use of printed maps as the primary and final product. Geo-communication, using cybercartographic atlases, proceeds in the multi-dimensional space and is composed of three axes: communication, models, and knowledge. In many cases the incorporated AIS, information and knowledge about human geography, landscape ecology, territorial planning, environmental science, and other relevant sources will be provided by a number of authors/users. There is an active cycle of scientific research that involves empirical work, creation of knowledge, and feedback between users and atlas developers, including experts, scientists, students, fieldworkers, and governmental officials. The cybercartographic MI-AIS execute their full cybernetic character through the interaction between all actors in the group-communication process, the role which is to facilitate human communication. Users and atlas get engaged in a process of conversation and knowledge construction within using the atlas (Reyes 2005). Exploring the Concept of Cybercartography, Brian et al. (2005, p. 53) consider the user in a broader societal/human context. In their model there is a synthetic cybercartographic human interface consisting of three interfaces/domains: cybercartographic or content processing

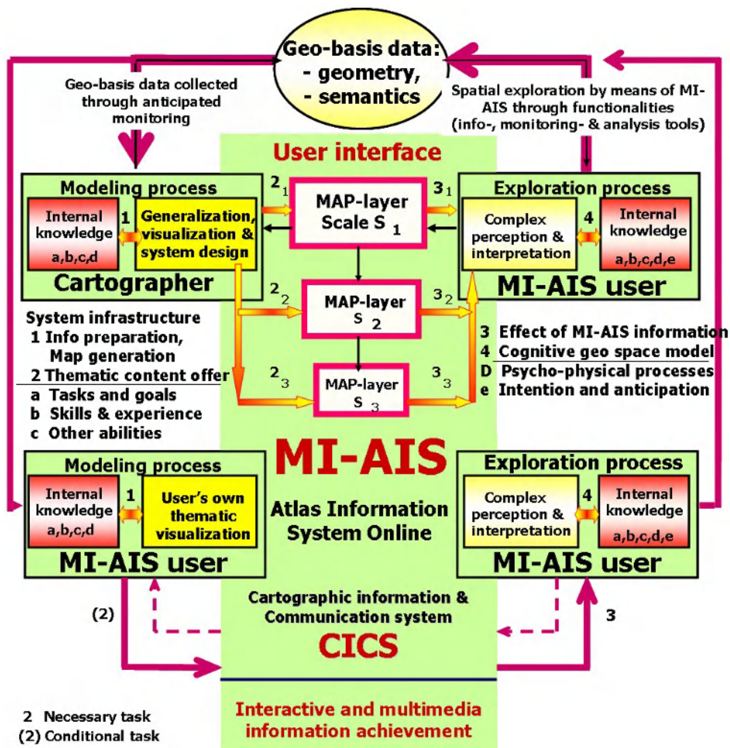

Fig. 24.1. Cartographic geo-communication process in CICS, especially in MI-AIS.

domain, human and interface domain and the complete information package, will be processed in sequential, hierarchical, and evolutionary patterns including three general levels: data (transactional processing), knowledge (analytical processing) and meaning (synthetic processing).

But back to the traditional geo-communication process in a CICS. Map generation without adequate application of cartographic knowledge and working with the restrictions of current visualisation tools for different cartographic media in CICS often do not conform to "ideal" cartographic modelling instructions and principles.

24.3 Characteristics of Cartographic Media

The goal of cartography is to communicate clear and legible information about geo-space objects, states and phenomena via geo-coded map-objects in various cartographic media *(Figure 24.2),* in which the map is most often used.

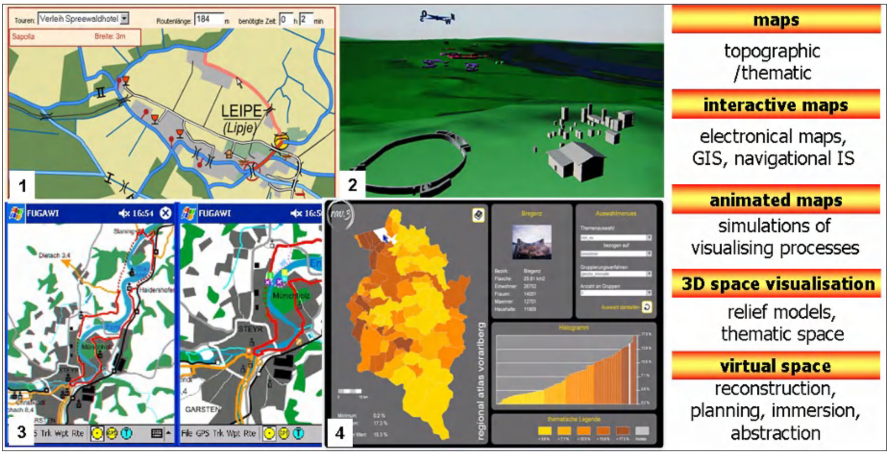

Fig. 24.2. Cartographic media involved in CICS (1: Blum 2003, 2: Jobst 2003, 3: Leitner 2003, 4: Stadler 2006)

Cartographic modelling for all cartographic media includes the complex iterative process of cartographic generalisation, visualisation and unavoidable harmonisation of graphically transformed geo-objects from the primary spatial model into map-objects of the secondary spatial model (Lechthaler 2007). Description or meaning, i.e. geo-object semantics, is tied to the map graphics, whose form and position is defined by the scale. The meaning is generalised and is related to a previously determined hierarchy (i.e. roads classified into groups). In this way, individual marks of individual geo-objects are changed, represented incompletely not sharp enough or disappear completely. For cartographic models, in order to be legible and understandable for the user, the map graphics have to be adjusted to the user's perceptive parameters a as well as to technical restrictions of the publishing media: paper or display. These are immanent characteristics of the cartographic model as an efficient geo-communication tool and have to be applied unconditionally in all cartographic media.

24.4 Characteristics of Atlas Information Systems

As defined in the Lexicon of Cartography and Geomatics (Bollmann et al. 2002), an atlas map work is understood as a target and purpose oriented systematic set of maps in book form or as an AIS with global, regional and local character, which offers static and dynamic maps (2.5D and 3D), texts, tables, pictures and graphics as well as computer-aided sequences like language, sound, animations and videos.

Abraham Oertel, named Ortelius (1527–1598), published his "Theatrum Orbis Terrarum" as the first map collection satisfying the atlas definition, and in 1585, Gerhard Kremer, called Mercator (1512–1594) was the first to give his map collection „Atlas sive Cosmographicae Mediationes de Fabrica Mundi et Fabricati Figura" the name "Atlas" (Lechthaler 2009).

In accordance to formal and relevant features, Bollmann et al. (2002) distinguish among atlases with regard to:

- output medium/presentation form (paper, haptic, electronic, multi-media atlas),
- thematic contents (complex thematic atlas, special atlas),
- format and content size (giant-, hand-, book- and pocket atlas),
- representation area (world-, countries-, regional-, town-, space-, moon atlas).

Beside these traditional classifications of atlases, digital atlases are classified more specifically. Considering the level of interactivity and the analytic potential, Ramos et al. (2005) and Ormeling (1996) categorise digital atlases as:

- view-only atlases (print-only atlases or digital static maps without interactivity or dynamics),
- atlases that generate maps on demand (interaction with data sets, changes of colour schemas, classification methods or number of classes), and
- analytical atlases based on GIS capabilities (database queries through a map as a graphical interface, in addition to provided map possibilities to create, analyse and visualise new data sets).

An AIS is primarily used to locate geographic phenomena and to enable users to understand geo-spatial patterns related to the physical, temporal or socio-economic human environment. Atlases belong to the first cartographic products that people use, as they are introduced to students early in their education. Further, atlases can be considered as the most widely known and ultimate cartographic product (Kraak 2001) and play an important role in cartographic geo-communication.

A national atlas is the cartographical calling card of a country (Hurni 2004). Unlike topographical maps of a country, national atlases additionally convey thematic information based on a consistent succession of map scales. A number of electronic national AIS have been produced within the last twenty years. Due to the new potential of the global net, national atlases become more and more important in society. Ormeling (2001) defines the concepts for multimedia national AIS and points out the new meaning of the Web atlas map as an interactive interface, which provides access to the current elementary geo-data portal (sub national, national, translational and global data bases). Naturally, there are still many unanswered questions, especially regarding national geo-data policy.

As an example of European national MI-AIS, the following atlases have to be mentioned (this list is not exhaustive): National Atlas of the Federal Republic of Germany, Atlas of Switzerland, Online Atlas of the Netherlands, Online Atlas of Canada, GeoInfo Austria and ÖROK Atlas Online – AIS Austria.

24.5 Paper Atlases Versus Web AIS in the Cartographic Geo-Communication Process

Analogous maps in an atlas are dual-purpose. On one hand they must store information, and on the other hand they communicate information about geo-objects and -phenomena. The extent of spatial semantics related to qualitative and quantitative characteristics should be harmonically organised as well as constructed on a piece of paper. Markers and various kinds of stickers are employed by atlas users in order to find or compare map contents and define relevant objectives. Atlas maps are accompanied by explanatory booklets, containing notes, profiles, statistics, diagrams, pictures, etc.

AIS dates from the eighties of the last century and was characterised by hardware limitations (storage capacity) as well as software limitations (lack of interactive tools). The first developed digital atlas was the Electronic Atlas of Canada in 1981. Since then, increasing research efforts have been carried out in this field by governments, universities and private companies (Kraak et al. 2003, Peterson 2005).

Some of the important differences between paper atlas and contemporary digital AIS are the kind of atlas storage and the publishing of geo-space information. The expressive growth of the Internet audience (Peterson 2005) allows distributing the atlas content via wire/wireless network ubiquities to countless people. This is also a very effective way of distributing the meaning of cartography.

In modern cartography, the Web offers an ideal platform for enhancing geo-communication by means of map information. But at the same time, it is necessary to understand the process and the methods of how to generate cartographic models and how to accurately and efficiently communicate spatial data and information. Due to this focus, cartography is obliged to achieve both – the creation of cartographic media and the acceptance of being responsible to understand the deep relationships between the whole CICS, which includes the user, the models and the data transmission.

Furthermore, this article is focused on cartographic visualisation in the MI-AIS cartographic media.

24.6 Cartographic Visualisation in the MI-AIS Cartographic Media

Cartography is exposed to constant changes in the technical environment. The largest technical revolution of the 20th century was the transition from static paper-printed maps to interactive display visualisations in MI-AIS. This transition was probably the most significant innovation in the history of cartography (Hurni 2005, 2006).

Computer-aided cartographic modelling and processing, and the representation of map-objects in vector space heavily influenced the rapid development of MI-AIS. The use of innovative functions and tools in technological systems, e.g. geographic information systems (GIS), computer-aided modelling (CAD), desktop-publishing, raster graphics processing, Web geo-communication, as well as the development of various program languages actually are the catalysts in the development of digital and interactive cartography.

Today, the choice of interactive CICS has become immense and is very wide in technological and thematical terms (Hurni 2006). From the cartographic perspective, the mentioned systems attribute completely different importance to the principles of cartographic modelling, where the cartographer's experience and knowledge often takes the back seat.

Using legible map graphics that are adapted to the technical requirements of the output medium (Lechthaler et al. 2007a) is one of the main criteria for user acceptance of MI-AIS. Concerning the definition of cartographic legibility regarding the printed maps, much experience has been gained within the last few decades.

The situation is not the same for screen visualisation. Electronic atlases have not yet reached a high level, especially concerning the legibility of the represented geo-information (Prohaska 2005), although the increased demand for interoperability and flexible exchange of formats is impelling a greater standardisation of geo-data. The "standard" discourse of recent decades has largely ignored graphic quality and visual effectiveness (Monmonier 2005). Due to their technical restrictions, screen presentations suffer from deformation of the graphic elements that limit the legibility of the map.

Therefore, the adaptation of these map graphics is essential. This could be achieved by (Lechthaler et al. 2007b):

- defining minimal dimensions (size and distance) of map graphics and lettering which is dependent on direction and shape,
- careful choice of the basic elements for graphic representations (points, lines, polygons, complex map signs and characters), and
- deliberate choice and combination of graphic variables (size, shape, colour, orientation, lightness, and patterns).

The application of screen-adapted map graphics requires more map-space. This has an effect on the information content of the atlas map in terms of insufficient information transfer due to larger map graphics. However, lower graphic density is compensated by the ability to fully investigate the range of content with implemented interactive facilities to access primary geo-data. This leads to a more efficient system with hardly any capacity limits.

24.7 Some Interactive and Multimedia Cartographic Applications in CICS

The general borders that define cartographic communication are changing. Cartographic presentations, which no more only remain static but become dynamic, – interactive and animated – whenever possible, have become a new input/output user-controlled interface. The cartographer is no longer constrained to create a single map for a single user or well-known user group. In the cartographic communication process the user has more possibilities to go beyond the limitations of static maps through new technologies which are linked to presented map information. Such information systems using cartographic models as a user's interface for gathering selective and targeted geo-information are associated with unlimited information capacity on the one side, and, on the other, they demand changed habits due to the readout the system offers.

Prototype of Interactive and Multimedia Atlas of Austria "Geo Info Austria© [1]" *(Figures 24.3* and *24.4)*

The MI-AIS consists of several scales, i.e. inherent information levels (geometry and object-semantics) (Kelnhofer 2000). The topographically and thematically defined interactions, animations and multimedia sequences guide the user on his way to information acquisition through Austrian space by using the maps as interactive interfaces. User defined queries in topographic and/or thematic domains can be analysed or visualised by cartographic means. The legibility and quality of cartographic information is of permanent importance.

Prototype of the PC school atlas InMuCIS „Interactive Multimedia Cartographic Information System about geo-phenomena©" *Brunner-Friedrich (2004)* *(Figure 24.5)*

Brunner-Friedrich (2004) presents the concept of a school atlas and postulates that users of MI-AIS show different abilities and preferences within their scientific information perception.

Each individual student needs a different approach to the learning matter (in this case cartographic topics) and a different kind of presentation to improve his memorisational skills. Students exhibit different learning styles and can therefore be classified in different types of learners. Today's teaching aids often address only some or just one of those learning types, whereas others are left completely unattended.

[1] AIS GeoInfo Austria is the result of a FWF project (1995–2000), developed at the Department of Cartography and Geomedia Technique (today Department of Geoinformation and Cartography, Research group Cartography), University of Technology, Vienna (Kelnhofer 2000).

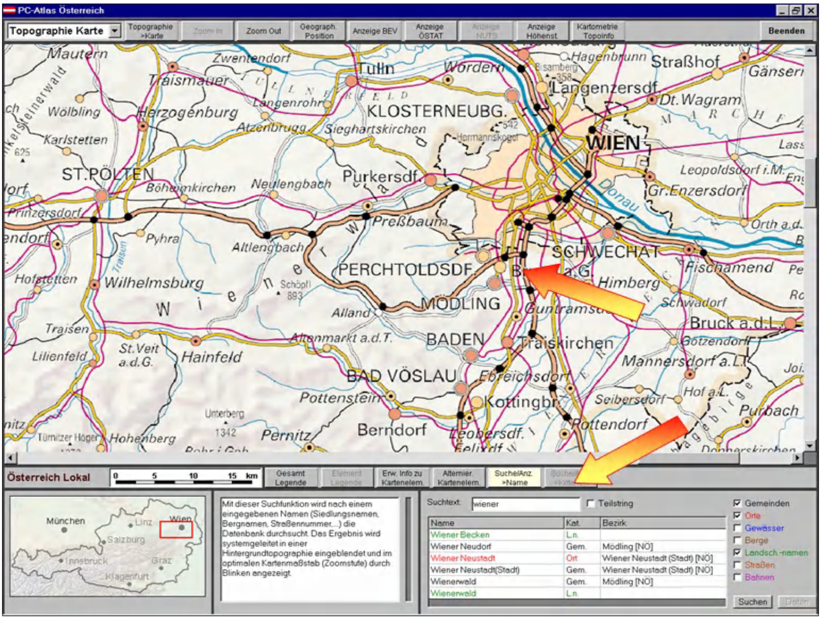

Fig. 24.3. Example of user's information acquisition by queries and interaction within the topographical map-space in "Geo Info Austria©".

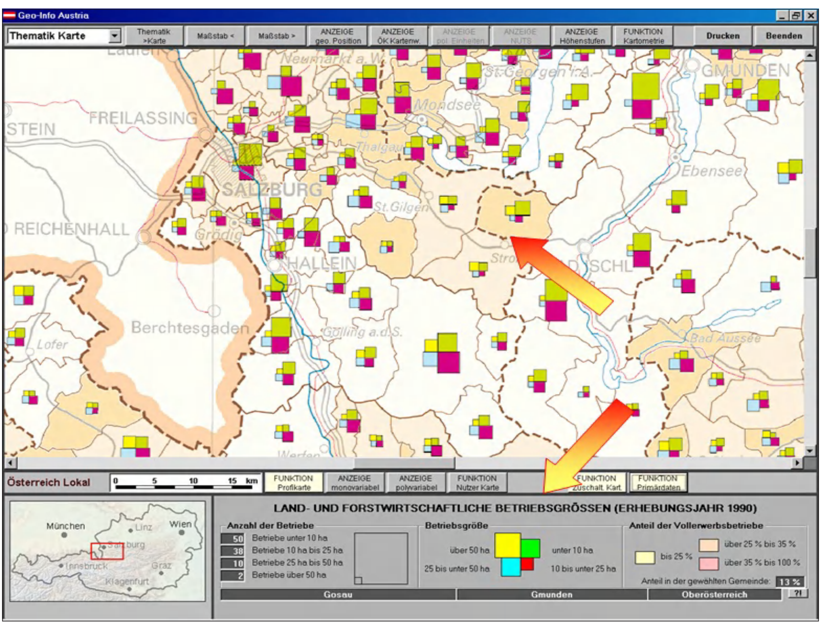

Fig. 24.4. Example of user's information acquisition by queries and interaction within the thematical map-space in "Geo Info Austria©".

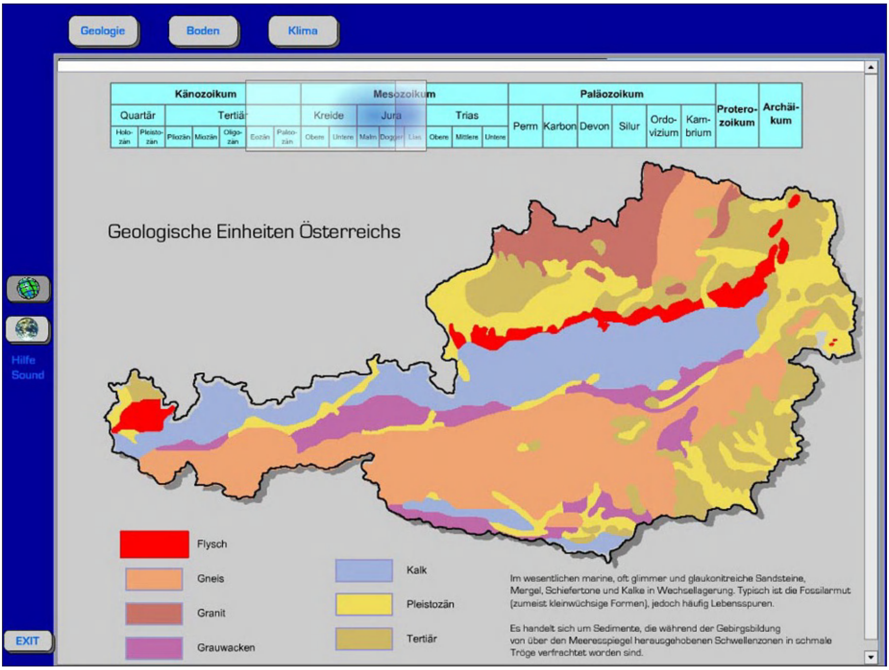

Fig. 24.5. Example of user's information acquisition by queries and interaction within the thematical map-space in Prototype of the PC multimedia school atlas InMuKIS „ Interactive Multimedia Cartographic Information System" Brunner-Friedrich (2004).

To consider these differences it seems necessary to offer the same (spatial) information in various ways, i.e. no change in the information content but in the type of presentation. This could be done by applying some new technologies on spatial data which are delimited in a fuzzy manner in this CICS. To avoid overlays in maps a new display concept is used. A new display concept is used, which incorporates user strategies (such as individual knowledge or learning habits) based on findings in cognition psychology.

Independent exploration is supported by the use of different media (interactive maps/"view-only" maps; maps with/without acoustic elements; written/spoken text), different cartographic presentation forms (e.g. map/aerial view), and different cartographic symbols (from geometric-abstract to pictorial).

ÖROK Atlas Online – AIS Austria

"ÖROK Atlas Online – AIS Austria" is an interactive and multimedia rule based thematic atlas provided by the Austrian Conference on Spatial Planning (ÖROK) *(Figures 24.6* and *24.7),* which is an organisation set up by federal, regional and local governmental administrations of Austria to coordinate spatial planning at the

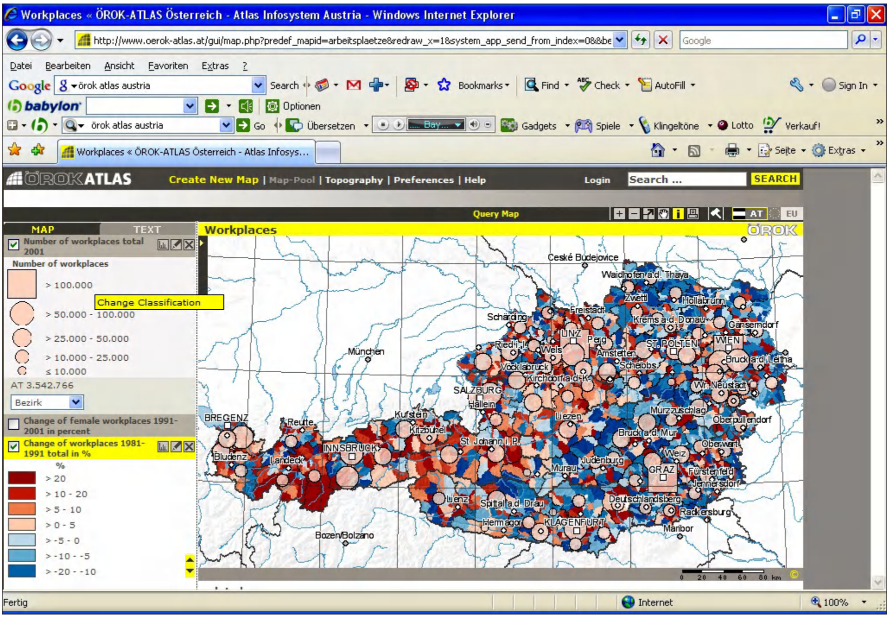

Fig. 24.6. Example of user's information acquisition by queries and interaction within the thematical map-space – Workplaces 2001 – in ÖROK Atlas Online (www.oerok-atlas.at).

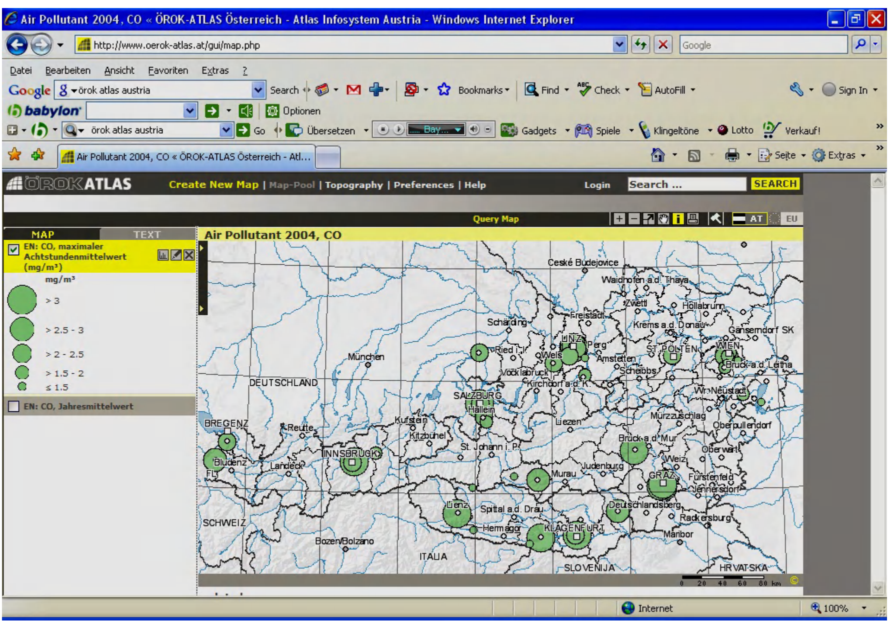

Fig. 24.7. Example of user's information acquisition by queries and interaction within the thematical map-space – Air Pollutant 2004 – in ÖROK Atlas Online (www.oerok-atlas.at).

national level. The atlas application is the result of a cooperative research and development project of the ÖROK, Department of Geoinformation und Cartography, University of Technology, Vienna/Austria[2], Department of Geography and Regional Sciences, University of Vienna[3] and ÖIR-Information services, Vienna[4]. (Prototype's timetable was: September 2004 – February 2006).

This atlas is a web online system which enables the user – lay persons and experts – to explore national and international (European) basic geo-data. Users can perform tasks like searching, comparing, analysing and visualising data. The system allows the cartographical visualisation of geometry and statistical data from the elementary geo-data pool in different map scales and in a high quality. Graphics, statistics and texts as well as queries of the data base are accessible over the interactive map based graphical user interface as a communication portal (Lechthaler 2007).

The main research emphasis of the "ÖROK Atlas Online – AIS Austria" as a national MI-AIS lies in the formalisation of the cartographical rules for proper thematic online modelling and visualisation of geometry and thematic data in the given scale resolution, further in the definition and realisation of required functionalities which make efficient communication possible, and in the system navigation and applied interactions which support a sensible and meaningful "restrictive-flexible" user leadership.

In accordance to the theme choice the system navigation has to support the users in their exploration. It can be assumed that system users usually are not interested in undertaking several experiments, or in using different kinds of e.g. symbols, symbol sizes, line widths, or patterns until they have achieved an acceptable map. Therefore, a so-called system control should support the efforts of system users in the process of map making. In the system background data queries as well as meta-data and data analysis, cartographic data modelling (selection of the best method for the scale-dependent and graphic-defined data translation), and cartographic visualisation are formalised. Predefined processes have been deliberated by the consortium group in order to give the user a restricted freedom. Within the restrictions defined by the system control, the user can explore the geo-space via AIS Austria in a flexible way according to his questions. In such way, only sensible, convincing and useful cartographical data presentation are permitted (Lechthaler et al. 2005b).

[2] http://cartography.tuwien.ac.at
[3] http://www.gis.univie.ac.at/karto
[4] http://www.oir.at

24.8 Summary and Conclusions

Technological developments of the last two decades have led to a wider range of different cartographic media implicated in cartographic information and communication systems (CICS). The most important and complex systems enabling the user to search for new knowledge are interactive and multimedia atlas information systems (MI-AIS), which include cartographic, linguistic, mathematical, statistical, acoustical, and visual languages. Cartographic information in thematic and/or topographic maps, virtual space maps, dynamic three-dimensional satellite images, geo-texts, videos, photos, sound, computer simulations, statistical graphs, and diagrams allow to construct individual worlds of space information.

Atlas Information System (AIS) as a cartographic geo-communication platform is different from pure GIS due to its strong cartographic character. This is particularly shown by the fact that it is not merely a collection of GIS based tools, but a system which subdivides all functionalities into a cartographically coherent and structured order. It must correspond with the characteristics of the cartographical, rule-based and personalised information system, which enables different user groups to explore current elementary geo-data from different geographical and thematic sources. Hence, the formerly passive user of a map becomes an active manager in geographic information acquisition and visualisation. The role of cartographers as designers of AIS has changed, too. They are not only responsible for transport of cartographically legible screen information via the Web, but also for all applied technological functions which allow the user to communicate online with the system.

Acknowledgement

The author has worked on many maps in both MI-AIS applications: Geo Info Austria and ÖROK Atlas Online. My thanks for permission to present the results in the *Figures 24.3 – 24.7*. Many thanks also for the permission to use the images of diverse diploma theses in *Figure 24.2*.

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Section V: Cartographic Applications

Chapter 25

Integration of Hightech Components for Operating Ragweed Mapping and Control System in Hungary Using Remote Sensing and GIS

Gábor Csornai, Gábor Mikus, Gizella Nádor, Irén Hubik, István László and Zsuzsanna Suba

FÖMI Remote Sensing Centre, Institute of Geodesy, Cartography and Remote Sensing, Budapest, Hungary
{csornai.gabor, mikus.gabor, nador.gizella, hubik.iren, laszlo.istvan, suba.zsuzsanna}@fomi.hu

Abstract

The Institute of Geodesy, Cartography and Remote Sensing (FÖMI) has a 30 years programme and experience in the applications of remote sensing. The methodology of the operational Crop Monitoring and Production Forecast Programme (CROPMON, 1997–2003) provided a basis for further applications development. One of the operationally proven programme components supports the ragweed control. The ragweed pollen induced allergy came an important issue in Hungary. It is at the point of a special kind of disaster and serious threat to the health of the citizen. Some 80 MEUR cost in medication annually is duplicated by the loss in the agri production. All these constituted a need for a National Ragweed Control Program revision. To the efficiency of this program, the government amended the plant protection law in 2005. This authorized the Plant and Soil Protection National Service to eliminate the infected areas immediately after their detection. In Hungary, some 500.000 – 700.000 hectare area is estimated to be strongly infected by ragweed. About 80% of this area can be pinpointed by remote sensing on the arable land. The development of remote sensing (RS) and GIS methods plus the GPS technology makes the tasks of the reconnaissance and in situ control more efficient. This system increases the success of the preventions of ragweed development. The system is a model for a range of integrated thematic applications of remote sensing. The four years' operational experiences in Hungary provide a realistic basis for adaptation.

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Keywords: ragweed monitoring, remote sensing and GIS methods, GPS technology, central ragweed server, ragweed risk map, non characteristic spectral, temporal behaviour

25.1 Introduction

The Remote Sensing Centre (FÖMI RSC) of the Institute of Geodesy, Cartography and Remote Sensing (FÖMI) has provided many services in the past 30 years to the Ministry of Agriculture and Rural Development (MARD) and the Ministry of Environment and Water (MEW) and also accumulated operational experiences in the applications of remote sensing (Csornai et al. 1983, 1988, 1990). The unique methodology of the operational Crop Monitoring and Production Forecast Programme (CROPMON, 1997–2003) provided an excellent basis for further applications development (Csornai 1997, 1998). One of the operationally proven programme components could be support the ragweed control in Hungary (Csornai et al. 2006, 2007, 2008, Csornai 2007). During CROPMON, the accuracy of identification of the sporadic or dense ragweed cover using their spectral, temporal characteristics was studied (2002–2004). A dedicated ragweed recognition methodology was developed and validated. Because of the results an ambitious national Operational Ragweed Control Program could be designed and carried out in Hungary between 2005 and 2008 based on the integration of hightech components (RS+GPS+GIS+WEB system).

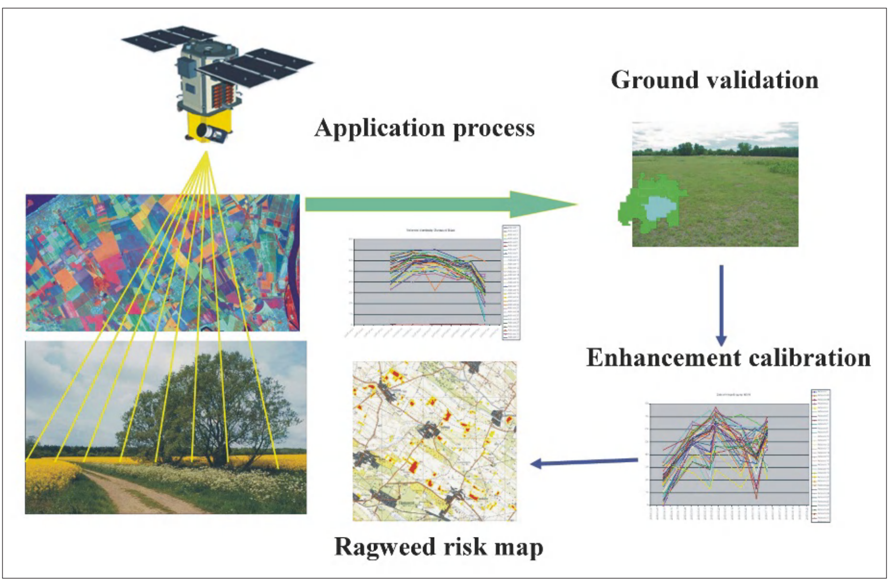

Fig. 25.1. Process of ragweed risk map production

The identification of ragweed infection by remote sensing was an important issue of AFEDA (Association Francaise d'Etude des Ambroises), France. First they use only one high resolution satellite image for detection of ragweed infection (Déchamp et al. 2005), but than they recognized the advantage of using multitemporal images for this purpose (Déchamp et al. 2008.).

25.2 Operational Ragweed Control Program (2005–2008)

In this chapter the main pillars of the control program are presented, such as the methodology and production of the ragweed risk map *(Figure 25.1),* the services of the Central Ragweed Server and the activities and results of this program carried out between 2005 and 2008.

25.2.1 Ragweed Risk Map Production

The ragweed recognition by remote sensing is much more difficult than the crop identification. The evolutions of weeds are not so regular in time. Weeds usually do not cover the whole agricultural parcel and in most cases weeds are grown sporadically in the crop fields. A temporal profile of spectral characteristics method has been developed that has a fundamental importance. For the effective control it is vital to prevent the pollen spreading. In the monitoring of weed's development assessment more measurements, satellite images are needed than for crop identification. This makes the task more difficult. The method is general but the actual application is tuned to the ragweed occurrence parameters in Hungary. The ragweed recognition model, based on the temporal profile of high resolution satellite data series performed very well. The same model can apply different ground resolution satellite images. In Hungary, because of large contiguous ragweed stands on the wheat stubbles the 30–60 m pixel size was a tradeoff for cost. The spatial characteristics and size distribution of the ragweed stands compromised to pick up areas bigger than 0.8 hectare. This is why the application of high resolution satellite images are appropriate in Hungary as the majority of pollen strain comes from rural lands from larger stands. During the monitoring process medium resolution (IRS AWIFS) and high resolution (Landsat TM, IRS LISS, SPOT) satellite images were used simultaneously.

The classification methodology developed makes use of the spectral characteristic of the satellite images. Vegetation indices temporal profiles are used indicating the crop and weeds growth. A regional ragweed map simply can not exist in the practice. The produced ragweed risk maps provide a spatial guidance where the stands could be recorded accurately. The derivation of the primary ragweed risk map is validated by a 10% sample on the ground. The necessary tuning of the classifier is followed by enhancement of the map. The validation ensures the optimisation of the ragweed stand identification accuracy. The major factor in the efficiency of the control program is the high reconnaissance performance and accuracy (better than 90%) of the spots independent from the terrain, location and environment. C***ountrywide ragweed risk map*** are produced focusing to the most heavily infected croplands. The more rigorous ground recording can be done very efficiently by the local Land Offices experts. Important sources of ragweed pollen are non-cultivated arable spots and the stubble-fields of cereals.

Ragweed risk and spatial statistics plus on line maps are public and also available via the FÖMI's website (www.fomi.hu).

25.2.2 Establishment of the Central Ragweed Server

The countrywide ragweed map delineates the ragweed infected spots. This map is utilised by the organizations that participate in the prevention, in the planning of on site control for the optimisation of field spots. These organizations are as follows: Land Office Network (LON), Plant Protection and Soil Conservation Directorate/Central Agricultural Office (PPSCD/CAO), FÖMI, Agricultural and Rural Development Agency (ARDA). Ground data collection is managed by the Land Offices Network (LON) of MARD, with a use of a GPS based integrated ground data collection GIS system over the country. In 2005 FÖMI started to develop the ***Central Ragweed Server and Information System.*** This ensures the fast data exchange among the authorities and stores information about the infected

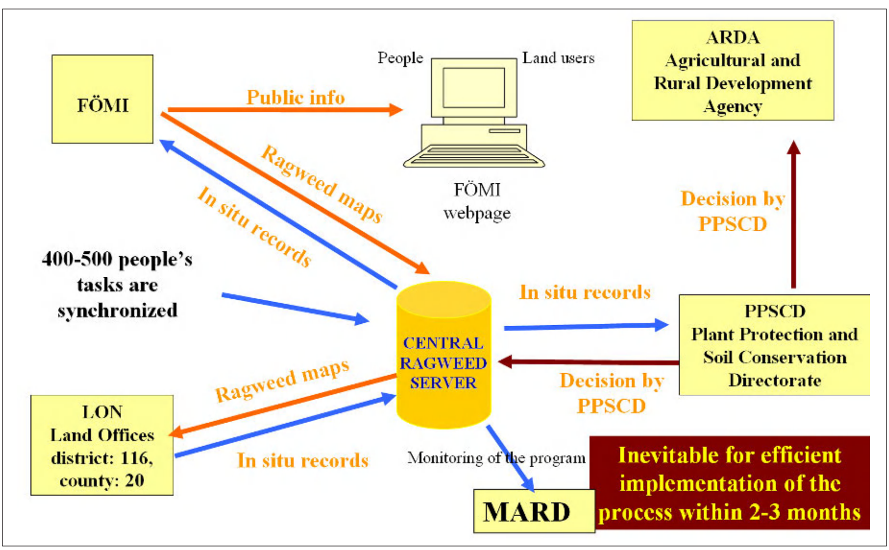

Fig. 25.2. Ragweed control data and documents flow among involved institutions

spots. The central server synchronizes and facilitates the work of 400–500 officials in July-September during the most critical ragweed-growing period.

The Central Ragweed Server facilitates the following activities among the involved institutions including the detection, measurement and recording of contaminated areas during the on the spot check procedure of LON's experts *(Figure 25.2):*

The experts of LON plan and optimise the route of their on the spot checks based on ragweed risk maps of FÖMI. They watch the fields, and if they find ragweed infection, they have to measure it using GPS and PDA for the measurement of contaminated area. They send back their feedbacks about the control of risky areas. Parallel to this, an official procedure starts against the owner or user of the area and the ragweed eradication is executed on the contaminated spots (PPSCD report). ARDA is also informed in connection with the payment of EU subsidies. All these information are stored in four different layers of the Central Ragweed Server as follows:

1. Ragweed infected areas: contain the data of the ragweed infected areas registered by experts of LON
2. Remote sensing spots: contain the data (vector and descriptive) of spots identified by remote sensing
3. Public announcements: contain the data of the announcements of civil people (name of the announcer, date of the announcement, description of the location)
4. PPSCD reports: contain the data of spots found by PPSCD experts (name of the expert, location, date of the observation)

These layers *(Figure 25.3)* are displayed through the ragweed server individually or all at once. The records of these layers can be loaded to the GPS for ground control carried out by LON's experts. The process of the LON record generation during ground survey is shown in *Figure 25.4.* These records are stored on the layer called "ragweed infected areas".

The LON record contains the following data about the spots involved in the ground survey:

1. Unique central identifier created by ragweed server
2. Date of ground survey
3. Photo taken about ground survey
4. Degree of ragweed infection: percentage of ragweed infection
5. Area of the surveyed spot determined by GPS in m^2
6. Phenological state of ragweed
7. Height of ragweed in cm
8. Type of cultivated plant
9. Other kind of allergenic weed
10. Identifier of remote sensing spot
11. Precision of the GPS (PDOP)

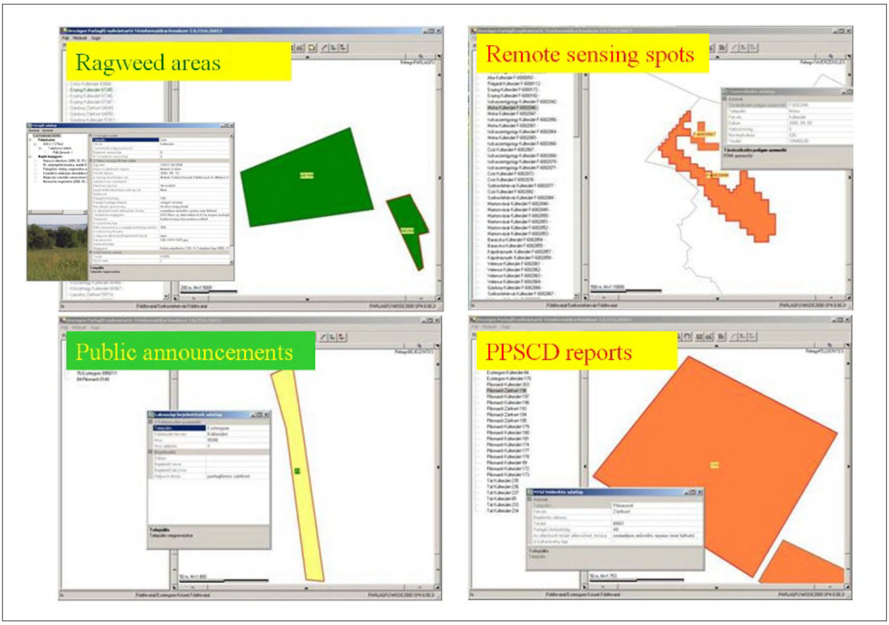

Fig. 25.3. Layers of the Central Ragweed Server

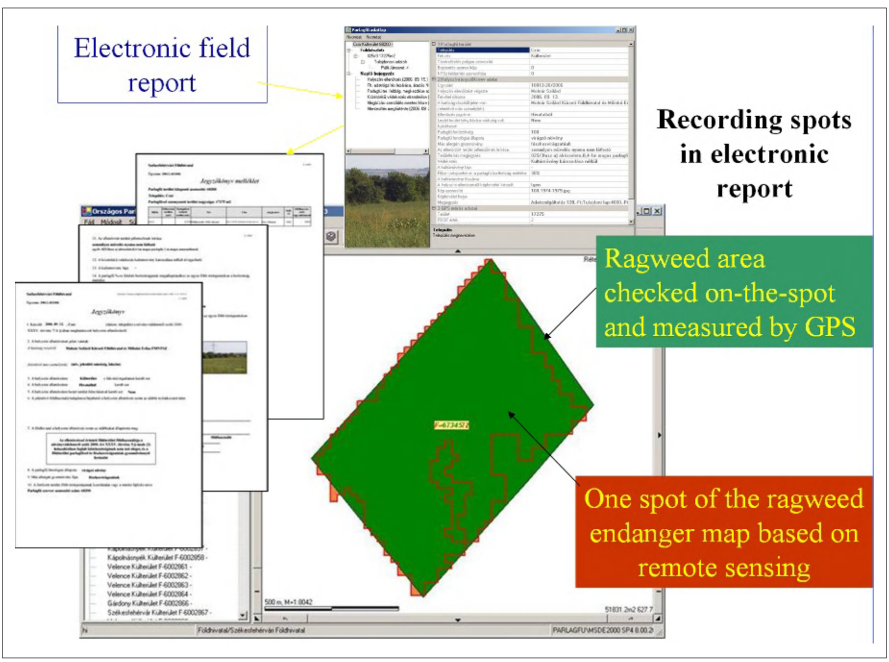

Fig. 25.4. Process of LON records generation

The summary of the LON records stored on Central Ragweed Server between 2005 and 2008 is shown in *Table 25.1.* It contains a valuable and abundant GIS database about ragweed infected areas in Hungary. This GIS database can be used for retrospective analysis of ragweed spreading and for different scientific objectives to increase the efficiency of the ragweed identification by remote sensing.

Table 25.1. Summary of the LON records stored on Central Ragweed Server

	spots involved by ground control		ragweed infected from these	
period	number of fields	area (ha)	number of fields	area (ha)
2005	17 635	17 499	7 308	14 866
2006	7 140	13 947	6 009	13 066
2007	7 988	13 005	5 740	11 155
2008	8 522	16 561	7 239	14 042
total	41 285	61 012	26 296	53 129

25.2.3 Activities Carried Out in the Framework of the Ragweed Control Program Between 2005 and 2008

In 2005 ragweed risk maps were produced several times. The first risk map was the result of a retrospective analysis of the year 2004. Based on ground data from PPSCD and satellite images from the previous year a substantial model validation was carried out. It was found that about 10 times bigger area (approx: 100.000 ha) was delineated by 2004 images than the ground recorded cases of PPSCD when even the 0.8 ha or larger stands were collected. The operational ragweed monitoring started to examine the current (2005) status. The target of remote sensing detection was non-cultivated arable spots and the stubble-fields of cereals. Some 20 000 spots of 60 000 hectares were identified in Hungary, in 2005.

In 2006 a very limited ragweed monitoring program was performed (due to financial reasons). The emphasis was put on the further development of the Central Ragweed Server (CRS). The reduced program brought up about 3 500 spots (18 601 hectares) of ragweed spots in the reduced area. Beyond the remote sensing based ragweed risk maps and the LON's on-the-spot checks that are supported by a dedicate integrated hand-held GIS-GPS equipment, The CRS synchronized 400–500 people's job in the most critical July–September period.

The redesigned Ragweed Control Program certainly builds on the co-operation of the land users primarily. To catalyse, ragweed infection spatial statistics in map form are available for people, via the web sites of FÖMI and MARD. After developing the server in 2006 and providing multiday-trainings for users, the Central Ragweed Server provides a more efficient service.

In 2007, we identified high risk ragweed spots in several time periods on the highly infected areas in the whole Hungarian territory. The number of spots was more than 4 000 (10 000 hectares). Some new functions and modules for the CRS were developed and added that made the processing easier. New modules were developed to speed up the administration and documentation of the Ragweed Control Program.

In 2008, the focus was on the produced risk maps: to the most infected areas 3–5 times from mid-July. The thematic focus was on the cereal stubbles areas usually strongly covered by weed after harvest. IRS LISS, IRS P6 AWIFS and SPOT satellite images were used during the remote sensing assessment. The basic spatial scale and scope of the field measurements and recording (1–5 m) and that of the remote sensing one (20–60 m) sometimes caused conflicts together with the improper application and interpretation of the "risk map" notion. In 2008, the real accuracy and also potential of ragweed risk maps were cooperatively assessed on two test areas. The assessment was managed by the experts of MARD, FÖMI and LON. Collective on-the-spot checks were carried out in Somogy and Bács-Kiskun counties in 10 days after than the ragweed risk map production. The accuracy of remote sensing survey was 90%. Based on the risk maps, the Land Office experts recorded some 300 hectares of affected areas in two days! These collective checks proved that the risk maps are so efficient that 50–100 times bigger ragweed infected areas can be recorded and documented in situ if the remote sensing risk maps are applied properly. *Figure 25.5* shows the spatial statistics of ragweed risk in the settlements fields. These statistics are developed from the ragweed risk maps having been derived from satellite data.

25.3 Conclusion

The remote sensing based ragweed risk maps that orient and optimize the field inspectors and handled by the Central Ragweed Server contributed significantly to the successful Ragweed Control Program in Hungary. The good qualities of the quickly produced ragweed risk maps raise some interesting issues in cartography as well in remote sensing and integrated GIS techniques' applications. The generalization and accuracy assessment of the final product, the ease of adaptation to other areas in Europe are just some of them.

Ragweed pollen decreased by 15–20% temporarily. Ragweed area has decreased but not substantially. Unexpected, off the road monitoring stimulated to a good cooperation with land users. All performance parameters improved sharply after the introduction of the remote sensing based system in 2005. The factors of the pinpointed ragweed area improved by 40, the area in penalty cases by 10, the elimination „for the public interest" by 10 times respectively. The combat against ragweed/

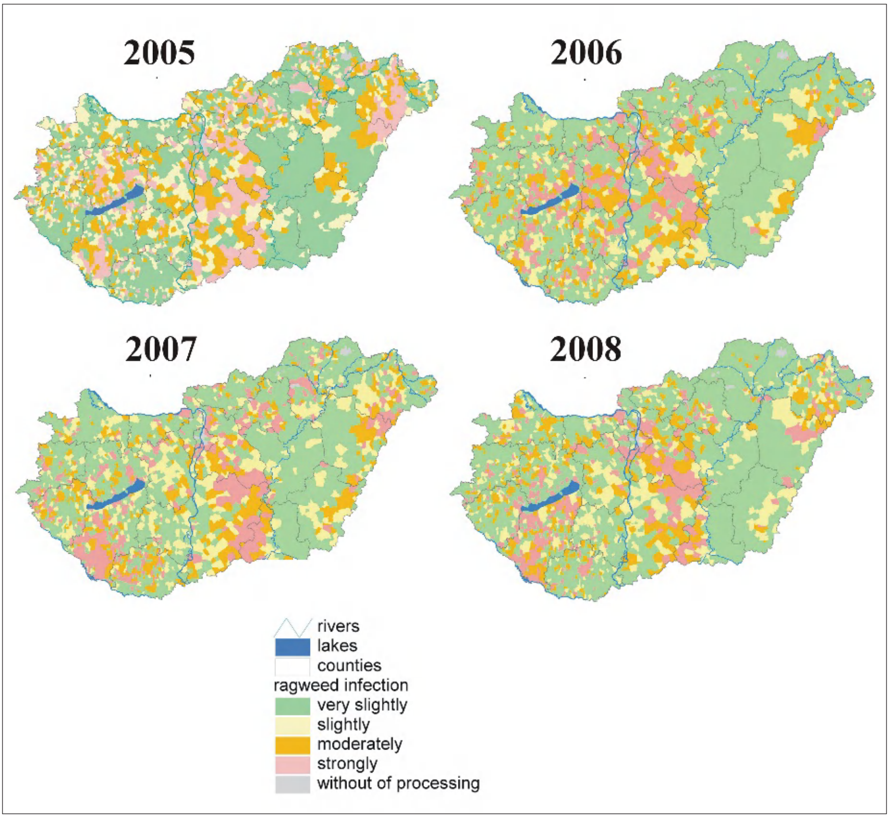

Fig. 25.5. Ragweed-risk spatial statistics of the settlements between 2005 and 2008. These data come from the quantitative evaluation of high-resolution satellite data

allergenic plants became much more organized and adequate. The system and the tasks of authorities are much more transparent. The probability of getting fined became balanced for all land users in all sectors: private, municipality, state. Four services, 400–500 officers are coordinated and controlled by a RS+GPS+GIS+WEB system.

Based on the results we can conclude that the immense problems of ragweed and pollen allergy in Hungary could not be controlled without space technologies. The introduction of four high tech components (RS+GPS+GIS+WEB) was inevitable to improve the control for a far better and efficient control. The remote sensing assessment covers the whole arable land and helps in the optimisation of in situ measurements and their documentation. The speed of the ground based components was dramatically increased by a productive geo-informational provision (remote sensing), +GPS+GIS techniques, the data exchange and the new legal provisions of the Plant Protection Law.

The Ragweed Control Program has been operational since 2005 to date. The utilizations of up-to-date remote sensing and GIS methods plus the GPS technology simplifies and makes more efficient the tasks of the site control and ground measurement with also reducing the time needed for the administration in the control. Thus it increase the success of the preventions against ragweed. This is apparently the only way to implement a system that can be successful for the ragweed control in Hungary. The model can utilize a range of satellite images. In Hungary higher resolution satellite data should be used to more radically decrease the ragweed area and their health impact.

At system level: it can influence the decrease of ragweed infected areas and pollen load. It is "spatially fair", helps to maximize the due counter actions in situ by any authorities or responsible institutions within their limited resources. The system is also a model for a wide range of integrated thematic applications of remote sensing. The most determining and inevitable subsystem is the ragweed recognition by remote sensing. It is objective, accurate, reliable, and can be used in quite different ways by adjusting the spatial-temporal-spectral image data set to the regional/local need in the same methodology framework. The applied remote sensing surveillance can certainly be used alone, for reliable information collection only. The four years' operational experiences in Hungary (~ 100 000 km^2 area) provide a good example for adaptation. All the subsystems can be tailored and adapted to a wide variety of special local and regional needs, terrain and environmental conditions ragweed stands occurrence e.t.c. Parts, components or the whole system can be operated in the European regions.

Acknowledgement

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Chapter 26

Detailed Mapping of Landslide Susceptibility for Urban Planning Purposes in Carpathian and Subcarpathian Towns of Romania

Bogdan Mihai, Ionut Sandric, Ionut Savulescu and Zenaida Chitu

Faculty of Geography, University of Bucharest, Romania
bogdan@geo.unibuc.ro, {sandricionut, savulescui, zenaidachitu}@yahoo.com

Abstract

The Carpathian and Subcarpathian towns in Romania developed under different geographical and historical conditions. Their built-up areas cover mainly slopes and sometimes terraces and higher floodplains. Some towns are old (mainly since the 14–16th centuries) but there are also newer settlements (since the 19th and even the last century). Mass movements and mainly landslides, are active morphodynamic features of the built-up areas. Since the liberalization of the immobiliary market they became important for the urban planning projects as well as for local people and the immobiliary sector. The paper we propose compares the cartographic results obtained within two case studies, featuring middle size and small towns, with two different geomorphic conditions: Predeal, a traditional mountain resort and Orsova, an entirely new rebuilt town, upstream from the Iron Gates Dam, on the Danube River in Banat Mountains. The maps were created using two different methods for landslide susceptibility assessment: probabilistic (Dempster-Shafer) and multidimensional analysis (Principal Components Analysis with logistic regression). For each town both methods were applied and the results were compared. In both cases the methods spatially delineated approximately the same areas as susceptible to landslides but with different susceptibility levels.

Keywords: landslide, mapping, susceptibility, urban development, principal components analysis, logistic regression, Dempster-Shafer

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26.1 Introduction

Since the year 2005, different regions were affected by heavy rainfalls that led to dramatic floods with important damages, in terms of life, houses, crops and infrastructure. These phenomena start to have a periodicity, related to snowmelt, in spring (March to May), then to the big rainfall and storms in July and August. The heavy rainfall that led to floods had also triggered landslides, mostly by reactivations of the old landslides. These phenomena affected also the settlements with a dramatic impact in the hilly and mountain areas where urban/rural infrastructures are old and not well maintained (bad roads, old and inefficient water drainage pipelines on slopes, old protection walls affected by the older mass movements etc.). Most of the urban settlements within these areas include districts with rural features since the 1968 administrative reform. There are some situations of some ”urban districts” which moved since 1975 from their original place to another like for example the former village of Irimesti, belonging to Breaza town in the Prahova Subcarpathians as an effect of the deep mass movements (Sandric 2008).

Mapping these phenomena became an important task for the future development of each Carpathian and Subcarpathian urban settlement. In 2007, The Romanian Government started to develop a methodology for risk mapping and assessment. This task is a part of the National Data Infrastructure Project with the main goal to finish the basic level of risk mapping in 2013, and to start the detailed risk mapping. The regional planning documents, like the territorial development plans appeared after 1991, contains schematic maps of hazard and risk phenomena to the level of each county

26.2 Data and Methodology

Detailed mapping of landslide susceptibility (Crozier & Glade 2005) is an approach that needs a big amount of data. This is the reason of developing GIS applications since the 90s (Carrara et al. 1991, Carrara et al. 1995, Van Westen 1994).

Several approaches in the international literature focuses on different featured mountain areas and put the emphasis on different type of geomorphic hazards at different scales (Donati & Turini 2002, Edbrooke et al. 2002, Gornitz et al. 2002, Giumaraes et al. 2003, Mihai 2005, Moon & Blackstock, 2004, Pasuto & Soldati 2004, Lundkvist 2005, Komac 2006 etc.).

Our approach is a synthesis of some case studies regarding two towns from the Romanian Carpathians. The paper we propose compares the cartographic results obtained within two case studies *(Figure 26.1),* featuring middle size and small towns, with two different geomorphic conditions: Predeal, a traditional mountain

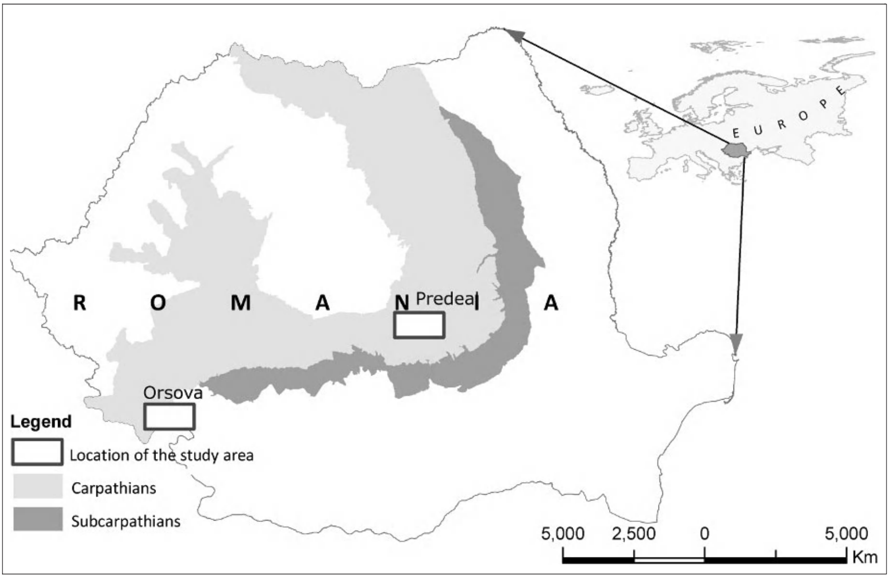

Fig. 26.1. The geographical location of the case studies urban settlements in Romania

resort to the springs of the Prahova River and Orsova, an entirely new rebuilt town, upstream from the Iron Gates Dam, on the Danube River in Banat Mountains.

The **data sources** for each of the analytic map are different. These are in fact maps, aerial and satellite imagery and field topographic and GPS measurements. One of the key features of the data for detailed mapping in Romania is the limited availability in digital format.

Various thematic maps were mostly available on analog format printed on paper and this made difficult and cumbersome the data acquisition process. These were scanned at a high resolution and then georeferenced with high precision in Stereographic 1970, datum Pulkovo 1942, the national coordinate system. Two map categories were available: the topographic maps 1:25,000 (for Predeal and Orsova case studies) and 1:5,000 (for the other analysis) and the geological maps at a scale of 1:50000. These data were sufficient in order to obtain reliable DEM in order to calculate the slope gradient, curvature, aspect and other geomorphic features. Additional data were brought through topographic and GPS survey especially on landslide bodies with an active dynamics. Geology layer was not satisfactory in terms of information amount and quality. The paper map sheets (since the 70's and the beginning of the 80's) drawn by cartographers from the Geological Institute in Bucharest were quite general and field mapping was needed especially for landslide areas and superficial deposits and soil cover. For the land use we relied on the maps provided by the local authorities. These were geometrically corrected with less than 2.0 meters RMS and then integrated into the GIS application.

Aerial imagery has been a very useful data source. Image interpretation process took a long time because the lack of data and the age of their sources (mainly 70s and 80s) made necessary the filling of these information gaps. Orthophotos since the year 2005 at 0.5 m resolution were used for digitizing the land cover data and also the infrastructures in Orsova and partially in Predeal. The last case was covered by the maps (since 2002 Predeal Master Plan, unpublished) which were updated through GPS field surveying, together with aerial photo examination (monochromatic imagery since 1985). The land cover data was derived using the classification of Corine land cover system, adapted for each case study.

Field data was essential for developing the GIS applications. Landslide areas were mapped mainly using this method. Within the built-up areas, houses, streets and other infrastructure elements superposes on landslide bodies. Most of them are dormant or with a smooth movement in time. In the most of situations, the topographic visual examination of the ground was not a source of reliable spatial data. Geotechnical studies were available only for small areas of the built-up areas (few square kilometers) and the data obtained were old (more than 10 years and not every time corresponding with the ground truth). Pedological sounding together with the rocky outcrops analysis (helped by the new building foundations opening) helped us to generate the corresponding vector layers, with the help of a GPS receiver (3–4 m error) and sometimes with total station (ca. 1.0 m of error for the largest bodies in Orsova and Predeal).

Another dataset was related to the urban landscape features. Building mapping was done in detail in Predeal, for the entire town, because new investments within this mountain resort increased their density. The existing maps were old in terms of building data; a field survey together with photography brought different data in vector format like for example the relative age, the number of floors, the destination, the degradation/improvement level of the buildings etc. Within the town of Predeal, we mapped more than 3500 buildings.

26.3 Methods

The methodology used for the landslides susceptibility mapping in Predeal and Orsova was: Dempster-Shafer theory as probabilistic model and PCA with Logistic Regression as multidimensional analysis

The Dempster-Shafer, a variant of Bayes probability theory, makes it possible to use incomplete knowledge in the susceptibility analysis (Eastman 2003, Sandric 2005).

The PCA analysis (Gorsevski 2004, Chitu et al. 2009) was used to reduce de number of variables and to eliminate de redundant information from these variables.

Table 26.1. Data used for the susceptibility assessment

Case studies (maps)		Data layers and spatial resolution						
Town	Year	DEM	Lithology	Superficial deposits	Land cover	Landslide bodies	Building, infrastructures	Method (model)
Predeal	2005	Yes 5 m	Yes 5 m	Yes 5 m	Yes 5 m	vector	vector	Dempster-Shafer, PCA with logistic regression
Orsova	2007	Yes 10 m	20 m	Yes 10 m	Yes 5 m	vector	vector	Dempster-Shafer, PCA with logistic regression

The variables were previously classified and the classes were created to maximize the information and minimize the variance inside a class.

Logistic regression (Gorsevski 2004, Chitu et al. 2009) was applied using only the first three principal components obtained from the PCA analysis, because for each town the most of the information were retained by the first three principal components. The principal components were used as independent variables and the past and present shallow landslides as dependent variable and the result was the landslides susceptibility map for each of the combination, indicating the probability that a pixel will contain a landslide.

26.4 Results

26.4.1 Landslide Susceptibility Mapping in the Town of Predeal, Curvature Carpathians, Upper Prahova Valley

Both methods (probabilistic and multidimensional analysis) were used to map the landslide susceptibility in Predeal. An important task was first to map at a more accurate level (more than 4–5 m) the landslide areas within the Predeal town built-up area. The geotechnical data available was limited only to the north-western part of the built-up area and its age (1990) limited its value. A field survey using a GPS receiver, together with a pedological surveying made possible the mapping in vector format, of the landslide areas.

The maps with the susceptibility assessment produced using the Dempster-Shafer and PCA with Logistic Regression are presented in the *Figure 26.2.* The main factors that contribute to the high susceptibility values were the slope declivity (0.61–0.65), together with land-cover (0.47–0.5), and then slope deposits and lithology. For each map three classes of susceptibility were defined. The classes were created by splitting in three equal intervals the 0–1 probability scale resulted for each map/each method.

The risk assessment can be made by overlaying of the urban built-up area features and infrastructures on the detailed susceptibility map obtained. The resulting docu-

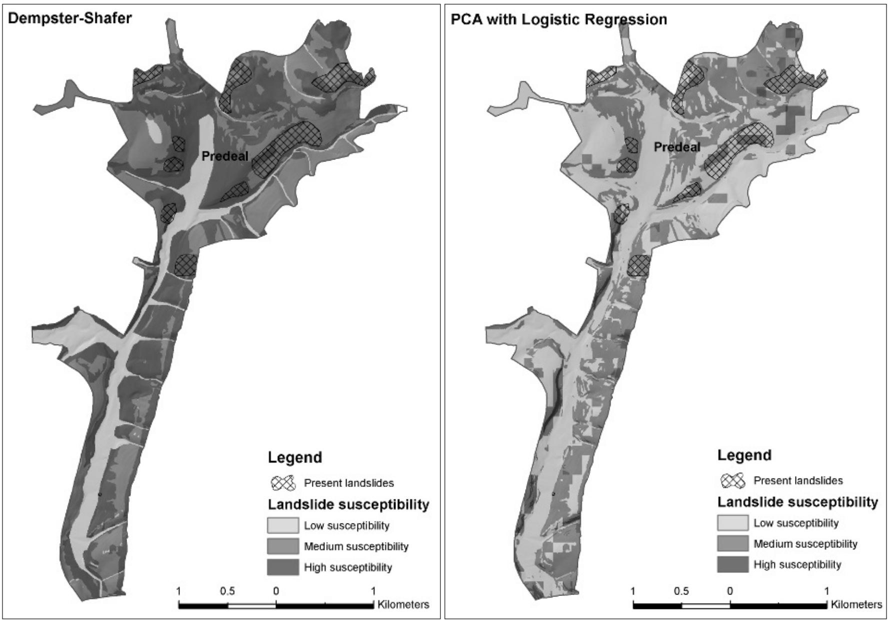

Fig. 26.2. Susceptibility assessment produced using the Dempster-Shafer and PCA with Logistic Regression

ment, updated from the most recent Master Plan of Predeal (drawn by Proiect Brasov since 2002, unpublished) can be useful for the new urban development plans. The town is featured since 1992, but especially since 2001 (the Law for the Restitution of Nationalized Houses to their former owners) by a real immobiliary fewer. Old houses since the 30s and 40s were repaired, destroyed and rebuilt, but new secondary residences and small private hotels and inns appeared within areas where landslides started to reactivate because of deforestation and topographic reshaping of slopes. The visualization possibilities can improve the mapping because we have developed for each building an attribute table with all their main features (year of building, degree of conservation, number of floors, destination etc.). Since 2005, some of the oldest houses started to be affected by mass movements and cracks within their walls are evidence.

Both methods had identified approximately the same areas as susceptible to landslides, but with different susceptibility degrees. The ROC analysis (Pontius 2001) was used to validate the results obtained for both methods and is presented in *Figure 26.3*.

The ROC analysis values resulted for the both maps were between 0.74 for the PCA wiuth Logistic Regression (LR) and 0.73 for the Dempster-Shafer theory, bu the ROC curve from the *Figure 26.3* clearry display a sliglty better result for the PCA with LR in identifying the areas susceptible to landslides in Predeal.

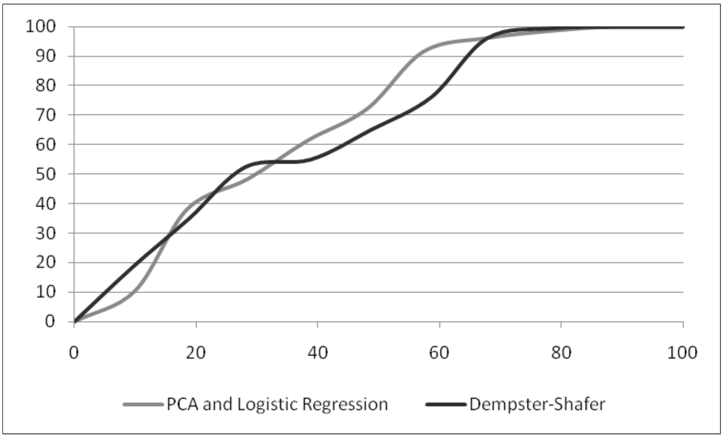

Fig. 26.3. ROC graph showing the validation of the two susceptibility maps for Predeal town

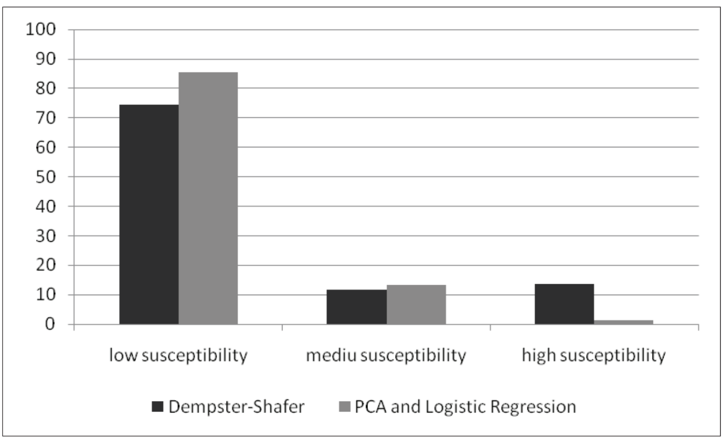

Fig. 26.4. Differences in the percent of the areas identified as susceptibile to landslides for Predeal town

From *Figure 26.4* we can see that the PCA with LR has identified more areas as low and medium susceptible to landslides, but far less areas with high susceptible to landslides that Dempster-Shafer. By comparison the best result is the map obtained from the PCA and LR for the low and medium susceptibility levels and the map obtained from the Dempster-Shafer for the high susceptibility maps, as can be seen, also, from the ROC curves presented in *Figure 26.3*.

26.4.2 Landslide Susceptibility Mapping in Orsova Town, Danube Valley, Banat Mts

The town has a particular evolution, because since the creation of the Iron Gates Dam Reservoir in 1964–1972, between Romania and Serbia (the former Yugoslavia at that time), all the settlement along the Danube's Iron Gates Sector (The Djerdapska Klisura in Serbian or Eisernes Tor in German), had to move up on the slopes. About 17,000 inhabitants lost their homes which were rebuilt within new settlements built-up areas. Water level rise with 35 m behind the new created dam building designed for navigation improvement and hydroelectric power.

Orsova town was one of these settlements which emerged on the mountain slopes of the Almaj Mountains and the Mehedinti Plateau, between 1966–1971, when the old town together with other three villages (Coramnic, Jupalnic and Tufari) situated on the terrace tops around the Cerna- Danube rivers junction disappeared after the controlled flooding of the lowest level of the small depression of Orsova (floodplain and the lowest terrace levels).

Mapping the landslide susceptibility became a necessary task because the new town site was a less stable one. New buildings (block of flats, villas, public buildings, including the railway, bus and boat station) moved on new grounds, some of them stable (top of terrace remnants), but a lot of them less stable (old landslide bodies superposed on the Miocene sandy-clay with gravel deposits filling the Orsova-Ogradena basin). A relevant thing is the occurrence of a betonies clay big body to the upper part of the basin, an area where houses and the national road to Moldova Noua were yearly affected by mass movements and even seriously damaged.

The landslide bodies were mapped in field, in built-up areas through sociological investigation and house state examination. We convert them to vector format, after

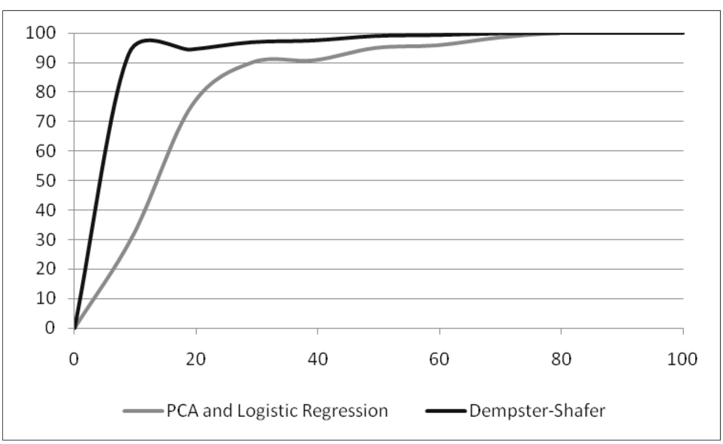

Fig. 26.5. ROC graph showing the validation of the two susceptibility maps for Orsova town

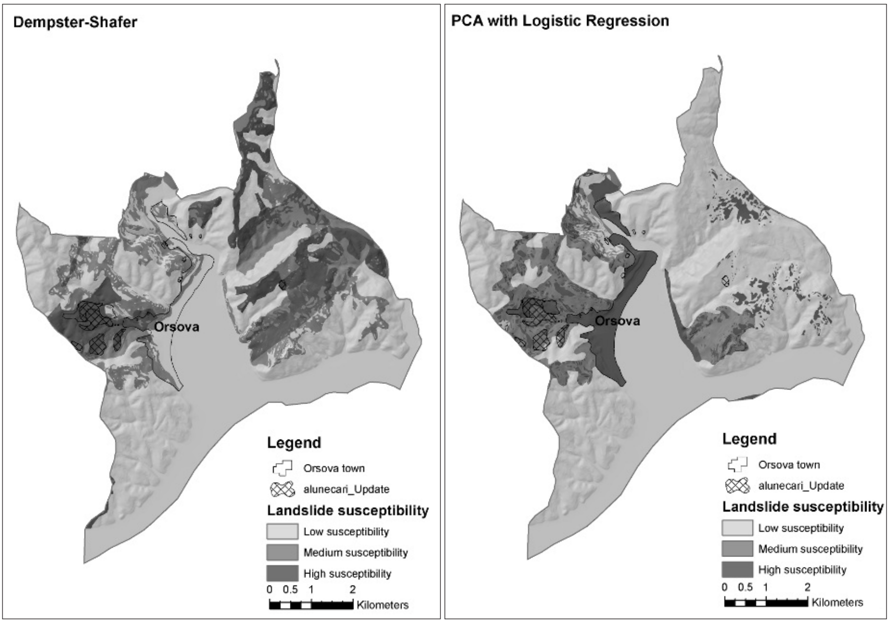

Fig. 26.6. Landslides susceptibility maps for Orsova

a complete examination of ortophotos. A field validation followed with a complete updating of these areas through a GPS survey. Finally all the landslide occurrences were recognized in field, and redrawn according to the field situation. It was possible to discover and map new landslides areas and the slope susceptibility to landslides was confirmed (4–5 bodies on less than 10 km^2).

The ROC analysis values resulted for the both maps were between 0.83 for the PCA wiuth Logistic Regression (LR) and 0.94 for the Dempster-Shafer theory from which we can conclude that in the case of Orsova the Dempster-Shafer theory has better identifed the spatial distribution of the areas susceptibile to landslides. The ROC curves shows a very good validation of the Dempster-Shafer theory and in the same time a good validation for the PCA and LR model, the differences beeing for the all three levels of susceptibility

From *Figure 26.7* we can see that Dempster-Shafer method has identified more areas as medium and high susceptible to landslides and a bit less areas as low susceptible to landslides. By comparison the best result is the map obtained from the Dempster-Shafer, which has identified better the actual landslides bodies and areas with similar conditions. From the *Figure 26.6* we can observe that areas with high susceptibility to landslides are present on the hill slopes of Orsova town, very close to the Cerna bay. For this area the high susceptibility is false, the result being highly influenced by the contribution of the built-up area from the north-eastern part where due to lithological background, the landslides have a high density.

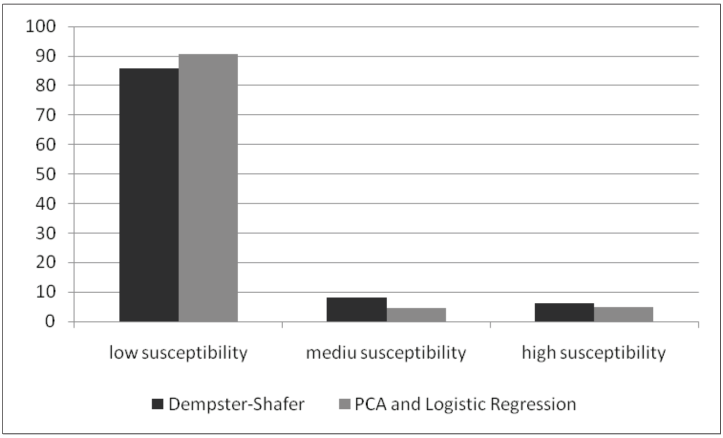

Fig. 26.7. Differences in the percent of the areas identified as susceptibile to landslides for Orsova town

From the maps analysis is easy to observe the areas where landslide bodies features mainly the Turlui catchment where the town centre and the western districts developed, along the national road to Moldova Noua. The landslide high susceptibility areas correspond for Dempster-Shafer method to more than 80% of the mapped landslide bodies and more than 60% for the PCA with Logistic Regression method, but there are also some dormant areas of future mass movements. These are overgrazed areas with poor quality roads and footpaths and less efficient slope drainage works. Superficial landslides could appear on the slopes of the gullies within the town built-up areas where poor quality old drainage works occur. The maps show the situation of a town rebuilt in a short time (5 years) with a population of more than 12,000 inhabitants, covering a limited area, less stable than the former town site.

26.5 Discussion

The landslide susceptibility maps for each town were drawn with slightly different datasets. The main problem was the data availability, and the data quality. Data was seldom available in digital format, in all these situations. Some maps were scanned a stitched using the image processing packages (the Predeal town master plan maps). Other maps were like the topographic plans of Orsova town (1:1,000) were in a digital drawing format, which was converted into shape file format but with a poor geometric quality. This was the reason they were used only on fieldwork for data display and validation to the level of topography, building and urban infrastructures.

Another problem is the amount of digital layers integrated within the analysis. Their number is usually limited because the subsequent data acquisition needs fieldwork investigation and measurements. An example is the availability of underground water data, which represents a condition for landslide triggering. The water table is not continuous and the existing hydro-geological data is old and of quite poor quality. Other data, like the pedological data was available because of the pedological sounding carried for slope deposits morphological analysis.

Mapping of landslide susceptibility is a long process. Database building takes a long time because of the low data quality which needs also new data sets acquiring. For example, land use- land cover data was not enough within the available cartographic documents. Topographic maps at different scales are old and does not show a detailed data (1:5,000 dates since 1975 and 1:25,000 were updated since 1982). Satellite imagery usually available had a limited role within the data acquisition process because the towns are quite small and their resolution is limited. The best image used was the SPOT a high resolution visible image since 1997 for the Predeal area (10.0 m); this was subjected to a complex visual interpretation. The best available data is represented by the orthophotos in digital format, since 2005, which were interpreted for the land cover classification using the CORINE land cover legend system.

Validation was the most important step for mapping. This is a longer process, because landslides can occur in different places but not every time along the years. For some of the maps this process almost finished but for some of them we evaluate the result. For example, in Predeal town the validation was done in different points were shallow landslide occurs on almost all slopes where spruce fir trees were removed for making grounds for new villas. Small cracks were mapped on the walls of houses in Orsova towns and they must be followed in time. Local enquiries help the validation process.

26.6 Conclusion

The maps presented within the paper are the first similar applications in Romania, although there were few similar contributions at lower scales previously (Armas *et al*. 2003) for the Subcarpathian sector of the Prahova River Valley. The approach had three main goals: the searching of a better digital modeling and mapping methodology, the evaluation of the results and also the transfer of the validated maps to the local authorities. These objectives can be reached when the local authorities collaborates with the research team. They can help the data acquisition process and then the validation process of the final maps. Fieldwork difficulties can easily appear because of the permanent need to access on private ownership. Sometimes, aerial ortophotos can help the ”access” in this areas but their resampling level can affect the detailed visual analysis. The detail degree of these maps is another discussion topic. Usually we start from the DEM resolution and from the other data resolution. GPS data is available at resolution of 3–4 meters, but this can be improved for landslide body limits to tens of centimeters using total station (Orsova biggest landslide in the Turlui catchment or differential GPS surveying (Predeal northern area on Cioplea Hill). The mapping scale can help the distribution of errors to the level of the whole digital map.

These maps will be a necessary document for the urban planning project development, like there are in a lot of European Union countries. They can be attached to the master plan maps which must be updated every ten years. The building licenses can be issued also taking into account these maps.

Acknowledgement

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Chapter 27

Dynamic Cartographic Methods for Visualisation of Health Statistics

Radim Stampach[1], Milan Konecny[1], Petr Kubicek[1] and Edvard Geryk[2]

[1] Department of Geography, Masaryk University, Brno, Czech Republic
{63780, konecny, kubicek}@mail.muni.cz,
[2] University Hospital Brno, Czech Republic
egeryk@fnbrno.cz

Abstract

The article deals with interdisciplinary research on health status data analysis and so-called ‘health cartography’ mapping approaches. In the first part existing cognitive studies and recommendations on map design are discussed.

The following part describes current trends in cartographic visualisation and non-traditional methods for exploratory cartography. Examples and possibilities of modern cartographic tools for dynamic presentation, publication, and analysis of health data are mentioned. The term ‘dynamic presentation and publication’ describes the possibility of selecting the required scale to allow interactive creative communication of users and map authors and also the presence of active statistical tools.

A medical web portal project for presentation of health data with special focus on cancer prevalence is described in the last section. The portal should be used for educational and informational purposes and exploratory tools will be part of it. Suggestions as to which tools would be appropriate for particular demands are offered.

Keywords: cartographic visualisation, health data, exploratory cartography

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Lecture Notes in Geoinformation and Cartography, DOI 10.1007/978-3-642-03294-3_27,

27.1 Introduction – Why Use Maps for Health Statistics Presentation?

It is estimated by the IARC Lyon Globocan database that 10.862 million new cases of cancer were diagnosed worldwide in 2002. In the same year 6.724 million people died. The situation in the Czech Republic is no brighter. Data from the Czech National Cancer Registry predict that the number of cancer cases will increase year to year. In 1989 the figure was 174 000, in 2004 it was 434 000 and 610 000 is predicted for 2015 (Geryk et al. 2007). It means that 6% of the inhabitants of the Czech Republic will live with a diagnosis of cancer in 2015! More than 30% of the Czech population is confronted with cancer during their lifetime and 25% die of it. The incidence of some cancers is moving to younger age groups (Dite et al. 2008).

The phenomenon places stress on the health care system. A higher number of cases needs greater expenditure on health care – 300 million Euros were accounted for by all cancers in 2005, according to Czech cancer sites. The state budget, however, is not increasing as quickly as the number of cancers. The situation is like a time-bomb, and there is only one possible answer. We have to support people to change their lifestyle and to use prevention. Early recognition of cancer increases probability that therapy will be successful and cheaper. We must inform the general public about the problem and the possibilities. Actually, it might be better to say ‘terrify them’.

Cartographical visualisation is a possible method for presentation of health statistics, including cancer. A good map is more interesting and visually pleasing to the user than a table with numbers. Cartography can be also used for monitoring and analysing a situation – in space as well as in time. The oldest known medical map is probably Arietta’s map of plague in Bari from 1694 (Koch 2005, p. 19). Maps were also created during the epidemic of yellow fever in New York harbour in the 1790s. The most famous is the map of the London cholera epidemic in 1854 published by John Snow in 1885. Since that time, numerous medical and health status maps and atlases have been published. During the last twenty years maps have been created mostly by computers and cartographic software. At the present time more and more medical information is published over the internet and visualised in a different cartographic manner.

This article is organised as follows. *Section 27.2* describes the main results of health statistics mapping cognitive studies and the appropriateness of traditional cartographic methods used. *Section 27.3* deals with the cartographic exploratory techniques for health data mining, exploration, and visual analysis. *Section 27.4* focuses on the preliminary results and future plans of the experimental web portal for dynamic presentation, publication and analysis of medical statistics in the Czech Republic.

27.2 Cognitive Studies of Health Statistics Maps and their Recommendations

Medical as well as other maps should accept cartographic legibility rules, regardless of whether a map is printed on paper or published on the web. They are not only used by professional cartographers. They are used by medical specialists and also by the general public. Too complex or confusing a map can cause users, especially non-cartographers, to misinterpret its data. Health maps and statistics are used for important decisions, e.g. disease predictions, and serve for prevention planning. A bad interpretation can therefore have far-reaching consequences.

Personal data protection is also an issue. Data about patients and health are very sensitive. Current practices in spatial analysis of health (specifically cancer) data as well as methods to protect confidentiality were described by Bell et al. (2006). The authors treated effective health statistics mapping very seriously to inform different groups of end users. Because health maps have raised public concern, it is essential that these maps are designed to be accurate, clear, and interpretable for the broad range of users who may view them. Map design includes deciding on the purpose, and knowing the audience and its characteristics, skills, preferences, etc. The best way to evaluate the effectiveness of a specific map design is still to ask potential users to talk about what they see (Bell et al. 2006). It is also useful to get inspiration from cognitive studies.

In the last decades many cognitive studies have dealt with the best way to visualise statistical data in medical maps and make them easily readable. A complex set of experiments is described by Pickle (2003). As regards earlier works about this topic, the work of Lewandowsky et al. (1993) is worthy of mention.

In Pickle's study (2003), maps of various styles were tested by medical specialists. They assessed how they worked with maps, if they could read rates from maps accurately, if they were able to identify cluster patterns and how they compared two maps. This research showed that non-cartographers liked classic choropleth (classed, area shaded) maps and used them accurately (Pickle & Herrmann 1994).

Searching for an ideal colour combination for a map is also described by Pickle (2003, pp. 4–6). The results agree with general cartographic recommendations. The well-composed double-ended colour scale was better than the grey scale, although, consistent with expectations, the grey scale was only slightly inferior to colour for cluster identification.

An important part of each cognitive study is the question of how to indicate rate reliability in some areas. Many works solved this problem by blanking out areas with unreliable rates. Experiments show that it is not a good way (Lewandowsky et al. 1995). MacEachren et al. (1998) compared three methods of data reliability visualisation – colour saturation reduction, double white-black diagonal hatching, and separation of the rate and reliability information into two separate maps. The result of the comparison was: 'Map pairs (separation of the rate and reliability information into two separate maps) and hatching performed better than the color saturation reduction method for comparison of regional rates and selecting the most reliable region' (Pickle 2003, p. 7).

General recommendations from the mentioned studies for making statistical maps for non-cartographers can be summarised as follows:

- choropleth maps are preferred
- colours should be chosen consistently with colour conventions
- identify unreliable rates; do not blank them out.

27.3 Exploratory Cartography – New Technologies, Tools, and Possibilities

Nearly all maps recently produced by modern technology are based on computers and many maps are published on the newest medium – the internet. A combination of these facts brings new possibilities for cartographic visualisation and map use. Nowadays users can not only read the data which map-makers have prepared for them, they can explore data they are interested in, and they can find new hypotheses in this way. This is a base for 'exploratory cartography' – connection of the advantages of maps and an electronic environment controlled interactively by a user. The term 'exploratory cartography' was introduced by Dykes (1997).

Exploratory tool principles have been explained by Robinson (2005, p. 1): 'Geovisualization tools are born from a desire to build maps that people can interact with and explore in a real-time, dynamic manner. As analysts are faced with ever-increasing amounts of spatial data, we need to provide maps and other visualizations that facilitate exploration'.

27.3.1 Correlation-Exploring Tools

Many types of exploratory tools are tools for exploring the relationships between two or more variables and can help to make hypotheses, e.g., between cancer rates and risk factors. The commonest tool of this type is a **scatter plot**. Values are displayed as a collection of points, each having the value of one variable determining the position on the horizontal axe and the value of the other variable determining the position on the vertical axe. In a **parallel coordinate plot** (PCP) each observation is drawn as a string passing through vertical axes, which represent data categories. Robinson (2005) and Pickle (2003) wrote about PCP implementation.

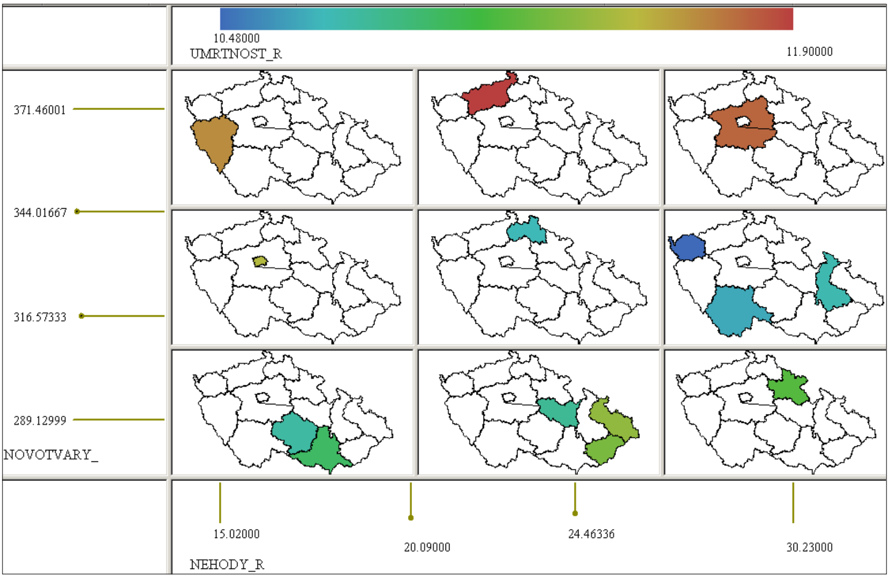

Fig. 27.1. An example of conditional maps. It searches for the correlation between general mortality of men (colour), mortality of men caused by car accidents (horizontal axe), and mortality of men caused by oncological diagnoses (vertical axe) in the Czech Republic in 2003. Administrative units with high values of the general mortality (dark colours) are visualised in the upper row – in the interval with high mortality rate. Therefore these variables probably correlate with each other. No correlation between general mortality and car accident mortality is visible. Program: GeoDa (Anselin et al. 2006). Data: Institute of Health Information and Statistics of the Czech Republic

The conditional maps tool is different from other 'correlation exploring' tools because it uses maps. It makes it very interesting for cartographers. A single choropleth three-class map is decomposed into nine micro-choropleth maps constructed by conditioning on three intervals for two conditioning variables. An implementation of conditional maps is described by Carr et al. (2002) and Anselin et al. (2006). An example is shown in *Figure 27.1.*

27.3.2 Other Tools for Exploratory Analysis

Not only correlation exploring tools are important for exploratory analysis. It is also very useful to know the **statistical distribution** of visualised variables. The distribution is important for setting the number of intervals and interval borders. Many tools can also find 'outliers' – values which are very different from the rest of the dataset. Geographical data differ from place to place but values can also vary in time. One tool which shows change in time is called a **time series graph**. It was described in the work of Robinson (2005). This tool does not use maps, as variables are visualised in a customised x-y graph.

Some tools belong to a map-based exploratory tool. A **cartogram** is a classic cartographic technique used in statistical maps. An area border (e.g. administrative or enumeration unit) is adjusted to represent a value of some statistical variable in this area. It helps to compare values of the variable in various area units. This technique is not often used in electronic maps because of difficult implementation. Sometimes an areal unit is replaced by a single geometrical shape (e.g. circle), as in *Figure 27.2.* This type of cartogram is described by Dorling (1994) and an implementation of this approach is described by Anselin et al. (2006).

Animations are favourite tools of many users, especially those who are not used to working with graphs and other statistical utilities. Animations have great potential, especially for the visualisation of changes in time. Ogao (2006) pointed out that animation can be a very helpful tool but only if users can interact with it. which means it should not only have play/stop control but also connection with other visualisation types like scatter-plots, graphs, overview maps, etc.

27.4 Exploratory Tools for Web Portal Project for Medical Statistics Presentation

An interdisciplinary team including cartographers, epidemiologists, media specialists, and computer scientists from Masaryk University, the University of West Bohemia, and University Hospital in Brno is currently solving two projects (MediCarto and VisualHealth) dealing with medical statistics visualisation and its effective presentation to different end-user groups.

The MediCarto project concentrates on utilisation of modern cartographic tools for dynamic presentation, publication and analysis of data concerning health condi-

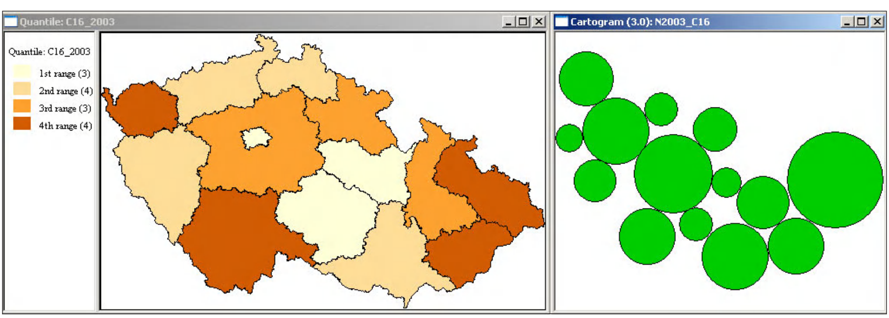

Fig. 27.2. A combination of a classic choropleth map and a circular cartogram. The map on the left shows the prevalence of stomach cancer per 100,000 men in the Czech Republic in 2003. The cartogram on the right represents raw values of the prevalence. Program: GeoDa (Anselin et al. 2006). Data: Institute of Health Information and Statistics of the Czech Republic

tions and healthcare. The term 'dynamic presentation and publication' is used chiefly to describe the possibility of interactive creative communication of users and map authors, and also the presence of active cartometric and statistical tools. The basic conditions for such a publication are cartographic correctness and legibility of given visualisation.

VisualHealth is partly exploiting the interactive tools developed within the framework of MediCarto, making them publicly available as part of a web portal for medical data presentation and visualisation or for educational and other purposes. A substantial part of the portal will consist of tools for health statistics visualisation and exploration. Following the recommendations summarised in *Section 27.2,* these tools must not be too complex, because the portal is primarily intended for general use. As Anselin et al. (2006, p. 6) have pointed out: 'It was readily recognized that a major instrument in disseminating and facilitating spatial data analysis would be an easy-to-use, visual, and interactive software package aimed at the non-GIS user and requiring as little as possible in terms of other software (such as GIS or statistical packages)'.

For the MediCarto project, different types of data have been collected and analysed including: demographic data, health condition, health care and economic data – e.g. numbers of cases of various diseases including cancer, numbers of patients and hospitalisations, economic data of hospitals and many other indicators related to health conditions and healthcare. The sources of data are official national statistical databases like the Institute of Health Information and Statistics of the Czech Republic, the Czech Statistical Office and others. All data are publicly available and are collected and stored with respect to personal data protection. The data have been analysed with the focus on the dynamics of their development. The statistical modelling and prediction of selected indicators of health condition and healthcare have been accomplished (Geryk et al. 2008, Odehnal et al. 2007) and will be part of a data visualisation time series. For purposes of data presentation on the web portal the data will be stored in a PostgreSQL database. The web portal exploration and presentation tools will connect to the database and visualise data stored in it. Web portal tools were selected according to the data that are available.

Most of the data will be updated annually, and longer or shorter time series of many medical variables will result. This is the reason why time series visualisation and trends representation tools will be implemented. An important part of exploring health statistics data is making hypotheses about risk factors and adequate prevention. An important project goal is research on correlation between the quantity and costs of health care. For this purpose some tool for exploring relations between data is essential.

It was recommended that two tools should be implemented in a first phase, one tool for time series management and a second tool for exploring correlations. Tools for our portal were projected to be easy to use and understand.

27.4.1 Time Series Visualisation Tool

Some existing programs can be used for visualisation of how values are changing in time. ESTAT (Robinson 2005), GeoDa (Anselin et al. 2006) and others can be mentioned. Tools for analysing change in time are implemented as an x-y graph in these softwares. We want to produce it as a map which is changing in time, however, because we believe that it is important to see the relation between value and its location in territory. This tool will be part of the medical web portal and be easily accessible by the general public. Java Applet technology was chosen because of its independence from the operating system of the user's computer.

In order to take into account the results of cognitive studies from *Section 27.2* (Pickle 2003, Lewandowski et al. 1993), the map is visualised as a classic choropleth map. The map uses administrative units for basic spatial differentiation, since all the health statistics are geocoded on these enumeration units with a different level of granularity (regions, districts, postcodes …).

Some authors argue that this can hide the real pattern of the topic because the disease does not respect administrative borders (Beroll et al. 2007, p. 9, Kubicek et al. 2008, p. 93) and because unreliable rates can occur for sparsely populated areas (Goovaerts 2006, p. 2). The variables that we want to present, however, are collected only for these administrative units. To minimise this problem, a user is given the chance to show the chosen variable in various administrative unit levels including municipalities. In such a small unit, a natural pattern would be preserved.

The tool presents values from the past but also values predicted for the future. The idea of its main window appearance is shown in *Figure 27.3.* The user drags the knob along the time slider (A) and the map changes. The user can choose from various colour scales (B). Naturally, we put the accent on cartographic accuracy, so colours are used according to Brewer (2008).

The map uses a continuous-tone scheme. A disadvantage of this type of scheme is that the user is not able to distinguish so many tones and s/he cannot eye-fix an exact value of the specific region. This problem can be solved easily in the electronic environment. Exact values (or other information) can be shown on demand – for example, when the user drags the mouse over the region (C). The user also has the possibility to change continuous colour scale to scale using quantiles and to decide the number of intervals. Quantile classification was chosen because it was recommended by Pickle (2003, p. 8) and because it is easier to find its interval limits than those of other classifications, e.g. natural breaks.

We also implement animation (E) of time segments chosen by the user. Animation interactivity is important, as mentioned in subsection 3.2. The user is able not only to start or stop it, but s/he can also choose the speed of animation. The exact value of each region can be checked by tooltips (C), even during animation.

When animation is used with continuous colour scale, the region's colour changes, even in the case of very small change of value. It means that nearly every region has a different colour every year. So many changes can be overwhelming for the user's eye. The problem can be solved by excluding part of the overwhelming signals from the representation and focusing on subsets of interest (Blok 2005, p. 77, Turgukulov 2007, p. 29). A type of 'zoom' is implemented into our time-series tool. The user has the chance to choose some subpart of the map, e.g. only one region instead of the whole Czech Republic. Changing of attributes in time is then visualised only in this subregion.

Probably users will want to compare two points in time or two attributes with each other. Our time-series tool can visualise two or more maps at the same time. It allows comparison of more variables or one variable in various years. The table allows the user to see the data from all years (D).

27.4.2 Correlation-Exploring Tool and Other Plans for the Future

It was recommended to implement a specific tool for finding relations between variables. From the tools described in *Section 27.3* we chose conditional maps as best suited to our scientific purposes. An example of their implementation is shown in *Figure 27.1*. They seem to be more user-friendly than the PCP or scatter plot, at

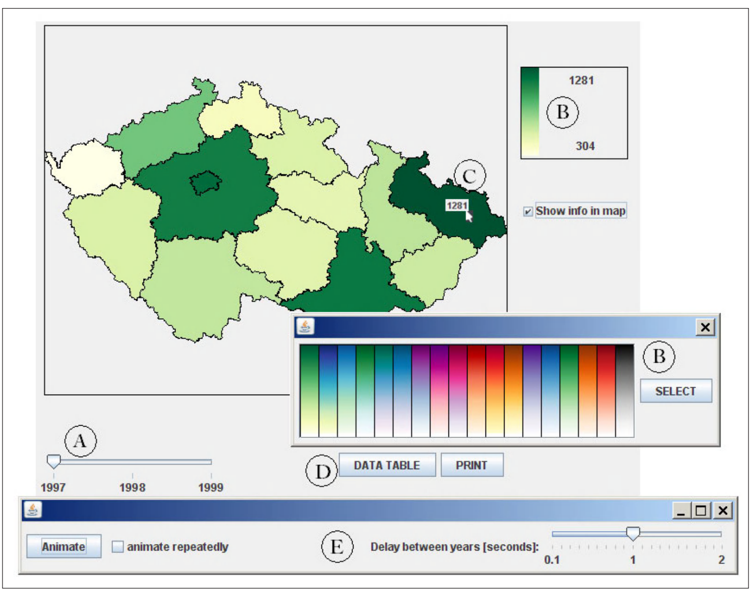

Fig. 27.3. Proposed main window of a tool for the presentation of change in time. An image of a map changes according to the user's manipulation with a slider. Choropleth map uses a colour gradient, which can be chosen by the user. Description in text

least for users with basic cartographic education. The user sees the value as a colour of the administrative unit in a map, not only as a dot in a scatter plot. Another advantage is that the user can modify intervals and explore data in real time. It helps the user to create and examine hypotheses about patterns in spatially-indexed statistics (Carr et al. 2002).

The design of our tool has not been finalised yet but these functions will be included:

- The user will choose two (or maybe three) variables whose relation s/he wants to find.
- The user will be able to choose a colour scale for the map. Colours will be implemented according to Brewer (2008).
- Exact values will be shown in the map on demand.
- A table with all values and attributes will be shown.

This tool was originally developed as a Java application to reside on the researcher's own computer (Carr et al. 2002). It is not proposed for connection to a database. Another implementation of this tool is in the desktop application GeoDa (Anselin et al. 2006). Our tool, however, will work on web servers with a connection to a database. For this purpose we will use and modify an original application from Carr et al. Completion of this tool is the most important part of our plans for the future.

When developing any new tool, it is important to know the feedback from users. What is missing? What is misleading? Testing and consultations with users are realised during the tool's development.

One possible improvement is statistical distribution visualisation in the main window of our tools. Users will have the chance to explore data outliers, data trends, etc. Statistical distribution will be connected to animation, so users will be able to see the trend of attributes in time.

27.5 Conclusion

Technological development brings new possibilities for health data presentation. Great amounts of data can be provided on the web for both the general public and groups of specialists and can be visualised and used for creating new hypotheses or for predicting future situations. Various tools of exploratory cartography are ideal for this purpose because 'a picture may be worth a thousand words, but a map can represent millions of data points' (Pickle 2003, p. 1). A map must present these data points in such a way as to be readily understandable by users. Cognitive studies suggest that classic cartographic rules are still valid even in an electronic or web environment.

The combination of an interactive exploratory-oriented tool with a classic type of cartographic visualisation will be also used in the projected web portal for medical data representation. In the first phase of its development one tool for time series management and one tool for variable-to-variable relation searching will be implemented. Improvement of both tools is planned on the basis of interactive questionnaire feedback by portal users.

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Chapter 28

A Multiresolution, Reference and Thematic Database as the NSDI Component in Poland – The Concept and Management Systems

Paweł J. Kowalski[1], Robert Olszewski[1] and Joanna Bac-Bronowicz[2]

[1] Department of Cartography, Warsaw University of Technology, Poland
{p.kowalski, r.olszewski}@gik.pw.edu.pl
[2] Institute of Geodesy and Geoinformatics, Wroclaw University of Environmental and Life Sciences, Poland
bac-bronowicz@kgf.ar.wroc.pl

Abstract

The paper presents the general concept of a multiresolution database and methodology of harmonisation of reference databases, which create the resources of geodetic and cartographic data in Poland. Utilisation of a coherent conceptual model of a reference database is of key importance for development of spatial data infrastructure in Poland. Such coherent mechanisms of spatial data exchange between many state registers have not existed in Poland. This situation may be changed as a result of introduction of one, coherent topographic database; this will also allow to synchronise those registers.

The authors have developed a concept of the multiresolution database, using the general concept of the MRDB type database, as well as Polish experiences existing in this area. The most important features of the Multiresolution Topographic Database (WTBD) are: possibility to integrate various information resources, systematisation of data integration processes, automation of map production processes and limitation of multiple data gathering by various map producers.

The authors have also proposed the concept of integrated systems of topographic and thematic map production basing on collected reference data and have implemented systems of management of elevation data, thematic data and a set of data stored in the National Register of Geographic Names. A prototype of geoinformation website have been also developed within the frames of the discussed Project.

Keywords: MRDB, reference database, thematic database, visualisation

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28.1 Introduction

The concept of development of a multiresolution database, as a key component of the NSDI appeared in Poland several years ago. The outline of the first ideas in this field was presented during the ICA Conference in A Coruna (Gotlib et al. 2005a, Gotlib et al. 2006). The concept of harmonization of reference databases resulted in launching the research and implementation project: "Methodology and procedures of integration, visualisation, generalisation and standardisation of reference databases, which are accessible in state geodetic and cartographic resources, as well as their utilisation for development of thematic databases".

The main purpose of this Project was to propose the rules of development of a multiresolution reference database for the entire country. The second aim was to develop the project of integration of various spatial data registers. The existing registers are maintained by various state institutions and co-operation of those registers has been considerably limited. The reference topographic database would be a platform of integration of state spatial data and should become the basis for development of official thematic databases.

Between many activities approved to be realized in the project there are:

- harmonization of conceptual model of the TBD and VMAP L2 of the second edition,
- integration of the DTM and thematic databases with vector data in MRDB reference database,
- implementation of the gazetteer (with hydrographic names, number of roads and names of localities),
- cartographic presentation of various levels of generalization,
- publication of geoinformation services with reference and thematic data.

The paper summarises the final results of research stage of the Project carried out by the Wroclaw University of Environmental and Life Sciences (formerly: Wrocław Academy of Agriculture) and commissioned by the Ministry of Science and the Head Office of Geodesy and Cartography (GUGiK) in the period 2005–2008.

28.2 Multiresolution Reference Database

In Poland many institutions deal with development and management of spatial databases and public registers, which depend on appropriate legal regulations. Such institutions include: the Head Office of Geodesy and Cartography (GUGiK), the State Geological Institute (PIG), the Institute of Meteorology and Water Management (IMiGW), as well as voivodship and marshal offices. The GUGiK maintains the state resources of geodetic and cartographic data, which comprises series of registers, spatial databases, maps in digital and analogue forms, as well as numerous geodetic elaborations.

The following databases, which are included in the state resources of geodetic and cartographic data, have been utilised for implementation of individual task:

- The Topographic Database (TBD) and its simplified version, the TBD2;
- The VMap Level 2 database and its useful version, known as the VMapL2u database;
- The new edition of the VMapL2+ database;
- Thematic databases: sozological (SOZO) and hydrological (HYDRO) databases;
- The General Geographic Database (BDO);
- EGiB – cadastral database;
- orthophotomaps (ORTO);
- altimetric data: NMT – a separate component of Topographic Database, DTM from Land Parcel Identification System (LPIS) database, DTM developed within the frames of SMOK – flood protection systems;
- state registers: The State Register of Borders, The State Register of Geographic Names, the Register of Territorial Units TERYT, the Hydrographic Division Database etc.

Issues which appear, concern various conceptual models, lack of mechanisms of their topological and attribute harmonisation, as well as diversified levels of the content timeliness. Therefore, the development of the concept of harmonisation of databases, within the multiresolution database has become the leading task within the discussed Project *(Figure 28.1)*. First of all this concerned specification of the basic, reference data set for Poland. The proposed concept is based on two basic assumptions:

- the necessity of maximum utilization of the existing resources of data,
- the possibility to maintain certain level of autonomy of particular databases and the possibility to perform stage synchronization with remaining databases.

It has been assumed that the Topographic Database (TBD), which implements possibly the best conceptual model of topographic databases in Poland, will be the basic resources of spatial data. Thus, the presented concept does not assume to develop one, integrated spatial database in Poland, but a system of databases, the core of which will be the Multiresolution Topographic Database (WTBD). It should be stressed that the discussed solution assumes that two levels of conceptual generalisation co-exist, providing that one level of geometric accuracy is preserved, which corresponds to analogue works performed at the scale of 1: 10 000.

The TBD data resources consist of four components: the vector databases (TOPO – DLM), the orthophotomap of 1m resolution (ORTO), the Digital Elevation Model

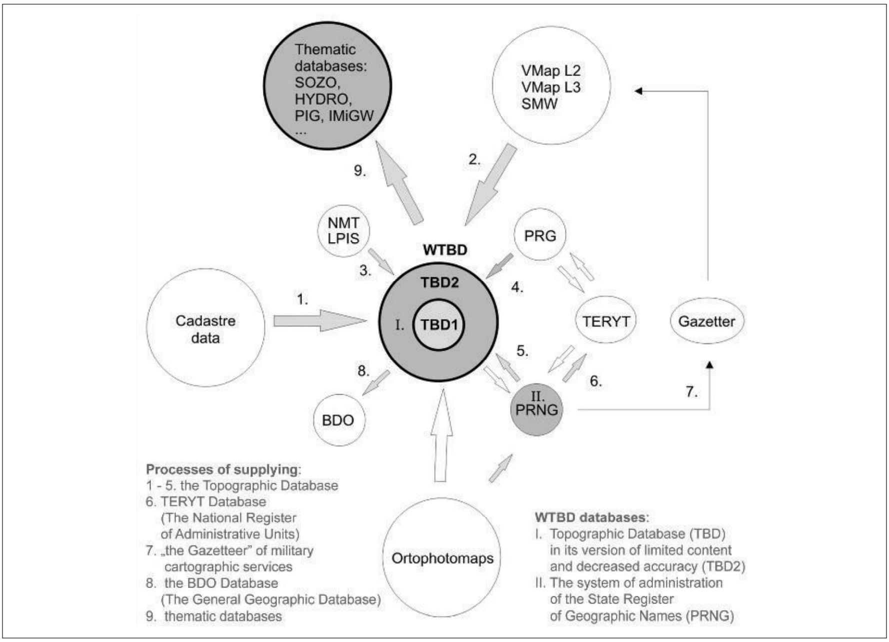

Fig. 28.1. The most important databases within NSDI with specification of elements and processes to be reviewed within the Project (Gotlib & Olszewski 2007)

(NMT) and the Cartographic database (KARTO – DCM). They are all referenced to the scale of 1:10 000 (with respect to the level of details) and are stored in the state spatial reference system "1992". The vector database (the TOPO component) contains information on location, attributes and relations between topographic objects; it is the spatially continuous and topologically settled, GIS vector database, recorded in the DLM model. Concerning its spatial coverage, the database covers the highly urbanised areas – about 10% of the area of Poland. The appropriate database structure and its three-level ordering, which includes about 60 classes of objects, allows to cover the area of Poland with topographic data of the level of details, which depends of particular needs.

Unfortunately, due to economic purposes, it is not possible to create, maintain and continuously update the Topographic Database for the entire Poland, with the highest assumed accuracy level (similar to 1:10 000 topographic maps). Therefore another solution has been proposed which would shorten the time for data acquisition and allow for acquire detailed data for those areas, where such data are acquired, as for example, areas of the future investments or areas hazarded with flood. The developed concept assumes that the reference database will be created for two (or more) levels of conceptual generalization, corresponding to the scale of 1:10 000 (TBD1) and 1: 50 000 (TBD2). Utilization of an orthophotomap, carried out from 1:26 000 scale aerial photographs will allow to maintain the similar level of geometric accuracy and the complete topological coherence of the entire database.

It has been assumed that the second level of accuracy provides VMapL2 database, concerning the scale level of 1:50 000 and covering the entire Poland. It is the product of military origin and it is distributed in the VPF format. Unfortunately the applied conceptual model is characterised by the structure of low transparency and high number of object classes. This has lead to development of two new versions of that database in Poland:

- VMapL2+ – the new version of the VMapL2 database, modified with respect to the conceptual model,
- VMapL2u – the useful version of the first edition of the database.

The VMapL2+ database (of the second edition) is the updated version, harmonised with the conceptual model of the TBD database. It is not limited by the VPF format, in particular with respect to topological data correctness and layering the map content. The concept of harmonisation of those databases was presented during the Cartographic ICA Conference in Moscow (Gotlib et al. 2007, Bac-Bronowicz et al. 2007).

Due to the full covering of Poland, the second, usable version of the VMapL2 database of the first edition has been independently developed (Bac-Bronowicz et al. 2007d). The VMapL2u contains the same content as the initial database, but its structure has been simplified, first of all, due to high reduction of the number of classes of objects. Names of those new classes have been selected aiming at easy readability by users. Names of particular object attributes have been also simplified. The new cartographic visualisation has been developed for this database; it is accessible for three application GIS platforms (ArcGIS, GeoMedia and MapInfo). At present it is being implemented in particular voivodship centres.

The General Geographic Database (BDO), used as complementary data at small scales, is connected with four scale levels: 1:250 000 1:500 000, 1:1 000 000 and 1:4 000 000. First of all, it is the vector database, recorded in the ArcGIS geodatabase format, stored and distributed in map sheets, following the division of the International Map of the World, or in map sheets referenced to administration regions (voivodships). Frequent references to sectoral databases – using object identifiers and their attributes – are characteristic features of that database. The cartographic version of that database is recorded both, in vector and raster formats and it has been recently accessibly in the Geoportal – GUGiK official website. The importance of the BDO database has been decreasing due to the development of the EuroRegional Map, which will be supplied with data from the TBD and VMapL2 databases, using algorithms, developed within the frames of the Project.

The main difficulties related to implementation of the proposed concept are, among others:

- differences in the conceptual model of the cadastral and TBD Databases, which make data acquisition, integration and exchange difficult,
- differences in the conceptual model of the VMap and TBD Databases,
- selection of the possibly minimum set of data, which would create the TBD2 Database, which would – at the same time – maintain the features of a topographic model and meet users' requirements,
- organisational and formal issues related with introduction of changes in technology of development of thematic databases, performed by various institutions,
- generalisation of the TBD data for the needs of generation of maps at smaller scales than 1:10 000 and for the needs of creation of a database at the scale level of 1:200 000,
- methodology of visualisation of multiresolution data.

28.3 Thematic Databases

The official thematic databases are created in Poland by three, mentioned above institutions: the Head Office of Geodesy and Cartography (GUGiK) , the State Geological Institute (PIG) and the Institute of Meteorology and Water Management (IMiGW). The state resources commissioned by GUGiK contain two thematic databases: the sozological database (SOZO) and the hydrographic database (HYDRO). The sozological database, the so-called Sozological Map of Poland ate 1:50 000 scale, presents the basic information on the natural environment and contains data concerning conditions and hazards for its basic components. It has been developed as the spatial database since 1994. The hydrographic database, the so-called Hydrographic Map of Poland at 1:50 000 scale, presents the conditions of water circulation in the natural environment, and, in particular, it specifies permeability of soils, the depth of the first, groundwater level and locations of surface waters, hydrographic phenomena and water management installations. It has been developed as the spatial database since 1997 *(Figure 28.2)*.

Creation of the NSDI in Poland requires utilization of the state reference systems as the source of topographic data for thematic works. This requirement is met by the sozological and hydrographic databases only (Bac-Bronowicz et al. 2007a). Guidelines concerning the development of both databases were modified in 2005; the idea of this modification concerned the possible utilisation of harmonised TBD and VMapL2+ databases, as reference data. At present, thematic databases cover the majority of Poland.

Utilization of the VMap L2+ (new edition) or the TBD databases as topographic reference data, does not complete the issue of modification of the current technology of development of the SOZO and HYDRO databases. Considering the role of those

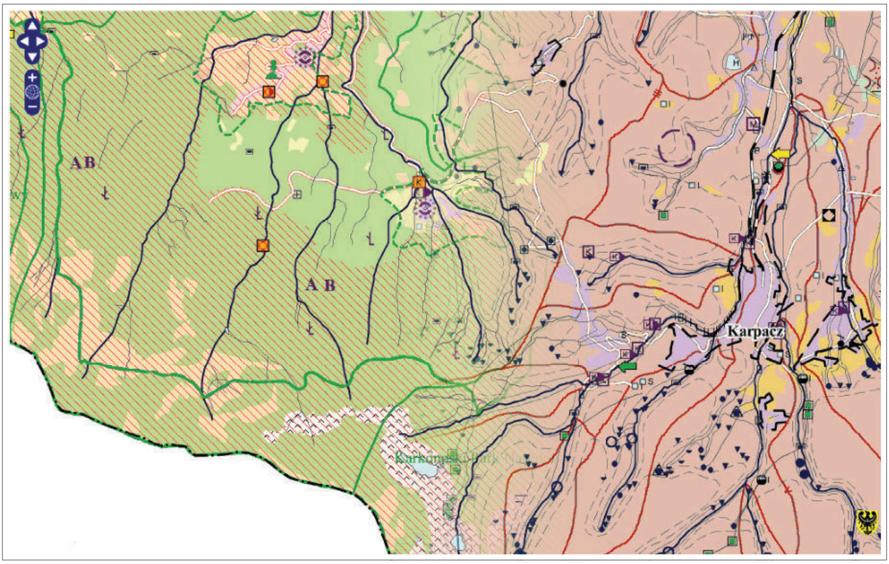

Fig. 28.2. Visualisation of SOZO (left) and HYDRO (right) databases (Berus et al. 2008)

databases as the basic component of the NSDI in Poland, the authors (Berus et al. 2006, Olszewski 2007) proposed a series of new conceptual and technological solutions. Below, selected proposals concerning substantial and technological modifications of the SOZO and HYDRO databases are presented:

- automation of the process of supplying the SOZO and HYDRO databases with VMap L2 data of the second edition;
- introduction of diagrams of topological relations;
- integration of layers of similar logical characteristics in order to present natural relations, which occur in the natural environment;
- indexing selected attributes.

28.4 Multiresolution DTM

Existing works mainly focus on multiscale or multiresolution modelling of the 2D vector topographical database. Development and implementation of such methodology for the needs of terrain relief modelling would allow implementing a coherent concept of the 3D multiresolution DTM. This approach allows developing the digital terrain model for two or more levels of generalization, in such a way that all functions are performed on a model considered as one entity. This also opens wide possibilities to maintain the spatial integrity between the model of the terrain relief and other topographic feature classes the river network, first of all (Olszewski 2007).

Several works aiming at acquisition of altimetric data – the digital terrain model in TIN and/or GRID formats, as well as drawings of contours – have been recently performed in Poland. For the needs of the NSDI development, and in particular for the needs of development of the concept of the multirepresentation, reference data base, the most important are the basic altimetric data – surveying data and the TIN, irregular model, which maintains the important topological relations. Data are stored in that form in three databases:

- in the Topographic Database (which covers about 10% of Poland; the digital terrain model ($m_s \leq 1$m) is developed as a separate component.
- in the course of development of the Land Parcel Identification System (LPIS) database, with the use of aerial photographs; the digital terrain model is being developed for the entire country ($m_s \leq 1.5$m)
- for big areas in the southern Poland (about 11% of the entire country) the digital terrain model of high quality ($m_s \leq 0.8$m) has been developed within the frames of development of SMOK flood protection systems.

At present the above stages are not harmonized and the data flow between them does not exist. Within the frames of implementation of the Project the authors have made an attempt to develop the concept of a conceptually coherent, multiresolution, reference database, the important component of which are altimetric data (the DTM component), integrated with the vector databases (the TOPO component). Modification of the existing concept of the DTM component aims, first of all, at achievement of a terrain model of higher level of coherence; which would similarly consider the terrain elements and the terrain relief description, as well as at maintenance of important topological relations between particular classes of objects. (Gotlib et al. 2007):

The approach proposed above allows for wider unification of the topographic database structure than it occurs in standard cases (Gotlib et al. 2005). It also opens wider possibilities with respect to maintenance of the ties of spatial integrity between the terrain relief model and the field objects (first of all, the hydrographic network). This will practically enable to develop the complete and topologically correct model of the terrain relief (Olszewski & Kochman 2005) and to perform the terrain relief generalization (Olszewski 2005), understood as generalization of the relief model with the maintenance of topological relations.

28.5 Cartographic Visualization

The following databases have been utilised for implementation of the task related to cartographic visualisation and presentation:

- The Topographic Database (TBD) and its simplified version, the TBD2,

- The VMap Level 2 database and its useful version, known as the VMapL2u database,
- The new edition of the VMapL2+ database,

Ordination of symbols have been developed for each of the above databases; those symbols are used for cartographic presentation separately. However, works aiming at development of the complex representation of those data files, have not been undertaken in the past. The primary goal of the elaboration of new visualization methods of spatial data in Poland was to obtain a readable and understandable cartographic composition for any scope of the national topographic databases.

Several preliminary assumptions were made, aiming at the universality and functionality of proposed solutions. The final cartographic presentation should fulfil the condition of readability, unequivocality and measurability both on the screen and in printed forms *(Figure 28.3)*. Many variants of the visualization of reference data and technology of producing the topographic map sheets at the scale of 1:50 000 have been worked out. The drawn up methods of visualisation will enable more extensive use of reference data in one of the GIS environments, as well as in map viewers or web browsers.

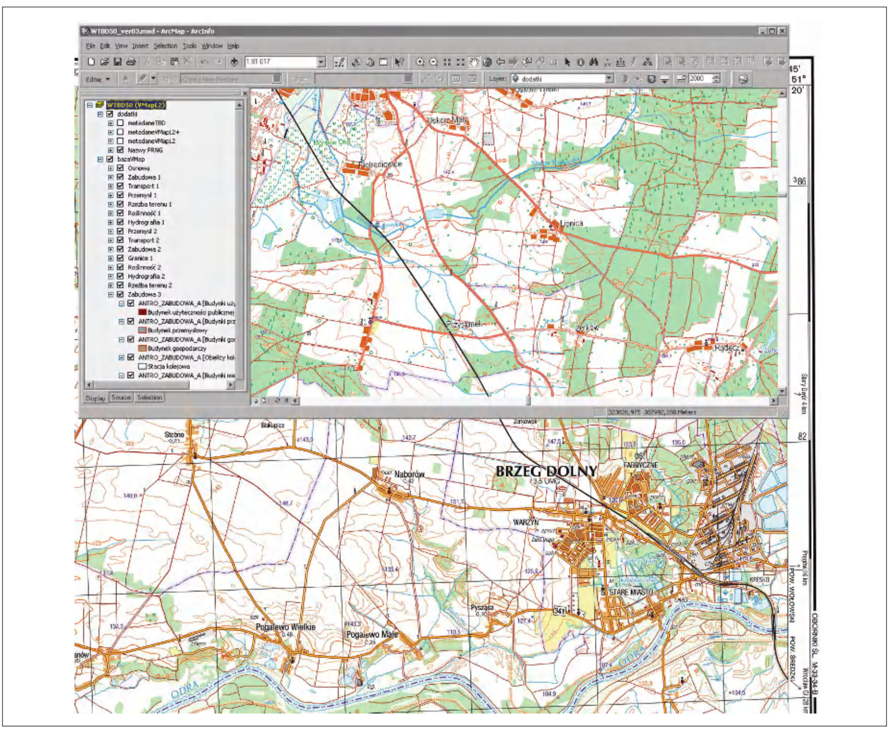

Fig. 28.3. Topographic visualisation basing on the VMapL2u in ArcGIS (application window) over the topographic map sheet at the scale of 1:50 000 basing on the TBD10 from the same region

The proposed scope of presentation content of the WTBD database and cartographic generalisation procedures consider the standards of the Polish topographic cartography; however the modified ordering of several classes of objects, as well as new symbols used for cartographic visualisation, have been proposed. This was required in order to unify presentation which uses various data sources (mainly the TBD and the VMap L2, with its different structure and content). At the same time, analysis of possibilities of utilisation of automated processes of generation of cartographic images basing on the WTBD in the GIS environment, was performed.

Practical results of performed works include:

- ordination of symbols used for publication at the scale of 1:50 000, modified with respect to the WTBD, as well as the test map sheet,
- WTBD cartographic visualisation of the TBD50 database (basing on the TBD10) and the VMapL2u database (in the usable structure),
- libraries of symbols and map documents for GIS application'
- The broader description of the task is in the paper "New approach to cartographic visualisation of reference and thematic databases in Poland".

28.6 Geoinformation Webservices

One of the final tasks within the granted Project concerned the development of geoinformation services, which distributed reference and thematic data, stored in the state resources of geodetic and cartographic data. Works performed in this area aimed both, at popularisation of valuable topographic and thematic data from the state resources, as well as at verification of the possibility to apply the, so-called, open source or free software licenses, which allows inexpensive and effective publication of geographic data via Internet.

The basic assumption was to develop simple and universal geoinformation services, which could be accessible for wide groups of individual and institutional users. An information system, consisting of several applications (GeoServer map server, Oracle Express 10g database, OpenLayers libraries, TileCache software tools) and standards of data WMS and WFS data distribution (promoted by the Open Geospatial Consortium) allowed for implementation of prototype geoservices for the area of the Lower Silesia Voivodship (Bac-Bronowicz et al. 2008). Besides, original applications were developed for thematic data.

At the first stage of development, data from the VMap Level 2 database in its usable version (VMapL2u) – the only vector database developed for the entire country – were made accessible (Kowalski & Olszewski 2008). In order to increase attractiveness of results, the functionality was amended with the possibility of hybrid visualisation of vector topographic data and satellite images, which are accessible

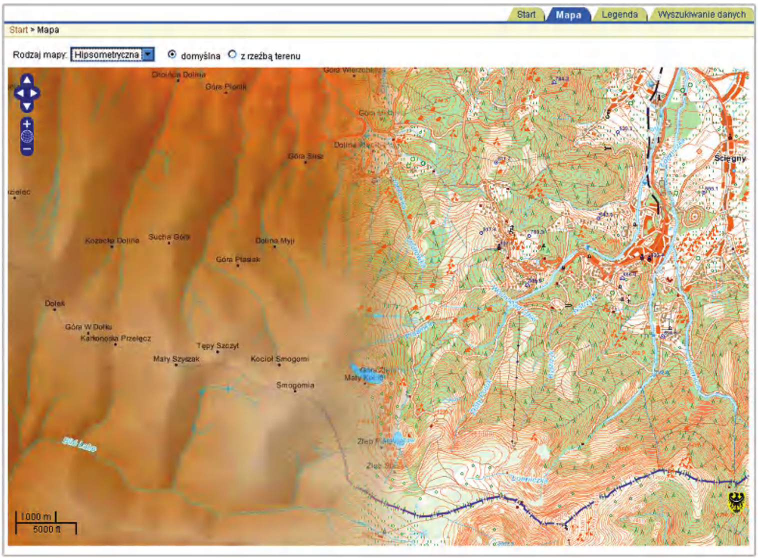

Fig. 28.4. Visualisation of the DTED2 elevation data (left) and the basic topographic data of the VMap L2u (Bac-Bronowicz et al. 2007d)

in Google Maps (Kowalski 2007). The satellite image presented in the background of the VMap enhances visual effects more than the aerial orthophotomap from the state resources, which could be an excellent background for the TBD database. General geographic data, amending topographic presentation at small scales, were also selected form the Google Maps services.

In the complete version of the system, successive components are: DTED2 elevation data, data from SOZO and HYDRO thematic databases and elements of names from the State Register of Geographic Names. Efficient integration and visualisation of those data resources in one service is possible due to the same spatial reference – military topographic maps at the scale of 1:50 000 are the sources for the majority of data *(Figure 28.4)*.

Visualisation of the basic topographic data is based on a system of symbols developed for the usable version of the VMap L2u database (Bac-Bronowicz et al. 2007d). The cartographic image refers to good patterns of civil topographic cartography, and first of all, to the map at the scale of 1:50 000. The topographic map is displayed at three visual levels, and, in the case of smaller scales, the standard visualisation of Google Maps appears. Thematic section of the services include: the sozological and hydrographic maps and the DTM visualisation in the form of the hypsometric map.

For an arbitrary thematic section and for an arbitrary scale level it is possible to display both, vector information layers as well as hybrid visualisation – maps on the background of satellite images or a map amended with shaded terrain relief. It results in the possibility of composing such presentation, which meets the user demands. Utilisation of maps is facilitated by the dynamic legend, which content is integrated with the map of each type, presented by the services: the topographic, sozological, hydrographic or hypsometric map.

The content scope and the functionality of geoservices allow for simple reviewing and searching for georeference data for a voivodship. The result of database queries may be displayed in the tabular form or on a map. Besides the standard access, performed by means of a web browser, the service may be accessed by means of an arbitrary GIS tool or a geobrowser, such as ArcGIS Explorer, which reads WMS or WFS services (Kowalski 2008). While the typical web browsers allow for implementation of the basic tasks, independent geoinformation applications allow to combine various data originating from external and internal sources, as well as for the advanced, usually 3-dimensional visualisation.

28.7 Conclusions

In Poland the key issues related to distribution of geodetic and cartographic data are connected, first of all, with integration of large, however non-uniform databases, as well as with their coherent visualisation and publication. The main purpose of the Project was to propose the rules of development of a Multiresolution Topographic Database for the entire country (WTBD). The most important features of the Multiresolution Topographic Database are:

- possibility to integrate various information resources,
- systematisation of processes of integration of various data stored in the state resources of geodetic and cartographic data,
- automation of production processes of topographic and thematic maps,
- possibility to perform geoinformation webservices basing on various resources of data,
- limitation of multiple data gathering by various map producers.

A series of applications, geoinformation systems and technological lines, which have been developed, are ready for implementation at voivodship and marshal offices, as well as at central data centre of Head Office of Geodesy and Cartography. The wide scope of applications ranges between local and national tasks – they may play the primary role of the national spatial data infrastructure. Implementation of the proposed concept would contribute not only to the NSDI development in Poland according to INSPIRE requirements, but also to automation and improvement of the quality of topographic and thematic map production processes, as well as to increase of their accessibility for people.

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Chapter 29

The Remote Sensing Based Hungarian Crop Production Forecast Program (Cropmon) and its Other Applications

Zsuzsanna Suba, Gábor Csornai, Csaba Wirnhardt, Gizella Nádor, László Tikász, László Martinovich, Attila Kocsis, Gyula Zelei, István László and Erika Bognár

Institute of Geodesy, Cartography and Remote Sensing,
FÖMI Remote Sensing Centre, Budapest, Hungary
lastname.firstname@fomi.hu

Abstract

The Hungarian Agricultural Remote Sensing Program led to a concise methodology that could further be applied operationally. First the main results of a substantial R&D investment and methodology plus validation results are summarized. The crops area assessment, through the processing of multitemporal Landsat and IRS-1C/1D data proved to be efficient at county level because of the accuracy of thematic classification. The novel combined high resolution images + NOAA AVHRR series based crop yield forecast methodology performed well for the major crops (8) at county level. Based on the experiences of the first 5 operational years (from 1997) a general evaluation on the Operational Crop Monitoring and Production Forecast Program (CROPMON) is given. The CROPMON system is a good platform for additional projects implementation as in the case of waterlog assessment and impact analysis (1998–) or flood and drought monitoring (2000–), the recent ragweed control program (2004–) and the remote sensing control of area-based agricultural subsidies (CwRS), that has been carried out operationally for nine years in 2008 in Hungary.

Keywords: crop monitoring, production forecast, drought monitoring, flood and waterlog monitoring, ragweed monitoring and control, subsidy control, remote sensing and GIS methods, GPS technology

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29.1 Introduction

Up to 1990 the crop production was based on some 1400 co-operative or state farms in Hungary. The crop information and production forecast system used their reports that were obligatory by law. This information system worked fairly well. Because of the dramatic changes in the Hungarian economy and also in the agriculture, the former crop information system became inadequate. The land privatisation brought dramatic changes in the holdings and parcel sizes, the number of farm owners or operators, the agricultural technology and also in the investment structure. In this very quick transition, the need for an efficient information system became even more imperative.

The priority Hungarian Agricultural Remote Sensing Program (HARSP) was launched in 1980 and has been implemented by FÖMI Remote Sensing Centre (FÖMI RSC). The final objective of the program was to introduce remote sensing to the operational agro information system in Hungary. In the beginning of HARSP *(Figure 29.1),* the satellite image analysis methods development and validation were the most important (1980–85). As early as in 1984 the reviews of the yield models showed, that the research for a direct relationship between the crop devel-

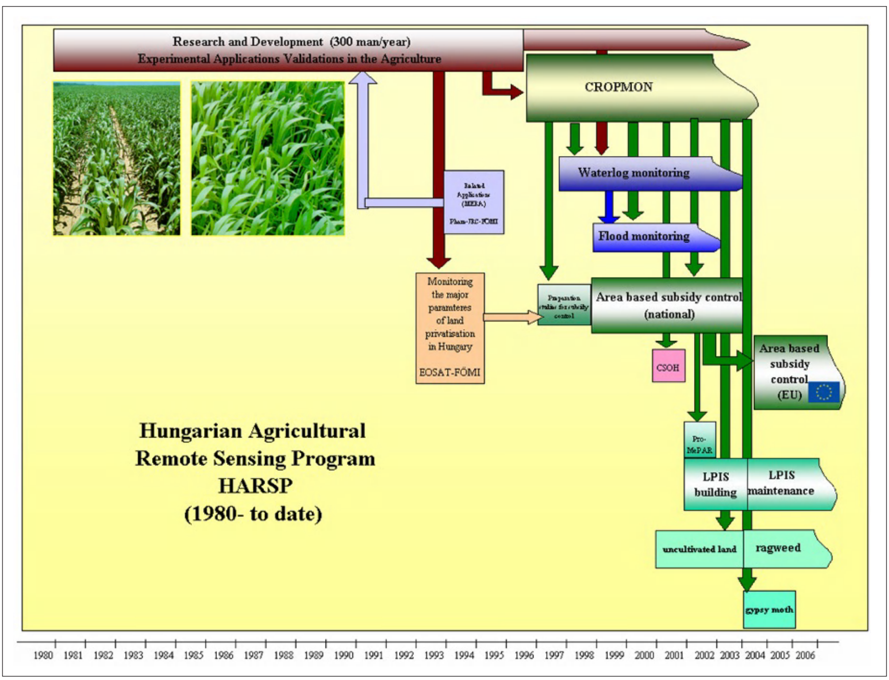


Fig. 29.1. The background and history of remote sensing based agricultural applications in FÖMI RSC, Hungary

opment, the expected yield and the crop canopy – that can be observed by satellite data – could be a good alternative. Despite of the first results in canopy development assessment by satellite data we studied the capabilities of agromet models (WOFOST-MERA, Csornai et al. 1996), but FÖMI put a real emphasis to the remote sensing based model.

The operational system was expected to be capable to monitor crops in the entire country, providing accurate, timely and reliable information on the area of the major crops, their development quantitatively. This should be accompanied by problems areas delineation focusing to drought assessment plus the provision of reliable yield forecast and final yield estimates. These data are to be available at the country as well as the counties (19) levels. The main user of the information included, primarily the Ministry of Agriculture and Rural Development (MARD) and has been indirectly gradually the grain processing and trading companies and associations, the farmers and their different organisations, associations. After a seven year of continuous operations (1997–2003) and having a lot of experience to meet the strict accuracy and deadline requirements there has been a continuous improvement in the technology applied. This led to a number of additional applications offered by this system *(Figure 29.2).* Although the CROPMON has been suspended to operate from 2004 because of the national resources are directed to EU memberstate obligations, in more recent cases, definite demand appeared for its revitalization.

29.2 The Three Main Periods of the Program

The HARSP (1980–) program can be divided into three main periods (Figure 29.1):

- the development of the methodology basis, the crop mapping and area assessment methods plus the yield forecast models and validation (1980–96) and
- 1st phase of CROPMON: the operational period (1997–2003). The final, most intensive period (1993–96) was the breakthrough in the development. This resulted in an operationally ready to use technology that had been validated prior to the operational phase on a 16 counties sample from quite a diverse crop years period: 1991–96 (Csornai et al. 1998).
- 2nd phase of CROPMON: from 2004 on: special agro studies and analysis focused to EU topics and related operational thematic applications have evolved from CROPMON's technological basis as in the case of waterlog assessment and impact analysis or flood and drought monitoring, the recent ragweed control program and the remote sensing control of area-based agricultural subsidies (CwRS).

29.2.1 The Operational Crop Area Assessment Method

The method was developed by FÖMI RSC. It applies high resolution satellite data series (e.g. Landsat, IRS-1C/1D, SPOT) in a multitemporal digital image analysis procedure for the crop identification and area estimation (Csornai et al. 1983). This approach was thoroughly tested by 1990 up to 3 counties region (Csornai et al. 1990). It was found that the traditional agro information system in Hungary, can only be surpassed in accuracy if advanced digital image analysis was used (Csornai et al. 1997). This approach also provides reliable crop maps, which are necessary to the crop development monitoring and production forecast models.

The performance of this approach in crop area assessment proved to meet the strict requirements *(Figure 29.3a* and *Figure 29.3b)* both for the validation period (1991–96) and in the operational one. The strong relationship in the Landsat TM derived (FÖMI RSC) and Central Statistical Office, Hungary (CSOH) data for the major crops proved, that this method was independent from the given year or the area, the different terrain and complexity of the counties.

The crop maps, made of high resolution satellite data were supported by a carefully selected area and farms sample. Annually, some 100–200 sets of agricultural fields associations, farms or parts of farms ground data were analysed, checked and got built in to train the classifiers or – on a disjoint subset – to validate the accuracy of the derived maps. Thorough on the spot studies revealed, that 85–95% of the confusion values in the accuracy assessment tables come from existing inhomogeneities on the ground.

This means that the confusion tables incorporate information relevant to the nonuniform development character of the crops. The raw confusion tables and measures showed steady 85–97% overall agreement before the compensation techniques application. Global estimation handled the empirical confusion matrices values (per stratum) that were spatially balanced.

29.2.2 Crop Monitoring and Yield Estimation Methods

The novel results of HARSP are the purely remote sensing based crop monitoring and yield forecast models. The models were developed by FÖMI RSC. They integrated NOAA AVHRR and high-resolution satellite data (e.g. Landsat, IRS-1C/D, SPOT). The models combine the benefits of both data sources: the frequency of NOAA AVHRR data and spatial resolution of high resolution images. This approach requires fairly accurate crop maps. Using these crop maps and pre-processed NOAA AVHRR time series a crop development assessment and quantitative yield forecast model was developed. This relies on crop specific AVHRR indices. The model was calibrated at the spatial units level of 400–500 ha. This was the second area where

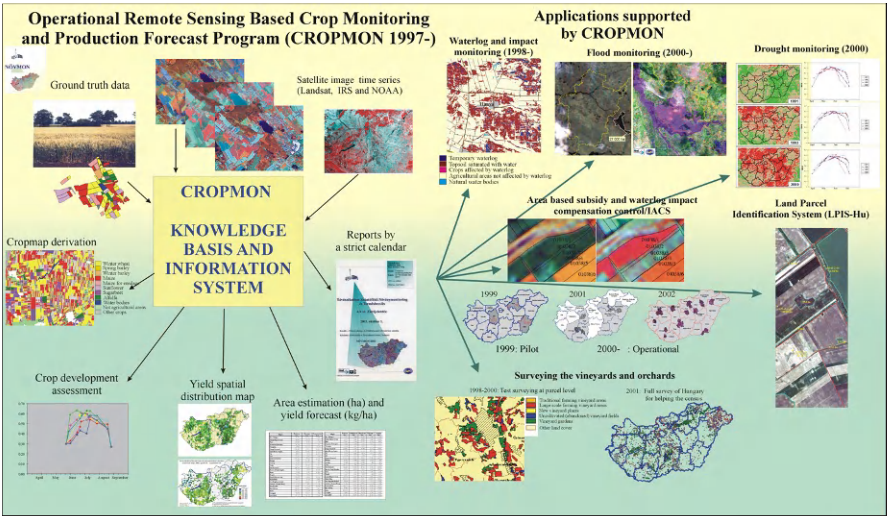


Fig. 29.2. The overall structure of CROPMON and the application supported by it

the sample of farms could help. That is the guarantee for its good performance at the counties level (approx. 0.5 million hectare each, in Hungary) and further. That is also why it can produce a crop yield distribution map. The county wheat and maize yields predicted by the model compared favourably to the official data *(Figure 29.4a* and *Figure 29.4b)* both in the pre-validation period (1991–96) and in the operational one (1997–2003) as well. The structure of the model is similar for different crops and it does not depend on the area and the given year's weather. It was also found that the timeliness requirement can be met by the yield forecast model.

There was a clear emphasis and determination in the design of our methodology and later system not to get validated by the CSOH county average yield data. We wanted to build an independent crop production model that covers the entire cropland.

29.3 Operational Crop Production: Area Assessment and Yield Forecast 1997–

The substantial R&D and validation provided a firm basis to move forward to an operational program: Crop Monitoring and Production Forecast Program (CROPMON 1997–2003). The crop data-reporting calendar was set by the customer, the Ministry of Agriculture and Rural Development.

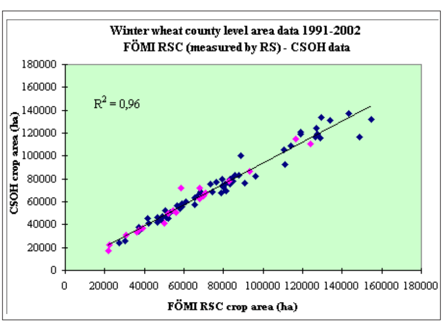
It consists of five dates from July 5 to October 1 in harmony with the existing traditional production forecast system of MARD. The area covered directly have been a characteristic subsample (6–9) of all the counties (19). This 40–57 % of the total cropland in Hungary was directly monitored, by remote sensing, while appropriate area and yield estimates for the non covered counties were computed by a historical spatial correlation of these values. This relationship was found quite strong suggesting an R^2~0.9 or better fit. Confidence values were also reported. From 2002 the whole country was covered by direct remote sensing measurements. The eight main crops monitored are winter wheat, winter and spring barley, maize, sugar beet, sunflower, alfalfa and maize to ensilage. These crops together represent the 78–82 % of the entire Hungarian cropland.

The crops area assessment is based on the quantitative analysis of multitemporal high resolution images (Landsat TM and IRS-1C/1D LISS III.) from early April (or earlier sometimes) through August, to compensate for the cloudiness. The comparison of the remote sensing results with CSOH data is obviously an indication only. The differences cannot be interpreted, by any means, as errors of the remote sensing technology. On the contrary, the area estimation bases, the crop maps were always thoroughly checked at some pixels detail.

The difference of crop areas estimates of FÖMI RSC and the Central Statistical Office, Hungary (CSOH) is in the range of 0.8–3.7 % for the entire cropland in Hungary. The county crop area differences occurred in the interval of 1.5–21 % depending on the crop and county. However the area weighted average difference was 4.08 %.

This partially can be explained by the main differences in definitions, that is the ownership based sampling of CSOH and the administrative boundary based total coverage of cropland by the satellite images (FÖMI RSC). The actual standard crop maps derived were also provided to MARD.

The crop yield forecast was accomplished by the application of FÖMI RSC developed model which combines high-resolution satellite (Landsat TM and



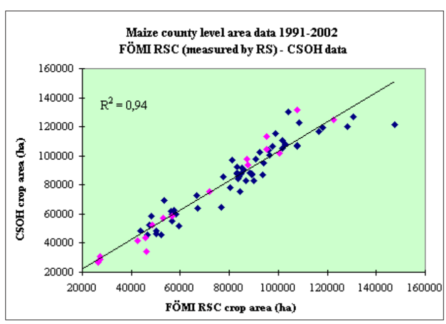


Fig. 29.3.a The area estimation for winter wheat shows a strong relationship between the traditional (questionnaire) method and the remote sensing one

Fig. 29.3.b The figures compare similarly to those of wheat. The relationship is somewhat affected by the practice and statistics of maize for silage

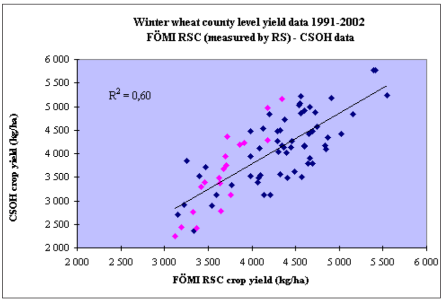


Fig. 29.4.a The wheat yields can be predicted by remote sensing prior to the harvest. The years covered comprise good and extreme bad ones as well

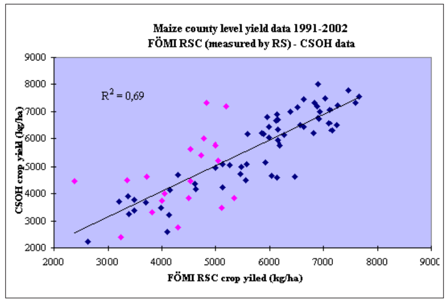


Fig. 29.4.b The maize yields can be predicted early prior to the harvest. The sample comprises diverse years. No CSOH yield data are available to date for 2001

IRS-1C/1D LISS III. or SPOT) data and NOAA AVHRR time series. The reporting dates corresponded to those of the operative Production Forecast System of the Ministry of Agriculture and Rural Development. Both appeared prior to the harvest. The earliest official production data estimates are available after the harvest: by the end of August for wheat and barley and in December (January) for the rest. Until 2002 FÖMI RSC provided yield estimates for the counties (6–9) and expanded these measurements to Hungary using a regional-historical correlation scheme. From 2002 all the 19 counties were covered directly, so there was no need for extrapolation any more. The country average yield data compare favourably with CSOH preliminary values, that appear six weeks later. The differences are less than 1 % for wheat and 4.5 % for maize average yields in Hungary. The differences at county level averages are somewhat bigger. Because of the method applied, yield spatial distribution maps could also be reported for the major crops.

Beyond the accuracy control built in the area estimation getting helped by the 2–4% ground sample and also the comparative analysis of the CROPMON predicted yield values and the respective farms after harvest data, the comparison to the final CSOH data is meaningful *(Figure 29.3a* and *Figure 29.3b, Figure 29.4a* and *Figure 29.4b)*. These comparisons of the county area and CROPMON predicted – CSOH after harvest yields were done by crop. Around 180 data pairs were available either for area or yield to compare in the 1987–2003 period. The differences and R^2 –s should carefully be interpreted! The inherent advantages and limitations of the traditional and remote sensing methodology suggest the handling of these data. The Ministry of Agriculture and Rural Development selected our data from the second year when there was a conflict.

29.4 Application of the Yield Model for Parcels and Farms

The crop development assessment plus yield prediction model performance suggested a step forward to the parcel level. In 1999 two large farms were studied. IRS WiFS 3.6 ha resolution data were used similarly in a 35 ha average field size environment. The two major crops were estimated: winter wheat and maize. The model seemed to work in this study providing some 3–5% difference between the remote sensing predicted and harvested yield after one year calibration. This could be achieved only to the farm total estimation only. The model may perform definitely better or at least as well in the operational way with a more appropriate field size/pixel ratio. Also, it was suggested that the individual fields' yield (production) values were not very accurate unlike those of the farm totals. This was characteristic in that period.

29.5 Drought Monitoring and Yield Loss Assessment (2000–)

The basic idea behind drought monitoring is the comparison of actual year's vegetation index maps (NDVI, MGVI) with the maps representing a mean of the vegetation index maps derived from the maximum value composites (MVC) of a reference period. This is the approach, that is most studies or systems pursue. FÖMI also explored and applied this approach, but having a strong yield prediction model, developed that performed well it was straightforward to use it for drought assessment and alarm. Beyond the widely used methods that apply NDVI or similar indices or their maximum values in a period to indicate the categories of drought or yield losses FÖMI utilized the yield model for this purpose. The quantitative yield model was used to the characterization the strength and spatial distribution of drought. This is quantitative and provides the expected yield for that particular area. To this not only the compared period – usually 1–3 weeks – but the whole growing season is compared by the model output in the different years.

In the frame of FÖMI-ESA co-operational programs (Prodex[1]: 2000–2004, PECS[2]: 2004–2007, Csornai et al. 2004, 2007) (see also 29.6.) the CROPMON based drought monitoring, crop development and yield loss assessment (2000–2003) activities based on NOAA AVHRR data received at FÖMI satellite station were also continued and developed further (2003-). Other available satellite data (SPOT VEGETATION, IRS WiFS, AWiFS and ENVISAT MERIS) were integrated into the regional drought monitoring model to detect the extension and intensity of

[1] Prodex= Scientific Experiment Development Programme
[2] PECS= Plan for European Co-operating States

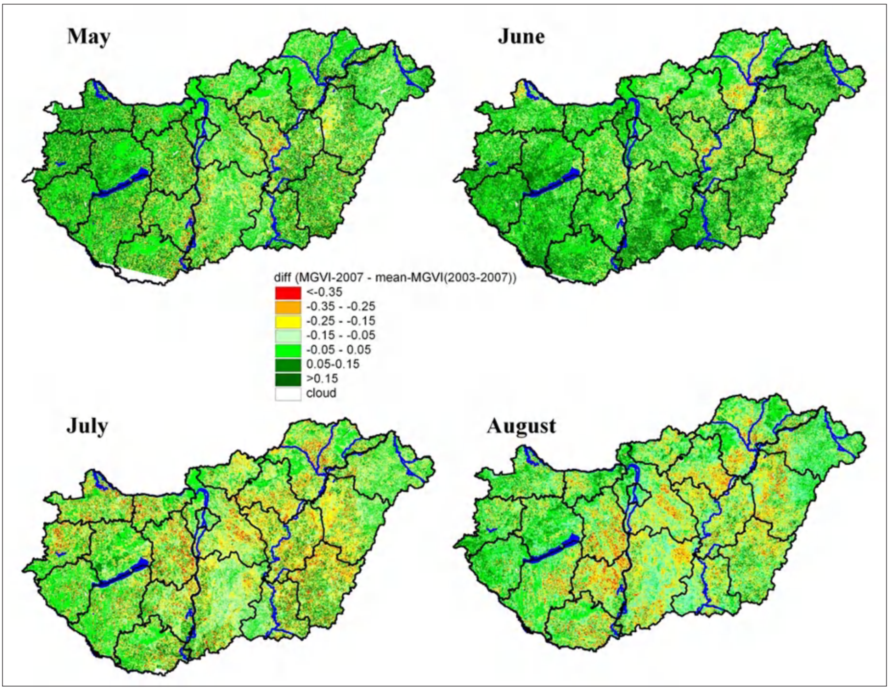


Fig. 29.5. Drought maps derived from ENVISAT MERIS satellite data in 2007. The drought maps reflected well the differences in crop developments – the central part of Great Plain was affected the most seriously in July and August – as the drought progressed. (Colours from red to yellow indicate areas being extremely or seriously or moderately affected by drought. ©ESA, 2007)

the drought at regional or country level (2003–2007). High and medium resolution images (AWiFS and MERIS) provide fast, objective and accurate information to the monitoring of spatial and temporal progress of drought. They can serve as a basis to drought loss compensation measures and to the consideration of such claims. In the final phase of PECS project the ENVISAT MERIS based drought model was extended to the whole country in 2007. The model utilized solely ENVISAT MERIS and also calibrated ENVISAT MERIS-IRS AWiFS time series data (2003–2007) for covering more drought monitoring periods (May, June, July, August 2007) in crop development. The derived drought maps *(Figure 29.5)* reflected well the differences in crop developments – the central part of Great Plain was affected the most seriously in July and August – as the drought progressed. The latter was justified by the deviation (yield loss) and strong spatial differences of the observed yields[3] of the main crops (wheat and maize) at the level of the counties. Further validation of the model was accomplished using IRS-P6 AWiFS based drought maps which

[3] derived from CSOH data.

were derived for May, July and August of 2007 applying an improved and strong intercalibration procedure of MERIS and AWiFS data over a three years period (2005–2007). The results of ENVISAT MERIS based drought and crop development monitoring, carried out in the framework of this project, provide a reliable basis to the drought impact assessment at regional and country level.

29.6 Waterlog/Flood and Impact Monitoring, Ragweed Monitoring and Control Program

As a component of CROPMON, further additional extension of remote sensing based operational applications were launched to extract information about those most significant factors, extreme natural disasters which occur on large areas and produce negative effects on crop development and crop production. Thus, satellite based waterlog/flood and impact monitoring (1998–), and recently ragweed monitoring and control program (2004–) were all growing out from the CROPMON methodology and technology basis.

Waterlog and impact monitoring program was initially launched for MARD, that covered the most affected 4 (in 1998) and 7 (in 1999) counties of about 4 million hectares. Reliable waterlog/flood maps and derived areal measures reflected the static status assessment of the areas under water or having saturated soil. Beyond this, temporal evaluation of waterlog/flood affected areas, impact analysis on the crops and the dynamism of changes could also be monitored quantitatively. During the combats against flood, when serious flood events occurred on Hungary's largest rivers, the Körös and Tisza, in April 2000 and March 2001, FÖMI RSC provided real time satellite data and flood maps for the disaster areas. The extent of flooded areas was evaluated and high-, low- and medium resolution flood maps were forwarded to the central and local management authorities through electronic transmission (Lelkes et al. 2001). These effectively helped the local water management authorities in planning the necessary steps and managing the fight against the flood. Further improvements of the models to map and monitor waterlog and flood affected areas were also carried out in the frame of FÖMI-ESA co-operational R+D programs. Yearly monitoring tasks were performed at regional level in 2005–2006 for waterlog and flood assessment using also integrated radar (ERS, Radarsat, ENVISAT ASAR) and optical (IRS WiFS, AWiFS, ENVISAT MERIS Landsat/ IRS LISS) satellite data sets. The previously applied waterlog/flood monitoring methodology had been significantly improved with new methodological elements in the preprocessing (radiometric calibration, speckle suppression, incorporating DEM data into the preprocessing chain and ortorectification), integration and classification steps of ENVISAT ASAR radar and through the utilization of multitemporal and integrated ENVISAT (ASAR+MERIS) radar and optical data set. The Kappa measures of the pixel by pixel based accuracy assessment of the derived waterlog maps proved that about 10% improvement could be achieved in the kappa measure of thematic accuracy by using the integrated multitemoral MERIS-ASAR data set (overall: 90%, kappa: 64–66%) comparing it to datasets consisted of solely mutitemporal ASAR or MERIS data (kappa: 52–54%).

The technique developed for ragweed monitoring and control (2004–) is based on the methods that had been used in CROPMON. However, the remote sensing identification of the areas contaminated by ragweed is much more difficult than the crop identification. About 80% of ragweed infected areas (of a total of 500.000–700.000 hectares) can be pinpointed by remote sensing on the arable land. The reconnaissance of ragweed spots are substantially helped by remote sensing as well as the ground measurement and record by GPS plus integrated GIS tools. The temporal development assessment of ragweed has fundamental importance. FÖMI RSC produces a countrywide ragweed risk map focusing to the most heavily infected croplands. The major factor in the efficiency of the system is the high reconnaissance performance and accuracy (better than 90%) of the spots independently from the terrain, location and environment. Ragweed risk and spatial statistics plus on line maps are public and also available via FÖMI's website (www.fomi.hu). FÖMI has developed the Central Ragweed Server and Information System. This ensures the fast data exchange among the authorities and stores information about the infected spots. The central server synchronizes the activity of some 400–500 civil servants of 4 institutions' network during the most critical ragweed-growing period (from July to September).

These ragweed risk maps are derived from time series of medium and high-resolution satellite images. In 2005, FÖMI RSC detected about 20 000 heavily infected spots (60 000 hectare) in the country. In 2006 a limited ragweed monitoring program was performed (financial reasons). The reduced program brought up about 3 500 spots (18 601 hectares) of ragweed infected areas. In 2007, we identified high risk ragweed spots more than once on the very infected areas covered the whole Hungarian territory. The number of spots was more than 4 000 (10 000 hectares) *Figure 29.6* shows the spatial statistics of ragweed risk of the settlements in 2007. These statistics are developed from the ragweed risk maps having been derived from satellite data. In 2008 we focused to the most infected areas and produced ragweed risk maps 3–5 times from mid-July. The four high tech components (RS+GPS+GIS+WEB system) were inevitable to adjust the ragweed control system for a far better and efficient one. The ragweed risk maps based on remote sensing, the Central Ragweed Server and Information System also contribute to the successful ragweed control in Hungary. At system level: it can influence the decrease of ragweed infected areas and pollen load. It is "spatially fair", helps to maximize the due counter actions in situ by any authorities or responsible institu-

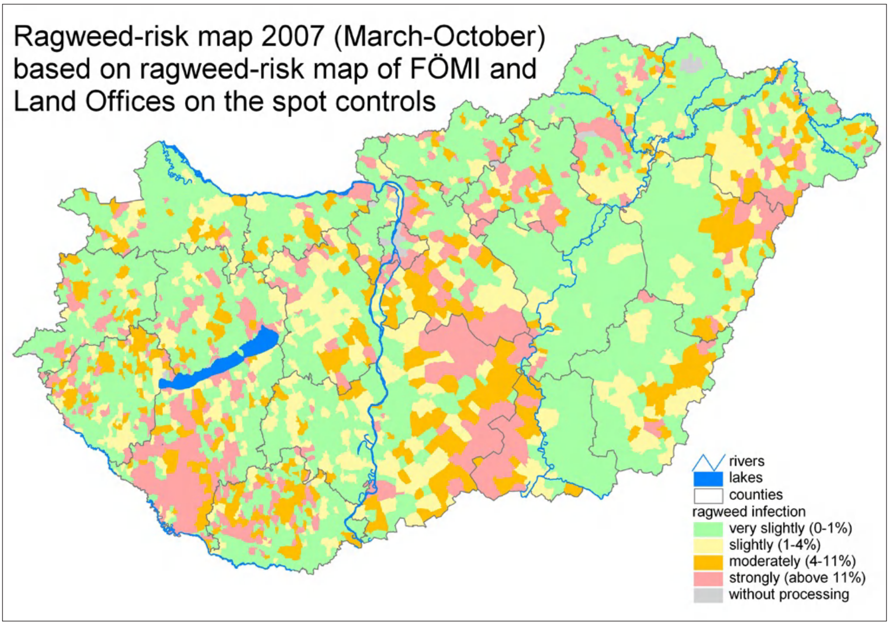


Fig. 29.6. Ragweed-risk spatial statistics of the settlements in 2007. These data come from the quantitative evaluation of high-resolution satellite data

tions within their limited capacity. The system is also a model for a wide range of integrated thematic applications of remote sensing.

29.7 Area-Based Subsidy Control with Remote Sensing (Cwrs, 1999–)

The methodology and technology basis of CROPMON can be used also to extract information on the agricultural areas at parcel level, thus to control of the agricultural subsidy claims with the use of satellite images. After controlling a 3 counties sample for MARD in a pilot project in 1999, FÖMI extended the remote sensing control of national area-based subsidies to the sample of 4–6% of all the dossiers (160–180 000) between 2000 and 2003. The CROPMON based digital crop maps were very effective tools to access the automatic control of the parcels and were an important part of CwRS technique in Hungary. Since 2004, in the EU system, FÖMI's CwRS control ran on the newly built and updated Hungarian Land Parcel Identification System (LPIS-Hu, 2004–). The total number of submitted claims in Hungary grew to about 200 000–210 000. In 2004, 8 660 dossiers were controlled by remote sensing. This number grew to 11 000 in 2005, 12 124 in 2006, and it was approximately 12 000 in 2007 and 2008. This sample is considered a rather big sample among the EU member states. The successful control of the amounts of dossiers (4–6%) within a very short period of time could proved that the only feasible solution to carry out on-the-spot checks is the use of remote sensing and GIS techniques for the majority of the claims.

29.8 Conclusion

Both the validation of the developed remote sensing based crop area assessment and yield forecast methods plus the first Operational Crop Monitoring and Production Forecast Program (CROPMON 1997–2003) in Hungary clearly demonstrated that these methods can be efficiently applied for the entire cropland. Substantial background and investment were certainly needed. About 300 man/year was invested by FÖMI RSC in the framework of the Hungarian Agricultural Remote Sensing Program (1980 to date). The CROPMON reporting calendar was very strictly set up by the Ministry of Agriculture and Rural Development, Hungary, to be in synchron with its existing farms' reports based operational production forecast and monitoring system. The 8 most important crops were covered and monitored merely by remote sensing methods and technology. The CROPMON is objective and validated in a series of years and for very different areas.

Remote sensing could be very efficiently used for precise crop area estimation and provision of crop maps. The results suggest that the necessary classification performance can be obtained in most of the cases, therefore the analysis could be cost effective. The investment to achieve this seems to be worthwhile.

The new primary quantitative crop development assessment and yield prediction model works on the basis of a combined AVHRR and high resolution images based crop monitoring. The quantitative yield prediction model performed properly and efficiently in a more counties' area application and also for the entire country. This model produces spatial distribution map for the predicted yields.

CROPMON was extended into different directions. The model could be adapted to IRS WiFS data applications to farms. Also, CROPMON provided a tool for going far beyond the qualitative comparisons of vegetation periods through non crop specific NDVI-values and provided potential yield estimates to characterize the extent of drought. Parallel to these, many other applications could efficiently be added similarly to the waterlog assessment and ragweed monitoring and the remote sensing control of national area-based agricultural subsidies.

Acknowledgement

The whole HARSP had been supported jointly by the National Committee for Technological Development and the Ministry of Agriculture and Rural Development, (1993–96) Hungary. The Operational Crop Monitoring and Production Forecast Program (CROPMON) from 1997–2003 had been supported by the Ministry of Agriculture and Rural Development where the program reports were widely used. The FÖMI-ESA Prodex and PECS programs were carried out from ESA fund and FÖMI's own resources.

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Chapter 30

The Blind Mouse – A Game for Developing and Popularizing Cartographical Skills

Eszter Simonné Dombóvári[1, 2] and Mátyás Gede[2]

[1] Institute of Geoinformation and Cartography, Vienna University of Technology, Austria
eszter@cartography.tuwien.ac.at
[2] Department of Cartography and Geoinformatics, Eötvös Loránd University, Budapest, Hungary
saman@map.elte.hu

Abstract

In the past few years an exciting map game has been developed for entertainment and for drawing the attention of the users to cartography. It was originally prepared for education. This program and such developing areas of webcartography should be of interest to anyone who is involved in teaching or using cartography in schools or at university. It is an amusing way of learning and it can help pupils to practise what they have learnt previously, that is the curriculum itself. On the other hand it is able to popularize the cartography discipline in different age-groups.

Playing the game can be useful at home or in teaching. The levels of the game correspond to the Hungarian National Core Curriculum and are based on the topographic requirements of primary schools, of secondary school final exams and of university geography courses. This website of the game is presented for Hungarian pupils to develop their cartographical skills and for teachers to help their work. Beside this, it is recommended to anyone who likes to test his/her knowledge of maps and geography.

The currently available themes are: Hungary and Turkey, while Austria and some other areas are under construction. This programme was implemented into English, German and Turkish. In the future we have to find answers for two questions: Is there any need for this game in education in other countries of Central and Eastern Europe? Which role can it have in the education of a country?

Keywords: Cartographic Education, Webcartography, Map Game, Curriculum

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30.1 Introduction

These days we witness an unexpected development of Information and Communication Technology (ICT). Its rule and importance is determinative even in schoolwork (Eurydice 2004). During the past decades the use of computers in educational settings has increased dramatically. Since pupils in today's classes tend to surround themselves with technology in their daily lives, they may grow to expect it in the classroom as well beside simple classroom aids (books, workbooks, visual aids: maps, atlases, globes, foils, slides etc.). With these, method and content of teaching expands and new quality comes into life in teaching and training (Makádi 2006). As a new resource to help, promote, enhance and facilitate learning, the computer has fostered high expectations of more effective, more relevant, more motivating, and more innovative new learning experiences.

As far back as the history of geography teaching goes, conscientious teachers have sought new and better ways to facilitate and accelerate geography learning. Challenging questions have always confronted them: What else can we do, beyond and beside what we are already doing to promote more efficient learning for more learners? What new techniques could increase the rate and quality of learning of our pupils? What techniques are useful at certain stages of teaching and learning?

We all know that people's best learning experiences come when they are engaged in activities that they enjoy and care about (Resnick 2004).

Nowadays the number of geographical and cartographical websites is continuously increasing. These are e.g. geography homepages and portals, encyclopaedias, guides, methodological assistance, databases, map- and outline map catalogues. A website containing map games can be included in this category, because it is planned to entertain. At the same time, it is also able to develop the user's cartographical skills. One of the most important requirements of the web map games is interactivity, which is supported by tools and languages like Flash, Java, JavaScript, SVG. This new technique lets the developers use interactive and multimedia elements to make dynamic websites (Zentai & Dombóvári 2005). In respect of education, an increasing number of GIS adoptions are important. If they correspond to various school levels, they can be an important part of learning.

Edutainment (concept from words *education* and *entertainment)* is a method of amusing teaching and learning with multimedia applications (Bollmann & Koch 2002). The use of it is fundamental even in the field of geography teaching as it can help practicing and enlarging the store of learning in particular by map reading and geographical concepts. The edutainment games have some basic elements, such as educational content, interactive components and attractive interface that can draw the attention of the users (Zentai & Dombóvári 2005). The main types of traditional cartographic edutainment are as follows (Dombóvári 2005):

- **Outline map game:** the users have to identify map features or position on a map (e.g. Wo befindet sich eigentlich …? http://www.rtl.de/news/games/europa_dart/ or Geographie-Spiele http://www.gamerevolt.com).
- **Puzzle:** the elements like administrative areas (countries or counties) are to be built up from elements (e.g. Map Games http://www.maps.com or Sheppard Software – Geography Games http://www.sheppardsoftware.com).
- **Cross-words:** is a combination of the normal cross-word and the outline map (e.g. Maps.com http://www.maps.com/ or AgameAday – Inquiring Cartographer http://www.agameaday.com).

Their main aim is to raise the attention of pupils and teachers and anyone interested. All these provide an opportunity for teachers to introduce not only educational but playful elements as well. Beside schoolroom exercises they enable home-schooling through personal home computers for pupils to practice what they have learnt previously, namely, the curriculum itself. And they build on the fact that everybody likes playing and testing their own knowledge. These games assist people in learning a skill as they play. Edutainment becomes more and more popular.

30.2 The Blind Mouse Game

30.2.1 Aims

The Blind Mouse is a mute map game on the web to educate as well as to amuse, which was originally prepared as the part of a MSc degree thesis in cartography at Eötvös Loránd University in Budapest (Dombóvári 2005). Our aim was to make an online and easily usable application to anyone who likes playing and testing his/her knowledge of maps and geography. It raises the attention for geography knowledge and more extensive use of maps. The criteria of developing the game was firstly creating a game with which you can check your knowledge of position and identifying map features, you have learnt previously. Secondly developing a game which is able to promote its build up and programming in the future. The top list with the average score of the users invite pupils to play again.

However, it can be a great tool in education to prepare for the exams at different grade levels. The levels correspond to the Hungarian National Core Curriculum. With this tool we can meet two important aims of the education: the game itself with the attractive interface can catch the attention of the users or rather the pupils to the maps and geographic concepts; on the other hand, because of the education components in the game, it can be an important way of learning and teaching.

30.2.2 Introducing the Game

The game starts with an introduction screen *(Figure 30.1).* Users can select their language, can register and log-in here. After logging in, the game settings page appears *(Figure 30.2),* where the themes, levels and the categories can be selected. It is also possible here to select which layers are to be displayed in the map.

The difficulty of the game increases with the decreasing number of visible layers, so this number is taken in account during the score calculation.

After these settings the game starts *(Figure 30.3).* The user's task is to place ten map objects by dragging them with the mouse cursor to their place. When it is finished, the program shows the real position of the objects and calculates the actual score *(Figure 30.4).*

The score depends on the average value of displacement (i. e. the distance between the place the user put the object to and its real position), and the number of visible layers. More layers and/or bigger distances mean lower scores.

After finishing the game, the user can select four options: to start a new game with the same settings, to change the settings, to view the „top list" or to log out.

The top list shows the average score of the users (i. e. not the best score but the average is stored). It seems to be a more realistic measure than the best score, which can easily grow high by an eventual lucky set of objects. The scores are separately stored for each theme and difficulty level.

30.3 Preparation

30.3.1 Sources

Two sources are used for this map game: maps and topographic requirements. These mean the graphic and text background of the program.

The maps from these areas are prepared in the graphic program CorelDRAW. These are geographic maps for the education. Therefore, they have more details in the graphic than they would have in this scale for the web. The map areas and the composition of the map are the same as in the atlases and in school books. The legend of the maps consists of relief with eight colours, hydrology, state and administrative boundaries. These layers make the map more efficient. They should be useful for pupils to identify the map objects and position on the map.

The maps are prepared for web browsers. Their interactivity is in the mouse-moving and deciding the mouse-positions. An opportunity of the map games not used so far is the choice of the map layers. It is also a part of our game. In addition to the grid system lines the user can choose other layers or variation of layers out of relief, hydrology, state boundaries, and administrative boundaries *(Figure 30.5).*

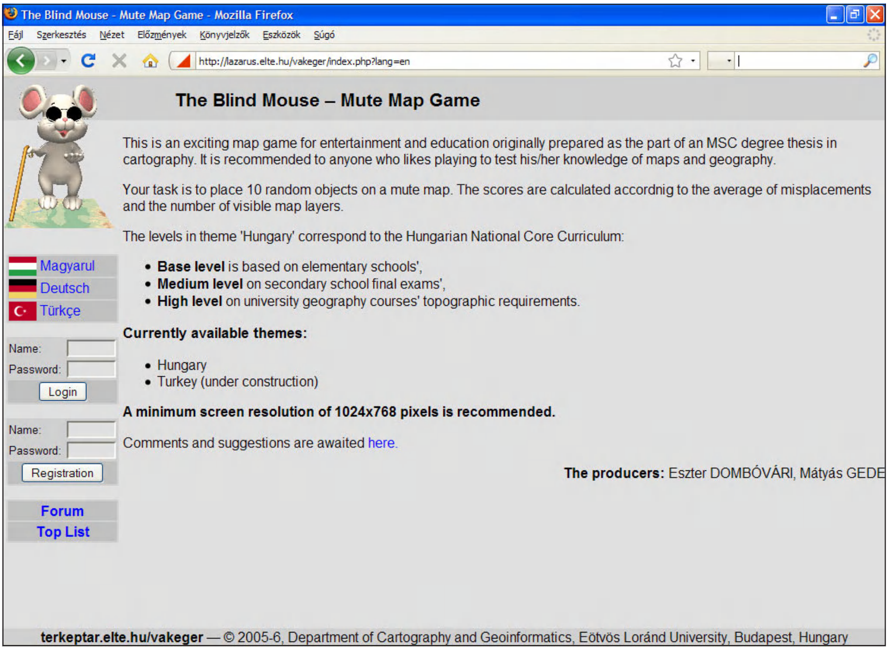

Fig. 30.1. The introduction screen

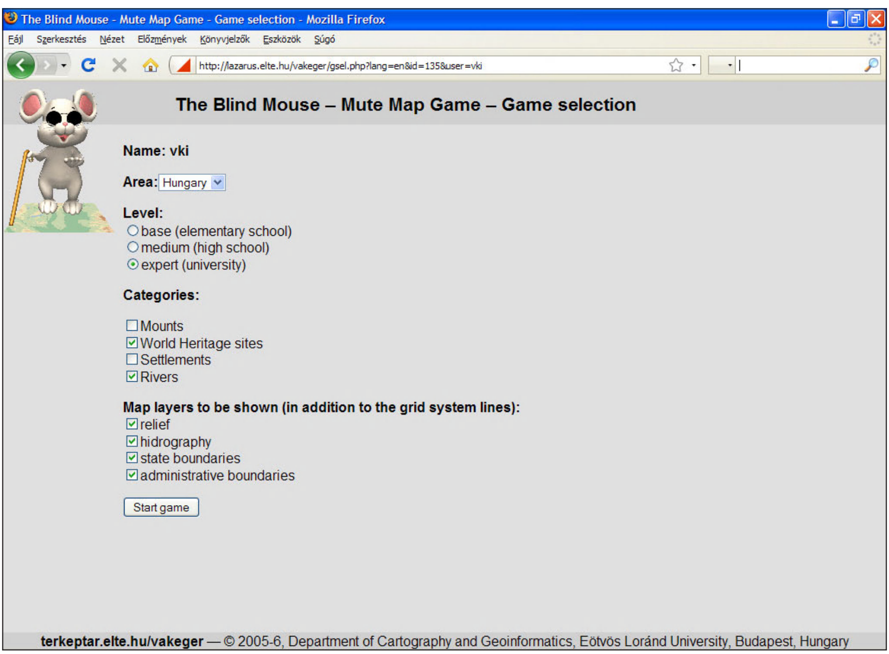

Fig. 30.2. Game settings page

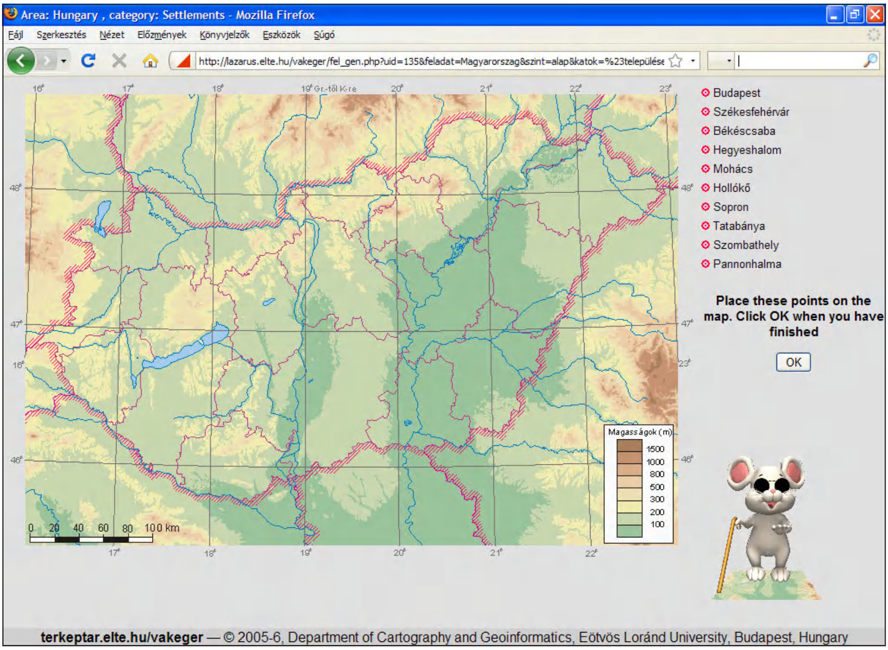

Fig. 30.3. The game starts

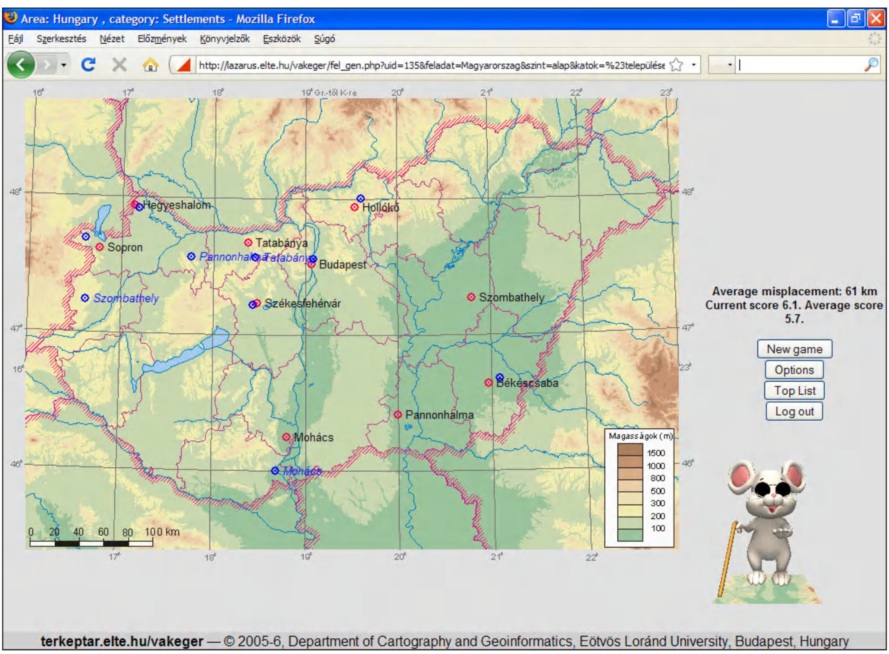

Fig. 30.4. Result evaluation page

The other part of used sources was the list of topographic requirements. The levels of the theme 'Hungary' correspond to the Hungarian National Core Curriculum (OKM 2005). The purpose behind this was that the developed game should be used at all levels:

- **Base level** is formed on the *elementary school requirements* (35 settlements). The public education law lets schools make their own curriculum and pedagogical programme. The National Basic Curriculum does not lay down compulsory expectations: primary and secondary schools express minimum requirements according to the "skeleton" curriculum. We used that of Apáczai Primary School, the training school of our university.
- **Medium level** is based on the *secondary school final exams* (70 settlements, 8 world heritage sites, 13 rivers). The list of geographic names comes from a list containing the requirements of the school leaving exam published by Ministry of Education. This has to be used since 2005. (OKM 2005)
- **High level** is founded on the topographic requirements of *university geography courses* (435 settlements, 8 world heritage sites, 38 mounts, 13 rivers). The law on higher education (2003) does not have any compulsory lists. Therefore, we used the requirements for geography pupils of our university.

30.3.2 Data Processing

The data processing and build-up of the game consists of two parts:

- **graphical data** – this means the export of the map layers in the correct raster data format,
- **text data** – the levels of topographic requirements and the coordinates of the elements as text files.

The map game gives you the opportunity to choose the map layers and various map layers can be shown (in addition to the grid system lines). This is realised with the availability of transparent GIF-files for each map layer *(Figure 30.5):* grid system lines, relief, hydrology, state and administrative boundaries. One colour – in this case, the white – can be transparent, so in these pixels you can see the graphics in the background. Placing the images in the right order onto the same place on the display produces a map with the layers previously chosen by the users.

The text data used by the system includes the following items:

- **description of themes**: the theme name in various languages; references to the map images; the km/pixel rate of the map (this is used to calculate the value of displacement)
- **description of categories** (in all available languages) with references to the icon images that represent the items in the map

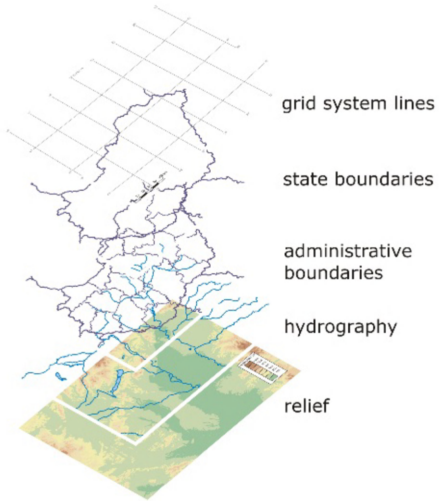

Fig. 30.5. Layers of the Hungarian map game

- **object list of the different categories**. Each object has one or more names, and a pair of coordinates. The system provides the ability of using exonyms for each object. If there is an available exonym in the language that was selected in the beginning of the game, it will be shown in the map. In the other case the default name will be used.

All the maps and text data are stored in a directory structure *(Figure 30.6)* that allows an easy upgrade: each theme has its own directory. This consists of the image files of the theme, the theme description and three additional sub-directories for the three game levels. In these levels there are files for each category (e.g. towns, mountains etc.) that contain the category description and the object list. Adding a new category to a theme means copying the appropriate category file to the directory structure. Adding a new theme can be done by creating a new directory with its sub-directories and files. The system will automatically find them when starting a new game.

30.3.3 Programming

The system was planned to be portable, so all codes were written in scripting languages (PHP and JavaScript). The scores and user information are stored in MySQL tables *(Figure 30.7)*. This allows an easy migration as PHP and MySQL are usable at most Internet-providers (Gede 2008).

The client-side JavaScript realizes the interactivity of the game: the drag-and-drop of the map objects. It was chosen because it is recognised by all of the web-

```
vakeger/ (home directory)
|
+- (various script files)
|
+- feladatok/ (themes directory)
  |
  +- Magyarország/ (Theme: Hungary)
  | |
  | +- (theme description file & map layer image files)
  | |
  | +- altisk/ (Base level)
  | | +- (data files for different object categories)
  | |
  | +- kozepisk/ (Medium level)
  | | +- (data files for different object categories)
  | |
  | +- egyetem/ (High level)
  |   +- (data files for different object categories)
  |
  |
  +- Törökország/ (Theme: Turkey)
    |
    +- (theme description file & map layer image files)
    |
    +- altisk/ (Base level)
    | +- (data files for different object categories)
    |
    +- kozepisk/ (Medium level)
    | +- (data files for different object categories)
    |
    +- egyetem/ (High level)
      +- (data files for different object categories)
```

Fig. 30.6. Directory structure

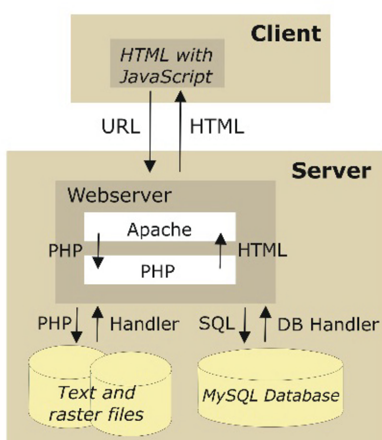

Fig. 30.7. The technical environment

browsers and there is no need to install any kind of plug-ins in order to play the game. Of course, it brought a lot of problems to solve, because different browsers (e.g. Internet Explorer, Mozilla, Opera) use different object structure – we can say, different „dialects” of JavaScript – so the scripts have to determine the browser type and run the appropriate code variation.

The server-side PHP scripts implement the user management (user registration, logging, score storage, top list generation), the theme and category selection, the random object selection for every new game, and the forum page of the game (Achour et al. 2007).

The portability of the game performed very well when it had to be migrated because of a server breakdown. The whole process required only half an hour.

30.4 Use of the Website

Since the game’s completion 7258 players have entered and 61101 games have been played. On the average 12 people have played per day. But days can be found when 676 people registered. The most enthusiastic player has played 1 891 times altogether.

All the computers connecting with Internet have a special identification, a so called domain name which helps to prove that this web page has been visited from 23 countries: beside Hungary, from Romania, Germany, Austria and Slovakia. It also has been tried in Cyprus, Singapore and Australia. What’s more, there are schools in different parts of Hungary which regularly visit this page.

For the last three years it has been shown on different programmes such as:

- university programmes (Neumann Day at ELTE, open day),
- pedagogical and school programmes (Pécs, Apáczai Educational Centre, Budapest Pedagogical Days, Corvinus University)
- or nationwide exhibition (The year of the Earth, Earth Sciences for Mankind, Budapest Scientific Museum)

30.4.1 Feedbacks

The real usefulness of any web service is shown through the feedbacks. That is why the forum page was attached to the game. In the first few months, several notes arrived about program errors and other faults which meant big help in debugging. Later we were glad to see that most of the users found this game very useful and entertaining in the geography education. Some teachers even started to make pupils play this game during Geography classes. Because of the top list they are in a sort of

Fig. 30.8. Presentation of the game on different programs

competition with their classmates, friends, and they play more and more to reach a better rank in the list. Luckily, pupils feel that they are only playing, while the game helps them memorise topographic information.

30.4.2 Further Development Ideas

The game is evaluated with the help of comments and suggestions made by users. According to the forum notes, users would like to see more themes (whole continents, other countries etc.). Although the system structure allows easy theme addition, creating a new map takes a lot of work. An automatic map generation (from free data sources) would largely accelerate this process.

Some of the users think that the lack of any time limit makes the game unfair, because people can look up places in an atlas, and this way produce brilliant results.

Another shortage is that only point features can be defined. There is no possibility to add lines (like rivers) or polygons (like big lakes, administrative units, mountain ranges etc).

The main horizons of the future developments are the elimination of the previously mentioned shortages. The plans are:

- Defining a time limit: a game could only take thirty seconds. A clock would show the remaining time, and after the time limit the game would be automatically evaluated.
- Adding new themes: currently Europe and the Carpathian Basin are under construction. Later we would like to add all the continents, and at least the major European countries. The system structure allows easy map addition.
- Adding line and polygon features. This is the hardest problem, as we need to figure out how a game with points, lines and polygons to place would work. What would be the users' task: simply dragging the features to their place, or

drag and rotate them, or should they draw the outlines directly to the map? The work can start only after it is made clear.

- Adding zoom tools. This allows a more correct identification and position of the map objects on the outline map.

30.5 Conclusions

The Blind Mouse mute map game is founded on a concept of edutainment; it has been developed for entertainment and for education. This website was prepared to raise the attention of pupils, teachers and anyone interested who likes playing and testing his/her knowledge of maps and geography. It is originally addressed to pupils in different school levels. It corresponds to the Hungarian Curriculum requirements. Therefore its education component makes it an important way of learning and teaching at home or in the classroom. The feedbacks show the real usefulness of the website. Our aim is to develop it. There will be a complete web application for enriching topography knowledge with the help of new functions.

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Section VI: Historical Cartography

Chapter 31

Orientation of the Map of Lazarus (1528) of Hungary – Result of the Ptolemian Projection?

Gábor Timár[1], Gábor Molnár[2, 1], Balázs Székely[2, 1] and Katalin Plihál[3]

[1] Dept. of Geophysics and Space Science, Eötvös University, Budapest, Hungary
timar@ludens.elte.hu
[2] Institute of Photogrammetry and Remote Sensing, Vienna University of Technology, Austria
{gmo, Balazs.Szekely}@ipf.tuwien.ac.at
[3] Map Archive, National Széchenyi Library, Budapest, Hungary
kplihal@oszk.hu

Abstract

The strange orientation of the map of Lazarus (1528) has been a subject of a long debate of Hungarian cartographers in the 20th century. In this map, northeast is up, instead of the normal and traditional orientation where the north is up. It was long ago supposed that this orientation is a result of the local/regional usage of the Ptolemian projection of the world maps of the age of the map construction. If a Ptolemian conic projection is defined in the GIS environment with the parameters of Φ_1=0°, Φ_2=64°and Λ_0=90° (from Greenwich), interestingly enough, the map can be rectified and the resulted image has right angles at its corners and all sides are horizontal or vertical in the Ptolemian coordinate system but not, of course, in the modern ones. The linear rectification errors in this projection are more or less equal to the quadratic ones in fitting to modern coordinate systems eg. to a UTM zone. This suggests that the above projection can be considered at least as a substituting one or even the real projection of the Lazarus map. If we consider this projection as a Ptolemian one, it leads to a more general indication: the Ptolemian projection used also by Lazarus has two standard parallels, the Equator and the Northern Circle, which is more or less the same as the mysterious Parallel of Thule in the maps of Ptolemy. In the map, however, the main directions are rotated by 90°; the grid north points to the original left indicated by the word 'Occidens' (west), which is considered as an error of the press preparation.

Keywords: Lazarus Secretarius, Ptolemian projection, historical maps, Pannonian Basin, georeference, GIS

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31.1 Introduction

The map of Lazarus (1528) is the first map showing the historical Hungary and its surroundings in one cartographic product consisting of four sheets. The orientation of this map, however, is strange for the modern reader; the geographic north is rotated to right by cca. 40–45 degrees *(Figure 31.1).* There were a lot of explanations of this rotation in the past decades. The debate followed two line of thoughts. According the first one, the reason would be the usage of the world projection of Ptolemy (cf. Snyder 1987, 2007). The other opinion is that either the map or its orientation is not related to anything like projections, geodesy and modern topography (eg. Bede 1987, Lotz 1988, Fleck 2003). These authors consider the selection of the orientation as a tool that provides the most comfortable display of the territory of the country.

The first explanation appeared earlier: it was first presented by Cholnoky (1943), who pointed out that the orientation of the Lazarus map is natural if we put this piece of land to the conic world projection of Ptolemy *(Figure 31.2).* In the terms of the modern cartography, the network north in this projection is up, while the geographic north considerably differs from it. This idea was supported later by Fodor (1952) and Irmédi-Molnár (1958, 1964), too.

The following literature focused mainly on the reconstruction of the geographic coordinate network at parts of the map (Hrenkó 1974, Érdi-Krausz 1976, 1982). Fleck (1979) provides the first analytical review of the location coordinate data available of the time of Lazarus. The distortion of the map shows considerable regional differences, which led to opinions denying any projections of the map of Lazarus. The systematic projection analysis, based on distortions represented by the Tissot indicatrices of the map was made by Stegena (1976, 1982).

There is one point that is accepted by all researchers: the basis of the survey was the itineraries (Cholnoky 1943, Plihál 1990, Plihál 2003, Török 1996), whose one-dimensional character excludes the geodetic approaches. In our previous work (Molnár et al. 2008), however, we showed that the map of Lazarus could be rectified with surprisingly good accuracy using the modern GIS tools. The GIS methods offer also a possibility to check, whether the above mentioned opinion of Cholnoky (1943) is correct and with what accuracy. For this, we have to have an assumption about the way of creation of the Lazarus map. Besides, the results provide interesting additions to the practical modelling of the Ptolemian projection.

31.2 How Would *We* Make the Map of Lazarus?

Besides of reading the literature, it is worth contemplating on how we could solve the surveying and drawing if *we* were in place of Lazarus with the available knowl-

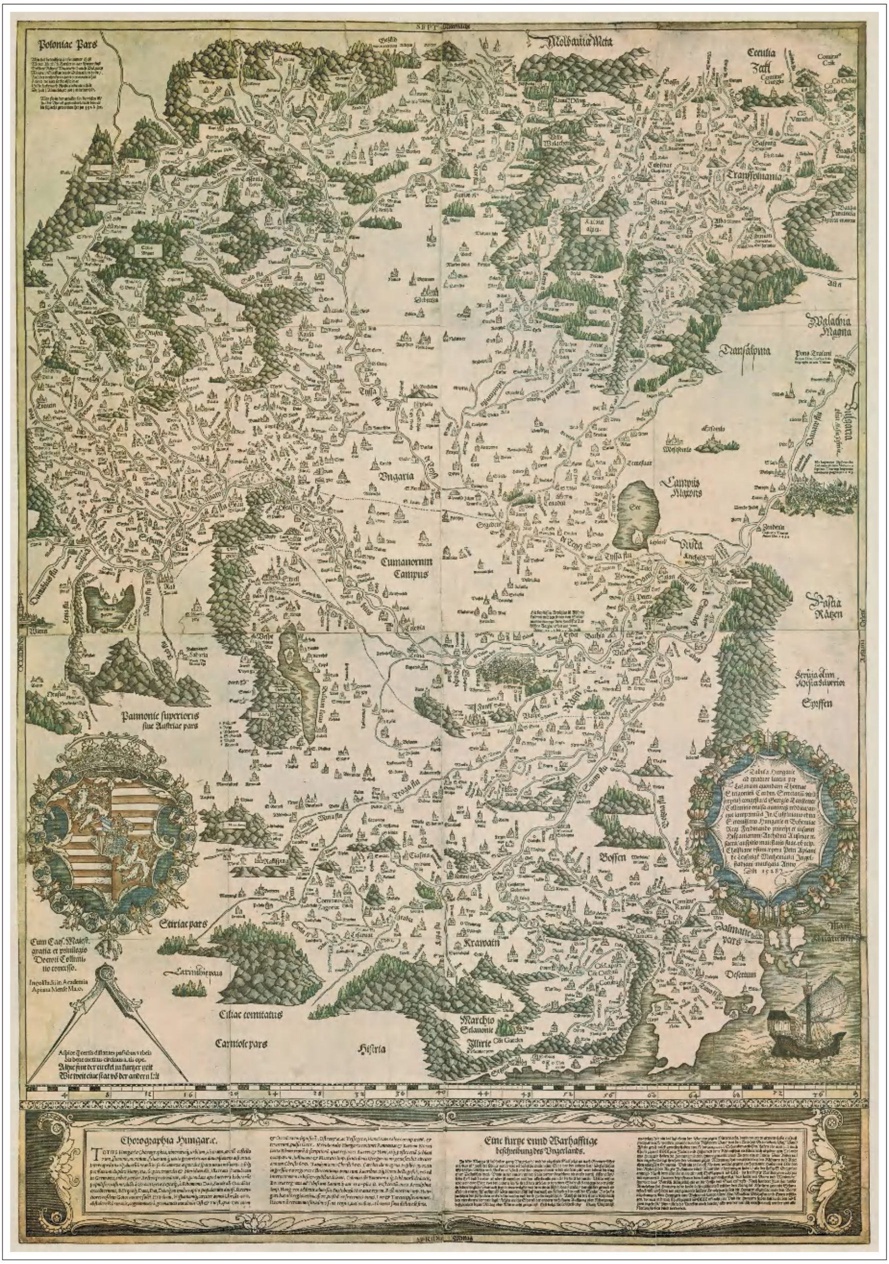

Fig. 31.1. The map of Lazarus (1528), the first cartographic work of the whole historical Hungary and its surroundings

edge of the early 16th century. We have to know *some* control points to start the survey from. In such a big area that the Pannonian Basin is, these points have to be

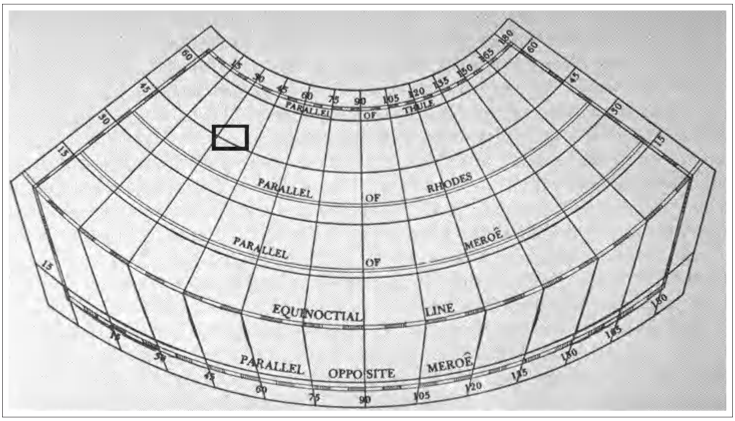

Fig. 31.2. The structure of the world maps of Ptolemian type and the location of the Lazarus map in it

defined by geographic coordinates. Besides, we have to have a rule describing the location of the control points in the coordinate system of the map. These requirements are somewhat the historical equivalents to the ’first-order geodetic network’ and the ’map projection’. However, the latter one was not defined by equations but by geometric drawing rules.

Could have been point coordinates known for Lazarus? Of course, the coordinate list of Ptolemy (83–161), with several thousands of locations (almost fifty of them lying within the extents of Lazarus’ map) were available for him, as well as the lists of Regiomontanus of Alphonsus. From Ptolemy’s *Geographia* and *Almagest*, it was also known, how to place these coordinate pairs to the cosmographic (world) map used since the ancient times. Several points, located in *Pannonia Superior* and *Inferior*, *Noricum*, *Illyricum*, *Dacia* and *Sarmatia* (Fehér 2004), could be drawn in the empty paper or pergamen as a starting step of the map making. The details between these control point could have been based on the itineraries (Plihál 1990, Török 2007a), which was the ancient counterpart of the modern traversing, along the roads of the country. Some fortresses appear doubled in the map; the traversing could be a possible explanation to that; their locations resulted to different places according to different traverse lines, all affected by local errors. The map maker hasn’t decided, which location is the ’correct’ one – he had no tools for cross-checking – so he drawn both in the map.

Based on the above considerations and speculations, we argue any statements about the ’projectionless’ character of the map, based on the local errors of the detailed surveys. Of course, the coordinates of the control points are also burdened by errors (Fleck 1979), and the errors of the survey method increase these, resulting the total error of the map positions. If the accuracy of the georeference is not worse than that (and, as we see later, it is not worse), we can suppose the application of a map projection. Let's see, could it be the Ptolemian projection, which was used at the world maps of this time?

31.3 Ptolemian Projection in the GIS Systems

If we assume that the map of Lazarus has the Ptolemian projection and we want to support it by GIS tools we have to know the type of the projection and also its parameters. The type is obviously the equidistant conic projection (Snyder 1987). In our opinion, the scale factor (the character of one or two standard parallels used) is not important. What is vital, is the peak angle of the cone, therefore the angles between the meridians. We used the ER Mapper GIS software for the analysis. It enables to define the equidistant conic projection with two standard parallels. We could try to estimate the location of the standard parallel using the meridian angles (Timár et al. 2003). The problem with this method is that the longitude values in the Ptolemian maps are considerably over-estimated (cf. Török 2007b).

To estimate the parameters of the projection (the location of the projection center and the standard parallels), we can use the map of Lazarus itself. In our recent work (Molnár et al. 2008) we defined a database of more than 600 control points about the written locations in the map. These points are defined (1) in the image coordinate system of the scanned map image and (2) by the modern geographic coordinates of the settlements. The Ptolemian projection type was tried with several standard parallel pairs and with different projection centers. Using the tested parameters, the geographic coordinates of the database locations were recomputed to planar coordinates. Linear function parameters were estimated between these planar coordinates and the known image coordinates of the points. As a result, we found that the position of the standard parallels affects the corner angles of the resulted rectified map, while the projection center affects its rotation. Both are important for the projection parameters; we were searching a parameter set providing a rectified map with right angles in its corners and its border lines are horizontals and verticals *(Figure 31.3)*. This result appears when the projection parameters are the following:

$\Phi_1=0°$

$\Phi_2=64°$

so the first standard parallel is the Equator and the second is the one that marked as 'Parallel of Thule' in the Ptolemian maps. This latter one is, in our opinion, the ancient version of the polar circle. Its latitude slightly differs from the modern value of 66.5 degrees.

The latitude definition of Ptolemy is basically not explained in degrees but the length of the longest daylight of the year. Therefore, no latitudes north of the polar

Fig. 31.3. Rectification of the map of Lazarus (a) with incorrect standard parallels and projection center (b) with incorrect standard parallels but correct central meridian (c) with correct standard parallels but incorrect central meridian (d) with correct parameters

circle, are given. It can be imagined that the maximum daylight length of 24 hours were detected at this latitude, because of

- the planetary precession (a periodic change of the angle between the rotation axis and the Ecliptic, which is now 23.5 degrees; between 20 and 24.5 degrees with a period of 40,000 years), which altered the position of the polar circle by about half degree since the 2000 years of the Ptolemian observations;
- the real extents of the Sun in the sky, which is about half a degree, and
- the refraction, also causing ca. half a degree.

These three factor can explain only 1.5 degrees of the real 2.5 degrees, so our explanation that the 'Parallel of Thule' is the ancient polar circle is not evidenced. Although it not relevant in our analysis, it can be hypothesized that these two parallels were selected for standard ones because they are the locations of the shortest (at the Equator) and longest (at the northern polar circle and northwards) period of the maximum daylights.

If these two parallels are selected for standard ones, the corners of the rectified map are right angles, not depending on the location of the projection center. The projection center affects the angle between the map bottom and top lines to the horizontal. The longitude of projection center, which provides horizontal top and bottom lines, is:

Λ_0=90° (from Greenwich)

At first sight this figure is not surprising as it is expected that the central meridian is in the halfway of the known world of 180 degrees longitude range in the Ptolemy's maps. However, these maps have the prime (westernmost) meridian not at Greenwich, but more to the west, at the westernmost point of the Old World, in the Canary Islands, practically at a meridian that was later called Ferro. The central meridian from Ferro is no longer 90 but 107–108 degrees.

If we look a Ptolemian world maps *(Figure 31.2),* we see the Old World from the Canary Islands to Japan, which is a longitude range of 160 degrees. Most of the maps of Ptolemy's type indicate this range as 180 degrees but some of them (see eg. Török 2007b) take a larger angle. Consequently, all longitude values have a longitude-dependent distortion. The longitude of *Aquincum* (ancient Roman settlement at Budapest) should be 36–37 degrees from Ferro, while its position is 43 degrees in the Ptolemian coordinate list. Therefore, the longitude distortion is larger in the western part of the *oikoumene* (οἰκουμένη), the Old World. This results that the optimal position of the projection center is not ninety degrees from Ferro.

Nevertheless in case of the equidistant conic projection, defined with the above parameters, the rectified version of the Lazarus map has right angles in the corners and horizontal and vertical borders *(Figure 31.4).*

Further explanations are needed about the direction descriptions in the map. Namely, the western direction ('*Occidens*') is up, which is mostly irregular. A speculative explanation can be the following: The original manuscipt could be in Landscape format, with the north up. During the press preparation works it was re-designed to Portrait format while the title and the coat of arms were also placed in the map. These two elements divided the original structure into three parts. The printer, who placed the direction descriptions to the press form, was not aware of the above modifications or the content of the accompanying text. This latter information says 'If you turn the map correctly to the directions, you'll see, which town lies to west or to east from each other, or similarly to south or to north". This message would be not needed at all, if there are direction descriptions in the map (Plihál 1990).

31.4 Rectification of the Lazarus Map in the Ptolemian Projection

It is worth comparing the rectification accuracy of the Lazarus map in the above defined Ptolemian projection (henceforth referred to as LP-projection) and in the

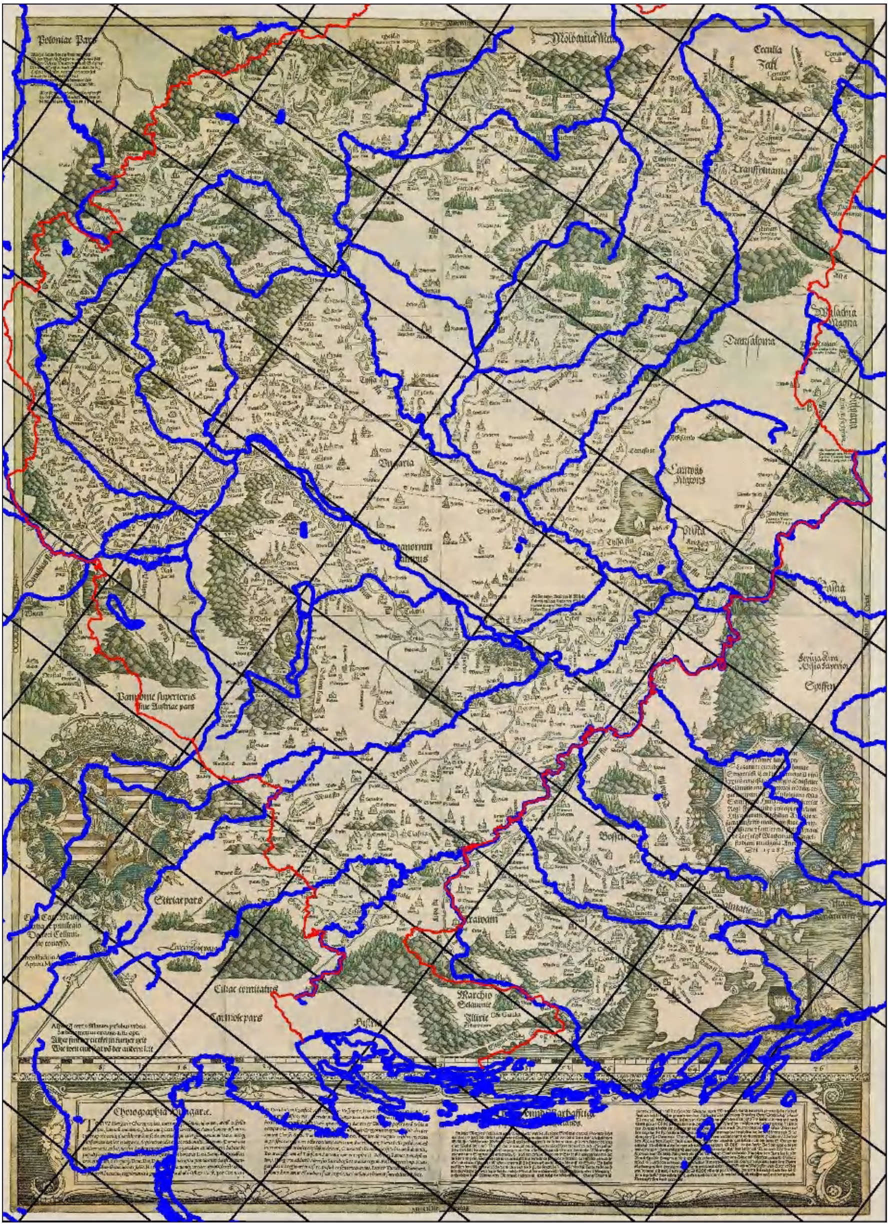

Fig. 31.4. The rectified map of Lazarus with the modern vector data showing the latitude-longitude grid and the drainage network. Borders of the historical Hungary are indicated by red line.

modern projections (Molnár et al. 2008). The *linear* rectification to the LP-projection can be made with similar accuracy as the *quadratic* rectification to the modern projections. This advocates the concept of the usage of the LP-projection at the map of Lazarus. The average accuracy of the rectification is 15–20 kilometers. The errors are considerably lower in the central part of the country. Around some cities where astronomical observatories could be present in the second part of the 15th century (Vienna, Buda, Várad [Oradea], Gyulafehérvár [Alba Iulia]) there is almost zero error. In the external parts of the map, at the Adriatic coast, at the lower reach of the Danube and Sava Rivers and in Eastern Transylvania, the accuracy is lower, errors of ca. 30 km occur. It has to be noted that these zones belonged to chapters of the Ptolemian point list other than the Pannonian one (*Dacia, Moesia, Illyria*).

Finally we mention that the latitude of the projection center is insignificant in case of correct setting of the standard parallels, therefore. the false eastings and false northings of the projection center were set to zero. As there is no indication of the projected coordinates in the map of Lazarus, the coordinates in the LP-projection are merely auxiliary variables; those values depend on the latitude of projection center, but it does not affect the rectification in the modern coordinate system.

31.5 Summary

Based on a control point list, containing around six hundred localities in the map of Lazarus, we concluded that the map can be rectified in the equidistant conic projection (the first Ptolemian projection) with the following parameters: Φ_1=0°; Φ_2=64°; Λ_0=90° (from Greenwich). Applying this projection, the rectified map has right angles in its corners and horizontal and vertical borders. The latitude of the projection center is indifferent, the projected coordinates of the center were set to zero. The average accuracy of the rectification is 15–20 km, the maximum errors are slightly over 30 km. If we accept that the ’Ptolemian projection’ was used in that period, then the map of Lazarus provides indirect evidence that the two standard parallels of this conic projection were the Equator and the northern polar circle (or, the perhaps similar, ’Parallel of Thule’).

Acknowledgements

The authors feel deeply indepted to the numerous unknown anonymous monks, whose copying work made the survival of Ptolemy’s works and his coordinate register possible.

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Chapter 32

History of the Hungarian Geological Maps – An Overview from the 18th Century to Nowadays

Csilla Galambos

Geological Institute of Hungary, Budapest, Hungary
galambos@mafi.hu

Abstract

The first geological map about Hungary was published by Robert Townson in 1797. He mapped the geological features along his route only. The map of the French Sulplice Beudant was issued in 1818. This is the first geological map that covers the whole territory of Hungary, using number codes to indicate the different features. The usage of the colors and surface symbols were rather random selected in these maps. The 2nd Geological Congress held in Bologna, 1881, brought change in the color codes of the geological maps, introducing an internationally accepted system. The later geological maps of János Böckh (M=1:1,000,000; 1896) and Lajos Lóczy sen. (M=1:900,000; 1922) were compiled according to this new system, showing the whole Carpathian Basin, the historical Hungary. Between the two WWs, only parts of Hungary were mapped (the map of the Great Hungarian Plain by József Sümeghy, 1944, should be mentioned). From the 1950s, the maps were using unified symbol system. An official age table and the color and surface signs connected to the geological features became widely used. This progress is clearly seen on the geological maps of Balogh (M=1:300,000; 1956) and Fülöp (M=1:500,000; 1984). Nowadays, the official geological map of Hungary is an electronically designed map with GIS background, developed by the Geological Institute of Hungary; its printed version has a scale of 1:100,000. Relational databases of lithology, boreholes and outcrops are connected to this vector-based electronic map product.

Keywords: geological maps, map colors, map signs, map

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32.1 Introduction

The usage of the colors is continuous since the dawn of the history. Looking back at it, we see that every age had its own color and shape fashion. A continuous development is outlined as every age formed its tradition to the utilization of the colors.

The application of the maps shows a similar movement: a huge development occurred from the wooden and shell maps of the natural tribes via Ptolemy to nowadays. Ore sites, water sources and mines are shown even on the oldest maps. Later the signs of postal directions, agricultural features became also frequently applied. The specialization of the maps, therefore the appearance of the geological maps, began in the late 18th and early 19th centuries. In the 19th century the general development of the sciences brought advances in the geological mapping. Instead of the random usage of colors and signs, a mostly unified system spread worldwide.

Geological maps have three important factors to be analyzed: their topographic base maps, their projections and their symbol systems. The first two factors are somewhat connected: the geodetic basis and the applied map projection go together with the topographic basis. However, for cartographic analyses, they can be handled separately, as the topography provides the connectivity of the thematic content to the terrain features; the geodetic basis is the key for the geo-referencing, the application in these maps in modern GIS environments.

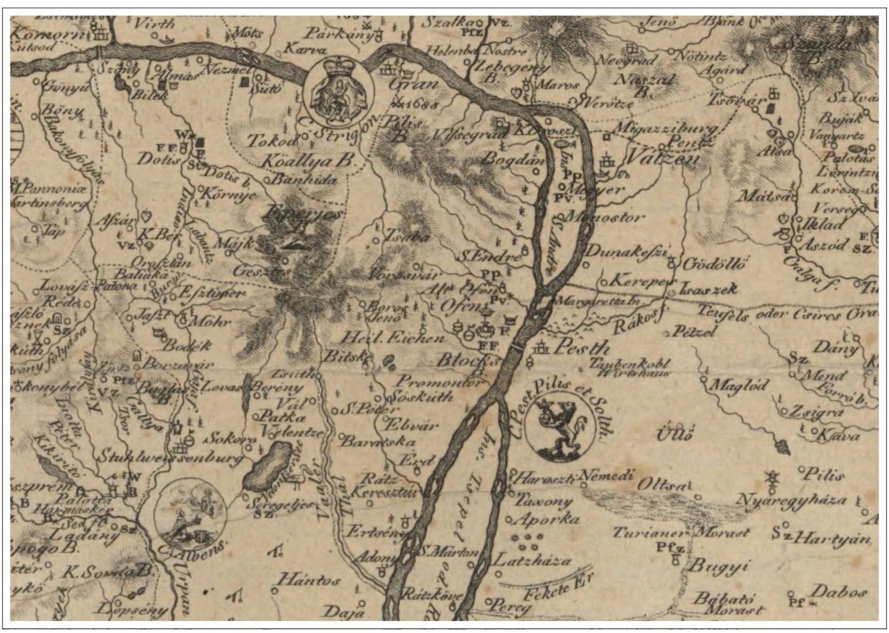

Fig. 32.1. The map of Korabinsky (1791); the first indications to mines and mineral occurrences in a full-country map of Hungary

In this paper the story of the Hungarian geological maps is given with the special emphasis to the applied map symbol systems and colors. As the mentioned cartographic products are too big for fully displaying them, a sample area, the surroundings of Budapest and its western foreland, was selected in case of all maps.

32.2 Geological Mapping in Hungary Prior to the Bologna Color Protocol (–1881)

The description and understanding of the lithological units, the stratigraphy was turned to a systematic observing science by mainly of the work of Abraham Werner Gottelob, the professor of the Mining Academy of Freiburg in the late 18th century. The compilation of the geological maps in the base of stratigraphy started in the first decades of the 19th century by the work of William Smith (Fülöp et al. 1975).

The first map systematically indicating the mines of Hungary was issued by Johann Matthias Korabinsky (1791). The symbol set of this economic-geographical map is rich; besides the occurrence of the minerals, it contains symbols for the industry and the agriculture *(Figure 32.1).*

The publication of the English traveler Robert Townson, member of the Royal Society, documenting his 1793 visit to Hungary was issued in 1797 in London *(Figure 32.2).* The abovementioned Korabinsky map was attached to this report as an appendix. He showed 13 geological formations in it along his travel route. These formations were indicated by color patches and color codes. This is the first color map of Hungary, showing the geology of large parts of the country, with the observation stations along the route of Townson (Fülöp 1968, Galambos 2004). The map indicates also the overlapping lithological strata and outlines its information sources: *'When Colours in Stripes run diagonally, there the Rocks are composed on the different kinds of Rocks signified by those Colours. The Colours which form only an Outline, do not refere to the Petrography, but to the People'* (Townson 1797).

The first real geological map of the country was compiled by a French geologist Francois Sulpice Beudant (1822) in the scale of 1:1 million *(Figure 32.3).* In this map the formations are indicated by numbers, the sixteen units of the legend go from the oldest to the younger units. The volcanic formations are at the end of the legend. Beudant used articulation in the legend as *Terrains Primitifs, Terrains Intermédiaire*, *Terrains Secondaire, Terrains Terciaires* and *Terrains Indépendants*. This map was the first metric one, showing the historical Hungary (Brezsnyánszky & Síkhegyi 2007).

In the early geological maps of Townson and Beudant, the geological formations were indicated only by numbers and colors. The usage of the colors is quite random and unique as there were no protocols for the indication of the different rocks.

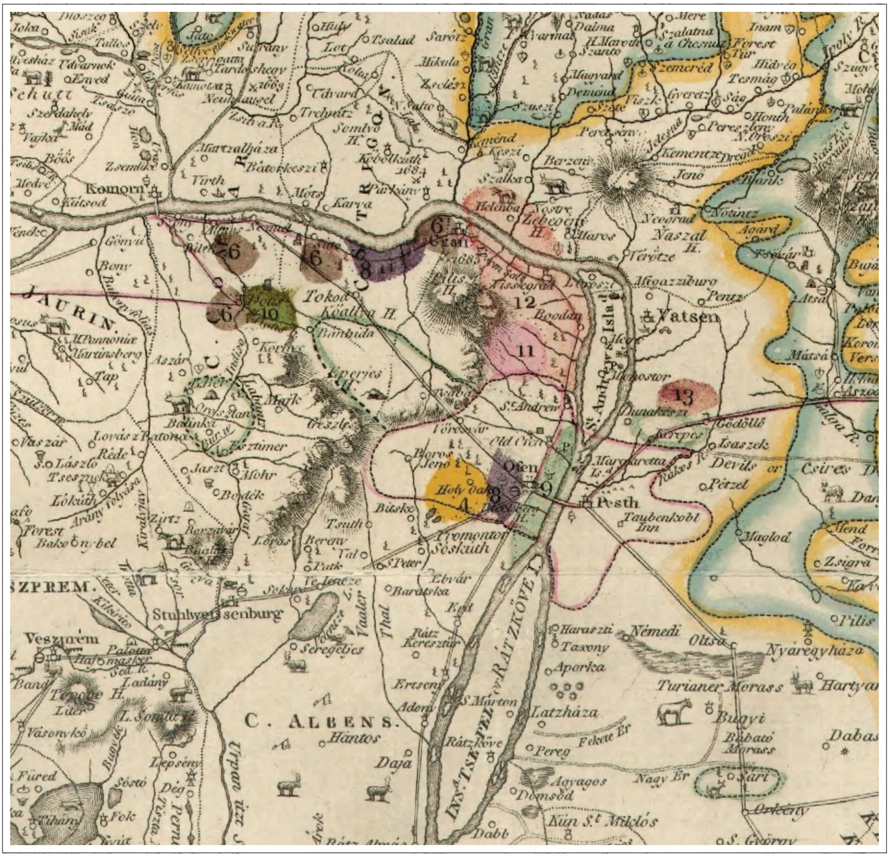

Fig. 32.2. The map of Townson (1797) is rather a travel report; some geological formations are indicated along the route of the map maker.

The Hungarian geologist József Szabó published three geological maps about the surroundings of the city of Budapest in the second half of the 19th century (Szabó 1858, 1878, 1887). It is interesting to follow the development of the map element in these maps that have the same extents. In the 1858 map he shows rock types, indicated also by number for the easier identification. For some rocks and for the alluvial units, surface signs are used on white background. In the 1878 and 1887 maps he uses also numbers but the ages of the formations are also appeared. These latter two maps are identical; the only change is in the color system, which is the effect of the Bologna color protocol.

In the Habsburg Monarchy, similarly to numerous other European countries, the systematic geological mapping has been started from the mid-19th century. The Hungarian Geological Society was founded in 1848 in Videfalva (now Vidiná in central Slovakia). The Geological Institute of the Monarchy was founded in 1849

Fig. 32.3. The first systematic geological map, showing the whole country is made by Beudant (1822). Number codes make easier the identification of the color patches, the symbols of the lithological units.

in Vienna and the Royal Hungarian Geological Institute became independent (in 1869) after the 1867 compromise between Austrians and Hungary, forming the Austro-Hungarian Monarchy. For comparison, the British Geological Survey was opting out from the Ordnance Survey in 1835, and the U. S. Geological Survey was founded in 1879. This is the period of the starting of systematic geological survey of the Pannonian Basin, too (Stegena 1998, Brezsnyánszky & Síkhegyi 2007).

32.3 The Bologna Convention (1881)

The development of the stratigraphy brought the renewal of the display method of the geological maps. The First Geological Congress in Paris (1878) put the unification of the stratigraphic classification and nomenclature to the agenda. Finally, the unified color and symbol system of the geological maps was accepted at the Second Geological Congress, held in 1881 in Bologna (Capellini 1882).

The basic of the color usage is that the older a formation the darker the hue indicating it. The geo-chronological color distribution used to nowadays was also

Fig. 32.4. Part of the chrono-stratigraphic and coloring protocol, accepted at the 2nd Geological Congress in Bologna, 1881 (from Capellini, 1882)

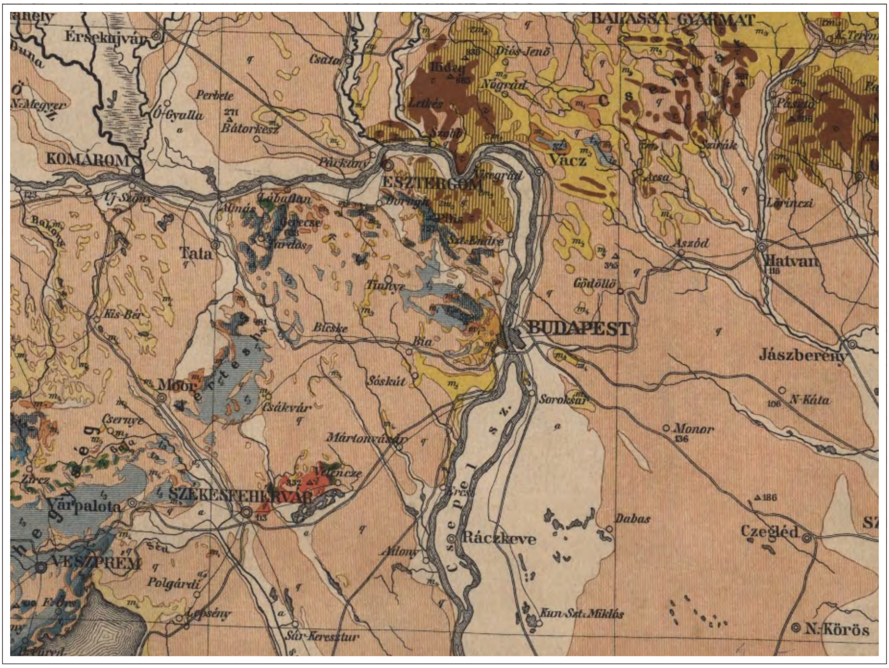

Fig. 32.5. The nice map of Böckh et al. (1996) was awarded by gold medal at the 1900 World Expo in Paris. The influence of the Bologna protocol is clear. The colored patches bear indexes for better identification of the formations.

accepted in Bologna *(Figure 32.4)*. The Third Geological Congress was called to autumn 1884 and was finally held in 1885. This congress finalized the unification of the geological symbols and aimed the compilation of the geological map of whole Europe.

32.4 The Geological Mapping in Hungary after 1881

The summarizing work of the Hungarian Geological Society, the Geological Map of Hungary was completed in 1893, by manual painting into a printed topographic base map. Its printed version was issued in 1896 *(Figure 32.5)* and was awarded by gold medal in the 1900 Paris World Expo (Pálfy 1901, Böckh 1903).

Lajos Lóczy completed a geological map of the Hungary and its surroundings in the scale of 1:360,000, in manuscript form, between 1890 and 1910. After his death, and also after the partitioning of the historical Hungary by the Treaty of Trianon, this map was printed as an issue of the Hungarian Geographical Society in 1922 in the scale of 1:900,000 *(Figure 32.6)*.

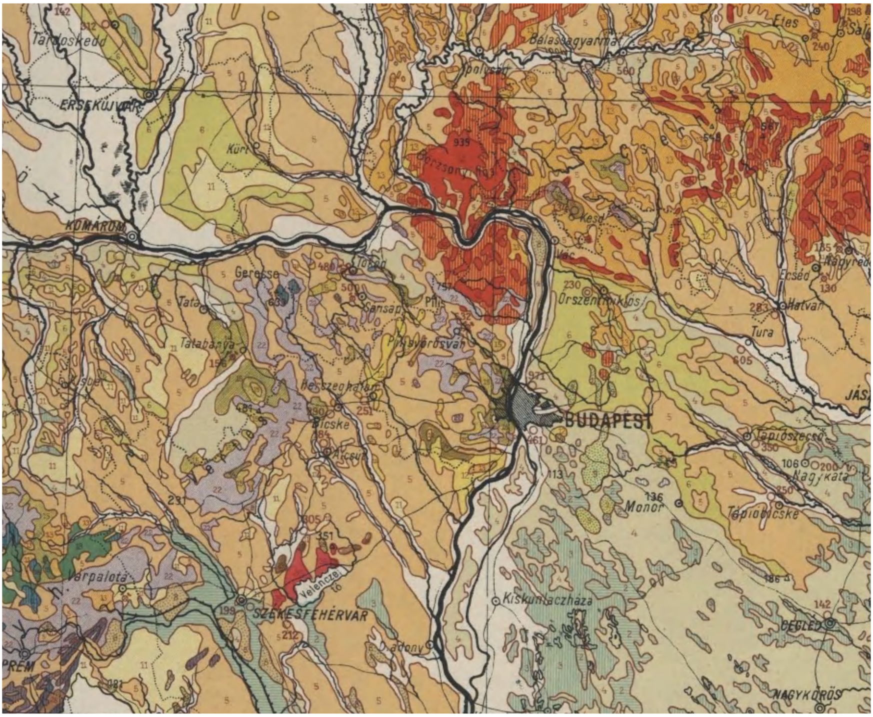

Fig. 32.6. The map of Lóczy at al. (1922) was compiled in 35 different colors – this results in a very aesthetic appearance.

The above two maps are very similar in their symbol system and also in their color usage, which is now conform to the Bologna protocols. The main difference is that the first one shows only the historical country inside its borders, while the second displays also the surrounding territories with striking details. The map of Lóczy was compiled in 35 independent hues, which is an extreme high number not only in the geological mapping but in the whole cartographic history.

There were no newer geological maps compiled about the whole country until the 1950s, however, the Hungarian Royal Geological Institute was issued a series of geological maps covering interesting parts of the country. The largest projects in this period were the geological (Sümeghy 1944) and pedological mapping (Kreybig 1944) of the Great Hungarian Plain, a huge alluvial flatland, representing the majority of the territory of Hungary, which attracted only a few specialists before. The geological and stratigraphic survey of this area was continued after the WWII (Rónai 1972).

The geological maps showing the (now considerably smaller) country, issued from the 1950s used more unified symbol systems. The chrono-stratigraphic table,

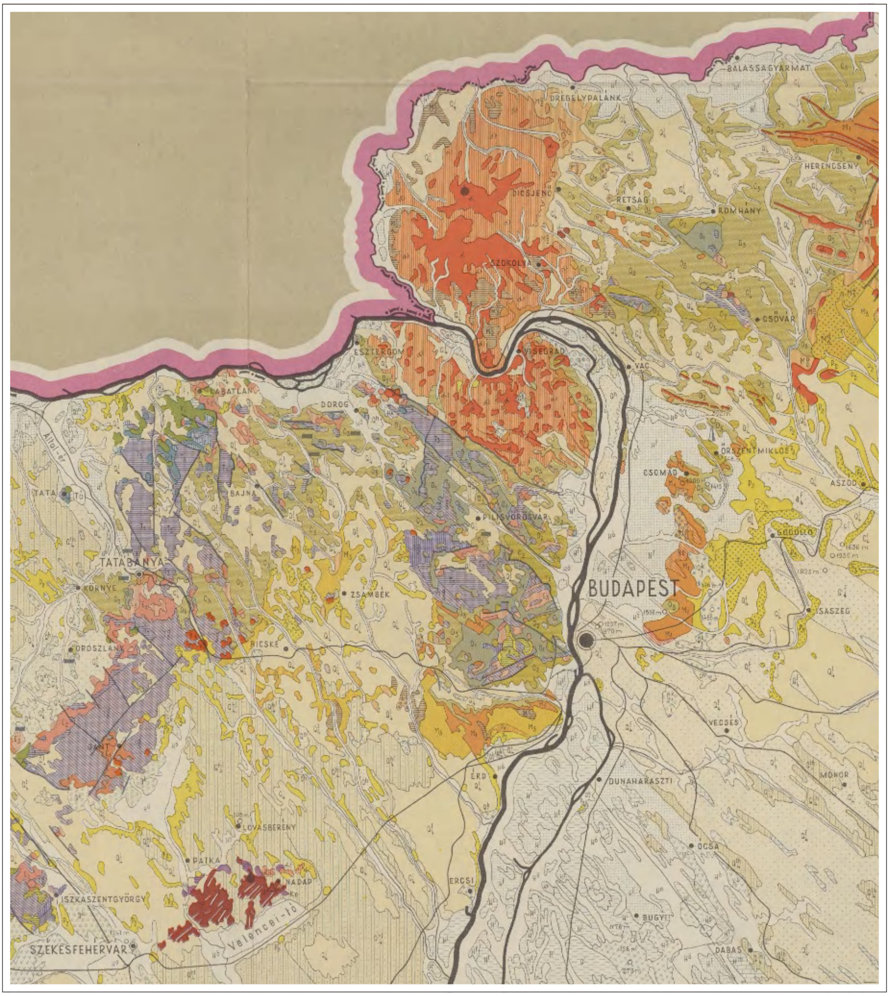

Fig. 32.7. *'Extra Hungariam non est vita'* – during the communism, a national authority cannot issue maps about the territory of the neighbors. The first country-wide geological map of the present (smaller) Hungary, the content of the map of Balogh (1956) ends at the borders.

that is used until nowadays, was formulated as well as the colors and surface symbols connected to the different formations. The map of Balogh (1956), in scale of 1:300,000 is characterized by unified stratigraphic and lithological legend and shows 30 Quaternary and 67 older formations *(Figure 32.7)*. The map of Fülöp (1984) in scale of 1:500,000, is somewhat resembling to the earlier displaying methods. It uses the unified chronography but the formations are indicated also by number codes *(Figure 32.8)*. The map uses 26 Quaternary and 101 older formations.

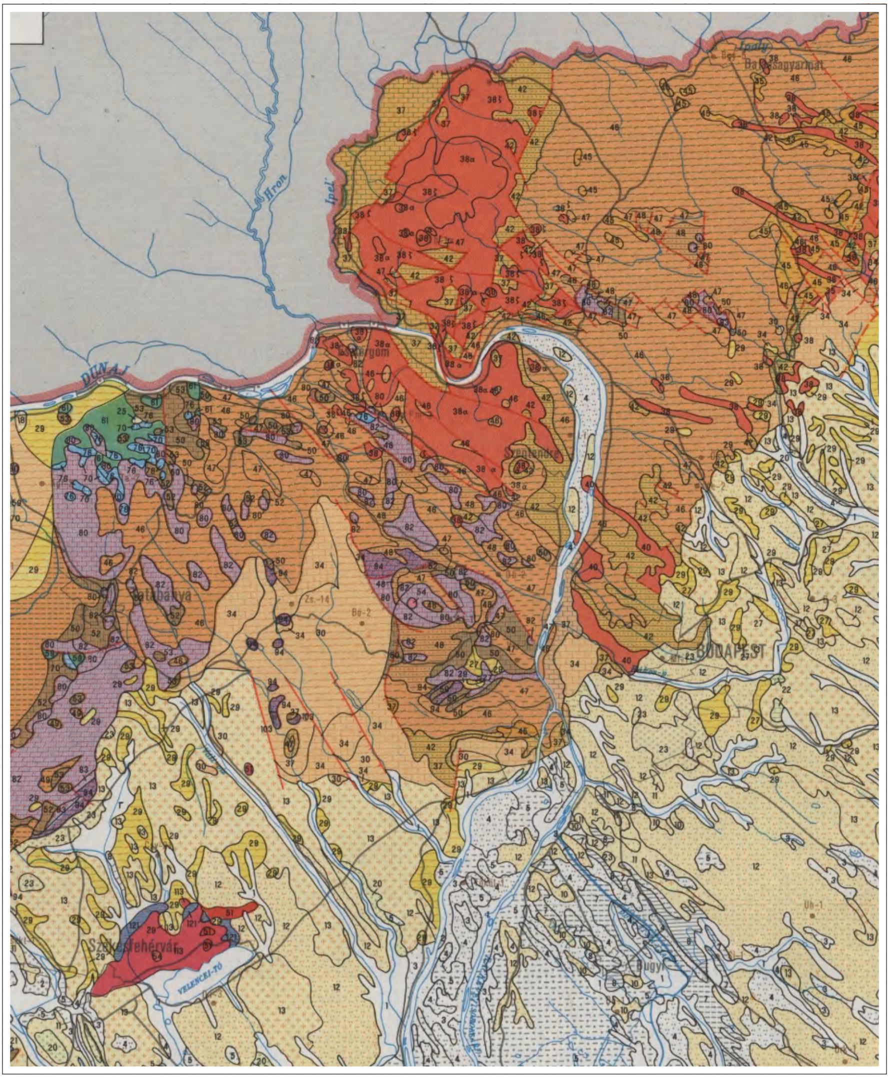

Fig. 32.8. Map of Fülöp (1984) – colored patches with surface symbols and numbers as identifiers

(Gyalog 2004). The history ends now at the modern, 1:100,000 scale geological series of the Hungarian Geological Institute, which was compiled using GIS environment and relational databases. Its colors and surface signs are also database elements and were compiled according to the most up-to-date international geological standards (Galambos 2004; Galambos & Simonyi 2006).

32.5 Summary

In the early maps, the formation were indicated by colors and numbered identifiers. The first surface symbols in the Hungarian geological maps were appeared in the map of Lóczy. The continuous numbering made easier the identification of the patches; however, it impeded the paste of further objects during the compilation. The first proposal to the usage of the symbols was issued in the 1881 Bologna Congress. The symbols that used nowadays are not so far from the Bologna protocols. The unified Bologna color code system was effective in the Hungarian geological maps from the end of the 19th century (Galambos 2009).

As the extents of the country became considerably smaller after the WWI, the characteristic scale of the maps increased respectively. The early maps of the 18th and 19th century as well as the printed map of Lóczy had a scale around 1:1 million, while the scale of the new country maps are doubled. The detailedness of the new, electronically compiled modern database is appropriate to the 1:100,000 scale printing.

Acknowledgements

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Chapter 33

Cartometric Analysis of Old Maps on the Example of Vogt's Map

Tomáš Bayer, Markéta Potůčková and Miroslav Čábelka

Department of Applied Geoinformatics and Cartography, Charles University in Prague, Czech Republic
{bayertom, mpot, cabelka}@natur.cuni.cz

Abstract

The article deals with the topic of assessment of the accuracy of Vogt's map of Bohemia. This map belongs among significant cartographic works depicting the Czech Lands in the period 1526 – 1720. The methodology of accuracy assessment is based on cartometric and geometric analyses of sets of identical points in the old map and of a reference map, using the technique of multiquadratic interpolation. The national topographic database is used as a reference data set. The results of the analysis including scale isolines, rotation, displacement vectors of identical points were visualized using the MapAnalyst software and the extension software ArcGIS, 3D Analyst.

Keywords: cartometric analysis, isolines, distortion, MapAnalyst, old maps of Bohemia

33.1 Introduction

Thanks to modern tools cartometric analysis of old or historical maps enables us to verify and assess their accuracy. The results present a valuable source of information about the way of map creation, mathematical-cartographic bases, and technique of processing. They also illustrate the development of map representations of the Czech Lands. They can be used for the study of evolution of landscape and the process of settlement taking into account long-term context. The methodology of

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cartometric analysis used in this article is based on comparing an old map with the current situation, and subsequent identification, analysis and interpretation of discovered changes. The article deals with the analysis of Vogt's map of the Czech Lands – an important map work which original is deposited in the Map Collection of the Faculty of Science, Charles University in Prague.

33.2 Related Work

Old and historical maps are an integral part of our history. Andrews (1975) emphasizes reasons for their analysis and purposes. The theory of cartometric analysis of historical maps and old maps describing relationships between map objects are mentioned in Blakemore & Harley (1980). They differentiate planimetric, geodetic, and topographic accuracy. Visualization of planimetric accuracy of the map allows to discover, describe and interpret possible relationships, links, patterns between map objects that, using classical analytical methods, may not be noticeable. Oehrli & Forstner (1998) described some techniques based on analysis of corresponding set of points. The method of the multiquadratic interpolation minimizing the influence of points with big errors was introduced by Hardy (1971). This method provided a theoretical basis for cartometric analysis algorithms developed by Beineke (2001). Software MapAnalyst enables a visualization of results of cartometric analysis of old maps, it uses algorithms developed by Beineke. This software has been implemented by Jenny & Weber (2001) from the Institute of Cartography of Zurich. It has a wide set of analytical tools, a well-arranged graphical interface and it is designed as an open-source tool. Features of this software, types of analysis, its visualization capabilities are introduced in Jenny (2006), Jenny et al. (2007). All analyses described in this article will be realized using MapAnalyst. The last stable version 1.3 has integrated OpenStreetMap client.

Cartometric analysis of old and historical maps that has recently been discussed include Portolan Charts (Loomer 1987), Portolan Maps, (Loomer 1990), Helwig

Fig. 33.1. Figural decorations of the Vogt´s map, left shows two-tailed lion and agricultural motives, right represents a personification of Czech rivers.

map of castles (Beineke & Brunner 1996), Pfyffer's Relief (Niederöst 2004), Map of the Coast of South America (Hesler 2005), Maps of the Shenandoah Valley (Pearson 2005), Ptolemy's Geographia Europe Tabula X (Liveriatos et al. 2007), Atlas of Amsterdam (Ormeling & Heere 2007), Gough Map of Great Britain (Lloyd et al. 2009). Following publications of Czech authors can be mentioned Second and Third Military Mapping (Veverka 2003), Second Military Mapping (Čada 2005, 2006), Military Mapping (Zimová et al. 2006), Müller's Map of Bohemia (Cajthaml 2009).

33.3 Characteristics of Vogt's Map

Vogt's map is an important cartographic work dated in the first quarter of the 18th century. Because it is not known to the wider public[1] as other maps from this period are, let us characterize it briefly, basing our description on works of prof. Kuchař (Kuchař 1958, 1960, 1961). The map was part of the book "Das jetz-lebende Königreich Böhmen in seiner historisch und geographischen Beschreibung vorgestelt" published in 1712 whose author was the abbot of the Plasy Monastery Johann Gregor Vogt. The map's size is 853 x 656 mm, its scale along the central meridian is quoted to be approx 1:396 800. The map covers the area of Bohemia between the parallels 48°– 51°30′, it does not directly include geographic grid, around the map frame there is a scale with the division of 2′ in the direction of longitude and latitude. The map is not created following a particular map projection. This map can be labeled as the last independent work created by a single cartographer in Bohemia.

Figural decorations. The map is richly illustrated, thus being not only an important cartographic but also a significant artistic work. Vogt´s map has three figural decorations. The first decoration shows the symbol of Bohemia, two-tailed lion with a crown on its head, see *Figure 33.1 left.* The second figural decoration represents the personification of Czech rivers by figures standing bellow Sněžka hill, see *Figure 33.1 right.* An old man pouring water symbolizes the longest Czech river Elbe, other figures (women, an old abbot, men, Eros) represent other important rivers and creeks in Bohemia (Vltava, Ohře, Otava, Berounka, Sázava). An interesting detail, 3 devils climbing the Sněžka hill, can be found on this figural decoration. The third figural decoration describes economic and agricultural characteristic of Bohemia, an allegory shows typical plants (a women harvesting grain) and animals (cows and sheep lying on the meadow), see *Figure 33.1 left.* The title of the map, engraved in the stone block, is located at bottom right.

[1] Not many copies of the Vogt's map were printed. It was firstly published at the time of preparing Müller´s mapping.

Fig. 33.2. A depiction of the Vltava river meander and map labels for Krkonoše mountains

Fig. 33.3. Illustration of Vogt's map from the Map Collection of the Faculty of Science, Charles University in Prague

Map content and symbology. Vogt's map represents altogether 3110 objects: 24 different symbols used for settlement (cities, villages, castles, ruins, churches, mines …), perspective images for castles, e.g. Bezděz (Bösig). It shows more than 100 mountains and has a high density of rivers and ponds, some of them drawn oversized up to 5 times. Vogt's map brings one of the first depictions of Vltava's meander, see *Figure 33.2 left.* The map contains geographic names in two languages but it conforms to German custom. Let us mention map labels for Krkonoše mountains: Das Riesen Gebirg, Riphael Montes, Ribizal Revier as the place, where the "Lord of the Mountains", Krakonoš (Ribizal), lives (see *Figure 33.2 right).*

33.4 Digitalization of Vogt's Map

Digitalization of the original of Vogt's map by scanning was our first step. Further progress was influenced by the mechanical characteristics of the original. The material used for manufacturing Vogt's map is paper pasted on canvas. The map had been folded several times; at these places there is mechanical damage of the paper and uneven stretching of the canvas. The map is compiled of 18 map fields, see *Figure 33.3*. Digitalization of the map with subsequent creation of continuous raster image presents a relatively difficult problem because of the above stated reasons.

The original of Vogt's map was scanned using the large-format scanner Contex CRYSTAL XL 42 with the resolution 200 dpi in the format TIFF. Pixel size was 0.127 mm. Then retouching of raster was performed removing impurities with software. This step was performed with the help of the tool Remove Speckles in the program MicroStation Descartes XM.

33.4.1 Creation of Continuous Map Image

Because of repeated folding of Vogt's map and its long-term storage in folded position a slight shift and rotation of individual map fields occurred. Therefore, the creation of continuous map image of Vogt's map was performed in three stages. The operations were completed using the software MicroStation Descartes XM.

Cutting scanned raster along map fields. The scanned raster was cut by software along the boundaries of map fields into the total of 18 raster images (3 rows, 6 columns). These images were not always rectangle-shaped, in some cases they were shaped like trapezoids. On several places the mechanical wear of the original caused spontaneous removal of small parts of the map drawing, especially along the folds. Therefore, the reconstruction did not result in an entirely continuous image of Vogt's map.

Projective transformation of map fields. Map fields are shifted in relation to each other and partly rotated. Because of using sheet-feed scanner with a material with higher basis weight some map fields were distorted towards a trapezoid shape. These places are unambiguously identifiable on the raster image. For removing this trapezoid distortion we used projective transformation representing the relationship between two planes in central projection. Identical points represented the corners of the reconstructed map fields. The size of the reconstructed field was derived from four adjoining fields.

Linking boundary contacts of adjoining fields. At the contact places of map fields' edges there still were reciprocal shifts in the image, even after projective transformation. For linking boundary contacts of the neighbouring fields, non-residual Jung's transformation was used with the aim of decreasing the extent of image transformation inside the map field to a maximum. Identical points in the local coordinate system were selected at contact places of neighbouring raster images in the areas of linking line elements (waters, roads). The corresponding identical point in the global coordinate system represented middle position of both identical points, its coordinates can be determined as the arithmetic mean of the coordinates of these points.

For each raster we used approx. 20 identical points selected according to the above stated principles. We do not enclose the overview of the coefficients of Jung's transformation because of the extent of this article.

Merging raster images. Individual raster images were then trimmed along vectorized boundaries of neighbouring map fields. In the program Descartes, using the function Merge, all 18 raster images were put together creating a final raster image which represented a continuous variant of Vogt's map. Existing jointing at contacting map sheets were filled with a mask in the colour of the maps background due to aesthetic reasons.

33.4.2 Transformation of Vogt's Map

The next step was the transform ation of raster Vogt's map into the JTSK[2] coordinate system. Here, selection of a set of identical points used for the calculation of transformation key played an important role. We will discuss this step in detail because it considerably influences the analysis results. Because of the fact the Vogt's map represents the area of all Bohemia we used the database ZABAGED[3] as our reference map. The database is available thanks to WMS services at the CENIA[4] portal. However, the map represents also the area of Kladzko which had been part of the Czech Lands in the period of the origin of the map. Because the database ZABAGED does not offer any map materials for this area we did not include it into the cartometric analysis. The positional accuracy of chosen objects

[2] JTSK represents a National Coordinate System of the Czech Republic.
[3] ZABAGED represents a National Geographic Database corresponding to a topographic map at scale of 1:10 000.
[4] CENIA, Czech Environmental Information Agency, providing information on the environment enabling the public to get a comprehensive view of the condition and sustainability of the environment we live in.

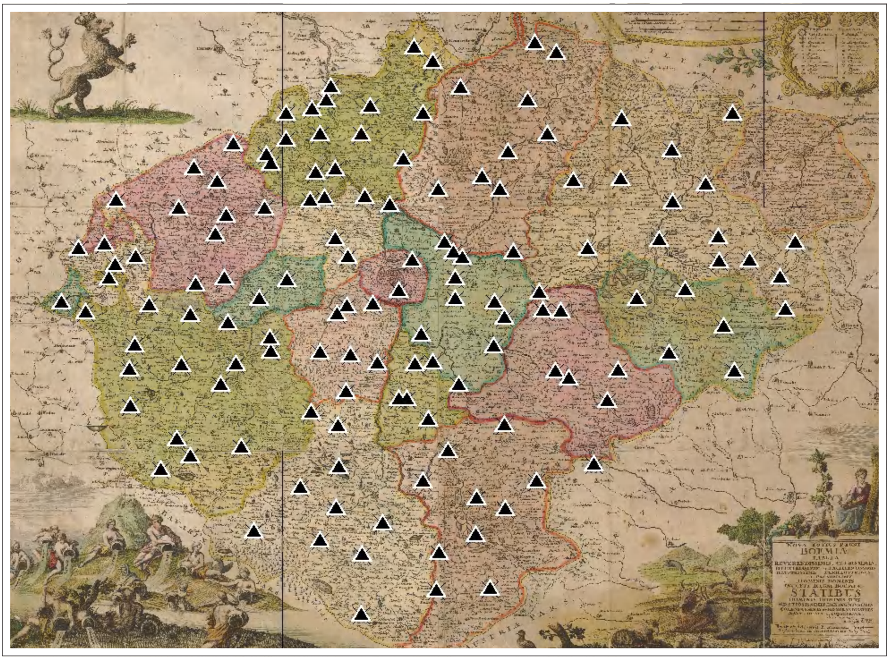

Fig. 33.4. Distribution of 137 identical points for the calculation of a transformation key

in the database ZABAGED characterised by middle position error of approx. 10 m ensures a sufficient basis for georeference of the raster image, taking into account Vogt's map scale.

Selection of identical points. The selection of identical points used for the calculation of a transformation key is a relatively complicated matter. When a map contains a geographical grid it seems best to use nodal points of meridians and parallels supplemented by significant and easy-to-identify points in the map. With such points we suppose that their position does not change significantly with time. Identical points should be distributed around the whole area, ideally in an even manner, so that the resulting transformation key has a global character, i.e. takes into account the geometrical-cartographic characteristics of the whole cartographic work.

Because the Vogt's map does not contain a geographical grid it is not possible to use nodal points. To calculate the transformation key we selected 137 identical points out of the total of 3110 elements found in the map (≈ 4.5%). This number can seem relatively small at first sight. However, the points were chosen carefully, taking into account the above stated principles, and they apparently constitute a relatively representative sample, see *Figure 33.4.* A similar result is presented in Vejrová (2008) using a set of 447 identical points. A complex cartometric analysis

Table 33.1. Values of affine transformation coefficients calculated from 137 identical points and standard deviations σ of the coefficients.

Coefficient	Value	σ
m_x	53.162318	0.37
m_y	54.841211	0.50
Δx	-65191.91 m	9.20 m
Δy	-19082.63 m	9.20 m
α	10.4152	0.31

of Vogt's map would be possible only after its complete vectorization, which was not done due to time reasons. The set of identical points is “almost" convex, with the exception of the south-east and north-east parts.

Types of identical points. Identical points represented towns, castles and chateaus evenly distributed around the area of the Czech Lands. A number of smaller towns depicted in the area of Sudetenland do not exist anymore these days, and most of the towns expanded considerably due to social or industrial reasons. When looking for corresponding points in the database ZABAGED we respected the historical development of particular towns and tried to select the position of each identical point in the area of the original centre of the town: square, church, fort, castle, chateau, ruin. In some cases these points are not situated in the centre of the currently built-up area and are noticeably oriented towards the periphery. This is the case in towns whose expansion is influenced by the shape of the surrounding relief, typical for hilly areas or foothills. Among other identical points there could be e.g. river confluences, ponds or other easily identifiable elements. However, it was not possible to perform further work on this topic due to time reasons.

The idea of cartometric analysis in the context of individual map topics could also be interesting, e.g. analyses of the accuracy of depicting municipalities, rivers or ponds. The map was not assessed as a whole but according to particular content elements. This topic could be dealt with in another article.

Transformation. To prevent distortion of the geometrical and positional relationship between the points we used affine transformation of first order. Higher-degree transformations were not used for the analyses because they cause unnatural distortions of the map image. Because of the redundancy of identical points the transformation coefficients were adjusted according to the method of the least squares $v^T v$ = min. The affine transformation equation can be written in a general form

$$X = m_x \cos(\alpha)x - m_y \sin(\alpha)y + \Delta x,$$
$$Y = m_x \sin(\alpha)x + m_y \cos(\alpha)y + \Delta y,$$

where *x, y* represent the coordinates of the local coordinate system, *X, Y* the coordinates in the global coordinate system, m_x, m_y the scale coefficients in the direction of the *x, y* axis, *α* the rotation angle. The parameters determined from the set of 137 identical points using the software MapAnalyst and supplemented with the characteristics of accuracies of their determination represented by the standard deviation σ are stated in *Table 33.1*.

Let us notice the similarity of two scale coefficients which differ by approx. 3%. Vogt's map as a whole is rotated in comparison to reference data set from ZABAGED by approx. 10°.

33.4.3 Cartometric Analyses

The aim of cartometric analyses is to verify cartographic parameters of the map. Because of the fact that cartographic work is a relatively extensive set of point, line and areal cartographic signs (its vectorization may take a long time), it is not usually possible to perform an analysis of the map as a whole, due to time reasons. Therefore, it is necessary to choose only a subset of such elements which represent a sample set in which we can suppose a higher degree of positional accuracy.

The basic set of points which was used for cartometric analyses contain 137 identical points. After completing affine transformation we could perform the cartometric analyses of Vogt's map. The results of the analyses serve as an approximate assessment criterion illustrating the accuracy of the map's construction. The results are presented in the form of tables or graphical outputs.

It is necessary to emphasize that the below stated results of cartometric analyses are *dependent* on the choice of the set of identical points serving for the calculation of the transformation key. If the number or distribution of identical points changed the results would be slightly different.

Positional displacement on identical points. Affine transformation belongs to the group of residual transformations; identical points in both coordinate systems are not fully identified. The values of corrections v_{xy} of identical points can be used to assess the accuracy of depiction of elements on the map, see *Figure 33.5*. It is interesting that using the stated transformation key the depiction of the town of Plasy (West Bohemia) was assessed as the most accurate (residuals 0.1 km). The town was Vogt's birthplace. The ruin of the castle Žampach in East Bohemia (identical point 133) was depicted very inaccurately (residuals 19 km); here the value of correction is three times bigger than standard deviation.

Positional accuracy of Vogt's map. Based on selected identical points, a standard deviation describing positional accuracy of Vogt's map reviled 8256 m. This value is rather remarkable considering the fact that Vogt's map was not created on solid geometric and geodetic basis[5]. Moreover, the stated value is highly influenced by errors that originate in the incorrect placing of some objects into the map. After

[5] Compare with result 8381 m published in Vejrova (2008), pp. 40.

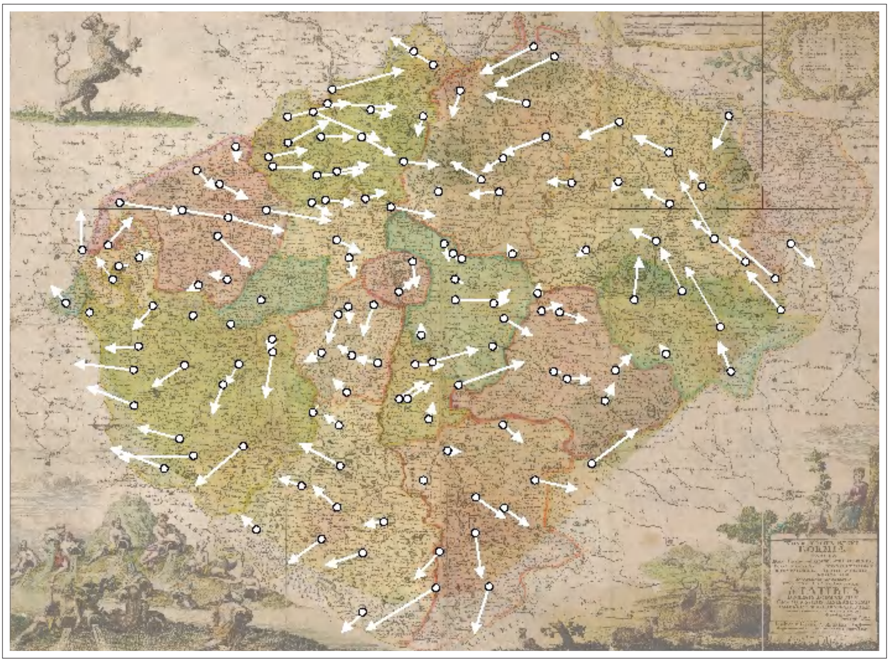

Fig. 33.5. Positional displacement of 137 identical points represented in the relative scale 2:1

eliminating an identical point no. 133, the standard deviation in position decreases to 8068 m.

Calculation of the map's scale When we know the resolution of the scanned raster image defined by the pixel size d and the scale coefficients m_x, m_y of the affine transformation we can determine the scale numbers of the map M_x, M_y in the direction of the x, y axis using the relations

$$M_x = \frac{1000 \cdot m_x}{d}$$

$$M_y = \frac{1000 \cdot m_y}{d}$$

After inserting the values the following results are obtained: M_x = 418 865, M_y = 431 865 and average scale M= 425 365. The calculated data deviate by approx. 6% from the scale number 396 800 stated in available literature[6].

[6] Compare with results M_X = 436 400, My = 430 800, M = 434 000, published in Vejrova (2008, pp. 40).

Fig. 33.6. Scale isolines of the longitudes of Vogt's map generated with the step 0.05

33.4.4 Calculation of Scale and Rotation

Analyses of scale and rotation are an important factor illustrating the accuracy of the construction of a cartographic work. We used the program MapAnalyst which is specialized for cartometric analyses of old and historical maps. For this purpose the program contains a complex geometrical-analytical apparatus using multiquadratic interpolation of a set of identical points. The process of cartometric analysis is fully automated, with the exception of collection of identical points. This fact contributes to speediness and overall reliability of the analytic process.

Using the set of 137 of identical points and parameters of the affine transformation the program MapAnalyst generated isolines of scale and rotation. Because of the fact the isolines generated by the program were not straight (but curved) and it is not possible to work out their description, the visualization was performed in the program ArcGIS. For this purpose we used the extensions SpatialAnalyst and 3D Analyst. Data of the old map were gradually exported into the formats DXF and SHP, in attribute table we completed the information about the coordinate *z* necessary for the creation of a 3D model. The function TopoToRaster was used to generate a 5m raster model from these data. This process lead to the creation of two 3D models showing the dependence of the scale and rotation on the geographical position of the point. Using the extension 3D Analyst isolines of scale and rotation were generated for these two models. Their descriptions were created in the extension Maplex.

Scale isolines, see *Figure 33.6,* show that the positional accuracy of Vogt's map changes depending on geographical position. Taking into account this criterion the best results in the map are reached in the area of Central and West Bohemia, the worst ones in the area of North and East Bohemia. This is the consequence of some objects (Žampach, Frýdlant) being incorrectly depicted, in the order of approx. 15 km. Distortion values come under interval ⟨1.4, 1.8⟩. Rotation isolines, see *Figure 33.7,* indicate that the biggest rotation appears in the areas of East, South and West Bohemia. On the other hand, the centre of Bohemia demonstrates relatively small rotation values. Rotation values for Vogt's map come under interval ⟨-5°, 50°⟩. If we assess Vogt's map taking into account both viewpoints, the following conclusions will be drawn. Vogt's map demonstrates the smallest accuracy in the area of East Bohemia where there are considerable positional and angular distortions. The highest accuracy has been detected in the area of Central and partly West Bohemia where there are minimum positional and angular distortions.

33.4.5 Result Evaluation

The question is why the area of Western Bohemia shows the best results (the highest scale and rotation accuracy) and the area of Northern and Eastern Bohemia has significantly worse results in all criteria. One of the possible explanations can be put into context with the place where Johann Gregor Vogt lived – the city of Plasy. The Plasy Monastery is located in Western Bohemia and this territory Vogt, who was a surveyor, probably mapped in more detail than other parts of Bohemia. The question is how many times the area of Eastern Bohemia Vogt visited and whether he did not use older cartographic works for these areas as a base map. These considerations would be necessary to support by archival materials but the authors did not find any relevant information in scientific publications. If we project a boundary of Bohemia in the Vogt´s map into current state map and if we neglect boundary changes in the last 300 years (a loss of the territory of Kladzsko), we find the largest positional differences between two boundaries in Northeastern Bohemia, see *Figure 33.8.* This fact confirms the results of the cartometric analysis and explains the different positional accuracy of the Vogt´s map.

Factors affecting results. The results arising from cartometric analyses are influenced by a number of various factors. The following three important factors can be considered as crucial in our case:

- *The original's quality:* The quality of the scanned original plays an important role in the process of cartometric analysis. In this case only the original was

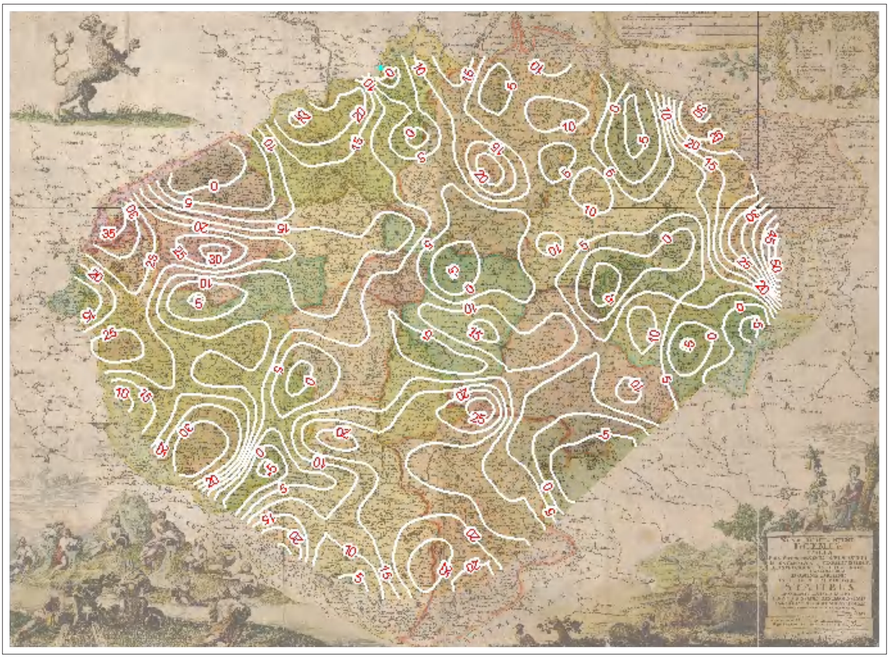

Fig. 33.7. Rotation isolines of Vogt's map generated with the step 10°

available. It had to be transformed into a continuous raster map using several heterogeneous geometrical procedures. It is probable that non-linear changes in the reciprocal position of some identical points of both sets appeared, thus influencing the achieved results.

- *Selection of identical points:* It is best to perform cartometric analysis in a completely digitalised cartographic work. If it is not possible due to financial or time reasons, it is possible to perform the analysis only for a subset of the map's content. In such case testing points have to be selected so that they are evenly distributed around the whole surface of the map, and their position has not significantly changed with time. Interpolation techniques based on multiquadratic interpolation are suitable for processing a set with approximately the same density of points. Unevenly distributed clusters of points or places containing no points negatively influence the achieved results. The used set of 137 identical points can be considered as sufficient; however, it was not always possible to maintain the same density of points. In mountain areas, especially in the Krkonoše or Šumava mountains, the necessary number of identical points was not available. Often these points are situated on the edge of the area; this is the reason we can suppose they will have higher weight when calculating some parameters of the transformation key (rotation).

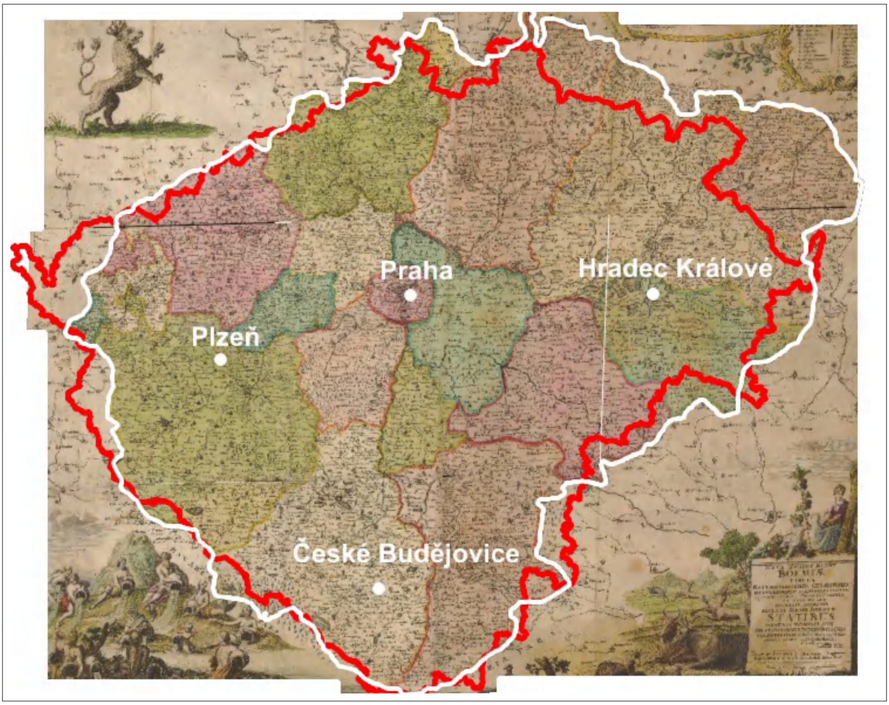

Fig. 33.8. Positional differences between boundary of Bohemia in Vogt´s map (white line) and a current boundary of Bohemia (red line)

- *Interpolation technique:* The technique of multiquadratic interpolation also played an important role. It was performed in the program MapAnalyst to reconstruct the continuous surface from discrete data. It is necessary to take into account the fact that the results represent only one of other possible mathematical models constructed for the input data.

Even in spite of the above stated facts the achieved results can be considered valid. None of the factors probably played such a significant role that would considerably influence the results of the cartometric analyses. However, to verify this it would be necessary to perform further tests of statistical character.

33.5 Conclusion

This article dealt with the process of digitalization and cartometric analysis of old maps, in particular the analysis of the original of Vogt's map, using the technique of comparing sets of identical points on an old and a modern map. The methodology used during the work enables to analyze inaccuracies in old maps, making use of modern mathematical-geometrical procedures, thus contributing to the speediness and reliability of the analysis.

Let us briefly summarize obtained results of cartometric analysis. An important quantitative characteristic of Vogt´s map represents the positional accuracy determined as 8256 m. It supports the fact, that Vogt's map was not created on solid geometric and geodetic basis. From the known resolution of the scanned raster image and the scale coefficients we determined the scale number 1:425 365 and the rotation of the map 10.4°.

The calculated parameters were visualized using the software MapAnalyst and ArcGIS, giving us interesting information about the accuracy in the construction of Vogt's map depending on the position of points. The results were influenced especially by the selection of identical points which served as a basis for determining a transformation key, and by the method of multiquadratic interpolation which was used.

The Map Collection of the Charles University in Prague currently contains several other cartographic works from the period 1518–1720. Their cartometric analyses of some of them are planned to be presented in cartographic journals and conference proceedings.

Acknowledgments

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Chapter 34

Structural Lineaments Derived from Planforms of Watercourses in the Second Military Survey of the Habsburg Empire

Gábor Kovács

Institute of Geography and Earth Sciences and Department of Cartography and Geoinformatics, Eötvös Loránd University, Budapest, Hungary
s_kovacs_gabor@hotmail.com

Abstract

Second Military Survey of the Habsburg Empire, carried out in the 19th century, can be very useful in different scientific investigations owing to its accuracy and data content. The fact, that the mapmakers used geodetic projection, and the high accuracy of the survey guarantee that scientists can use these maps and represented objects can be evaluated in retrospective studies. The streams were drawn with very thin lines that also ascertain the high accuracy of their location.

The goal of the study was the investigation of accuracy and usability of the Second Military Survey. The case study is the neotectonic evaluation of the western part of the Pannonian Basin, bordered by Pinka, Rába and Répce Rivers. The watercourses, especially alluivial ones, react very sensitively to tectonic forcing. However, the present-day course of creeks and rivers are mostly regulated, therefore they are unsuitable for such studies. Consequently, the watercourses should be reconstructed from maps surveyed prior to the main water control measures. Second Military Survey is a perfect source for such studies.

Maps show intensive agricultural cultivation and silviculture in the study area. Especially grazing cultivation precincts of the streams is important for us. That phenomenon and data from other sources prove that streams have not been regulated in that time. The streams were able to meander, and flood its banks, and only natural levees are present.

General morphology south from the Kőszegi Mountains shows typical SSE slopes with low relief cut off by 30–60 meter high scarps followed by streams.

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That suggested us to investigate the neotectonic features, what also indicated by the alternate meandering of surveyed streams. Geocoding of the maps of the area was followed by digitisation of the streams and calculation of their sinuosity. At some places significant difference of sinuosity has been observed along the streams, it can be considered as indicators of differential uplift or subsidence of the bedrock/alluvium. Since these places area aligned with direction of the steep scarps in the hilly region, we conclude that they are of neotectonic origin.

Keywords: Second Military Survey, neotectonic, sinuosity, watercourses

34.1 Introduction

The Second (also known as Franciscan) Military Survey is a masterpiece of the map series representing the territory of Austro-Hungarian Empire. It is outstanding in quality regarding its data content, drawing features and aesthetic appearance.

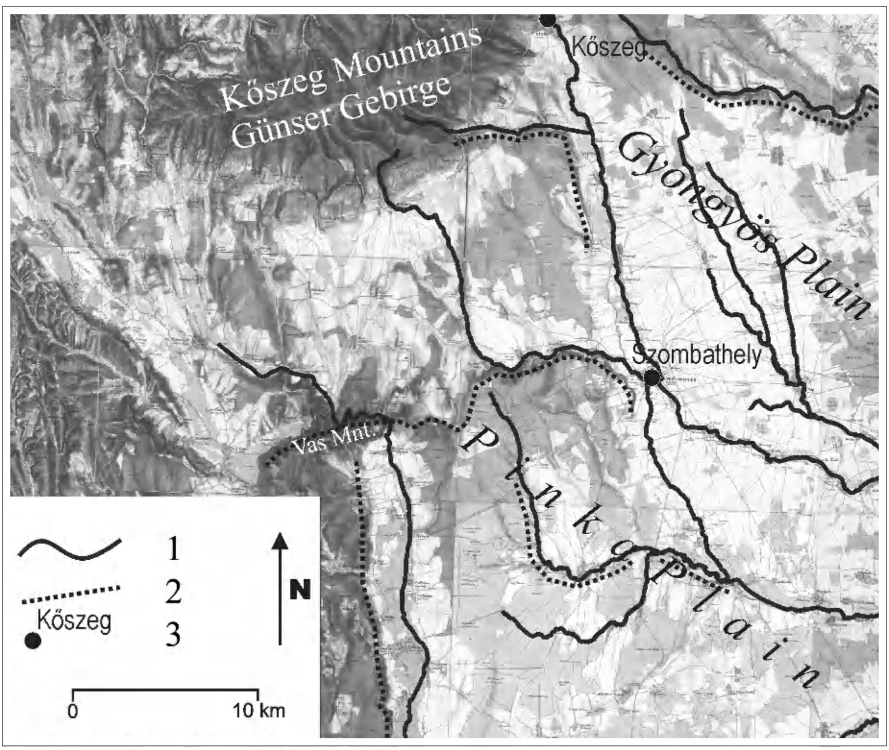

Fig. 34.1. mosaic using map sheets of the Second Military Survey regarding to the study area. 1 – streams; 2 – scarps; 3 – major cities

Although the series is not uniform in its content and in its implementation due to the extended period of time of the mapping (1806–1869), according to recent experience in its present-day usage, its map sheets are fairly well applicable even today (Timár et al. 2006).

From the beginning of the 1990s specialists of various branches like archaeology, hydrology, forestry and nature protection started to used the map sheets for reconstruction the contemporaneous landscape. Despite the difference in the mapping style, the excellent geodetic basis of the cartographic work made possible to compare the recent and former topographic features in specific study areas with acceptable accuracy. Hungarian Institute and Museum of Military History and Arcanum Ltd. published a series of DVD-ROMs containing the scanned digital and rectified map sheets. Timár et al. (2006) described their method of rectifying map sheets with 150–200 m average accuracy, but for certain map sheets the accuracy can be twice better.

My goal was to verify the accuracy of the rectified map sheets of my study area in order to test the applicability of such an analysis of the represented geomorphologic features like relief and streams. In the geomorphologic investigations high geometrical accuracy is needed due to the quantitative character of measurements. The study area is at the Austrian-Hungarian boundary, south from Kőszeg Mountains/Günser Gebirge and west from Rába River/Raab Fluss.

34.2 The Character of the Study Area

Topography of western Hungary is characterised by slightly tilted blocks to SSE bordered by relatively steep scarps; the latter features often define the course of several streams dewatering the area. In our previous studies (Kovács et al. 2008) we considered the neotectonic origin of these scarps. These remarkable topographic features are depicted in the Second Military Survey by the hachuring technique; furthermore they are also detectable as borders between agricultural cultivation and silviculture. *Figure 34.1* is assembled by neighbour map sheets in order to show that the invesigated survey is also useable in lower scale to observe aforementioned phenomena.

Other typical geomorphic characteristics of the area that can be deduced from the archive maps is the planform of the watercourses. In the study area they have a tendency to flow from NNW to SSE with sudden, almost perpendicular curves to left, eastwards. This secondary direction usually is not followed by scarps, occurs on almost plain areas. The creeks are arranged in a parallel pattern that has a typical spacing at ca. 1.5–2 km distance, the dendritic pattern and bifurcations are subordinate. The parallel pattern becomes complicated with the aforementioned set of eastward offsets that also seems to follow a regular structure.

34.3 Problem Setting

The above described specific behaviour may indicate neotectonic activity; however it may also be caused by human influence in case the watercourses were affected by flood control measures or defence efforts. The Second Military Survey, owing to the period of surveying, is one of the few cartographic works that provide information on the almost natural, uncontrolled state of the watercourses. Furthermore, although there is no detailed information on the elevation, the aforementioned hachure and the fine drawing of the watercourses together makes the map sheets suitable for such analyses.

34.4 Method

The rectified map sheets are comparable to other surveys by any GIS software; in this study Leica Geosystems ERDAS IMAGINE 9.2 was used to rectify map sheets into the same geodetic system. The scanned map sheets of the Second Military Survey are already rectified on the above-mentioned DVD-ROM, furthermore it is possible to export maps in the whole area of interest. Especially helpful that it is possible in a lot of geodetic systems. ESRI ArcView 3.3 was used to digitise and compare the different kind of map sheets and ESRI ArcGIS 9.2 to calculate sinuosity.

The first step was to digitise the stream network from different map surveys in the same applied geodetic system and compare them with each other. The topographic maps I used for reference were the First Military Survey (1763–1785, scale 1:28800) and the Hungarian National Mapping System (1991–1998, scale 1:10000), the geodetic system used was the Hungarian National Grid (EOV).

34.5 The Potential Use of the Topographic Surveys

The important structures and phenomena that had military relevance in the 19th century are represented with high accuracy and are rich in details. Therefore these elements of the topographic maps can be evaluated and are useable for other natural sciences. The relief was illustrated with hachuring technology that is not quantitative (Jankó 2001). This is because the accurate elevation is not readable from the maps, only the slope angle changes can be revealed. This inaccuracy was not disadvantageous at all; the map fulfilled its original aim as this kind of representation was enough for planning the troop's campaign. For our study the very thin and accurate lines of stream-pattern was a quite valuable feature of the survey. The scale of 1:28 800 and the usage of thin lines result very high geometrical accuracy what is the most important for our method. Rivers with higher discharge, illustrated with double-line, are 2 or 3 times wider than in reality. This line style decreases the geometrical accuracy.

34.6 Advantages of the Second Military Survey

I suppose that this second main direction of stream pattern is also evolved by neotectonic movements. The main question is what kind of movements shaped that. The measurement of sudden changes in the stream's flow direction is a good way to detect the uplifting or subsiding areas (Schumm & Khan 1972, Ouchi 1985). In case of the area is covered by accommodating sediment only the vertical movements shape these forms. The substance of this phenomenon is that the rivers try to hold its slope in case of the areas dip changes. If downstream area is uplifting, the dip increases and the river will tend to develop meanders which lengthen the course and consequently decreases the gradient. In the tectonic setting of the Pannonian basin this technology has been successfully used in low relief areas: in the Great Hungarian Plain (Timár 2003, Petrovszki 2008) and NE from my study area, in the Little Hungarian Plain (Zámolyi et al. 2007). In this study the classic processing method was used: I measured the thalweg and straight distances between many point pairs of the stream and obtained results show the level of the meandering.

There is a complex reason why I have chosen the Second Military Survey. The today pattern of the stream network is not modified by natural impacts, because most of the streams are already regulated. The typical pattern of the earlier meandering streams is only seen on local relief as curving dry gullies, but due to their shallowness these are usually not illustrated in recent topographic maps. In my method the most important phenomenon is the distribution of variable meandering. The purpose of regulation was to straighten these curves so the older map we use the less artificial changes occur. The other limiting factor is, however, the geometric accuracy of the map: it is only usable if it can be rectified accurately enough. *Figure 34.2* shows that there are less illustrated watercourses, in spite of the fact that recent maps of Hungarian National Mapping System are of higher scale. This decrease is may be explained by the variable detailedness of different surveys.

The level of accuracy of the geocoding also visible on *Figure 34.2,* which is represented on a section regulated in the Roman Age. Between the two different surveys the section was not modified by natural impacts as the previous regulation remained in its original shape. It proves that the Second Military Survey was really carried out with the necessary geometrical accuracy, what is very important in geosciences.

The distance of the artificial divergence on two maps is approximately 60 meters *(Figure 34.2:* p1–p2). This value is map sheet specific and not an average value. To

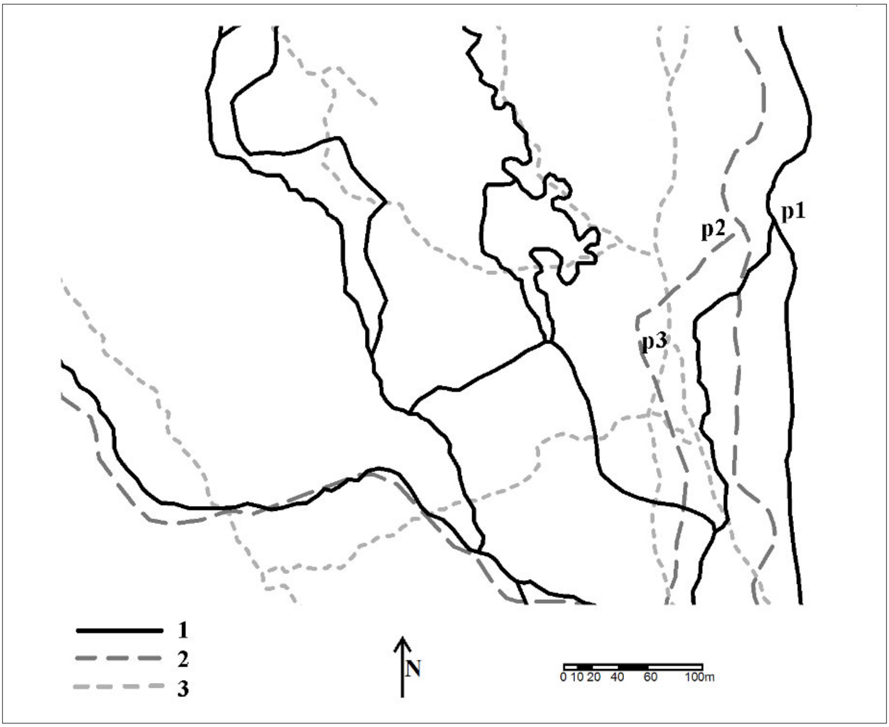

Fig. 34.2. comparing of three states of stream network from different aged surveys. 1 – the examined Second Military Survey (19th century); 2 – Hungarian National Mapping System (end of the 20th century); 3 – First Military Survey (18th century); p1–3 – represented beginning of the roman trench (indexed according to the surveys' number)

obtain an average, one has to measure different fix point pairs to be able to estimate the average value. The differences (calculated on similar shaped sections) occur between 40 and 120 m, thus the average is approximately 70–80 m. This number is below the value that Timár et al. (2006) suggested, consequently the maps sheets of this area could be considered as more accurate. These facts strengthen our previous assumption that the Second Military Survey and the used rectifying method provide the suitable accuracy.

Another advantage of the Second Military Survey is that it shows different countries in a universal map system which is especially important for my area: it is currently split by the national border. Because of the different national mapping standards and geodetic datums, scientists have to purchase topographic maps from both neighbouring countries. To integrate two different mapping systems into a common geodetic system can also be a good challenge achieving the required accuracy level.

The question immediately arises, why I did not use the First Military Survey – prepared decades before the second one – which shows even more natural state?

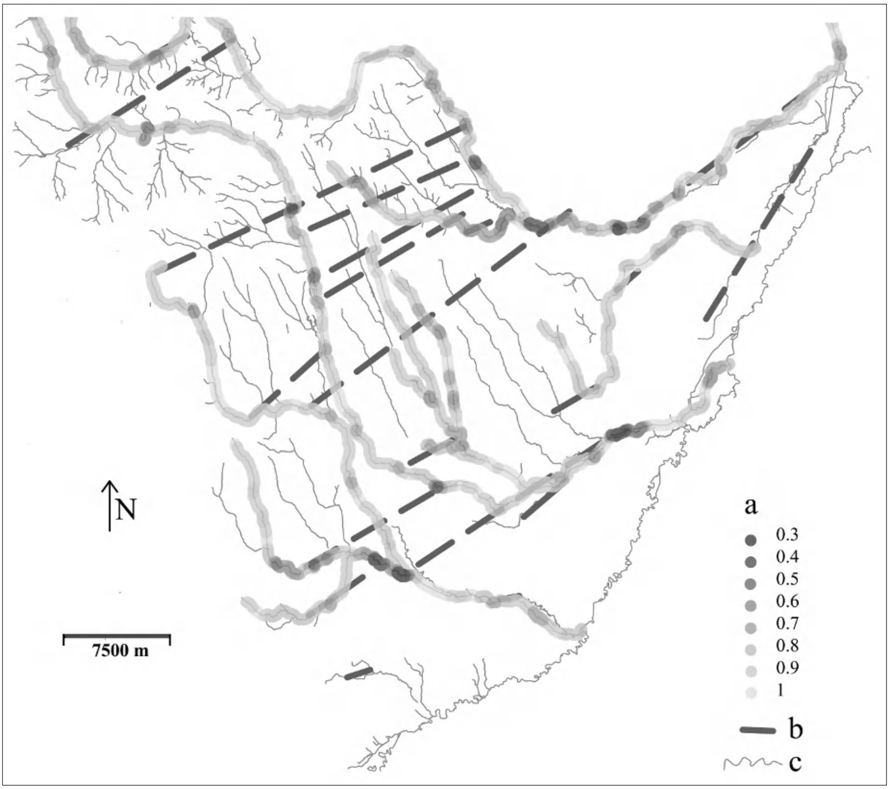

Fig. 34.3. changing value of sinuosity along major streams. a – values of calculated sinuosity; b – derived lineaments; c – stream network

The reason is simple: we can not trust the accuracy of that survey because the mapmakers did not use any projection. In this way the rectification of the map sheets only possible with GCP-points, what cause more distortion on the shape and either on the location. *Figure 34.2* shows what a big difference is between the shape of the roman artificial section on the First Survey and its real form. That fact is very important for us, because the base of our method is the geometry of the streams. The smaller problem is the 250 m distance of the divergence on different maps *(Figure 34.2:* p2–p3). A further important observation that the first survey does not contain as much streams as the second one does. The reason also can be the variable detailedness of different surveys. Even so I used the digitised data from the first survey as well (not for the measurement, only to check lineaments), in case if the stream has already regulated in the time of the Second Military Survey.

Relevant accuracy, especially in geometry of illustrated stream network, can be seen on *Figure 34.3* that shows the result of sinuosity measurements. Sinuosity means the difference between distances of stream points along the stream and bee-line. The method of calculation is that the bee-line distance is divided by the distance along the river in every 50 meters. The light colours show the almost straight sections and dark colours the sinuous sections. The fact that these sections appear almost parallel on the different streams means that our method gave good result. If the map sheets were geometrically incorrect, the variable sinuosity would not be seen as significant as on *Figure 34.3.* The accuracy of the rectification is proved enough to place the structural lines.

34.7 Discussion

As specified above the relief, illustrated with hachuring techniques on the Second Military Survey, is only useable in small scale, just for identify the location of the scarps, but are very useful to illustrate the state of relief due to the hachuring method (the steeper slope represented in darker). As a consequence of the same reason the usage of these maps can be worse on areas with higher relief.

As with our study we could prove the geometrical accuracy of Second Survey, other natural scientist can trust the data of its maps. It is in accordance to the previous sinuousity investigations (Timár 2003, Petrovszki 2008, Zámolyi et al. 2007) that used the same method but on different places in the Pannonian Basin. If any scientist needs to compare the natural estate with the recent one, Second Military Survey is useful. Not only in lower scale, because we proved, that the linear segments appear correctly, thus elements like road network, boundaries etc. can be studied.

34.8 Conclusion

As we saw, the theory that more modern map is more useful for scientists have just broken. The next step can be the rectification of necessary map sheets one by one for our study area using GCP points for higher accuracy. It is possible if we need only a few map sheets and if our area contains enough fix points. The stream network can be investigated from other side, for example the moving of curves or artificial effects on stream network.

Other survey's verification and comparison is among our plans. The first cadastral survey (Arcanum 2006) can be useful and more accurate due to higher scale and provide more detailed topography content. Integrating several survey data from different times results a database about the stream pattern which can be useful for analyzing the variable fluvial structures in longer timescale.

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Chapter 35

The Austro-Hungarian Triangulations in the Balkan Peninsula (1855–1875)

Béla Kovács[1] and Gábor Timár[2]

[1] Dept. of Cartography and Geoinformatics, Eötvös University, Budapest, Hungary
climbela@map.elte.hu
[2] Dept. of Geophysics and Space Science, Eötvös University, Budapest, Hungary
timar@ludens.elte.hu

Abstract

The Turkish part of the Balkan Peninsula was an area of extensive geodetic surveys between 1854 and 1875. These works were carried out by the Austro-Hungarian authorities, partially in the frame of the International Arc Measurements (*International Gradmessung*). These activities were made in the present territories of Bosnia-Herzegovina, Albania, Montenegro, southern Serbia and Kosovo, Bulgaria, southern Romania, Macedonia and also northern Greece. Astronomical points were measured throughout the area, mainly along travel routes of the surveying parties, and then other points, mainly mountain peaks, were determined by triangulation (intersection) from the astronomical points. No geodetic network adjustment was applied to the point sets. Based on these geodetic base point data, 1:75,000 scale maps of the Austro-Hungarian Monarchy was issued from the 1880s to WWI, as well as local Serbian maps after the independency of the state. The existing geodetic datasets formed the base of the utilization of the Hermannskogel datum in the later Yugoslavia, even the territories that were not part of the Habsburg Empire. For present GIS applications it should be underlined, that the Yugoslav version of the Hermannskogel datum used a different Ferro-Greenwich longitude shift, thus the datum description parameters differ from the ones used in Austria.

Keywords: historical geodetic surveys, Balkan Peninsula, Habsburg cartography, European Arc Measurements, Turkish Empire

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35.1 Introduction

There are many printed map sheets that show the Habsburg Monarchy and its adjacent territories prior to WWI; available in the antiquary book shops throughout the Central Europe. A series of these sheets, issued after 1880, is available in georeferenced form on DVD (Biszak et al. 2007). Besides, a whole series of maps in 1:200,000 scale, covering even larger parts of Central Europe and the Balkans were issued around 1910 by the Austro-Hungarian cartography (Crăcuinescu 2006, Jankó 2007 Timár et al 2009). The accuracy of these sheets is quite surprising considering the technology level of the production period. Except for some sheets with obvious blunders and errors over the kilometer-level, most maps can be rectified with an error not more than a quarter kilometer (Molnár & Timár 2009). Some maps were published by the Romanian authorities in 1:75,000 scale (Osachi-Costache 2000, Mugnier 2001, Rus 2008, Timár & Mugnier 2009) and in the same scale, by the Serbian Institute of Military Geography (Kovács 2009), also prior to the WWI.

A simple question arises about these products: how could the Military Geodetic Institute (MGI) of the Habsburg Empire gather the necessary geodetic data to compile these maps? It is obvious that these accurate maps could not be made without geodetic basis. In the 19th century, the countries and empires seldom let foreign geodetic surveyors enter and work in their own territory. Making military maps was always a part of military preparation to operate (in other words: to invade) the mapped area. The Turkish (Ottoman) Empire was somewhat friendly to the Habsburg Empire though they were not allies. Later, the newly independent Balkan states were rather hostile ones to the Austrians. How could the MGI manage this work under these circumstances? Or was the geodetic survey done by the Turks or the Balkan states, and did the Austrians spy the results? An archive query in the Austrian State Archive (ÖStA Kriegsarchiv) assures us that the survey was made by the Austrians themselves. A series of reports describe this huge project.

35.2 The Historical Background of the Balkan Surveys

In the 19th century, the European borders and the sovereignty of many regions changed much more frequently that is usual nowadays. In the middle of the continent, the Habsburg Empire always played an important role in any hostilities. This resulted not only in the frequent change of the Habsburg borders but also in occupying – at least temporarily – many important pieces of land. During these ‘visits’, they started to survey these territories. As a result, we can find coordinate lists for the whole Italian peninsula in the Military Archive in Vienna (see e.g. MGI 1853).

Concerning the Balkans, the role of the Austrians there is more important. When Russia occupied the Danube Principalities (the Old Romania) in 1853, the Turco-

Russian tension led to the Crimean War. During this war, Austria forced its former ally, Russia, to give up this occupation, and Austrian armies took their place between 1854 and the Paris conference resolving the peace at the end of the war. The MGI at the time made a complete geodetic survey in Wallachia (Oltenia and Muntenia) and Northern Dobrogea (MGI 1859). This survey was the first systematic geodetic triangulation in Romania (Timár 2008).

If you are a geodetic surveyor and you are not allowed officially to work in a country, some tricks could be used to get the permission, without using an occupation. Although no evidence exists about this, the authors think that the Central European Arc Measurement, later the European Arc Measurement (*Mittel-Europäische Gradmessung* and *Europäische Gradmessung*, respectively; Kretschmer et al. 2004), brokered by the Prussians in the 1860s, had this secret agenda. These projects aimed to determine the real and accurate size and shape of the Earth. However, not all European countries were prepared to make the necessary measurements and provide them to the community. This could be a possibility for the Austrians to offer their help to the Turkish Empire to make the necessary measurement. Whatever was the background, the Turkish authorities entered the Austrian survey teams to the European parts of the empire *(Figure 35.1),* and the survey was made between 1871 and 1875 in the whole European territory of the Turkish Empire (Ganahl & Sterneck 1871, 1872a, 1872b, 1874, Ganahl & Milinkovič 1873, Ganahl & Gyurkovics 1873, Ganahl & Hartl 1875; *Figure 35.2).*

It was almost the last moment to do it. The tension between Russia and Turkey broke out in a new war in 1878. The Congress of Berlin, resolving the peace after the hostilities, let the Serbs and the Bulgarians to form their own countries. As Serbia seeked for any possibility to unite all southern Slavs into a country (in the later Yugoslavia), it was a 'natural' enemy of the actual ruler of the claimed territories, the Habsburg Empire. The tension was increased further by the occupation of Bosnia-Herzegovina by the Austro-Hungarian Monarchy. No further Austrian surveys were made here prior to the WWI.

35.3 Technology of the Survey

The surveys were based in two different methods:

- observation of astronomical coordinates, usually in towns, and
- computation of coordinates of fairly visible locations, mostly mountain summits, by triangulation (intersection) from the astronomic base points.

During the astronomical measurements the latitude and longitude of the points were determined separately. The latitude was estimated by measuring the elevation of the North Star in the night and the Sun at local noon. Auxiliary information about culmination of other stars were used for obtain more precision *(Figure 35.3).*

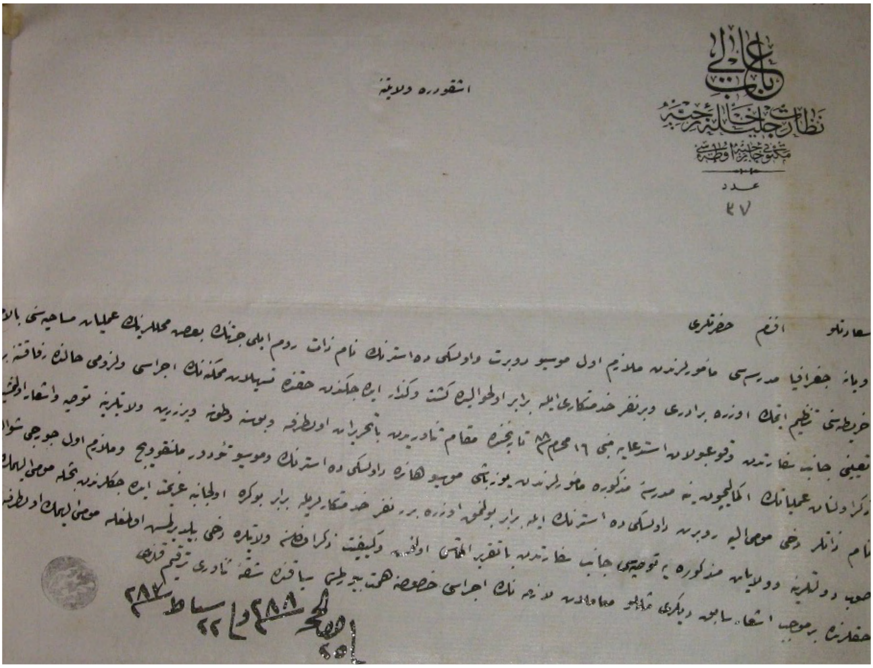

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Fig. 35.1. The *ferman* (Turkish: permission, document) of the *pasha* (Turkish: governor) of Sarajevo from 1871, permitting the mapping of the Austrian surveyors (from Ganahl & Sterneck 1872b)

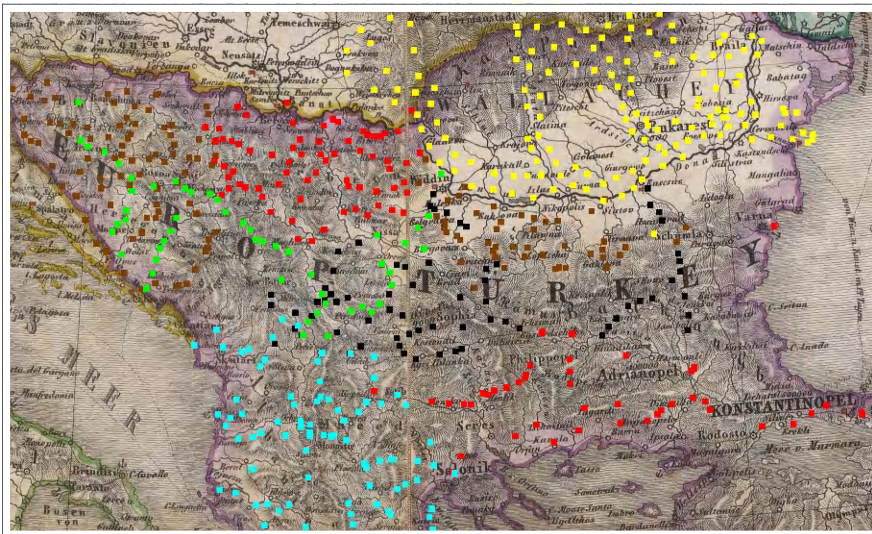


Fig. 35.2. Habsburg geodetic surveys in the Balkans, color codes: yellow: the Wallachian triangulation (1855–57, in connection with the Crimean War); green: 1871, brown: 1872, cyan: 1873, red: 1874, black: 1875

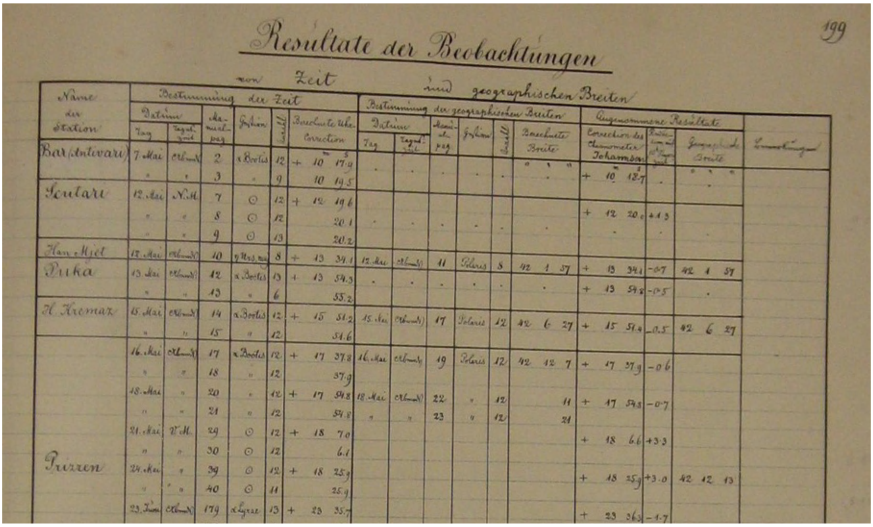


Fig. 35.3. Results of astronomical observations at different locations (Ganahl et al. 1899–1900)

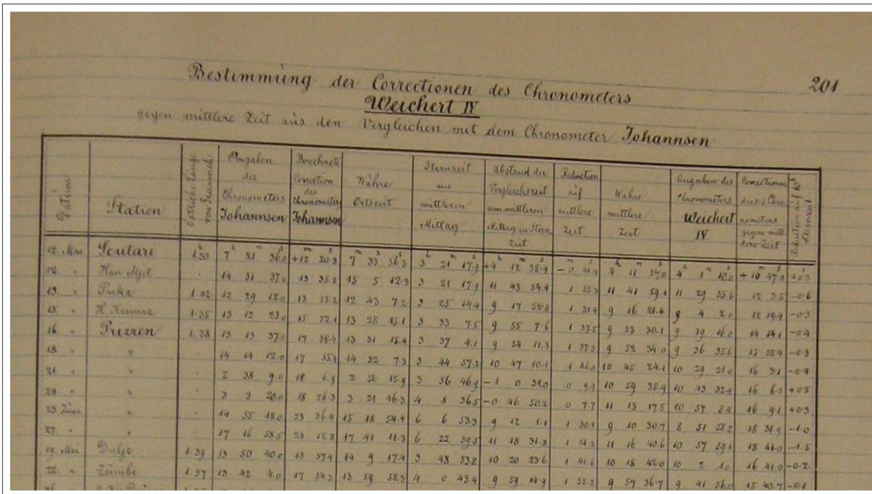


Fig. 35.4. The different types of chronometers were cross-calibrated at the observation points

The longitude was derived from time measurements of different chronometers at the local noon. The longitudes are given mainly from Ferro but in Macedonia and Greece (Ganahl & Gyurkovics 1873), Rumelia, Turkey, and in the summary of Serbia (Ganahl & Hartl 1875) they are given from Paris. The longitude difference between these prime meridians is 20 degrees in round numbers, which is the real definition of the Ferro prime meridian. The drift of the chronometers were clearly noted *(Figure 35.4)*. Although it does not concern the horizontal control of the network we mention that the altitude determination at these points was mostly based on barometric method.

From the astronomical base points, azimuth and sometimes elevation angles to the summits (later used as trigonometric base points) were measured and noted. In many cases, the skyline was also drawn in the protocol, with surprising accuracy *(Figure 35.5)*. Location of these summits was determined during the winter office work, using these observations.

The results of these methods are burdened by several error sources. The main factor of them is the real potential field shape of the Earth. Deflections of vertical occur as positional error of the points in a range of several arc seconds. We could not find any notes about real geodetic adjustment in the Balkans.

35.4 The Resulted Data Sets and Maps

The structure of the numerous reports is mostly identical, following a protocol of the measurements. The content page of Ganahl et al. (1899–1900) shows this usual structure *(Figure 35.6)*. It starts with the description of the background and the process of the measuring campaign. It followed by the collected data about the chronometer corrections and drifts, and the results of the longitude estimations, and the list of the geographic positions of the base points – different lists for the astronomically and trigonometrically measured points. Ganahl et al. (1899–1900) show the point set provided by the surveys in maps with the scale of 1:200,000.

These core data are followed by the systematic details of the calculations (“Berechnungen”) of the astronomical, the trigonometric and the barometric data. As the longitude determinations were given in the core part, the calculations of determination of the latitude using the North Star and the zenith distance of the Sun are listed here. In the trigonometric part, first, the calculations of the triangles are given, followed by the determinations of the azimuths. The last two subsets here are the calculations of the geographic positions and the heights of the trigonometric points.

In the part about the barometric data, time series of some fixed stations are first listed, followed by the calculations (estimation) of the heights of the base points, and the results. Although the order of these data items can vary from report to report, they are given in them. E.g., sometimes the list of the geographic coordinates is given at the very end of the report under the title of Results (“Ergebnisse”) but sometimes at the end of the core part, before the calculations. The results are always given separately for the astronomically measure points and for the trigonometrically derived ones.

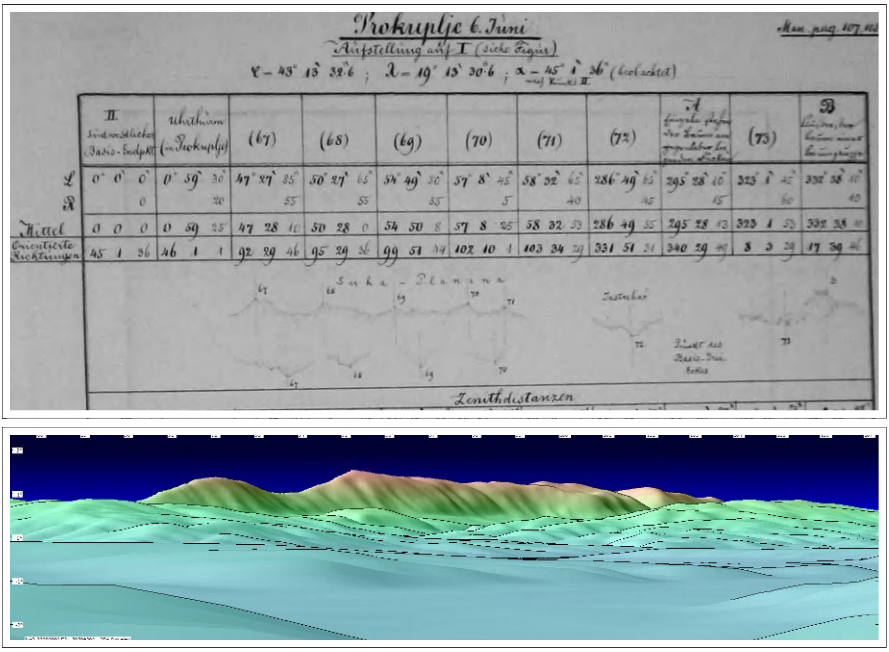
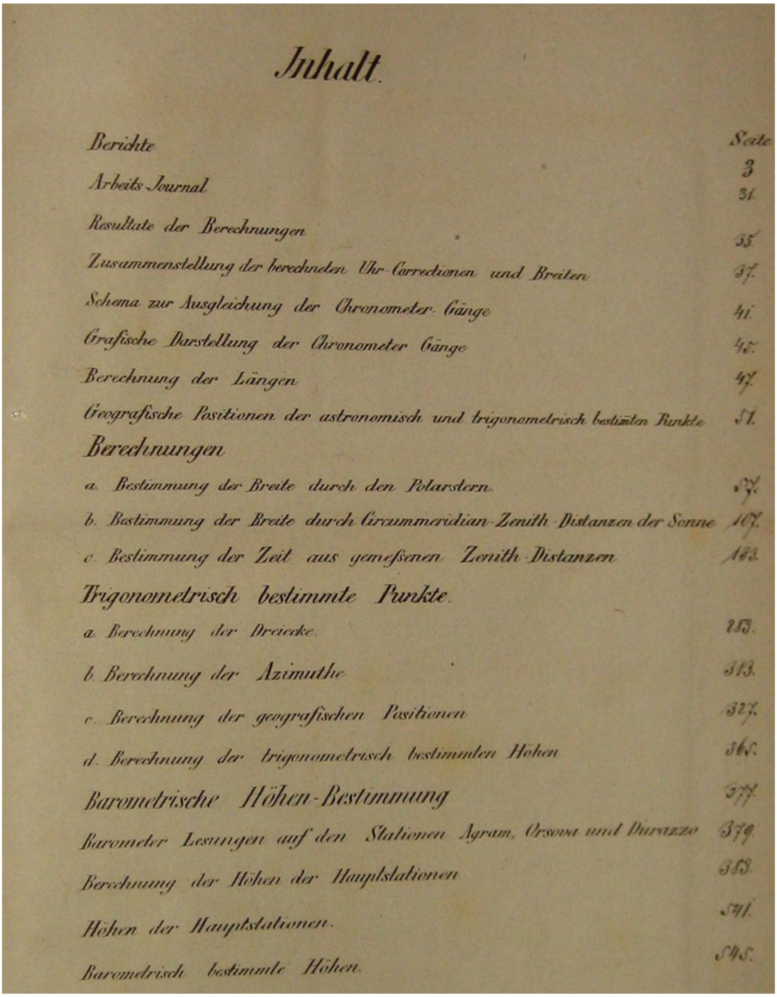


Fig. 35.5. The skyline of the Suha Planina from the observation point Prokuplje, drawn in the original notes (Ganahl & Hartl 1875, top) and the skyline from the same point derived from the SRTM elevation dataset (Werner 2001, bottom)

The base points covered practically the whole European part of the Turkish Empire in 1871–75 *(Figure 35.2)*. The density of the points, however, are different; the point density is relatively high in Bosnia, Serbia and NW Bulgaria, medium in Albania, Macedonia and northern Greece and quite low in South Bulgaria (Rumelia) and around Constantinople (Istanbul). We found almost no data about the Bulgarian coastal zone and about central Greece (along the Turkish-Greek border of that period). In the Old Romania, a frame of geodetic points was developed, consisting of four triangle chains along the main rivers. The cartographic products, listed in the Introduction, were developed using this geodetic datasets. The 1871–72 survey of Bosnia was soon obsoleted by the new Habsburg measurements after the 1878 occupation of this land, incorporated in the survey and results of the whole Monarchy (MGI 1901), defining the Hermannskogel datum for all parts of the empire.

35.5 Summary

The military cartographic survey of Austria-Hungary made a tremendous effort to survey most of the Balkans, in two waves. Geodetic base points in Old Romania



Inhalt

Berichte	Seite
	3
Arbeits-Journal	31
Resultate der Berechnungen	35
Zusammenstellung der berechneten Uhr-Correctionen und Breiten	37
Schema zur Ausgleichung der Chronometer-Gänge	41
Grafische Darstellung der Chronometer Gänge	45
Berechnung der Längen	47
Geografische Positionen der astronomisch und trigonometrisch bestimmten Punkte	51
Berechnungen	
a. Bestimmung der Breite durch den Polarstern	57
b. Bestimmung der Breite durch Circummeridian-Zenith Distanzen der Sonne	107
c. Bestimmung der Zeit aus gemessenen Zenith Distanzen	183
Trigonometrisch bestimmte Punkte	
a. Berechnung der Dreiecke	253
b. Berechnung der Azimuthe	313
c. Berechnung der geografischen Positionen	327
d. Berechnung der trigonometrisch bestimmten Höhen	365
Barometrische Höhen-Bestimmung	377
Barometer Lesungen auf den Stationen Agram, Orsova und Durazzo	379
Berechnung der Höhen der Hauptstationen	383
Höhen der Hauptstationen	541
Barometrisch bestimmte Höhen	545

Fig. 35.6. The content page of Ganahl et al. (1899–1900) shows the usual items of information given in these datasets.

were measured during the 1855–57 occupation connected to the Crimean War. Survey of the Balkans was carried out between 1871 and 1875, providing several hundred base points throughout the European territory of the Turkish Empire, possibly in connection with the European Arc Measurements. This dataset was used for the compilation of the 1:75,000 and 1:200,000 scale Habsburg maps, as well as the 1:75,000 scale maps of the newly independent Serbia and Romania. The usage of the Hermannskogel datum in Yugoslavia (and in the former Yugoslav republics even nowadays; Mugnier 1997) is based not only on the surveys made in the Austria-Hungary prior to the WWI but partially on these early measurements.

Acknowledgements

The authors are grateful to the Map Archive of the ÖStA Kriegsarchiv, Vienna, Austria, personally to Dr. Robert Rill (head of Map Archive) and to the Hungarian Delegation to the Archive for the full access of the geodetic archives. This research was inspired by the project of Arcanum Database Ltd. to publish the maps described in this paper. Samples of archive Serbian maps were provided by the University of Bucureşti, Romania, special thanks to Dr. Ştefan Constantinescu for that.

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Chapter 36

Maps of Czech Lands in the Period 1518–1720 from the Map Collection of Charles University in Prague

Miroslav Čábelka, Markéta Potůčková and Tomáš Bayer

Department of Applied Geoinformatics and Cartography,
Charles University in Prague, Czech Republic
{cabelka, mpot, bayertom}@natur.cuni.cz

Abstract

Preliminary results of research on old maps of Czech Lands deposited at the Map Collection of Charles University in Prague are presented. The extensive cartographic collection belongs among the most important collections in the Czech Republic. The goal of the research was to document the development of cartography during the period 1518 (Claudianus's map) to 1720 (Müller's map). More than 50 originals or facsimiles of different maps were found during inventory phase of the work. The paper concentrates on a description of most interesting maps discovered from the point of view of their content, map symbols and cartometric characteristics.

Keywords: old maps, map collection, map analysis

36.1 Introduction

Maps of Czech Lands, i.e. Bohemia, Moravia and Silesia, created by individuals in the period of 1518 – 1720 are part of our history and represent important cultural heritage of immense value. They give evidence about the period in which they originated. Old maps reflect the society and culture, and they become important historical sources. These sources are used especially in social sciences, namely in history of cartography, historical cartography, historical geography and historiography.

G. Gartner, F. Ortag (eds.), *Cartography in Central and Eastern Europe*,
Lecture Notes in Geoinformation and Cartography, DOI 10.1007/978-3-642-03294-3_36,

Fig. 36.1. Bohemian Lion on Aretin's map of Bohemia from the year 1623

The map collections in the Czech Republic preserve a considerable number of old maps. This article presents an overview of the most significant cartographic works from the given period deposited in the Map Collection of Charles University in Prague, which is one of the most important map collections in the Czech Republic. Its objective is also to indicate various levels of the art of cartography and outline the extent to which old maps can serve as a source of knowledge of geographic areas of the past.

The research was conducted within the project "*Cartometric and semiotic analysis and visualization of the old Czech Lands maps in the period 1518 – 1720*". In relation to the project the research of the Map Collection of Charles University in Prague focused on map works of Bohemia, Moravia and Silesia created by individuals in the above mentioned period. The map research then centered on the analysis of the map content and on cartometric analysis.

The results of the research are described in the text below using knowledge from historical and cartographic studies of the last decades.

36.2 Map Collection of the Charles University in Prague

The Map Collection of Charles University in Prague was founded by professor Václav Švambera in 1920 as the State Collection of Maps of the Czechoslovak Republic. The basic elements of this collection were represented by the funds from the Department of Geography of the Faculty of Science, some map sheets from the Vienna War Archives after the collapse of the Austro-Hungarian Empire, and cartographic archive materials from various libraries. After the World War II the State Collection of Maps acquired map funds from the German University in Prague.

Fig. 36.2. Complement placed in the corners of map sheets of Müller's map of Moravia

Later, the fund was enriched by cartographic archive materials from the National Museum. Since 1994 the Map Collection of the Charles University has served as a workplace of the Faculty of Science. Professor Bedřich Šalamon and Professor Karel Kuchař belong among its prominent representatives.

The collection funds contain originals and facsimiles of cartographic works from the 8th century up to now. Maps from atlases from the 16th, 17th and 18th centuries can probably be declared as the most beautiful cartographic works. They are connected to the names of cartographic giants like Mercator, Ortelius, Blaeu, Delisle, Homann, Seutter. There are also maps created by the representative of cartography in Czech Lands – Müller.

The Map Collection of the Charles University nurtures the legacy of inestimable value, provides materials for research and study, as well as for wider cultural purposes. Its cartographic fund places among the most significant in the Czech Republic. It is composed of over 2,000 atlases (since the 16th century), 60 globes, approximately 100,000 map sheets and books and magazines.

36.3 Analysis and Assessment of Old Maps

During the 1st half of 2008 the map fund of the Charles University was researched thoroughly, with particular emphasis on map works of Bohemia, Moravia and Silesia

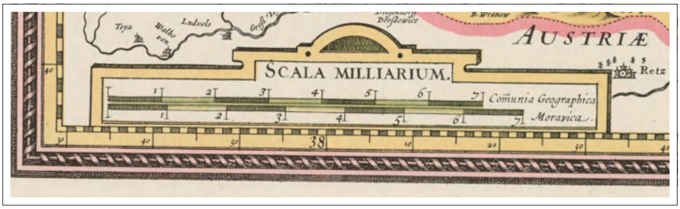

Fig. 36.3. Scale on Comenius's map from 1627

from the period 1518 – 1720. During the analysis and assessment of these old maps a number of questions and problems arouse. The works' dating details served to determine the author, year of publication and name of publisher. In case only some data were stated on the map or they were completely absent, the map's date of origin was determined following the characteristic features for particular phases of cartographic production, for individual authors or publishers. The representation of map content, typeface, material used, reproduction technique and artistic elaboration are among such features. Authors of the maps were mostly cartographers, land surveyors, draftsmen, engravers, publishers, printers, clerks or artists. The information whether the work is an original, facsimile, copy or derivative was also important. In our selection Comenius's map of Moravia is a facsimile. Other maps are originals.

The analysis of map content can provide us with answers to other relevant questions related to analysis and assessment of maps. Similarly to modern maps, old maps also include some map elements which were becoming more and more precise with the development of cartography and geodesy. However, some map elements were absent, like date or name of the author. For example, Mercator's copy of Criginger's map of Bohemia is not dated. In some cases the maps were made without a map frame or a scale. The scale of old maps was indicated by words comparing length in the map to real length, or graphically as a line segment, rectangle or trapezium segmented into smaller parts which represented the ratio of distance on the map and real distance.

The basic elements of map content are: settlements, paths and roads, granges, castles, monasteries, baths, vineyards, waters and various natural-history curiosities. Political and territorial self-governing divisions of depicted areas are represented by various types of boundary lines and surfaces of different colours.

Geographic name is a changing map element. Various language versions of maps of Czech Lands were predominantly Czech, Latin and German.

Another assessed element of map content is the relief. Till the end of the 18th century relief used to be represented by a stylised drawing of elevations using pictures of hills and mountains, so called hill method (in Czech *kopečková* or *pahorková metoda*). "*Hills*" and their ranges informed the user about the character of the represented landscape. This method was used in all the maps we assessed.

Fig. 36.4. Legend and scale on Aretin's map from the year 1623

The position of the legend is also important. The legend contains a group of symbols for elements used in the maps, together with verbal explanation of their meaning. Usually they are arranged according to a determined hierarchy. Old cartographic works often contained decoration in the area of title, scale or legend, or a so called paregon, i.e. a graphical complement placed in the corners of map sheets. And also a cartouche, i.e. decorative or ornamental framing of the map's title.

36.4 Analysis of the Content of Selected Maps

Maps from the period 1518 – 1720 representing the area of Bohemia, Moravia and Silesia were chosen from the Map Collection of Charles University in Prague. After assessment of the extent of damage and degree of legibility their suitability for further processing was decided. Selected maps were scanned by large-format scanner Contex Crystal XL 42 Plus with the resolution of 200 dpi and in the format .tif. After scanning them the paper originals were no longer used and all further analyses were performed using the scans in electronic format. Analyses of map content as described in *Chapter 36.3* were performed. Cartometric analyses are currently completed only for Vogt's map. Other maps are in progress.

After completing the analyses the following maps were chosen: Criginger's map by Gerhard de Jode, Mercator and Kaerius, Aretin's map of Bohemia, Vogt's map of Bohemia, map of Moravia by Abraham Ortelius based on Pavel Fabricius, Comenius's map of Moravia and Müller's map of Moravia.

36.4.1 Chorographia Insignis Regni Bohemiae

Author: Johann Criginger
Year of publication: 1584
Author of engravings: copies by Gerhard de Jode
Approx. scale: 1 : 683 500

Johann Criginger (1521 – 1571) created a map of Bohemia oriented to north – Bohemiae regni nova chorographica descriptio. The map is historically the second map image of Bohemia. The map of Bohemia was adopted from many Dutch atlases – Ortelius (1570), Mercator (1585). The precious copy by Gerhard de Jode is less known. Its reprint was found in the Map Collection of Charles University in Prague.

The map's title is "*Chorographia insignis regni Bohemiae, autore Ioanne Cригingero*". Its content does not depart from the original Criginger's map. However, it does not contain the original depiction of four rulers of the Czech Crown countries in the map's corners. It contains a very good representation of Czech mountains and waters. There are altogether 292 settlements in the map represented by four symbols. The map contains a detailed network of water streams and mountain ranges represented by hummocks and groups of trees.

Mercator's and Kaerius's Copy of Criginger's Map

A well-known copy is that by Mercator (1585). It is not dated and its title is "Bohemia". It was supplemented with topography of South Bohemia. The description is done by Latin italics, minuter but also unequivocally much more legible than in the original. Among the most beautiful copies of Criginger's map of Bohemia is the 40 x 50 cm big map by a Dutch engraver, publisher and bookseller Peter Kaerius. It is decorated with vedutas of Prague and Hradčany (Prague castle). It contains a detailed topography, the relief is represented by hills and trees, the scale is provided in Czech miles.

36.4.2 Regni Bohemiae Nova et Exacta Descriptio – Aretin's Map of Bohemia

Author: Petr Aretin of Ehrenfeld
Year of publication: 1623 (second publication – first published in 1619)
Author of engravings: Paulus Bayard sculpsit Prague
Frame size: 766mm x 574mm
Approx. scale: 1 : 504 000

The map titled *Regni Bohemia nova et exacta descriptio* (New and exact description of the Bohemian kingdom) was created by Petr Aretin of Ehrenfeld (1570–

Fig. 36.5. Surroundings of the Prague City on Criginger's map of Bohemia, copies by Gerhard de Jode

Fig. 36.6. Surroundings of the Prague City on Aretin's map of Bohemia from the year 1623

1640) as the historically third map image of Bohemia. The map was first published in 1619. In our collection we found the second and third publication of the map. The second revised and supplemented publication is dated 1632 and was used as a military map during the Thirty Years War. On the right and left edge of the map there are six figures in period garments. Six female figures on the right edge and six male figures on the left edge. In the upper right corner the Czech lion is represented and in the upper left corner there is the imperial eagle.

The map contains 1157 settlements, including an alphabetical index of names and coordinates in Czech miles in the upper left corner of the map. A mile scale is drawn on the map's frame and a network of coordinates (width 42 Czech miles, height 35 Czech miles). On the left edge the scale is printed; it was to serve for subtracting coordinates after a wooden lineal was pasted. At the end of the index important cartometric information is given stating the circumference, surface area of Bohemia, and the west-east and north-south distance.

The map is described both in Czech (capital letters) and German (small letters). Aretin's map represents first political division of Bohemia into fifteen regions. On the map we can find sixteen determined symbols representing for example free Royal towns, aristocratic residences, monasteries, mines, warms springs and glass-works. Moreover, the map also contains notes on the discovery of most beautiful pearls and gems.

The map contains hydrography which is changed in comparison to the first publication. The following rivers are described: Labe, Úpa, Metuje, Orlice, Chrudimka, Jizera, Cidlina, Ploučnice, Ohře, Vltava (its spring is covered by a drawing of an angel), Malše, Lužnice (with the pond Jordán u Tábora), Blanice, Mže (its tributaries are depicted but not named). Many other water streams, including foreign ones, are depicted but not named.

Orography is relatively accurate but its description is missing. Road network is not represented.

The third publication in 1665 was done by the copperplate engraver Daniel Vusín (1626 – 1691). In the Map Collection of Charles University in Prague another, undated and changed publication was found. This copy was done by his son, the copperplate engraver and bookseller Kašpar Vusín (1664 – 1747, Prague).

36.4.3 Vogt's Map of Bohemia

Author: Johann Georg Vogt
Year of publication: 1712
Frame size: 853mm x 656mm
Approx. scale: 1 : 396 800

Vogt's map is an important cartographic work dated in the first quarter of the 18th century. Its author is Johann Georg Vogt, the abbot of the Plasy Monastery. The format of the map is 853 x 656 mm. The scale along the central meridian is 1 : 396 800. The map is not created following a particular cartographic representation. The map is inserted in a frame which is divided by a two-second scale.

The legend includes 24 determined symbols. Vogt's map represents altogether 3110 elements. It differentiates walled towns, small towns, villages, churches, castles, ruins, mills. Gold, silver and cupriferous ore mines are also represented in the map, as well as pearl oyster sites, thermal baths, glassworks, vineyards, ironworks and custom stations. In addition to these symbols Vogt also used perspective miniatures, e.g. the castle of Bezděz. Discontinuous representation of mountains leads to the fact that the main characteristics of Bohemia fade down. The water network is dense, e.g. in Prague the characteristic meander of the river Vltava is

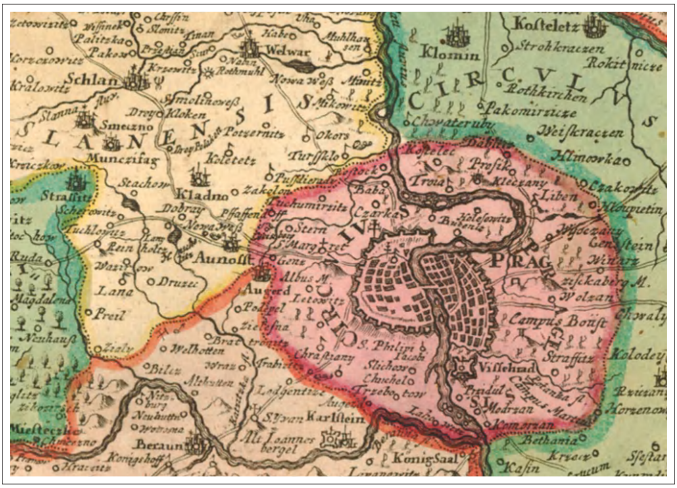

Fig. 36.7. Surroundings of the Prague City on Vogt's map of Bohemia from the year 1712

depicted correctly. Vogt dedicated close attention to the shapes and locations of water surfaces, especially the pond system in the region of Třeboň a Přelouč are outstanding, nevertheless, the surface areas are overdrawn. The map contains nomenclature in two languages but it conforms to German custom. The map is coloured and richly illustrated.

Vogt's map is the last private work of the early period of Czech cartography created by one cartographer.

The original Vogt's map was used at the Department of Applied Geoinformatics and Cartography for the first cartometric analysis. This analysis found out that the value of the medium scale along the central meridian is approximately by 6% bigger than the currently stated value of 1:396800.

36.4.4 Map of Moravia by Abraham Ortelius Based on Pavel Fabricius

Author: Pavel Fabricius (1519 – 1589)
Author of copy: Abraham Ortelius
Year of publication of Ortelius' copy: 1573
Frame size: 469 x 345 mm
Approx. scale: 1 : 455 000

Fabricius's map from 1569 is the first autonomous map of Moravia. Moravian aristocrats later wrote their comments to the map which were used to publish a corrected map in 1572. Fabricius represented not only Moravia, but also a considerable part of North Austria. The original map is printed on six copperplates and its overall format is 946 x 846 mm; the engraver's name is unknown. The scale is

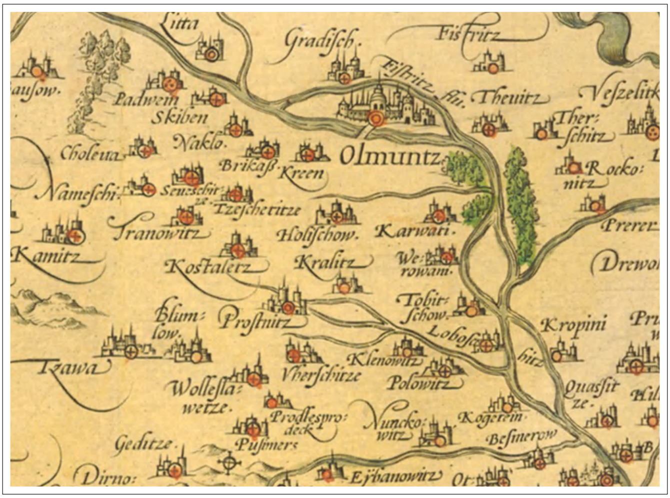

Fig. 36.8. Surroundings of the Olomouc City on the Map of Moravia by Abraham Ortelius based on Pavel Fabricius from the year 1573

Fig. 36.9. Surroundings of the Olomouc City on Comenius's map of Moravia from 1627

approximately 1 : 288 000. The map's frame is divided by 5´ in the direction of meridians and parallels.

Several copies of the map are preserved. The most famous one was included by a prominent Dutch publisher Abraham Ortelius in his atlases. The title of Ortelius's copy is: „*Moraviae, quae olim Marcomannorum sedes, corograraphia, a D. Paulo Fabricio medico et mathematico descripta et a generosit Moraviae baronibus quibusdam correcta.*". It reminds us of Marcoman history. Ortelius's copy from

1573 is printed on one copperplate in the format 469 x 345 mm. The map is scaled down and its graphic scale is 1 : 455 000.

From topographic point of view some places on Fabricius's map are overloaded with topography and others are left without description. The map contains 347 local names for Moravia and 134 for the adjoining part of Austria. The nomenclature is German. The names of some settlements cannot be identified because they had been distorted. The map represents towns, small towns, castles and monasteries. Orographic drawings (using the "hill method") in Ortelius's copy are considerably simplified, almost left out. All significant water streams are also represented. The map frame is divided into plots. The map uses fathom scale.

36.4.5 Comenius's Map of Moravia

Author: Jan Amos Komenský – Comenius (1592 – 1670)
Year of publication: 1627
Frame size: 544mm x 422mm
Approx. scale: 1 : 530 000
Printed from Abraham Goose's second printing plate

Jan Amos Komenský (Comenius) was born in the region of Uherský Brod in 1592. In 1616 he was ordained a priest. After the battle of White Mountain in 1620 he had to emigrate; he went to the town Lešno in Poland where he worked as a teacher and from 1648 as a bishop of the Bohemian Unity of Brethren. He wrote a number of pedagogical and theological works. After a devastating fire in Lešno Comenius left for Amsterdam, where he died in 1670.

Comenius's map places among the most famous and most popular maps of Moravia. The map was being created for ten years during which a huge amount of materials was assembled. Comenius wished that the map would serve as a pilgrimage map for all people. It is possible that it was ordered by Dutch atlas publishers.

Comenius's method when processing the manual copy of the map was based on adapting Fabricius's map which he supplemented on the basis of his own travels, testimonies of his contemporaries, printed itineraries and written records of distances. When creating the map classical geodetic construction foundations were not used. Comenius´s map of Moravia was published in 1624 from big Goose´s plate in the Amsterdam workshop of N. J. Visscher-Piscator.

The map's title is Latin: „*Moraviae nova et post omnes priores accuratissima delineati. Auctore I. A. Comenio*". In the lower right corner there is the name of the publisher Nicolas Johann Piscator. A strip of perspectives of four cities situated on the upper edge is characteristic to the map. The four cities are Polná, Olomouc, Brno and Znojmo. In the upper left corner there is a dedication to Ladislav Velenov of Žerotín written in Latin. Here Comenius explains why he created the map and what his technique was. The map has a simple outer frame whose size is approximately 544 x 442 mm. The map's scale according to the represented geographical network is approximately 1 : 480 000 and according to the drawing of the map content approximately 1 : 530 000. The legend is situated in the lower right corner.

The nomenclature of Comenius's map is Czech, important settlements include also their German name. In the upper left corner there is a scale in Moravian miles.

The map represents 720 geographical names, out of which 667 are settlements, 28 are rivers and ponds, 16 are orographic names, 8 are countries and 1 is vegetation. The representation of the river system is very thorough. The main river directions are expressed, the streams flow through the correct settlements and interflow as in reality. Mountains and elevations, passes, forests, bridges and river crossings are represented in the map. In addition, the map includes objects important for orientation, selected mines, glassworks, baths, healing springs and vineyards. The oldest Goose's printing plate was used as a model for a second plate called AGoos sculpist.

Facsimiles of the copy printed from Abraham Goose's second printing plate from 1627 are part of the Map Collection of the Charles University in Prague.

36.4.6 Tabula Generalit Marchionatus Moraviae in Sex Circulos Divisae – Müller's Map of Moravia

Author: Jan Kryštof Müller
Year of publication: 1716
Frame size: 484 x 581 mm
Approx. scale: 1 : 630 000

The map content was engraved by the engraver Jan Kryštof Leidig from the city of Brno.

Müller's map which contains a Map of Moravia from 1716 belongs to works giving vivid evidence about the change in Czech and Moravian landscape at the beginning of the 18th century. Five decades before the first military mapping it represents in detail the landscape of the Czech Lands with a lot of information concerning geography, economy, nomenclature and culture.

In 1708 the Emperor Joseph I. issued an Imperial Patent which Jan Kryštof Müller used for the mapping of Moravia.

The mapping was done from 1708 to 1712. The map represented "*all roads and tollgates for the needs of the country and for the safety of travellers*". According to Müller's plan each of the six Moravian regions was mapped individually. These regional maps were used to compile an overall map of Moravia. The final revision was created in 1716 and the documents necessary for the engraving were handed over to the engraver Jan Kryštof Leidig from Brno.

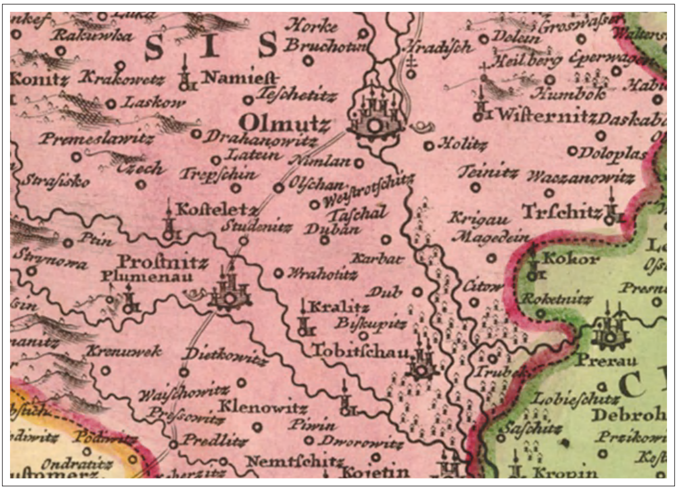

Fig. 36.10. Surroundings of the Olomouc City on Müller’s map of Moravia by J. B. Homann

The individual plates held the map‘s title „*Tabula generalis marchionatus Moraviae in sex circulos divisae quos mandato caesareo accurate emensus hac mappa delineatos exhibet Joh.Christoph Müller., S.C.M. capitaneus*“. The map was engraved on four plates. When their imprints are put together their format is 1374 x 974 mm. The map‘s scale is in Moravian miles, after conversion this four-sheet or estate map has the scale of 1 : 180 000.

From the topographic point of view Müller‘s map contains all settlements, which are labelled by determined symbols. The road network is very sparse; main routes start in the city of Brno and have four directions, then they branch out further. The terrain was drawn using the hill method with illumination coming from the west. The orography scarcely contains nomenclature, only important peaks are named.

Müller‘s map of Moravia became a model for the work of German, Austrian, French and Dutch cartographers and publishers. They started to publish well-arranged one-sheet maps of Moravia of medium and small scales. Their content was generalised, the format reduced, their titles and scales changed.

One of these publishers was Johann Baptista Homann from Nuremberg. His reprint of the Müller‘s copy is deposited in the Map Collection of the Charles University in Prague. It is a map of Moravia after 1726. In the upper left corner there is the title: „*Tabula generalis marchionatus Moraviae in sex circulos divisae quos mandato caesareo accurate emensus hac mappa delineatos exhibet Joh.Christoph Müller., S.C.M. Capitan editore Ioh. Bapt. Homanno Norimbergae*”. The map is an undated (approx. 2nd quarter of the 18th century) coloured copper engraving. It graphic scales is approx. 1 : 630 000.

36.5 Conclusion

This article dealt with assessment of content of old map works created by individuals in the period 1518 – 1720. Its objective was to introduce the methodology and results of basic analyses of works selected from the Map Collection of the Charles University in Prague. However, not all necessary data was available and many questions still remain unanswered. Nevertheless, the result will serve as a first stage preceding other detailed analyses of map content and cartometric analyses of these works. Currently, a detailed cartometric analysis of Vogt's map is completed. Its methodology and results are described in another article.

The Map Collection of the Charles University currently contains several other cartographic works from the period 1518 – 1720. Their content and cartometric analyses will follow.

Fig. 36.11. Persons on Vogt's map of Bohemia from the year 1712

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Chapter 37

The Dilemma for the History of Modern Maps Based on Neo-Cartographic Technologies

Markus Jobst[1], Georg Gartner[2] and Jürgen Döllner[1]

[1] Hasso-Plattner-Institute, University of Potsdam, Germany
markus@jobstmedia.at, doellner@hpi.uni-potsdam.de
[2] Department of Geoinformation and Cartography,
Vienna University of Technology, Austria
georg.gartner@tuwien.ac.at

Abstract

Nowadays map repertoire expands the outcome of traditional mapping technologies by digital-, multimedia- and neo-cartographic aspects. Especially neo-cartographic characteristics (ubiquitous cartography, user participation and geo-communication) are new paradigms in modern cartography. This new expansion of digital-, multimedia- and Internet-cartography combines the latest Web developments with traditional cartography and psychological imagery research. In terms of a prospective cartographic heritage these modern developments lead to a starting dilemma on the archiving of involved digital technologies and map contents. Even if new archiving methods for digital applications and data were developed in the past decade, Service-Oriented Architectures (SOA) and distributed network applications still wait for appropriate archiving procedures. Initial considerations and questions on solving this starting archiving dilemma for the history of modern maps are this discussed in this contribution.

Keywords: cartographic heritage, neo-cartographic technologies, archiving, history of modern maps

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37.1 Introduction

Historic geospatial contents form an important part in actual planning, documentation and cartographic applications. Spatial planning situations take historic developments or states into account and therefore use historic maps, cartographic applications and geo-reference data. The main dilemma with historical geospatial content occurs, when the required content cannot be accessed, understood or (geo-) referenced, which is a result of technological dependencies, loss of semiotic description and loss of metadata descriptions. Analogue maps, like paper maps, offer a visible depiction at any time and request a legend and reference frame in order to be spatially usable. Simple digital maps need much more: beside an application that offers some interaction with the digital map, the format, the data´s reference frame, transmitting media and transmitting media´s characteristics / requirements need to be supported in order to receive a visible map. This requirement´s complexity is also true for (primary) digital geoinformation, which is mainly stored in bits and bytes. This ongoing investigation within the commission on digital technologies of cartographic heritage focuses on the latest developments of modern maps, which lead to neo-cartographic environments and its related archiving concepts. The steps from digital maps to multimedia-, web-, and Service-oriented maps result in real-time content which is affected by user participation in ubiquitous environments. It becomes obvious that these distributed, interactive, multimedia and real-time maps can hardly be archived by following old archiving paradigms: to keep the application/content in a save place forever. Instead, new methods have to be developed in order to ensure historic applications of tomorrow. Accompanied by technical methods, legal issues and the interdisciplinary understanding of archiving have to be adapted to the prospective historic use of digital geoinformation and modern maps. This is a starting point to overcome the main dilemma for the history in modern cartography.

37.2 Towards the Understanding of Modern Cartography

Modern cartography is heavily influenced by digital approaches. Reproduction processes as well as dissemination procedures make use of digital mechanisms that mostly enhance traditional processes. This technical changes lead to new and extended applications as well as use cases. Thus the access to geospatial information becomes public and even the creation of maps can be done by public too, as it is shown with the OpenStreetMap (www.openstreetmap.org) initiative. In terms of cartographic heritage these technological developments of neo-geography result in new challenges for enabling sustainable cartographic heritage for the future. Their conceptual structure, intermedial dependencies and technical requirements lead to a more complicated framework. These technological developments of cartographic visualization come up with new notions, which should be briefly explained in order to provide an overview of the successional meaning.

Geovisualization includes scientific visualization of geospatial content, which is mostly derived from data analysis (Andrienko et al 2007). Geovisualization focuses on the use of computer graphics to create visual images which aid in understanding of complex, often massive numerical representation of geospatial concepts or results. It emphasizes knowledge creation by different information visualization and therefore extends knowledge storage. The combination of GIS (analysis) and geovisualization allows for a more interactive exploration of data with the base functionalities of map layer exploration, zooming, altering of visual appearance and digital interfaces (Jiang et al 2003). Additionally geovisualization advantages concern the ability to render time- and space-changes in real time, expand the visual exploration to n-dimensions and allows users to adjust mapped data abstraction in real time (MacEachren et al 1997).

Web mapping describes creation and dissemination processes for maps that make use of the Internet. These processes cover the designing, implementing, generating and delivering of maps via the World Wide Web (Peterson 2003). Beside the technological issues of how to establish Internet maps, theoretic aspects concern additional studies of web mapping: the usability of web maps, the techniques and workflows' optimization and even social aspects (Kraak et al 2001). Therefore web mapping serves as presentation media with an increasingly amount of analytical capabilities (Web GIS, Web Services). In addition developing client devices, like PDA, hand-held or mobile phones, expand web mapping to ubiquitous cartography, where maps are time- and space- independently available (Raper et al 2007).

Geospatial Web Map Services (WMS) focus on a server sided processing of geospatial information with the general aim to render simple images and send these to the client. Variations of Web Services (WFS, WCS, WPS, WPVS ... www.opengeospatial.org) even enable direct manipulation of geospatial database contents and analysis, which simulates full GIS functionality via the Internet. As effect these services have great impact on expert's and layperson's user experience.

Location Based Services (LBS) make use of Web Services by reason of utilizing the geographical position of a device and offering location and task relevant information and entertainment services. Thus LBS incorporate services to locate the device, to access content gazetteers, which enable the use of various information, and to possibly track user moods. For example LBS include personalized weather services or location based games (Reichenbacher 2004).

Locative Media describe media of communication that are bound to a location. Accompanied by the technical possibilities of Web Services and LBS, digital presentation media (pictures, video, sound ...) can be virtually applied to locations.

This leads to a triggering of real social interactions. Although mobile positioning technologies, like GPS or mobile phones, enable the intense spreading of location media, these technologies are not the main aim for an ongoing development in projects in this field. Instead the social component, which provides information on the relationship of consciousness to a place and other people, forms the framework to actively engage, discuss and shape spatial bound topics in a very wide public environment (Galloway et al 2005).

The notion neo-geography subsumes public use and creation of geospatial data. It can be seen that the public use of web technologies is a major development in cartography that opens new opportunities. Neo-geography is a notion for "new geography", which bases on a public access to geospatial data and participation in geographic applications (Turner 2006). The access to geospatial data is executed via the Internet and various Web Services. One does not have to load complete datasets to the client computer, but receives simple pictures according to the requests of Web Services that may be used by specific applications (like Google Earth). The participation in geographic applications describes the user's possibility of recording and sharing geospatial data, which have special personal/individual importance.

In addition to the public recording and exchanging of geospatial data, the notion neo-cartography combines neo-geographic characteristics with ubiquitous cartography and geo-media techniques. Beside a time- and space-independent access to maps and modification of geospatial data, neo-cartography takes the characteristics of transmitting media, the impact of information-content and user needs for the presentation of geospatial information into account. The new aspects of neo-cartography indicate the possibility to directly access mental imagery by using user inputs. The ubiquitous existence of maps and a public participation develop a social imagery of space that should be used for the abstracted and simplified presentation of space.

37.3 The Technological Environment of Modern Maps

The development of digital environments in GIScience over the past decades has been resulted in a diverse amount of tools available for cartographic multimedia applications. This ongoing evolving process has led to new methods, formats and applications for playing, reading or accessing incorporated content. One main reason for this rapid development may be motivated by adapting the latest technology available, which concerns processing and displaying resources using hardware or new software creations. In this sense the impact on cartographic multimedia applications is characterized by new technical possibilities, like interactivity, dynamic animation techniques or immersive information transfer. Additionally the domains of GIScience benefit from decentralization of software architectures and data management, which enables a more effective recording of data and interoperability (Kraak et al 2001). These decentralized and service oriented architectures are consequently used by cartographic applications on the basis of the Internet and ubiquitous frameworks. In terms of cartographic heritage digitalization of creation processes and end-user products basically lead to changes within the archiving paradigm, which generally means to store and save information. An advanced expansion to decentralized architectures then causes massive challenges in technical-, legal- and theoretic aspects of archiving geoinformation.

Independence by time and space: One main characteristic of modern cartography, especially ubiquitous cartography, is its time- and space independence. Cartographic applications and geospatial content can be accessed any time and everywhere for any occasion. The Internet as well as wireless transmission technologies make this access possible. Therefore a highly context sensitive content, which covers all possible eventualities, describes the basement for most usable ubiquitous cartographic applications (Reichenbacher 2004, Nivala 2005). The content and application should be usable in any situation, like a leisure- or business trip, which may also change during a journey. In consideration of cartographic heritage this content flexibility leads to a complex archiving structure that needs ongoing investigation. On one hand masses of information wait for their combination and appropriate use, on the other hand distributed networks, ad-hoc connections and active as well as passive sensors establish an ubiquitous environment. Neither emulation nor migration, as these are in use for archiving information and applications nowadays, can help for archiving an ubiquitous environment. This special cartographic application, which depends on distributed networks and ad-hoc connections in order to build up an ubiquitous environment, cannot be isolated, put in an image and kept functional (of the user interface and content exploration) by reason of archiving. Thus the development of appropriate archiving strategies is requested for future investigations.

User participation is another big aspect in modern cartography. Using special devices/sensors and distributed networks (or more general: ubiquitous environments), map users are able to collect geospatial data and even leave their “moods” for specific places behind. These collections are then incorporated into the geospatial environment/application, which may be used by others. The same social mechanism and technology is used for the collection of geodata in order to establish freely available geodatasets. As consequence of this “social mapping activity”, social interesting areas and topics can be identified, which is most essential information for a series of user-oriented cartographic tasks. In terms of cartographic heritage it becomes obvious that “saving” this dynamic content leads to more questions than solutions at the moment. How can we deal with the notion of completeness? What does actuality mean for these social-based data? Can incremental archiving procedures created? In fact the social image of geospatial facts will also be influenced by individual knowledge/perspectives, social preferences, political motivated interests and so on. Maybe the social interest can also be motivated in a way that sustainable archiving can be solved in distributed networks in future.

The cartographic heritage relevant core aspects of modern cartography show the increasing complexity of digital heritage architectures. In addition to digital requirements, individual and social interests are increasingly embedded in geospatial structures, which leads to unrevealed archiving processes. In the end the question for sensitive map content and applications arises. What are the historical values that are worth saving? Is it enough to keep original data (first model data) or do we have to save the map product or even entire virtual environments for keeping our cartographic heritage?

37.4 Archiving Aspects for a Prospective Historic Use

From a historical point of view, maps can tell a lot of passed and unknown circumstances, either by means of topography or the influence of policy, culture and pragmatics on the content. Thus the exploration of the past can be supported by accessing this documented information in maps for some extend. This is the main reason and importance for saving and disseminating cartographic heritage also in future decades. Historical values in context with maps generally cover cultural, geometric and informative values. Cultural values show how the map content was actually understood or used and thus became abstracted/depicted within the map graphics. For example political influences become obvious when map graphics were distorted for specific propaganda expressions. Geometric values describe the precision of map projection on one hand and document the relation to reality on the other hand, like topographic elements show the location of real world objects. Informative values mainly discover influences of technical driven processes. Due to technical developments, map production technologies change.

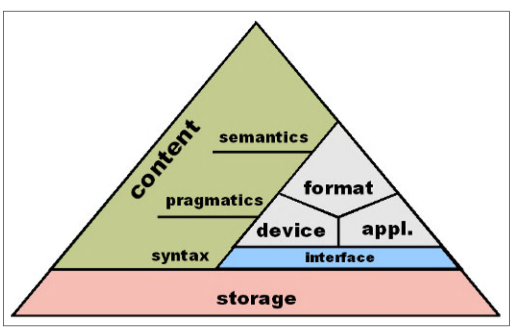

Fig. 37.1. A simple cartographic heritage structure that depicts dependencies for digital based technologies

The depiction of a conceptual cartographic heritage architecture shows main dependencies of considered core components. On one hand this graphic additionally shows the grade of digitalization, on the other hand cartographic heritage depth can be defined. The grade of digitalization starts with content and its storage media. In principle this categorization begins with analogue media, like a paper map on its storage media paper and a printed content. As soon as a digital content has to be processed, the device and format of the data become important. Consequently the processing application and its dependencies have to be considered. Cartographic heritage depth covers content-based- and artistic-based parts of historic values. Thus a very first description of cartographic heritage starts with storage media, its material, fabrication and condition. In a next step the content with its syntax, pragmatics and semantics adds to storage media. Storage media and content together form some kind of artefact, which allows to suggest the application and usability framework. Finally full cartographic heritage depth for an digital cartographic tool additionally covers device, format and application.

The format, application and device form a triangle, which depicts a very close relation of these components. The format has to be processed by an application and therefore understood by this piece of software. In addition the format has to make sense for the device, which means that e.g. sound formats will not be usable by graphical devices. The application needs to support a format and the device. Normally the application transforms a file's content for a specific device. For example a mixture of 2D geodata are processed by an application to show a virtual 3D city model. According to this, the specific device including its processing hardware has to understand the output of an application and present it in a most appropriate way (which includes that the interface is capable and best suited for this specification). For example the rendering of a virtual 3D city model will deliver a more immersive information transmission on stereoscopic interfaces than on standard displays.

The content with its semantic, pragmatic and syntactic dimension bases on the triangle of format, application and device. Looking at a bottom-up approach in the given graphic, the dimensions of content are accordingly placed to the device, application and format. In terms of cartography the syntax of the content follows characteristics of the device (resolution, immersion ...) and application (interaction, dynamics ...). For example the resolution of a device defines information depth and therefore affects the preparation of information. The pragmatic dimension relates to the device, application and format. All three parts guarantee best/appropriate usability in specific situations. The semantic dimension mainly pertains to the format, which can additionally map the meaning of a content. For example an object-oriented structure may map the meaning and relations of natural element structures.

However, the described graphic from above can only depict a first conceptual architecture of cartographic heritage. In fact more aspects have to be considered,

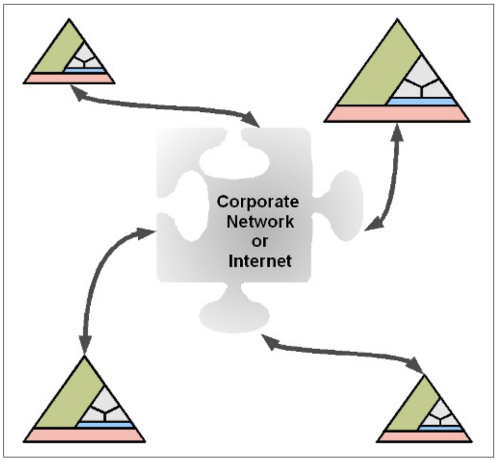

Fig. 37.2. The conceptual cartographic heritage structure in a distributed (Service-oriented) architecture. In addition to the complex single cartographic applications, the network structure or at least its functionality, protocols, actuality and integrity needs to be mapped.

when looking into detail. For example storage strategies vary for applications, formats, content semantics or devices (Borghoff et all 2003). Instead of one single technique to comprehensively save cartographic heritage, different methods are needed for the different parts. From another point of view a lot of questions arise when thinking on service-oriented architectures (e.g. Hagedorn et al 2007): How can we archive service-oriented applications, that depend on the Internet, communication protocols and ad-hoc connections? The conceptual architecture may help to keep the main dependencies within the range of vision when going into more detail.

37.5 Starting Points for Solving the Dilemma

The dilemma for the history of modern maps bases on long-established paradigms of archiving, the legal framework for archiving institutions, digital media lifetimes, missing responsibilities and so forth. Established paradigms of archiving with their understanding of "keep and save" cannot be adapted to digital media, because digital media´s lifetimes are too short. Additionally their technical (hardware) dependency leads to a loss of all embedded information in the shortest time. Either the information carrier (e.g. floppy, CD ...) becomes damaged, a reading device is missing or interfaces between device and computer do not exist anymore. This leads to copying procedures from old storage media to latest available information carriers (as it is done in data center). But this will not prevent from data loss due to outdated software and formats. This situation makes it obvious that new archiving paradigms are needed for the digital era.

Legal issues (especially in Germany and Austria) concern the archiving concept, its understanding of the notion archiving, the role of archiving institutions and their activities of selection. In general the understanding of "archives and collections" is formed by collecting media that felt into desuetude and which document political decisions. Therefore archives will undertake massive selections of worthy information/applications and cartographic contents. At the moment the status and digital procedure of archives and collections is not that clear and has to be discussed. Especially responsibilities to collect, to sustainably store, to keep read- and playable and to provide the access to geospatial content/applications have to be defined in a legal framework, in order to establish working and sustainable sequences for "digital archiving". Until then there is an urgent need to "keep modern maps online", in terms of keeping the knowledge of their existence, metadata and technical dependencies. As long as responsibilities for archiving are not legally effective, the creators of digital data and maps are responsible for their long-term existence on their own, otherwise the loss of digital geospatial evidence for our geospatial era is in all probability (Bergeron 2002).

37.6 Conclusion

Concluding this first valuation for the expected history of modern maps it becomes clear that a legal framework will help to structure responsibilities. According to these responsibilities technological archiving procedures can be adapted and implemented. Thus an intense discussion concerning the prospective cartographic heritage within an interdisciplinary environment has to be firstly done to clear next urgent steps for archiving distributed networks and modern cartographic applications as well as digital geographic base data.

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