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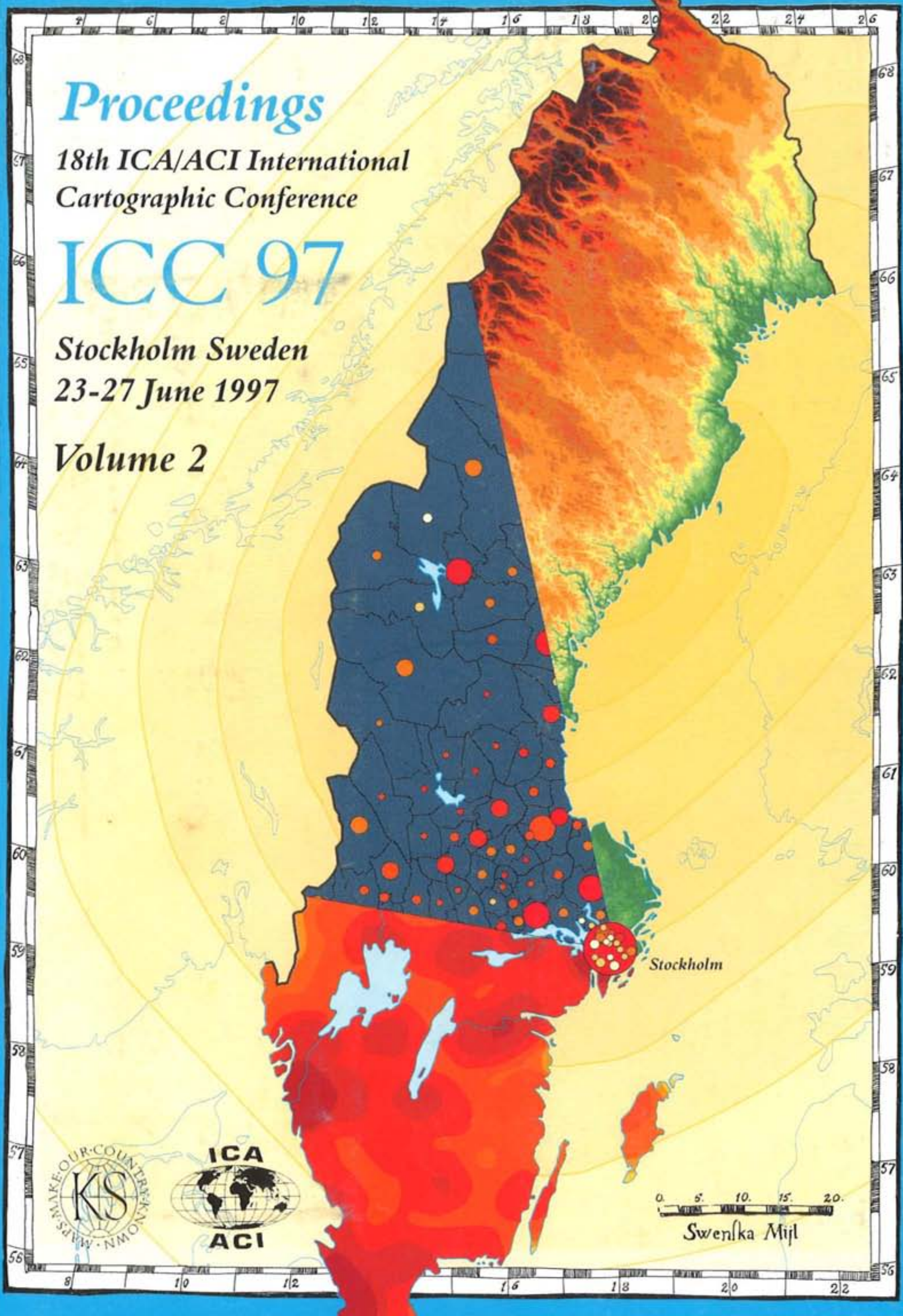

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18th ICA/ACI
International Cartographic Conference
Stockholm, Sweden 23 - 27 June 1997

Swedish Cartographic Society

ICC 97

PROCEEDINGS

Volume 2

of the

18th International Cartographic Conference
18e Conférence Cartographique Internationale

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Lars Ottoson

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PREFACE

The Call for Papers for the 18th ICA/ACI International Cartographic Conference, ICC 97, was met with a very good response. Thus, almost five hundred proposals for presentations to the Conference were submitted to the Scientific Programme Committee for review. The Organisers decided to include 144 oral presentations divided into 24 sessions in the programme as well as a special lunch session for oral presentations of papers prepared by seven ICA/ACI travel awardees. Moreover 8 poster sessions each including presentations of some 25 papers complete the scientific conference programme.

The review of submitted papers has been carried out by members of the Scientific Programme Committee. Committee members also helped organising the oral and poster sessions. I gratefully acknowledge the help rendered by the following members of the Committee: *Wolter Arnberg, Ulla Ehrensvärd, Curt Fredén, Margareta Ihse, Liqui Meng, Ulf Sandgren, Mats Söderberg, Kennert Torlegård* and *Anders Östman*. Grateful acknowledgement is also due to *Alan McEachren, Andrew Tatham* and *Bengt Rystedt* for assisting in paper review.

Special thanks are extended to all authors contributing to the Scientific Programme of ICC 97. Due to the large amount of papers it has been necessary to divide the Proceedings into four volumes. The papers presented in the Proceedings offer a comprehensive review on contemporary cartographic research and development. The Proceedings will hopefully promote discussion and contribute to progress of cartography.

Finally, the Scientific Programme Committee would like to extend a sincere acknowledgement to the Chairpersons of the Plenary Sessions for accepting this important task for the realisation of the 18th International Cartographic Conference.

Lars Ottoson
Chairman Scientific Programme Committee

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COMPLEX ATLAS OF BARNAUL

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Abstract

This poster paper presents the first results of joint scientific project - the complex atlas of Barnaul - within the framework of cooperation between the Institute of Cartography, Dresden University of Technology and Geographical Faculty of Altai State University.

1. Introduction

The thematic mapping of cities as one of directions of atlas cartography in Russia holds a special place but still not attract one. According to encyclopedic data /Goroda... 1994/ Russia has more than 80 district, regional and republican centres. There are not more than 10-15 atlasses published until now. Unfortunately, the most existent atlasses of Russian and former Soviet cities are restricted to special fields, as a rule the touristic one and are dedicated to big cities and capitals of republics /Kiev... 1989; Leningrad... 1989; L'vov...

1989; Moskva... 1985, 1988; Moskva... 1989; Tbilisi... 1989/. There are examples of atlasses of scientific-information nature, e.g. the geographic altas of Tashkent /Taskent... 1984/ or atlasses with a pronounced historic-geographic orientation /Peterburg-Leningrad... 1957; Leningrad... 1981, 1989/ or with a historic-propagandistic aim /Atlas. Goroda... 1975/.

2. Joint scientific project

Within the framework of the scientific project (Dr. Wolodtschenko and Prof. Rudsky are heads) and cooperation between the Institute of Cartography, Dresden University of Technology and Geographical Faculty of Altai State University joint development of series of Barnaul's atlasses has been done. Taking into consideration the edition only map-schemes of Barnaul cyti by various organizations but no atlasses were published, we had planned the projecting of the next atlasses:
- scientific atlas;
- atlas for tourists;
- atlas for student (or atlas-guide)
- atlas for children und parents.

Working out atlasses, we adhered to the two-stage approach: the developing of common program of atlas and the developing the separate maps. Bearing in mind our financial and scientific possibilities, we confined our researches to the first stage. The experience of other countries in creating the city atlasses was taken into account. For that the literary and cartographical funds of library of Dresden University of Technology were used. Previous analytical works were conducted: the comparative analysis of diverse city atlasses and cartosemiotical analysis of atlasses (WOLODTSCHENKO 1994). The students of the geographical faculty of Altai university took an active part in researches (one diploma thesis and several undergraduated project thesises were carried out).

3. Developing the complex atlas of Barnaul.

The combining of scientific and tourist information in developing atlases for big cities can lead to the interesting results. To our mind all district, regional and republican centers should have their own scientific and/or tourist atlasses, which can be combined. Firstly planned separate projecting of scientific and tourist atlasses of Barnaul, we had realized as one complex atlas. This subject was approved in a diploma thesis (KUZNETSOVA 1996).

Barnaul is centre of the region of Altai, a big cultural and industrial city of Western Siberia. The city has six universities and some research institutes. Proceeding from the complexity of the research object, a complex atlas can be deemed the most representative type of its cartosemiotical model. Such atlas is to consider as a collection of knowledge of natural territorial features and social-economic development of Barnaul.

The program of the atlas includes three parts: introduction, natural conditions and social-economical part. The introduction takes 5-10%, natural conditions (including the ecologic component) 30-35% and the social-economic part 50-60% of the total scope of the atlas. Explanatory texts are very signifitant in the atlas, comprising up to 40% of its total scope. Atlas format is A4. Its main scales are 1:100 000 and 1:65 000.

The recommended list of maps:

map-scheme	physical-geographical map	popuiation
the center of the city	climate	education and
	ecological map	science
	hydrographycal net	public health
		culture and sport
		tourism
		transport
		industry
		architecture and
		town building
		along the Ob river

4. Conclusion.

Development of any atlas is a complex matter. The first experience with a complex atlas of Barnaul shows that not only state but also commercial structures are interested in atlas products which are able in the modern situation to finance scientific projects as creation and production of city atlasses. When projecting the atlas of Barnaul there were financial problems as well. After the development of first stage of atlas layout, the city municipality undertook financing of further work. An editorial staff of 9 people proceeds with work. The publishing of atlas is planned in December 1997.

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DESIGNING A NEW
NATIONAL ATLAS OF THE UNITED STATES

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ABSTRACT

The U.S. Geological Survey (USGS) is planning and designing a new *National Atlas of the United States*, using electronic technology. The project is envisioned as a joint government and industry venture conducted under partnership agreements with private firms that will participate in creating the *National Atlas* in a variety of formats, such as CD-ROM, World Wide Web (WWW), and printed editions. The *National Atlas* project will provide a showcase for earth science data and mapping technology and will illustrate, at a national level, the concepts of a national spatial data infrastructure and a geospatial data framework.

Introduction

The U.S. Geological Survey (USGS) and other agencies of the Federal Government have amassed a large volume of earth science and other geospatial data, but these data sets are not easily accessible and useable together. The *National Atlas* provides a mechanism to bring diverse national-level data sets together in a way that has not been done before. The project depends on the participation of nongovernmental partners to provide consumer-level geographic information system (GIS) software, assistance with publication formats and marketing strategies, and development of widespread sales and distribution networks.

Product Design

The *National Atlas* project will use GIS technology to bind together diverse sets of geospatial information into definitive information resources and to furnish uniform access capabilities to display and analyze the data. *National Atlas* products would use GIS data viewing and analysis tools combined with definitive sets of geographic reference, thematic, and statistical data to provide users with the capability to make their own maps. Users will have the flexibility to select, combine, symbolize, and display the data sets of interest to them. Printed maps of visually interesting and relatively stable subject matter (for example, image map of the United States, shaded relief, land cover, surficial geology, roads, drainage and political boundaries) may be sold separately or bundled with CD-ROM products. In addition, Internet access to USGS data sets would allow users to get the latest information on earthquakes, stream flow rates, and other events where knowledge is time-sensitive. World Wide Web (WWW) pages would describe atlas content, provide graphic examples, and enable electronic ordering.

A successful public and private partnership will enable the *National Atlas* project to provide two key outputs:

> A set of integrated, consistent, and authoritative data that can be used to answer a wide variety of questions regarding the physical and societal conditions of the Nation. These data will be conveyed to the users through various media, including CD-ROM's, WWW pages, and printed maps.
>
> A geographic information system tool that can be used to display and analyze a wide variety of geospatial data. The provision of this standard tool will encourage other data producers to take advantage of its capabilities and to offer their data in a form that can be used with the existing national level data sets or with sets of regional or site-specific data.

A key feature of the *National Atlas* is that the data sets will be processed so that different themes of information can be combined, displayed, and analyzed together. This requires that the data are geographically registered to the same coordinate system, are of comparable spatial resolutions, and are logically consistent. Many of the desirable data sets exist in digital form but need further processing to ensure consistency between data sets. The data sets to be provided by the USGS include the following types of information relating to:

highway systems (with route numbers)
rail systems
river systems (with names)
populated places
Federal lands
elevation (relief)
land cover and land surface images
sea floor images (Exclusive Economic Zone)
surficial and bedrock geology
mineral occurrences
organic fuels
geophysics
land forms
geochemistry
faults and historic seismicity
marine and sea floor characteristics
coastal erosion
surface and ground water
water use and quality

In addition, major sets of geospatial data will be obtained through partnerships with other Federal agencies, including the following:

Department of the Interior (public lands, wetlands data)
National Oceanic and Atmospheric Administration (climate and geophysical data)
Environmental Protection Agency (environmental data)
Bureau of Transportation Statistics (roads, railroads)
Department of Agriculture (soils, forest data)
Bureau of the Census (political boundaries, Congressional districts, socioeconomic, agricultural, and demographic data)
Bureau of Labor Statistics (economic data)
Other agencies that collect relevant statistical data

The first planned product will be a CD-ROM containing various digital data sets linked to the GIS software. Information from the Internet and printed maps will follow. After the first release, subsequent CD-ROM and printed folio editions will include newly available data sets. Editions based on States or national regions are also possible.

User Needs

The *National Atlas* project addresses the needs of three user communities: the educational sector, the general public, and the public policy sector. Specific products and groups of products can be tailored and targeted for several markets. The potential for outreach into the educational sector is great. In addition to being available in public and school libraries, the data and GIS capabilities could be used in geography curricula in K-12 classrooms to meet the National Geography Standards. Success in the educational sector would augur well for success in marketing to the reference work segment of the general public. The geographically referenced earth science and statistical data, available for display and manipulation in the *National Atlas*, would support informed public policy decision making. Widespread use of *National Atlas* products by those in the public policy field would create an influential constituency for project support.

Production Requirements

The USGS has two unique capabilities that complement the expertise of private sector partners in the production of the *National Atlas*:

Provider of credible data sets - Data provided in the *National Atlas* should be authoritative; this is difficult for a private sector firm to achieve without close collaboration with the appropriate government authorities. The USGS will act as a "data consolidator" in arranging cooperative agreements with other government agencies for data on a certain theme; it will ensure that the data sets are appropriate for that theme and can be used with related data. The USGS is in a unique position to perform this data collection, evaluation, and integration.

Expertise in GIS and digital cartography - The project will require personnel skilled in creating GIS applications software, in developing digital data bases related to their disciplines, and in knowing how these data can be combined. Likewise, it will require experts in the appropriate scientific methods needed to analyze the data sets. Also needed will be experts in the cartographic display of the data sets. The USGS has personnel with these various skills, thus enabling private firms to bring more innovative technology and richer data sets to the market in a shorter timeframe.

The project depends on nongovernmental partners to provide user-friendly GIS software, to assist with publication formats and marketing strategies, and to develop a widespread sales and distribution network. Private sector skills in identifying specific target markets and developing appropriate products are key facets of this program.

Marketable products are expected as early as May 1998. The dates and nature of the initial products will be the subject of analysis and negotiation between the USGS and the private sector firms. Subsequent editions are planned to incorporate more comprehensive data sets and (or) GIS technology. State or regional editions, incorporating more detailed spatial data, are possible as part of an expanded product line.

Prototype Design

The USGS has developed a working prototype of the electronic *National Atlas*. The prototype uses a simple user interface to select and manipulate a sampling of national data sets. Work on the prototype has enabled us to gain experience in developing the user interface, demonstrate to potential partners the functions envisioned for the atlas, begin integrating national digital data sets, develop preliminary design and functional specifications, and receive feedback from interested parties. Figure 1 shows the opening screen and pull-down menu bars. (The *National Atlas* displays are in color; the figures here are reduced in size and shown in black and white)

Figure 1. Opening screen of *National Atlas* prototype.

Figure 2 shows descriptive text about one of the data themes (physical - fauna) and large choice buttons allowing the user to display map data and metadata, access a multimedia presentation, or link to the World Wide Web.

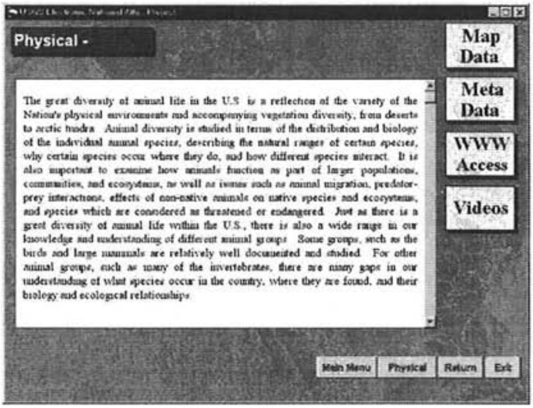

Figure 2. Navigation of a data theme.

Figure 3 shows a simple map display including shaded relief, roads, lakes, and streams. Menu buttons along the top of the window allow the user to add more data and perform various specialized functions, such as overlay analysis and buffer generation.

Figure 3. *National Atlas* map display.

Figure 4 shows the results of a query of a gazetteer containing about 2 million names. In addition to information about the characteristics of the named feature, a map showing its location is displayed.

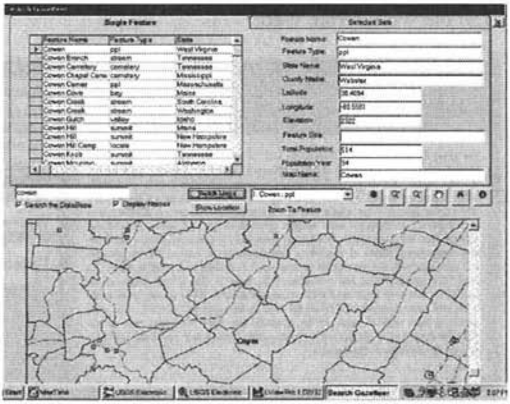

Figure 4. Results of gazetteer query.

Figure 5 shows a part of a data base for all of the national parks, with links to map data and WWW pages. The Internet link would allow users to find out information on the latest park activities and conditions.

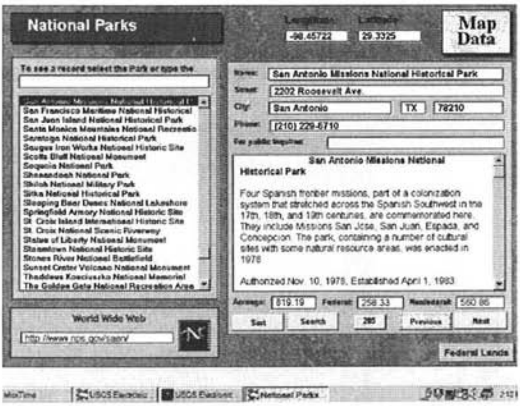

Figure 5. Query of a national parks data base.

The prototype is being used in a variety of customer evaluation and testing situations to help design a compelling product. In this version of the prototype, data sets are stored on CD-ROM and the application software runs on the local (client) machine. Internet capabilities allow the seamless integration of more current or additional attribute information with that contained on the CD-ROM. Alternate designs, where more data and software functionality reside on network servers, also are being evaluated.

Summary

The *National Atlas* project provides a showcase for geospatial data and mapping technology. The project will increase awareness not only of the geospatial information collected and analyzed by the USGS and other agencies, but also of the use of GIS technology in the display and analysis of geographically referenced statistical data. The project will benefit from a synergistic relationship between the public and private sectors in the production of the *National Atlas*. The real beneficiaries will be the atlas users, who will be able to readily access and use large amounts of geospatial information about our country.

MAPS AND THEIR USE ON THE INTERNET

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The aim of research into the use of maps is to improve the effectiveness of these tools for geoinformation transfer, e.g. by means of recommendations for symbol design and for setting up systems for generating maps. As a consequence of developments in, among other things, computer technology and GIS, in the past few years more maps than ever have been used and produced, not only on paper but, increasingly, as ephemeral displays on computer screens. As current hard- and software tools allow almost any user to generate his or her own map -also those users without sufficient cartographic knowledge and experience-, at the same time more and more mistakes are being made with these maps or the cartographic tools are not used to their full potential. All this has led to a revival of the interest in map use and design research.

Nowadays, we are witnessing again another great increase in the use of maps by a constantly growing audience through the World Wide Web (WWW) on the Internet, due to its increasing appeal and consequent ease of public, continuous and boundless access. Even if they do not specifically intend to, it is very likely that people come across maps when they are 'surfing' on this global network of computer networks (FLYNN, 1996). At the same time technology allows the creation of novel and often innovative cartographic products such as dynamic and interactive maps, animations of various kinds, multimedia and hypermaps. The nature of the WWW-medium allows (and demands) for many of these new products, if not already now then in the near future. But again, the greater the number of maps that appears through the Web, the wider the spectrum of their contents, types and purposes, the greater also the possibility that non-cartographers are involved in their creation and use, and, consequently, the greater the risk that design rules are violated or not applied to their full potential, with the resulting loss of effectiveness. Therefore, it is very much needed to start research into the use of maps on the Internet. The ultimate purpose of that research is to make maximum use of the cartographic possibilities and potential offered via the Net, in order to serve the needs of the users in the most efficient and effective ways.

This paper can be considered as an initial step into the research required. First, a

survey is presented of various maps available through the WWW. By including the URL addresses of websites we are inviting readers to an on-line illustration of this paper. We will not deal with the possibilities to download geographical data (even digital map files) which are further processed locally with the help of cartographic or GIS software (which may also be downloaded). The focus will here be on map types, sources, contents and functionalities on the Internet itself. Quantitative indications of the current use of maps through the WWW are given in the paper by Peterson elsewhere in these Proceedings.
A next section of our paper deals with the limitations of the Internet from a cartographic point of view. Thereafter, we will attempt to identify different modes of use and the users of maps on the Internet, now and in the future. The paper is concluded with some recommendations for further research, including tests with real users in real surfing conditions. These tests may lead to a better understanding of the reasons why and how people make use of cartographic tools through the Internet.

Cartographic possibilities on the Internet

The access to the Internet through the WWW is expanding and consequently its use is growing and expected to continue to do so: the Web could be considered as the newest electronic mass medium. It can be argued that there are two main aspects which form the character of this medium: its ease of public access (hence its mass-media nature) and its computer-based environment. This combination creates the broader map use context within which the cartographic possibilities of the Web are considered.

A considerable amount of maps can be found on the WWW. These relate to a wide spectrum of users and tasks. However, before attempting to give an impression of the extent of map use on the Web, some remarks regarding its particular nature have to be noted. First, at this moment, the main WWW-users are rather young people, with students and schoolchildren constituting a growing group among them. This adds to the pedagogical and educational potential of the medium from a cartographic point of view, since it can introduce future map users to the world of maps. If these maps are ineffective, wrong or not interesting, the chance is lost. Another problem is that currently on the Web only a very limited use is made of the cartographic potential. Many of the subjects which are to be found on the Internet have a strong spatial component but are not presented in the best ways: a common example are themes related to tourism and travelling which -in their majority- cannot be viewed in a spatial context (many websites only contain descriptive text and pictures). Although the environment of the Web is graphically appealing -more than in the traditional mass media- it still is primitive from a cartographic/geographic point of view.

Nevertheless, still a great number of maps intended for various map users already exists on the Web. Cartographic sites could be identified by common search engines such as Yahoo or Alta Vista, but maps may be found more directly through the home-page "Cartography Resources" (*http://geog.gmu.edu/gess/jwc/cartogrefs.html*) or the very rich cartographic source Oddens' Bookmarks (*http://kartoserver.frw.ruu.nl/html/staff/oddens/oddens.htm*). Map curator Oddens took up his traditional and important task to create order in the chaos of information on the Web to make it better accessible. The WWW-maps which may thus be located are related to various map use tasks, like:

- General reference (e.g. *http://www.parc.xerox.com/istl/projects/mapdocs/*), or getting information about:
- Weather - in general and for special situations (hurricanes, cyclones etc.) (e.g. *http://www.nosc.mil/planet_earth/multimedia/Weather/Weather.html*)
- Transportation, navigation and traffic (e.g. *http://www.proximus.com/ yahoo/*)
- The environment and natural hazards (e.g. *http://www.ns.doe.ca/inform/points/ env.html* or *http://www.ns.ec.gc.ca/how.html* or *http://www.ns.ec.gc.ca:80/epb/ sfish/maps/nf/nf.html* or *http://www.abag.ca.gov/bayarea/eqmaps/eqmaps.html*)
- Events of current interest (e.g. *http://www.delorme.com/newsmaps/* or *http://www.knbc4la.com/seismo/index.html*)
- Tourism / travel (e.g. *http://www.vtourist.com/webmap/* or *http://www.city.net/ indexes/top_maps.html* or *http://www.virtually.com/los_angeles/*)

Depending on the purpose of map use another broad categorization of websites is:

- General use: map sites intended for general information or search, for example to view and identify places in the United States and to obtain census data of them (*http://www.census.gov/cgi-bin/gazetteer*) or to get a general impression of the spatial aspects of crime (*http://www.accessone.com:80/~kwirth/crimeone.htm*).
- Sites for specialized users, where they can get more specific information and data on subjects of professional or research interest. For instance: temporal urban mapping (*http://edcwww2.cr.usgs.gov/umap/umap.html*), satellite image maps for agriculture (*http://www.intranet.gr:80/ceo/intro.htm*) and historical cartography (*http://www.stub.unibe.ch/stub/ryhiner/ryhiner.html*).

A category of particular interest is formed by the educational map sites of the network. These include maps which can be used in cartography classes but also the respective lecture materials, instructions and exercises (e.g. *http://info.er.usgs.gov/education/ teacher/what-do-maps-show/index.html*). Commercial cartographic firms are also present on the Web to offer the users their services, for instance for the creation of conventional and electronic maps (e.g. *http://www.cartographics.com/*) or just for ordering paper maps to be sent by ordinary mail.

According to their functionality characteristics, the maps found in sites like the ones referred to above can be divided into the following broad categories:

- Static, inactive maps: previously prepared maps, often scans of existing paper maps, which have been converted to GIF- or JPEG-formats.
- Simple clickable maps: these maps usually function as indexes or interfaces to other information on other pages of the Web (in the form of text, pictures, other maps, etc.). When clicking on 'hotspots' in the map, other documents are retrieved and displayed on the screen (e.g. *http://www.atlantagames.com/atl/drivtour.htm*). Sometimes maps are even applied as spatial metaphors, or means of organization, to guide users around the wealth of information on the WWW in cases where the spatial component is not immediately obvious or of prime importance (e.g. Autodesk Map Guide, available through *http://www.argusmap.com*).

- Interactive and/or dynamic computer maps with more options for interaction. The user can select an area to map, choose or alter the map content, select an area of coverage, map layers, etc. Maps can also display dynamic phenomena, either in a real-time situation where the map is frequently updated, or with the help of animations. Often the maps are linked to other objects in a database (e.g. the interactive atlas *http://www.mapquest.com/*, a real-time traffic congestion map of Athens (*http://www.transport.ntua.gr/map/*), an interactive surface water pollution analysis (*http://poca.osmre.gov:80/form/swpa.html*), an animated frontlines map of Bosnia (*http://aaln.org/~wharmby/matt/bosmap.htm*) and the earthquake animation *http://www.abag.ca.gov/bayarea/eqmaps/animation.html*).

Especially after considering this latter category it seems there are no limitations or problems related to the use of maps on the Internet. But there definitely are.

Problems and limitations of maps on the Internet

The WWW on the Internet has some particular characteristics as a map use environment. For those who start exploring, it is unavoidable to pass through a stage where they will be overwhelmed by the amount of information available ("drinking from the fire hose") (BUTLER, 1995). Abundant information is a general characteristic of the Internet, which, however, is not necessarily negative, particularly from an educational point of view. The volatility of this information is another matter: unlike usual computer maps, Web maps are both virtual and ephemeral, since what appears in a site today might be gone tomorrow. The positive aspect of this changing nature of the map environment is that it allows for easy and fast map updates (e.g. *http://www.subed.com/caltrans/transnet.html* with real-time status maps of highway travel speeds and road conditions, which are updated about every minute).

Practical limitations, such as accessibility of information and capacities of available equipment, which determine the quality and ease of the connection (e.g. computer, network and modem speed) are issues of general concern when using the Internet. They strongly depend on the technology available to each user, not just his or her own PC but, for instance, also the capacity of the local telephone network. Because of the increasing use of the Internet, reference is now often made to the World Wide Wait.
Cartographic information providers are also facing the economic problems of the Web. There is the issue of potential copyright infringement (CRAMPTON, 1995) and there still are no simple, safe and reliable solutions for financial transactions over the Net. The use of credit cards still appears to be too dangerous. With increasing possibilities for direct interaction with the data themselves, security problems are emerging as well.

Other limitations are a consequence of the computer nature of the medium (as opposed to traditional paper maps), like limited portability and lack of ease in manipulating the map (folding, turning, drawing or measuring on it) and limited display size. The latter may be overcome by options such as panning or zooming, but the limited possibilities for overview are still a disadvantage. In addition, screen and colour resolution usually limit the amount of detail present on a monitor screen map (compared to a paper one with higher resolutions at the same scale). In this context it should also be noted that the hardware environment of the Internet end users is variable (STYNES et al., 1997). Nevertheless, despite these limitations posed by the map use environment, the advanced map functionalities which are offered by the Web create many new potential benefits for the users.

Modes of using maps on the Internet

Nowadays, the Internet is often viewed primarily as a very rich information source, rather than a means of communication (PARSONS, 1996, p. 28). Indeed, it is also rich in geographical information. And as maps remain very efficient and effective means for the transfer of this kind of information, they often appear on the monitor screens of users during WWW-sessions. Sometimes, users did not specifically ask for a map display to appear, but they simply posed a geographical question, like "is there a Greek restaurant near the hotel in Stockholm where I will stay" or "how can I reach Stockholm by car from Enschede?" (*http://shell.route66.nl/shell/routenl.html*). Next to some textual information, the answer is provided by means of a customized route map. Other users of the Internet may specifically look for a particular map of a particular area because they know or expect that this map will meet their need for geographic information. Sometimes, they may even create the map they want on-line through the WWW. But in all these cases the question may be posed whether these maps really are as efficient or as effective as they could be.

In order to come to better grips with the different kinds of map use on the Internet the so-called 'map use cube' of MacEachren may well be used as a starting-point (*Figure 1*). The three axes in the cube represent three different map use continua and any map, also the maps generated in an Internet session, may occupy any position in the three-dimensional space defined by these axes, depending upon what a user does with the map for what purpose (MACEACHREN, 1994).

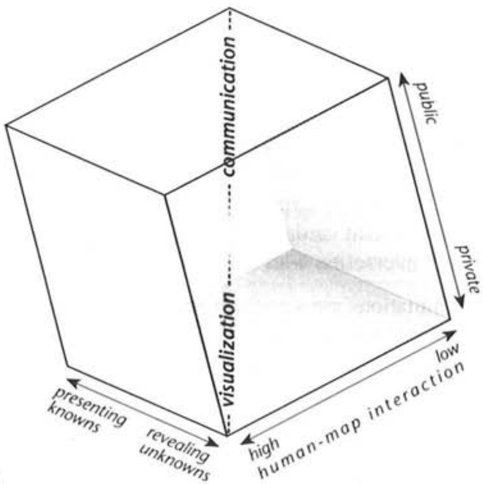

Figure 1:
The map use cube of MacEachren
(Source: MacEachren, 1994, p. 6)

On one side of the public to private axis we find the kind of maps which were put on the Web first a couple of years ago. These are the 'static' maps referred to above, with which no interaction is possible but visual. Many of these static maps can be retrieved through the PCL Map Collection site (*http://www.lib.utexas.edu/Libs/PCL/Map_collection*). Typically, these maps were designed for a wider group of users and often also not for just a single purpose. In contrast, on the other side of this first axis we can find the maps that may actually be created through the WWW by an individual user to suit his or her private needs. In practice, these possibilities for on-line map creation are often limited to the selection of an area, a projection method, one or more layers of map details and the design of the symbols representing these details, including the selection of colours (see e.g. *http://www.aquarius.geomar.de/omc/make_map.html*).

The presenting knowns to revealing unknowns axis of the map use cube also reflects very well different conditions of map use through the Web. On the 'presenting knowns' end, users know exactly what geographical information they want and often also what map on which website supplies that information to them (e.g. traffic congestion maps on *http://www.vauxhall.co.uk/trnet*). On the other end we find the Web surfers who do not have specific goals yet and, for instance, browse through one of the atlases on the Web (e.g. *http://ellesmere.ccm.emr.ca/wwwnais/wwwnais.html*).

In the near future, on the Web many new developments may be expected on the third axis of the map use cube, which is related to the amount of human-map interaction. The first maps which were used on the Internet were just static and view-only equivalents of their paper counterparts. But more and more the medium now allows the users a higher and higher interaction with the maps. In a sense, clickable maps or hypermaps may already be regarded as a kind of interactive map. In other interactive maps on the Web, users may also change the area portrayed (panning) or the scale (zooming) (PETERSON, 1996) (e.g. *http://www.lonelyplanet.com.au/dest/dest.htm*). But interaction with maps also means manipulating maps by switching map layers on and off, by changing the legend of a map (e.g. the classification of the data) or by completely changing the way of representation. An important development in this respect is the "frames" layout possibility of the WWW browser Netscape, which allows putting several independent pages within one window. This technology may be used, for instance, for the visual comparison of maps. In geographical research such higher human-map interaction takes place in the exploration of geographical data, called (geographic) visualization by MacEachren (1994, p.7) in the private, revealing unknowns, and high interaction corner of his cube.

The introduction of this kind of GIS-functionality on the Web, allowing direct interaction with geographical data with the help of cartographic tools, for the purpose of exploration and analysis, has only just begun (see e.g. Autodesk MapGuide Author, *http://www.mapguide.com*). Gateways to existing databases may be created through the WWW, which then serves as a shell ready for use. Alternatively, users may also input their own data. Linking powerful GIS-functionality to the distributed access of the Web brings with it problems of interfaces, real on-line interactivity, graphical data format (raster versus vector) and security (CHOPRA, 1996). But it is expected that sooner or later solutions will be found to solve many of these problems, for example with the help of the Java programming (cf. STYNES et al., 1997), making possible a true variety of uses of maps on the Internet by a great variety of users.

Users of maps on the Internet

The current group of users of maps on the Internet may pretty well be defined, if only because the group of people actually making use of the Net is still not very diverse at the moment. In many places in the world, e.g. in developing countries, many people do not have access to the Internet yet. Even in Northern America and in Europe it seems that currently it still are mainly the relatively young (15 to 40 years of age) people with a high level of education, with an interest in science, technology and/or computers and in the possession of a PC who are making profitable use of the WWW on the Internet.

But things are changing rapidly nowadays. Developments are taking place which will lead to an Internet system for the ordinary TV set. Soon, many PC's at home will also be replaced by simpler and cheaper NC's (Network Computers). And education at all levels also has discovered the power of the Web. So, it may be expected that more and more different users, including "ordinary ones", will soon be surfing on the Web and will also be using the maps generated through it. For these kinds of users, who would normally not consider buying e.g. GIS software, Internet will also make it possible to really interact with maps, so that all kinds of individual geographical problems may be solved much more efficiently and effectively than ever before.

However, things are not as simple as that and a number of problems still have to be solved in order to make this possible. One problem, in addition to the limitations mentioned above, is that currently users still have to be proficient in the use of the English language if they want to surf on the Web. Another problem is that those who create websites can only provide users with the cartographic tools they really need, if they know what these users need and how they are using these tools.

Conclusion

The Net revolutionizes the ways in which people acquire the geographic information they need and, therefore, also the ways in which they use maps. Interactivity is a key concept in this respect. But in order to let the medium be as powerful as it could be, the maps should be adjusted as much as possible to the purposes for which they are used and to the people who are applying these tools. In order to be able to do this, more research needs to be done first to identify the different purposes and the different users.

To some extent, this research is not different from map use research in other map use environments than the Internet; after all, in essence the Internet is just a means of communication. E.g. the answers to questions like when, why and how people are using maps in the exploration of geographical data are as much needed in the stand alone GIS-environment as in the Internet environment. Likewise, the results of research into the perception properties of visual variables (including the new 'dynamic' ones) as applied to cartographic symbols are relevant in all circumstances in which maps are displayed on monitor screens. Knowing more about the specific backgrounds and characteristics of users which affect their ability to perceive and/or to comprehend the geographical information inherent in the map (e.g. age, previous education, existing knowledge and experience) is not only relevant for the development of cartographic tools for the Internet.

But some aspects of map use may be very specific for the Internet-environment and will have to be investigated separately. E.g.: What are the typical characteristics of the Web search process in which answers are sought (to be given through maps) to various geographical questions? What is the role of the user interfaces in this process? And do the resulting individual maps actually provide the information required, or do they give cause for misinterpretations? Finally, what is the quality and reliability of the geographical information transferred through cartographic displays on the Internet?

In order to be able to find answers to these and other questions tests may have to be carried out with users of maps on the Internet. This may be done on the basis of clearly defined task scenarios in real surfing conditions with keyboard touches recording software and performance testing, perhaps even from a distance through the WWW itself. At the same time, before and after these kinds of tests, it may be useful to develop a typology of map uses and map users on the Internet, perhaps partly based on the map use cube of MacEachren. The ICA Commission on Map Use, of which both authors are members, may play a coordinating role in this.

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FROM THE WORLD ATLAS OF SNOW AND ICE RESOURCES TO GLACIOLOGICAL GIS

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Introduction

The modern development of geocomputer science gives new opportunities for management of huge volumes of the information, saved in all areas of geographical knowledge, including the glaciology. The reality of these opportunities is defined first of all by the fact that the basic tool of geographical researches - the cartographic model - becomes a central figure in structure of geoinformation system.

25 years back we have begun creation of the World Atlas of snow and ice resources. [6]. The work with the Atlas has coincided with wide introduction in a geographical science of the system approach and statistical methods of processing of glaciological data, and then and electronic mapping.

At the moment conducting positions wins automated mapping on the basis of geographical information systems. Purely the geocomputer science was born on a joint of geography, computer science, theory of information systems and cartograrhy. [1]. The automation leads to complete merge of methods of creation and map using, when cartographic models, their transformations, analysis and synthesis will form uniform chains. Glaciology has appeared one of the most prepared for perception modern geoinformation methods.

The world atlas of snow and ice resources as a model of the glasiological GIS

The world atlas of snow and ice resources is a prototype and model of structure of glaciological geoinformation system, cartographic basis for a database of glaciological GIS..

The atlas has precise thematic, spatial and scale structure. In atlas all regions of the earth, connected with glaciosphere are submitted. The glaciological characteristic are interconnected with climatic and orographic data. The atlas allows to see the basic laws, fixed in average long-term meanings of characteristics, determined on 30-year period of the investigations. Such nucleus of cartographic base opens ample opportunities for the analysis of glacio-nival systems at different scale levels, allows to reveal peculiarities of spatial distribution of components and their interrelations, to build the forecasts. The system analysis of a glaciological material, applied during creation of the Atlas, has allowed to allocate levels of mountain glacio-nival systems research and to coordinate them to scales of the Atlas [7].

On definition, given in the Glaciological dictionary [4], the glacio-nival system is a natural system with a conducting role of a snow cover and ice in its material structure and processes, determining development systems and its interaction with an environment.

At the lowest level there are the systems, formed separate glacio-nival objects. They can be considered as independent closed systems, reacting to external influence. The feedback at this level are less essential. Scales of the image of these systems in the Atlas - 1:25 000 - 1:250 000. Here, mainly, series of separate glaciers maps, reflecting their spatial - temporary characteristics are submitted.

The following level - local glacio-nival system, where the interconnected processes occur on rather detached sites of large regions. In the Atlas glacier regions at this level are given in scale 1: 600 000 -1: 1000 000. Glacier systems are displayed by actual data on separate elements of glaciers. These maps give the mass information on a geographical position of glaciers, their configurations, area, morfology, peculiarities of a regime and run-off, about their qualitative interrelations with relief and other glaciers. Scale of these maps is possible to consider finest for the image of the characteristics separate glaciers and largest for display mountain glacier systems. Thus glacier regions almost of all mountain countries of the earth are submitted in the Atlas.

The following level - regional glacio-nival systems, generated in limits of large regions: the whole mountain areas, archipelagoes of polar and subpolar islands. A wide spectrum of the snow-ice phenomena, widespread on extensive territory and in a significant range of heights, is here submitted. All these snow and ice phenomena represent independent systems (glacier, avalanche and etc.). In Atlas this level is submitted by maps of scales from 1:1 500 000 up to 1:3 000 000, sometimes up to 1:7 500 000.

With transition to small scales objects of mapping and ways of their image vary. If on maps of large and average scales, as a rule, separate snow and ice phenomena and actually measured their parameters are represented, with transition to small scales the ideology of glacier systems mapping changes. On the first plan a problem to represent on a map not so much actual data of separate object, but spatial peculiarities in similarity or distinction of the phenomena of one class and scale level. The main way of the cartographic image at this level - isoline one, allowing to use a continuous way of the image to display discrete objects.

The highest level is occupied by global glacio-nival system - glaciosphere, representing the important part of a geographical environment, connected with other by other natural systems direct, but also so by strong feedback. In the Atlas this level is submitted by maps of scales 1:20 000 000 - 1:90 000 000. It is maps, giving representation about borders of distribution of the snow-ice phenomena on the Earth, maps of glaciological regionalization, maps of climatic conditions of glacio-nival systems existence.

This classification has become standard not only in the World Atlas of snow and ice resources, and in glaciological researches in general and is very convenient for creation of glaciological of data bases in geoinformation system.

Summarizing, it is possible to tell, that the World Atlas of snow and-ice resources is a noncomputerised glaciological database , as in it the system approach is used, levels of research are allocated, statistical processing of a material is done, spatial connections between natural processes are designated, glaciological regionalization of the earth is done at different levels of research and, at last, universal scope of the snow-ice phenomena in all regions of the Earth is supplied. Lacks of the Atlas - large format, complex configuration, large density of the information - easy are eliminated in GIS.

Principles of glaciological GIS design

GIS is an automated geographical system for the collection, processing, storage and distribution of new knowledge about the natural phenomena and processes. Any information in this system is adhered to district through system of geographical coordinates. GIS consists of information fund, and programs of data processing of this fund, which provide search, updating and scientific analysis of information.

There are usually four necessary blocks in GIS: 1) data input, 2) storing and search of data, 3) manipulations and analysis of data and 4) output of data [2]. The first and fourth blocks can work independently, they represent in GIS information fund (sometimes primary data) and are qualified as a Databank. Ordered databank together with the programs of processing and search these data (the blocks 1, 2, 4) are a Database. And, at last, all four blocks, the database with the programs of processing and analysis data to get the new information, represent GEOINFORMATION system.

Prime problem of creation GIS is construction of a database (DB), development of its conceptual model, describing objects of researches, their territorial arrangement and interrelations. Just in BD information modeling comes true. The process of data processing in GIS is supplemented by scientific modeling and analysis.

The DB development includes two aspects: content and technological one.

The content aspect of glaciological GIS Database development consists of classification of the initial information in frameworks of the concept and GIS technology, selection of the base information about glacio-nival systems, selection, updating and ordering glaciological and cartographic material (including one used in the Atlas) in view of accepted classification and peculiarity of electronic cartography; determination of hierarchical levels of glacio-nival data, preparation information for input into computer.

The technological aspect includes the following problems: development of a technique for input of the glacier contours and the isoline characteristics at different scale levels; scaling maps in geoinformation space; identification of maps projections form the Atlas for converting the information into international formats.

The classification of a material, connected to conceptual organization of Data base, defines the logic scheme of creation of files, their groups and directories according to chosen attribute: territorial, thematic, scale or any other.

Process of input of the information in GIS, according to logic of the World Atlas of snow and ice resources structure, has to begin with territorial attributes. In a glaciological department of Institute of geography RAS sets of maps on territory of Russia, Caucasus , Pamirs are already entered in the computer. In a database the material can be packed as by territorial, and thematic attribute, and also by levels of research and etc..

To input of the information into glaciolgical Database traditional and specially developed original methods are applied. Simple thematic isoline maps are translated in the electronic form with the help of digitizer.

For input of the cartographic information of a complex configuration a technique, based on technology of interactive translation of the raster image into vector format, is developed. The technique allows effectively to carry out input of the cartographic information of a regional level into an electronic database with the minimum losses of individual glaciers peculiarities.

The cartographic information in GIS is stored as thematic layers of multi-layer Database, that allows to carry out with these layers various arithmetic and logic operations. It, perhaps, main difference between cartographic Database and traditional cartographic product.

Glaciological Database has to be look like the huge meccano and at the finishing stage to represent hierarchical structure, where on vertical axes levels of research (global, regional and local), connected with a scale of the Atlas maps, place, and on horizontal axes there are the separate components of glacio-nival systems, their territorial, spatial, attributes, temporary series, structures, describing interrelations and interaction of these components. Such complex database will form the basis of glaciological monitoring, to provide this monitoring with data and necessary initial parameters.

The development of the logic schemes of Database, creation of files, groups of files and directories for subsections of GIS, i.e. purely geoinformation modeling, should be directed first of all on rational reflection of glaciological data and their interrelations. The catalogue of Database is built by a principle of the library catalogue (with division on thematic and author's). In our case there are as a minimum two catalogues: thematic and regional. Besides mutual relation Database with sources of the information, with process of modeling and with the consumer is very important. Special language of inquiries should allow to make search of the information according to a location (or any other attributes) of spatial elementary characteristics.

Structure of glaciological GIS database

The whole material, entered in Data base, is divided first of all by the form the information, then by levels of research. In cartographic Data base there are, supplementing each other, the following kinds of the information: 1) cartographic, 2) tabular, 3) remote sensing. First kind, as a rule, except the own information, is the base for drawing up other, derivative, maps. Two other kinds of the information are used more often for monitoring of the natural phenomena.
The cartographic information includes both basic maps, and temporary maps. It is possible to divide basic maps into a purely geographical basis of the territory and thematic base. The first includes information about projections, geographical coordinates, information of used scales of the territory, and also digital version of a coastal line, hydrographic and relief features, glacier contours. Thematic data base includes isoline coverages of the average long-term characteristics of glacio-nival systems, entered from the maps of the World Atlas of snow and ice resources.
So, there is the cartographic information of three types in Database : basic maps, thematic maps of the average long-term characteristics and operative maps.
The tabular information includes: data of the glaciers catalogues, information of glaciers fluctuations, data of climatic and hydrologic year-books, snow data banks. Tabular information it is possible to divide by base and operative. The base characteristics are submitted by data of the glaciers catalogues. The operative files of tabular data is constantly increased with hydrometeorological data, results of field researches and etc..
The space-born information concerns to the operative information. It is representing a material for maps of glaciers dynamics and glaciers systems.
In geoinformation environment it is possible to receive any desirable scale of image. The range of scales is defined by concept and kind of generalization. Therefore information in Data base has to be classify more pertinent not by scales, but levels of research.
In the World Atlas of snow and ice resources there are five levels of researches. In Data base it is possible to be limited by three basic levels: global (including continental), regional and local (including middle- and the large-scale maps of glaciers) .As well as in the Atlas, in a Database principles of generalization are very important. With transition to a new level generalization becomes conceptual - there is the transition to the essentially new image: from glaciers - to glaciosystems and further - to glaciosphere. Each new level of research contains the new information about an object.
Local database. The problem of this level of research consists in presenting actual data of glaciological researches. Unfortunately, only few glaciers have a long-term data. Such data (results of glaciological investigations on glaciers, snow data) represent the information of the first order (from the first hands). Less valuable, but more mass information is large-scale topographical maps of region glaciosystems with updated glacier contours. Scale is desirable largest, in a range from 1:25 000 up to 1:200 000. The topographic maps is the basis for design maps of individual, well investigated objects : external glacier mass balance, ice movement and tectonic of ice, change of the sizes and height of a surface, morphological types of glaciers.
The regional database gives the best opportunities for study of laws and interrelations of glacier systems. Almost all natural components at this level are submitted in the Atlas by maps

with a continuous way of the image. It opens ample opportunities for their joint analysis. The geographical basis is represented by typical bases maps of the Atlas in scales 1:1 500 000- 1:3 000 000. The basic information - geographical grid, coastal line, hydrology, relief, glaciers. Thematic information - standard set of the average long-term characteristics of a glacier regime, climate of cold and warm periods, solid precipitation, snow cover and etc., and also maps of glaciological regionalization of territory and storage of snow and ice .The separate coverages gives detailed contours of glaciosystems , and as the additional information - derivative maps.
The global database represents glaciosphere of the Earth. There are two levels in a cartographic database : maps of the world and continents, which generally have illustrative character..

The software or glaciological GIS

This part of GIS consists of two parts: 1) software for input and modeling of the cartographic information and 2) sets of the programs for statistical processing of cartographic materials and further scientific analysis. The basic software - GIS PC ARC\INFO, auxiliary - GIS EPPL7. The named systems are compatible with each other and with the software of the main global natural resources databases. Except ARC\INFO and EPPL7, another formats are available : ASCII, TIFF, DXF, DLG, ERDAS, RASTER, TIGER, MOSS and other. The tabulated information can be given in dBASE format. The original programs are also compatible with ARC\INFO and EPPL7.
ARC\INFO allows to store the cartographic information as thematic layers of a multy-layer database and to carry out with these layers various arithmetic and logic operations. More than 4000 records of the tabulated information can be referred to each spatial point or each spatial element. Special language of inquiries allows to carry out search of the information by a site of various spatial elements. There are the ample opportunities for manipulation and analysis of the cartographic information with the help of the logic overlay software package. The software packages PLOT allow to generate and to give out through plotter or printer initial and derivative maps with legends and other cartographic design. The additional opportunities are given by package TIN, allowing to analyze 3D information (relief) and package ARC\VIEW, giving ample opportunities of demonstration and distribution of cartographic production. There is the opportunity of transfer of data by telecommunication channels: a Fax and E-mail.
For the analysis spatial glacioclimatic and hydrologic characteristics it is useful to construct background surfaces, free from excessive local variability. The original program for IBM PC with the purpose of statistical processing of the spatially distributed information was developed. For each series of isoline maps used an identical grid of control points, from each map meanings of the characteristics are removed and are entered in the computer as a file of regular numbers. Such kind of information is stored in the computer in a textual format. The basic principle, underlying offered of a technique offered an a technique of a sliding window. All statistical accounts are made inside a window, the size of which is set and can accept any meanings, limited on the one hand to meaning in a point, and with other - size of an initial file. For visualization of received numerical files in the program translation of a working format in a format of the standard software package GOLDEN is realized which provides interpolation of regular and irregular numerical files, automatic draw of isoline on the screen of the display and putout maps on the printed device.

The maps of interrelations of the glaciological phenomena are design with the help of maps of one regional series, included in the Atlas, not leaving its limits and without attraction of additional materials..

The purposes and problems of glaciological GIS

The basic purpose of development and creation GIS is organization of system of geoinformation modeling for an estimation of a condition, dynamics and forecast of development of glacio-nival environment at different scale levels. Data base is built, standard methods of analysis are selected and new receptions of the analysis of the glacio-nival information are developed accordingly to this aim.

The main problems, which are solved : revealing of synchronism of glacio-nival components dynamics; study of glacio-nival components reaction on global climatic changes; research of influence of a glacio-nival complex on an environment, research of interrelations between elements of a glacio-nival complex.

First experimental and methodical researches have shown perspective of the scientific geoinformation analysis of glaciological data. In result of processing of maps into a database, statistical maps, describing a condition, change and interrelations of glacio-nival systems components are received: background fields of the characteristics of glacio-nival systems, fields of interrelations ,annual and averaged for different intervals of time fields of glacier fluctuations, maps of anomalies of glacier fluctuations, maps of a positive and negative difference of glaciation and other.

Background maps, on which are submitted the averaged characteristics, free from local variability, allow to see spatial laws of the phenomenon, to reveal similarity of the glacioclimatic characteristics.

Used materials of an International service of fluctuations of glaciers, annual fields of background fluctuations of glaciers on territory of the Alps are constructed [5].

The study of fluctuations of mountain glaciosystems and their reaction to climatic changes with use of a technique of construction of glacier fluctuation fields has enabled to find out synchronism of glaciosystems fluctuations of Caucasus and Alps in 1986-1990 yy. The annual fluctuations occurred with the consent of annual snow store change on these territories, consent with changes of average summer temperatures of air was not observed.

The correlation maps enable to study spatial peculiarities in distribution of interrelations between the characteristics of glaciers systems, to estimate the contribution of the different factors to formation of glaciers systems and conditions of their existence [9]. Drawing up of background correlation maps allows to judge how main laws will be coordinated among themselves, what changes local peculiarities bring in [10]. On the basis of the analysis of correlation maps, glacier regions, the most sensitive to changes of this or that components of environment are revealed, that can form the basis for regionalisation, forecasting and reconstruction [3].

Thus, it is obvious, that basic methods of the glaciological analysis are statistical methods of background surfaces construction, design of correlation maps and maps of anomalies in time, received by addition and subtraction of initial cartographic surfaces.

The first researches have shown necessity of expansion of a circle of glacio-nival regions, researched with this technique, to understand, as spatial peculiarities of structure and interrelations between components of glacio-nival systems differ, how glacio-nival systems reacts to climatic changes in different climatic zones.

All this represents long-term the perspective program, which is supposed to be realized stage by stage. In parallel with experimental and methodical researches, creation of completed geoinformation products is planned which will be the parts of future GIS. The basic directions of realization of the program are planned.

So, the glaciological GIS is the source of accessible for the consumer, the operative information about glacio-nival processes, snow and ice resources and the negative glacio-nival phenomena. In regions, where the glacio-nival complex have influence to human existence and environment, it is impossible to solve problems of regional planning, development of natural resources, an environment protection, without consideration the similar information. The database, representing a set of layers of the thematic information at one scale level, adhered to the same territory, will allow to carry out a complex estimation of those regions, where the natural ice plays a determining role.

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ATLAS OF CAESIUM DEPOSITION ON EUROPE AFTER THE CHERNOBYL ACCIDENT. POSSIBILITIES OF ITS FURTHER DEVELOPMENT

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In the year following a sad celebration of the tenth anniversary of the Chernobyl NPP accident "Atlas of caesium deposition on Europe after the Chernobyl accident" was published in the framework of the program "International collaboration on the consequences of the Chernobyl accident".

The Atlas is devoted to displaying the caesium-137 deposition on Europe, the caesium-137 being the most widespread long-lived artificial radionuclide. Vast areas were contaminated, mainly in Europe. This contamination was laid over the low-level (below 4 kBq/m2) global fallout field, originated from the atmospheric testing of nuclear weapons.

The Chernobyl accident

As a result of a primary thermal accidental explosion at Unit 4 of the CNPP, a radioactive cloud was formed in the atmosphere which when spreading in the prevailed wind direction started the radioactive contamination of the environment.

The subsequent fire of he graphite masonry in the reactor core, maintained by substantial energy released from the on-going decay of radionuclides accumulated during the reactor operating period, resulted in a continuous release of radioactivity into the atmosphere in the form of a plum which changed its original direction in accordance with the wind direction. An intensive release in the form of a plume was observed for about 10 days (till may 6, 1986).

On April 26, 1986 a part of the air mass trajectory, with the Chernobyl NPP as its original point, directed over Belarus and the Baltic states to Finland, Sweden and Norway (most likely it was "explosive" release), while the other part directed over the Ukraine and Poland to Germany, Denmark, Belgium, Netherlands and northern France.

On April 27, 1986 the atmospheric trajectories spread from the CNPP again over Belarus to Scandinavian countries having turned over Kola peninsula eastward. On April 28, 1986 the prevailed conditions were close to still with the prevailed eastward wind. On April 29, 1986 the trajectories were mainly eastward, while on April 30, 1986 they turned over the south towards south-west and west. Thus, the contaminated air began to spread over the entire European part of the USSR and then over most European countries already at first days.

The assessment, measurements and analysis of the radiation situation and radioactive contamination of natural environments in Europe were started since the way first day of the Chernobyl NPP accident and are still in progress.

Caesium radionuclides

Within a few weeks of the accident, when short-lived radionuclides decayed, deposited caesium-134 and caesium-137 became the main sources of exposure of the European population, and caesium-137 will remain so for many decades to come. The overriding importance of caesium-137 in determining the medium and long-term exposure of the population is the reason why the Atlas focuses on the deposition of the nuclide across Europe. The justification of the choice of caesium-137 in the Atlas is becides its long-life and, also, that caesium-137 was deposited in measurable quantites on a large area, due to its volatile nature. These two statements being mainly the reason for the large amount of measurements available throughout Europe.

Since our Atlas is mainly devoted to caesium-137 one should dwell on the importance of two other caesium isotopes: caesium-134 and caesium-136.

Ration of activities A_i of significant radioactive isotopes of caesium in the Chernobyl release to the environment at the moment of the accident were:

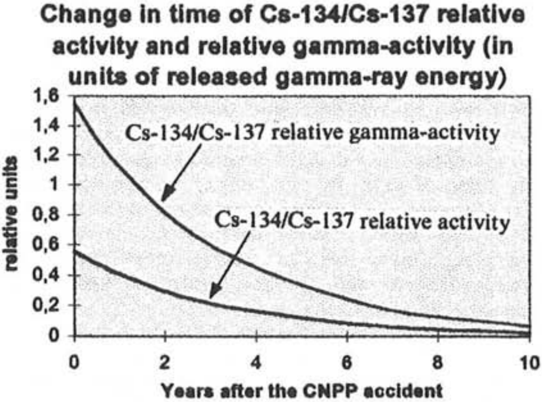
$$A_{137} : A_{136} : A_{134} = 1.0 : 0.28 : 0.56.$$

Each isotope is of a certain importance when assessing the consequences of the Chernobyl catastrophe. If caesium-136 (its half-life is 12.98 days) is important only when assessing the internal exposure via the inhalation path, which explains why one should take account of its air concentrations at the initial time (both peak and integrated for the time the cloud passes by), caesium-134 (a long-lived isotope - 2.06 year) when supplementing caesium-137 is of substantial importance when deposited over the ground surface, since it plays a significant role in the formation both of external and internal exposure dose of the population, with account of possible contamination of water and food-products by this isotope.

Since the energy yield of caesium-134 as a gamma-emitted is rather high (1.55 MeV/decay) and exceeds almost three times the energy release of caesium-137 with a short-lived product of its decay, barium-137 (0.56 MeV/decay) the importance of this radionuclide, after fallout fields are formed, in the formation of the external and internal exposure dose is above that of caesium-137 during the first year after the accident. This circumstance is particularly important for the remote zone where a most part of Europe can be referred to, and where after a fast decay of iodine-131, tellurium-132 with iodine-132, barium-140 with lanthanum-140 and caesium-136 both long-lived isotopes of caesium become main radionuclides forming the dose.

The Figure shows changes in time for the last 10 years after the accident of the caesium-134/caesium-137 activity ratio (the upper curve) which makes it possible, when the map of terrain contamination by caesium-137 is available, to compile the map on terrain contamination by caesium-134 for the same time.

The lower curve gives some notion about a relative importance of both isotopes when a gamma-dose rate is formed after the deposit over the ground surface. It follows from the Figure that for a period longer than 1.5 year caesium-134 contributes much to the total dose rate produced by two isotopes, and even 6.5 years later its contribution makes 20 per cent.



Information on the European countries

The information on radioactive contamination was entered to the database in the form of x, y, z, where x, y are geographical co-ordinates, z is the value of caesium-137 deposition (normalised to 10 May, 1986). For most countries these values and co-ordinates were attributed to the location of soil sampling or in situ measurements. When transmitting information, the time of sampling was indicated as well. Most of the data have been provided by or through national contact points in each country who were responsible for the quality of the data.

For the territories of Belarus and Ukraine, where mass sampling was conducted in settlements, the co-ordinates of the settlement centre were represented, as well as arithmetic mean value calculated from all the samples taken during the decade after the accident. For some settlements the number of sampling points amounted to several hundreds, and the scatter of values showed the peculiarities of the Chernobyl deposition, when levels differed by tens of times over a comparatively small area. It is clear that the mean value for a settlement does not demonstrate deposition field variations within it, however this value is sufficiently reliable and does not contain random errors, as in taking single samples.

The data for Russia were represented in the form of an inverse distance grid (distance between points). The automated processing of the data of air-γ-spectrum surveys combined with those of soil sampling had been already completed in Russia by the beginning of the project on the atlas of Europe The processing of this information and compiling maps on its basis in Russia took several years and represented an important scientific generalisation with validation of the maps, when comparing the data obtained by various methods for a number of areas, specially assigned for such cross-studies. that is why the data bank for Europe received a practically completed map from Russia, on which the data on the eastern Chernobyl pattern were represented with density of 1.3' by latitude x 3' by longitude, and 3' by latitude x 6' by longitude for the remaining part of the European Russia and Ural region.

Geographic information systems and their role in compiling the maps of the Atlas

Mapping of radioactive contamination over vast areas is a comparatively new scientific direction whose particularly intensive development started after the Chernobyl accident, when this type of anthropogenic impact was transformed into a global environmental issue. The period coincided with a period of a great jump in the development of computerised means and information technologies for processing large arrays of spatially oriented data. In this connection the combination of an urgent scientific task of investigation into radioactive contamination and the use of the newest available technical and software means for mapping was inevitable. Dut to the political changes that took place during this time period, more open and flexible scientific collablration between Eastern and Western institutes became possible and data, equipment and scientists could be exchanged.

The Geographic Information System (GIS) that was used in this project is ARC/INFO, version 6.1. ARC/INFO was used because it is probably the most used GIS in the world, which implies that the exchange of information between collaborating groups is relatively straightforward and simple. The bulk of the cartographic detail for virtually all the maps in the Atlas is provided by information contained in the Digital Chart of the World (DCW). The DCW is a global product produced for the US Defence Mapping Agency from aeronautical charts at a scale of 1:1,000,000. The DCW data have been supplemented by additional information from the European Commission's GISCO database (Eurostat 1994) and from the Lowell Johns 1:5,000,000 European Digital Database. Extensive editing and re-coding of these datasets were undertaken in order to satisfy the needs and objectives of the atlas. Some original data capture was performed in order to provide the necessary geographic detail for the larger scale maps.

Initial proofing of the maps were carried out on a computer monitor and on paper plots from colour plotters.

Compiling maps of radioactive contamination in isolines, the inverse distance weighted (IDW) method was preferred due to its ease of use and because it provided a good compromise between calculation speed and quality of the interpolation. The use of more sophisticated tools would, in general, have greatly increased the resources needed with only marginal improvements in the estimated patterns of deposition. A disadvantage of using the IDW method is that using weighting functions may introduce ambiguity if the experimental data are not sufficient. Furthermore, the type of interpolation under consideration is a smoothing procedure, which processes maxima and minima located in measurement points.

During the interpolation procedure the estimated values of the contamination were calculated at regular places structured as a grid. Based on the real sampling density the interpolated values were determined in grid cells 2 x 2 km for countries, and for hot spots maps the grid cells were smaller. In some cases the output from the strict application of this methods was further refined to take account of additional information. This additional information was represented by the data of more detailed investigations which were at the disposal of organisations participating in this project. In practice, such refinement of the output from the application of the methods of interpolation and construction of isolines was limited to the maps of the more contaminated areas of Belarus, Russia and Ukraine. It is in these countries that the density and diversity of measurements were greatest, and within the framework of this project there was no necessity and possibility to process again all these measurements which formed the basis of the national maps of these three most contaminated countries compiled during the decade after the accident.

The formal-mathematical procedure of interpolation and computerised mapping cannot take into account all peculiarities of the environment, which affect the formation of the real contamination field. However, the maps compiled, particularly for territories with high sampling density have a high confidence, since they are based on very precise measurement results.

The maps on the deposition of caesium-137 on the territory of Europe

The essential content of the Atlas, i.e. the maps of caesium-137 deposition on the territory of Europe, are presented in certain sections: European, regional and local. Consideration is given to the situation just prior to and immediately after the Chernobyl accident. Just prior to the accident the deposition was mainly a result of fallout from the testing of nuclear weapons in the atmosphere; these deposits occurred predominantly in the mid 1950s and early 1960s. In a few localised areas, enhanced levels (i.e. enhanced relative to levels typical of global fallout) of deposition existed due to accidents other than Chernobyl and as a result of discharges to the environment from nuclear installations. There are two significant sources in this latter context: firstly, discharges of liquid effluents from the fuel reprocessing plant at Sellafield in the United Kingdom , and the accident that occurred in 1957 at the industrial complex "Mayak" in Russia located east of the Urals, i.e. formally not belonging to Europe.

The spatial distribution of global caesium-137 is illustrated on the maps of the Atlas where the deposition levels are those pertaining just prior to the accident. The quality or reliability of the deposition patterns from global fallout varies considerably over Europe. For the European part of the former Soviet Union the deposition patterns are based on aerial gamma surveys (with flight paths of 50 km separation) carried out in the period 1969 to 1973 (i.e., after atmospheric testing of nuclear weapons had largely ceased). Given quality of these surveys, the resulting deposition patterns can be viewed with high confidence. The global deposition patterns for Western Europe are based on relatively few measurements and, consequently, are associated with much greater uncertainty that those for the European part of the former Soviet Union. UNSCEAR reports contain estimates of the average levels of deposition of fallout nuclides as a function of latitude. For caesium-137, average levels just prior to the Chernobyl accident were about 1.8, 2.4-2.2 kBq/m^2 for latitudes 30-40°N and 50-60° respectively; these are, in general, consistent with the levels depicted in the Atlas.

The deposition pattern of caesium-137 across the whole Europe immediately after the Chernobyl accident are presented in the Atlas. It is one of the achievements of the project. This map like all the maps of this Atlas is based on real measurements in which caesium-137 of global and Chernobyl origin is not separated. Therefore the map represents the total pattern of deposition of this radionuclide. The national maps are used for a fuller appreciation of this aspect.

The enhancement of deposition at distances far removed from the CNPP is best illustrated by the situation in Austria, Finland, Norway, Sweden, the southern Germany, and the Middle Volga region of Russia. In these regions (which are more than 1000 km from Chernobyl) there are significant areas where the deposition levels is greater than 40 kBq/m^2.

Maps have been compiled of the total deposition of caesium-137 for each country of Europe (apart from a few exceptions). Some 21 maps have been prepared with scales ranging from 1:1,000,000 to 1:2,500,000. The highest levels of deposition occurred on the territories of Belarus, Russia and Ukraine (above 555 kBq/m^2). Levels in excess of 40 kBq/m^2 occur in many countries outside the former Soviet Union and, in several of these, the levels exceed 100 kBq/m^2.

Zones of higher deposition in the Atlas denote the territories with levels of caesium-137 deposition in excess of 40 kBq/m^2. Outside these zones the annual mean effective equivalent dose of population exposure does not exceed 1 mSv with a high confidence. This very value of exposure dose which is above the level of the natural and technogenic background is used as the basis for taking countermeasures and introducing privileges for the population in three countries most affected by the Chernobyl NPP accident: Belarus, Russia and Ukraine; the caesium-137 deposition level of 37 kBq/m^2 being accepted for identifying the boundaries of territories within which these states' laws are in force concerning social protection of the citizens suffered the effects of radiation from the Chernobyl NPP accident.

The total radioactive release of caesium-137 which was deposited over the European territory amounted to 15 % or ~ 78 PBq of the total caesium-137 accumulated in the reactor at the time of the accident beginning(~ 40 PBq of this amount was deposited over the former USSR territory) [1].

Possibilities of the further development

Completion of the project of compiling the caesium Atlas on Europe showed a number of aspects to be further developed.

Unfortunately, there are "white spots" on the European map (e.g., Bulgaria, Yugoslavia, Island, New Land in Russia). There are also some countries that presented insufficient data to compile satisfactory maps even of a small scale (e.g., Spain, France). Additional information from these countries could sufficiently improve the scope of the Atlas.

Unfortunately, in the framework of this completed project, we had no financial support to conduct intercalibration of the records across all the countries. In this connection, this Atlas has (in a number of cases) some discrepancies along the frontiers. It would be highly expediently to carry out such work in future, to demonstrate the reliability and trustworthiness of all the maps incorporated in the Atlas.

The Atlas compiled in the framework of the project is presented on the paper basis, i.e. in a traditional form. But at present, when geoinformatic systems are progressing, it would be desirable to compile a digitised version of such an Atlas.

Collecting data on European countries, we made a conclusion that, like the maps on caesium-137 deposition, one could compile the maps on less widespread long-lived radionuclides, e.g. strontium-90, and possibly transuranium elements. A problem of compiling European map on iodine-131 deposition would be of a great interest and importance (iodine -131 is an artificial radionuclide spread as wide as caesium-137, and, however, with a half-life of 8 days).

Using the experience in compiling the atlases and maps on radioactive contamination, it would be possible to make much more voluminous scientific conclusion concerning the spatial distribution of artificial radionuclides, and to make attempts to compile atlases on radioactive contamination of the globe considering and summarising all the global aspects of this new kind of ecological risk.

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COMPLEX MAPPING ON THE BASE OF CAESIUM-137 TERRAIN CONTAMINATION DATA

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For the last decade after the Chernobyl NPP accident two considerable cartographic creatures devoted to radioactive contamination were compiled: Atlas of Radioactive Contamination on European Russia, Belarus and Ukraine (Atlas 1), and Atlas of caesium deposition on Europe after the Chernobyl accident (Atlas 2). Subject maps of the Atlases represent the results of mapping over vast areas contaminated by long-living radionuclides of Chernobyl origin, first of all by caesium-137 - the most widespread one. Comparison of these maps with these ones of another subject-matter enables to make conclusions as to the contamination levels in ecosystems of different range and lands in different countries. However, carrying-out evaluations of such a kind, we should realise it is unlikely that the contamination levels lower than 80 kBk/m^2 on Cs-137 are a real danger for a man and the biosphere. So, the evaluations concerning the territories far distant from the Chernobyl NPP, or the zones affected by the accident relatively negligibly, should not be considered as a demonstration of danger of the land use, or of undesirability for a man to stay in these ecosystems. However, such evaluations are needed when an ecological state of any territory is characterised in general.

An example how to compile the complex maps on the base of radioactive contamination maps are two maps: "Caesium-137 radioactive contamination of the lands in Germany and Poland" and "Caesium-137 radioactive contamination of high range landscapes of Russian plain". Both the maps are combinations of two subject coverages presented on a standard cartographic base. The first map combines the load of the maps of Germany and Poland from Country Section of Atlas 2 and the load of Land use map of Europe (Cartographia, Budapest, 1980). The second map combines the load of View Section maps from Atlas 1 and the load of Landscape Map of the USSR edited by N.S. Gudilin (Moscow, 1989). In order to increase understanding of the summary maps, the outlines of the primary maps were some generalised. The scale of the maps is 1:2 500 000. The characteristic feature of the maps is representation of their legends as matrix tables. Their lines contain information on the type of the landscape, or of the land use, and their columns - on the contamination levels. It the points of intersection of the lines and columns are shown the areas within certain geosystem or land with their contamination levels (in a small range).

Let us present some conclusions made from the analysis of the summary maps.

Tables 1-2 show the legend of the map of the caesium-137 contamination of the lands in Germany and Poland. Figures 1-2 represent the land-use structure in the considered countries on their areas characterised by the contamination levels above 40 kBq/m^2. One can conclude that the most part of arable lands in Germany and Poland belongs to the zone of low contamination (below 10 kBq/m^2 on caesium-137). The levels increase up to 20-40 kBq/m^2 on the lands of the Bavaria Upland and the northern slopes of the Alps (vineyards, alpine grasslands) and Sudetic Mountains (mainly forests); in Poland some relative increase in contamination levels is observed (up to 20 kBq/m^2) in the forests in the east of the country. The contamination levels in these countries do not exceed 100 kBq/m^2.

Table 1.

Caesium-137 contamination levels on the German lands
(state on 10.05.86)

Lands	Cs-137 contaminated areas, thous.sq.km					
	<2 kBq/m^2	2-4 kBq/m^2	4-10 kBq/m^2	10-20 kBq/m^2	20-40 kBq/m^2	>40 kBq/m^2
Arable lands	42.6	74.2	64.1	14.7	3.43	0.11
Pasture lands	11.1	16.1	15.1	5.95	5.72	0.16
Renascent cultural vegetation	1.86	1.89	0.27	0.00	0.06	0.00
Forests	16.5	43.9	28.6	5.06	3.92	0.00
Alpine grasslands	0.00	0.00	0.00	0.26	0.34	0.07
Σ	72.6	136.09	108.07	25.97	13.47	0.34

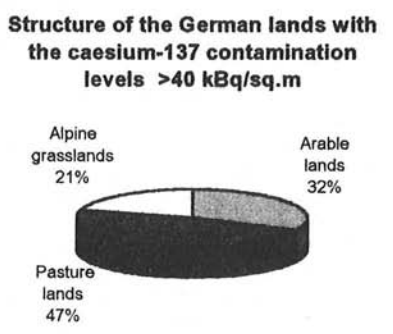


Figure 1

Table 2.

Caesium-137 contamination levels on the Polish lands
(state on 10.05.86)

Lands	Cs-137 contaminated areas, thous.sq.km					
	<2 kBq/m²	2-4 kBq/m²	4-10 kBq/m²	10-20 kBq/m²	20-40 kBq/m²	>40 kBq/m²
Arable lands	48.5	95.2	56.4	5.82	5.51	0.02
Pasture lands	15.5	17.6	13.9	0.71	0.14	0.03
Renascent cultural vegetation	0.00	0.45	0.43	0.00	0.00	0.00
Forests	14.3	24.1	12.4	1.31	0.63	0.05
$\sum$	78.3	137.35	83.13	7.84	6.28	0.10

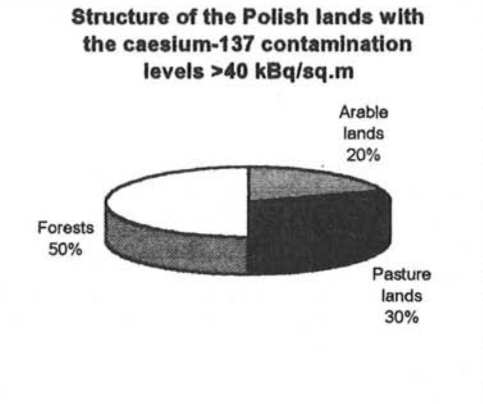
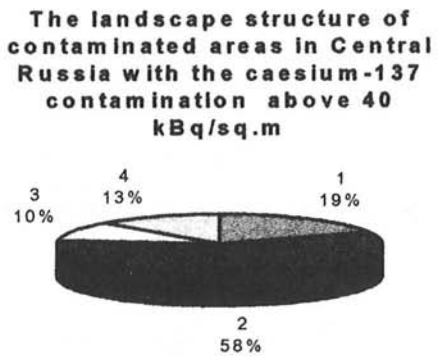


Figure 2

The map of the caesium-137 radioactive contamination of high range landscapes of Russian plain shows that within the eastern Chernobyl pattern in Russia the coniferous forests' geosystems in the zone of fluvial-glacial sedimentation in Polesye are the most contaminated; contamination levels reach 1500-3000 kBq/m² there, and the mean levels vary within the limits of 200-800 kBq/m²; territories characterised by abnormal contamination levels (the mean values are 20-80 kBq/m²) are situated mainly in the forest-steppe zone with relatively fertile soils and general ploughing, the mean contamination levels being relatively increasing by 1,5-2 times in the geosystems of errosional-denudative and accumulative-denudative hills.

Figure 3 was compiled on the base of the legend to the map "Caesium-137 radioactive contamination of high-range landscapes of Russian plain". It shows landscape structure of the contaminated areas of Russian plain with the levels above 40 kBq/m² (57750m²).



1 - accumulative geosystems of the forest zone;
2 - accumulative-denudative geosystems of the forest zone;
3 - accumulative geosystems of the forest-steppe zone;
4 - accumulative-denudative geosystems of the forest-steppe zone;

Figure 3

Dividing the territory within the pattern into accumulative and accumulative-denudative landscapes enables to distinguish certain districts within the pattern according to the influence of natural processes to the secondary re-distribution of the radionuclides. The most considerable re-distribution with time is expected within the limits of the accumulative-denudative landscapes. 1:2,500,000 scale map gives a possibility to distinguish such regions, and to focus on them when studying the influence of the radionuclides' migration to formation of geochemical radionuclide barriers. Namely this map was used to choose the area for radiological investigations supported by INTAS-RFBR grant N 95-0737. The chosen area is located in the intersection of Central Russian Uplands and the eastern Chernobyl pattern where the initial caesium-137 contamination levels are evaluated as 100-550 kBq/m^2. This area is a system of attended landscapes of bulging and wholly ploughed interfluves, and those of balkas (small flat-bottom valleys) under meadow vegetation used as pastures.

The analysis of caesium-137 horizontal migration within a typical drainage area of a balka in the basin of the Lokna-river was carried-out by landscape profiling and statistic processing of gamma-spectrometry data. The balka of typical size was chosen, namely Gusinaya Lapka, with the length of 3 km, and the drainage area of ~10 sq.km. The mean values of the caesium-137 stored on the bottom, on the slopes and nearby interfluves demonstrate insignificant increase in the growth of the levels in the low accumulative land forms (386 kBq/m^2 on the bottom of the balka; 354 kBq/m^2 on its slopes; and 314 kBq/m^2 on the interfluvents. The values of the mean square error σ exceed the variations of the store in the considered geosystems ($\sigma_{bottom} = \pm$ 48 kBq/m^2; $\sigma_{slopes} = \pm$ 81 kBq/m^2; $\sigma_{interfl.} = \pm$ 49 kBq/m^2). It shows that the horizontal migration of the caesium-137 can not be considered as a significant parameter influencing the changes in the structure of the primary contamination field, even in the case when the most intensive erosion processes take place on Russian plain. Relative error δ inherent to registration of the contamination levels within all considered geosystems, is also insignificant. In all the cases it is less than 25 per cent, being the highest on the slopes. It is inherent to the transit zone when soil is washed-off from the interfluves.

In the parallel with he work mentioned above, the analysis of soil sampling was carried-out on abnormally vast watershed of a balka also belonging to the Lokna-river basin. It was Chasovenkov Verkh balka, with the length of 10 km and drainage area of sq. km. The analysis detected hat a decade after the accident the balka's facies are contaminated significantly higher than the interfluves (up to 5 times). The mean value of the caesium-137 contamination of the interfluves is 107 kBq/m^2. The geochemical barrier is located in the boundary between the facies of "the arable land" and "the slope under meadow vegetation" where the contamination level rises up to 420 kBq/m^2. The levels also increase on the accumulative facies of the balka's bottom (up to 550 kBq/m^2) where there were no erosion wash-off during the last decade. Calculation of the deposition balance showed that about 93 per cent of the soil washed-off from the ploughed interfluves are accumulated in the balka's facies.

Studying the features of the erosion-accumulative process detects variations of the contamination levels within the spots marked on the middle- and small-scale maps. The re-distribution of the radionuclides within the considered geosystems for the last decade can lead to irregularity in the contamination field differing from the primary one. However, the secondary contamination spots are evaluated by the size not exceeding some dozens square metres. It can not be reflected in the middle- and small scales.

Users of the small-scale maps of the radioactive contamination should realise that the contamination levels within accumulative- denudative landscapes characterised by intensive wash-off and deposition of the material, can be shown as an even field on the middle-scale map. However, in reality the contamination levels can vary within the limits of 25 percent and above in the attended landscapes.

ATLAS OF RADIOACTIVE CONTAMINATION OF EUROPEAN RUSSIA, BELARUS AND UKRAINE. POSSIBILITIES OF ITS USE AND PERSPECTIVES OF DEVELOPMENT

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On April 26, 1986 a major accident took place at the Chernobyl Nuclear Power Plant (CNPP) followed by partial destruction of Unit 4 reactor, and significant release of radioactivity into the natural environment. The magnitude of the release far exceeded that of previous accidents at reactors in Windscale (Great Britain) and Three Mile Island (USA).

The accident was accompanied with a thermal (non-nuclear) explosion, when a fraction of radioactive products accumulated in the reactor for three years was released into the atmosphere in the form particulates of various size. After the explosion the fire of the graphite masonry began, resulted in long-term release of volatile radioactive products. The intensive release in the form of a plume was observed till May 6, 1986.

Radioactive products from the radioactive cloud formed during the accident and later from the plume, were deposited over the terrain - particulates of the destroyed reactor and graphite were deposited near the CNPP, small particles - at substantial distances. Volatile products such as iodine-131 (half-life time of 8 days), tellurium-132 (3,2 days), and long-lived caesium-134 (2,06 years) and caesium-137 (30,1 years) were transported over some hundreds and thousands kilometres from the point of explosion in accordance with wind direction during two weeks and later after the accident.

It was already in the first days after the accident that ground-based measurements and air-γ-surveys of the contamination were started on the territory of the USSR. Over the whole territory of the USSR a ground-based network of stations under "Goskomhydromet" was in operating and represented information (some thousand stations). In the parallel with these observations, wide-scale soil sampling was carried-out on the contaminated areas, with subsequent laboratory analysis of the samples using methods of γ-spectrometry and radochemistry. Combine with the air-γ-spectrum survey data, it enabled to compile a data base for the further mapping of the terrain contamination.

On the base of the results of the radioactivity measurements it was determined that volatile fission products (tellurium-132 and iodine-131) were deposited in the close-in zone (up to 80 km far from the CNPP) amounted to about 5 per cent of those accumulated in the reactor; refractory products - about 1 per cent, and caesium-137 - about 2 per cent.

The total radioactive release recorded over the territory of the whole Europe, amounted about 4 per cent of the total activity accumulated in the reactor (on energy release), and about 25 per cent, or 2,1-2,2 MCi on caesium-137 (1,1-1,2, MCi being deposited over the European territory of the USSR).

It was also determined that the maximum dose exposure was stipulated by iodine-131 during the initial period, and during the next, longer periods it was stipulated by caesium-137 and caesium-134 over vast territories outside the evacuation zone. For the period from 1 to 50 years on the patterns of different directions the external exposure dose-rate from caesium-137 will be equal to 70-90 per cent of the dose from the total amount of the radionuclides deposited over the terrain.

Goals, objectives, and structure of the Atlas

The radioactive terrain contamination resulted from the Chernobyl accident fro the initial period of time was largely stipulated by the release of short-lived radionuclides. Later their radiological significance decreased. One year after the accident the radiation situation over the most part of the European territory of the USSR was stipulated by long-lived caesium isotopes - ^{137}Cs and ^{134}Cs, and three years after the accident - by ^{137}Cs. In approximately 60-km zone around the CNPP, in addition to the caesium radionuclides, fission fragment radionuclides (^{90}Sr, ^{95}Zr, ^{95}Nb, ^{106}Ru, ^{144}Ce), and transuranium ones (^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{241}Am, ^{242}Cm, ^{244}Cm) were registered on the soil samples.

Thus, the main goal of the Atlas is to carry-out scientific systematisation of unique data on the terrain contamination by long-lived radionuclides of the Chernobyl origin; much attention is to be paid to caesium-137 , the most widespread radionuclide.

The Atlas will promote the solution of the following problems:

1. To provide a basis for developing national economy on the contaminated areas including the developing of principally new basis of the land-use;

2. To provide a basis for applying the law of the Russian Federation "On social protection of the population against the radiological consequences of the Chernobyl NPP accident", as to information on the zones contaminated by radioactive caesium-137;

3. To provide data to compile geoinformatic data bases including information on the radioactive contamination;

4. To obtain data to carry-out evaluations of the influence of the radioactive contamination to a man, living organisms, and ecosystems;

5. To acquaint the general public, mass media, governmental and municipal bodies with an objective picture of the radioactive contamination of the territories of Russia, Belarus and Ukraine resulted from the Chernobyl accident.

The Atlas incorporates 145 pages (A3 format) with 100 maps and supplementary texts. As to its structure, the Atlas is divided into 5 main sections: overview small-scale maps on the radioactive contamination over the European territory of the former USSR; medium-scale maps on the radioactive contamination in the CNPP close-in zone; ^{137}Cs contamination maps over administrative districts and republics of Russia where the contamination levels are above 1 Ci/km^2 (>37 kBq/m^2) were observed; medium-scale maps of "hot" and "very hot" zones within the territories of administrative districts and republics of Russia; reference and information. Each next section decodes and supplements the previous one.

The techniques and management of the terrain contamination surveys after the Chernobyl NPP accident

γ-spectrometer mounted aboard a helicopter makes it possible to rich high productivity and representation of the results of measurements. Besides the spectrometer, computer technique is mounted aboard the helicopter to process spectra quickly and to compile a data base; altimeter is mounted to correct the degree of absorption of the soil radiation in the air layer under the helicopter; navigation apparatus is used "to set" the obtained results on the map. The results of the measurements include γ-quantum number in the gamma-spectrometer channels per unit time, and the altitude of the flight.

Detector of the air-γ-spectrometer records soil radiation within the belt along the trajectory of the flight, the width of the belt is approximately 3 times the height of the flight. It is very useful for compiling the maps, because the results of the surveys generalise the store of the contaminating radionuclides, and the natural radioactive elements content.

Over routes distances (for the air-γ-spectrum survey) were stipulated by expected levels of the radioactive contamination: above 500 kBq/m^2 on ^{137}Cs - 0,5 km (scale of the survey is 1:500,000), 20-500 kBq/m^2 - 2 km (scale of 1:200,000); below 20 kBq/m^2 - 10 km (1:1,000,000). The elementary routes providing integral measurements of the γ-radiation spectra, were 0,1; 0,4 and 2,0 km correspondingly.

The flight altitude should be as low as possible. The maximum possible altitude (100-150 m) corresponds to the weakening of the non-dissipated ^{137}Cs radiation flux by 10 times, as compared with the height of 1 m.

The vertical distribution of the γ-radiation intensity depends on the degree of the deepening of the radionuclide into the soil. So, to calculate the radionuclide content on the base of the radiation intensity, measured at the altitude of the flight, one should possess the data on the deepening into the soil. They can be obtained by ground-based soil sampling (on the layers). Another way to take into account the deepening of the radionuclides into the soil is the following: to detect the character of deformations of the γ-radiation energetic composition over the territory of the surveys. In particular, it is the ratio between the intensity of direct (non-dissipated) γ-radiation from caesium-137 with the energy of 0,66 MeV, and the dose-rate of the γ-radiation originated from it.

Air-γ-spectrum survey was carried-out over certain administrative districts, and was accompanied with soil sampling. Special ground-based sampling supporting the air-γ-spectrum survey, was conducted in some thousand points. Besides, to compile the maps, the results of the analysis of dozens thousand soil samples from settlements were used. As a rule, relative mean square errors in the values of ^{137}Cs contamination obtained on the base of the air-γ-spectrum and ground-based data, did not exceed 40 per cent, being about 20-25 per cent. Systematic errors were taken into consideration when the maps were compiled.

The radioactive contamination survey over the European part of the former USSR was conducted by Institute of global climate and ecology, methodically and organisationally supported by certain institutions under Mingeo of the USSR and Goskomhydtomet (later - Geolkom of the RF and Roshydromet). 10 helicopters equipped with γ-spectrometry apparatus were used. 11-channel γ-spectrometry stations of Mingeo of the USSR, multi-channel complexes of Canadian company "Makfar", and experemental multichannel spectrometers of the institutes belonging to hydrological and meteorological service, were used. Energetic resolution of scintillation detectors used with the multichannel amplitude analyser, was 8-9 per cent, and in few-channel spectrometers it was 12-13 per cent.

The results of the air-born surveys after their initial processing were presented in the form of tables showing the values of ^{137}Cs stored, ^{134}Cs stored, the natural radionuclides content in the soil (U, Th, K) over the elementary routes. Each series of the measurements was accompanied with rectangular co-ordinates of the centres of the elementary routes.

Let us present some data on the soil sampling techniques. To obtain representative results, the sampling point is to be located not nearer than 20 m from roads, trees, buildings, and other obstacles. It is desirable to conduct soil sampling on the interfluve area under natural vegetation (meadow), where wash-off and erosion do not take place.

Conducting soil sampling in the settlements, one should choose such a site where there are no influence of the wastes from roofs, sewerage systems, the soil cover is not disturbed by construction works, etc. After 1987 the depth of the soil sampling was not less than 10 cm. About 15 per cent of the samples were taken by the layers: 0-1, 1-2, 2-3, 3-5, 5-10, and 10-15 cm. During the processing each soil sample was weighted and carefully mixed. The radioactivity measurements of the soil samples (on ^{137}Cs content) are carried-out using laboratory methods of γ-spectrometry with semiconductor and scintillation detectors. The content of ^{90}Sr and transuranium radionuclides is measured using radio-chemical methods α- and β-spectrometry.

Compiling the maps on ^{137}Cs terrain contamination

The process of compiling the maps on ^{137}Cs terrain contamination of different scales was developed from the methodical point of view during the investigations of the radiation situation after the CNPP accident. Compilation of the maps is based on information of two kinds: obtained with the help of air-γ-spectrum surveys; and obtained by γ-spectrometry of the soil samples. Both the information blocks are considered to be equal as to their significance to obtain a map which is to be compiled as a summary one.

Compiling the summary maps on ^{137}Cs terrain contamination includes the following steps:

1. Comparison of air-born and ground-based data, accompanied with estimation of systematic and random errors;
2. Deleting the errors. Systematic errors are to be deleted by introducing corrections to the automated process of compiling the isolines; random errors - by expert correction of the isolines obtained on the base of air-born surveys at the soil sampling points;
3. Automated compiling the isolines taking into account the primary data analysis, and plotting the maps in isolines;
4. Combination of the terrain contamination field (in isolines) with topographic and cartographic bases.

It was assumed to use the results of the air-γ-spectrum surveys to compile the maps of the atlas at scales not larger that the scale of the survey. So, the maximum permitted scattering of the point data did not exceed 1 cm on the map.

To compile the maps at smaller scales than the scale of the investigations, these information can be surplus. In this case the generalisation of values was conducted. They can be averaged along the survey route, or over certain area covered by the survey, using weight functions. In this case, an expert had to be involved in the process of automated mapping to estimate the quality and permissibility of the formal mathematical operation of the averaging.

The maps of the Atlas were compiled as a result of processing of vast data sets obtained by air-γ-spectrum surveys, and numerous results of the analysis of soil samples. On the base of these data were obtained the maps on terrain contamination with ^{137}Cs, the main long-lived dose-forming radionuclide, the most widespread as a result of the CNPP accident. The range of the mapped contamination levels extends from the background ones, formed as a result of atmospheric nuclear tests, mainly in the 60s-70s, and characterised by the amounts of about 4 kBq/m^2, to the highest ones in the close-in zone of the CNPP, reaching 18500 kBq/m^2.

Software support to compile the terrain contamination maps

The system of automated compiling the maps on radioactive contamination includes two complexes of the software: to analyse the initial information, and to compile the isolines.

As a result of wide-scale works in the framework of radiation monitoring over the vast areas, a data set was formed at Institute of global climate and ecology. It includes the results of air-γ-spectrum surveys and ground-based control soil sampling.

The results of the air-γ-spectrum surveys are presented as data sets of the values of certain variable (^{137}Cs, ^{134}Cs, U, Th, K) at the grid points of a regular rectangular grid. The soil sampling data are presented as a set of geographic co-ordinates of the soil sampling points, with the value of the ^{137}Cs (and the other measured radionuclides content in the sample).

The software complex enables to apply the following operations:

1. To compile maps in isolines on the base of the initial data presented both as regular data set, and as chaotically located points.
2. To generate digital model as grid, if the initial data are presented in isolines.
3. To carry-out the analysis of air-γ-spectrum surveys data and the soil sampling ones: to compare the values of these two data sets, to calculate random and systematic divergence between the values of these data sets; if necessary - to make automated corrections in one of the data sets.
4. To correct isolines on the base of the soil sampling data; to ensure coincidence of the isolines on the boundaries of two map sheets (in mapedit).
5. To check the maps using monitor, printer, plotter, and also to export the maps into vector (dfx-) and dot-matrix (pcx-) formats for using and processing by the other geoinformatic programmes.

Namely these operations were used to compile the maps on the radioactivity.

Caesium-137 contamination over European Russia

Section of the Atlas "Radioactive contamination of the territories of the subjects of Russia with levels above 37 kBq/m^2 on caesium-137" incorporates maps detailing the map on ^{137}Cs contamination presented in Section 1 ("Summarised small-scale maps"). According to the law of the Russian federation "On social protection of the population against the radiological consequences of the Chernobyl NPP accident", the isoline of 37 kBq/m^2 is the low threshold to introduce privileges for the population. The maps are compiled in 1:1,000,000 scale that enables to present the territories of the pointed districts and republics of Russia in convenient table variant, by a way giving a possibility for user to detect the main settlements and other objects within the limits of the highly contaminated zones (above 37 kBq/m^2) with privileges for the population. It also enables to distinguish the regions with low contamination levels, or practically not damaged by the contamination resulted from the CNPP accident. The isolines of the terrain contamination density below 37 kBq/m^2 are presented on the maps for this purpose. The territories with contamination levels above 37 kBq/m^2 on ^{137}Cs are called in our Atlas the zones of high contamination. This section presents the maps on ^{137}Cs contamination at a scale of 1:500 000, showing the zones with levels above 37 kBq/m^2, and neighbouring territories within the limits of each subject of the RF. The analysis of the maps shows that the areas in European Russia, contaminated by ^{137}Cs as a result of the Chernobyl accident, are the following: 310 km^2 with he levels above 1480 kBq/m^2, 1900 km^2 with the levels from 555 to 1480 kBq/m^2, 5326 km^2 with the levels from 185 to 555 kBq/m^2, 49509 km^2 with the levels from 37 to 185 kBq/m^2.

Maps on the caesium-137 gamma-dose rates

Calculated maps on the ^{137}Cs γ-dose rates at the height of 1 m were compiled taking into account the weakening of ^{137}Cs γ-radiation in different degree by its deepening into the soil. Conducting the calculations, the authors took into consideration the landscape structure of the areas, location of arable lands and parameters, approximating the ^{137}Cs distribution with depth in the soils of different landscapes. Namely so the γ-dose rate maps do not repeat the maps on ^{137}Cs contamination. Outlines of the spots resemble each other in some degree. On some maps the dose-rate isolines outdrow long landscapes of river vallies under natural vegetation, easily detected on the background of the wholy ploughed interfluves; or otherwise, large forest massives on the interfluves on the background of vallies used for agricultural purposes, and accumulative land forms. As a result, the variability of the isolines on the γ-dose rates maps is higher than this one on the maps on ^{137}Cs, because it depends on the landscape structure of the territory, and land-use structure in a greater degree.

Direct measurements of the ^{137}Cs γ-dose rate are not possible, because dose-measuring equipment is not selective, which presents the results of measurements as a sum of γ-radiation both from ^{137}Cs, and natural radionuclides dissipated in the soil and in the earth crust.

The dose-rate field over the soil contaminated by radionuclide depends on the amount of the radionuclide stored, its vertical distribution, and micro-relief of the territory. Coefficients were obtained by the method of numerical integration to compile calculated maps on the dose-rates taking into account the deepening of caesium-137. Dose-rates were integrated, resulted from radiation from thin layers of soil at varying depth, containing ^{137}Cs store according to accepted model of deepening (exponential model for natural landscapes, and even one for arable lands). The maps were compiled with the help of the matrix algebra rules, on the base of grids of ^{137}Cs conamination data.

Analysing the maps, one can conclude that over vast territories of Russia caesium-137 does not from dose-rates exceeding 10 nSv/h, and within the spots characterised by the levels of 40-80 kBq/m^2 - not more than 200 nSv/h. It does not result in the exceeding the external radiation dose of 1 mSv/year permissible in Russia.

Terrain contamination in the close-in zone of the Chernobyl NPP

The Chernobyl accident lead to the release of long-lived radionuclides to the atmosphere; their deposition resulted in origination of an anomaly with certain unique radionuclide composition in the close-in zone.

Just after the accident a series of urgent measures was undertaken to record the radioactive contamination of the atmosphere and the territory; and later complex investigations were carried-out to study the radioactivity in all the natural environments.

The first complete map of the close-in zone (at a distance of 100 km from the explosion point) was compiled on May 1, and presented to the Governmental Commission on May 2, just after getting a possibility to distinguish γ-radiation from the plume, and this from terrain contamination, rather reliably (although the contamination field was not completely formed, especially its southern part).

Gamma-field map was compiled on the state on May 10, 1986. Namely this map became a basis to make many decidions. The boundaries of the evacuation zone (radiation level above 5 mR/h), the zone of estrangement (above 20 mR/h), and the zone of strict control (above 3, but less than 5 mR/h) were fixed on the base of this map.

To carry-out detailed studies and long-term observations the changes in structure and composition of the CNPP close-zone anomalies, a system of radiation monitoring was established in 1986. Its basis is a network of permanent observations in the zone around the CNPP with the observation points are marked along 36 radii (each 10 degree) at the following distances from the center of unit 4 of the CNPP: 1; 2; 3; 4; 5; 6; 7; 8.3; 10; 12; 14.5; 17; 20; 25; 30; 37.5; 45; 52.5; 60 km.

A lot of information was obtained on the close-in zone by 1990. First of all, it is the permanent observations network data set, where soil sampling was conducted twice a year. The results of the analysis were normalised to May and January of each year, correspondingly. Five separate samples were taken near each registration point as "an envelope". However, the maps compiled only on the base of these data, are not wholy satisfactory, because the distances between the registrations remain uninvestigated, and interpolation of data on these distances is not always reliable because of high variability of the radioactive contamination field in the close-in zone. Namely so, the air-γ-spectrum survey data are of great importance for exact mapping of the CNPP close-in zone. The air-γ-spectrum survey was carried-out in the CNPP 30-km zone by Production State Entreprise "Aerogeologia" under the Mingeo of the USSR at a scale of 1:100,000, and in the 60-km zone - at scales of 1:10,000-1:50,000. Such surveys gave a possibility to fix the variability of the radioactive contamination field in the close-in zone with high detailing; soil sampling data on the permanent observation network and in the settlements being a good base to control calibration of γ-spectrum apparatus. The measurment error did not exceed 30 per cent on the results of comparison of the sampling data and the air-γ-spectrum surveys one. The maps on ^{137}Cs, ^{134}Cs, ^{144}Ce, ^{106}Ru contamination in the CNPP close-in zone were compiled as a result of summarizing the soil sampling data and these of air-γ-spectrum surveys.

The map of ^{90}Sr terrain contamination was compled only on the base of soil sampling data on the permanent observation network and in the settlements, with further radiochemical analysis of the samples. Besides, compiling the map, the data of special pattern which was appeared to be relatively rich in ^{90}Sr and transuranium radionuclides, and poor in the caesium-radionuclides. In the meanwhile, the south-western pattern on the settlement Polesskoye is practically absent on the ^{90}Sr map, while it is clearly detected on the ^{137}Cs map.

Maps on the terrain contamination by transuranium radionuclides

These maps on ^{238}Pu-238, $^{239+240}Pu$, ^{241}Am and ^{244}Cm contamination were compiled on the base of radiological analysis of the soil samples obtained on the permanent observations network. Compiling the map, the 1987 data of air-γ-spectrum survey on ^{144}Ce were used to fix all the significant spots in the space between the radii of the network and between the permanent observation points (it was necessary to take into consideration high variability of the radioactive contamination field, mentioned by mapping of the other radionuclides deposition). Because of similar physical and chemical properties of all the transuranium radionuclids, the structures of their deposition fields are similar to each other, and they differ only as to their absolute values of the terrain contamination density. We would like to draw your attention to a special role of americium-241 in the formation of alpha-active terrain contamination. It is fission product of plutonium-241, and its amount will increase with time in the deposition structure. 50-70 years later it will be more than 6 times its initial activity, and the total activity of three alpha-radiating radionuclides (^{238}Pu, ^{239}Pu, and ^{240}Pu) - more than two times.

Using of the Atlas

The maps of the Atlas and supplementary texts are addressed to educated users realising real danger of radioactive contamination of different levels. Small scale maps presented in View Section (1:2,500,000 - 1:10,000,000) are addressed to scientists investigating the contamination fields features, applying the methods of spatial analysis and developing the models of consequences of hypothetical accidents. the maps can also be used for educational purposes in ecological courses in higher educational institutions. The medium-scale maps are addressed to scientists investigating migration of the radionuclides, including this one in food chains. These maps are a base to calculate radiation burdens to population and ecosystems. These maps will by widely used by administrative, planning and social protection bodies of different levels. At the same time, the Atlas acquaints the general public with an objective picture of the present contamination. Some of its texts are of popular, explanatory character.

Perspectives of further development

The perspectives of further development of the presented cartographic creature are: to compile a digitised Atlas on the base of the existing one giving a possibility to recalculate any map to the time chosen by the user, taking into account radioactive decay and migration of the radionuclides; the digitised version of the Atlas will assume the possibility to calculate external dose rates of the population in any settlement and in any time; registration and systematisation of the information on radioactive contamination in Siberia and the Far East, i.e. the extension of the area to be mapped; data on radioactive contamination in the regions of Transurals will lead to compiling the maps of the consequences of the Kyshtym accidents and incidents, the Totsk exercises, nuclear explosions in the New Land and Semipalatinsk proving grounds, as well as the consequences of the activities of a number of military and atomic industry plants.

THE APPLICATION OF A NEW METAPHOR SET TO DEPICT GEOGRAPHIC INFORMATION AND ASSOCIATIONS

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Abstract

The most popular method for the depiction of the attributes which combine to present a picture of reality is the use of the map metaphor. The map metaphor design remains almost unchanged from that developed for topographic maps and their use by eighteenth century generals and nineteenth century engineers. Whilst still an effective means for the portrayal of geographic information, the map metaphor can be enhanced using other metaphors, which can be readily delivered using contemporary technology and communications. The author has investigated the use of a suite of metaphors that complement the map metaphor, developed a prototype multimedia mapping product that embraces them and has tested the effectiveness of this hybrid product. The product was developed using Director and written to CD-ROM The metaphors developed were given the names of The Storyteller; The Navigator; The Guide; The Sage; The Data Store; The Fact Book; The Gameplayer; The Theatre; and The Toolbox. The Storyteller metaphor is used to provide a rich, simulated environment. This paper outlines the concept of the on-line Map Shop and the GeoExploratorium and describes the hardware and software used to develop a prototype product for evaluation.

Introduction

Users of geographic information resources are usually adequately provided with paper and electronic mapping artifacts with which to plan and undertake tasks that demand that they have an understanding of the area they are working with or the terrain they will travel through. Suppose a traveller was planning a trip to a city they had never been to before. If they wanted to be attuned to that city, to know how to get there and back, to have a reasonable knowledge about how the city developed and how it 'worked', to be able to find their way around once they'd arrived and be able to navigate to different areas of the city, as well as finding a hotel and knowing what to tip the doorman and the bellboy they would need to assemble a wide range of resources to become a 'literate traveller'.

Traditionally, the user would assemble a wide range of paper and digitally-derived maps and travel guides to help the trip go smoother. But, nowadays, with access to wide-ranging information sources, maps and their complementary partners from various publishing houses, all of which are able to be enhanced by accessing on-line information, the traveller can be armed with tools for voyage planning before setting a foot outdoors. The provision of information that has currency and credibility is now a matter of how far a user really wants to go and the money they are willing to expend. But the way in which the user 'learns' about geographical space is limited to the use of information resources that are generally provided via the traditional map metaphor. If methods and means were developed to enable the user to 'experience' geography in other ways and through other methods, in association with, or by completely excluding (in some cases) the use of maps, a better 'picture' of geographic reality could be assembled and experienced.

This paper proposes a metaphor set that could be used as the basis to construct a 'GeoExploratorium' that would provide resources, both discrete and on-line, and would offer the means for users to explore geographical information in ways that they feel most comfortable with and which impart the 'best' image of their particular (geographical) area of interest. The GeoExploratorium would work co-operatively with an on-line 'Map Shop' that would be provisioned with artifacts for geographic exploration and discovery. These concepts, and the metaphor set that provides the basis for developing the GeoExploratorium, are discussed in the paper as well as the methods used to develop a prototype.

The On-line Map Shop

Imagine yourself in a Map Shop. In the drawers and on the racks are maps of places and countries throughout the world. They range from general interest map, to tourist map to road map. It seems as if almost every map that was ever produced is there. But there is also atlases, globes, city plans, political. This fictional Map Shop would be an ideal place for prospective travellers to gain access to a wide range of geographical information resources before actually beginning their journey. They could select the combination of artifacts that best provides their preferred tools for preparing for a personal voyage of 'geographic discovery'.

Now imagine that the walls of the Map Shop were removed and that resources beyond the physical room were made available. By making the map room accessible through the use of electronic digital communications it no longer has to be the repository of geographic discovery tools that is frozen in time. Links to other map collections, databases, film archives, news services, map publishers and related information providers expands the scope of the Map Shop well beyond the limitations imposed by the physical presence of walls and existing resources, to one that can act as both a storehouse of geographic information within and a link to useful resources without.

Links could be provided to update discrete resources available in the map room like map collections and atlases on CD-ROM, to show other paper maps of the same series or complementary series that exist in other map rooms, map collections, or those that can be purchased from commercial and government mapping agencies. Connections to databases at numerous national geographic information providers can give links to digital map files and databases. Map and guide publishing houses could allow access to updates of their maps and directories to expand and make more current their printed publications between issues. Access to book publishers' databases and the tools to conduct Boolean searches on books in print would enable users to find travel stories, biographies, historical novels and factual accounts of adventures that are directly related to the parts of the world about which information is being sought. Geographically-related games like *SimCity 2000,* that would normally only be made available for individual gameplay, could be used by connected players and made more relevant when other players, from anywhere in the world, could participate.

This Map Shop could also provide tips for the intrepid traveller by providing publications and 'marked-up maps' that had been used previously by other customers in the shop. Some of the products could physically reside in the Map Shop, whilst others could be provided through on-line connections. Email would be an ideal communication medium for establishing links between expert travellers and naivé first-timers. Willing experienced voyagers could make their services available (even for a fee) to give insightful information about places that they are most familiar with or about thematic aspects of certain areas about which they have expert knowledge.

The expanded Map Shop would need to be manned with a curator to provide advice and guidance about finding the most appropriate resources and to generally assist to ensure that these products and resources are used in the most beneficial manner. The curator can reside physically or be available on-line. The curator would be an invaluable component of the Map Shop.

GeoExploratorium

Metaphor models form a pivotal link between learning and memory through the abstraction of relevant properties of a situation into a simplified and convenient forms. In so doing they are usually dynamic and their development is effected by situational factors. Users interact with artifacts and then form mental models. Therefore interface metaphors attempt to map knowledge already held by a user group to a normal problem area (Smyth and Knott, 1994).

Many of the components of the on-line Map Shop would be uplicated in the GeoExploratorium, but they would be able to be used in combination with the metaphors provided within the GeoExploratorium. The concept of the GeoExploratorium can be viewed in a similar way to the Geographer's Desktop (Egenhofer and Richards, 1993) and the prototype developed is not unlike the Covent Garden Hypermap (Parsons, 1992), but it does differ in the use of a different metaphor set and the links to external resources that provide 'reality links' (Cartwright, forthcoming).

As well as providing access to multimedia and hypermedia and interactive maps, the GeoExploratorium would also provide links to other 'world wise' resources. These links to reality are illustrated in Figure 1.

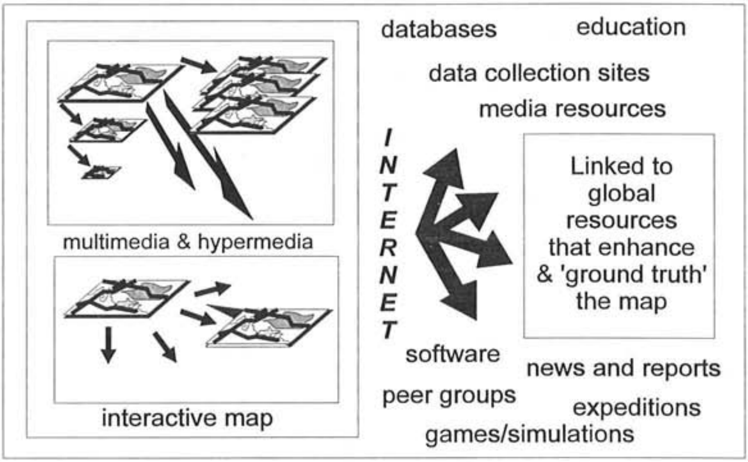

Figure 1. Links to reality. By providing links (via the Internet and the Web) the GeoExploratorium empowers users to access timely and appropriate geographic information 'support' resources. Knowledge is also available using connections to peer groups and on-going expeditions and surveys.

What is proposed is the development of a GeoExploratorium, a virtual space that would enable users of the Map Shop to be able to explore geographic information using different metaphors. This concept is shown in Figure 2.

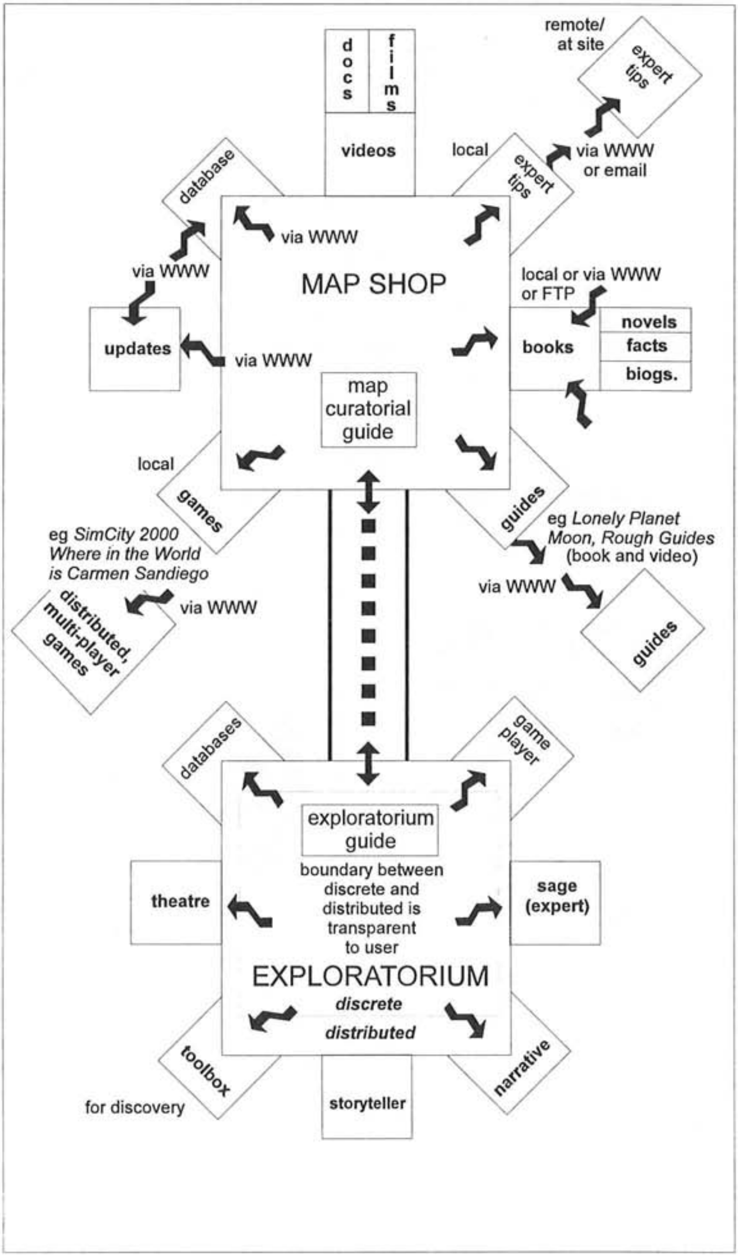

Figure 2. The Map Shop and GeoExploratorium - both an enclosed and an open spatial information virtual 'space', linked to databases and resources.

An 'Exploratorium Guide' would assist users in selecting the appropriate metaphors to use and find appropriate information through links to distributed resources. When using the World wide Web for resource access, this Guide could be called an Agent. The Guide would liaise with the Map Shop Curator to ensure that the user obtained the required or ideal mixtures of resources from both the Map Shop (discrete and on-line resources) and the GeoExploratorium.

Metaphors

A metaphor set has been developed to extend the concept of the Map Shop and to link it to the GeoExploratorium, that provides complementary ways to understand and comprehend geographic information using multimedia. The metaphors were originally conceived and developed with discrete multimedia products as 'targets', but the concept can be extended to distributed multimedia, as is outlined later in the paper. The metaphor set includes the Storyteller, the Navigator, the Guide, the Sage, the Data Store, The Fact Book, the Gameplayer, the Theatre and the Toolbox. It is argued that the combination of these metaphors, when used with the map metaphor would provide the means to deliver the contents of the Map Shop using multimedia mapping packages.

The Navigator provides the means by which the user can experience the story from their own perspective and to 'own' the unique version of the story they construct. Navigation can enhance the way in which a user moves through an 'information space'. The Guide metaphor enables users to be 'led' to where particular types of data sets and resources are located. The Sage provides access to the expert who, when providing information, draws upon extensive experience during re-telling or informing and takes a 'story' beyond mere description by providing authority. The Data Store makes available large amounts of support data that can be used to complement the main mapping package. The Fact Book links to collections of 'facts' available as CD-ROM publications and on-line services. The Gameplayer can be used as a means of allowing the user/viewer/participant to discover patterns of phenomena which are meaningful for each individual user. The Theatre metaphor involves functionality and thus allows the user to be engaged/pleased with the experience of being immersed in the data 'scene'. The Toolbox provides the means for users to furnish themselves with appropriate tools of discovery and learning.

Development of a prototype

The prototype development process began with the capture of resources using audio digitising equipment, a digital camera, a video camera and a scanner.

Authoring was then undertaken using a proprietary authoring package, in this case Macromind *Director* (versions 4 and 5 using both the Macintosh and the PC (Windows) platforms). Once the package was complete three further processes were undertaken: the burning of a CD-ROM for a discrete product; processing the files through a filter, in this case Macromedia *Afterburner*, to produce a product for access and viewing through the Netscape Web browser with both *Shockwave* and *QuickTime* 'plug-ins'; and adding extra functionality to the Web product by additional HTML authoring. What was a discrete multimedia product, albeit one that could be accessed via an Intranet or the Internet using a browser with the appropriate Macromind *Shockwave* plug-in, was developed into one that could be linked to outside resources, or those resources that could be said to provide the 'real world' links to an otherwise isolated product. The package can also be linked to hardware devices like CD-ROM drivers or videodiscs. Software connections can enable links to be made to packages like databases and GIS. Figure 4 illustrates the multimedia production process that was followed for this particular prototype.

Discussion

According to Allen (1996), there are still vast opportunities for the GIS profession to extend its reach by providing services, that currently are perceived as being too expensive, or do not yet exist, to an ever growing field of technologically literate individuals. The development of an on-line Map Shop that links to a GeoExploratorium containing many different ways to explore and appreciate geographic information may be one of these services.

What sort of interface for the Map Shop and the GeoExploratorium is needed? Three types of interface exist: spatial, semantic and networked. Donald Norman (Steinberg, 1997) thinks that the desktop metaphor has outlived its usefulness. It was useful when all that was available for personal computing was a 128k Mac with no Hard disk drive, but an interface that was inappropriate for modern-day machines that could be hampered by such access systems. Most popular now is the networked interface, that began with Bush's *Memex*, developed through Nelson's *Xanadu* and is currently being used as the World Wide Web. The networked interface would suit a product like the GeoExploratorium.

A product is being developed that is mooted as a system that will provide a service to residents of the City of Bologna, Italy, but on a much, much grander end expensive scale than the proposed GeoExploratorium. Italian novelist, Umberto Eco is promoting the development of a project called *Multimedia arcade* (Marshall, 1997). It will feature a public multimedia library, computer training centre and Internet access. It is sponsored by the Bologna Town Council and, for a fee, citizens of the town will be able to use the Web, send and receive e-mail and learn new computer programs. It will contain a large multimedia, software, and print library, as well as a staff of teachers, technicians, and librarians. The success of this type of project will certainly be of great interest to the mapping community.

Problems have been highlighted about the Internet's slow delivery of data (14.4/28.8KB through a typical modem), that would restrict the speedy delivery of digital geographic data, images and movies. This problem of poor transmission rates has increased the interest in the production of hybrid CD-Web links (Reis, 1996). This combination of discrete and distributed electronic mediums enables the 'bulk' data to be delivered on CD-ROM or the emerging DVD-ROM (Digital Video Disc or Digital Versatile Disc) (Fritz, M., 1996), and then used as a base or archival information starting point for information that can be updated by 'current' or real-time information provided via the Internet and the Web. The GeoExploratorium could provide geographical information efficiently using such a system, especially if 'jukeboxes' of DVD-ROMs and fast modems providing on-line, interactive updates were used.

Conclusion

The paper has proposed the development of an on-line Map Shop and an associated GeoExploratorium for the provision of geographic information and support resources. The GeoExploratorium could use a metaphor set comprising of the Storyteller, the Navigator, the Guide, the Sage, the Data Store, The Fact Book, the Gameplayer, the Theatre and the Toolbox to present information in ways that complemented the map metaphor. The on-line Map Shop, supported by a map curatorial guide (real or virtual), could be provisioned with maps, videos, books, guides, games and databases of facts and could provide expert tips. The Map Shop could be linked locally or internationally through the Internet and, more specifically, the World Wide Web. A prototype package has been developed to attempt to ascertain how such a system would work and to provide a model to be used for the development of a functional product. The GeoExploratorium could provide the means for geographic exploration and discovery and it would offer both discrete and distributed resources and be hosted by a virtual guide that could use agents for Web data gathering. From the user's perspective the boundary between discrete and distributed multimedia would be transparent, presenting the most current and customised information possible.

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A VIRTUAL ATLAS ON THE WORLD WIDE WEB: CONCEPT, DEVELOPMENT AND IMPLEMENTATION

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Abstract:

The authors have developed a 'Virtual Atlas' on the World Wide Web. The atlas is a user friendly interface to spatial information resources including maps, satellite images, aerial photographs and statistical information. This paper describes the design concepts behind the development and authoring of the Virtual Atlas, it illustrates the major components of the product and provides comparisons between the Virtual Atlas and its printed paper counterpart. The atlas has been tested with secondary school students and been found to be more effective in the location of geographical information compared to a printed paper atlas. The provision of such an interface or Virtual Atlas has been found to be necessary as spatial information resources are stored as images on the Internet and are therefore not directly indexed or searchable. The atlas supports the user by providing various modes of operation for the location of spatial information as well as containing an index, regional maps, and gazetteer that might be found in a paper atlas. With cartographers embracing the use of the Internet, the provision of a user friendly interface is imperative.

Introduction

The Internet is a growing computer-based activity with rapidly increasing numbers of people being connected world wide (Arthur, 1995) (Pitkow and Kehoe, 1995). It can be described as a massive distributed database. The main reason for accessing the Internet is for the wide range of up to date information that is available from anywhere in the world. The professional users of these resources include cartographers, mapping scientists, land managers, geographers, geologists, GIS scientists, travel agents and planners.

The Web can be considered as a graphical interface to the Internet. Web documents are written in HTML (HyperText Mark-up Language) where any element of the document can be a link to another document. Text, images, sound, animation and movies can be incorporated into Web documents.

Because of the vast amount of information available via this resource, estimated at 54 million documents by *HotBot* (1997), it is increasingly difficult for users to find information relevant to their interest (Yuwono et al, 1995). Universities and private companies have been developing search engines, such as *AltaVista, Infoseek, Yahoo* and *Excite*, that index text in Web documents by keyword. In many cases the link to an image, which is what spatial resources predominantly are, does not contain appropriate descriptive text, or text that average users would consider to be a keyword search (Duval and Olivié, 1993). As the growth of Internet publishing has increased, locating specific information has become more difficult.

The Web provides mapping scientists an opportunity to disseminate information to users worldwide in a timely manner. Information resources already available via the Web include maps, satellite images, aerial photographs, GIS, weather, world facts and travel. Provision of data that exists in digital form can be provided free or at a cost to the user with the order handled complete on the Web.

The problem of locating spatial information resources on the Internet has only been tackled in an ad hoc manner in the past. 'Links' pages have been placed on the Web were in effect a list of sites that were found to be useful in certain subject areas. Some of these links pages are unstructured and do not have complete coverage of the globe. Another problem with some of these pages, and the Internet generally, is that pages can 'disappear' or move to other locations with no notice.

There has been sparse research in the area of directly providing an interface to resources on the Internet. The popular solution has been to build bigger and better search engines. This is increasingly becoming impractical (Yuwono et al, 1995). There is a need to construct interfaces to specific collections of resources on the Web, including spatial resources.

This paper outlines the extension of 'links' pages to what has been called a 'Virtual Atlas', (Ashdowne, et al, 1995; 1996) created a Web site that provides a graphic interface to spatial information resources on the Internet. It discusses the concept, development and implementation of the atlas in terms of Hypermedia and the Internet, while differentiating it from the links pages that already exist. The title Virtual Atlas was chosen for this prototype because the atlas is not a collection of physical or digital spatial information resources, but a collection of 'pointers' to spatial information resources and is thus virtual. The paper further discusses the methods that have been used in development, testing and evaluation.

Spatial Information Resources on the Web

Resources available on the Internet include libraries of maps such as the PCL Map collection (http://www.lib.utexas.edu/Libs/PCL/Map_collection/Map_collection.html) that contains 230,000 maps (many of which are on-line), the CIA World Factbook (http://www.odci.gov/cia/publications/95fact/), the USGS (United States Geological Survey) (http://www.usgs.gov/) and various interfaces to GIS systems.

Concept of a Virtual Atlas

The Virtual Atlas is a prototype graphical user interface to the World Wide Web that helps users locate existing map resources on the Internet by providing pointers to these resources. The atlas expands upon links pages, that have been used previously, by providing a simple user interface. The interface does not contain hundreds of links on one page in an unstructured form. The atlas has a complete user interface with different modes of access to information. The atlas has been designed to evaluate possible methods of helping users locate information in an easily used and visually pleasing manner. Quoting Duval and Olivié (1993, p161): "The main focus here is on user friendly access".

Proving the pointers to information provides the opportunity to have resources that are created and updated by the local authority. Spatial information can then be "...maintained by various custodians over the network" (Crossley and Boston, 1995). Having local authorities that are already responsible for producing spatial data of their region publish on the Internet allows for increased accuracy and access to timely information.

The design of the atlas involved providing access to different levels of information. Each subsequent level brings the user to a new level of detail, from a world view to that of an individual country. Navigation to the required information resources can be made in various ways:

- the default 'graphical' mode presents a world map to the user who can then 'click' their way to a continent and country (similar to a multimedia CD-ROM);
- the 'themes' section provides information resources that are more thematic in content;
- the 'text' mode allows the user to quickly navigate to their location of interest by following alphabetical text menus;
- the 'search' mode allows the user to enter a keyword to search the Virtual Atlas; and
- the 'gazetteer', provides a full listing of all resources references by continent.

The user has the opportunity to select any of these different modes available to access information. The atlas provides for individual users who use differing methods to locate information.

Development of the Virtual Atlas

The program was begun in mid 1995 and many things have changed due to development in that time. New resources have emerged, others have changed location or been removed. This is the very nature of the Internet. Most of the interface was basic HTML, however as this standard has evolved, new features and functionality were continually implemented. An example is 'image maps' which early versions of the HTML standard did not include, but are now widely used.

The first stage was to find and index relevant locations of spatial information resources. These resources were collected manually by finding existing 'links' pages, reading related newsgroups, performing directed searches and canvassing input from colleagues. Once links were located for every country they were separated and categorized (where there were too many to otherwise easily navigate).

The next stage was to implement the user interface by creating Web pages in HTML. There were many considerations to be made: the design needed to be user friendly; relatively quick to access; visually appealing; simple to navigate; and it had to conform to the general criteria of the host university's 'Style Guide'.

To make the atlas user friendly, visually pleasing and simple to navigate, image maps were essential. The first implementation of image maps relied on the server to do all the work, slowing down response times. The introduction of 'client-side image maps' transferred that demand to the client, or browser, where it is handled faster with no additional contact of the server. The atlas utilizes client-side image maps (that most browser's now support). Client-side image maps give the link location for each part of the image. This had the effect of instilling confidence in the user.

The 'home page' of the atlas presents the user with a world map divided by continent. When the user clicks on any continent they are presented with a map of that continent showing all the countries that they may select to get a list of resources for that country.

Figure 1 illustrates the home page of the Virtual Atlas.

Figure 1. The Virtual Atlas User Interface (http://www.srl.rmit.edu.au/va/)

The structure of the Web site as a whole "should help users build mental models of the underlying structure and interrelationships of information resources" (Cochenour et al, 1995). This was accomplished with a consistent title and providing access to the home page and other modes of access. "A visual consistency (cited in Grabinger, 1993) should tie the image map and its related information resources together" (Cochenour et al, 1995).

Each of the images needs to have a balance of being visually appealing and small in file size, so that it loads quickly. Users soon lose interest in a Web site where the images take a long time to load. This is another reason why a text interface has been provided for users with slow connections or for those who know exactly what they need.

This graphical mode is the equivalent of the index maps in a paper atlas. This allows the user to navigate by clicking through the various levels: World - Continent - Country. The text mode is designed to allow access to the same resources while navigating without images. It has been developed with the same levels as the graphical mode for consistency and speed of access. The title is replaced by text which provides the same navigational links. The 'themes' section provides information resources which are more thematic in content such as environmental, aerial photos, satellite images, multimedia, historical, railways, education and map projections. The search mode has been implemented by installing "Excite for Web Servers" and creating a searchable database of the Virtual Atlas site. This allows for the user to enter a search by "keywords" or "concept" and be presented with results from pages in the atlas. The gazetteer mode could be regarded as an index of the site by continent. Each continent has a page that collects all the links for each country and presents them all on a single page.

Implementation of the Virtual Atlas

The structure of the site is such that each country page for a continent are stored in their own directory. The site has been designed to conform to the DOS 8.3 file naming convention, except for the home page which is named 'index.html'. This was done because the server recognizes this as a special file that will be accessed if no file name is specified. This allows for shorter addresses. The 8.3 file naming convention was used so that it was transportable to other platforms to serve or run locally.

It is possible to control what is returned from certain search engines that look at the <META> tag in the header of Web pages. The META (meta data) tag allows for the control of which keywords are used to index the page and which text appears in the brief summary from a search. The use of the META tag has been implemented in every Web page of the atlas. The code used on the Virtual Atlas home page is:

```
<META name="description" content="Explore the Virtual Atlas for
geographic information. Links to: maps, tourist information, satellite
images, aerial photos, historical, railway, map projections">
<META name="keywords" content="atlas, map, geography, tourist">
```

Once the Web site was complete, the home page location was submitted to all the major search engines.

Evaluation and Testing

The evaluation and testing process was undertaken to determine the effectiveness of the user interface and the overall design of the Atlas. This involved the participation of 163 year 7-9 students from 8 schools. Specific goals were set for the students to accomplish using both the Virtual Atlas and a traditional printed atlas. The aim was to compare how users of atlases locate information and to determine any advantages the new medium has for the location of geographic information. The traditional atlas used was the Jacaranda *Junior World Atlas*.

The evaluation was developed from Barker et al's (1993) procedure and based upon giving subjects a number of information retrieval tasks involving the use of the parallel information delivery environments for looking up specific items of information. The students had five tasks to complete, then provide responses as to how they located the map related information requested in the task, rated from Very Easy to Very Hard. The tasks included questions on location, finding specific cities, countries and neighboring countries, and locating appropriate statistical and thematic information. They were also asked for any additional feedback they would like to make in regard to the design of the Virtual Atlas and printed atlas.

Examples of the tasks and questions used are in the appendix, for more information please contact me.

Results

Many students indicated that they liked the Virtual Atlas as it was on a computer. However, some students found it difficult initially. The students that found it difficult had little prior knowledge or use of computers. This information was obtained by discussion with the teacher and students before the class. As many schools did not have an Internet connection they were unable to use the 'Search' feature. This required the students to use 'trial and error' to locate places unfamiliar to them, which is not a practice they are familiar with. If the students were able to use the search feature I believe that there would be a greater number who both prefer the Virtual Atlas and find it easier to use.

A summary of the results are provided in Table 1 and 2.

58% (95)	preferred the Virtual Atlas	50% (81)	found the Virtual Atlas easier to use
25% (40)	preferred the Printed Atlas	33% (54)	found the Printed atlas easier to use
17% (28)	did not respond	17% (28)	did not respond

Table 1. Preference and ease of use indicated by students

	Correct	Incorrect	No response
Virtual Atlas	90% (731)	5% (44)	5% (40)
Printed Atlas	81% (663)	14% (117)	5% (35)

Table 2. Students responses to tasks

More than double the number of students preferred the Virtual Atlas over the printed atlas. This margin was reduced in the number of students found the Virtual Atlas easier to use. These figures are supported by the number of correct and incorrect responses to the tasks. More students found the correct answer using the Virtual Atlas than did in the printed atlas, with approximately 5% of unanswered questions.

Discussion

The pages of the Virtual Atlas were accessed approximately 5,700 times in October 1996. Users searching for spatial information have found the Virtual Atlas particularly useful. Feedback from many of the students and teachers in schools that participated in the evaluation was very encouraging. They indicated when they became connected to the Internet they would use and contribute to the improvement and update of the atlas.

At the continent index level there are regions in which many countries are located in a small area which creates a problem. This has been overcome in by placing the text a small distance from the country and placing a connecting line. The problem in Europe is more difficult as the countries that create problems are centrally located. Here the text has been reduced slightly and, where necessary, abbreviations have been used.

A program for Web servers that periodically checks links on a site reporting errors encountered would be an invaluable tool in the maintenance of the Virtual Atlas. There are programs available that are being tested for their suitability. The ultimate goal would be to have an automated system to fulfill the role of building the Virtual Atlas. Such a system would need to allow for sites or Internet connections being down temporarily, as a link would not need to be removed in such a case and human checks are required for verification.

There is a problem for users locating appropriate information on an ever-increasing large unindexed database that is the Internet. At this time there is no simple way to index graphic images on the Web and some research is being done in this area such as "The EUREKA effect" (Nelson, 1996) and "Toward Image Content-based Retrieval for the World Wide Web" (Feder, 1996).

Another area of research that has yet to produce widely available software is that of 'agents'. An agent would check for new map links and verify that they did not already exist in the atlas. The use of agents would also require some level of human control to check for appropriate information and perform categorization if necessary.

Conclusions

The evaluation has proven that the Virtual Atlas is a valuable resource for a rapidly increasing number of users worldwide. Many of the students stated that they found it difficult to understand the Virtual Atlas initially, but became more comfortable in the limited time available. The amount of traffic the site attracts is very encouraging and all feedback has been positive. It is acknowledged that the Virtual Atlas is not a replacement for the printed atlas or more structured digital atlases but it is a resource that can provide easy access to diverse spatial information worldwide.

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APPENDIX

TASKS - PRINTED ATLAS

1 Your family has planned a trip to a country called Benin, what continent is it in?

2 You are flying over Canberra, what would your view be like? (**hint**: air photograph)

3 Your penpal lives in the capital city of Paraguay, what is the city's name?

4 You are planning a trip from France to Austria, could you travel by yacht?

5 If you were a farmer, would you move to south-west Tasmania?

TASKS - VIRTUAL ATLAS

1 There is a great surf beach at Kiribati, where is the country Kiribati?

2 You are flying over Canada and take a look out the window, what would the ground look like from here? (**hint**: air photograph)

3 Would Kenya be a good place to find gold?

4 There is a school ski trip to the country of Latvia, what continent is Latvia in?

5 How far would it be to walk all the way around Australia's coastline?

RESPONSES - PRINTED ATLAS

1 Benin is in which continent:

To locate Benin was: (circle one)

Very Easy Easy Average Hard Very Hard

2 I found a photograph of Canberra from a plane on page number : _______

To locate this photograph was: (circle one)

Very Easy Easy Average Hard Very Hard

3 The capital city of Paraguay is: ____________________

To locate the capital city of Paraguay was: (circle one)

Very Easy Easy Average Hard Very Hard

4 Could you travel by yacht from France to Austria? [ ] Yes [ ] No

If Not, why not?

To work this out was: (circle one)

Very Easy Easy Average Hard Very Hard

5 As a farmer, would you move to south-west Tasmania? [ ] Yes [ ] No

What information did you use to work this out?

To locate this information: (circle one)

Very Easy Easy Average Hard Very Hard

OVERALL

Would you say the printed atlas was: (circle one)

Very Helpful   Helpful   OK   Difficult   Very Difficult

What things helped you?

What made it hard to use?

RESPONSES - VIRTUAL ATLAS

1 Kiribati is in which continent?

To locate Kiribati was: (circle one)

Very Easy   Easy   Average   Hard   Very Hard

2 The page I found the air photograph on was titled: Netscape: ____________________

To find this page was: (circle one)

Very Easy   Easy   Average   Hard   Very Hard

3 Would Kenya be a good place to find gold?   [ ] Yes   [ ] No

To discover this was: (circle one)

Very Easy   Easy   Average   Hard   Very Hard

4 Latvia is in which continent?

To locate the Latvia was: (circle one)

Very Easy   Easy   Average   Hard   Very Hard

5 The distance around Australia is: ______________ km

To discover this was: (circle one)

Very Easy   Easy   Average   Hard   Very Hard

OVERALL

Would you say the Virtual Atlas was: (circle one)

Very Helpful   Helpful   OK   Difficult   Very Difficult

What things helped you?

What made it hard to use?

The Virtual Atlas could be more helpful by...

RESPONSES - COMPARISON

Which Atlas would you prefer to use: [ ] Printed Atlas   [ ] Virtual Atlas

Which Atlas was easier to use?   [ ] Printed Atlas   [ ] Virtual Atlas

The best things about the Printed Atlas are:

The worst things about the Printed Atlas are:

The best things about the Virtual Atlas are:

The worst things about the Virtual Atlas are:

AN INVESTIGATION INTO THE USE OF CYCLING MAPS BY TOURING CYCLISTS

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Introduction

In the whole world, there are now more than 1,000,000,000 bicycles (RAI, 1996). Most bikes -more than 450 million- are in use in China. In the Netherlands there are only about 16 million of them, but this means that there are about as many bicycles as inhabitants and there is no other country in the world with a higher relative number. The Netherlands is indeed an outstanding country for cycling, among other things because of its flat terrain. Bikes are used very much for travelling to work, school or shops (on average 1,000 kilometres per cyclist per year), but recreational cycling is very popular in Holland too (another 200 kilometres) (FIETSPLATFORM, 1997). Particularly for the latter purpose the demand for cycling maps has increased rapidly in recent years. Such maps have to inform the cyclists, for instance, about how to avoid the motorized traffic as much as possible. It should be noted that there are more than 18,000 kilometres of special cycle paths in the Netherlands (VAN BERCKEL, 1996).

Therefore, cycling maps were considered as an outstanding subject of the first project of the new Working Group on Map Use of the Netherlands' Cartographic Society (NVK). A special Project Group on Cycling Maps was established and started with an investigation into the suitability of 5 different maps which are often used in the Netherlands for recreational cycling. The investigation was carried out by real map users: almost all participants of the 1996 cartographic conference of the NVK made a cycling-tour in the surroundings of the conference venue in Helvoirt.

This paper is a summary of the full report (written in Dutch by SIMON VAN LEEUWEN & VAN ELZAKKER, 1996) of this map use investigation. It contains a justification of the plan and method of research, as well as a description of the characteristics of the map users who took part in the investigation. The many detailed results per map, which are included in the full report, are summarized here into some general recommendations for an 'ideal' map for touring cyclists.

Plan and method of research

So far, in general too little scientific research has been executed into the functioning of maps in the use of spatial information and particularly not enough research involving the users themselves. This kind of research into the use of cycling maps should perhaps not be expected outside the Netherlands, but also in this country not much has happened in this field so far. Worth mentioning is only the research into cycling maps, executed by the cycling association ENFB in 1981 and 1991 (BOSMA, 1981 and CAMPS & BARTLEMA, 1991). But these projects were mainly carried out from behind writing desks and actual and structured use and user investigations did not take place.

It appears that the field of research into the use of cycling maps is still largely unexplored and, therefore, we decided to try to give a first impulse to a real map use investigation. It was known beforehand that the scientific value of this research could not be very high and not many concrete results could be expected. The reason for this was not only the lack of earlier research, but also the relatively small number of users who took part (70 people, employing 5 different maps). Therefore, the main objectives of this research were to make an inventory and may be also to form hypotheses. An inventory in the sense that we hoped to be able to reveal some factors that play a role in the evaluation of the quality of existing maps from the perspective of the user, the cyclist. After forming hypotheses, those factors would have to become subject to further and more thorough research. Possibly, in such further research some more attention could also be paid to the specific characteristics of the terrain in which the cycling takes place. The investigations as described in this paper took place in the area surrounding the conference venue in the south of the Netherlands. This area is reasonably representative of a large part of the country, but perhaps the research results would be different in a terrain with more relief, like in many other countries, or even more flat, more large-scale or more open. Derived objectives of the research were to make some first recommendations for the improvement of the maps investigated and to make a first step towards the development of general criteria for the 'ideal' cycling map in the Netherlands. It is hoped that (potential) producers of cycling-maps may take advantage of this. An objective of the research project, which was somewhat more hidden, was, of course, also to let the map producers who attended the conference find to their cost what may be the problems of the map users in practice.

Considering the potential users of cycling-maps, a distinction may be made between four groups of cyclists:
Utilitarian cyclists are cyclists who mainly use their bikes as a means of transportation in order to reach a destination. Speed, road and social safety and comfort are more important for determining the route than landscape or cultural attractions.
Touring cyclists move rather slowly on quiet, scenic roads. Cycling is a goal in itself. In determining the route, characteristics of the landscape and avoiding busy car traffic play an important role and, to a lesser extent, the metalling of the roads and the presence of objects of interest and catering establishments.
Recreational *racers* want to have room to cycle fast. For them the environment is

subordinate to the condition of the road. By preference, the road surface must be smooth and there should be as few obstacles (like traffic lights and bends) as possible. The *ATB-ers* (All Terrain Bikers or Mountain Bikers) prefer to ride in nature reserves. For this, they often use unmetalled footpaths which have been opened to them.

Together, the latter three groups of cyclists form the category of recreational cyclists. In this category, a final distinction may be made between those cyclists who make a day's tour (starting and ending at the same place) and cyclists who ride from one place to another. The distances covered may vary greatly.

The research conditions at the conference were such that there were only one and a half hour and ordinary touring bicycles available for the cycling tour. Besides, the number of participants was limited and for organizational reasons the place of starting and ending the tour had to be the same. Therefore, it was decided to limit the investigation to the use of cycling maps by *touring cyclists* who want to make a tour. Participants were given the task to map out an attractive cycling tour of about 15 kilometres from the conference venue with the help of the cycling map given to them and to actually cycle that tour afterwards with the help of the same map. The cyclists were sent in different directions to give a large variety of possible tours.

In the task and in the investigation attention was therefore paid to two aspects of the use of cycling maps: planning and mapping out a cycling tour before departure and actually following the planned route on the bicycle. The participants were asked to fill up two separate questionnaires regarding both aspects. In addition, they were asked to complete again another questionnaire with some questions on their usual cycling behaviour and related map use.

In the Netherlands, there are cartographic products which are very specifically intended for use by cyclists as well as maps with more general objectives (for example, tourist and topographic maps). In principle, both kinds of cartographic products may be used for planning and following recreational cycling tours. The following maps were used in the investigation:

1. Fietstochten in de Meierij van 's-Hertogenbosch en wijde omgeving - Publisher: Dwarsstap - scale 1 : 50.000 (special cycling map)
2. De Meierij 's-Hertogenbosch - St.Oedenrode - Heusden. Kaart voor vakantie en vrije tijd, nr. 34 - Publisher: Suurland Falkplan - scale 1: 50.000 (leisure map)
3. ANWB / VVV Toeristenkaart Noord-Brabant - Publisher: ANWB - scale 1 : 100.000 (general tourist map)
4. Landelijke Fietsroutes deel 2, kaart 15 - Publisher: Buijten & Schipperheijn - scale 1 : 150.000 (special map with cycling routes)
5. Toeristenkaart 8: Midden-Brabant - Limburg - Publisher: Smulders Kompas - scale 1 : 150.000 (general tourist map)

These five maps were selected from a greater supply of maps available of the area surrounding the conference venue. A selection had to be made, because on the one hand the number of participants of the cycling-tour was limited and, on the other hand, the relative unsuitability of certain maps for touring cyclists was already known. For instance, there is a map available which pretends to be a special cycling map of the Netherlands, but which, for a start, is at a scale (1 : 300,000) which is far too small for successful use. Just on the contrary, we considered the scale of special walking maps or the topographic map 1 : 25,000 as being too large. With such a scale the cyclist would have to change maps too often and the overview would be insufficient. A final factor that played a role in the selection of maps to be investigated was the requirement that the maps had to differ clearly from each other. For example, the Dwarsstap map is based on the official topographic map 1 : 50,000 and that is the reason why the latter was not investigated separately.

Each of the selected maps was tested by 4 groups of 3-4 cyclists on their suitability for planning and following a cycling tour. Before discussing some results, it is important to know what kind of cyclists participated in this research.

Participants

Information about the characteristics of the participants in the cycling map use investigation has been obtained from one of the completed questionnaires. Almost 60% of the cartographers who attended the conference possesses one bicycle, almost 40%, two or more bikes and only two participants none. They mainly use their bikes for short utilitarian journeys. Only the touring bicycles with more than 7 gears (in the possession of about 17% of the participants) are mainly used for the recreational purpose for which they were designed. Throughout the year most of these cartographers do not make a very intensive nor very conscious use of cartographic products for cycling purposes. Remarks like "I use my own mental map" or "I know the way" occur more than once on the completed questionnaires. If they do use maps, they are often topographic or general tourist maps "which happen to be in the cupboard by accident". Logically, the touring cyclists among the participants make a more conscious and intensive use of maps.

It may be concluded that, in general, most cartographers who participated in the investigation are not fanatical cyclists and definitely not fanatical users of cycling maps. On the one hand, for the research this could be seen as an advantage, because in this way the maps tested could be considered with an open mind. Besides, herewith the hidden objective was met to let -for a change- map producers experience themselves what may be the problems of map users in practice. Of course, on the other hand, it was a disadvantage for the research that the maps could not be tested by a sufficient number of experienced users of cycling maps. It may well be stated that the group of respondents was not representative of the real users of cycling maps in the Netherlands. Nevertheless, some interesting results came out of the investigations.

Results

In general, the participants mainly passed negative criticisms on the maps tested. Apparently, deficiencies strike the eye more than positive aspects. The replies to the questions posed also had to be reviewed clearly, as sometimes participants drew conclusions without having carefully studied the maps. We also had to take with a grain of salt the reactions on the manageability of the maps, since the size of the map compartment of the handlebar bag offered to each participant clearly influenced the judgement. Finally, regrettably some of the questions in the questionnaires led to interpretation mistakes. Therefore, on some aspects of the maps tested no clear conclusions could be drawn. But on many other aspects useful results emerged.

The data that came out of the questionnaires have been worked out per map in detail. These results, which have been made available to the producers of the maps tested, show how the cycling cartographers evaluated each individual map on its use before and during a cycling tour. The reports also contain facts collected by the members of the Project Group, which are related to the contents and design of the maps tested, but lie outside their actual use. These objectively measurable characteristics have been summarized in *Table 1*. In this way, in the final report for every map detailed information is given about its general characteristics (including e.g. costs, size and up-to-dateness), the (suitability of the) representation of road surfaces, accessibility, traffic intensity, distinctive landmarks, landscape, cultural sights, provisions for tourists and cycling routes, the possibility to derive distances, the amount of information in the map and its correctness, the manageability, the legibility, the functionality of the sheet line system and, finally, about the extent to which the maps gave satisfaction in planning and following the routes, i.e. whether they met the expectations of the participants.

For the purpose of this paper it does not make much sense to present the detailed results per map here (and there is also no room for it!). The prime objective of this investigation was also not to establish what is the "best" map for touring cyclists. The limitations with respect to the investigation and the respondents, as well as differences in specific user needs, would not justify such conclusions. However, from the detailed results general recommendations may be derived for an 'ideal' map for touring cyclists. Some of these recommendations are:

<u>Scale</u>

The investigation made clear that for a short recreational cycling tour in the Netherlands the scale 1 : 50,000 is suitable for orientation and to get an impression of the route to be followed. Such a scale allows the inclusion of a lot of topographic and touristic information which is of interest to touring cyclists. For cycling a small tour the number of maps to be used will be limited at this scale. At larger scales too many maps will be needed and users will lose the overall picture of the route to be followed. At smaller scales (e.g. 1 : 100,000) fewer landmarks may be included. But the advantage of a smaller scale is that a cyclist will not "ride off the map" so quickly and that he/she will have to refold the map less often. Besides, a smaller scale provides a

Table 1. Some objective characteristics of the maps investigated

	Map 1	Map 2	Map 3	Map 4	Map 5
Meta-information:					
Scale denominator on map cover	no	yes	yes	no	yes
Scale denominator in legend	no	yes	yes	yes	yes
Scale bar	no	yes	yes	yes	no
Date of revision	yes	no	no	no	no
All map elements shown in legend	no	yes	no	no	yes
All symbols in legend shown in map	yes	yes	yes	no	yes
Symbols in legend and map identical	no	yes	no	no	yes
Map representation of information on road surface and accessibility					
Distinction unmetalled/metalled roads	yes	yes	yes	yes	yes
Semi-metalled roads	no	no	yes	no	yes
Distinction detached cycle paths / cycle paths beside the roads	no	yes	yes	no	no
Distinction cycle paths allowed / not allowed for mopeds	no	no	yes	no	yes
Roads forbidden for cyclists	no	no	yes	yes	no
Roads forbidden for cars	no	yes	yes	no	yes
One-way roads for cyclists	no	no	no	no	no
Ferry services	yes	yes	yes	yes	yes
Landmarks					
Numbers of signposts for cyclists	no	yes	yes	few	no
Numbers of other signposts	no	no	yes	no	no
Road numbers	yes	yes	yes	no	yes
Names of important streets	yes	yes	yes	no	no
Distances shown in the map					
Distances between road crossings	no	yes	yes	no	yes

better overview. However, the respondents indicated that a scale of 1 : 150,000 or smaller is not suitable for use on short cycling tours. Too much information is lacking, as a consequence of which one misses the nice little roads while planning the route and one has orientation difficulties whilst cycling. A scale between 1 : 50,000 and 1 : 100,000 could well be an acceptable compromise between high detail and overview.

Size, folding and materials

Users prefer small cycling maps that do not have to be folded often. Ideal materials for maps are fold-, tear- and waterproof. Such a base is used, for instance, for waterway maps. But the price may be a limiting factor for cycling maps.

Legends

The consensus of opinion was that a legend must be printed on every single map sheet (i.e. not in a separate booklet) and, if possible, it should be positioned in such a way that users can refer to it easily. Besides, by preference the legend should not be printed across a fold of the map. The symbols in the legend must be identical to those in the map, i.e. they must have the same size and colour. Finally, all map symbols must be explained in the legend.

Date of revision

For the user it is practical if it is clear at the first glance when the cycling map has been revised for the last time. But not many maps include this information.

Extensive classification of cycle paths

Cycling map users require extensive information about cycle paths. They want to be able to distinguish the wide comfortable cycle paths from the narrow and bumpy little ones. To this end a classification of cycle paths has to be made, in which the width, the nature as well as the quality of the road surface stand out. In addition, the users want to read the traffic situation from the map. They want to know whether mopeds are allowed or not, and whether the cycle path is detached or part of the road. It should be clear from the map if there are cycle paths on both sides of the road. Information about the accessibility of roads for cyclists is essential. Cyclists do not want to end up on private land. Nor is it attractive to have to find at a late stage that a certain road is only accessible to motorized traffic. On the other hand, cyclists want to know specifically which little roads are closed for cars, but open to them.

Landmarks

With the help of cycling maps users want to form a correct notion of the landscape and, conversely, particularly for the sake of orientation, they want to be able to find on the map landmarks in the terrain. That is why it is important, for instance, to include in the map the unique numbers which all signposts in the Netherlands carry. Also the traffic junctions (tunnels, bridges, viaducts, crossroads, etc.) have to be represented in a realistic way. The quality of the road surface has to be visible, e.g. wether metalled or unmetalled and, preferably, also wether asphalt or brick surface. Roads of a particular category have to be represented in a consistent way, or consistently omitted. On the map, churches (especially those with high towers), windmills and cemetries are of high importance as landmarks for orientation, but so is the representation of woods, agricultural landuse, heathland and sand blows. Finally, orientation is also served by including in the map the names of the most important streets and roads.

Conclusion

In 1997 the Project Group on Cycling Maps (in a changed composition, with an even better representation of the users themselves) will continue to strive for more recommendations for an 'ideal' map for touring cyclists. A follow-up investigation is needed with a bigger and more representative group of users of cycling maps. The research described in this paper had its limitations indeed, but, in any case it offers sufficient starting points for further and deeper research into, for instance, the contents and legibility of cycling maps. Currently, the Project Group is designing and actually producing a new prototype of a cycling map for touring cyclists. The legibility and usability of this prototype will be tested by means of a new and far more extensive user investigation. It is hoped that this may lead to the formulation of new standards which ideal cycling maps for touring cyclists would have to achieve.
After careful definition of the various categories of users a similar approach may be followed for maps intended for other recreational cycling purposes than just touring. In addition, the Project Group would like to pay attention to the relationship between the map and other means of information supply to the users, for example by means of booklets and signposting. There are plenty of plans and possibilities for further research into the use of cycling maps. We hope we will get support for this kind of research outside the Netherlands, if not from users of cycling maps then from as many users of as many other types of maps as possible. For real map use research involving real map users has to be executed much more often!

Note

The members of the Project Group on Cycling Maps of the Working Group on Map Use of the Netherlands' Cartographic Society who contributed to this investigation are: P. Benjaminse, H. Bosma, L. Camps, D. Dijkstra, J. Eberhardt, C. van Elzakker, P. Geudeke, E. Massop, A. Ras, R. van der Schans, A. Simon van Leeuwen, A. Snelderwaard.

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WWW-TECHNOLOGY AS MEANS OF TRANSFER AND VISUALIZATION OF GEOGRAPHIC OBJECTS

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Abstract

The number of WebTop GIS applications is increasing rapidly. Besides of the traditional HTML- and CGI-based solutions, new object-oriented services are emerging. In this article the Java programming language as a tool for implementing WebTop GIS -applications is introduced. Java offers several features that support object-oriented representation and processing of geographic information. These include the inherent object-model of the language, object transfer over network in serialized form, ability to communicate with remote objects, and object inspection. Java's rich set of user interface components and built-in support for multimedia datatypes facilitate the dynamic creation of efficient user interfaces also for GIS -applications.

1. Introduction

Information networks are the most actual application of information technology today. The networks open equal possibilities for every citizen to use and transfer information, independently of geographic locations. This development will very soon influence also the GIS community. In particular, the rapid expansion of the Internet that is driven by the popularity of the World Wide Web-environment (WWW, Web), provides the data suppliers with a completely new possibility to disseminate geospatial information to every citizen. At the same time, digital maps can be seen as an interface to the vast amount of information contained in the public networks (McKEE 1996).

A research project has been started at the Finnish Geodetic Institute in order to investigate the feasibility of an interactive, Web-based application for processing geographic information in object form. The test data for this research project is retrieved from the geographic database for topographic maps at National Land Survey of Finland. The initial goal of the project is to enable transferring, displaying and querying of geographic data, as individual objects and their multiple representations, including multimedia components, in the Web environment.

As the Web environment as a platform for GIS has been widely accepted, in this paper the idea of WebTop GIS is introduced. The paper begins by briefly describing some existing WebTop GIS -technologies. After that, the emerging implementation of the object-oriented computing model in the Web environment is presented. Finally, the Java language as a tool for WebTop GIS is introduced and some of its favourable features, specially related to object-model and multimedia capabilities, are discussed.

2. WebTop GIS -technologies

2.1 Traditional techniques

Most of the map related services currently available in the Web use components defined in the HTML -form (W3C 1997), together with raster image display, to implement the user interface. All the processing is done in the server, employing a gateway technology called Common Gateway Interface (CGI), (NCSA 1996).

Maps in raster form can easily be displayed in a Web browser, simply by embedding an image of the map into the document. The basic HTML -standard provides only for a static pre-defined information display. To overcome this limitation, a standard gateway interface specification was defined. The general idea of CGI is the use of external applications to process the requests coming from Web browsers. This makes the dynamic creation of HTML -pages possible. By using the CGI technology existing databases can be connected to the Web (Figure 1). The query can be constructed by means of the input into the fields of a form. The components of the query will then be sent to a CGI -program, which builds up an appropriate query sentence and forwards it to the DBMS. The retrieved results are coded back to an HTML -document and returned to the browser.

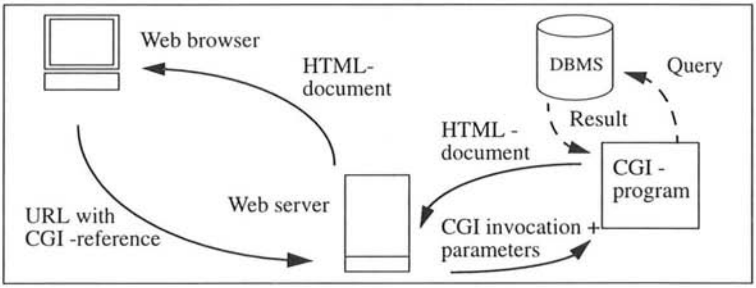

Figure 1. Common Gateway Interface -process.

Most of the existing map-related Web applications are based on CGI -processing. There are a few problems in this approach. All the processing is done on the server side of the connection. A specific problem is presented by the fact that every time the user clicks on the form input field displaying the map, a new http-connection to the server is opened, which makes it difficult to implement multi-click operations and adds the network traffic significantly. The results created by server-side CGI-process must again be coded into an HTML-document, which limits the display of geographic information to the raster form.

The user interface is limited to the capabilities of the HTML -standard. The only available user interface components are those provided by the form fields. Forms, together with the CGI -standard, started the evolution of interactive Web -applications. They provide the means for the user to send feedback to the server. An appropriate process is then executed by the server, with the help of a CGI-program, to produce the requested results. The latest developments in this area, like Java (JavaSoft 1997) and ActiveX (Microsoft 1996), take the interaction to a completely new level and shift a significant share of the processing to the client side.

One workaround for the limitations set by the HTML-standard for the processing of geographic data in a Web browser is presented by the use of plug-ins. The plug-ins are software modules running on the top of a traditional Web browser to provide new browsing capabilities. The drawback in this approach is the extra work needed to separately download and install these components. Another problem is that the plug-ins are essentially platform- and browser-dependent.

2.2 New Web -solutions

Some new technologies have emerged, as possible alternatives for plain HTML - CGI -solution, to implement more intelligent, interactive, vector based map applications. With the emergence of these technologies, an access to geographic information in intelligent, object oriented form is opened to the wide Internet audience. The popularity of the Web -environment offers a chance for data providers to make their data accessible to a casual end user (Bertazzon and Waters 1996). One of the biggest barriers blocking the wide use of digitally stored geographic information is the need to install special software in advance. This barrier could be removed by the new computing paradigm: The program code for manipulating spatial data can be downloaded together with the data itself.

The Java programming language (Arnold and Gosling 1996) is one of these new technologies. Java language has gained a quick and large-scale acceptance as a prominent programming language for the Web. The first GIS solutions available in the Web today, are shown in Table 1.

Project name	URL address
IRIS	http://allanon.gmd.de/and/java/iris/Iris.html
ActiveMaps	http://www.internetgis.com/
Virtual Boston	http://www.pmg.lcs.mit.edu/~ng/Map/
MapCafé	http://maps.esri.com/ESRI/arcview/demos.htm
IDGIS	http://starr-www.tamu.edu/choo/idgis/intro.html
DOOGIS/GeoViewer	http://www.dis.anl.gov:8001/GIS/
JaGo	http://columbus.cnam.fr/MapView/CarteIHM.html
Regio Data	http://home.pi.net/~hverbeek/server_gis.html
MapQuest	http://www.mapquest.com/
Map Viewer	http://www.cs.berkeley.edu/~fccheong/mapview/

Table 1. Examples of Java WebTop GIS development projects

The standardization organizations have also noticed the possibilities provided by the new Web technologies. Open GIS Consortium (OGC) has published a Request for Proposals in order to establish a standard programming interface for geospatial objects in the Internet (OGC 1996).

3. Object technology in the Web

The popularity of the Web technology makes Internet an ideal platform for introduction of any new computing architecture. The distributed computing model, based on components loaded dynamically in the networked environment, fits well to the Web. The first practical implementation of a software object included in an HTML -document is the Java applet. Java applets are small software modules designed to run inside the Web browser and providing means for interactivity and live contents. Java code is interpreted by Java Virtual Machine (JVM). The latest proposals for additions to the HTML -standard reflect this development. The HTML version 3.2 defines a special tag `<applet>`. The following example illustrates its use in a HTML-document.

```
<applet code="SomeJavaCode.class" width=300 height=300>
<param name=input1 value="value1">
<param name=input2 value="value2">
Your browser does not know how to exec Java applications.
</applet>
```

The plain text inside <applet>, </applet> tags is displayed only in the browsers that do not support Java. Parameters can be delivered to Java applet by name/value pairs in the `<param>` tag.

The W3 Consortium has adopted a more general approach, which is described by Ragget (1996). This proposal for the future extensions to the HTML -standard defines a generic object tag:

```
<object
   classid="java:SomeJavaCode.class"
   height=300
   width=300
>
Your browser does not know how to exec Java applications.
</object>
```

This tag makes it possible to define the object to be included by URL-like syntax indicating the type of the object. If the browser does not support the object type, the contents between <object> and </object> tags is displayed instead. This definition includes all kinds of software components, programmed in arbitrary languages. The only limitation is the ability of the browser to run them.

4. Geographic objects and Java

4.1 Java as an object-oriented language

Java is an object-oriented programming language. All the generally accepted benefits of the object-oriented programming technique (data encapsulation, inheritance, polymorphism) are thus available. Java does not support multiple inheritance. Instead a similar functionality is provided by a concept called interface. Interfaces are like ordinary Java classes, but they only define methods without providing the actual implementation for them. Every object in Java class hierarchy can declare a specific interface. The code for the class must then contain implementation for every method in the interface. In this way a class can commit itself to a certain behaviour, which is not defined in the parent classes up in the object hierarchy. The flexible structure of the object definition can also easily encompass new multimedia datatypes. The methods needed to handle these datatypes can be defined as interfaces. Classes in different parts of the objectclass hierarchy may implement these interfaces, thus assuming behaviours independently of the traditional inheritance mechanism.

4.2 Transferring objects; Serialization and Remote Method Invocation (RMI)

One of the difficulties facing a programmer in distributed computing model is the need to transfer objects from one platform to another via network. A typical example is the communication between a server program sending geographic objects to a client, which takes care of the display and user interaction. One possible solution would be to transfer each variable separately, using a specially-tailored protocol. Java offers a more efficient solution called object serialization. In this approach a programmer can make use of an object stream, i.e. a communication channel provided by Java i/o-libraries, which facilitates coding of the object into a serial byte stream, and enables its transfer as a complete single entity.

Geographic objects can contain several different types of data: coordinates as floating point values, attributes in various datatypes, even images or other multimedia datatypes. From the programming point of view it would be rather cumbersome to implement transfer protocol for each of these components. Object serialization, together with automatic rebuilding of the objects in the receiving end of the communication channel, greatly simplifies the programming task.

The most typical use of serialization is in the remote object interaction. Remote Object Invocation (RMI) is the realization in Java language of the remote procedure call (RPC) mechanism found in other programming languages. The basic idea in RPC is to start procedures defined in a given program remotely, i.e. from another computer across network. The parameters for and return values from a remote procedure are typically objects, which are transferred through network by means of the serialization technique.

In addition to easy implementation of client/server -applications, RMI also facilitates the design of more complicated configurations. In RMI -environment each software entity is able to act as a server or a client, as seen appropriate by the designer. One widely discussed approach is the three-tiered programming model in which user interface, application logic, and database each form a separate entity in a distributed environment (Zhang and Lin 1996). Figure 2 illustrates an example of a three-tiered application model, which is easily realizable by RMI.

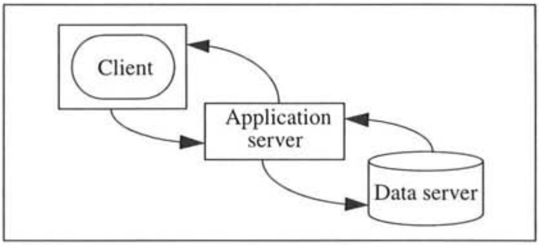

Figure 2. A three-tiered distributed application.

This model consists of a client module responsible for data display and user interaction, an application server providing functionality related to a specific application environment that is somehow related to geographic information, and a data server responsible for serving the data needed. RMI provides for a simple implementation of the dual role of the application server.

4.3 Inspecting objects; Reflection

In the current heterogeneous GIS environment it is important to be able to inspect a geographic object received through network connections. Pre-defining an appropriate communication interface for each imaginable implementation of a geographic object, and the functionality contained in it, is an impractical approach. The object inspection available in the Java Reflection API (Application Programming Interface) provides for the dynamic creation of the user interface for an individual object.

By reflection the browsing client can find out information about members (variables and methods) included in the received geographic object. The most important characteristics of the object's members are accessible through reflection: name and type of each variable, name and return type of each method. The parameter list (names and types) of the methods can also be constructed. Based on this information, the user interface for the object can be dynamically built up. This interface may consist of passive elements like attribute display lists (name, value) and active components like buttons to invoke object's methods (together with input fields to collect parameter values).

5. User interface and multimedia

5.1. WebTop GIS; a browser- based user interface

In this paper we apply the idea of WebTop into GIS environment. According to McNealy (1996), WebTop is a part of a system that allows us break the bond between the operating system, software application, and hardware so that users have safe and instant access to the network itself from any machine, using any operating system, at any time. By WebTop GIS we mean all elements described by McNealy, adapted to the user environment of GIS.

One possibility to implement interactive WebTop GIS is to utilize Java language. By exploiting the graphical capabilities of Java it is possible to create visual user interfaces as Java applets. An applet can be dynamically loaded into a Java-aware Web-browser, such as HotJava, Netscape Navigator or Internet Explorer, and executed as a local application, albeit limited by some security restrictions. The browser can thus be used as a platform for a new user interface, which is downloaded automatically via network. No plug-ins or help applications are needed; the only prerequisite being a Java-aware Web-browser. Bertazzon and Waters (1996) state that the management of geographic information in the Internet is difficult because of the heterogeneous computing environment. Java language offers a platform-independent, browser-based environment for creating user interfaces.

Java Application Programming Interfaces (APIs) contains various different graphical user interface (GUI) components. Abstract Window Toolkit (AWT) is the API for building the basic GUI for Java programs. It provides a set of ready-to-use user interface components, such as button, frame, panel, label, canvas and scrollbar, as well as basic tools for text handling and layout management. AWT includes also classes to make the interface user-friendly by using choice-lists, menus and checkboxes, and classes designed to make graphics rendering operations easier (colours, fonts, shapes, and images) (Nagaratnam et.al 1996).

Specialized, user defined control components can also be developed by writing appropriate code for display and event-handling of the component, extending a generic Java class. Application-specific responses for user interaction are defined by overriding event-handling for all GUI components. A major part of the processing can normally be handled in the client side.

Java supports such basic vector graphic operations as drawing of lines, open and closed polygons, arcs, rectangles and ovals. The missing capabilities include support for interpolated curves and variable line widths. A few image processing operations are provided: scaling, clipping and facilities for easy implementation of image filtering. The image formats currently supported include gif- and jpeg-formats. Also a support for simple audio files is provided by the applets. Additional image, audio, video and animation formats will be supported in future releases, described in the following as a part of Java Media APIs.

5.2 Multimedia objects; Java Media APIs

One of the goals of this research project is to develop methods for visualizing the multimedia representations of geographic objects in the interactive WebTop GIS environment. For example, buildings of cultural value may include image representations of their facades, or a central square may include voice representation in order to describe the traffic load at different times of the day. A couple of new APIs are being introduced into the Java programming environment, to support processes involved in the display of multimedia data.

Java Media APIs allow developers and users to take advantage of a wide range of interactive media on the Web. The Media APIs encompass these areas: Java 2D, Java Media Framework, Java Collaboration, Java Telephony, Java Speech, Java Animation and Java 3D. At the moment, the preliminary API specification for Java Media Player and the preliminary specification for the Java 2D API are available for review purposes (JavaSoft 1997). Also Java Telephony API is available, but not discussed in this paper.

The Java 2D API provides a framework for device and resolution-independent 2D graphics. It supports arbitrary shapes, text, and images and provides mechanism for performing transformations, such as rotation and scaling, on these objects. The Java 2D API also provides comprehensive text handling and colour support and enables vendors and application developers to support a wide array of presentation devices, image formats and encodings, colour spaces, and rendering techniques and effects.

The Java Media Framework (JMF) specifies a unified architecture, messaging protocol, and programming interface for media players, media capture, and conferencing. Java Media Player is part of JMF. It provides a platform-neutral framework for building media players. It is designed to support many media content types, including MPEG-1, MPEG-2, QuickTime, AVI, WAV, AU, and MIDI. Using Java Media Players, a programmer can synchronize and present time-based media from diverse sources.

The introduction of the new multimedia capabilities to the Java programming environment significantly simplifies the display of geographic objects with multimedia components.

6. The status of the project and conclusions

The experiences gained at the preliminary stage of this research project at the Finnish Geodetic Institute strengthen the assumption of Java's suitability for the implementation of a WebTop GIS -application. A simple object class hierarchy has been defined and a client/server -communication, based on RMI, has been established. The basic browsing operations have been implemented. These include: transfer of geographic objects from the server to the client, display of objects, zooming, panning, and selection of an individual object by a mouse click. An image related to the selected object can be displayed and a soundfile be played. A user interface for the object, based on the inspection by Java Reflection, can be dynamically constructed and displayed.

The new interactive WWW -technologies, of which Java language has been selected as an example, support the sudden emergence of the Web as a primary platform for disseminating geographic information to a wide audience, in an intelligent, object-based form.

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MAP-ORIENTED MARS DATABASE

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The conducted analysis [1] of existing Database (DB), namely: Planetary Data System (PDS), Centre of Mars Exploration (CMEX), Malin Space Science System (MSSS) and other has shown clearly, that in general they are represented by block of programs for educational and advertising purposes oriented on separate mission or on the only scientific direction. As a rule these Dbs are constructed by using a program of hypertext visualisation [2], but they do not provide a possibility of detailed work with different maps of Mars. From our point of view the existing Dbs are not universal and do not represent the complete knowledge about planet in a whole for today. Therefore it is useful to develop a Mars planet DB with a map-oriented data access. This DB includes the following main parts: brief-information, scientific-experimental (planet observations results with data from various missions and data from the Earth observations, scientific investigation results: theories, hypothesises, models and description of existing maps for the planet) and cartographical DB.

This idea is now realised on a base of Space Research Institute by Russian Academy of Science. This work describes cartographic part of DB. As an impulse for constructing of map-oriented DB serves a necessity to make possible an operative selection of perspective regions for explorations during space mission program, and also a demand and perspectivity of estimation for given region investigations by planning of experiments collection.

The problem of perspective region selection as itself is connected with problem of total planetary surface surveying. It is clear that making a high resolution survey (10 m/pixel) for the whole celestial body is very difficult especially because of safe-keeping and transmission of such information volume and also it is not necessary for scientific purposes. This survey must be local as for selected typical regions, so for selected anomalous ones.

At the same time only after orbit correction we receive an information about the width (~500 m) of strip area for every turn. Cartographical DB provides a possibility to select interesting regions along a final orbit in a very short time.

Two maps of scales 1:50 000 000 and 1:5 000 000 are used as a cartographical bases for this DB. The work with cartographical DB can be separated into three main stages.

Stage I. Working with small scale map

The maps of scale 1:50 000 000 are designed for selecting a region, that is interesting for more detail studies.

A user starts the work from visualisation of base map on the screen. He can select one of the following types of base map (scale 1:50 000 000): mosaic map, shaded relief map. The base map can be superposed by information layers, for example: coordinate grid, feature names, relief by signatures, topographic map and orbits of different missions (Figure 1). A user can put one or all pointed layers according to his intention. The following step is to superpose cartographic layers corresponding to various types of maps. Cartographical DB will consist of more than twenty cartographical layers. That layers can be superposed in any combination. A user observes areas along given turn and estimates them from point of view of different characteristics: it can be geology, mineralogy, morphology (Figure 2), atmosphere or any other characteristic. And also he can make their joint estimation. By this means he selects a zone of interest and zooms it for any cartographical layers or goes to Stage 11. A series of cartografical layers are presented in following list. This list will be given below.

1. Thematic maps
   1.1. Geology
      1.1.1. Geologic map
      1.1.2. Tectonic map
      1.1.3. Mineralogical map
   1.2. Geophysics
      1.2.1. Geoid altitude map
      1.2.2. Seismic activity map
      1.2.3. Gravity anomaly map
      1.2.4. Magnetic field map
      1.2.5. Hypsometric map
   1.3. Mars surface's physical properties
      1.3.1. Albedo map
      1.3.2. Surface's thermal properties map
      1.3.3. Colorimetric properties map
      1.3.4. Polarimetric properties map
      1.3.5. Chemical soil composition map
   1.4. Morphology
      1.4.1. Craters distribution Map
      1.4.2. Valleys distribution map
      1.4.3. Rimas distribution map

Figure 1. Working with a base map of small scale (example of screen).

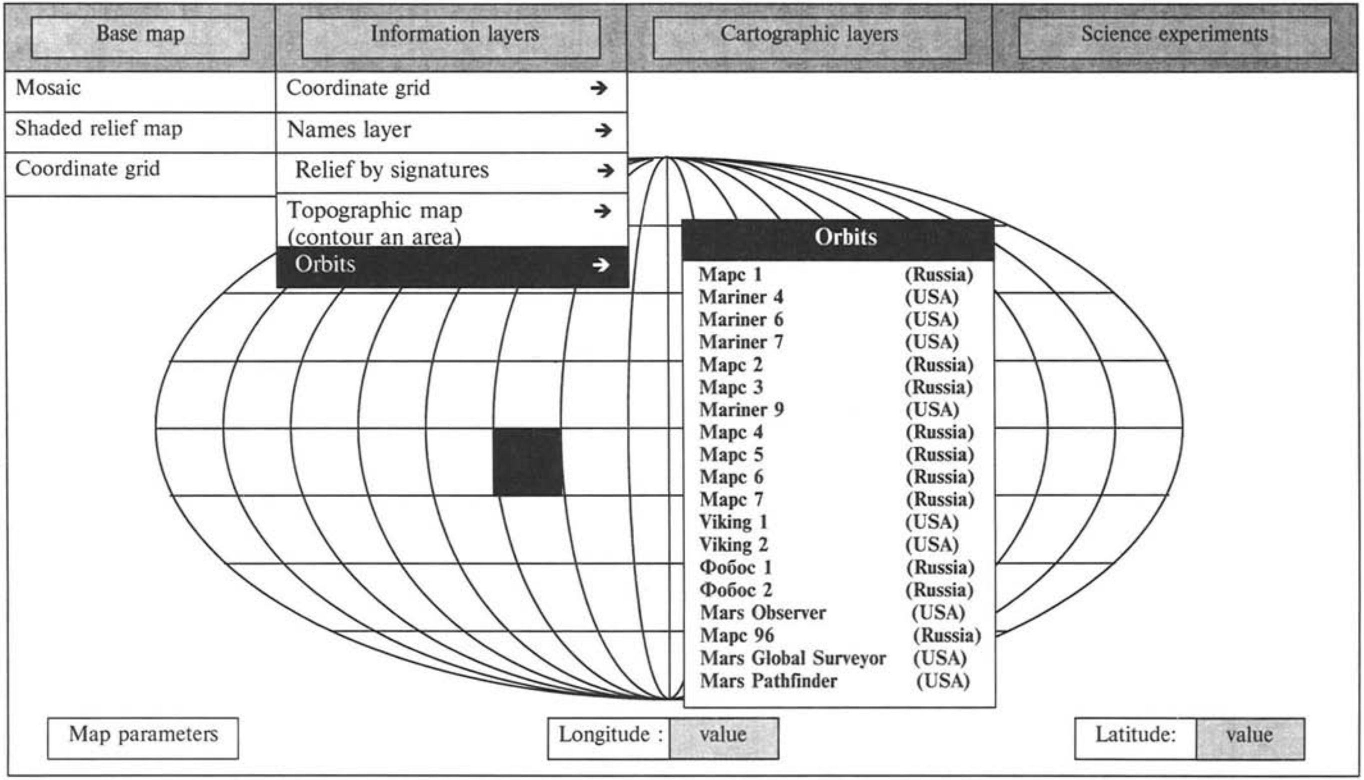
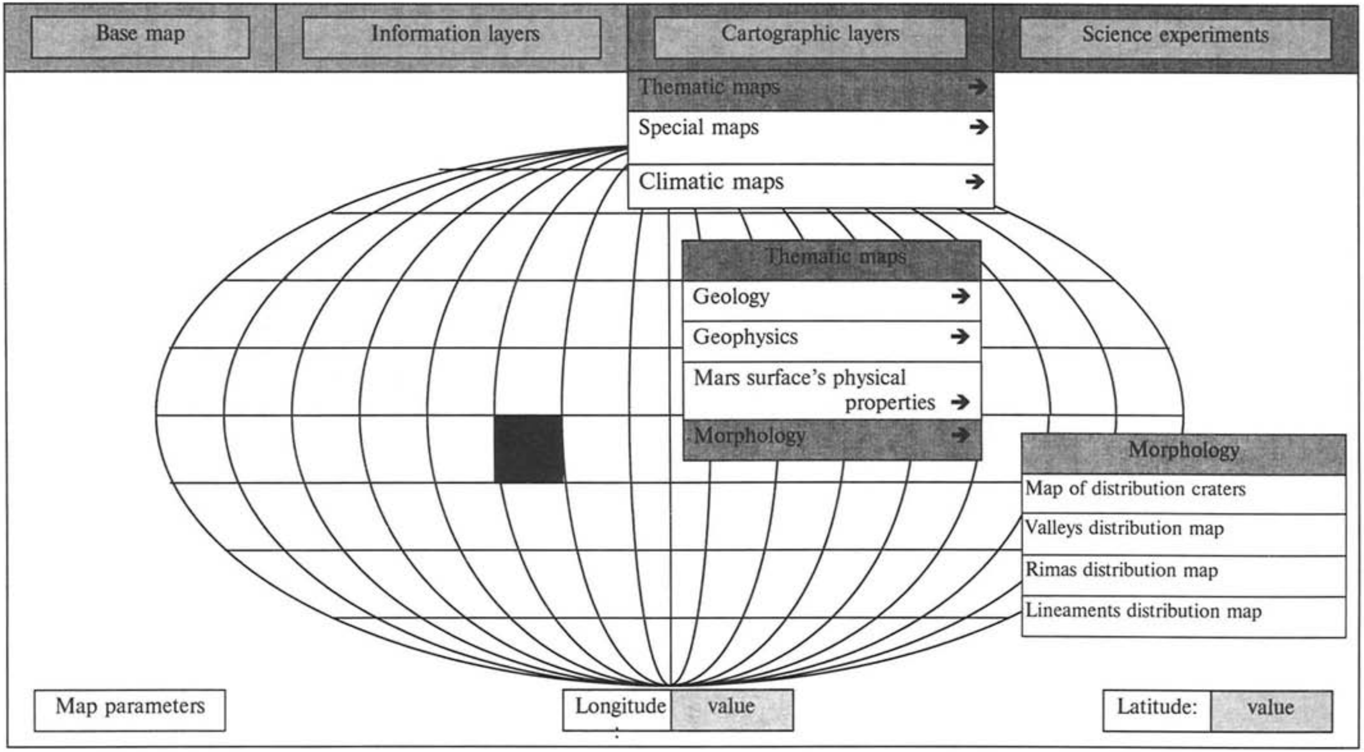


Figure 2. Working with cartographic layers of small scale map (example of screen)



1.4.4. Lineaments distribution map
2. Special maps
    2.1. Region's slopes map
    2.2. Map of surface roughness
3. Climatic maps
    3.1. Map of wind directions
    3.2. Temperatures season variation map
    3.3. Pressure season variation map
    3.4. Map of cloudiness
    3.5. Map of atmosphere dusting

It must be remarked, that for easy searching, selecting interesting areas and for convenient switching to second map a base map is devided into parts corresponding to sheets of 1:5 000 000 scale map. Terms "a map part" and "area" will mean a part of 1:50 000 000 scale map, constrained by 1:5 000 000 scale sheet. So, estimation will be done in three stages by areas along created orbit (width of covering is 500 m).

Stage II. Working with large scale map

On this stage a user can work with several larger scale maps by the same way as in the Stage 1. But the layers quantity in this stage is more less. A rectangle area named section is displayed in 1:5 000 000 scale. For more detailed and visual acquaintance with selected section and also for convenient work (later on) with images, a sheet of 1:5 000 000 scale map was devided into 9 parts along coordinate grid. As a result a user work exactly with 1/9 part of the sheet.

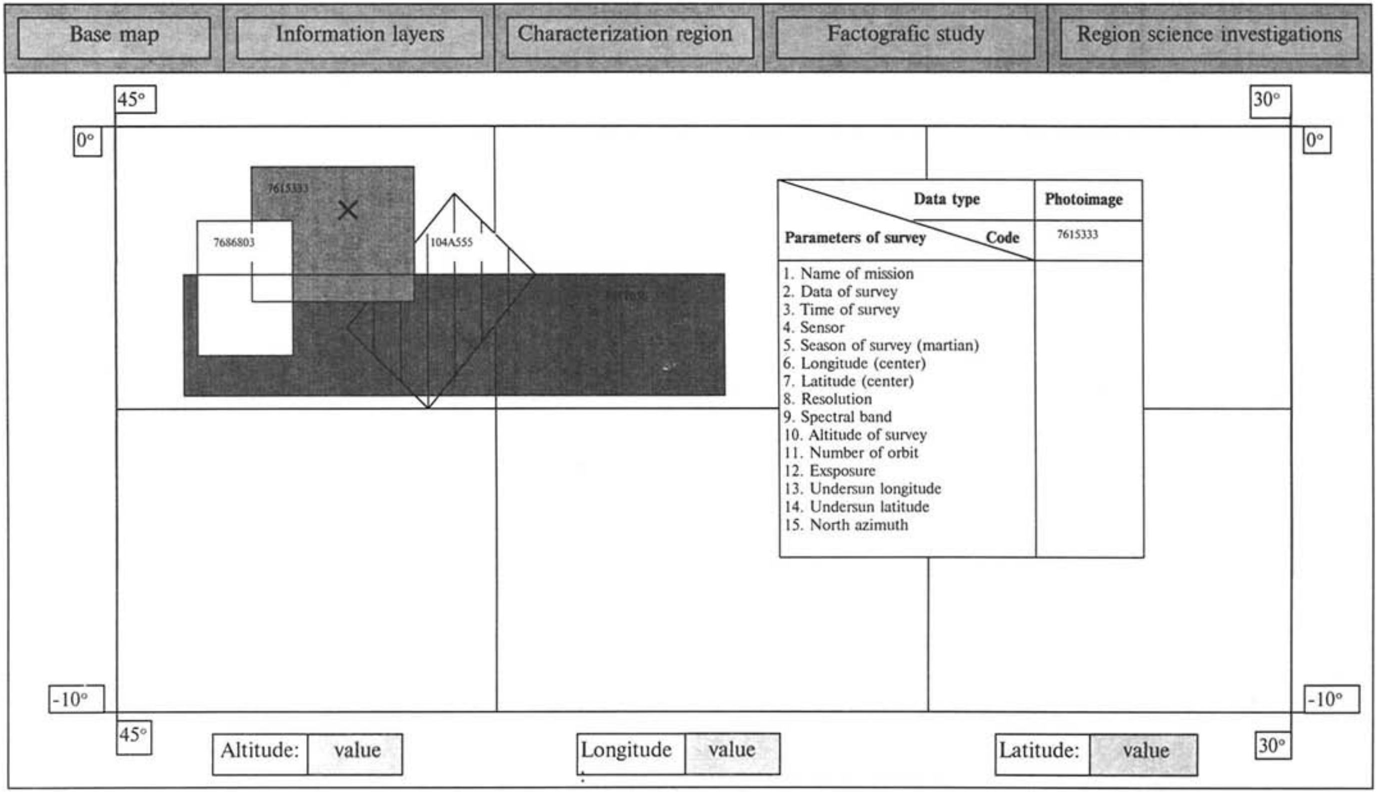
Each sheet of 1:5 000 000 scale map is provided with detail information such as: common description of an area, typical peculiarities of relief and their brief description, geohistorical reference. Another possibility is working with images from different missions. A user can select one or several missions and their experiments and than display boundaries of images on the selected map. A user can see the image and its parameters, if he click the image (Figure 3) Besides, it is possible to receive an information of all kinds of scientific experiments and their results, to acquaint with forecasts about perspectiveness and possible scientific interests presented by this area.

Stage III. Analysis of Received Information

Analysed of the set of information received on the previous stage, user will realise depending on the initial targets. Results of analysis have be either a scientific character or an applied interest.

In a first case it is a construction or control of model, theory, hypothesis in any field of knowledge or on the juncture at science of interests.

Figure 3. Working with images on the large scale map (example of screen)



In a second case it is a conclusion about necessity (if there is no such one) in conducting observations of given area [3]; about necessary parameters of survey (such as spectrum range, resolution, season and so on), select survey equipment and necessity in attaching other instruments included in payload.

The idea presented here is under design and possibly, will stand some changes and additions.

A similar structure of cartographical DB is thought to be easy in use, flexible in getting changes and improvements in its structure, rapid in searching necessary characteristic and it will provide a possibility of all round estimation of given area.

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COMPLEX MARS ATLAS PROJECT

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Since in August 1996 a new data have appeared concerning the existence of organic life on Mars the efforts to prepare Mars expedition will become more and more intensive. Among other problems the problem of choosing a region for the first expedition landing is one of the most urgent questions. The Complex Atlas of Mars can play an important role in the decision making process because all knowledge about Mars will be in it systemized on an up-to-date level and this information would be possible to analyze for a detailed elaboration of the projects.

Before we shall describe the conception of Complex Mars Atlas it is useful to make some remarks concerning modern state of information representation by means of Atlases in general and especially for planetary exploration results. At first it is to underline that the tendency of changing Atlas traditional structure and form is now very clear. Today the cartograthic atlases include not only various kinds of geographic, thematic and specific maps, but also a lot of tables, pictures, scientific data and detailed text with some explanations. It seems to us very useful to bring such a method in the cartographic representation of planetary investigation results. Till now we have for some planets and their moons the photographic atlases with different collections of surface images or cartographic ones , but the last usually consist of reduced sheets of any map at scale 1:5 000 000.

Today it is clear that the systemness and complisity must be used for planetary atlas cartography. Here it is possible to define three main types of these atlases, namely

1. Creation of atlases including series of original images of celestial body surfaces; the same series, but with improved images by means of computer corrections and at last these images with printed cartographic grid.
2. Creation of complex atlases for various celestial bodies with up-to-date state of knowledge.
3. Creation of complex atlases for some groups of celestial bodies (terrestrial planets and their moons, moons of giant-planets and so on), which will give a possibility to analyze represented information with the methods of comparative planetology. In this case it must be used results of all kinds of survey (photographic, television,

radar, IK- and UF- bands) and also different methods of data representation. It means not only cartographic methods.

These three types of complex atlases have a good correlation with three chronological phases of data receiving for planetary mapping. Really the atlases with original images correspond to the first phase of celestial body exploration, the complex atlases giving the whole information about definit planet or moon - to the second phase and the third type of atlases characterizing definit stages of origin and evoluation of Solar System - to the third phase.

Relative to Mars we have now only the first type of atlases. It is represented by collection of Mars images from Mariner 9 and Viking missions and by reduced sheets of Mars map at scale 1:5 000 000 (30 sheets in the whole). published as an album. For Mars moons we have the same production. But on our opinion it is time to make a project and to prepare the Complex Mars Atlas.

Such an atlas can consists of three main parts published separate. Namely, the first part is the review one containing the general information about the planet as a whole and small-scale maps. the second part should be dedicated to the information about the important regions and the third one - to separate local sites (both reference and anomalous). Preliminary the first part will include the following sections: introduction with schemas of photographic and cartographic study of the planet, geographical maps (surface map, basis map for thematic mapping and hypsometric map), various general thematic maps (geophysical, geological, morphological, geochemical, climatological, maps of the surface properties) and others. Some additional information on the regional level using middle-scale maps will be collected in the second part. The most perspective for the exploration of local sites will be represented in details on large-scale maps in the third part with description of main relief features and area peculiarities.

To present the surface of celestial body as a whole in small-scale maps we usually use classic pseudocylindrical equivalent projections. The Sanson (sinusoidal) projection and the Molveide (elliptical) one are concerned first of all. The Sanson sinusoidal projection and its modification (Ekkert projection) are convenient for the presentation on the near-equatorial zones.However from the 60 degrees latitudes to the poles there is an abrupt increase of the scale distortion. Consequently it is preferable to use the elliptical Molveide projection for the presentation of the surface of the body approximated by a sphere as a whole. This projection provides surface presentation that is easier for interpretation. Therefore Molveide projection was chosen to show the entire Mars surface in a single sheet without breaks. This basis map has a scale of 1:40 000 000.

The maps will be plotted in separate sheets collected in a portfolio. Numbering of sections provides for a possibility of adding sheets in a section as far as new information becomes available. That is of a special importance for the sections containing various thematic maps.

Last time Russian Mars 96 mission started in November 1996 was unsuccessful, but now two USA stations , namely Mars Surveyor and Mars Pathfinder continue their way to Mars and it is to hope, that in the next summer we shall have a new Mars data. Therefore it is necessary to be ready with Atlas project and program.

We suppose, that such an atlas will be important for different kinds of users, namely for specialists planning space missions, for education purposes (for students, pupils, amateurs), for scientists of closed up science branches.

MONITORING OF INFORMATION LOSS IN SATELLITE IMAGES DURING CARTOGRAPHIC GENERALIZATION PROCESSES

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Abstract

In this paper, two methods of numerical generalization of rasterized images have been tested. The test site is located in the Lannemezan region, in southwest of France, where principal landuse classes are forest and agricultural fields. Analysis of both methods tested on two SPOT-HRV images demonstrate how processes modify the spatial structure of the image. Loss of information is assessed from statistical and cartographical analysis. Structural generalization of the image (Woodcock et Strahler, 1987) and the categorical amalgamation (Wilkinson's algorithm, 1993) show several thresholds related especially i) to the quality of the classified image, ii) to the methods of digital generalization used and iii) to the structure of the landscape. The consistency of results during these processes is often proved with comparison with the Digital Elevation Model.

1. Introduction : central problem and study area

Since synthetic works have been published by Laubenfels (1975), Ozenda (1986), Rouleau (1991), Küchler (1967, 1973), Küchler & Zonneveld (1988), technics of vegetation mapping have improved thanks to recent developments of tool performance in processing speed and geometrical accuracy. These tools essentially include different types of sensors, processing operations and Geographic Information Systems (Dubois & Blasco edit. 1993, Blasco, 1996).

Among present non resolved problems remains the evolution of mapping information during scale transfers as well as generalization operations. This is confirmed in cartography as well as in any environment and ecology sciences (Beck 1997).

In the particular case of digital mapping of ecosystems and landscapes, the evolution of methods and technics tends to copy, in an automatic way, the perception of the skilled cartographer who extracts essential information from the image. Nevertheless, the individual judgement is very subjective. Because of this, recent works are moving towards the understanding of information supplied in any pixel or groups of pixels when image processing is in progress. This would allow the establishment of process operations and the reduction of intuitive decisions of cartographers. These works are essentially based on digital mapping using satellite images.

These researchs, both technical and epistemiological (Brassel & Weibel, 1988, Goffredo, 1995, Baize & King, 1991, Jaakkola, 1995) have emphasized that numerical generalization can have disadvantages as important as the subjectivity of the traditional photointerpreter.

Mac Master & Shea (1992) were concerned that several decades of cognitive research would be required before understanding and reproducing visual rules used by skilled cartographers.
With present scientific and technical abilities, generalization operations of raster data seem compulsory when it is needed :

- i) to eliminate not necessary detail for a particular thematic mapping,
- ii) to reduce the volume of information,
- iii) to change the scale of a map or the image resolution in order to give on one hand, the consistency of geographic location of different patterns of the image, and on the other hand, the legibility of the information for an easy, direct and fast understanding.

In cartography, everything is a question of scale (Woodcock & Strahler, 1987). When present operations of digital generalization focus on the objects of nomenclature defined like a type of forest, or agricultural field ; invariably it results in a modification of the original image which will be reorganized and homogenized to the detriment of its initial accuracy. Non essential patterns will be automatically eliminated and pixels with radiometric and geographical similarity will be regrouped for the benefit of more clarity.

In order to give a more precise position of the test site without details of ecological, floral and agronomic properties (map of vegetation at 1/200 000 scale by Gaussen & Rey, 1947), it is located in the South of France, on the Lannemezan plateau (Northern side of the Pyrénées). The geomorphologic situation of the valleys are very conspicuous because of their fan-shape. Globally, the relief shallow forms (between 100 and 120 meters unlevel) make easy works of image processing and mapping. It can been seen that strip-shaped forests are located essentially on western hillsides with regular and structured agricultural fields located at the bottom and on eastern hillsides.
This test site with its characteristic landscape represents an additional element indispensable in order to display in evidence the thresholds of generalization methods.

2. Materials and methods

2.1 Data at disposal

The SPOT/HRV data used are acquired in spring and summer 1989 (KJ 40/263 25th April and KJ 41/263 9th August). The test site is an extract of these images (1020x1020 pixels, around 400 km^2). The first image processing operation was the supervised classification (maximum likelihood algorithm), with only eight landuse classes. Types of crops have been simplified into winter crops (cereals, colza) and summer crops (sunflower, maïze and soyabean).(Table n°1).

	Winter crops	Summer crops	Grassland	Urban	Forest	heath	water	non classified	**Total**
Wint. crops	1 599	340	947	8	40	37	0	236	**3 207**
Sum. crops	132	8 307	630	30	122	110	0	555	**9 886**
Grassland	1 152	720	11 005	144	1 066	1 673	0	276	**16 036**
Urban	0	13	36	2 037	0	74	0	150	**2 310**
Forest	114	333	617	32	24 993	960	0	917	**27 966**
Heath	252	127	701	6	1 114	999	0	178	**3 377**
waterbody	0	0	0	5	0	0	996	34	**1 035**
Total	**3 249**	**9 840**	**13 936**	**2 262**	**27 335**	**3 853**	**996**	**2 346**	

Table n°1 : confusion matrix for Lannemezan (truth : 78,25 %)

2.2. Structural generalization (Woodcock & Strahler, 1987)

This method executes a change in the pixel resolution, a resampling of the image with pixels of different resolution compared to the reference image. The number of pixels in the new image is reduced related to a chosen factor. The value of the most frequent pixel (modal value) in a moving window will be the single value in the resultant image. It will represent geographically and categorically all the values of this window. This process exagerates the spatial and landuse organization especially when the resampling factor is high. But with such a generalization process, dominant classes will be largely promoted compared to the smaller represented classes. Thirteen new images with pixel resolutions varying from 40 to 320 meters have been made and tested.

Procedures of structural generalization have been applied over two types of data :

- any of the SPOT/HRV image channels of the test site for the local variance calculation
- and the classified image in order to monitor pixel movement when new images are compared with the reference classification.

2.3. Categorical amalgamation (Wilkinson's algorithm, 1993)

This method is based on the improvement of classifications of satellite images. Classified images are often considered as spatially « noisy ». For Wilkinson, this noise is the result of both a misinterpretation of the classification and the complexity of the landscape. A simple technic like major filter helps greatly the clarity of classified image when used iteratively. The single problem is that dominant classes are promoted statistically and cartographically compared to the smaller represented classes.

Wilkinson succeeded in making good this disadvantage with his algorithm detailed in two stages :

- Iterative Major Filter (IMF), and
- Iterative Reduced Classes Growing (IRCG) which takes into account the pixel numbers and the weight of the classes. It is set up on the statistics of the reference classification, considered as the perfect statistical data towards the new image tends to come.

The parameters modified are the size of the windows and the numbers of iterative passes in both stages. The processes of the categorical amalgamation are applied only on the classified image.

2.3. Evaluation of the results

The main action of the generalization operations is the change in pixel attribution. A visual mapping homogeneization of classes which also has consequences on the distribution of the pixel numbers in any class with statistical homogeneization.

Pixels can be separated into two groups : pixels which do not shift and pixels which shift classes. This is described as pixel movement during digital generalization processes.

2.3.1.Local variance

This measurement has been calculated for use on any channel of both satellite images of the test site but only in the case of structural generalization.

Woodcock & Strahler (1987) demonstrated that local variance works like outline detectors, a good way to better know the spatial structure of the image.

This value is both related to the size of the patterns in the scene and to the spatial resolution. Geographical consistency needs to be taken into account when generalization processes are applied. For Mering (1990), the maximum value of the local variance (the peak of the curve) shows the thematic resolution, the one which is the most adapted for the analysis of a particular theme.

2.3.2. Statistical analysis.

It is essentially based on the pixel population of the classified image from SPOT data. The new statistical distribution of the landuse classes is calculated at any stage of generalization and for both methods used.

Landuse classes		Nb of pixels	%
1	Winter crops	55 038	5,3
2	Summer crops	150 634	14,5
3	Grassland	387 160	37,2
4	Urban	14 930	1,4
5	Forest	309 674	29,8
6	Heath	69 087	6,6
7	Waterbody	328	0.0
8	Non classified	53 549	5,2
	TOTAL	1 040 400	100

Table n°2 : distribution of the pixel population in the reference classification of the test site.

2.3.3 Cartographic analysis

This analysis is essentially set up on the elimination, the emphasis, and the form transformation ; then finally the whole modifications of the local composition of the image. Its main interest remains in mapping performance and its aim lies in the ability of the human eye to analyse the different stages of the generalization. This is more a qualitative approach. Both landuse classes **forest** (class 5) and **summer crops** (class 2) provide the qualities to give a structure, to form a sort of spatial skeleton of the landscape with their strip-shaped forests and regular fields of summer crops located bordering the forests in a complementary way.

The outlines of these classes coming from the reference classification (20 m SPOT pixel resolution) are vectorized and overlaid onto any image created during generalization operations for both methods in order to make the analysis easier.

2.3.4. Digital Elevation Model

Relief is one of the components of the structure of a geographic area (Brossard & al, 1994). Using D.E.M data is an additional item which allows the improvement in the definition of thresholds set up with statistical and cartographic analysis. One should be aware of the most factual dimension in the perception of the landscape.

3. Results

3.1.Local variance

Woodcock & Strahler have essentially worked on the red channel (0.61 - 0.69μm), but results on the other channels give interesting information. The area of the test site can be considered as a complex model of scene (several classes have various field sizes). The analysis of the local variance values at different periods of the vegetation cycle brings material on the spatial structure of the image. And the analysis, channel by channel, shows that there is not only a single value, considered as the thematic value (Table n°3). We have to be aware of a large interval between 80 and 200 meters (between 4 and 10 times the SPOT pixel size).

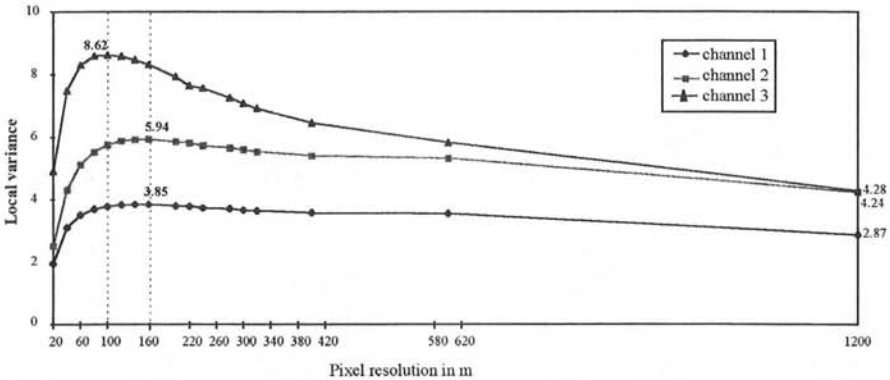

Table n°3 : Local variance over the 3 channels of the summer SPOT image.

Note : Three values have been added (400, 600 and 1200 m) in order to give a better curve of local variance.

3.2. Statistic analysis

For the structural generalization, the dominant classes in the reference classification are well distributed all over the image. **Grassland** (class 3) with more than one third of the initial population ends up with almost half of the image factor 16 (320 m pixel size). When **forest** (class 5) with more than a quarter at the beginning will represent more than a third at the end. The other six classes share the remaining third with only a sixth of the population in the last image (320 m pixel size).

For the categorical amalgamation, such differences cannot be shown. Classes have populations which remain very close to the ones in the reference classification. There are neither dominant classes which take all the place, nor smaller classes which disappear.

For **forest** (class 5)

In the structural generalization, more than 75% of the pixels which did not shift remain in the image factor 16 (320 m pixel size). After processes have been applied, four steps related to the structure of the parcels in the image have been emphasized and two are similar to the ones of the local variance.

For the categorical amalgamation, 72% of the pixels did not shift in the last generalized image, three steps are found related to the change in the window size essentially due to the IMF process.

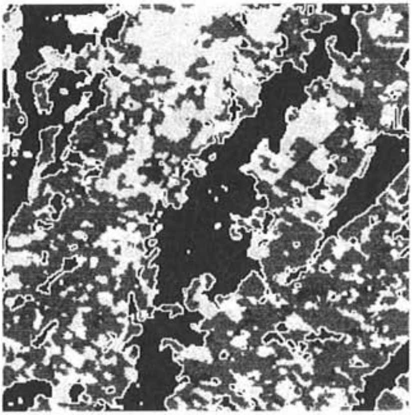

Fig.1.a. Reference classification
with outlines of forest class.

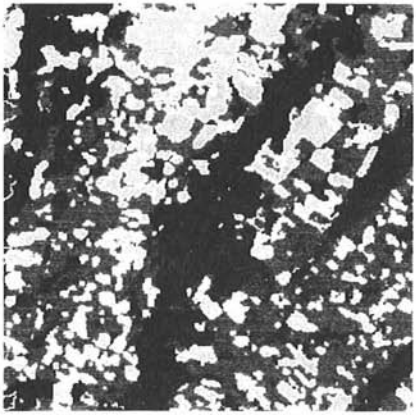

Fig.1.b. Reference classification
with outlines of summer crops class .

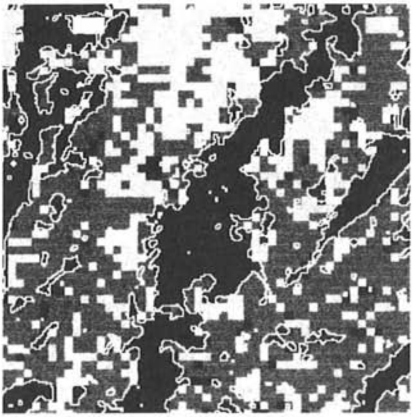

Fig.1.c. classification (Woodcock & Strahler),
100 m pixel resolution, with reference outlines of forest class.

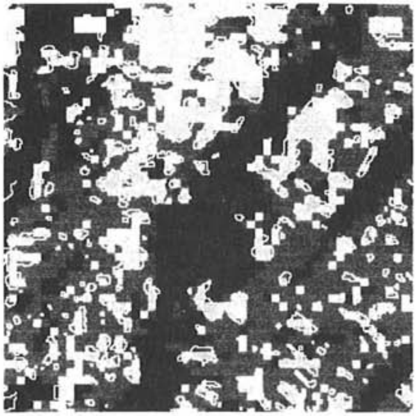

Fig.1.d. classification (Woodcock & Strahler),
100 m pixel resolution, with reference outlines
of summer crops class.

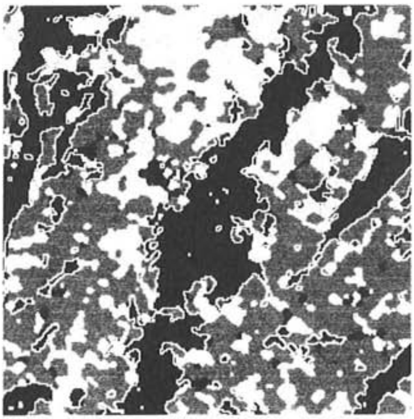

Fig.1.e. classification (Wilkinson), IMF window 5 x 5.
with reference outlines of forest class.

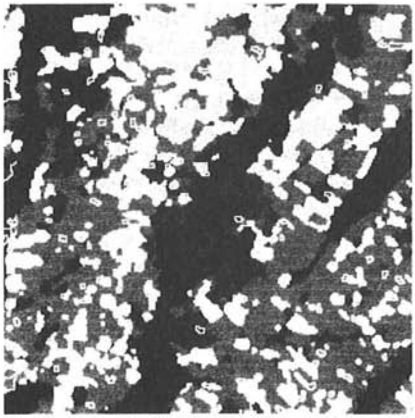

Fig.1.f. classification (Wilkinson), IMF window 5 x 5.
with reference outlines of summer crops class.

- winter crops
- summer crops
- grasslands
- forests
- heaths
- non classified

Figure 1. : Examples of cartographic results obtained
with the both methods of generalization.

For **summer crops** (class 2)
In structural generalization, summer crops suffer large losses, only 42% of the pixels did not shift in the image factor 16 (320 m pixel size). It means that more than one on two pixels is not at the right place and/or from the right landuse class, statistically, this is not acceptable.
A statistical threshold of 60% has been set up : the image factor 8 (160 m pixel size) will be the last image tested for summer crops.
In categorical amalgamation, only 47% pixels remain in the most generalized image. There is a statistical threshold, the WIL5 image (IMF window 5 x 5) will be the last one analyzed (still 60% of the pixels which did not shift).

3.3. Cartographic analysis (Figure n°1)
The generalized images have been analyzed cartographically in order to display in evidence, helped by the human eye, the modifications visible on a map. Therefore with structural generalization, forests and fields have strong stair boundaries compared to categorical amalgamation where limits are more rounded and fields more regrouped.

For **forest** (class 5)
For structural generalization (Figure n°1.c), the information loss is characterized by the change in the spatial structure (density in the larger forests and loss of the smaller ones). The size of enlarged ones varies from 0,5 ha to 5 ha, with lost ones varying from 0,04 ha (SPOT pixel) to 10 ha.
For categorical amalgamation (Figure n°1.d), the size of enlarged forests goes from 0,5 to 8 ha and lost ones from 0,04 and 15 ha.
Similar step changes as steps emphasized in statistical analysis have been set up.

For **summer crops** (class 2)
For structural generalization, (Figure n°1.e), the major trend is the loss of smaller fields with their size varying from 0,04 ha to 3 ha.
For categorical amalgamation (Figure n°1.f), the same sizes have been defined.
Similar steps as steps emphasized in statistical analysis have been set up.

Discussion and conclusion

It has been demonstrated in this study that the spatial image processing and generalization methods when strictly controlled, provide a very useful mapping tools.

Finally the generalization methods, statistically and cartographically analyzed constitute approaches to promote the perception of different types of landscapes in high spatial resolution images.

The generalization processes and the use of the D.E.M (slope and aspect) force to situate the content of the image in any of their determinent geomorphologic components. These are essential elements for changing a strictly radiometric approach of the image (pixel-to-pixel) for a more combining approach (for the landscape) set up on statistical and specific regroupings of pixels in thematic patterns.

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MULTI-SCALE LAND COVER DATABASES BY AUTOMATIC GENERALIZATION

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Abstract

The problem of generalizing spatial data is studied in the context of multi-scale land cover maps. A review to the theory behind the used automatic generalization method is given. Common requirements of producing multi-scale land cover databases are given. The case study includes the implementation of a raster modelling for the land cover generalization. The case study is related to the conversion of a detailed land cover database of Finland to a series of generalized land cover databases. All input data in different formats is rasterized and combined to a detailed land cover with a very small minimum feature size. Then the developed method automatically generalizes the coarser land cover databases. The accuracy tests confirm that the optimal solution can fulfill the manual land cover quality specifications.

Introduction

The basic cartographic problem of generalizing maps is studied in the context of producing multi-scale land cover data. Cartographic mapping in overall is a process that attempts to generalize, and thus simplify, complex world phenomena continuously variable in space and time. Maps aim to identify features which are supposedly uniform in content. In overall, the rules of generalization depend upon complex interactions between the size and patterns of ground features, the user objectives, the operator, and the input and output information scales and formats. This research aims to build deeper understanding of generalizing land cover features, and of using generalized data in conventional maps, geographical analysis, and spatial statistics.

Large amounts of digital data produced by using satellites, Global Position Systems, and other new mapping methods have emphasized the need for linking and joining existing land cover datasets of different sources, content and scale. The GIS community requires the possibility of navigating dynamically from one scale to another scale automatically. In addition, the duplication of efforts that occur in land cover map series, as well as inconsistencies which may arise through separate processes could be avoided by automatization (see Müller et al. 1995). There is increasingly wider agreement that some of the different land cover projects should be brought together so that e.g. the separate mapping efforts in Europe should be merged with automatic generalization methods. It also helps us to understand the usability of different land cover mappings in various applications, and to update the different maps more regularly and consistently.

Methodology

Generalization has received more and more interest in cartographic research. Generalization may be viewed as an interpretation process which leads to a higher level view of some phenomena, looking at them 'in a smaller scale'. Also, generalization can be viewed as a series of transformations in graphic representation of spatial information, intended to improve data legibility and understanding, and performed with respect to the defined end-product. Automatic generalization can be defined as the process of deriving a less detailed (small scale) data set from a detailed (large scale) geographic data source, through the application of spatial and attribute operations (Jaakkola 1995a).

Generalization is one of the most challenging aspects of automating maps and geographical information production. Most of the recent research in this field has concerned with line simplification or smoothing in a vector environment (e.g. McMaster & Shea 1992). Also, there is a group of modelling the knowledge for generalization, with a aim to transfer the knowledge 'skill' of a holistic manual process to the digital environment (see Richardson & Muller 1991, Lee 1993). On the implementation side, the automatic generalization systems for land cover features have been proposed e.g. by Goffredo (1995), which includes low-level and high-level generalization using both raster and vector domain procedures. Other vector domain proposals for automatic generalization have been given e.g. by Fuller & Brown (1994). Schylberg (1993) describes a new approach to generalization, namely an object-based raster generalization. Eventually, the automation of generalization will lead towards a new way of compiling map databases at different scales (Jakobson 1995, Kilpeläinen 1995).

The most significant difference between manual and digital generalization is that the manual process is holistic in its perception and execution. In comparison, the digital generalization process operates much like the finite logic of a serial computer, manipulations are treated independently, and applied in a predetermined, sequential fashion. (McMaster & Shea 1992.) This is the reason why the modelling of land cover generalization in this research refers directly to the data transformations based on different database definitions on different scales. The database descriptions of the input data and of the CORINE land cover output, i.e. the definitions of features, the desired minimum accuracy level, and the semantic relations of the features have been available. They include geometrical minimum dimensions of feature size, shape, and distance between features, and also the priorities 'semantic relations' within hierarchical classification (Jaakkola 1995b). Thus, in the generalization modelling we have analysed and extracted the data models of different scales, used the database descriptions as parameters of the change between different scales.

The modelling of the generalization processes has been using a raster-domain modelling language called the Map algebra. The concepts of operations are adopted from the generalization literature (Aasgaard 1992, Grünreich 1995, McMaster &

Shea 1992, Weibel 1995, Ruas & Lagrange 1995) by using techniques originally invented by Schylberg (1993). I have partly simplified, partly extended these methods, and combined these operations in a more faster and easily modifiable manner. The great majority of generalization research is mainly dealing with vector-based methods, thus the operators used in the raster generalization have to be defined again. In the generalization, there are two types of operations, namely attribute and spatial operations (Jaakkola 1995a, 1995b). One attribute operation has been used in the generalization of land cover data, namely reclassification. Seven spatial operations have been used in the generalization of land cover data, namely resampling, aggregation, merging, amalgamation, exaggeration, smoothing, and simplification. Only simplification operates in vector domain (TABLE 1).

TABLE 1. The developed automatic generalization operations in the order they are normally executed.

Operations	Domain	Parameters
reclassification	raster	classes included
resampling	raster	pixel size, filling method
aggregation	raster	minimum distance between features in same class
merging of heterogeneous features	raster	classes included, and percentual limits for shares of different classes
iterative amalgamation	raster	minimum size and width of features
exaggeration	raster	minimum width, and size of features or parts of features
smoothing	raster	minimum width of inlets, outlets in features
simplification	vector	minimum distance between feature border points

Requirements of multi-scale land cover data

There are certain the general requirements for generalizing multi-scale land cover databases. We may set conditions for the input data, output land cover, the required usage of the data, system requirements, and operational requirements for modelling land cover generalization. The system and operational requirements are easy to overcome, since with a standard platform and raster based GIS we may do all the necessary generalization operations. The role of user is more complicated, and deserves more profound treatment than in here (see João 1991). We may then concentrate on land cover input and output datasets, because not in all cases we may automatically derive the coarser land cover databases through the application of generalization operations.

Since the developed automatic generalization procedure operates in raster environment, the input data requirements have to be specified. The method assumes that all input data is first rasterized to the same pixel size. Therefore, as with the Finnish data, first some of the input data in vector format have to be rasterized. In GIS the raster-vector conversion is nowadays quite simple and self-evident conversion where also the identity of classes and its attributes may be reserved.

Also, when converting different datasets together, we have to consider the accuracy requirements. The positional accuracy requirements are the most obvious. Generally the datasets should be of equal positional accuracy of better than the pixel size. If the output land cover data is considerably generalized the need for positionally accurate data could be relaxed, e.g. for CORINE land cover the requirement is 75 metre, 3 pixels. In overall, the positional accuracy of completely automatic generalization in raster environment is easier to keep in control than in manual procedures, and small positional errors are often removed during the generalization procedure. The positional accuracy varies also across the classes and areas, noting the spatial and attribute differentiation (see Jaakkola 1994), and therefore it is related to attribute accuracy.

The tested attribute accuracy of multi-scale land cover databases is highly dependent on the input data quality. The large erroneous features are kept or even enlarged during the generalization procedure, although fortunately the small ones are normally removed. Also, by the definition the large scale land cover features include the features smaller than the minimum feature size, which makes it difficult to test the error rate by simple point count. The generalization reduces the complexity of the data structure and adds heterogeneity to the database. The quality is always deteriorated in favour of simplicity and legibility. Most of the quality assessment procedures do not take this generalization level into account. Therefore we have to understand that the tested error rate in the generalized database includes both the degree of generalization and the real error, the bias in summary measures and unintended positional and attribute errors produced by generalization (Jaakkola 1994).

The consistency is related to the attribute accuracy of features. The definition consistency is most obvious of them. In manual procedures there are human beings interpreting the semantic and syntactic relations of attribute classes, and also giving the operational interpretation to these relations. Since there are often many interpreters also there is natural variation how these definitions are applied in mapping process. In a supervised classification and automatic generalization procedure the procedural variation is significantly smaller, and arises mainly from the variation in the classification phase. Therefore, the generalized datasets are internally homogeneous, and could be repeated as the same all through. The automatic generalization may be used for giving this homogeneity condition, since different levels of input data can be homogenized and brought together by using the operations developed in the study.

The completeness requirement is obvious. The multi-scale land cover databases require quite complete attribute databases. If the input data is too much oriented towards certain application, it may not be used for other applications. Therefore, the input classification should be quite detailed and complete description of land cover features present in area, and allowing us then to generalize coarser datasets to various applications. In Finland, the most detailed land cover database includes 63 classes (Vuorela 1997), but nevertheless in order to produce CORINE land cover there was a need to add few more classes.

The spatial and attribute differentiation make the complete generalization procedures always more or less specific to the certain datasets and certain areas. The overall structure of generalization procedure may be kept very similar, we may apply consistently the same generalization operations, although there may be a need for local adjustments to the values of parameters. One example of local adjustments is the generalization of the islands along Finnish coast and lake areas. Obviously, as we can see from the Appendices, the present parameters loose too many islands, and therefore the new corrections made afterwards, aggregate the islands from more far away from each other. The adjustment is specific to the islands, since in the land areas the aggregation distance should be different. Also, since there are now more specific operational guides for the CORINE land cover data generalization, there are still some other minor adjustments to be made.

Results

The automatic generalization of land cover data is resolved with raster methods using the formal language of the Map algebra. Theoretically, the developed generalization operations are not directly linked to the present generalization theory. The operation concepts have been modified a little, and thus it is difficult to assess the theoretical validity of the generalization modelling approach used. Nevertheless, the practical validity is easier to evaluate with the quality testing methods developed. The formal quality evaluation for the automatically generalized CORINE land cover data support the hypothesis that it is possible to fulfill the quality standards specified for the manual procedure (Jaakkola 1994). Automatic generalization produces a database of good positional accuracy, as well as of reasonably controlled attribute accuracy, for the class features and for the areal statistics of classes. The results have been tested with quantitative methods of multivariate statistical description, error matrix, and of derived quality measures e.g. for class areas and shares. Also, the difference maps and overlay maps of vector and raster have been used to describe the spatial distribution of accuracy (Jaakkola 1994).

In addition, the used operations and parameters are easily modifiable according to the needs of generalization, e.g. it is possible to change the size or the width of the minimum feature. Similar operations can be used for correcting databases, and for checking the homogeneity of different input data. Automatic generalization provides a tool to propagate, i.e. generalize automatically, updates for maps at different scales with different minimum mapping units (see Appendices). The integrity of different scale products is kept. Besides the spatial parameters, developed generalization methods can handle semantic information, and indirectly also topological relations (Jaakkola 1995b). In addition to CORINE land cover, a similar automatic generalization has been used in generalizing areal features for small scale topographic maps. Also, the method has been used in generalizing land cover data for monitoring agricultural areas. Some of the maps have covered large areas, and still the generalization is done with one overnight batch process. We may change the pixel size from infinitely small to very large, and influence the positional accuracy of the data, and the speed of processing. Thus, we may adjust the resolution level, and thereafter use the operations at this level. In overall, the automatic generalization is considerably faster than manual generalization.

Extensions of results

The automatic generalization procedure developed for land cover data opens many previously unseen opportunities. The methods are equally suitable for any nominal scale categorical areal data. Therefore, besides the land cover data, we can use similar procedures for producing multi-scale soil maps, forest and other vegetational species maps, topographical areal features etc. We may also specify the parameters for certain type of application, i.e. for using the generalized data as conventional maps, as input for different kind of geographical analysis, or as spatial statistics. The multi-scale approach could be used for integrating data at various generalization levels in compiling more comprehensive databases of different sources. It also allows us to give different types of topological constraints to areal features, e.g. in order to integrate land cover features to certain linear features like roads or rivers.

Certainly, one of the most important result of automatic generalization is that it enables us to examiner the dynamics of land cover concept. The multi-scale land cover data helps us to understand the multidimensional character of land cover features, and that we may approach land cover data at various scales, and in every scale we may find new properties (see Aspinall 1995). It helps us to understand that geographical features are often not clearly delimited, and that the size of geographical area varies with scale, from large scale with small areas to small scale with large areas (Appendices). The size of the areas is dependent on the purpose of the stratification, and the heterogeneity of areas increases when the areas become larger. The multiple representations of land cover data help in enrichment and development of previously unimaginable spatial structures and concepts.

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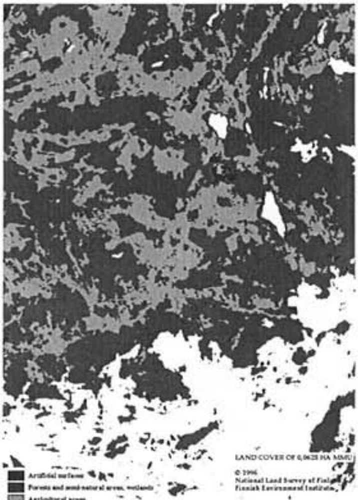
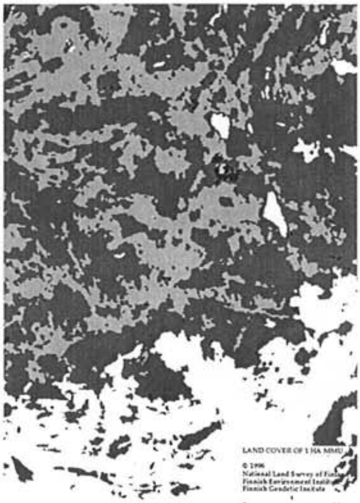
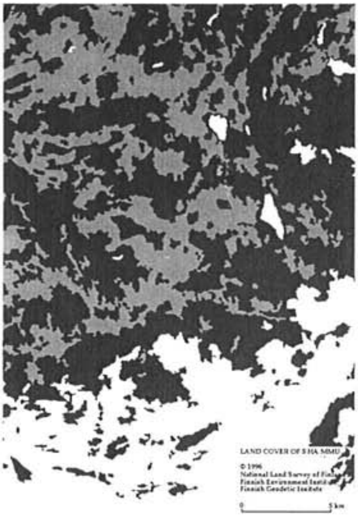
Appendices



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© 1996
National Land Survey of
Finnish Environment
Finnish Geodetic Institute
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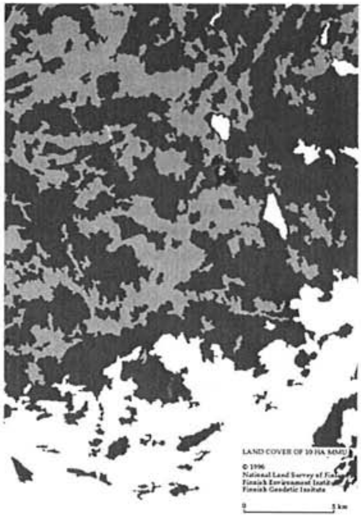
5 km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© 1996
National Land Survey of
Finnish Environment
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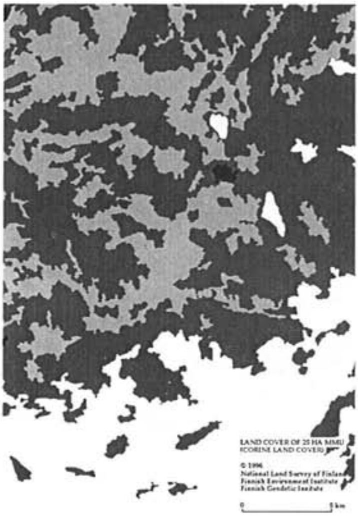
0
5 km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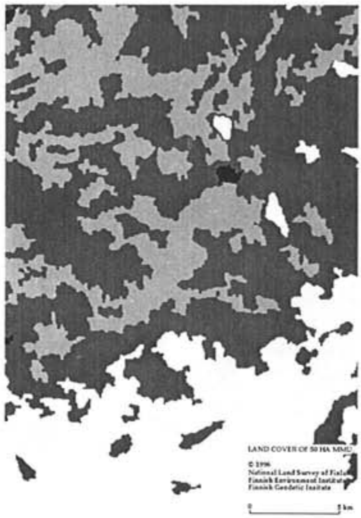
(CORINE LAND COVER)
© 1996
National Land Survey of
Finnish Environment Institute
Finnish Geodetic Institute
0
5 km


LAND COVER OF 50 HA MMU
© 1996
National Land Survey of
Finnish Environment
Finnish Geodetic Institute
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EFFECT OF PERCEPTION ON CARTOGRAPHIC GENERALIZATION

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Abstract

Perception or intuition, formed from several sources and upon multiple influence factors, is the synthetic impression of map graphics. It can play an important role in the implementation of cartographic generalization, especially in simplification of complex graphics. However, current attitude toward perception is trying to marginalize or neglect its effect on cartographic generalization, especially in computer-assisted generalization, partly because it is too difficult to realize in computer programming.

This article discusses the role and utility of perception on generalization by analyzing its forming mechanism, its components, its characteristics, the way it functions in generalization in comparison with the utility of rules.

Introduction

People have been keeping to say, 'I feel the drawing should be like this.', or 'This makes a better whole feeling of the graphic'. An experienced cartographer may even tell you that 'feeling good' is the reason for he/she to choose a route as the simplification of a line. They are doing the generalization work upon their perception--not upon logically reasoning! This could occur to even experienced professionals.

The effect of perception on cartographic generalization is a fact that we must face to. However, till now the negative part of perception is enlarged too much and the positive effect of it is neglected, perhaps because it is very hard to computerize.

The perception of cartographers is the result of a general procedure of feeling, understanding, and then generalizing of map graphics. It may help the progress of cartographic generalization for us to make some reasonable analysis and examination to its formation, characteristics and effect on cartographic generalization.

The above mentioned concept *perception*, as we think, is in fact a general, mixed result of human's thinking. It comes into being in the cartographer's mind after he/she performed a quick, subconscious and complex visual-thinking. To do this the cartographers must use their visual ability to obtain the source graphic, their memories about the common rules and disciplines they learnt from books and teachers before, their impressions of sample graphics they met in their former work, together with their judgment or reasoning mechanism. Certainly many times the perception is not so perfect, sometimes even wrong. But what we are interested in now is **why** and **how** this perception forms in human's mind, and why it is so hard to perform--if not impossible-- by computer systems.

Formation and Factors

The correct feeling of graphic generalization grows from accumulation of non-symbolic knowledge and graphic impression. The items that contribute the most should be long experience of map generalization and educational learning including that from textbooks and ruling specifications. As for the factors that contribute to the formation of perception, at least the following ones should be considered.

- ✧ Accumulation of map graphics: which is the basis for the cartographer to think *cartographically*.
- ✧ The accumulation of rules and customs they learnt: which *guides* the way of thinking when trying to solve problems, to perform tasks, etc. .
- ✧ Basic rules of human's behavior and thinking, in the sense of psychology, physiology, etc. .
- ✧ The commonsense which the ordinary human beings own.

Characteristics

Though the perception of each individual and each time differs significantly, it shows the following features commonly:

- ✧ Reasonable: the perception is right and showing high accordance with the final result of analysis for most events and most individuals, even to a quite complex graphic.
- ✧ Practical: the perception is ready to function on the behavior of human beings. It helps to get you a quick and outlined understanding of the information.
- ✧ Fault-tolerant: often it's tolerant to uncompleted, fuzzy or even partly-wrong information.
- ✧ Analyzable: though the perception is complicatedly formed, the conclusion of it can at many times be reasoned back to the origin of thinking.
- ✧ Uncertain : of course! The perception isn't close inference. It may change from

time to time and to different persons, even for the same graphics.

Functions

Experience

When settling down for the generalization work, a professionals of much experience will most probably operate depending on the perception of good experience. When not sure for the answer or running into some new problems, the person would try to find rules for this situation. If no rule were found, he would guess from his early experience. In this case the task is accomplished mainly on perception, with rules as the necessary supplement.

For a freshman the task will mainly be performed under the direction of rules. He is accumulating the experience and developing the perception.

Rules

If there are clear directions to do the job, the rules play the most controlling role, occasionally a little perception is utilized.

If rules are not clear or practical enough, perception will form the main part of the basis to finish the job, the rules function only when available.

Problems

A clear question will be solved mainly by rules; but in the solving of an ambiguous or complicated question, perception will play a much more important role. The rules are used mainly as a standard for 'check and correct' now.

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DESIGN OF NEURAL NETWORK FOR AUTOMATED SELECTION OF SOUNDINGS IN NAUTICAL CHART MAKING

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Abstract

The complexity of cartographic generalization is reflected by the fact that it deals synchronously with both spatial and attributive characteristics of the chart features. Because of this complexity the problem of sounding selection in chart generalization can not easily solve with current programming techniques.

The article discusses the potentialities of neural network technique in automation of cartographic generalization, then designs a scheme to implement the sounding selection with respect to the special demand of arranging soundings in a rhomboidal net. Also, the necessary characteristics of soundings and pre-processing for evaluation are concisely mentioned in this article.

Introduction

<u>Sounding Selection</u>

Even in manual generalization of nautical chart, the selection of soundings is one of the most difficult and time-consuming link in the production chain, not to mention in the automated charting procedures. Perhaps this is mainly because it has to deal with both the depth values of the points (attribute) and the distribution pattern (spatial relations) at the same time. Rules for sounding selection include:

- ✧ soundings which are at the top of a raised under-water area(shoals, rocks, etc.) have the highest priority to be selected;
- ✧ then choose the soundings which show the waterways;
- ✧ then choose the soundings which represent the outline of sea bottom the best;
- ✧ choose the other soundings to fulfill the chart;

- ✧ traditionally the soundings should spread in such a way that they form a net of rhomboidal shape.

Usually the soundings selected by the first three rules are scattered on the chart irregularly. Under the limitation of source data, the cartographers have to repeat the manual selection procedure for several times to get the satisfactory result that best represents the underwater relief with soundings scattering in the required pattern. The knowledge and steps of thinking for this job is highly complex, difficult to explain, thus hard to computerize in ordinary ways.

Neural Network Technique

In many tasks such as decision-making with many trade-offs, the current computer systems cannot do better than humans. It is conjectured that the structure of the brain is somehow suited to these tasks and not suited to tasks such as high-speed arithmetic calculation. Neural network is inspired by the mechanism of the brain, trying to solve problems simply by example mapping instead of explicit describing and modeling.

A neural network contains a large number of simple neuron-like processing elements and a large number of weighted connections between the elements. Even though each individual element works slowly, they can still quickly find a solution by working in parallel. A neural network can learn by itself, tolerate faults, and manage fuzzy information. Its non-traditional, connective, parallel and brain-like style of working offers a better alternative to current programming ways of cartographic generalization.

Neural Network and Cartographic Generalization

Complexity of cartographic generalization

The collectiveness and artistry of cartographic generalization makes it hard to find a good explanation to the mechanism and basis of it. It's still hard to represent the knowledge and experience in the form of mathematical models or algorithms, or in the form of knowledge representation(as in an expert system), thus set strict limitation on the applying of current automation way of the 'examining, modeling, programming, running' cycle.

Neural network approach needs no mathematical pre-modeling. It can learn by the facts presented to it how to accomplish the cartographic generalization and later apply these skills to finish the logically work like an experienced cartographer. It might be a practical solution to the above obstacles.

Multi-faces of cartographic generalization

Cartographic generalization system must be highly flexible for a variety of tasks and demands of processing features. For example, though both line simplification, the one for depth-contours differs significantly from the ones for roads and rivers. To develop a solution for each of the feature generalization tasks means much space and time requirements in both developing and running stages.

Neural network approach is more convenient for this situation, for it is able to adjust itself to fit the tasks. A neural network can be trained by suitable samples to process different features or deals with different problems as a brain does to many types of questions. Furthermore, neural network may be able to imitate the style of a generalization of a special cartographer by learning from his/her works.

Neural Network for Sounding Selection

Problem Description

As mentioned above, the selection of sounding in nautical chart production is a repeated course of judging and choosing based on the sounding's importance to navigation(thus to the chart). The purpose of operation is to decide whether a sounding should be represented on the new chart, or in other word, to reserve or delete it. So the neural network for this task could be a classification-oriented one, with each sounding as an event, and the function of network is to classify each event into two classes: selected and deleted ones.

Structure

The neural network uses an *input layer* to encode the information presented to it for processing. Each of the nodes in the input layer(input units) is designed an attribute value possessed by the presented instance.

It outputs the running result through an *output layer.* The nodes in it(output units) encode possible attributes to assign to the instance that is under consideration. Since there are only two output values, two or one output unit(s) is enough to show the examination result.

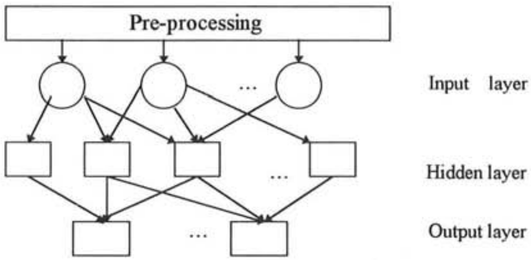

Figure 1: Structure of Neural Network

The operation of sounding selection is quite complex. The relationship between attributes of soundings(input) and conclusion(output) is non-linear, so a *hidden layer* is necessary to reproduce this nonlinearity for the network. Number of the hidden units in hidden layer varies with the different demands, mostly around the number of 16.

Input Vector

Input vector consists of the characteristics of soundings that affect the final decision of selection and that is to be encoded by the input units. There is an input vector for each sounding point. The items in each vector function on the final result through the individual weight values assigned to the connections between the layers.

The chosen attributes of sounding poits include:

- ✧ depth range around the sounding (grade of average depth);
- ✧ relative difference of depth to neighbor soundings;
- ✧ average distance between or density of soundings on source chart;
- ✧ terrain types;
- ✧ regional types (in waterways, straits, on shoals, etc.);
- ✧ feature types;
- ✧ relationship with formerly-selected soundings (distance, shape, etc.);
- ✧ relationship with qualities of the bottom;

and so on.

Preprocessing

Commonly the data stored in chart database don't meet the demands to input vector, and the data of items in the input vector may vary greatly in units and value. It is necessary to normalize them before transferring to the network. The designed preprocessing includes:

- ✧ searching and marking the soundings at first level of neighborhood;
- ✧ establishing the topology of concerned sounding with depth-contours, coastlines, and edge-lines of dry shoal (on, near, or off the lines);
- ✧ establishing relationship between concerned sounding and other point features (rocks, wrecks, etc.);
- ✧ setting up the flags of regional types;
- ✧ setting up the flags of terrain types;
- ✧ establishing the topology with quality of the bottom;

and so on.

Conclusions

The new, intelligent computation of neural network points out a hopeful, brain-style approach for building a powerful system of cartographic generalization. By now, more than a dozen well-known neural network models have been built, each with distinct performance features. By correct describing of the cartographic tasks and suitable choosing of neural network models, cartographers could build up a functional neural network of cartographic generalization; and would approach greatly to the old dream of a practical automated cartographic generalization system. As Dr. Morrison said, 'If we are to survive as a vital profession we need to … systematize new processes that electronic technology has made possible.'[2]

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CARTOGRAPHIC MODELING TO MONITOR LAND USE AND LAND COVER CHANGE IN PONDICHERRY REGION, INDIA

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Introduction

Land Use and Cover Changes are known and undisputed aspects of global environment change (Skole 1996). Before the start of the agricultural revolution, the land was covered by `Potential Vegetation' which was determined solely by physical factors with no anthropogenic intervention. Changes in land cover (potential vegetation) in response to climate and/or anthropogenic activities are particularly large on the humid Indian sub-continent and on the north China plains (Kayane,I 1996). These local changes in land cover reach a regional /global dimension by patchwork addition, in a process identified as globally cumulative (Turner et al.1990). Hence there is a need for the study of `driving forces' of land use and cover dynamics in a nation (such as India) which undergoes rapid and large scale changes. Interpretations of how such land use/cover driving forces act and interact is still controversial,especially with respect to the assesment of the relative importance of the different forces and factors underlying landuse decisions in specific cases. In order to investigate this problem ,a pilot study has been carried out in Pondicherry region,South India to attempt modeling land use related drivers and their temporal and spatial variability. Potential land use drivers for Pondicherry region were identified and combined in geo-referenced census and biophysical data set.

Study Area

Pondicherry Region is situated on the Coromendal coast between 11 45 and 12 30 N latitude and 79 37 and 79 53 E longitude. The region covers an area of 293 sq.km. and consist of one agglomeration and 174 villages. The variations (1962-92) in annual rainfall (Mean 1111mm and s.d 382mm) and in seasonal Northeast monsoon (Mean 810mm and s.d 337mm) are significant from the view that it drastically affects agriculture and groundwater recharge. Rainfall in excess of the normal results in floods while inadequacy causes droughts. Alluvial soils are the dominant soils in this region. The reconnaissance soil survey of the region list 19 soil series. Cuddalore, Recent Alluvium, Vanur and Ramanathapuram are high yielding potential aquifers.

In the Pondicherry region, there has been a phenomenal growth in population in the region rose by 240 percent, urban population rose by 800 percent in the period between 1961 - 1991. The standard urban area of the region has increased from 6.2 sq.km in 1971 to 18.46 sq.km in 1981 to 70.33 sq.km 1991. As per 1991 census, urban population accounts for 2/3rd of the total population of 6,07,600. The remaining 2,06,263 population resides in 174 rural settlements. The Pondicherry urban agglomeration with a population of approximately four lakhs (1991) is growing at a decadal rate of 59.63 percent.

The trend in land utilization shows that more and more of the land is going for non-agricultural use and only 51.31 percent of land is under cultivation. But the cropping intensity has increased from 174.4 to 181.5 during 1975-76 and 1990-91. There is a marked increase in fertilizer and pesticide consumption. The increased use of chemicals percolate to the groundwater and pollute it. Enhanced irrigation has posed problems of salinity, waterlogging, erosion and leaching of nutrients.

Results and Discussion

Spatial distributions of potential biophysical (relief ,precipitation ,and soil) and human (population density)are related to the distribution of pastures, arable lands, and natural vegetation. GIS based cartographic model describing land use/cover variability indicates a considerable spatial scale dependence of land use and its drivers.

In Pondicherry region ,two land use /cover trends between 1981 and 1995 can be discerned:

1.Intensification of urban land use in the vicinity of Pondicherry urban agglomeration.

2.Extension of urban land use at the cost of fertile agriculture land

Most changes in land use from 1981 to 1995 seem to be driven by changes in population density.

Conclusion

A reliable methodology has been formulated with cartographic modeling, in which biophysical and socio-economic driving forces of land use and land cover change are selected, weighted by importance and linked together to form and index, sustainability. This index has been used to map areas with different sustainability for agriculture land use.

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THE CARTOGRAPHY OF THE ANCIENTS AS THE REPRESENTATION OF A DIALOGUE BETWEEN THE LEGEND AND THE DIRECT EXPERIENCE

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Abstract

In the archaic world, to depict the land means at the same time to join the transcendent side of their reality to the pragmatic one and to think of them as a single shape. The glitters of the mythological world shine through the thin pattern built by direct experiences. In the run of the time, this 'fabric' gets thicker and thicker until the last sparkles become invisible.

".... and Hercules then said: «far from here, towards the west, over the ocean, at the extreme border of the world, there is a Garden where eternal spring reigns (....) over the mountain where Atlantis keeps the vault of heaven on his shoulders ....»

Preliminary Considerations

The primary goal for this paper is to show how the course that the archaic cartography plots follows a double parallel track: one side, that I define "of the experience" built by the will of reorder and transmit primary importance experiences and knowledge, such as shorelines, mountain passes, distances, foreign cities shapes, etc., and the other "of the myth", fruit of complex cosmologies which form the base system shared by all the following formalized religious structures.

For the above mentioned reasons I have used two different ways of conceptual construction: the deduction and the inference. The paralogy with consolidated theories of cultural anthropology and of history of the religious thought allows to construct a reliable logical system but it doesn't warrant from errors and misunderstandings.

I hope that my experience is not fallen into the common mistake of manipulating, for teleologically different purposes, noble conceptual paradigms, born in order to support different and independent theoretical structures.

Report

The first current use of cartography is normally attributed to the Mesopotamian cultures. From the several archaeological campaigns which concerned the area of the modern Turkey in the last years of the XIX century and the first of the XX came out the first real historical witness: the wall paintings in Tell Uquair, dated around 3000 b.C., represent in a very schematic way what should be a protohistoric building, while the relatively well known sumeric tables found during the Nippur's excavations (1500 b.C.) have been immediately charged with the role of main historic trace for proving the diffusion of the habit to represent the space.

There exist, anyway, even out the Mesopotamian area, other important examples of the use of protohistoric forms of cartography. The wall painting found in Katal Höyuk on the Anatolian highlands even if dated around 7000 b.C., that means straight into Superior Neolithic, impress for the abstraction level which reaches: the settlement is represented from a zenithal point of view, while the background is made by the portrayal of an active volcano painted in a kind of side view.

The general characteristic of the Nippur tablets, undoubtedly the most important and valuable traces from the reliability point of view, is the particular care the drawer put in plotting the course of the rivers and of the canalization and of peculiar details, such as palaces, fortifications, city walls, and monumental doors, while any kind of reference to the shape of the connecting tissue of the building blocks, to the streets, to the whole urban morphology misses, even if these cover the largest part of the town soil.

In all of the ancient civilizations the development of a settlement has always been connected to the availability of water resources. This explains the will to describe the soil in its links with the rivers and the canalization: water abundance, besides assuring the harvest, was a prestige and authority index for the neighboring villages people.

So, in the same way mathematics sciences development derived a fundamental impulse from the need to build canals and water networks, the cartography gave two other problems a solution: the question to graphically support the calculus and the need for, let me say, "propaganda".

In one of the Nippur's tables transcription we can read names, such as "The brook which gives to drink" or "The canal for the loading", while the cultivated soils are indicated with the owner's name ("Marduk's field", "Kurili's field"), usually a merchant or a priest .or, if they were public soils, with names deriving from their relationship with the water, ex. "The field between the canals", or "The 8 guls field of the palace", marking in this way the mainly public ownership of the water ways: they were too important items to be left to one private citizen's will.

On the same tablet the extremely symbolic representation of the urban poles of Quatnu Hamri, Biktar Nusku, Ba-Lu highlights again the will to witness in a stronger way their closeness to the rivers than their real shapes or dimensions. It was just the only parameters of the position on the territory and of the relationships that this implicated to be charged with pragmatic meanings, in order of the absolute immanence which this represented, with a total independence from the morphologic aspect.

The problem of the shape itself can be faced, in its most general meanings, considering *how for the archaic man any reality is what it is because it is the imitation of a celestial* *archetype.*[1] The mythic tradition of the Mesopotamian peoples themselves, tells how the two large rivers which border the whole world, the Tigris and the Euphrates, have two well individuated transcendent models. The Tigris has its celestial archetype in the Anûnit star and the Euphrates in the Swallow star. It is known a fragment, interpreted in 1924 by the paleographer E. Chiera[2] of a sumeric text which tells about a "house of the form of gods", where "[the gods] of the herds and of the cereals live".

According to the belief of the althaic peoples all the terrestrial mountains correspond to their ideal prototypes, which live in the cosmic space: the Egyptians too searched for the acknowledgment about the "celestial fields" and of their names, for being able to restore their complex phenomenological tissue in the places of the real geography.

This mutuality between the immanent and the transcendent reality is clearly highlighted by the Iranian cosmology of Zervanian tradition in the way it is shown by the religion historian H.S. Nyberg[3] "..each terrestrial phenomenon, abstract or concrete it is, corresponds to a celestial term, which is transcendent and invisible; it corresponds to an "idea" in the platonic meaning. Each thing, each notion shows under a double aspect: *mênôk* and *gêtîk*. There is a visible sky and a *mênôk* sky which is invisible (*Bundahishn,* ch.1). Our Earth corresponds to a celestial Earth. Each quality, here in the *gêtâh,* has a celestial counterpart which represents the real truth [....]. The year, the prayer [....], as a matter of fact all what shows in the *gêtâh* is at the same time also a *mênôk* reality. The creation is simply split in two. From a cosmogonic point of view the cosmic stage called *mênôk* is prior to the *gêtîk* stage [....]."

In the Old Testament a Text generally shared by Christian an Hebraic religions, we can find the evidence of how deep the awareness of a celestial reference was located in the archaic cultures. "You will build the Tabernacle with all the furniture, following exactly the model I will show you" (Ex. 25, 8-9), Jayvee said to Moses on the Sinai; and little further "Look and built all these objects, following the model I have shown you on the mountain"(25,40)

David, while giving his son Solomon the plan (map) of the Temple foundations, of the Tabernacle and of all the Furniture assures him that "[....] all of this [....] is shown by a script of God, who showed everything to him" (1 Chron). So, he had seen the celestial model.

The famous description of the Celestial Jerusalem in John Apocalypse is an extraordinary collection of the recursive kinds and models with which the archaic mythological underground is revised inside a great revealed religion such as the Christianity, for going to build its dogmatic plane: "And I saw the Holy Town, the New Jerusalem, while is was coming down from the Heaven from close by God; prepared as a bride who adorned herself for her spouse"(21.2)

"The celestial disposition of Jerusalem.

And the town had great and sublime, it had twelve gates, twelve angels were sitting on the gates and there were some names written, the names were those of the twelve tribes of Israel: on the eastern side there were three gates, on the northern side three gates, on the southern side three gates, on the eastern side three gates. And the walls of the town had

[1] M.Eliade, *Il mito dell'eterno ritorno,* It. Transl.. Rusconi, Milano, 1975, pagg. 16-24.

[2] E.Chiera, *Sumerian Religious Texts,* Upland, 1924, pag.29.

[3] H.S.Nyberg, "Questions de cosmogonie et cosmologie mazdéennes" in *Journal Asiatique,* Jul-Sept. 1931 (pp.1-134), pp. 35-36

twelve foundations and over those there are the twelve names of the twelve apostles of the Lamb.

The dimensions of Jerusalem

The person who was speaking to me was holding a golden stick as a measure for the town, its doors and its walls. The town is disposed as a square and its length is equal to its width. And that one with the stick measured the town for twelve thousand stadia: its length, its width and its height are all alike. And he measured the walls too for one hundred cubit at the size of a man, or rather of an angel.

The constitution of Jerusalem.

Its walls structure was jasper made, while the town was made of gold, similar to bright glass. The walls foundations are adorned by any kind of precious gems. The firs foundation is made of jasper, the second of sapphire, the third of chalcedony, the fourth of emerald, the fifth of sardonyx, the sixth of carnelian, the seventh of chrysolite, the eighth of beryl, the ninth of topaz, the tenth of chrysoprase, the eleventh of jade, the twelfth is amethyst.

The twelve doors are twelve pearls and each of them was made of a single pearl. The main square of the town was made of gold so fine as light glass." (21, 12-21)

The morphology comes from the knowledge of the celestial model: the men obtain it by the hand of God, the nature owns it by itself because it is a part or a manifestation of God[4].

The very famous inscription found in Tellah over the base of the Gudea statue has often been considered "a fortified building or a urban wall"[5] but the Babylonian mythology explains us in a very clear way that it is the oldest document concerning the archetype of a sanctuary. The bas-relief refers to the Temple that Gudea himself rose to the god Lagash.

"The king sees in a dream the goddess Nidaba who shows a panel where the beneficial stars are listed, and a god who reveals to him the plan of the temple".

"All the Babylonian towns had their archetypes in some constellations: Sippar in the Cancer, Ninive in the Ursa Major, Assur in Arthur and so on. Sennacherib make Ninive built following a project established in the eldest times in the configuration of the sky.

The graphic sign testifies with pride and skill the existence of perimetrical walls, carved with a double line, answers for the city access monumental doors, two parallel lines crossed to the above mentioned other two, for the palaces, the temples, with a single but double wide line, and over all, of the privileged relationship with the water and with its courses.

The double nature of the Babylonian cosmographic culture, suspended between the reproduction of the myth and the affirmation of the experience, declares itself in a very visible v way in the "Mesopotamian map of the world", where the practical skills join the image of the archetypal world in its totality. The far away people territories, known because of the commerce and the mirror images on the earth of the transcendent sites share a disk shaped world, where the town of Babylon occupies the center and seven near cities are distributed on the territory close to it, parted by the rivers. The "Bitter River" (the ocean) separates this circular land from the seven far away regions, some of which are called with names like "Twightlight reigns" "Region where you can't see the Sun" "Here raises the sun". Over this area, on the upper side there is the description of the sky, the Celestial Ocean,

[4] See also. The rabbinical traditions in R.Patai, *Man and Temple*, London, 1947, pag. 130 and following.

[5] Docci, Maestri, Il Rilevamento dell'Architettura" Laterza, 1989.

and the Zodiac". The recurrence of the number seven (towns, regions), the centrality of Babylon, the fact that some distances between cities are given in empan (Babylonian foot) and the typology of the names given to the far away territories declare the nature of these representations, that is their doubleness. Their appearing under sometimes as tries to describe the real world and sometimes as the mirror of deep mythological masses is the consequence of the will to transfer into practical mechanisms, such as the directly experienced measures, superior order cosmological symbolism, unknowable but by a mythological way.

Denying the incomprehensibleness of this dichotomy acquires a meaning only accepting that "in the particular of his conscious behavior, the archaic man do not know any action that has not been previously made and lived by someone else, someone who is not a man. What he does has already been done, his life is the uninterrupted repetition of deeds inaugurated by others.

This conscious repetition of paradigmatic and traditional achievements, shows an original ontology, that is what comes from the astral forms is the fruit of the Eternal Beings (or of the ancestors or of the heroes) actions and designs, and it is known by the truth expressed by the myth: what on the contrary comes from the terrestrial forms and has been generated by the men, which are forced to repeat and repeat, is perceived by the sensible experience, as true as the myth is. In this way the logic which sustains the meaning of representations such as the "Mesopotamian map of the world" is built, as they represent from both the points of view just "what is true"

With a second mythic model, the original chaos, we can put in a relationship all what does not participate to the frame of the cosmogonic idea of the repetition. As a matter of fact the savage, uncivilized, wild and untamed lands, the unknown seas where no navigator dared to venture out, or the monsters populated deserts, where no repetition of the mythic creation or generation acts happened by human will , are not depicted.

We have already noticed that in the Nippur tablets too, the connecting tissue of the town has been ignored to favor a detailed representation of the main and monumental items: maybe it is a sliding, an assimilation, a kind of modal traction, that brings to repeat the act of the representation of a "miniature world", such as the city, in the same way they do at a global scale. The urban areas which have not been "cosmizated" are still undifferenced and without any shape: they cannot appear because they do not contain any truth, that is the fruit of the repetition of a mythic act, and they are inhabited by some beings that do not share with the elects, (priests, courtiers, merchants - they travel, explore and discover and so they "create"-, warriors - they are conquerors and emulators of the ancient heroes -) any kind of nobleness, they are a part of the undistinguished matter: the archaic world has always lived on the base of horizontal cuts which traced completely divided sediments in the social structure.

In all the archaic cosmology the transcendent model comes before the terrestrial monument architecture, and it is generated in an ideal region of the eternity. Solomon claims "You ordered me to build the temple in your very holy Name, and also an altar in the town where you live, following the model of the very holy tent, that you prepared from the beginning". (Sap. 9,8), the apocryphal prophet Baruch confirms it in the Syriac Apocalypse (2,42,2-7): " Do you really believe that the town where I said 'I founded you in the palm of my hands' is there? The building that now stands among you is not the one that has been revealed in me, the one that was ready from the time when I decided to create the Paradise and that I showed to Adam before of his sin [....]"

The strength of the hyerogamic track, between myth and experience, which is shown by the protocartographic representations follow, allows the sidetracking towards the one or the other direction, without the general value of the conceptual paradigm failing.

In the archaic and protohistoric eras the universality is a characteristic for the beliefs, for the mythical traditions, for the technical skills and for the social customs. In geographically and ethnically close areas that means the direct share of many forms and many ways of the myth and at the same time the techno-cultural homology.

The only cartographic image of land and non of an architecture, which came to us from the ancient Egypt, testifies how the *nomo,* (the cosmos, in the meaning of the "elect territory") once it has been known and covered with a particular meaning in thanks to a repetition if the original theophany, could also be the object of a really positive description.

This papyri (XX dynasty, 1184/1087 b.C. cat. # 1879 Turin Museum) represents the basalt quarry in Hammamâth Uadi and the gold mines in Fanahir Uadi. This map can be defined geological and topographic: the mining production areas are colored with pink, the unproductive with black, the main road system is drawn with a double line and there is a schematic representation of the orography, given in side view.

It is a practical cartography, were the places are known by direct experience: the village that we can see around the temple of Ammon, whose ideographic symbol can be seen on the papyri, is depicted without emphases, without any centrality, it is located exactly where it is".

This situation is not in contrast with the generalization of what defined before, talking about myth reproduction in the Mesopotamian people traditions, but goes beside, building the second buttress of the main conceptual building.

Conclusions

The ancient cartography has a double soul: by one side it is the manifestation of the will to know the cosmos and to describe its shapes and dimensions, by the other it is the product of a ritualization that, towards the symbolic act of drawing, includes or excludes parts of the territory from the universe of one's people.

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- **Figure 1.** Tablet found in (transcription) probably representing the City monumental (16th cen. b.C.). *[from M.Docci, D.Maestri, op.cit.]*
- **Figure 2.** Tablet found in Nippur. (16th-14th cen. b.C.). *[from M.Docci, D.Maestri, op.cit.]*
- **Figure 3.** Base inscription on the Gudea statue in Tellah transcription (21th cen. b.C.). *[from M.Docci, D.Maestri, op.cit.]*
- **Figure 4.** Mesopotamian Map of the World (6th cen. b.C.)

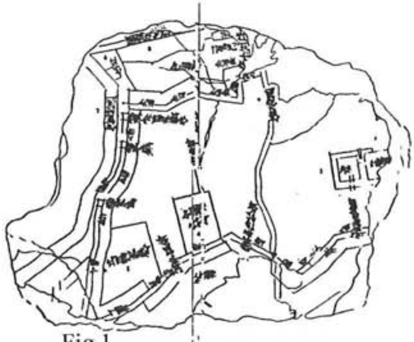
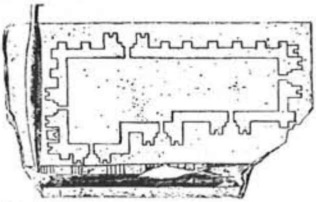


Fig.1

Fig.2



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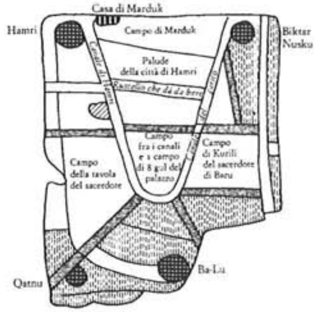

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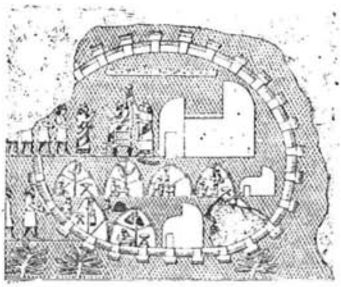
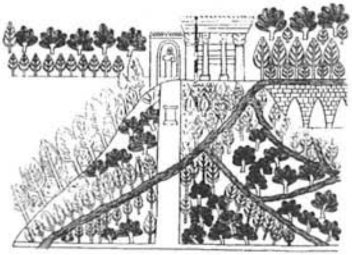


Fig. 5.

Fig.6



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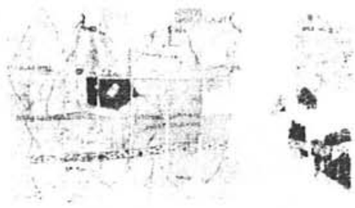

Fig. 8

- **Fig. 5.** Assyrian bas-relief representing a town. *[from M.Docci, D.Maestri, op.cit.]*
- **Fig. 6.** Assyrian tablet showing another town, its wall and its river. *[from M.Docci, D.Maestri, op.cit.]*
- **Fig. 7.** Niniveh Palace Garden, bas-relief. *[from M.Docci, D.Maestri, op.cit..]*
- **Fig. 8.** Papyrus n. 1879 from Turin Museum of Egyptology. *[from J.Ball, Egypt in the classical Geographers, The Cairo, 1942 7th and 8th tabs.. See also. C.Palagiano, op.cit.]*

HYBRID „WYSIWYG“ TECHNIQUES FOR UPDATING THE SWISS TOPOGRAPHIC MAP SERIES

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In this paper, the detailed functional demands for a new digital cartographic production system at the Federal Office of Topography in Switzerland are given. First results of interactively updated topographic maps in hybrid raster/vector mode are shown. Finally, future demands concerning the combination of cartographic and topological data models are presented.

1. Introduction

Modern geographic and cartographic information systems allow to record, to edit and to display spatial topographic and thematic information. The task of digital cartography is to finally make a useful selection out of the processed basic data and to present it in a perceptable, graphic form on paper or on electronic media (Hurni/Leuzinger 1995). The cartographer therefore must be equipped with an ergonomically designed graphics software containing a comfortable and powerful set of special cartographic functions.

In 1994/1995, an interactive cartographic system has been evaluated at the Federal Office of Topography, partly in collaboration with the Institute of Cartography at ETH Zürich. In a first step, the national topographic map series are being updated in hybrid raster/vector mode. Later, the vector-based production of entirely new topographic and thematic maps is planned.

One major functionality of the new cartographic system is its hybrid «WYSIWYG» («What You See Is What You Get») capability. The scanned binary color separations are stacked and displayed according to their correct priorities. Overprints and masking effects can be visualized. Additionally, newly digitized vector objects are truly symbolized and can be edited in real time mode. Interactions between raster and vector elements can be seen in true «WYSIWYG»-display as well.

The authors hope that this paper may help other cartographers when evaluating similar systems.

2. Functional demands for a digital cartographic production system

2.1 Input of analog and digital map data

2.1.1 Scanning

- Scanning of opaque and transparent originals in binary mode.
- Optical or mechanical devices for exact positioning of the originals on the scanner.
- Different (if possible variable) scanning resolutions (at least 1000 dpi).
- Scanning in continuous tone mode (256 gray values, 8 bit).
- Scanning in RGB color mode (3 x 256 gray values, 3 x 8 bit).

2.1.2 Digitalization

- Input of small data sets by manual digitalization on screen or using tablet.
- Input of large data sets using (semi-)automatic vectorization programs.

2.1.3 Data import

- Import of common raster data formats (e. g. TIFF, Intergraph, Scitex,...).
- Import of common vector data formats (e. g. dxf, dgn, PS,...).
- Possibility of unsupervised batch conversion of multiple files by command lines.

2.2 Visualization of data on screen

- „WYSIWYG" („What You See Is What You Get") display of fully symbolized map elements on screen.
- Fast build-up of screen image; fast change of screen images.
- Excellent display resampling in all zoom positions.
- Possibility to choose any zoom positions; standard zoom positions (1:1, 1:2, 2:1,...).
- User defined windows, scrolling in predefined steps in x/y direction.
- Overview window showing extent, position and coordinates of working window.
- Storing of user defined windows and zoom positions.
- Different shapes of cursors (point, circle, cross,...).
- User definable color tables.
- Statistical information about raster images (dimensions, resolution, histograms,...).

2.3 Internal coordinate system

- Pixel coordinates.
- Metric „drawing sheet coordinates" (pixel coordinates x resolution).
- National coordinates (pixel coordinates x resolution x map scale denominator).
- Freely positionable origin for all three coordinate systems.
- Measurement of distances and areas (along linear, polygonal and interpolated elements) in all three coordinate systems and units.

2.4 Preparational work

2.4.1 Global raster image manipulations (binary or multicolored files)

- Rectification (Helmert, affine, projective, rubber sheet and other transformations).
- Change of projection; programming interface.
- Overlay of several raster files; structuring in different, multicolored layers; selection of one or more layers for editing.

- Transparent display of common overlapping parts of two or more layers; selection.
- Placement of a single raster layer in any level of the stack.
- Merge of several layers (also with different resolutions) into monochrome or multicolored files.
- Separation of combined color raster image in original single color layers.
- Insertion of continuous tone images as background images.
- Global raster manipulations: Move (x/y), scale (x/y), rotate, mirror (x/y, specific azimuth), cut, append, recolor, resample (up/down), mosaiking, masking and Boolean operations.
- Line/area thinning/thickening by n pixels.
- Deleting or separation of isolated pixels or pixel groups.
- Skeletting of lines down to a one pixel axis.
- Line and edge smoothing, filter operations.
- Detection of line gaps and nodes.

2.4.2 Global vector manipulations

- Rectification (Helmert, affine, projective, rubber sheet and other transformations).
- Change of projection; programming interface.
- Overlay of several vector files.
- Move (x/y); scale (x/y); rotate; mirror (x/y, specific azimuth).
- Cut inside/outside: Edge elements cut, suppressed or fully included.
- Merge of several vector files or parts of files.
- Structuring of vector data in different layers; selection of layers or element groups.
- Turning on/off and change of line interpolation.
- Detection and elimination of duplicate elements.
- Algorithms for data reduction and line simplification.

2.5 Editing of raster data (line art)

- Different shapes of brushes (round, square, rectangular, flat,…).
- Variable line thickness (1–n pixel).
- Freehand drawing mode in order to create irregular structures (cliffs, hachures,…).
- Drawing mode for lines and linestrings.
- Drawing mode for geometrical objects (squares, rectangles, circles,…).
- Positioning of symbols: Interactive, automatic (using coordinate file), horizontal, vertical, rotated, reduced, enlarged, repeated (within an area, along a line).
- Selection of any section (pixel groups) and manipulation of its content: Delete, recolor, cut, insert, copy, scale, distort, rotate, masking and Boolean operations.
- Filling of areas formed by contours consisting of one or multiple colors (even in different layers); with incomplete contours („viscous“ filling): Global, local, full, textured.
- Area spread by n pixel.

2.6 Editing of vector data

- Editing of 2D and 3D data.
- Attributing, selection and manipulation of element by type color and layer.

- Symbolization of vector elements after map legend; „WYSIWYG" display (Fig. 1).
- Possibility of detailed editing of symbolized elements (e. g. road junction).
- Global change of map legend and all symbolized elements.
- Construction, placement, deletion and modification of linear map elements:
  - Construction: Lines, polygonal lines, arcs, interpolated curves (splines, Bézier), combinations.
  - Placement: Single, connected, variable, parallel.
  - Deletion: Complete, partial, grouped.
  - Modification: Prolongation by distance x, prolongation till next crossing, cut, move, move vertex, move parallel, copy, copy parallel, group/ungroup, simplify, type, color, layer; underpass/overpass, tagging of contour lines.

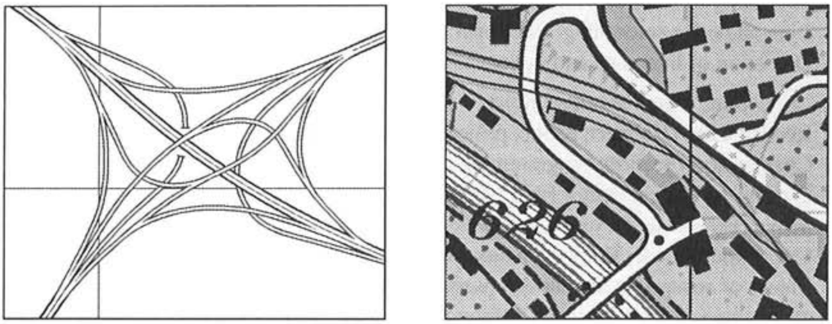

Fig. 1/2: Symbolization of vector-roads (left), hybrid WYSIWYG display (right).

- Construction, placement, deletion and modification of simple area map elements and symbols:
  - Construction: Rectangles, polygons, orthogonal polygons, circles, symbol cells.
  - Placement: Interactive, automatic (using coordinate file), horizontal, vertical, rotated, enlarged, reduced, repeated.
  - Deletion: Complete, partial, grouped.
  - Modification: Type, color, layer, group/ungroup, simplification.
- Construction and modification of complex area map elements:
  - Construction: Digitalization, construction from existing linear features.
  - Modification: Gap filling, closing of area, adaptation to neighbor areas, fill with textures, area attributing by centroids, other manipulations (like above).

2.7 Hybrid processing of vector and raster data

The combined (hybrid) editing of vector and raster data is essential in a modern digital cartographic production environment. The raster format is needed for scanning existing analog map originals. It is necessary for image transformations, for area manipulations and masking operations. Furthermore it is needed for the output of print-ready films on a laser film recorder. If necessary, new vector elements must be adapted to the existing map image. Then they must be symbolized according to the map legend (usually during rasterization) and be united with the raster graphics.

2.7.1 General demands

- Placement of vector and raster layers into foreground and background according to the user's needs. Possibility of almost simultaneous editing: Fast switching between the two modes.
- Cartographic objects can be extended over several layers. They must be simultaneously manipulateable.
- Possibility of hybrid plotfiles with raster data and symbolized vector data.

2.7.2 Vector ⇒ raster conversion (symbolization)

- Definition of all map elements in a symbol/style library according to the map legend.
- „WYSIWYG" display on screen to avoid conflicts between map elements (Fig. 2).
- Automatic adjustment of dashed lines between start and end point. Possibility of interactive, local adjustment in order to avoid gaps on bending points.
- High quality of symbolization/rasterization at any resolution.
- Definition of different styles of line terminators and bending points.
- Global and local vector ⇒ raster conversion.

2.7.3 Raster ⇒ vector conversion (symbolization)

- Batch vectorization, global and local.
- Supervised, semi-automatic vectorization.
- Vectorization of double lines (axis).
- Vectorization of dashed and non-symmetric lines (axis).
- Vectorization of lines with different thickness, classification according to thickness.
- Pattern, symbol and text recognition functions.

2.8 Text processing

- Import of any vector font in different formats (PostScript, TrueType,...).
- Interactive placement of text objects with different text attributes.
- Automatic placement of text objects out of name databases and other pre-formatted text documents, automatic attributing.
- Text placement along a smoothed (interpolated) vector line.
- Variable change of text attributes as font, size, orientation, character spacing, word/symbol spacing, line spacing, color, bold, italic, shaded, superior,....
- Interactive change of existing text objects: Move, rotation, alignment, centering, deletion, re-attributing.
- Global change of text attributes using a formatting table.
- Export of names, positions and attributes in a report file.

2.9 Processing of continuous tone data (image processing)

- Display of shaded reliefs and orthophotos with 256 gray values (8bit).
- Display of color images (RGB, 3 x 8 bit).
- Global transformation of gray values: Change of gradation, contrast, brightness,....
- Local change of gray values: Filter operations.
- Interactive retouching.
- Reduction of number of colors.

* Rectification, fitting onto vector data and binary raster data.

2.10 Data output

2.10.1 Output on film (laser recorder)

* Maximum film format needed?
* Devices for exact positioning of the film on the scanner.
* Variable resolutions; high resolutions (≥ 2 x input pixel resolution) recommended.
* Choice of variable screen percentages, angles, frequencies and dot shapes.
* Recording of different screen percentages, angles and percentages on one film.
* Recording of screened continuous tone images (AM and FM, Fig. 3/4).
* Combined recording of line art, screened tints and screened continuous tone images; clearing of single elements against background elements.
* Combined recording of raster data and symbolized vector data (RIP, online/offline rasterization).
* Batch oriented lithographic copy work: Screening table containing raster layers with information about priority, masking, overprints, effective depth, CYMK values.
* Output of map extracts.

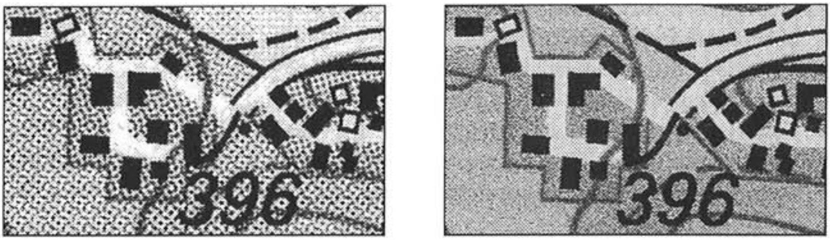

Fig. 3/4 Conventional AM- (left) and FM-screening (right), 4-colour offset printing.

2.10.2 Other output

* Output on hardcopy devices (printers, digital proof devices) and softcopy devices (computer screen).
* Output of map data in different raster, vector and hybrid formats.

2.11 General demands on computer equipment

In this section, general demands on hardware and basic software are given. Depending on the specific task, the configuration can differ from case to case, of course. Thus, only the most important topics are listed here. More information about how to define a „scope of duty“ for computer system evaluations can be found in SVD (1985).

2.11.1 Hardware

* General requirements (processor, RAM, etc.).
* Communication.
* Periphery devices.

2.11.2 Software

* Operating system.

- Graphics standards.
- System administration.
- Text processing.
- Backup, data safety.
- Communication.

2.11.3 Performance requirements

It does not seem useful to prescribe any MIPS, Spec, or similar indicators here. The interaction between different software modules and the peak load of graphic operations must be benchmarked separately using typical (large!) data sets and workflows.

2.11.4 General aspects

- Hardware maintenance.
- Update of software.
- Documentation of hardware and software.
- User training.
- Planning of installation.

3. Solution at the Federal Office of Topography

The major difficulty met during the evaluation process was to find a multipurpose system with good raster, vector and hybrid „WYSIWYG“ functionality. This finally led to the decision to distribute the work on two systems: **MicroStation/IRASB** by Intergraph and **Dry/Nuages** by LORIK (Ertle/Lauinger, 1995). The resulting workflow consists of four major parts:

3.1 Input of map data

Existing map separates are scanned at a resolution of 50 lines/mm (1270 dpi) from film mounted on a white background. Extensive tests using the Scitex LRP scanner/laser film recorder have been made in order to obtain optimal results. Copying the films onto opaque material proved not to be necessary. At medium-term it is planned to replace the scanner by a newer model.

3.2 Preparational work

The scanned raw data is now imported into MicroStation/IRASB and MapPublisher/PixelPro by Intergraph. The system is mainly used for rectification, geocoding, Boolean and masking operations, automatic „dirt“ remove and manual retouching in raster mode. Some deletion masks are also created in raster („brush“) mode which proved to be more comfortable than in vector mode.

3.3 Interactive map updating

The main interactive cartographic work is done in DRY/NUAGES. Raster layers can be stacked and displayed in the background according to their correct priority. New, fully symbolized vector elements are placed on top of the raster background. The „WYSIWYG“ mode allows to visualize interactions like masking and overprints between vector elements as well as between vector elements and raster layers. Finally, symbolized vector elements are „burned in“ to the corresponding raster layers according to predefined color separation attributes of each element.

3.4 Output of the map data

The modified raster layers can be plotted on the same Scitex LRP laser film recorder. Conversion to Scitex Handshake format is done using Intergraph software. Special Boolean and masking operations could be done with Intergraph MapPublisher, if necessary. The Federal Office of Topography is currently evaluating a new large-format film recorder.

4. Future demands

Today, modern cartographic production systems allow to produce topographic and thematic maps entirely by digital methods. The produced maps have a high graphic quality comparable to analog products. In some areas like topographic area elements the production methods can be simplified and the quality of output and representation can be improved. Cartographic „finesses" which are essential in order to create an easily perceptable map image can be worked out with modern „WYSIWYG"-based systems. The expenditure, however, is comparable to analog production. The advantage is effective when updating maps or when carrying out variant studies. In the future researchers and developers must focus on the combination of cartographic and topological (GIS) data models. Map elements often are placed according to design and generalization rules the way the map „looks well". Topological rules are broken (Fig 5/6). Dual, consistent data models combining the two „worlds" wait to be developed!

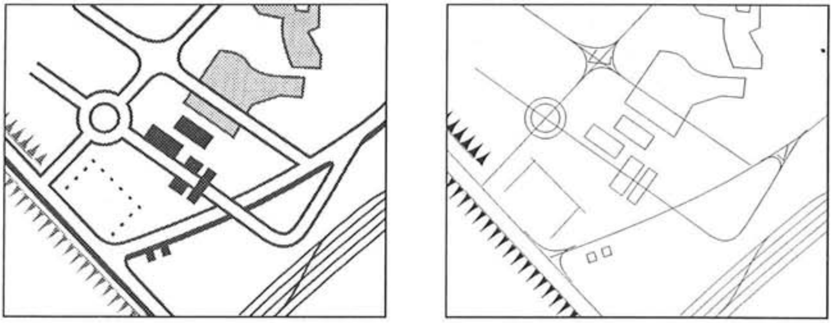

Fig. 5/6: Symbology turned on/off: Cartographic design breaks topology!

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RÉSOLUTION DES PROBLÈMES DE GÉNÉRALISATION LIÉS À LA SYMBOLISATION DANS PLAGE

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Abstract

In order to study cartographic generalization problems, the COGIT laboratory has developed a research platform, called PlaGe. This platform allows to tackle generalization problems that are entailed by symbolisation, notably from the superpositions of cartographic symbols. This text, and the poster, give illustrations of generalization operators, with a focus on caricature and displacement, and some tools to detect conflicts automatically.

Introduction

Lors de la généralisation cartographique d'informations linéaires, notamment les routes, de nombreux problèmes résultent de l'emprise cartographique prise par les différents symboles représentant ces routes. Afin de conserver la lisibilité de l'information, le cartographe effectue des opérations de généralisation comme le déplacement, la simplification et la caricature. Avant d'obtenir une solution automatique entièrement fiable et afin de progresser dans ce but, le laboratoire COGIT a développé une plate-forme de recherche en généralisation, appelée PlaGe, permettant en particulier de visualiser ces problèmes liés à la symbolisation. Le poster associé à ce texte (à défaut d'une démonstration sur écran) permet de visualiser, d'une part, les résultats, dans PlaGe, des différents algorithmes proposés pour résoudre les problèmes liés à la symbolisation et, d'autre part, les différents outils existant pour détecter les conflits en vue d'automatiser le processus de généralisation.

La Plate-forme de Généralisation PlaGe

Pour étudier les problèmes de généralisation, le laboratoire COGIT a opté en 1992 pour le développement d'une plate-forme servant de support à toutes les recherches algorithmiques en généralisation cartographique en mode vecteur et permettant des expérimentations sur des lots de données importants. Les grands axes qui ont guidé la création de la plate-forme PlaGe sont :

* Disponibilité de structures de données riches en topologie,
* Possibilité de visualiser les données linéaires sous différentes formes, en particulier avec l'emprise du symbole choisi pour l'échelle de rédaction souhaitée,
* Facilité d'implémenter et d'intégrer à la plate-forme les algorithmes de la littérature et ceux proposés par le laboratoire,
* Facilité de tester ces algorithmes et de définir les paramètres adaptés,
* Possibilité d'étudier le séquencement d'opérateurs de généralisation,
* Possibilité de réaliser des traitements numériques importants,
* Modularité de l'implémentation et de l'interface.

Soulignons l'importance de ce dernier point dans le cadre d'une équipe de recherche. En effet, plusieurs chercheurs travaillent au COGIT sur la généralisation dans des domaines proches et le laboratoire accueille aussi de nombreux stagiaires. C'est pourquoi, il est intéressant de disposer d'un environnement de développement commun et que chaque utilisateur puisse ajouter aisément dans l'interface ses propres développements. Progressivement, la plate-forme s'enrichit des travaux de chaque chercheur.

Pour analyser les problèmes de généralisation liés à la symbolisation cartographique, un menu spécifique concerne le mode de visualisation des données, particulièrement celui des arcs. Il est possible d'afficher les arcs sous quatre formes :

* l'axe de l'arc seul,
* l'axe de l'arc et les points intermédiaires,
* un ruban dont la largeur est fonction de l'attribut cartographique de l'arc et de l'échelle de rédaction,
* un ruban et l'axe de l'arc.

Précisons que les deux premiers modes s'affichent plus rapidement que les deux derniers, mais ceux-ci permettent de visualiser les problèmes liés à l'emprise cartographique. Dans ces deux derniers modes, la modification du zoom d'affichage ou de l'échelle de rédaction conduit à modifier l'emprise du symbole affiché à l'écran, garantissant, à la résolution de l'écran prêt, un affichage identique à celui obtenu sur la carte papier rédigée à la même échelle et visualisée éventuellement avec une loupe. La figure 1 fournit un exemple d'affichage sur PlaGe.

En visualisant des données routières sur PlaGe, les problèmes liés à la symbolisation apparaissent alors clairement : la superposition des symboles cartographiques empêchent une lecture satisfaisante de l'information. Ces problèmes sont présents :

* pour des routes proches parallèles : l'un des signes cartographiques est empiété ou disparaît complètement (Cas 1 sur la figure 1),
* au niveau des intersections en sifflet de routes où la localisation du carrefour est difficile à effectuer (Cas 2 sur la figure 1),
* dans le cas des virages serrés où on observe un empâtement du signe cartographique (Cas 3 sur la figure 1).

Pour chacun de ces problèmes, des algorithmes spécifiques ont été implémentés sur PlaGe à partir soit de textes publiés dans la littérature de généralisation, soit de travaux effectués dans le laboratoire. Différentes illustrations vont être fournies par la suite sachant que la description détaillée des algorithmes peut être trouvée dans les publications citées en référence.

Figure 1 : Visualisation sur PlaGe de données routières de la BD Carto saisie au 1 : 50 000 et visualisée ici avec une symbolisation au 1 : 250 000. Les différents problèmes sont : Cas 1 = Superposition de routes

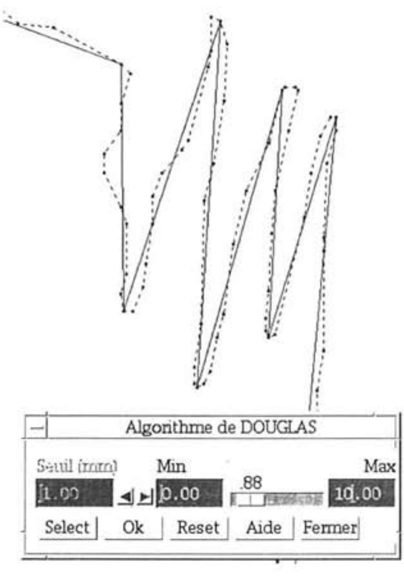
Cas 2 = Intersection en sifflet

Cas 3 = Empâtement de virages

Opérateurs élémentaires de généralisation

Différents algorithmes ont été implémentés dans PlaGe afin d'étudier leurs effets. Pour tous ces algorithmes, un menu d'interface permet d'appliquer le calcul soit dynamiquement sur un arc afin d'analyser l'effet de la variation de la valeur du ou des paramètres (Cf figure 2a et 2b), soit non dynamiquement avec une valeur fixée pour chaque paramètre applicable sur un ensemble d'arcs. Quelques exemples sont illustrés pour les différentes catégories d'opérateurs traditionnellement définies en généralisation. Pour toutes les illustrations, le trait pointillé correspond à la ligne initiale, le trait noir ou blanc à la ligne après application de l'opérateur de généralisation, en gris l'emprise du signe cartographique.

* Algorithmes de filtrage : destinés à diminuer le nombre de points intermédiaires de la ligne. Le plus utilisé car conservant le mieux les points remarquables de la courbe est l'algorithme de [Douglas et Peucker, 1973]. Les autres algorithmes de filtrage implémentés dans PlaGe sont ceux de [Thapa, 1989], [Van Horn, 1986], [Wall & Danielsson, 1984], [Lang, 1969].



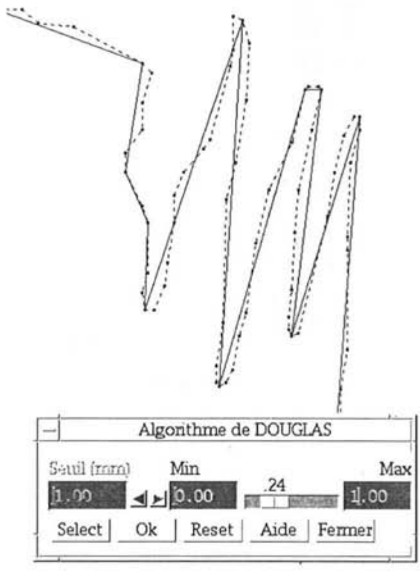


Figure 2a et 2b : Algorithme de Douglas & Peucker avec 2 valeurs de paramètre différentes et le menu de l'interface utilisateur

* Algorithme de lissage : destinés à diminuer les angularités des courbes. Les algorithmes implémentés dans PlaGe sont le filtre gaussien et les algorithmes de [Brophy, 1973], [Beard, 1991], [Mc Master, 1989].

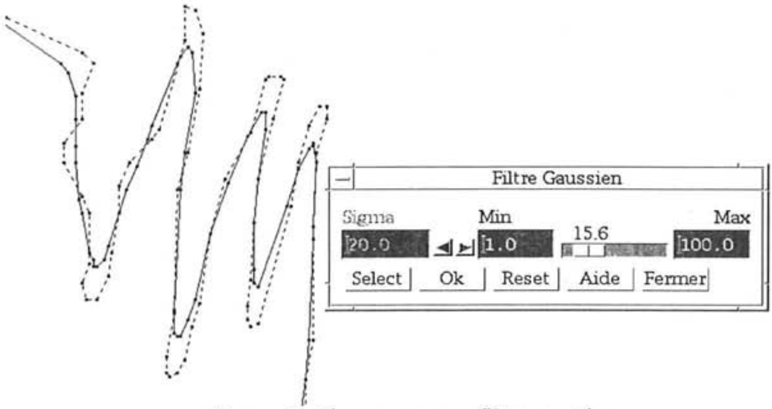


Figure 3 : Lissage avec un filtre gaussien

*Algorithmes de caricature : destinés à exagérer les formes afin de les rendre visibles. Cet opérateur dont la nécessité apparaît fortement lorsqu'on applique sur les routes la symbolisation à l'échelle de rédaction finale a été jusque là peu abordés dans les recherches en généralisation. Le laboratoire COGIT a proposé différents algorithmes :

- *Algorithme de l'Accordéon* : destiné à écarter les séries de virages empâtés, cet algorithme provoque un étalement des points d'inflexion des virages dans la direction qui est celle de la droite de régression des points d'inflexion ([Plazanet, 1996])

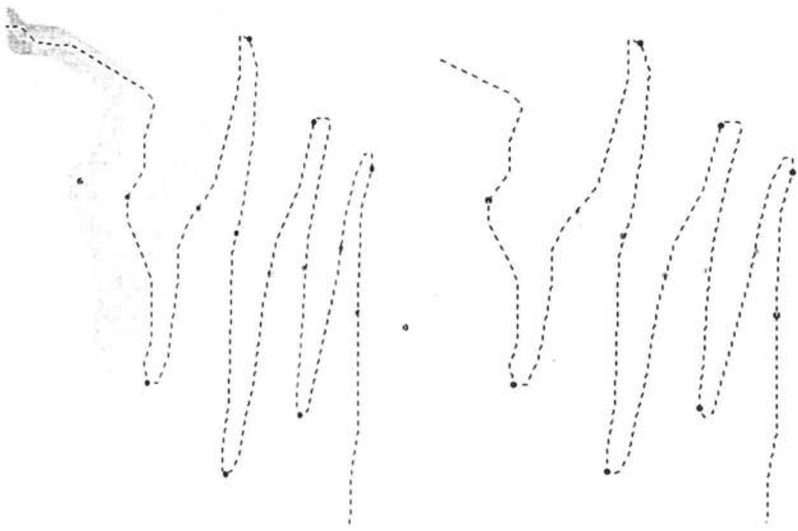


Figure 4 : Algorithme de l'Accordéon *Figure 5* : Algorithme de la Baudruche

- *Algorithme de la Baudruche* : destiné à écarter les sommets des virages empâtés, cet algorithme produit un gonflement proportionnel à l'abscisse curviligne du point considéré entre le point d'inflexion du virage et le sommet du virage, le maximum du gonflement étant provoqué au sommet du virage. ([Lecordix & al., 1997])

- *Algorithme Plâtre* : basé sur un lissage de la courbure, cet algorithme permet de fixer un rayon minimum de courbure provoquant alors une caricature du virage ([Fritsch, 1997])

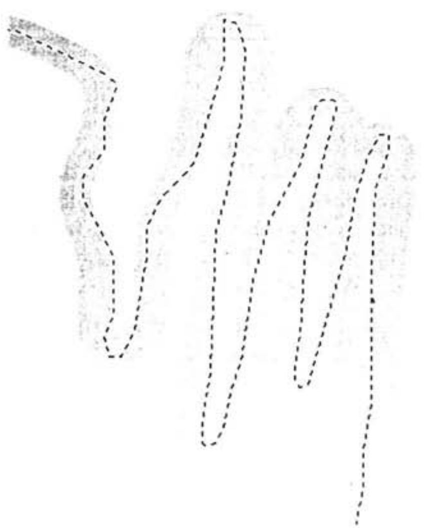


Figure 6 : Algorithme Plâtre

Figure 7 : Algorithme de Schématisation

- *Algorithme de Schématisation* : destiné à supprimer deux virages successifs dans une série de virages en lacets lorsque l'emprise du signe est trop importante pour pouvoir conserver lisiblement tous les virages. Cet algorithme utilise des principes voisins de ceux de l'algorithme de l'Accordéon (points d'inflexion + droite de régression des points d'inflexion) après élimination des 2n derniers virages ([Lecordix & al., 1997])

Outils de détection automatique de conflit

Pour détecter les problèmes liés à la symbolisation, un algorithme a été développé pour calculer en mode vecteur les bords pris par l'emprise du symbole cartographique à l'échelle de rédaction finale ([Mustière, 1995]). Cet algorithme est à la base de la détection des problèmes d'empâtement, de proximité entre routes et d'intersection en sifflets.

Pour l'empâtement, à partir de ces deux bords de route, on détermine les points de l'axe de la ligne qui sont éloignés d'un des bords d'une valeur supérieure à la demi-largeur du signe cartographique plus une tolérance. Un exemple de détection automatique dans PlaGe est fournie dans la figure 8.

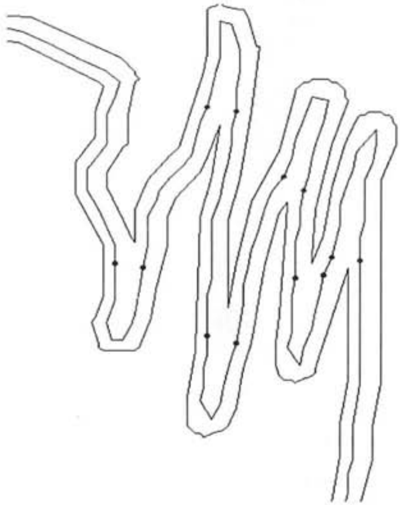


Figure 8 : Détection automatique des portions de courbe empâtées sur PlaGe (entre 2 points successifs noir ou gris)

Pour les problèmes de proximité entre routes et les intersections en sifflet, la méthode utilisée repose sur les travaux de [Nickerson, 1988]. A partir du calcul des bords des symboles des routes, on détermine les intersections entre bords. Ceci permet de déterminer les arcs qui sont en conflit avec l'arc considéré, de les classer suivant la gravité du conflit et de proposer une solution de déplacement pour résoudre la superposition des arcs (Cf. figure 9).

Lors d'une intersection de routes en sifflet, un déplacement spécifique de l'arc est proposé aussi par Nickerson. Cette méthode a été aussi implémenté dans PlaGe et une illustration des résultats obtenus est fournie dans les figures 10a et 10b.

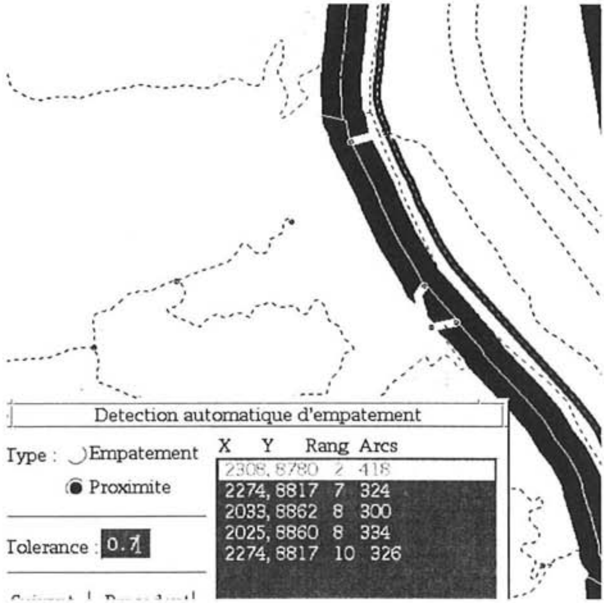


Figure 9 : Déplacement automatique des arcs se superposant avant généralisation en utilisant la méthode de Nickerson

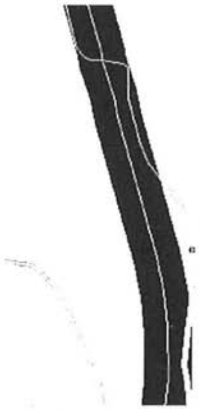


Figure 10a : Intersection en sifflet avant généralisation

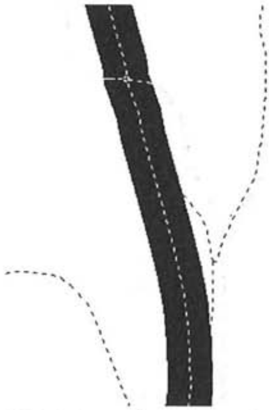


Figure 10b : Résolution automatique du conflit par la méthode de Nickerson

Conclusion

En combinant les outils de détection de conflit et les opérateurs élémentaires de généralisation (filtrage, lissage, caricature et déplacement) dans PlaGe, le laboratoire COGIT dispose d'une plate-forme pour détecter et résoudre semi-interactivement les problèmes de généralisation liés à la symbolisation. Dans le but de progresser dans l'automatisation de la généralisation, les recherches se poursuivent pour déterminer automatiquement les algorithmes ou les séquence d'algorithmes, ainsi que les valeurs des paramètres à appliquer sur chaque portion homogène de la ligne suivant un processus décrit dans [Ruas et al., 1996].

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ORBITAL IMAGES POTENTIAL IN CARTOGRAPHIC UPDATING

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Abstract

The main aim of this paper is to evaluate the orbital images potential in topographic map updating. The work scale is 1:50.000 and the images evaluation involves geometric precision and the information content. The alternative methodology proposed here to cartographic updating uses non sophisticated and low cost hardware and software, as 486-DX-50 personal computer and AUTOCAD R.10; IDRISI 4.1, respectively. The orbital images are SPOT-P (panchromatic) and Landsat-TM bands 1, 2, 3, 4, 5 and 7. Image enhancement technics as Linear Stretch, HSI transformation and Principal Components transformation were used with success specially regarding the information content. The three best images with enhancement were chosen: SPOT-P with Linear Stretch; the SPOT-P and TM-347 colour composition from HSI transformation and finally the 3rd component from Principal Component transformation using SPOT-P image and the 6 bands from Landsat-TM image. The linear features studied here were roads, railways and energy transmission lines. Urban area expansion was mapped too. The final maps present a large quantity of details, indicating all tested images as viable to 1:50,000 maps updating. The field work was indispensable in verifying the image interpretation. Graphics and tables show quantitative results of features length from updating maps elaborated from three chosen images, comparing them with the original map. The quantitative analysis of geometric precision of generated products presented RMS equal to 18 meters, result according to the research expectancy. The comparison of informative content performed, shows that all images conform the updating prerequisites, providing a high number of features. The results demonstrated the potential of a low cost alternative methodology for updated topographic maps at 1:50,000 scale, according to specific needs of regional planning users.

1. Introduction

Nowadays, cartography has countless technological resources to construct and update maps. GIS technology and remote sensing systems appear as alternatives in substitution for conventional mapping. The possibility of using low cost geographic information systems, usually academic and orbital images with high geometric precision, such as SPOT-P (panchromatic) and high radiometric precision, such as Landsat-TM, with 6 bands available to cartographic applications are more compatible with the user reality in developing countries.

The advantage of mapping using orbital images consists in the periodicity, repetition and/or the pre-programming possibility associated with lower costs when compared with the topographic and photogrammetric proceedings. The limitations consist of resolution of available images and their contents. In reality, there are many papers showing that orbital images perform geometric requisites for any scale but few perform the information requisites.

1.1. Objectives

The main aim of this paper is to evaluate the orbital images potential in topographic map updating. The work scale is 1:50,000 and the images evaluation involves geometric precision and the information content.

The IDRISI 4.1. system is used in updating tasks involving linear features of topographic maps such as roads, railways and energy transmission lines. The SPOT panchromatic and Landsat-TM images, bands 1, 2, 3, 4, 5 and 7 are used in the project. The enhancement technics are applied to orbital images with the objective of highlighting features of interest.

The hidrographic and altimetric features are not included in the study because, in general, these have little transformation with time. Besides, these altimetric features have difficult treatment with available resources and the relief does not experiment high variations in the 1:50.000 scale, with 20 meters between the level curves.

This paper intends to attend a typical regional planning user whose best scale is 1:50,000 and who cannot afford sophisticated hardware and software acquisitions.

1.2. The necessity of updated maps in Brazil

Publication [5] alerts to the importance of updated maps for the development of any country. It presents United Nations statistics from 1987 which indicate that only 56% of the world territory is covered with 1:50,000 maps, increasing this area on average by 2% per year. Unfortunately, when available, the maps in Brazil are in unsatisfactory scales or not up-to-date. It's important to note that maps in useful scale for planning are about 30 years old. All this emphasises the necessity and importance of developing quick and cheap updated methodologies offering acceptable precision. The situation of systematic mapping in Brazil, according to [1] is critical. The usual scales for planning projects such as 1:100,000 and 1:50,000 in a publication dated 1991, accounted for 65.9% and 13.1% respectively of existing maps. Which means that 34.1% of 1:100.000 maps and incredible 86.9% of 1:50,000 maps are still to be executed, corresponding respectively at 3,049 and 11,928 of foreseen maps. The main challenge of this paper is to prove that orbital images are, nowadays important data source alternatives and will in the near future be a solution to the systematic mapping and updating lacuna in Brazil.

1.3. Area of Study

The area of study is a sector of a topographic map from IBGE (Instituto Brasileiro de Geografia e Estatística), Brazilian Institute of Geography and Statistics, SF-22-R-IV-3, called Botucatu, scale 1:50,000 edited in 1969 and based on aerial photographs from 1965. This is a map in Universal Transverse of Mercator Projection (UTM), fuse 22. The area of study corresponds to 8,520m x 8,440m, with latitudes 22°53'S and 22°58'S and longitudes 48°25'W and 48°30'W.

2. Updating methodologies

The paper [5] is a comparative study of orbital images performance in mapping and updating tasks in 1:50,000 scale. The use of a stereoscopic pair of SPOT images led to a greater quantity of information when a non updated 1:50,000 topographic map was used. The field work was an important complement of the mapping with the SPOT image. The same potential was detected with the KFA 1000 and MK4 cameras, the author having observed no significant differences between SPOT and KFA 1000 products. Concluding that the orbital images studied were economical alternatives to mapping and updating in 1:50,000 scale, with the exception of KATE 200.

Paper [7] presents a software called monocomparator plotter digital, developed for the compilation and revision of digital maps resulting from satellite images and orbital photographs. This is a new photogrammetric instrument to replace conventional photogrammetric devices by digital memory with the floating point as a screen cursor. This study highlights the importance of the informative content in cartographic applications using orbital images.

A prior paper [6] showed the mapping and revision work with Landsat TM images and orbital photographs from a Metric Camera in scales 1:50,000, 1:100.000 and 1:200.000 from France, Libya and Brazil. Also, image maps were generated for revision.

As a conclusion, the author points out that most of the maps are in the standards of cartographic precision. The Metric Camera images provide detection of a large number of features but a significant portion of this information was not clear or was lost. The same occurred with the TM images from Brazil, presenting inadequate results to mapping and revision in the 1:50,000 and the 1:100,000 scales. Therefore, although the cartographic and geometric precision were standard, the informative content limits the use of these orbital images and photographs for mapping and revision in middle scale.

A multiresolution composite image was produced in [8] for mapping at 1:50,000 scale using Landsat TM and SPOT P. The HSI transform was used with the two kind of Landsat-TM compositions, choosing to test the TM-432. The SPOT-P was used to replace the component intensity (I) in order to improve the geometric resolution of the resulting images.

The software IDRISI, adopted in this project, is an academic geographic information system, in raster format, developed and improved since 1987 by the Graduate School of Geography at Clark University, projected to provide professional-level geographic research tools on a low-cost non-profit basis, according to [3].

The version 4.1 [4], launched in 1993, is used in this paper. It has the possibility to receive and generate vectorial features, besides a complete image processing module, recourses explored in this paper.

3. Methodology

3.1. Data Acquisition

In this paper we used one Higher Resolution Visible (HRV) image, from SPOT satellite, panchromatic mode from May 21, 1991 (K712 - J396), with 10 m resolution. One Thematic Mapper (TM) image from Landsat-5, with six spectral bands and 30 m resolution from October 14, 1991 (Orbit 226 - Point 76A). Also, topographic maps from IBGE in 1:50,000 scale, from 1969 and from IGC (Geographic and Cartographic Institute) in 1:10,000, from 1978, both in the Universal Transverse Mercator (UTM) projection. The original data from IBGE topographic maps were digitilized using AutoCAD R.10, with features distributed in layers corresponding to existent information. The basic layers were urban area, paved roads and streets, roads and streets without pavement with continuous traffic, roads without pavement and periodical traffic, trails, railways, energy transmission lines, drainage and altimetry.

The map was edited and exported to IDRISI using the DXF format. The ROOTSPRO software was used as an intermediary to the exportation of the DXF to IDRISI due to the limitations of the importation module of IDRISI v.4.1.

3.2. Image geo-referencing

Before enhancement of the orbital images, control points were selected for SPOT-P and Landsat-TM images to do the geometric registration, or geo-referencing. A total of 22 control points were detected in each image and in the original maps from IGC, scale 1:10.000. The 1st degree polynomial model chosen in IDRISI's resampling algorithm was based in [9] experience in mathematical models refining using Landsat-TM images. Due to the two sets of data presenting different spatial resolutions, the TM data were resampled by using an expansion factor of 3 times, resulting in a spatial resolution of 10 m.

3.3. Image Enhancement

Technics for the enhancement of orbital images are made to improve the quality of the images to visual interpretation of interesting features. Then, through a rigorous selection 3 images were chosen: the SPOT panchromatic with enhancement; the SPOT and TM merged image using HSI transform and the 3rd component from Principal Component transform.

The test using only the SPOT panchromatic (P) image, with low contrast in histogram, was to enhance with simple linear stretch using cut-values inferior and superior to 15 and 76 gray levels. That stretched image was used as the first updating test.

The second test, using an integration method of two data sets was the HSI transform. The space colours in HSI are defined by hue, saturation and intensity attributes. Before doing the transformation the histogram equalisation by manual method was applied to the images involved in the research, searching for a higher balance among the associated colours in RGB (red, green and blue) space. The process involved the transformation of each chosen TM band from the RGB space into HSI colour space and the replacement of the intensity component for the SPOT panchromatic data. Then, the inverse transformation of H, S and I (with SPOT-P) was performed by using simple linear stretch, resulting in a RGB merged image. This procedure intends to combine the higher spatial resolution of SPOT-P with the best spectral resolution from TM bands, according to [2, 8]. In order to choose the best merged image to the linear features detection considered in this study, the HSI transformation was applied for the following TM-RGB compositions: TM-321, TM-432, TM-543, TM-743, TM-435 and TM-437. Control features were analysed concerning the following elements of interpretation: shape, pattern, colour, texture and association. In general, the results are good. Through all visual analysis of control features, the best image for those updated objectives resulted from TM-437 composition plus SPOT-P image.

The last test using data integration methods was the Principal Component Transform. All the 6 Landsat-TM bands and SPOT-P images were used in that transform. The first step was the manual gray levels equalisation for bulk image. The Principal Component transform generated variance-covariance matrix, auto-value and auto-vector values. Analysing the correlation matrix data and the resulting images, the PC3 image was chosen to update the interesting features while the classification information from railways, roads and streets with pavement was extracted from PC2.

3.4. Screen Digitalisation and Edition

The screen digitalisation was made with the IDRISI's digitalisation mode. The new linear features were registered by observing the image in the background and the original map on the screen. Non detected features were kept for future ground verification. Files with the updated maps were generated in vectorial format, transformed in DXF and exported to AutoCAD R.10. The edition in AUTOCAD R.10 involved basically the closing of polygons and intersections. Then, for each image tested, the features were distributed in layers: new roads with pavement, new roads without pavement, new railways, new energy transmission lines, new urban area, repeated features and undetected old features.

3.5. Preliminary Verification and Field Work

A preliminary verification of updated features was scheduled due to the availability of maps in the 1:10.000 scale, from 1978, and viewing the reduction of field. The reduced copies of the maps from 1978 composed an analogic mosaic at the 1:30.000 approached scale, with interesting features highlighted by colours, using pens.

The updated maps without field work were named “Updating Drafts”. These drafts were increased to a 1:30.000 scale in transparent material (polyester) and a visual verification of the new features present in 1978, was made.

Features present in the 1978 maps and not registered in the updated maps were included in the polyester for future verification in the orbital image. In the case of

possible identification in the orbital image, the features were included in the new map.
After this step, the field work was done to solve problems unsolved in the preliminary verification. Six sections of field work were done, of approximately 12 hours each, in order to verify features with different interpretations in the updated maps and 1978 maps, and those not registered in the 1978 maps. The field work offered important information about the classification of dirt roads (with permanent traffic, periodic traffic and trails) and about the energy transmission lines (high tension and low tension).

3.6. Final Interpretation

The aim of this step is to complement the first interpretation with the field reality. A new interpretation was made using the updated maps plus the field reality registered in transparent material (polyester).

4. Results

The results are presented as updated maps without verification drafts, updated maps with field verification and tables concerning information content's data for the 3 kinds of images studied.

4.1. Updated Topographic Maps

The updated maps resulting from SPOT panchromatic image, from merged image, resulting from HSI transformation and from 3rd component from Principal Component transformation were made by using colours. A total of 6 maps were generated, 3 without and 3 with field verification.

4.2. Geo-referring Precision Results

The geo-referring precision evaluation by RMS. analysis in generated products was performed by using 24 verification points for each image. The ground co-ordinates were obtained from IGC maps, the 1:10.000 scale and the results are showed in table 1. Analysing the results, it is possible to verify approximately the RMS. equal to 18 m, result according to the research expectancy for topographic map updating at the 1:50.000 scale.

Geo-referring Precision Results	SPOT-P Stretch Image	HSI Image (TM-347 + SPOT-P)	3rd Principal Component Image
RMS_E (m)	15	14	12
RMS_N (m)	11	11	13
$RMS_{E,N}$ (m)	**19**	**18**	**18**

Table 1: Geo-referencing precision results

4.3. Information Content

The measure of information content was made through AutoCAD R.10 using functions concerning polylines lengths and areas.
In a first step the results concern the total length and area corresponding to the features from original map and from updated maps without field verification, called updating drafts (Table 2).

Length and area of features without field verification - updating drafts -	Origin al Map (1969)	Map from SPOT-P Image (1991)	Map from HSI Image (1991)	Map from 3rd PCA Component (1991)
Urban Areas (m^2)	2,901, 747	11,575,73 1	11,568,291	11,317,177
Roads with pavement (m)	20,751	30,538	116,728	74,350
Dirt Roads (m)	136,15 8	268,075	203,176	282,386
Railways (m)	5,368	5,971	4,831	6,147
Energy Transmission Lines (m)	24,839	30,270	29,180	40,980

Table 2: Length and area of features from original map and updating drafts.

Table 2 shows both resulting maps adding a large quantity of information to the original map. There are little differences between SPOT-P, HSI and PCA transformation products in urban areas and energy transmission lines values. The great discrepancy in roads with pavement is due to the detection of paved streets in HSI and PCA images, which does not occur in SPOT-P image. The street arrangements look like roads without pavement in the original map. In general, there are difficulties in the identification of railways in HSI image and in energy transmission lines due to a loss of continuity of these features in the images. The second step of results concerns to final maps with field verification, presented in table 3.

Length and area of features with field verification - final maps -	Origin al Map (1969)	Map from SPOT-P Image (1991)	Map from HSI Image (1991)	Map from 3rd PCA Component (1991)
Urban Areas (m^2)	2,901, 747	11,575,73 1	11,568,291	11,317,177
Roads with pavement (m)	20,751	85,899	96,821	99,479
Dirt Roads (m)	136,15 8	232,513	230,402	232,946
Railways (m)	5,368	5,971	5,368	6,147
Energy Transmission Lines (m)	24,839	55,992	53,049	50,526

Table 3: Length and area of features from original map and final maps.

Observing the quantitative values of final maps, table 3, comparing with table 2 values, it is possible to detect a reduction of paved roads in the final HSI map. It is due to an interpretation mistake in allotment around the urban area. An increase in the quantitative values of this theme in SPOT-P and PCA products occurred. The field work made possible the dirt roads classification in permanent traffic, periodic traffic and trails. The permanent traffic dirt roads increased 50% approximately for all products and the trails increased approximately 5 times the original quantity. The preliminary verification and the field work made possible the identification of trails that would not usually appeared in the 1:50.000 scale. The railways were mapped with details by the PCA image, making possible the detection of multiple trail. The energy transmission lines were divided in high tension and low tension and doubled its quantity in all generated products.

5. Conclusions

These results demonstrated the potential of orbital images as a low cost alternative methodology to updating topographic maps at the 1:50,000. The geo-referring precision analysis presented approximately the RMS equal to 18 m for studied images, compatible with the research expectancy. The comparison of informative content performed shows all images with potential to updating tasks. The HSI and PCA images make possible the identification of paved roads and streets. The dirt roads were better identified with PCA and SPOT-P images, with little field work, while the HSI image needed more field work. The railways were better detected in PCA image, followed by SPOT-P while the HSI image needed more field work. The energy transmission lines best results were from PCA image, followed by SPOT-P. Although all tested images provided good results in updating map tasks, if the issue is the minimisation of field work, then the HSI image is recommended for paved roads updating. The PCA image is recommended for dirt roads, railways and energy transmission lines, followed by SPOT-P.

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ELECTRONIC ATLAS AS INFORMATION BASIS TO STUDY ENVIRONMENT AND NATURAL RESOURCES AT THE RUSSIAN REGIONS

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Electronic atlas is complex cartographic product presented in digital form which characterizes the peculiarities of environment and natural resources potential of the region.

For atlas creation published and archived maps and schemes a different scales as well as another necessary information as graphs and tables are used. Under transition of these data into digital form there are certain difficulties because of variety of scales and cartographic projections. A choice of basic scale of the maps included into atlas depends upon detailed of including materials.

Electronic atlas is rationally created on the basis of Integrated GIS.
Integrated GIS are used to work with regional electronic atlases, for example, GIS software Geograph, developed by the Geography Institute of Russian Academy of Science, allows to analyze the data using wide scope of technical capabilities.
There are such operations as subdivision of maps on separated layers, combinations of separated layers from different maps, demonstration on monitor several maps or its fragments simultaneously, creation of intermediate schemes as a result of basic maps analysis.

Electronic atlas includes complex inquiry information in different scales and consists of the following general sections:

1. Geological structure and mineral resources
2. Relief (Digital Elevation Model, landforms)
3. Surface and ground waters
4. Soils
5. Vegetation
6. Animal kingdom
7. Economy
8. Climate
9. Medico-geographic conditions
10. Ecology
11. Satellite images

Every section consists of series maps and schemes including detailed information. For example, section entitled "Geological structure and mineral resources" includes the following maps: geological, tectonic, Quaternary sediments, neotectonic, seismic, geophysical, mineral resources (ore, oil, gas, building materials, underground waters and prospective maps on whole types of mineral resources, etc.).

Section "Ecology" includes maps of natural environment state showing pollution level of air, surface and ground waters, soils, vegetation as well as maps of reserves, protection zones, manmade disturbance, polluted resources, ways and halos of its spreading, etc.

Utilization of cartographic and remote sensing information included into atlas allows to examine at solution various problems, analyze different versions and select more rational one among others.

For example: at planning of geological-prospective works at the same time with geophysical information as usually used data on presence of agricultural areas, recreation zones, forests, water reservoirs, etc.; at the projecting of oil and gas pipelines information on relief, lithological composition of friable sediments, seismic properties of region, surface waters, swamping, population points, industrial and agricultural objects and other information needed for independent ecological examination are used.

Besides, by using of information containing in maps and schemes of electronic atlas gives a possibility to reduce time of preliminary examination at solution of such important for the Leningradian province problems as water supply, delineation of areas for widening of quarries at exploitation of building materials, development of motor transport net, creation of natural preserve park and recreation zones.

Important meaning has information included into electronic atlas for acceptance of operative decisions under extraordinary situations such as forest fires, oil, pipeline accidents, etc.

One of the way for efficient usage of electronic atlas is increase of its accessibility for large number of users.

Special versions of electronic atlas may be created for utilization at the regional level under acceptance of economic decision of district development at the certain time period. The more simple versions of electronic atlas are needed for students and school children in educational purposes.

INFLUENCE OF GEOMETRIC TRANSFORMATIONS TO THE POSITIONAL ACCURACY OF MAPS

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Abstract

This contribution deals with a general case of accuracy assesment of maps which incorporates accuracy and configuration of control points beside accuracy of points being transformed. The accuracy of a point is assumed to be expressed in form of probability density function (pdf) of its coordinates. The proposed method consists of two steps. Firstly, the pdf of the transformation parameters is estimated by application of Bayesian approach. Secondly, the pdf of position of a transformed point is computed by means of a special procedure that produces reliable pdf even when the transformation equations are approximated by simpler (linear) functions. The both steps together represents nonlinear Bayesian prediction with uniform prior pdf. The proposed approach have some remarkable advantages in comparison with the traditional least-squares method. Computational convenience of the traditional approach remains almost unchanged.

Keywords:

geometric transformation, Bayesian prediction

1 Introduction

Geometric transformation represents necessary step in digital mapping. It is especially important when cartographic data from different sources are combined. Typically, aerial photos, satellite images of various spectral bands, scanned or digitized maps are transformed to a unique cartographic coordinate system. Quality of geometric transformation determines the positional accuracy of objects in a map in combination with initial accuracy of local coordinates of the objects. Despite this fact, quality of geometric transformation is not fully considered in practice. Usually, once a specified quality of transformation is attained, only accuracy of local coordinates is used in subsequent assessment of positional accuracy. Such an approximate procedures are used to apply because the exact evaluation of accuracy characteristics is too difficult in general. Another reason for the approximate accuracy assessment is that geometric transformation does not significantly influence the positional accuracy in most cases. This assumption is, however, not valid in some special cases (high nonlinearity of transformation equations, too little control points in an image, not sufficiently reliable correspondence of control point pairs, etc.).

In this contribution, quality of geometric transformation is integrated with accuracy of local coordinates to evaluate the positional accuracy of maps properly. From the statistical viewpoint, geometric transformation is prediction (see e.g. [2]) of cartographic coordinates of an object in a map when coordinates of control points are given. The prediction consists of two steps: estimation of transformation parameters and density estimation of position of a transformed point. The main problem that is dealt with in the both steps is nonlinearity of transformation equations. Nonlinear statistical methods has been extensively studied by many authors, a number of momographs and articles have appeared in recent period (see e.g. [4], [1], [8]). In this contribution, a different approach was chosen that saves computational convenience of linear case and with a little additional effort a reliable pdf is estimated, that is not contaminated by any uncontrolable approximation. In this approach uniform probability distribution is employed as a prior distribution of linearization error.

Estimation of transformation parameters

In the first step, quality of geometric transformation has to be estimated. The most versatile quality measure of geometric transformation is joint probability distribution of transformation parameters. Traditionally, transformation parameters are estimated by the least-squares method. It means that the transformation parameters are normally distributed if the transformation equations are linear in parameters and the probability distribution of control points is normal. In such cases the subsequent operations (various statistical tests, positional accuracy assesment mentioned in the subsequent second step) can be easily performed. This convenience is disrupted if the assumption of linearity is not fulfilled or when a prior information on transformation parameters is put to use. The additional prior information can increase the quality of geometric transformation. In most mapping methods (eg. remote sensing, photogrammetry, map digitizing) the geometric relationship between local and cartographic coordinate systems is controlled and the values of transformation parameters are kept in predetermined ranges. This information cannot be utilized when the least-squares method is applied, since the transformation parameters are presumed to be completely unknown there. The natural generalization of the least-squares method is represented by Bayesian inference. This statistical technique incorporates the prior information in form of prior probability density. It can be easily applied when the transformation equations are linear in parameters and the prior distribution is normal, but causes great computational problems when the assumptions of linearity and normality cannot be accepted. For solution of those problems plenty of methods and algorithms were designed (see e.g. [9], [5], [3]). A special original method is proposed for reliable dealing with nonlinearity in this contribution. The Bayesian inference is applied so that the resulting posterior probability distribution incorporates probability distribution of the linearization error besides the probability distributions of control points.

Density estimation of position of a transformed point

In the second step a very complicated transformation of random variables should be evaluated. The transformation equations are usually simplified in a crude way to perform the computation easily. The influence of such a rough approximation to the final pdf of the predicted cartographic coordinates remains, however, unpredictable. The method applied in this contribution corrects the approximate pdf to produce a resulting pdf which is equally reliable as with using the original transformation model. For proper dealing with nonlinearity, similar idea as in the second step is applied. Nonlinear function is approximated by simpler function and estimation of approximation error is utilized in the transformation of random variables. The one-dimensional case of this approach is described in [7] and [6]. In the multidimensional case only linearization is admitted. Uniform probability distribution is attributed to the linearization error to form a random vector that is included among the random variables being transformed (local coordinates of a given point, transformation parameters).

2 Geometric transformation

To estabilish notation the problem of geometric transformation is briefly summarized in this section.

Geometric transformation is generally described by a vector equation

$$\mathbf{x} = \mathbf{T}_{\boldsymbol{\theta}}(\widetilde{\mathbf{x}}), \tag{1}$$

where

- $\mathbf{x}$ ... cartographic (global) coordinates of a point,
- $\widetilde{\mathbf{x}}$ ... local coordinates of a point being transformed,
- $\mathbf{T}_{\boldsymbol{\theta}}$ ... transformation model (congruence, affinity, collineation, etc.):
  $\mathbf{T}_{\boldsymbol{\theta}} : \widetilde{\mathcal{X}} \to \mathcal{X} : \widetilde{\mathbf{x}} \mapsto \mathbf{T}_{\boldsymbol{\theta}}(\widetilde{\mathbf{x}}), \quad \widetilde{\mathcal{X}}, \mathcal{X} \subset \mathbb{E}^2$,
- $\mathbb{E}^2$ ... Euclidean plane,
- $\boldsymbol{\theta}$ ... set of transformation parameters (angles of rotation, offset, scale, etc.),
  $\boldsymbol{\theta} = [\theta_1, \ldots, \theta_n]$.

Transformation parameters $\boldsymbol{\theta}$ are estimated with the aid of a set of control points by solving an overdetermined system of equations

$$\mathbf{x}_i = \mathbf{T}_{\boldsymbol{\theta}}(\widetilde{\mathbf{x}}_i), \tag{2}$$

where

- $\mathbf{x}_i$ ... cartographic coordinates of i-th control point, $i \in \{1, 2, \ldots, m\}$, $m \in \mathrm{N}$,
- $\widetilde{\mathbf{x}}_i$ ... local coordinates of i-th control point, $i \in \{1, 2, \ldots, m\}$.

3 Estimation of transformation parameters

Classical Bayesian estimation will be added by a general method of dealing with non-linearity of transformation equations in this section. In the linear and normal case a posterior pdf of transformation parameters $\boldsymbol{\theta} = [\theta_1, \ldots, \theta_n]$ is:

$$\widehat{g}(\boldsymbol{\theta} \,|\, \widehat{\mathbf{x}}_1, \ldots, \widehat{\mathbf{x}}_n) = \frac{\prod_{i=1}^{m} \widetilde{f}_i(\widehat{\mathbf{x}}_i - \mathbf{T}_{\boldsymbol{\theta}}^{-1}(\mathbf{x}_i))\, p(\boldsymbol{\theta})}{\int_{\mathcal{T}} \prod_{i=1}^{m} \widetilde{f}_i(\widehat{\mathbf{x}}_i - \mathbf{T}_{\boldsymbol{\vartheta}}^{-1}(\mathbf{x}_i))\, p(\boldsymbol{\vartheta})\, d\boldsymbol{\vartheta}}, \tag{3}$$

where $\widetilde{f}_i$ stand for pdf's of coordinate errors of control points $\widetilde{\mathbf{x}}_i$. Vectors $\widehat{\mathbf{x}}_i$, $i \in \{1, \ldots, m\}$ contains measured local coordinates of control points. For simplicity, global coordinates $\mathbf{x}_i$ of the control points are assumed to be sufficiently precise to neglect their uncertainty in comparison with errors of measurement of the local coordinates $\widetilde{\mathbf{x}}_i$.

The integral in the denominator of (3) can be easily evaluated in symbolical form if a prior probability distribution is uniform on an n-dimensional cuboid $\mathcal{T}' \subseteq \mathcal{T}$.

$$\int_{\mathcal{T}'} \prod_{i=1}^{m} \widetilde{f}_i(\widehat{\mathbf{x}}_i - \mathbf{T}_{\boldsymbol{\vartheta}}^{-1}(\mathbf{x}_i))\, p(\boldsymbol{\vartheta})\, d\boldsymbol{\vartheta} =$$

$$= \int_{\mathcal{T}'} \prod_{i=1}^{m} \frac{1}{2\pi\sqrt{\det(\mathbf{C}_i)}} \exp\left(-\frac{1}{2}(\mathbf{l} - \mathbf{A}(\boldsymbol{\vartheta} - \widetilde{\boldsymbol{\theta}}))^T \mathbf{P} (\mathbf{l} - \mathbf{A}(\boldsymbol{\vartheta} - \widetilde{\boldsymbol{\theta}}))\right) p(\boldsymbol{\vartheta})\, d\boldsymbol{\vartheta}, \tag{4}$$

where $\widetilde{\boldsymbol{\theta}}$ is an approximate value of an unknown vector $\boldsymbol{\theta}$, vectors $\mathbf{l}_i \overset{\triangle}{=} \widetilde{\mathbf{x}}_i - \mathbf{T}(\widetilde{\boldsymbol{\theta}})$ form a "long" vector $\mathbf{l} \overset{\triangle}{=} (\mathbf{l}_1, \mathbf{l}_2, \dots, \mathbf{l}_n)$. Matrix $\mathbf{A}$ is Jacobi's matrix of elements of vector functions $\mathbf{T}_{\boldsymbol{\theta}}^{-1}(\mathbf{x}_i)$, $i \in \{1, \dots, m\}$ defined as a block matrix:

$$\mathbf{A} \overset{\triangle}{=} \left[\left. \frac{\partial \mathbf{T}_{\boldsymbol{\theta}}^{-1}(\mathbf{x}_i)}{\partial \boldsymbol{\theta}} \right|_{\boldsymbol{\theta}=\widetilde{\boldsymbol{\theta}}} \right]$$

Matrices $\mathbf{C}_i$, $i \in \{1, \dots, m\}$ are covariance matrices of control points that form a block-diagonal matrix

$$\mathbf{P} \overset{\triangle}{=} \operatorname{diag}(\mathbf{C}_1^{-1}, \mathbf{C}_2^{-1}, \dots, \mathbf{C}_n^{-1}) .$$

Integral (4) can be further simplified and after omitting a multiplicative constant it has a form:

$$\int_{\mathbf{B}(\mathcal{T}'-\bar{\boldsymbol{\theta}})} \exp\left(-\frac{1}{2}\,\mathbf{y}^T \mathbf{Q} \mathbf{y}\right) \det(\mathbf{B}^{-1})\, d\mathbf{y} , \tag{5}$$

where $\mathbf{y} = \mathbf{B}(\boldsymbol{\theta} - \bar{\boldsymbol{\theta}})$, $\bar{\boldsymbol{\theta}} = \widetilde{\boldsymbol{\theta}} + (\mathbf{A}^T\mathbf{P}\mathbf{A})^{-1}\mathbf{A}^T\mathbf{P}\mathbf{l}$, $\mathbf{A}^T\mathbf{P}\mathbf{A} = \mathbf{B}^T\mathbf{Q}\mathbf{B}$ and matrix $\mathbf{Q}$ is diagonal, i.e. $\mathbf{Q} = \operatorname{diag}(q_1, q_2, \dots, q_n)$.

The n-dimensional cuboid $\mathcal{T}'$ have to be chosen in such a way, that his linear transformation $\mathbf{B}(\mathcal{T}')$ is parallel to the transformed coordinate axes y_j, $j \in \{1, \dots, n\}$. Then the multiple integral (5) can be factorized to simple integrals with constant bounds r_j, s_j, $j \in \{1, \dots, n\}$.

$$\int_{r_j}^{s_j} \exp\left(-\frac{1}{2}\, q_j\, y_j^2\right)\, dy_j \tag{6}$$

that can be explicitly evaluated in terms of error function (erf).

Linearized equation (2) with the linearization error $\mathbf{h}$ included has form:

$$\mathbf{T}_{\widetilde{\boldsymbol{\theta}}}^{-1}(\mathbf{x}_i) + \left. \frac{\partial \mathbf{T}_{\boldsymbol{\theta}}^{-1}(\mathbf{x}_i)}{\partial \boldsymbol{\theta}} \right|_{\boldsymbol{\theta}=\widetilde{\boldsymbol{\theta}}} (\boldsymbol{\theta} - \widetilde{\boldsymbol{\theta}}) + \mathbf{h} = \widehat{\mathbf{x}}_i + \mathbf{v}_i \,, i \in \{1, \dots, m\} , \tag{7}$$

where $\mathbf{v}_i$ are errors of measured coordinates $\widehat{\mathbf{x}}_i$. To keep the convenient form of the integrand in (4), the variable $\mathbf{v}_i - \mathbf{h}$ should be normally distributed. Under assumption that the linearization error $\mathbf{h}$ is small and has uniform distribution a special pdf of measurement errors $\mathbf{v}_i$ can be derived so that the difference $\mathbf{v}_i - \mathbf{h}$ has normal distribution. It can be shown, that a probability density function of the error of measurement $\mathbf{v}_i$ is very similar to normal distribution and can be adopted for the real measurement errors instead the normal pdf.

4 Density estimation of position of a transformed point

In this section the transformation equations (1) will be rewritten to the form:

$$\mathbf{x} = \mathbf{T}(\widetilde{\mathbf{x}}, \boldsymbol{\theta}) , \tag{8}$$

where

$$\mathbf{T} : \widetilde{\mathcal{X}} \times \mathcal{T} \to \mathcal{X} : [\widetilde{\mathbf{x}}, \boldsymbol{\theta}] \mapsto \mathbf{T}(\widetilde{\mathbf{x}}, \boldsymbol{\theta}) = \mathbf{T}_{\boldsymbol{\theta}}(\widetilde{\mathbf{x}}_i) \,,\ \mathcal{T} \subset \mathbb{R}^n$$

The pdf of coordinates $\mathbf{x}$ can be easily expressed as transformation of random vectors $\boldsymbol{\theta}$, $\widetilde{\mathbf{x}}$,:

$$g_{\mathbf{T}}(\mathbf{x}) = \int_{\mathcal{T}''} \overline{g}(\overline{\mathbf{T}}^{-1}(\mathbf{x}\,,\,\boldsymbol{\theta}))\,\frac{1}{\left|\det \dfrac{\partial \mathbf{T}}{\partial \mathbf{z}}(\overline{\mathbf{T}}^{-1}(\mathbf{x}\,,\,\boldsymbol{\theta}))\right|}\,d\boldsymbol{\theta}\,, \tag{9}$$

where $\mathbf{z} \stackrel{\triangle}{=} [\widetilde{\mathbf{x}}\,,\,\boldsymbol{\vartheta}]$, $\mathcal{T}'' \supseteq \mathcal{T}'$,

$$\overline{\mathbf{T}} : \widetilde{\mathcal{X}} \times \mathcal{T}'' \to \mathcal{X} \times \mathcal{T}'' : [\widetilde{\mathbf{x}}\,,\,\boldsymbol{\vartheta}] \mapsto \overline{\mathbf{T}}(\widetilde{\mathbf{x}}\,,\,\boldsymbol{\vartheta}) = [\mathbf{T}(\widetilde{\mathbf{x}}\,,\,\boldsymbol{\vartheta})\,,\boldsymbol{\vartheta}]\,.$$

Pdf $\overline{g}$ is joint pdf of random vectors $\mathbf{x}$, $\boldsymbol{\theta}$.

Formula (9) usually cannot be exactly evaluated for an arbitrary function $\mathbf{T}$. Therefore the right side of equation (8) is linearized at some point $\widehat{\mathbf{z}} = [\widehat{\mathbf{x}}\,,\,\widehat{\boldsymbol{\theta}}]$.

$$\mathbf{x} = \mathbf{U}(\boldsymbol{\varepsilon}\,,\,\mathbf{z}) \stackrel{\triangle}{=} \mathbf{T}(\widehat{\mathbf{z}}) + \widetilde{\mathbf{A}}(\mathbf{z} - \widehat{\mathbf{z}}) + \boldsymbol{\varepsilon}\,, \tag{10}$$

where $\boldsymbol{\varepsilon} \in \mathcal{U} \subset \mathbb{R}^2$ stands for vector of linearization errors, matrix $\widetilde{\mathbf{A}}$ is Jacobi's matrix of vector function $\mathbf{T}$, i.e.:

$$\widetilde{\mathbf{A}} = \frac{\partial \mathbf{T}}{\partial \mathbf{z}}(\widehat{\mathbf{z}})\,.$$

Vector function

$$\mathbf{U} : \mathcal{U} \times \widetilde{\mathcal{X}} \times \mathcal{T}'' \to \mathcal{X}$$

represents another transformation of random variables that has to be investigated.

The joint probability distribution of vectors $\boldsymbol{\varepsilon}$, $\widetilde{\mathbf{x}}$, and $\boldsymbol{\theta}$ has pdf in form:

$$f(\boldsymbol{\varepsilon}\,,\,\widetilde{\mathbf{x}}\,,\,\boldsymbol{\theta}) = \widetilde{f}(\widetilde{\mathbf{x}})\,\widehat{g}(\boldsymbol{\theta}\,|\,\widehat{\mathbf{x}}_1\,,\ldots,\,\widehat{\mathbf{x}}_n)\,p(\boldsymbol{\varepsilon}\,|\widetilde{\mathbf{x}}\,,\,\boldsymbol{\theta})\,.$$

Pdf $\widetilde{f}$ represents probability distribution of a local coordinates of transformed point, and conditional pdf $\widetilde{f}$ is the posterior pdf from (3). If the conditional pdf p is chosen to be uniform on a suitable rectangle parallelepiped in $\widetilde{\mathcal{X}} \times \mathcal{T}''$, the transformation of random variables can be performed similarly as in (9) with $\mathbf{U}$ instead of $\mathbf{T}$. After some additional formal arrangements the final pdf of $\mathbf{x}$ can be obtained in the factorized form (6).

5 Conclusion

The proposed method provides a cartographer with true estimation of the positional accuracy of maps which is not contaminated by any uncontrollable approximation. The outcome of the designed procedure is pdf of an arbitrary point in the map. The outcoming pdf depends on pdf's of control points in both coordinate systems, on the pdf of local coordinates of a point being transformed and on the bounds of linearization error of transformation equations.

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THE DEVELOPMENT OF AN INTEGRATED DIGITAL DATA BASE FROM LARGE SCALE AERIAL PHOTOGRAPHS AND CADASTRAL SHEETS: THE UGANDA CASE.

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ABSTRACT

The main objective of producing a digital data base from large scale aerial photographs and cadastral sheets, was to provide the Municipal Authorities and other users in the country with base maps for efficient planning and management of land developments within their jurisdictions. The topographical maps kept by the Surveys and Mapping Department (SMD), were too old and could not be used for generating a topographical digital data base.

The cadastral sheets at SMD had some problems as well. Due to frequent handling, some information on the cadastral sheets had become obscure, there were distortions resulting from sheet shrinkage and some of the sheets were torn. The other problems encountered were connected with the two different types of surveys, namely: theodolite and plane table surveys. The plane table (PT) surveys were carried out on most of " Mailo Land", while Public Land was surveyed by a theodolite. The various map projections used over time posed additional problems, involving transformation from other projections to Universal Transverse Mercator (UTM), which is the current projection in use. In this paper, we have outlined the problems encountered and the benefits realised when generating a digital data base from large scale aerial photographs and cadastral sheets.

1. INTRODUCTION

Most national mapping organizations and other agencies involved in special subject mapping, have adopted digital mapping methods. In Uganda, a decision was taken in 1992 to fully re-compile the topographical maps covering all urban centres in the country in digital format. A new aerial coverage of all urban centres was necessary since the existing topographical maps were out of date for over thirty (30) years, and could not be economically used as a source for digital data. A project was started with Kampala City Council (KCC) in 1993, and the exercise was executed jointly by a private German firm Survey International - GmbH (SIG) and SMD, under the framework of the First Urban Project funded by the World Bank. The first phase of the project involved establishing a control network within the KCC area using the Global Positioning System (GPS). Aerial photography covering the whole of KCC area was taken, and the

production of the digital topographical maps was initiated using stereo-plotters fitted with encoders and linked to computers. Editing for final map production was carried out using PC stations, a laser jet printer and a pen plotter. The main software used was Digimap, AutoCAD and AutoCIV for generating planimetric features and contours.
Most surveys for "Mailo Land" were done by PT and the data was available in sheets. This type of data had to be georeferenced before the digitization of cadastral sheets was done. For theodolite surveys, the digital data base was either generated from co-ordinates computed from field measurements or from digitizing the cadastral sheets. Some sheets had distortions, and the magnitude of the distortions had to be assessed. Transformation of co-ordinates from Transverse Mercator (TM) or Cassini projections to UTM which was adopted later on as the only projection for mapping in the country, was affected by lack of adequate and well distributed common points between UTM and other projections. The generated topographical and cadastral digital data bases were merged.

2. EXISTING TOPOGRAPHICAL MAPS

The basic topographical map series at the scale of 1: 2,500 was no longer efficient for use as a planning document since the maps in the series had become outdated and could not show the topographic changes which had taken place after they had been revised more than 30 years ago. In order to produce structural plans for the City of Kampala, KCC secured a loan from World Bank with the aim of obtaining aerial photographs covering Greater Kampala area involving about 600 sq.km. The plan was to fully re-compile 320 maps, 100 of which covered the city centre and had become out-dated and 220 had resulted from the extension of the Kampala Mapping Project area beyond KCC boundary. Although there was in existence map sheets which were part of the 100 maps which had become outdated, the revision changes could not be carried out on the same maps due to many topographic changes which had taken place. Besides, there was also need to adopt computer assisted methods which would make it possible to produce the required maps in about a third of the production time needed when using analogue methods. The ease of updating future map editions, and the ability of the user to interact directly with the data base [McGuiness et al., 1991] also necessitated the adoption of computer mapping techniques. Therefore, the new compilations had to be produced from a recent aerial coverage of the project area.
The first phase of the project involved establishment of ground control points (both horizontal and vertical). This was necessary since the geodetic network covering the whole country had been destroyed. Establishment of control points was done using GPS, and a total of 37 GPS main stations were positioned. The densification of the main control stations was also done to provide control for future surveys, and monitoring mapping accuracy within the project area. The second phase involved aerial photography which was taken at a scale of 1:8,000, and the new photographs were then used in generating a topographical digital data base.

3. PRODUCTION OF DIGITAL TOPOGRAPHICAL MAPS

The compilation of the digital data from the aerial photographs was done using stereo-plotters fitted with encoders and linked to computers which were available in the Department (WILD A10 and WILD A8). The new technology employed in the photogrammetric section substantially reduced the time needed to carry out the model-

orientation and digitization of topographic features.
The mapping package which was used in the compilation process is called Digimap. Approximate values of the orientation elements and the 3-D co-ordinates of pass points, derived from the aerial triangulation process, were input to the Digimap programme to determine absolute orientation. This was followed by stereo-digitization of the topographic features. The height information was sampled at 30 metre grid interval using a sub-programme of Digimap called Digidem.
The compilation process which was done at the scale of 1: 2,500 using diapositives contacted from the aerial film, was started by first defining a feature code, and in all 24 feature codes were used in the compilation. This being a compilation process at large scale, all the topographic features which could be recognised were interpreted and plotted. On average, 60 and 24 man-hours were required to plot a busy and non-busy model respectively. The capture of height data involved two phases, namely: registration of height information at grid-intersection points and measurement of mass points where there was significant change in height.
After collecting topographic and height data for each photogrammetric model, the data from the photogrammetric section was transferred to the mapping section.

4. EDITING OF DIGITAL TOPOGRAPHICAL MAPS

The data imported to the mapping section was in Digimap format. The digitized topographic information from photographic section was stored as BDP files, and the height information stored as HG and HP files. A number of BDP files are combined through Digimap software to generate DXF files covering a standard sheet. The generated DXF file is then imported into AutoCAD and the graphic information is saved as a drawing (DWG) file. This DWG file comes in with all features sorted out in different layers. At this stage the necessary editing is done to include: legend, grids and scale bars. Spot heights and contours are obtained from combining HG and HP files through AutoCIV software which generates the necessary Digital Terrain Model (DTM). The height information is inserted into the DWG file to come up with a map containing both planimetric and height information. Again, further editing, labelling and smoothening of contours is carried out on the new DWG file generated.
After editing the information for one map sheet, a field sheet is prepared using a laser printer and taken to the field by surveyors for field completion exercise. The plotting accuracy of the topographic features and contours would be checked in the field. On average both planimetric and height accuracies were found to be at the level of 0.4 m or better. Accuracy checks was done on each map sheet, and a sample of mean values for planimetric and the height accuracies for each map sheet are provided below on Table 4.

Table 4. Mean values of planimetric and height accuracies for each map sheet.

Map Sheet No.	Plan Accuracy X[m]	Plan Accuracy Y[m]	Height Accuracy H[m]
71/1/12NW/3	-0.43	-0.27	0.01
71/1/11NE/4	0.34	0.03	0.18
71/1/6SW/3	-0.09	0.44	-0.26
71/1/6SE/1	0.15	0.22	-0.29
71/1/6SE/4	0.98	-0.43	-0.20
71/1/7SW/4	0.26	-0.65	0.74

The surveyors would also collect place names and names of features. These names are added onto the digital map and a proof is plotted out. The proof plot is thoroughly checked, and if found correct a final plot is made using a pen plotter on the film for storage. A corresponding digital map would also be backed-up in digital form. A total of 320 maps covering the whole project area were produced, and the cadastral information in digital format was required to be added on each of them.

5. SOURCES OF CADASTRAL DATA

One of the major activities at the beginning of the Cadastral Mapping Project to generate a cadastral digital data base was to identify and assess the condition of various cadastral data sources available. Most of the cadastral data in co-ordinate form at SMD are kept in files called Job Record Jackets (JRJs) and the same data in the JRJs is also plotted on cadastral sheets. This type of data is from the field surveys done by theodolite. However, some cadastral data was from the field surveys carried out by PT, and this type of data exists only on sheets. Since the inception of the cadastral system in the country, various materials have been used as a base for cadastral sheets. Some of these sheets were plotted at different scales and some are based on different projections. Most of the theodolite surveys carried out after the introduction of the metric system in 1969 were computed on the UTM projection using the metre as a basic unit of measurement. However, in the project area some surveys were done before the introduction of the metric system, and these surveys were computed and plotted on either Cassini or TM projection using the British foot as the basic unit of measurement. The major problem experienced with the JRJs was that some of them were missing, and it was found that some of the cadastral sheets were in poor state due to regular handling. A total of 61 cadastral sheets in bad shape were identified, and these needed to be put on a stable medium prior to digitization. It was also noted that three different categories of cadastral sheets were available, namely: standard cadastral sheets based on theodolite surveys covering about 17% of the pilot project area, cadastral sheets based on PT surveys which also covered about 29% of the project area and finally, standard cadastral sheets which had both theodolite and PT surveys covering about 50% of the project area.

5.1. Cadastral sheets for theodolite surveys

Most of the standard cadastral sheets at the scale of 1:2,500 for theodolite surveys were available at the SMD Headquarters in Entebbe. These were the sheets used for plotting surveys approved by the Commissioner for SMD. These sheets were generally clean and in good state. Copies used to be made from the approved sheets by photomechanical means and sent to the branch office that supervised the surveys. The branch office would also incorporate new surveys in its area in these sheets. Most of these sheets from Kampala branch office were torn and some of the cadastral information was obscure due to poor handling, this posed a big problem during digitization process. The other worrying problem was that for some areas the cadastral sheets would have varying information due to the poor plotting accuracies of the cartographers.

5.2. Cadastral sheets for PT surveys

Some cadastral surveys done by PT were plotted on non-standard sheets, and were based on blocks which form major groups of plots (i.e. plots belong to blocks, blocks belong to counties and counties belong districts etc.). These sheets were of various scales, but typically in the Kampala central area, they were mainly at the scale of 1: 2,500, but larger scales of 1:1,000 and 1:500 were also used. For the rural areas scales of 1:5,000 and 1: 10,000 were used. These cadastral sheets were of different types of material. Most were fairly stable film, some were tracing paper and cloth material. Some of the sheets with cloth material had holes, and they were also rotting due to poor handling and storage facilities. The PT surveys covering 29% of the pilot project area had to be georeferenced using the newly established GPS network before the cadastral sheets could be digitized. The PT surveys were re-surveyed by theodolite, the main block surveys were found to be accurate though some problems were detected in the subdivisions surveys within the main blocks. Co-ordinates obtained from the field surveys were compared with those derived from the digitization process, and they were found to be in good agreement as shown by a sample of results shown below in Table 5.

Table 5: Showing accuracy checks on plane table surveys.

Block No.	Identical Point ID.	Co-ordinates from Recent Survey.		Co-ordinates from Digitizing.		dEast	dNorth
		East (E1)	North (N1)	East (E2)	North (N2)	(E1)-(E2)	(N1)-(N2)
210	401	453543.71	39716.11	453544.95	39721.52	-1.24	-5.41
210	701	453620.56	40113.67	453618.01	40118.32	2.55	-4.65
210	702	453635.87	40097.29	453633.38	40101.49	2.49	-4.20
210	703	453651.29	40080.70	453648.97	40084.42	2.32	-3.72
210	901	453655.57	40149.55	453652.97	40155.16	2.60	-5.61
210	902	453694.19	40197.33	453692.71	40201.34	1.48	-4.01
210	903	453716.47	40144.33	453714.47	40148.22	2.00	-3.89
210	1401	453221.88	39146.82	453224.11	39150.17	-2.23	-3.35
210	1403	453191.25	39198.30	453193.71	39201.91	-2.46	-3.61

5.3. Cadastral sheets with PT and theodolite surveys

There were also some standard sheets which were used for plotting both theodolite and PT survey information. These sheets were of cartridge paper, and those which were based in Kampala branch office were in very poor condition. The main advantage of having a PT survey plotted on a standard cadastral sheet was that the PT surveys are themselves georeferenced, and thus can be digitized in the same reference framework used for theodolite surveys. Again the block surveys were found to be more reliable, and also subdivisions done in the 1970's and earlier were also found to be more reliable than those done in the 1980's. It was also noted that more care and accuracy in plotting surveys existed in the 1970's and earlier compared to the 1980's.

6. CADASTRAL DIGITAL DATA BASE

For Kampala central area where most of the surveys were done by theodolite, the co-ordinates from the surveys for which the JRJs were readily available, were entered into a script file to be used to generate property boundary lines using AutoCAD draughting software. If the co-ordinates were computed on a different projection other than UTM,

the co-ordinates were transformed to UTM using TRANSFO software developed in the project. At times, a problem would be encountered during transformation of co-ordinates. This was connected with the poor geometrical configuration of common points. When the JRJs for particular jobs were missing, the cadastral sheet containing jobs for the missing JRJs would be digitized. Surveyors would also be sent to the field to have the affected plots re-surveyed and the co-ordinates obtained would be compared with digitized co-ordinates. A similar approach was also adopted for assessing the magnitude of distortions in some of the cadastral sheets which were in bad shape.
The PT surveys plotted on non-standard cadastral sheets were georeferenced using the newly established GPS network. All corner points for the main blocks would be co-ordinated and since the blocks are generally big, a sufficient number of well distributed points within the block would also be co-ordinated. The co-ordinated points were used to provide a reference framework for the digitization of subdivisions within the main PT blocks. But for PT surveys plotted on standard cadastral sheets, it was possible to digitize the plots.

7. TOPOGRAPHICAL AND CADASTRAL DIGITAL DATA BASE

Out of 320 topographical digital maps produced by the Kampala Mapping Project, 60 maps have had relevant cadastral information in digital form added to them. This was done in order to provide more information to planners and other map users in the country. Our final target however, is to have cadastral information on each topographical map. All Urban centres in the country are expected to be mapped in a similar manner.
After the cadastral information had been added to the topographical map in digital format, the merged data base was plotted on an A3 size papers at a scale of 1:2,500 using a bubble jet printer (BJ 300). These papers were joined for final checking, and if found satisfactory, the map is again plotted out for field checking. Finally, after all information from the field was incorporated, the map was plotted using an AO OCE plotter. The new topographical digital map with cadastral layers would be backed-up on tape in QIC-80 format, and onto a magnetic optical disk which proved to be more reliable. These maps are now made available in both digital and hard copy formats to the user community in general, but they were also advanced to KCC which was the client. We have also realized that updating a digital data base is cost effective [Dale and McLaughlin 1988].
The project has brought in some benefits to SMD. First, there has been a transfer of technology to the Department and training of Staff members. Secondly, the Department is now capable of providing accurate digital and hard copy maps to various users in the country at a faster rate than before.

CONCLUSION

The topographical maps covering the whole country are out of date, since they were revised thirty (30) years ago, and yet they are a valuable source of information for environmental monitoring, natural resources management, agricultural land use etc. We hope that once the urban centres have all been covered with maps in digital format, other topographical digital maps covering the rest of the country will be produced. The cadastral digital data base will also contribute towards the development of a national land information system (LIS), a program which will be executed jointly by the Swedesurvey and SMD.

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DEVELOPMENT OF A LOW-ERROR EQUAL-AREA MAP PROJECTION FOR THE EUROPEAN UNION

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Abstract

This paper presents a new low-error equal-area map projection for the European Union (EU), which is obtained by transforming the graticule of the oblique azimuthal equal-area projection so that its distortion pattern better fits the general outline of the EU. Optimization of the parameters of the projection has been based on the minimization of the mean scale distortion for a large set of distances spread randomly over the area. The new projection has less extreme distortion of scale than any standard equal-area projection. Maximum scale error at the extremities of the area is 1.21%, maximum angular distortion does not exceed 1°.4 throughout the whole of the EU.

Introduction

The growing importance of geographical information systems and the establishment of spatial databases at the regional and the global scale has promoted new interest in the subject of map projection selection (Clark et al. 1991, European Science Foundation 1992). In contrast to the paper map, digital databases are not physically restricted to a two-dimensional representation of the earth's surface. Storing data by their geographical coordinates (spherical or ellipsoidal) therefore seems the ideal solution, at least theoretically, since it allows cartometric operations to be performed with negligible error. Unfortunately most GIS software operates in two dimensions. Hence the traditional problem of map projection remains.

While for most applications at the local up to the national level the reference system which is used for official topographic mapping in the country can be adopted, the problem of map projection selection is encountered when data coming from different countries have to be integrated in a common reference system. The demand for a continuous coverage of an area formed by various adjacent or non-adjacent countries is likely to lead to a substantial distortion of geometry near the extremities of the area, and the use of standard map projections may be insufficient to meet the error conditions one is willing to accept.

Since the start of CORINE (Coordinated Information on the European Environment) in 1985 the problem of integrating spatial data, coming from different sources which may vary in their scale and projection, has been a key issue in the establishment of geographical databases for the EU (Mounsey 1991). In 1989 the British cartographer Derek Maling was asked to look at the problem of choosing a suitable projection for storage and continuous mapping of the CORINE data. In view of the actual use of the CORINE database an equal-area projection was seen as the most appropriate solution.

Using a combination of graphical and analytical methods - i.e. overlay of distortion isograms on an atlas map of the area and calculation of distortion values for selected points - Maling determined optimal projection parameters for several standard equal-area projections and compared distortion characteristics for the limiting extremities on each projection. Since the EU at that time consisted of twelve member states, extending in two major, nearly perpendicular directions, which Maling called the Belfast - Alexandria arc (NW-SE) and the Cape St.-Vincent - Gdansk axis (SW-NE), the oblique conical equal-area projection and the oblique azimuthal equal-area projection were expected to offer the best results.

Distortion at the extremities proved to be marginally better for an azimuthal equal-area projection with centre at latitude 48°N, 9°E, close to the small town of Tuttlingen in Bavaria, than for the conical equal-area projection which Maling included in his analysis, and which had its meta-pole at 55°N, 43°E, and its standard lines midway between the middle and limiting meta-parallels (Bornholm in the north-east and Cape St.-Vincent in the south-west). Maling therefore proposed the azimuthal equal-area projection centered on Tuttlingen as the best choice for the mapping of the EU, with a maximum scale error of 1.31% and a maximum angular distortion of 1°.5 at the extremities of the area (Maling 1992, p.256-262).

Meanwhile, with the reunion of Germany and the enlargement of the EU with three new member states (Austria, Finland and Sweden), the borders of the EU have changed considerably, and the distortion pattern of Maling's azimuthal equal-area projection no longer matches the shape of the area. The northern extremities of the Scandinavian countries have a maximum scale error and a maximum angular distortion which are twice as high as for the north-west, south-west and south-east extremities of the EU (fig. 1). As such the problem of selecting a suitable map projection for the EU deserves to be reconsidered.

Standard equal-area projections

In most atlases and geography textbooks maps of Europe are drawn on Albers' conical equal-area projection, Bonne's pseudoconical projection or the oblique version of Lambert's azimuthal equal-area projection. The use of the conical equal-area projection follows from a well-known, very simple rule in cartographic design which states that conical projections are the best choice for the mapping of areas in the middle latitudes. The latitudinal extent of Europe, however, is far too great for the conical projection to avoid extreme distortion in those areas which are far away from the chosen standard parallels. The use of Bonne's pseudoconical projection raises similar problems. While Bonne's projection is free of distortion along the central meridian and along a chosen standard parallel, distortion rapidly increases away from either line, leading to relatively high distortion values in the north-west, south-west and south-east corners of the EU.

Figure 1. Maling's oblique azimuthal equal-area projection with lines of constant maximum scale error (%)

	max. scale error (%)	max. angular distortion (°)
Utsjoki (Finland)	1.87	2.12
Thorshavn (Faeroer)	0.77	0.88
Stornoway (Hebrides)	0.49	0.56
Sagres (Portugal)	1.15	1.31
Tarifa (Spain)	1.07	1.22
Ragusa (Sicily)	0.77	0.88
Sitia (Crete)	1.59	1.80
Rodos (Rhodes)	1.61	1.83

Table 1. Optimized azimuthal equal-area projection, maximum scale error and maximum angular distortion for extreme points of the EU

Of the three equal-area projections that are mostly used for maps of Europe the oblique azimuthal equal-area projection proves to have the least extreme distortion, yet the variation in scale along the boundaries of the EU is still quite high. This is clear from table 1, which lists distortion values for a set of extreme points, after optimization of the projection's centre.

A close look at a map of Europe shows that the EU has rather irregular boundaries and lacks compactness. The shape of the area approximates a spherical triangle which is slightly inclined with respect to the direction of the meridians. One therefore might expect to obtain considerably less distortion than with the three standard solutions presented above by using a projection with a distortion pattern that more closely follows the outline of this shape.

Less familiar aspects of standard equal-area projections

One of the easiest ways to reduce map projection distortion is by moving the distortion pattern of the projection with respect to the earth's surface in order to put the area of interest in the least distorted part of the projection. Such a repositioning is denoted as a change of aspect. The technique is mostly applied to azimuthal projections where a change of aspect only involves the selection of an optimal position for the centre of the projection. Because azimuthal projections have a radial distortion pattern it is fairly easy to choose an appropriate location for the centre once the spatial extent of the area to be mapped is known (fig.1). Aspect optimization is much less frequently applied for other types of projections, partly because most map makers are unaware of the potential of the technique, partly because it is not that simple to choose optimal values for the parameters of an oblique aspect conical, pseudoconical or other non-azimuthal type of projection without using some numerical technique to reduce distortion. Unfortunately the use of software for aspect optimization is not wide-spread.

To see what can be gained from aspect optimization for the mapping of the EU, optimal aspects of the azimuthal equal-area projection, the conical equal-area projection and the Bonne projection have been derived. Parameter values for each projection were obtained by minimization of the mean scale distortion for a set of 5000 distances, randomly generated within the boundaries of the EU. Table 2 lists the mean distortion of distance (%) and the maximum scale error along the boundaries of the area for the three oblique projections. For comparison the results for the normal conical equal-area projection and the normal Bonne projection, both with optimized parameters, have also been included. It is clear from table 2 that a change of aspect may result in a substantial reduction of distortion. Especially the oblique Bonne has a very low mean distortion value. This is confirmed by the shaping of the isocols which closely follow the irregular boundaries of the EU (fig. 2). Unfortunately scale error at the extremities is still 1.8%, which is almost as high as for the optimized azimuthal projection. The meta-pole of the oblique Bonne is located at 52°N, 29°E and introduces a small gap at this location. This may be seen as inconvenient for mapping purposes.

	mean distortion of distance (%)	maximum scale error (%)
oblique azimuthal	0.26	1.87
oblique conical	0.24	5.94
oblique Bonne	0.17	1.80
normal conical	0.55	4.83
normal Bonne	0.44	1.22

Table 2. Mean distortion of distance and maximum scale error along the boundaries of the EU for several optimized equal-area projections

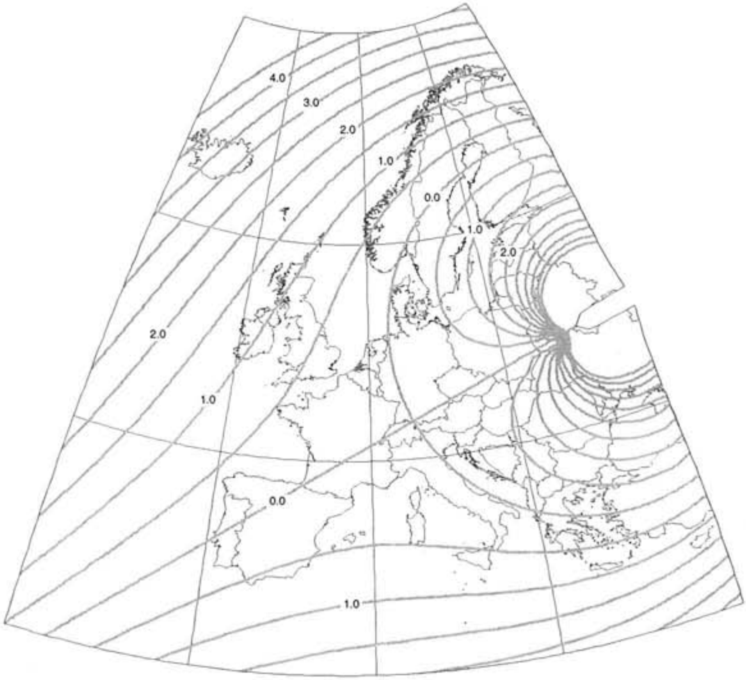

Figure 2. Optimized oblique aspect Bonne projection with lines of constant maximum scale error (%)

Polynomial transformation of map projection coordinates

If the optimization of aspect and projection parameters does not produce satisfying results one may try to obtain a more favourable distribution of distortion values by transforming the x,y coordinates of the projection in the plane. Transforming projection coordinates is only useful if some of the properties of the projection can be maintained, e.g. conformality, equivalence, equidistance along the central meridian, symmetry of the graticule, etc... Polynomial transformation is a good candidate since most geometric and distortion-related properties that are felt important in mapping can be expressed with ease using polynomial functions (De Genst and Canters 1996). Application of the technique is especially interesting for the reduction of error within irregularly shaped regions which do not fit well into the least distorted area of standard map projections. If map projection error is reduced through polynomial transformation the distortion pattern of the projection tends to adapt itself to the overall shape of the area to be mapped. So far the technique has been used almost exclusively for conformal mapping (see e.g. Miller 1953, Reilly 1973, Snyder 1985), yet it has equal potential for the reduction of distortion on equal-area maps.

A few years ago one of the authors proposed a double polynomial transformation based on two simple solutions of the general condition for an equal-area mapping in the plane (Canters 1991). Although the transformation was originally used for the development of equal-area world maps with low distortion, it can also be applied for regional mapping. First the x,y coordinates of the original projection are transformed:

$$X = \sum_{i=0}^{n} C_i x^i \qquad Y = y \Big/ \sum_{i=1}^{n} iC_i x^{i-1}$$

Then the same transformation is re-applied, but with the role of the x and y coordinates interchanged:

$$X' = X \Big/ \sum_{i=1}^{n} iC_i' Y^{i-1} \qquad Y' = \sum_{i=0}^{n} C_i' Y^i$$

The transformation becomes more general if the coordinate axes X,Y and X',Y' are rotated with respect to the axes x,y of the original projection before the stretching is applied. The number of coefficients to be determined depends on the order of the polynomials as well as on the geometric constraints which are imposed.

For the mapping of the EU the transformation was applied in its most general form, without imposing additional constraints. The oblique version of the azimuthal equal-area projection, which has already been discussed before, was used as the starting point for the optimization process. Polynomial coefficients were again derived by minimization of the mean scale distortion for a set of 5000 random distances. Best results were obtained with a 2nd-order transformation (fig. 3). Although the map has a mean scale distortion which is higher than for the oblique Bonne (0.22%), the maximum scale error at the extremities is only 1.21%. This implies that the maximum angular distortion does not exceed 1°.4 throughout the whole of the EU. All the isocols have a triangular shape which matches the general extent of the area. The isocol of 1% passes nicely through the extremities in the north, the south-west and the south-east of the map. The variation in maximum scale error along the outer boundaries of the EU is very small (table 3).

	max. scale error (%)	max. angular distortion (°)
Utsjoki (Finland)	1.10	1.25
Thorshavn (Faeroer)	1.21	1.38
Stornoway (Hebrides)	1.00	1.14
Sagres (Portugal)	0.99	1.13
Tarifa (Spain)	1.12	1.27
Ragusa (Sicily)	0.75	0.86
Sitia (Crete)	0.99	1.13
Rodos (Rhodes)	1.04	1.18

Table 3. Low-error equal-area projection for the European Union, maximum scale error and maximum angular distortion for extreme points

Figure 3. Low-error equal-area projection for the European Union with lines of constant maximum scale error (%)

Conclusion

The establishment of geographical databases for the European Union as a whole requires the definition of a common reference system with small geometric distortion. The oblique extent of the EU as well as its lack of compactness make it impossible to obtain a good distribution of scale error with standard map projections. A new equal-area projection has been presented, which is obtained by polynomial transformation of Lambert's azimuthal equal-area projection. The distortion pattern of the projection is optimally adapted to the shape of the EU. Distortion at the extremities is smaller than may be obtained with any regular projection. Given its favourable distortion properties the projection is suggested as a new reference system for GIS applications at the European scale and for the continuous mapping of the EU.

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RESOLVING CONFLICTS IN CARTOGRAPHIC GENERALIZATION WITH PROBLEM-RESOLUTION METHODS

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Abstract

In the cartographic generalization process, scale reduction leads to conflicts between mapped objects. Resolving these conflicts in an automated way constitutes a very complex task because of three major difficulties.

The first difficulty consists in the realization of generalization operators like displacement and aggregation in which distance and proximity relations between objects have to be identified.

The second difficulty arises from the complexity of interlacing these operators in an appropriate sequence, in order to rule out conflicts.

The third one is tight to the fact that the chosen sequence must obey layout constraints and show out a somewhat cartographic design.

To cope with these difficulties, we have decided to use problem-resolution methods of the AI research field. A problem can be resolved in a two-steps process: first by specifying a state space (a state being a collection of data that describes a configuration of this problem) where a set of operators rules transitions from one state to another; secondly, by finding a path from the initial state to a solution-state. This rapid presentation suffices to catch the possible parallelism between these methods and a conflicts resolution one, in which a state will represent a particular configuration of the cartographic objects in conflict and the operators will correspond to our generalization operators.

The major drawback of this kind of methods lies in the fact that they can induce very huge state spaces (the number of states grows exponentially with the number of objects and the different way of applying each operator), and the exploration of the whole state space can be intractable. By using state space traversal algorithms that embeds heuristic informations, this drawback can be minimized. Heuristic informations help to find a function that can valuate each state. The state space is then more efficiently traversed.

1 Introduction

The method presented in this article has been tested on the Walloon Region Base Map (see [3]). It allows generalization from 1/1000 to 1/5000 scale.

As we have to work out conflicts for a scale range from 1/1000 to 1/5000, we do not consider contextual generalization issues. We are focusing on local treatment, and not on 'gestalt' identification of frames of geographic objects in conflict, like the one discussed in [4].

In the cartographic generalization process, scale reduction leads to conflicts between mapped objects. We can identify three major difficulties in the very complex task of resolving these conflicts in an automated way:

- the identification of distance and proximity relations between objects;
- the sequencing of the operators;
- the achievement of a cartographic layout.

We will proposed in section 3.1 the neighbourhood notion to cope with the first one. The last two will be taken into account in the section 3.2.

2 General problem-resolution methods

The solution proposed is based on state space research algorithms. These algorithms are notably used in Artificial Intelligence (see [6]) to automate the resolution of problems (like Eight Queens or Travelling Salesman ones). They consist in finding from an initial state a path in the state space that leads to a solution(-state).

2.1 Definitions

We have to tackle off some terms. Given a problem, let's say P, we get the following definitions :

- a state is a set of data describing a particular configuration of P;
- the initial state for P will be the departure point for the search;
- a solution-state is a state resolving P;
- a state space is a collection of states where the transition between two states is ruled by a given set of operators (let's say S);
- an operator is a function taking a state as argument and returning a new state;
- a path between state i and state j is a list of operators (subset of S), which gives j when applied to i;
- the expansion of a state consists in applying all operators (from S) to it and thus produce a list of new states.

There are a lot of ways to proceed over a state space in search of a solution. Such a way is called a strategy.

Resolving the problem P will be possible after the completion of the following steps :

- choice of a strategy;

- representation of a state;
- definition of the solution-states;
- building up of the initial state.

2.2 Strategies

To describe it, we should first notice that a state-space can be associated to a tree whose root is the initial state and where each level corresponds to the expansion of the states of the preceeding level. This implies that one can get a very large number of states, and so leads fast to combinatorial explosion. In fact, the number of expanded states for a given level n is equal to N^n, where N is the number of operators available (cardinality of S in the preceeding section). Therefore, great care has to be taken in the decisions regarding state-space trees travesals. Two simple strategies can be exposed:

- the 'depth-first' strategy consists in going first to the deepest possible level in the tree. This strategy is often very fast but also relies much on the order followed to apply the operators, the first one being the most applied, a situation which can leads to distorted solutions.
- the 'breadth-first' strategy can be considered as the dual form of the preceeding one, because all the states of a level are first expansed before going to the next level. It is often slow or even intractable if N and n are great. However, that is the only way to obtain all the solution-states of a problem.

These two strategies constitute in some way the respectively lower and upper boundaries of the possible set of strategies that can be elaborated to browse a tree. They are used with success in many problems. But for particular classes of problems (like those we encounter in conflict resolution), another strategy has to be considered, the 'best-first' one. It is based on a state quality criterium to choose at each step, the state to expanse. This criterium has to assign a better quality to a state closer to the solution than another one. A function that gives the quality of a state is called an heuristic.

In general, there is no straightforward and reliable method to design such an heuristic, and one has to experiment by trial and error.

3 Conflict resolution

3.1 Distance and neighbourhood

The notion of distance is obviously very important for conflict resolution. But which distance should we use to characterize a conflict between two objects ? Is the minimal distance sufficient ? As we can see on the figure 1, the minimal distance a is not the only interesting information; distance b is also useful to characterize this conflict.

So, we have to go beyond this simple distance notion and introduce the neighbourhood notion, which can gather a set of distances between two objects.

Now, which representation to choose for this neighbourhood ?

In vector mode, a Delaunay triangulation made on all vertices allows to obtain a neighbourhood information under the form of simplex structures (see [1]). These are complex to handle, but offer the advantage of working directly on the basic vectorial data. In raster mode, distance information is discretized[1] and a model

[1] however, the discrete step has to be small enough to keep a good model of the reality.

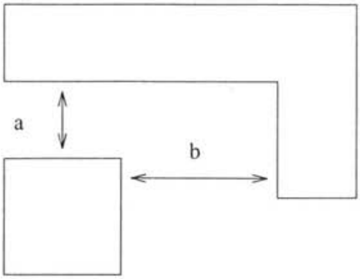

Figure 1: Neighbourhood between two objects

of the neighbourhood can be created by taking into account distances in the eigth standard directions (see figure 2).

NO	N	NE
O		E
SO	S	SE

Figure 2: Eight directions in raster mode

The neighbourhood between an object A and an object B (thereafter written out $n(A, B)$) can be defined by eight discrete values that stand out distances in the eight directions from A to B. A conventional value is used for directions with a infinite distance (ie. there is no contact between the two objects in this direction). Let's notice that $n(A, B) = n^T(A, B)$ if one consider neighbourhood as a matrix.

Our preference for the raster mode is based on the fact that this mode allows to deduce directly form the neighbourhood representation eight operators of basic displacement (one pixel is the base), which is especially adapted to state space research schemes.

3.2 Methodology's adaptation

We have adapted the abstract research methodology presented in the previous section to the conflict resolution problem by defining the following elements:

- a real conflict stands between two objects A and B when a distance of the neighbourhood $n(A, B)$ is inferior to a given threshold Sr [2]. A value of 0.2mm is widely sufficient (see [2]). Obviously, this value has to be transformed in a number of pixels for the particular scale.

- a potential conflict stands between two objects A and B when a distance of the neighbourhood $n(A, B)$ is inferior to a threshold Sp and superior to Sr. This implies that $Sr < Sp$. Sp corresponds to twice the maximal value of displacement applicable to a particular object.

[2]The separation threshold, a cartographic legibility rule, can be employed.

- conflicts are written down under the triplet form $(A, B, v(A, B))$.

3.2.1 State definition

We can now give a precise definition of a state. It embeds :

- a list of all objects in real conflict;
- a list of the real conflicts (triplets);
- a list of the potential conflicts (triplets);
- a list of the operators already applied.

3.2.2 Heuristic function design

As we have chosen a 'best-first' strategy, an heuristic function has to be designed; it will attribute a quality to each state. Let's give the H function which calculates for each triplet of the conflicts list, the sum of differences of the neighbourhood of this triplet with an ideal neighbourhood (ie. where each distance is superior to Sr). Then, we can deduce that a state e is a solution-state when $H(e) = 0$, because there is no more differences between the ideal and the current neighbourhood. It also implies that $H(e1) < H(e2)$ if the quality of $e1$ is better than $e2$ one.

Another criterium could be chosen: differentiate two states on the number of objects in conflict. So, the aim is to minimize this number. It seems to lead to configurations where few objects are moved a lot. The first criterium on the other side tends to make a lot of small displacements.

It is possible also to integrate the informations given by the potential conflicts in the heuristic function.

3.2.3 Initial state

The initial state is build by collecting all objects in real conflict and by determining for each of them, all the objects in potential conflict.

3.2.4 Sequencing

All the operators are applied to the initial state to generate a new list of states. This list is sorted on ascending order of heuristic function evaluations. Afterwards and until a solution-state is found, all operators are applied on the first state of the sorted list and the so generated list is merged with the old one (from which this first state has been removed). This algorithm is the basic state-space expansion and sort one (see [5]).

3.3 Results

A 1/1000 scale sample of the Walloon Region Base Map is sketched on figure 3 and results of the displacement operator for 1/2500 and 1/5000 on figures 4 and 5.

3.4 Pros and Cons

The best advantage resides in the non-deterministic research process: all objects are considered nearly on a simultaneous basis - in fact, it tends to simultaneity as the resolution (number of pixels used to discretize an object) is growing - and there is no choice in the displacements scheduling.

At this point of our research, we are only using displacement operators, but the model is really convenient to take into account other kinds of operators, like aggregation or elimination. Indeed the model can integrate any operator that takes a set of pixels and returns another set of pixels. The mix of all these operators will be supervised by the heuristic function.

A first drawback consists in the exponential increase of the possible number of states with the number of objects in conflict. Ideally, such large conflicts should be hierarchized to allows separate treatments.

A second drawback is that there are - in general - more than one solution-state and the first found could not be the best one. We can remediate partially to this problem by proceeding on other solution-states until a particular amount is found or the space states has been exhausted.

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DEM PRODUCTION FROM TOPOGRAPHIC MAPS: DIGITIZING OR SCANNING ?

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Abstract

This paper compares different digitizing methods of topographic map contour lines for DEM generation. Two principal aspects are considered. First, the accuracy achieved by the different methods, and then the time required and the work involved by the different approaches. Since the actual trend in digitizing is towards semi-automatic and automatic procedures, the assessment of the effect of geometric scanner calibration, scanning resolution, vector generalization, on the final precision of the outcome are also discussed in this study.

1. Introduction

Digital Elevation Models (DEM) provide the topographic and orographic information required for applications in space management and environmental assessment studies. These models constitute a basic information layer of Geographic Information Systems [1]. Topographic maps are the most common source of readily available altimetric information [2]. To produce digital elevation models, this information has to be digitized from the existing contour lines and spot height on the maps. Manual digitizing by means of a digitizing table is very time consuming and to say the least, implies very tedious and ungratifying work. Semi-automatic and automatic digitizing methods are relatively fast. They use scanned documents as input, and rely on appropriate digital image processing software and on raster to vector conversion algorithms. Which approach should be chosen to produce a DEM ? This article attempts to analyze this question by comparing the two methodologies. It focuses first on the DEM accuracy produced by the two methods: are the results obtained by the two methods in this regard equally reliable ? It then analyzes the time/cost requirements of the two approaches. Since, the actual trend in digitizing is towards semi-automatic and automatic procedures [3, 4], the assessment of the effect of geometric scanner calibration, scanning resolution, vector generalization, on the final precision are also discussed.

2. Description of the digitizing methods

Two methods for extracting and digitizing altimetric information from topographic maps are considered in this study. The first method corresponds to the traditional manual digitizing method by means of a GTCO Super LII (A0 format) digitizing table.

Contour lines and spot height are traced on the map with a digitizing cursor to directly produce a georeferenced vector datafile. This file is then edited to correct possible digitizing errors and then used as input for triangulation. This procedure was performed with the ARCTIN module of the ARC/INFO software and produces a triangulated irregular network (TIN) from which a DEM can be generated [5].

The second method uses scanned cartographic images on a HP ScanJet IIcx A4 flatbed scanner with a maximal resolution of 600 dpi. A resolution of 254 dpi (0.1 mm) corresponding to half the graphical error was chosen to scan our sample maps. Paper maps were color scanned at 24 bits per pixel and black and white positive film orographic plates were scanned at 8 bits per pixel. The color scanned images were processed by simple classification procedures [6] in order to produce a graylevel image pertaining only the contour lines of the map. The resulting images are then submitted to the vectorization process. Two vectorization methods were applied. The first one is semi-automatic and uses the PixelTrak™ software [7]. The contour lines are automatically traced by the program on a screen display of the image and the operator only intervenes to fix the vectorization parameters, to position the mouse on the lines to be traced, to introduce the altitude of a particular line and to take back the hand in ambiguous situations. Manual tracing can also be performed with this software to add point elevation data or to resolve some complex situations. The second method uses an automatic vectorization algorithm [8] and is automatic only in the sense that it can be applied to cleaned raster images of contour lines such as the ones obtained by scanning black and white positive film orographic plates. Final manual vector editing has to be performed to add the height attributes of the contour lines. The resulting vector files are expressed in image coordinates and have thus still to be transformed to the appropriate cartographic coordinate system by selecting a series of control points. This topic will be further analyzed in 4.1.

3. Comparing the digitizing approaches

3.1. The accuracy of the two methods

The two methods, manual digitizing and semi-automatic vectorization are considered. The automatic approach was not tested since it rests on the same principles as the semi-automatic approach (tracing of lines in raster format), and yields identical results. Three groups of study areas were analyzed. The first group corresponds to areas taken from the Belgian topographic base map at 1:25,000 scale (map sheets 40/5-6, 40/1-2 and 45/7-8 with a 2.5 m contour interval). The second group corresponds to two test areas of the new base map of Morocco at 1:25,000 scale (map sheets NI-29-IV-3d1 and NI-29-IV-3d2 with a 5 m contour interval). The last group is made up of four test areas from the 1:50,000 scale base map of Morocco (map sheets NI-30-XIX-3a, NI-30-XIX-3d, NH-29-XXI-4b and NH-29-XXII-3a with a 10 m contour interval). Principal results and terrain characteristics are summarized in Table 1, where α corresponds to the mean slope of the area expressed in percent and N to the number of height control points used to derive the precision of the DEM's.

Table 1. Accuracy of the manual and semi-automatic digitizing methods

Sheet	α (%)	Area (km)	N	Manual RMS (m)	Semi-autom. RMS (m)
40/5-6 (Belgium)	3.5	3.5 x 4	1510	1.20	1.17
40/1-2 (Belgium)	3.2	5 x 3	6894	1.50	1.38
45/7-8 (Belgium)	4.0	3 x 3.5	3686	0.95	1.01
NI-29-IV-3d1 (Morocco)	3.1	5 x 7	1516	1.73	1.80
NI-29-IV-3d2 (Morocco)	2.5	8 x 5.5	1090	1.62	1.51
NI-30-XIX-3a (Morocco)	9,8	4 x 3.5	2831	5.66	3.86
NI-30-XIX-3d (Morocco)	20.2	13 x 5	2971	-	5.15
NH-29-XXI-4b (Morocco)	3.7	9 x 7	340	4.28	4.30
NH-29XXII-3a (Morocco)	5.3	7 x 10	468	3.25	3.29

As can be deduced from Table 1, both methods achieve the same precision. For all but one test area the precision difference between the two methods is very low, less than 5% of the contour line interval. The more important difference observed for map sheet NI-30-XIX-3a, corresponds to an area with high relief energy. In this instance, manual digitizing becomes difficult because the contour lines are too close to each other and can not be resolved even with a magnifying glass attached to the digitizing cursor. This factor accounts for some accuracy loss. With the semi-automatic method however, where it is possible to use a large zoom factor, highly contrasted relief areas can still be digitized accurately. This is the case of map sheet NI-30-XIX-3d with a mean slope of 20.2 %. No manual digitizing was attempted for this test zone.

3.2. The time requirements for the two methods

To perform the comparison, systematic tests were carried out on three different areas. The two first ones were extracted from the map sheets NI-29-IV-3d1 and NI-29-IV-3d2. Test zone NI-29-IV-3d1 covers an area of 5 x 7 km and is characterized by a low relief energy and very little planimetric detail. Test zone NI-29-IV-3d2 of 8 x 5.5 km has a similar relief profile but is overcrowded with planimetric features. For these areas both paper maps and orographic films were available so that the three - manual, semi-automatic and automatic - digitizing methods could be applied. The third test area of 13 x 5 km was extracted from map sheet NI-30-XIX-3d. This area is characterized by a contrasted relief and a complex morphology, so that only automatic and semi-automatic vectorization procedures were applied. Moreover, a large DEM project was realized in our laboratory based on the digitized contour lines of the 1:25,000 base map of Belgium. This project allowed us to estimate the time to digitize semi-automatically a complete map sheet of 10 x 16 km. Table 2 presents the duration of the three digitizing methods for the different areas.

Table 2. Time requirements for the different digitization methods

Test zone	Document type	Digitization methods		
		manual	semi-autom.	Automatic
NI-29-IV-3d1	paper map	10 h	7 h	-
	orographic film	-	4 h	4 h
NI-29-IV-3d2	paper map	14 h	16 h	-
	orographic film	-	5.5 h	5 h
NI-30-XIX-3d	orographic film	-	18 h	21 h
39/7-8 (Belgium)	paper map	-	≈ 80 h	-

These results show that in the case of paper maps, semi-automatic vectorization has a clear advantage over manual digitizing, reducing the time necessary to perform the operation by 30 to 40 %. However, for some very dense maps, as is the case of map sheet NI-29-IV-3d2, where classification errors due to color misregistration of the scanned documents [9] frequently interrupts the contour lines, and where the operator constantly has to intervene to correct digitization errors, a manual digitization procedure can be less time consuming. Nevertheless the semi-automatic procedure which can also be used as a manual screen digitizing system is generally more user friendly than the digitizing table and for this reason less tiring and less prone to human errors. In the case of scanned film digitizing the semi-automatic method is a clear winner saving up to 60 % time as compared to the traditional manual approach.
The purely automatic approach that we have used has until now not proven to be much faster than the semi-automatic method. This is due to the fact that this method isn't really automatic enough: the scanned documents have to be carefully edited prior to the automatic vectorization to ensure line continuity and, on the other hand, that the different contour lines are not in mutual contact. In the case of the test map NI-30-XIX-3d, where contour lines frequently touch each other, this editing phase can take up more time than the semi-automatic vectorization procedure.
The experience acquired at the Laboratory SURFACES shows that the choice of an appropriate digitizing method is not always simple. Many factors have indeed to be taken into account, such as the available hardware and software, the experience of the operators, the type, size, quantity and quality of the cartographic documents, the topographic and orographic characteristics of the study areas, the final accuracy requirements of the project, and of course the budget constraints.

4. Important aspects of the digitizing methods based on scanned documents

4.1. The geometric calibration of the scanner

In order to detect the geometric distorsions of the scanner, a geometric correction of a very high precision centimetric reference grid, scanned at 400 dpi, was performed.

Based upon 30 regularly distributed control points over the whole grid, four different transformation models were computed: the Helmert transform and the first to third order polynomial transforms. A separte set of 187 (11 x 17) test points was then used to assess the quality of the transformation models. The results are shown in Table 3, where μ corresponds to the mean residual errors and Emax to the maximum residual error in both line (dx) and column (dy) direction.

Table 3. Geometric calibration of the scanner: residual errors of 187 test points

Transformation model	Helmert (*4 parameters*)		Affine (*6 parameters*)		Quadratic (*12 parameters*)		Cubic (*20 parameters*)	
	dx	dy	dx	dy	dx	dy	dx	dy
μ (μm)	-2.9	-12.2	-3.4	-9.7	6.4	-2.7	6.2	-2.7
Emax (μm)	238.8	175.3	128.8	104.6	84.6	57.1	68.9	51.5
RMS (μm)	69.6	62.3	45.7	38.2	32.3	23.2	28.4	22.9

It can be seen from Table 3 that maximum residuals are clearly more important along the scan lines (parallel to the detector array) than along the image columns (parallel to the scanning direction). The RMS residuals are always smaller than 0.1 mm. Hence the Helmert transform satisfies the accuracy requirements for cartographic documents. It should be noted however that for this model the maximal residual is 0.24 mm, somewhat higher than the tolerated graphical error of 0.2 mm. The affine model reduces the RMS residuals by 40 %, with a maximal residual value still above 0.1 mm (which corresponds to 5 m at a scale of 1:50,000). The second and third order polynomial transforms further reduce RMS residuals and maximal residuals remain below 0.1 mm. Both these models meet the precision requirements for scanned cartographic documents.

4.2. Effect of the scanning resolution on the accuracy

In order to assess the importance of scanning resolution on the DEM accuracy, a test area of 4.5 x 8.5 km on one sample map (NH-29-XXI-2d) was scanned at 127, 254, 350, 450, 550 and 600 dpi. The 127 dpi resolution corresponds to the graphical error (0.2 mm) characterizing topographic maps. Lower scanning resolutions were not further considered because they produced images where contour lines could not be extracted satisfactorily by classification procedures. Table 4 shows the impact of scanning resolution on the size of the image files.

Table 4. Size of the image files in function of scanning resolution

Resolution (dpi)	127	254	350	450	550	600
File size (MB)	1.1	4.3	8.1	13.3	19.9	23.7

After image processing to build the contour line masks, the six images were semi-automatically digitized with a vector generalization factor of 0.8 pixels (see further point 4.3). Table 5 compares the size of the resulting vector files and of the manually digitized file, expressed in number of vertices.

Table 5. Size of the resulting vector databases in function of scanning resolution

Resolution (dpi)	127	254	350	450	550	600	Manual digitizing
Size (number of vertices)	1655	2650	3149	3638	5441	6347	**1421**

For height accuracy assessment as a function of scanning resolution, six DEM's were computed. The DEM generated from the 600 dpi image was taken as a reference from which the mean height differences of the other terrain models were calculated. Results are summarized in table 6.

Table 6. Scan resolution versus DEM accuracy

Resolution (dpi)	127	254	350	450	550
Mean height differences (cm)	23.3	12.9	10.1	9.1	9.2

As can be deduced from Table 6, accuracy increases with increasing resolution of the original document. Already at 127 dpi, the mean height difference corresponds only to 2.3 % of the contour line interval (10 m in this case), which may be accurate enough in many circumstances. Doubling the resolution reduces mean height difference values by factor of almost two. Further increase in spatial resolution does not achieve a significant gain in accuracy and may thus not be worth the effort of processing bigger and bigger image and vector databases. A second accuracy assessment, based on 209 control points measured in the field, results in a RMS error of 4.02 m for all resolutions except the 127 dpi resolution where the RMS error is 4.05 m. Taking all these factors into account, it can be stated that the resolution of 254 dpi is well suited for the production of topographic map derived digital elevation models.

4.3. Vector generilization and accuracy

The generalization factor corresponds to the maximum distance tolerated between the "raster" line and its corresponding vector, and is usually expressed in pixel units. A 2.5 x 2.5 km test zone from sheet 40/5-6 of the Belgian topographic base map at a scale of 1:25,000 was scanned at 254 dpi and subsequently digitized with 9 different generalization factors ranging from 0 to 8, by the same operator. Table 7 presents for each generalization factor the corresponding vectorial file size in number of vertices.

Table 7. Vector database size versus generalization factor

Generalization factor	0.0	0.2	0.4	0.6	0.8	1.0	2.0	4.0	8.0	Manual digitizing
Size (number of vertices)	14526	7887	6022	4158	2082	1551	1045	808	507	**1022**

The influence of the generalization factor on the final accuracy depends on the scale of the map, the scan resolution and on the slope of the terrain. Indeed, the planimetric distance defined by a particular generalization factor induces an altimetric difference proportional to the slope of the terrain [10, 11]. This can be expressed by the following relation:

$$\Delta z = \Delta p \cdot \tan \alpha$$

where Δz is the altimetric difference, Δp the planimetric distance, and α the terrain slope. In order to analyze the impact of the generalization factor on the final accuracy, a DEM was generated from each vector database. Taking the ungeneralized DEM as reference, the mean height differences of the other elevation models were calculated. Results are summarized in table 8 where they can be compared to the theoretical height differences (Δz) computed on an average estimated slope for the study area of 1.26° ($\tan \alpha = 0.022$).

Table 8. Generalization factor versus altimetric accuracy

Generalization factor	**0.2**	**0.4**	**0.6**	**0.8**	**1.0**	**2.0**	**4.0**	**8.0**
Δp (m)	0.5	1.0	1.5	2	2.5	5	10	20
Δz (cm)	1.1	2.2	3.3	4.4	5.5	11.0	21.9	43.8
Mean heigth differences (cm)	3.0	3.1	3.6	5.1	5.9	8.0	13.4	33.1

Table 8 shows that accuracy generally increases with decreasing generalization factors. Again a compromise should be sought for between optimal accuracy and vectorial file size. As can be seen from tables 7 and 8, choosing a generalization factor of 0 or 1 corresponds to a vector database size difference of 90 % and results in a accuracy gain of only 2 % of the contour interval (2.5 m in this case). It should be mentioned however that the influence of the generalization factor on altimetric accuracy is proportional to the slope of the terrain. Any choice as to adopt the generalization factor should consider the particular relief characteristics of the study area. The same set of 9 datafiles was confronted to photogrammetric measurements on 1:6,000 scale aerial photographs [12] and yielded for each data file the same RMS error of 1.17 m. This fact strongly suggests that the influence of the generalization factor becomes negligible when the terrain slope remains small.

5. Conclusion

In this paper different methods for digitizing contour lines from topographic maps were compared. The semi-automatic screen digitizing method of scanned topographic maps has many advantages over the other methods described, and is in general well suited for this type of work. The geometric scanner calibration shows that a second order polynomial transform can correct for the main geometric defects of the scanned images, keeping them underneath 0.2 mm. The effect of scanning resolution on the final precision of the digital elavation models suggests that most of this type of work can be carried out by adopting a resolution of 250 à 300 dpi. The influence of the generalization factor on the final precision depends on the scale of the map, the scan resolution and on the slope of the terrain. This study has shown that a generalization factor of 1 pixel constitutes an acceptable compromise between database size and processing time on the one hand, and the required accuracy level on the other. Finally, it should be mentioned that these conclusions, although they propose clear guidelines for determining the choice of particular techniques, as well as for fixing important parameters, remain conditioned to the particular working environment of our study, i.e. the available hardware and software, the characteristics and the complexity of the study areas, the experience of the operators, etc.

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A GENERAL CONSTRUCTION FOR THE ANALYSIS OF THE INFLUENCE OF DIFFERENT POINT PATTERNS ON RELIEF MODELS, APPLIED TO BATHYMETRICALLY MEASURED SUBMARINE SANDBANKS

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Contents.

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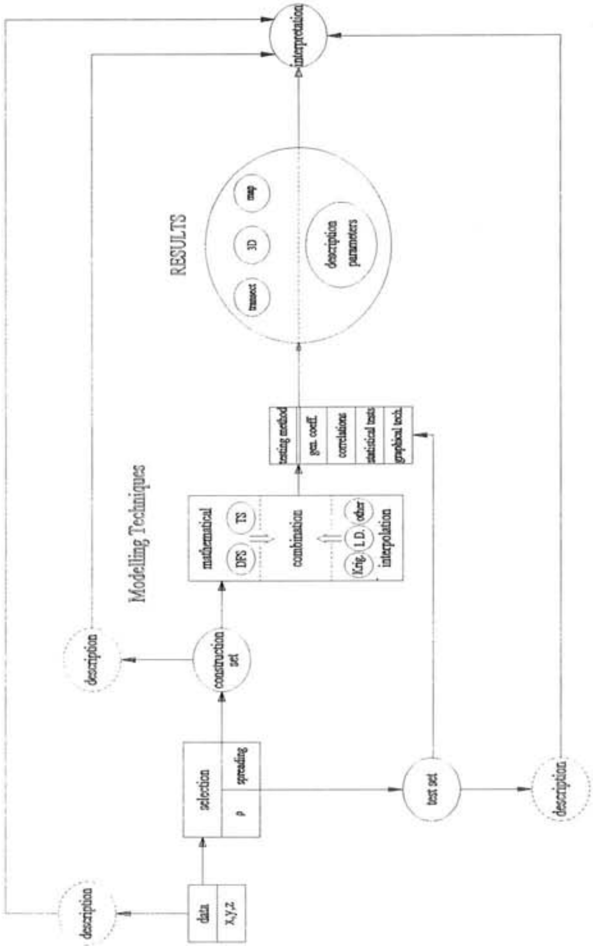
3. Problem approach.

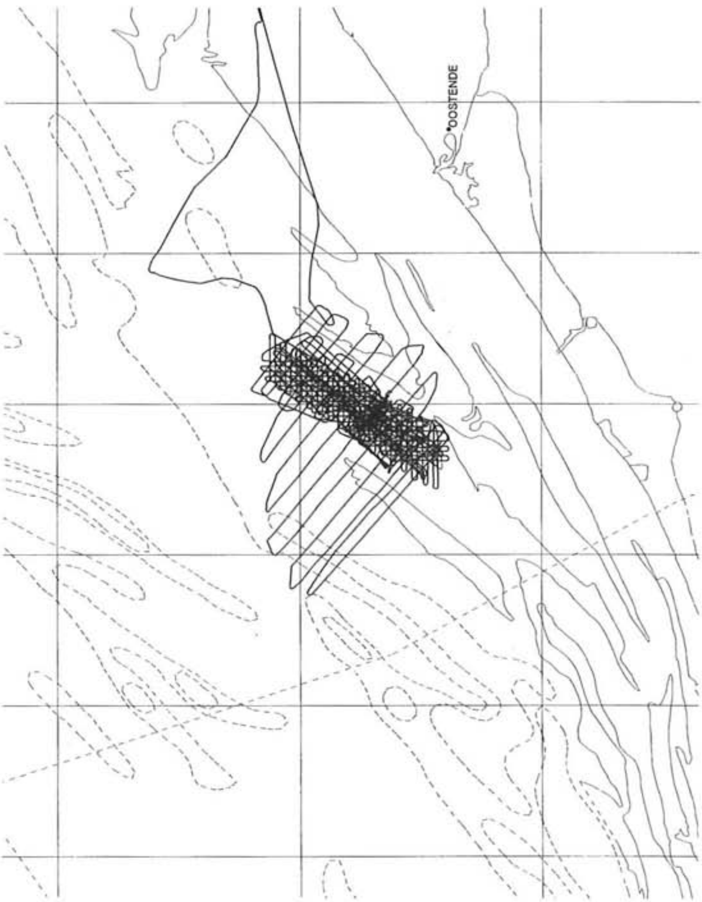
a. General overview.



To prove the effect of the density and the point dispersion we proceed as follows. Out of the original data set (x, y) we select a number of subsets according to a certain pattern and with a certain density (the construction sets). On the basis of these subsets the models are constructed. The patterns of these subsets differ from random to systematic and from uniform to clustered. By comparing the model results, obtained with the different subsets, it is possible to analyze the influence of the point distribution and the density. The model performances are obtained by applying the testing method. In addition to this we also have to take into account the properties of the test set that has been used for the calculations of the model performance. That is the reason why we can find the links between the interpretation and the description of the different data sets in the diagram.

b. Data selection and description.

The study area is the Kwintebank, one of the Flemish Banks that are situated in front of the Belgian coast near Oostende and Nieuwpoort.



The available data are obtained successively by sailing specific patterns. These patterns consist of tracks along the Decca's, tracks perpendicular to these Decca's, tracks in an east-west direction and tracks following a north-south direction. Also recordings of bathymetry were based on twenty randomly distributed samples.
Out of this data set we take the samples. We take random and systematic patterns with the possibility of clustering. Because of the restriction to the measured data we take the point closest to the theoretical calculated (x, y) coordinates of the pattern.
Concerning the data description we distinguish general description coefficients, spatial description and relief analysis. These can be subdivided further into coefficients based on numbers, coefficients based on extremes and coefficients based on deviations. We also make a subdivision for the description of the spatial distribution of the data points, in one respect based on the whole study area, on the other hand based on the nearest neighbors. The relief analysis is composed of geomorphological characteristics together with relief energy values.

c. The models.

The applied models can be classified theoretically in mathematical models (the basis is one equation) and interpolation models.
The mathematical models consist of trendsurfaces (algebraic) and surfaces based on double Fourier series (a goniometric equation).
The interpolation models are the classical inverse distance model and Kriging, and if desired supplemented with others such as triangulation networks.
A third type consists of a combination of a mathematical model and an interpolation model, which maybe will combine the qualities of both types.

d. The testing method.

The judgment about the quality of the model can only be made after the execution of a severe test. Therefore the testing method is taken very extensively and implies descriptive parameters, correlation coefficients as well as statistical tests and graphical techniques.
All the parameters rely on the results of the test set. From these data points, the x and y coordinates are imported into the model to predict the z values. The comparison of the predicted values with the measured values gives us the possibility to do the calculations mentioned.

4. Results and interpretation.

For a certain pattern, the model performances can be shown in function of the density. In this way we know (for this pattern) the influence of the density on the model. In an analogue way we can plot the model performances for a certain density in function of the pattern.

The final results will be a table with the model performances in function of both density and pattern and this for each type of model. This also gives us the possibility to check if certain inferior patterns can be compensated by higher densities. On the other hand there is also the possibility to choose a pattern that requires the least work and still yields acceptable results.

With the interpretation of these results, it is also necessary to take into account the properties of the relief that has to be represented and the properties of the test set that has been used for the calculation of the results.

NEW MILITARY MAPS FOR THE ARCHIPELAGO AND SEA AREAS AROUND SWEDEN

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A study is currently performed within the Swedish Armed Forces (FM) concerning new maps. Not only for the sea areas around Sweden (Skagerrak, Kattegatt, Baltic Sea, Bothnian Sea and the gulf of Bothnia) but also for the adjoining coastal areas.

The reason for the study is that modern naval systems with their integrated C^3I, Navigation and Weapon systems demand new information not currently available in charts, maps etc.

The character of combat has also changed from attacks from Naval, Air and Coastal systems separated in time and geography against separate targets to an integrated battle over a large surface at the same time.

The demands for maps at sea have mainly been dictated by the requirement to be able to navigate safely to the correct position, without running aground. In Sweden this is provided for through different types of charts (see figure 1) from the Swedish National Maritime Administration (SjöV).

Earlier and current types of maps and charts differs within the same area. They can be of different scale (i. e. maps at 1:50000 and charts at 1:60000 or charts at 1:200000 and maps at 1:250000), different projections (i. e. Gauss or Mercator) and have different shorelines. The Swedish National Land Survey (LMV) has had one definition of the shoreline and SjöV another. Due to that these units that are operating close to the coast "Brown Water Operations" have been forced to use two different sheets at the same time both for navigation and engagement (operations).

The new combat situation at sea demands some sort of Joint Operations Graphic in different scales for all mission phases (planning, preparation, action and analysis).

Planning and preparation as well as simulations and prognoses must be used to an increasing extent. This demands access to a meteorological "bank" of experience, for example where rough seas and high waves can be expected. Seabed condition, propagation and magnetic fields are other environmental issues that must be dealt with in a modern geographical information system.

This is were a **trial map** with such information in the **scale 1:250000** (see figure 2) may be one of the tools to use for planning.

To facilitate the necessary coordination of the naval operative activities, for example an antiship missile engagement, there is a need for a joint (integrated) map and chart for the joint coastal, naval and aerial units as a complement to the topographical maps, charts and aeronautical charts of today.

The *purpose* of such a joint digital map should mainly be

** to enable different staffs to plan naval operative activities on a joint foundation of maps.*

The detailed information shall be available in other analog map/chart products and those digital that will be available within the naval staff support system.

N.B this *coastal map in scale 1:250000* with land, nautical and aeronautical information shall not replace existing maps, charts and aeronautical charts and so on, but it´s important that the information is offprints from currently used maps in the Swedish Armed Forces plus necessary new information for the sea areas. It is also important not to create new symbols - other than for real new information - on the contrary it is important to use the symbols according to Military Aeronautical Information Publication (MIL AIP part II) och the Symbols-Abbreviations-Terms used on charts (INT 1).

The development of amphibious units operating in the swedish archipelago with higher mobility, increasing speed and an integrated command structure of combat at sea and on land requires maps where land and chart information is integrated in a totally different way compared to the charts and maps of today.

Also for the mobile base tactics for naval units in the archipelago there is a requirement for this type of map during replenishment and also for naval gun support.

For submarines there is also demand for information currently not available in traditional charts i.e the obstacle base from the aeronautical charts covering the archipelago. This is of utmost importance for our submarines operating with the possibility to be able to fix their own position relative to known objects, masts etc. The possibility to use this method gives submarines the choice not having to use radar (or other active systems) and also decreases reliance on GPS.

The requirement for depth data and other commonly stored geographical information (with high resolution) increases by the use of modern acoustic, magnetic and optronic sensor systems, fielded for different underwater applications such as mine counter measures, anti submarine warfare and submarine navigation.

The demands on resolution and accuracy has also changed due to the fielding of precision weapons. Weapons with electro-optical sensors set high demands especially in the case of night combat where weather prognoses are a very important issue.

Trial maps in **scale 1:50000** (see figure 3) with combined land and sea information is one way to meet the new requirements of these amphibious and other naval units.

The transition to smaller units in the Navy as well as the Coast Artillery means less space for personell and equipment. For instance this means that there is no space for a dedicated navigator but the navigation must be performed by for example the maneuver officer in a combat boat. At the same time these new units have longer range and greater endurance and the ability to operate over larger spaces which demands more map/chart volume for each unit. This negative spiral must be broken.

This can be done with the use of modern digital technique and the transition to electronic maps. This is not realistic in the immediate future, except for a minority of hightech units.

Due to this an *archipelago map in scale 1:50000* is being developed from existing topographical maps and archipelago charts both for navigation and engagement that will replace current maps and charts of this scale.

The trial maps are being produced in RT 90 system 2,5 gon V, using ellipsoid Bessel 1841 and Gauss´ projection with the middle meridian 15° 48´ 29,8´´ east of Greenwich.

The planar coordinatsystem (X,Y) - the Swedish National Grid RT 90 2,5 gon V - is imprinted where the middle meridian has a Y value the same as 1500000 meters and the X value is the same as 0 meters at the ecuator.

The geographical coordinatsystem (latitude, longitude) imprinted is the new swedish global referencesystem SWEREF 93 (~EUREF 89~WGS 84). GEOREF is also in SWEREF 93.

Height information is stated in the swedish height system of 1970 (RH 70). Depth information is stated in relation to the middle water level of a certain year. This annual water level can be converted into a height in RH 70 as a negative height. This is today normally not the case, but the height and depth refer to different zero levels in these trial maps. This is one of the problems that remains to be solved.

Trial map 1:250000 is being produced in cooperation with the Swedish Armed Forces (FM), Swedish Defence Materiel Administration (FMV), Geological Survey of Sweden (SGU), Swedish Meteorological and Hydrological Institute (SMHI) and Swedish National Maritime Administration (SjöV). It is being printed by SjöV.

Currently the SjöV are generating digital chart databases. From these databases they will generate traditional charts and digital charts for ECDIS. The work has due to its complexity been divided into two phases

Phase 1 consists of information such as shoreline, shoals, underwater rocks, depth curves and so on

Phase 2 consists of remaining information such as nautical information, fixed and floating marking/buoyage, soundings, quality of the bottom and certain land information.

The databases that SjöV is generating are not divided chartwise but in seamless databases. Information is divided into harbour, special, archipelago and coastal charts, each and everyone with its own degree of generalization and its own scale area. The databases are stored according to the international standard S57.

Phase 1 was finalised during 1996 and forms the base for the first edition of the base version of trial map VÄSTKUSTEN (western swedish coast) 1:250000. This coastal map is supplemented with land information from the Air Forces aeronautical chart and it was used during a naval exercise during autumn 1996. Two further releases are planned during 1997 and 1998 until trials are finished.

A trial map NORRLANDSKUSTEN (northern swedish coast) 1:250000 has been produced and it will be used during exercises autumn 1997. This coastal map consists of digital information from international charts (INT 1206, 1207) supplemented with land information from from LMV:s digital database for the topographical map 1:250000.

Trial map 1:50000 is produced in cooperation with the FM, LMV and SjöV. It is printed by Älvsby Tryck AB. Six different releases have been produced (trial sheets) with different contents of different areas within Sweden such as Gothenburg, Sandhamn, Sundsvall, Norrtälje and Kalix. The archipelago map has been used during a number of different exercise during 1996.

To sum up the trial maps for the sea areas around Sweden is developed according to the following principles:

> Existing topographical maps, charts and aeronautical charts form the base for the trial maps and especially *the archipelago charts and the coastal charts*.
>
> From the new digital databases a *base version* of the trial maps in scale 1:50000 and 1:250 000 is produced that presumably also has civilian applications.
>
> Studies are also being made concerning *additional prints* (overlay) such as
> * aeronautical and obstacle information
> * naval geological information
> * geophysical information (magnetism, gravitation, currents, wave heights)
> * specific military information (peace , crisis, war and international missions)
>
> according to the requirements of the type units.

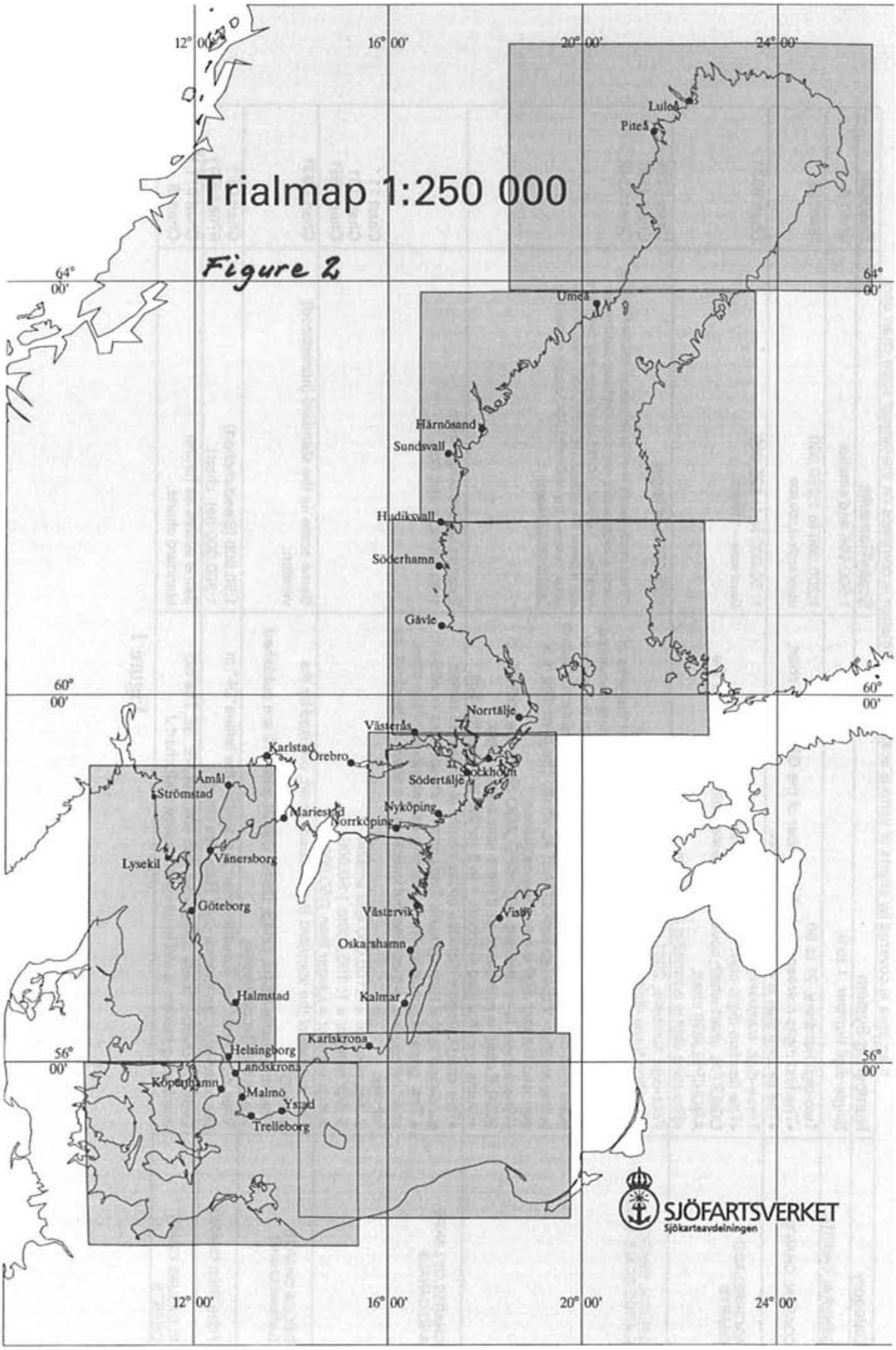
As said earlier there are still many problems to solve to make a good digital as well as traditionally printed product for civil and military use.

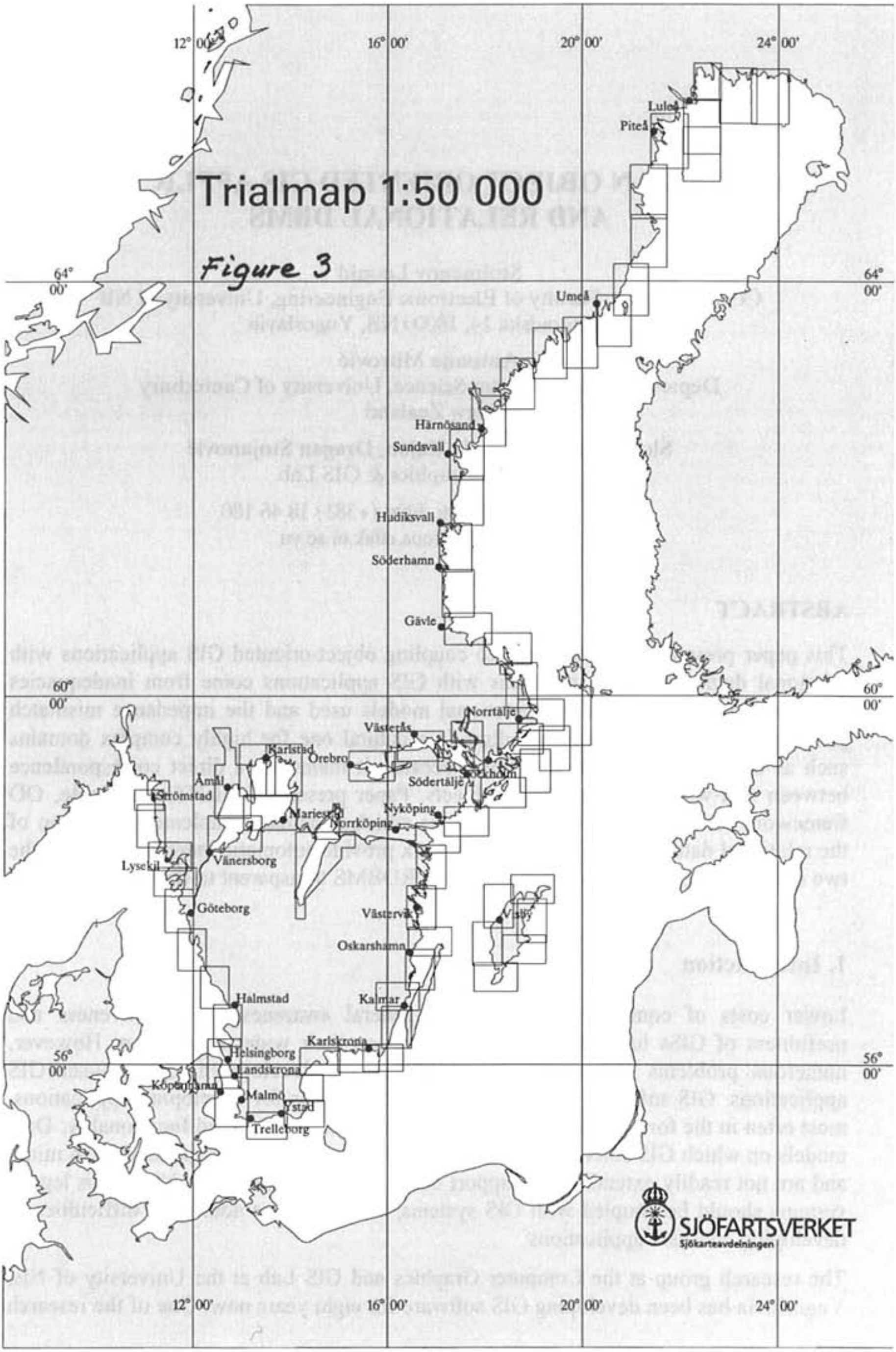
CATEGORIES, SCALES AND NUMBERING SYSTEM of SWEDISH CHARTS

If an area is covered by charts of various scales, the information is complete on the largest scale chart only.

Category	Numbering System	Scale/Remarks	Example
GENERAL CHARTS	Single-digit number, 1 to 9.	1:500.000 and smaller	Chart 4
COASTAL CHARTS	Two-digit numbers, 21 to 99. •The first digits correspond to the number of the GENERAL chart. •The second digit is a running sequence.	1:200.000 to 1:250.000 Usual scale=1.200.000	Chart 52
ARCHIPELAGO CHARTS	Three-digit numbers, 211 to 999. •The first two digits correspond to the number of the COASTAL chart which covers the greater part of the area of the ARCHIPELAGO chart. •The third digit is a running sequence	1: 50.000 to 1: 125.000 Usual scale = 1:50.000	Chart 933
SPECIAL CHARTS (LARGE-SCALE CHARTS)	Four-digit numbers, 2001 to 9999. •The first three digits correspond to the number of the ARCHIPELAGO chart which covers the greater part of the area of the LARGE-SCALE chart and the fourth digit is a running sequence. •If the LARGE-SCALE chart contains plans from within the area of more than one ARCHIPELAGO chart, the first two digits correspond to the number of the relevant COASTAL chart. The third digit is a zero and the last *digit is* a running sequence. •Where there is no relevant ARCHIPELAGO chart, the LARGE-SCALE chart is numbered as if there was such a chart. •Charts are allocated numbers 1 to 5 for the last (fourth) digit.	1:25.000 and larger (These charts consist of either sections of ARCHI-PELAGO charts at larger scales, or plans of harbours and harbour entrances. A LARGE-SCALE chart gene- rally comprises only a part of the relevant ARCHIPELAGO chart. In some areas, however, the ARCHIPELAGO chart is replaced by LARGE-SCALEcharts).	Chart 5121 Chart 4101 Chart 6142
CHARTS OF LAKES AND CANALS	•This chart category includes all the charts of lakes and canals published by the Hydrographic Department, irrespective of scale. • The general principles for numbering as described for the other chart categories, are applied but indicates the scale of the chart, as follows: 2-digit number = 1:100.000 and smaller 3-digit number = 1: 100.000to 1:50.000 4-digit number = Larger than 1:50.000	Existing scales range from 1:20.000 to 1:180.000	Chart 11 Chart 131 Chart 1351
DECCA CHARTS (Latticed Charts)	The number of the standard (nonlatticed) chart, prefixed by the letter D. Note that charts D54N, D54S, D515, D9331 and D13 are published only in the Decca version.	Same scale as the standard (nonlatticed) version.	Chart D931
FISHERIES CHARTS	Then number of the Swedish chart prefixed by the letters"DF",or the number of the international Fisheries chart.	1:50.000 (Swedishchart) 1:300.000 (Int. chart).	Chart DF1 5708 L(D7)
PLEASURE CRAFT CHARTS	Ordinary chartnumbers completed with NW,SW,NE, SE.The old numbering system is still in use in pleasure craft chart J	Same scales as for the standard charts.	Chart 611 NW Chart JI

Figure 1


Trialmap 1:250 000
Figure 2
12° 00'
16° 00'
20° 00'
24° 00'
64° 00'
60° 00'
56° 00'
Luleå
Piteå
Umeå
Härnösand
Sundsvall
Hudiksvall
Söderhamn
Gävle
Norrtälje
Västerås
Karlstad
Örebro
Åmål
Strömstad
Stockholm
Södertälje
Mariestad
Nyköping
Norrköping
Lysekil
Vänersborg
Göteborg
Västervik
Visby
Oskarshamn
Halmstad
Kalmar
Karlskrona
Helsingborg
Landskrona
Köpenhamn
Malmö
Ystad
Trelleborg
SJÖFARTSVERKET
Sjökarteavdelningen



Trialmap 1:50 000
Figure 3
12° 00'
16° 00'
20° 00'
24° 00'
64° 00'
60° 00'
56° 00'
Luleå
Piteå
Umeå
Härnösand
Sundsvall
Hudiksvall
Söderhamn
Gävle
Norrtälje
Västerås
Karlstad
Örebro
Åmål
Strömstad
Södertälje
Stockholm
Mariestad
Nyköping
Norrköping
Vänersborg
Lysekil
Göteborg
Västervik
Visby
Oskarshamn
Halmstad
Kalmar
Karlskrona
Helsingborg
Landskrona
Köpenhamn
Malmö
Ystad
Trelleborg
SJÖFARTSVERKET
Sjökarteavdelningen

BRIDGING AN OBJECT ORIENTED GIS APPLICATION AND RELATIONAL DBMS

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ABSTRACT

This paper presents a methodology to coupling object-oriented GIS applications with relational databases. Most problems with GIS applications come from inadequacies and low expressiveness of computational models used and the impedance mismatch problem. The object-oriented paradigm is a natural one for highly complex domains such as ones involving spatial entities, because it maintains a direct correspondence between real-word and application objects. Paper presents GinisNT, a scalable, OO framework for developing GIS applications which is actually implemented on top of the relational data model. GinisNT framework provide automatic mapping between the two data models, thus making the usage of a RDBMS transparent to the user.

1. Introduction

Lower costs of computer hardware and general awareness of effectiveness and usefulness of GISs have had valuable impacts on their wider application. However, numerous problems still remain, especially in the development of end-user GIS applications. GIS software is very complex and the tools for developing applications, most often in the form of macro languages, typically have restricted functionality. Data models on which GIS software is based have been developed with spatial data in mind, and are not readily extendible to support other real-world problems. Numerous legacy systems should be coupled with GIS systems, which present additional difficulties in developing end-user applications.

The research group at the Computer Graphics and GIS Lab at the University of Nis, Yugoslavia has been developing GIS software for eight years now. One of the research directions pursued has been the development of GIS architecture suitable for the implementation of end-user GIS applications under very limited resources. GINIS [1,2] is a GIS toolkit based on extended relational data model which has been successfully used in several applications [3, 4]. However, the development of new applications on top of GINIS is still quite time-consuming and requires detailed knowledge of the toolkit.

This paper presents our own approach for integrating OO GIS applications with relational databases. This approach is realized in an novel, scalable, object-oriented GIS framework., referred to as GinisNT. In the next section we consider basic concepts of object-oriented paradigm. OO paradigm has been a major research topic for a long time now, its main advantage being direct correspondence between real-world and application objects. The following section presents the requirements of spatial data management, followed by the analysis of existing approaches in coupling OO applications with databases. Section 5 explain the foundations of GinisNT and our own approach to mapping OO model into relational data model. Finally conclusions are reached in section 6.

2. OO Concepts

The main advantage of the OO paradigm is its ease of understanding; it enables natural representation of real-world objects, their mutual relationships and behavior and is therefore close to end-users. An OO applications consist of a set of objects with their own private state, interacting between themselves. OO systems are easy to maintain because they are modular and objects are independent of each other; a change in one objects should not affects other objects in the system. OO paradigm eliminates the need for shared data areas, thus reducing system coupling. The paradigm supports reusability: objects are self-contained and may be used in other, sufficiently similar applications.

Nowdays is no general agreement on what concepts an OO model should support or how these concepts are defined [5]. Here we will briefly list the concepts we see as fundamental and attempt to define them as well.

An *object* is an abstraction of an entity in the real world; it reflects the information about the entity and methods for interacting with it. Objects encapsulate complex structures of data with the behavioural component. The structural component of an object is described by means of attributes, or its characteristic features. The behavioural component of an object is represented as a set of methods (operations) that the object performs in appropriate situations. A *class* is a description of a set of objects describable with a uniform set of attributes and methods. A class therefore represents a generalization of a set of objects with common properties and behaviour. Objects are instantiated (generated) from this description.

Object identification enables each objects to be uniquely distinguished from all other objects in the database. An object identifier (OID) is generated by the system at the moment when object is created, independently of the values of its attributes. An OID is dropped only if the object is destroyed; furthermore, it should be used only once in the database in order to be associated with just one real-world object.

Inheritance is a mechanism which allows developing new classes by modifyng existing ones. This is mechanism which facilitates reuse of existing class hierarchies. Inheritance defines generalization and specialization relationships between classes, by developing abstractions or subtypes of classes.

Aggregation is the construct which enables objects of different types to be amalgamated into other objects. This concepts facilitates modeling complex objects. Aggregation corresponds to the "a part of" relationship between two objects.

Association enables specifyng relationships that exists between various objects in the database. Association may be expressed explicitly in some OO models, while in others they are represented as reference attributes.

Operator polimorfism (operator overloading) is the mechanism which enables operator to handle arguments of various types. It ensures that the appropriate version of the operator will be applied on supplied arguments.

3. Spatial data managment

Spatial entities (also referred to as spatial objects or features) are natural, man-made or abstract objects of interest. These objects are described by geometrical (position and shape of the feature), topological (relations to other features) and attribute (all other non-spatial, usually numerical and textual) data. Spatial data representation and managment have always been the primary concern in GIS research.

The commercial success of database management systems and their wide usage reflected in the area of GIS also. The first GISs based on relational databases stored only attribute (non-spatial) data in the database, mostly because of limited performances of contemporary computer systems. Spatial data were still kept in property data models; these two parts had links to each other, but were supported by separate data managers. Such a hybrid architecture was commercially successful (mostly due to successfulnes of ARC/INFO [6] and is still dominant at the market today. Despite of the success of hybrid GISs, the separation of the underlying data in two parts introduced significant problems, specially concerning the lack of support for ensuring data security, integrity control, multiple user access and concurency management for spatial component of the database.

A natural solution was to integrate spatial and non-spatial components under the control of a RDBMS. Initial efforts to implement spatial database on pure relational model [7] showed that such a approach, altough theoretically feasible, is unsatisfactory due to low performances. As pure relational data model is not suitable for spatial data, information concerning one object is spread over many relations due to the normalizaton performed upon the relations, and many join operations have to be performed in the order to recreate complex spatial objects. The relational data model alone cannot provide appropriate indexing and retrieval operations for spatial data.

There are two subsequent research directions in using databases for storing of both attribute and spatial data. The firs one is the application of OODBMSs, resulting from the general acceptance of C++ as the major implementation tool for GIS. The other approach is the extension of the relational data model and modification of RDBMSs so that spatial data can be stored while retaining the advantages of the relational data model. This approach is based on abstract data types and relaxing the constraints of the relational data model (normal forms).

4. Coupling OO applications with databases

Two different approaches have been distinguished in persistent storage for objects [8]. The *direct object storage* uses the same OO model for the application and the database. If data is stored in an OO database, the problem of impedance mismatch is avoided. This approach is known as direct object storage. However, OO databases still suffer from a number of difficulties, such as view integration, indexing and query optimization.

The other approach is *indirect base relation storage*, which couples an OO application with the relational database. The impedance mismatch problem becomes significant here, but, on the other hand, RDBMS are widely used and hardware and software platforms needed are already available. The problems of sharable concurrent access to data is solved, and the growth of the system is supported. The relational data model is the prevalent data model today and it will be the dominant one for at least the next decade.

The indirect base relation storage approach can be realized from two perspectives: *object-centered* and *relation-centered* [8]. The difference between the two comes for the primary source of data. In the object-centered perspective, relation schemas are generated from class descriptions. In the latter one, it is assumed that relation schemas already exist, and class descriptions are derived from them. As pointed out by Wiederhold, the query used to instantiate an object from corresponding relations can be quite incomprehensible for users because of the normalization process applied to the relations. Object-centered perspective gives more freedom to the programmer. GinisNT is one realization of this approach [9].

5. GinisNT approach

Starting from the above requirements [9], the goal of this research was the development a GIS framework which would enable extensibility of developed applications and databases. The cost of GIS applications development is very high, and therefore extensibility and reusability of developed software have the highest priorities. Taking into account all the previous factors, the object-oriented paradigm was chosen as the most natural one. It is logical to represent spatial objects as objects in the application. OO framework is highly expressive and easy to understand.

The main goal of the proposed approach is to provide a framework for developing GIS applications using an object-oriented methodology, while the underlying database is actually stored and maintained by a RDBMS. We use an OO model at the conceptual level and the relational data model at the implementational level. The implementation level is transparent to the end-user, which means that the framework supports OO paradigm completely. The user does not have to worry about data storage and implementation, and can concentrate on the application which appears to him/her to be completely object-oriented. The existence of a RDBMS is completely transparent to the user by existence of intermediary components in the system which perform mappings between the two automatically.

GinisNT provided support in OO modeling and design of the GIS application. OO model for the application can be developed by selecting some of the existing spatial and non-spatial classes from GinisNT class library, specifying new classes by inheritance from the existing ones or by developing completely new classes. The components of the system map the OO model of the application being developed into the relational schema and create necessary relations. GinisNT also provides run-time support for the applications, by interpreting user's request, invoking appropriate methods and generating database statements on the basis of information present in the metadata repository. As object creation, instantiation, update and retreival operations are provided automatically, the user is not aware of the relational database used on the internal level. More details about this approach can be found in.

Metadata Repository

In order to elevate the burden of the interaction from end-user, GinisNT uses metadata repository to find necessary data about organization of the database. This means that the end-user does not have to remember how data is actually stored and how to access it. The classes in the metadata model correspond to the concepts supported by the GinisNT object-oriented data model. Figure 1 illustrates the structure of the metadata repository. The repository is actually stored using a RDBMS, but this figure illustrates the organization of the repository at the conceptual level.

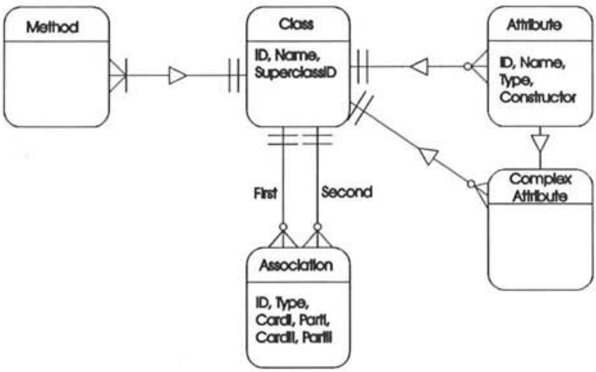

Figure 1. *Metadata repository classes*

Class library

The fundamental concepts of GinisNT include those of a spatial database, project, feature, project-organization classes, hierarchy of spatial classes and hierarchy of attributes. A spatial database contains data about various spatial and non-spatial entities of interest.

A project is a spatial database subset corresponding to particular GIS application being developed. The project model defines which entities are used, associations between them, the methods defined and types of analyses available.

The class library serves as the staring point for developing application classes. It consists of four groups of classes: metadata classes, used for describing the structure of the GIS application database, application-building classes, feature and attribute hierarchies. The first two groups of classes are fixed and present the framework for application development. The feature hierarchy consists of a number of predefined classes for modeling of both spatial and non-spatial objects. The attribute hierarchy supports three types of attributes, simple, composite and multivalued. These hierarchies are extensible, thus enabling the user to specify application-specific objects, their characteristics and behaviour.

A feature is an abstraction of all the entities of the same type. GinisNT provides definitions of the primitive types (aspatial and spatial ones, such as line, area and grid geometrical features, or node, chain, polygon and DEM topological ones) at the same type enabling the user to define new ones by inheriting the attributes of the existing classes.

GinisNT Mediator

GinisNT Mediator is a component which serves as an intermediary between the OO application and the relational database. It provides run-time support by processing user's demands. When a user requires some operation to be performed, Mediator retrieves appropriate information from the metadata repository to decide which relations to access in order to locate object's data or methods. It generates database statements and provides the user interface with the data necessary to customize its appearance. Also, Mediator automatically instantiates objects from relations without any interference from the user using the information in the meta-data repository.

Mediator uses services of the Spatial Data Manager, which provides spatial data storage and retrieval in a RDBMS using abstract data types and spatial indexing. A modification of the OneKey/FourKey method [10] is used for spatial indexing. It linearizes the two-dimensional problem of indexing, thus enabling the usage of B+ trees provided by the RDBMS. Since only an approximation of a spatial object is used for indexing purposes, SDM uses geometrical filters. SDM generates a spatial index entry for each new object, processes spatial and combined queries by generating appropriate parts of the query statements and provides geometrical filters.

GinisNT OO mapping algorithm

Many research have been working on coupling OO and relational data models, as illustrated in previous section. The essence of GinisNT is the object-centred relational approach: using an OO model at the external level, and the relational model at the conceptual level. The usage of a RDBMS is completely transparent to the user.

GinisNT OO model supports objects, classes, attributes, object identity, complex objects (aggregation), generalization/specialization (inheritance) and association.

The model of a project is mapped into the relational schema using the following procedure:

1. For each class *C* in the OO schema, create a relation *R* that includes all simple attributes of *C*. The primary key of a regular class *R* is its objects identifier (OID).
2. Convert each specialization with *n* subclasses *{S1, S2, ..., Sn}* and the superclass *C*, where the attributes of *C* are *{k, a1, ..., an}* and *k* is the primary key, into the relational schema by:
    - including in *C* an additional attribute *t* (the *type* attribute) that indicates the subclass to which each tuple (i.e. objects) belongs;
    - including *k* (the primary key of *C*) in each subclass, a foreign key.
3. Include in each embedded class *E* the primary key of the composite class *C*.
4. For each *1:1* association between classes C_1 and C_2, include in the class that appears totally in the association as a foreign key the primary key of the other class.
5. For each *1:N* association between classes C_1 and C_2, include in the class that appears on the *N* side of the association as a foreign key the primary key of the other class.
6. For each *M:N* association create a new relation *R* whose primary key is the combination of the primary keys of C_1 and C_2.
7. For each multivalued attribute *A* create a new relation *R* that includes an attribute corresponding to *A* plus the primary key *k* of the relation that represents the class that has *A* as an attribute. The primary key of *R* is the combination of *A* and *k*.

GinisNT Mediator also provide methodology for automatic generating of OID. Unique OID for each relation provide that all relations to be in 3rd normal form.

6. Conclusions

GISs are complex systems the requirements of which differ from the ones posed before traditional information systems. GISs manage huge quantities of data, require complex concepts to describe the geometry of objects and specify complex topological relationships between them.

Object-oriented paradigm is perfectly suited to such requirements. It is natural to represent spatial objects as objects in application. GISs request persistence storage of objects; therefore, the ideal solution is to use an OO DBMS to store data. However, there are still unsolved problems with OO databases. As the resources are available, in form of software and existing databases, we feel that the solution is to use the relational database on an internal level and to provide support for OO application development on the conceptual level. All the mappings between the two models are done transparently and the existence of a RDBMS is completely transparent to the user. We believe that the sound foundation of the GinisNT framework will result in fast development of high-quality GIS applications.

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MODEL AND MANAGE DYNAMIC GEOGRAPHIC PROCESSES BY TEMPORAL GIS

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Abstract: With aim to improve understanding of the dynamic geographic processes caused by human being, the nature or both, and to establish appropriate models of geographic dynamics, the geographic information system with full temporal capabilities must be developed. In this paper, the conceptual modeling of time as the fourth geographic dimension and the ways on which temporal GIS would provide efficient modeling and management of dynamic geographic processes are presented. In accordance with it GinisNT, the object-oriented GIS framework with full temporal capabilities is developed at CG&GIS Laboratory at the University of Niš along with HASIS (HAil Suppression Information System), developed on top of GinisNT for the purpose of modeling, visualization and management of dynamic meteorology processes.

1. Introduction

It is everlasting human need to better consider and understand various dynamic geographic processes and phenomena and to analyze the effects and impacts of its activities on the natural environment, which brings the appropriate nature responds. Most current geographic information systems assume and present the static world, the world that exists only in the present, or at the exact time slice in past. Information that exists in the spatial database may be updated over time, but the previous version of this information is not maintained. Thus the sense of geographic changes and dynamics through time is not evidenced, maintained and represented within GIS. This limitation of current GIS capabilities has recently become the focus of growing research interests within GIS community [1]. With aim to better understand geographic processes and establish appropriate model of geographic dynamics, the geographic information system with full temporal capabilities must be developed, capable for storing, retrieving, analyzing and displaying large amounts of spatiotemporal data about dynamic aspect of the real world. Temporal GIS can be utilized in many application areas that must explicitly integrate space and time, such as:

- natural resource management,
- urban and regional management,
- utilities management,
- transportation and satellite navigation,
- command, control and communication systems,
- natural disasters and human accidents' management.

Dynamic geographic processes and phenomena involve changes occurring on the geographic entities. In human perception change include reference to time. So the time as the fourth geographic dimension must be considered and modeled in integration with space, and appropriate spatiotemporal data model must be developed.

2. Time as the fourth geographic dimension

Time is a fundamental physical reality and the object of the study and discourse in whole range of scientific and technical disciplines since antiquity. The interaction of space and time is certainly one of the core elements of geographic thoughts. Time can not exist without space and vice versa. Time is normally perceived and understood via changes occurring to geographic objects in space, causing such objects to appear, transform, move, mutate and disappear over the time. Spatial object is fully described and defined by its geometry, topology and thematic properties and characteristics. If the time is considered as intrinsic part of our understanding of certain spatial object, and the basic property in its modeling, it is recognized as spatiotemporal object with the time as important dimension. For example temperature readings at certain time instants, the state of the forest fire at a given time, and a satellite image of the ozone hole taken on a given datum are the examples of spatiotemporal objects. Spatiotemporal object may change along all three non-temporal axes (geometry, topology and attribute) individually or simultaneously. Such changes are referred as mutations that separate different versions of spatiotemporal object along time. The events causing mutations of one or more objects, separate different states of geographic map as an abstraction of the real world [2] (figure 1).

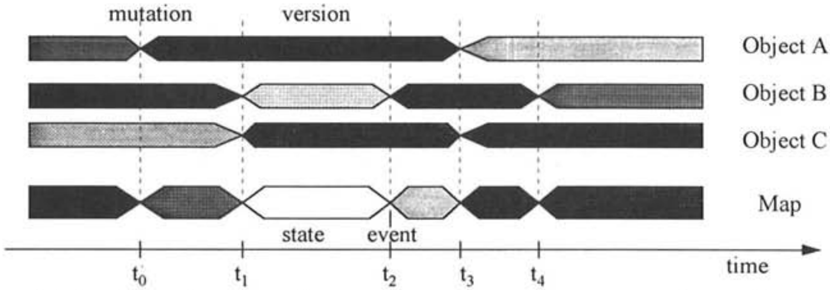
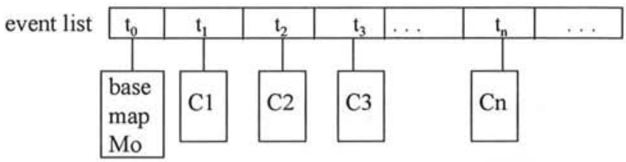


Fig 1. The relation between object versions and map states, and mutations and events

Time can be modeled very much as space, using similar constructs and relationships within geographic context [3]. A temporal object as a part of spatiotemporal object has its temporal geometry and temporal topology, defined in the temporal reference system. The two different geometric primitives can be attached to temporal object: the instant and the period. The instant is zero-dimensional temporal primitive geometrically equivalent to a point in space. Just as a point has a spatial coordinate, the temporal position of an instant can be specified by a temporal coordinate in the temporal reference system. The period is the one-dimensional element of time, equivalent to a line in space. Like a line, it has beginning and end points (each an instant) and a length (its duration). According to their geometry, all possible topological relations between temporal objects such as preceding, overlapping, containing, equal, etc., are defined [4].

In order to integrate space and time in geographic context various spatiotemporal data models have been proposed and developed. Most of them are based on the temporal extension of existed raster and vector data models. The only spatiotemporal data model currently available within GIS is a snapshot model, where the state of the world is given at regular or irregular intervals through the series of snapshot maps, one separate map for each state. Data redundancy and non-evidencing of changes and events are serious disadvantages of this model, however, it can be very useful in GIS based on remotely sensed images. The space-time composite data model is an interested approach that has been proposed by G. Langran [2]. It is based on the principle that every line in space and time is projected down to the spatial plane and intersected with each other creating a polygon mesh, where each polygon in this mesh has its own attribute history fully or partially common with other polygons. Event-oriented spatiotemporal data models [5-7] are based on the explicitly recording events and changes within data model. The sequence of events through time representing spatiotemporal manifestation of some geographic process is noted via time line (figure 2). The base state geographic map may be the latest or the most recent state of the map, so that all other states can be obtained by applying the amendments either in forward or backward manner.



ti - time value Ci - all changes occurred at time ti

Figure 2. Representation of change in an event-oriented data model

The large class of spatiotemporal data models is object-oriented data models based on the object-oriented theory and paradigm. OO concept has shown its applicability in GIS developments because of its natural way to present geographic entities uniquely as objects in GIS application. Most of the object-oriented spatio-temporal approaches are based on the definition of appropriate abstract structures in 3D or 4D space-time, where time is one of the dimensions [8-10]. Such models enable integration of both raster and vector spatial data, temporal information and thematic attributes in a single data structure.

3. Temporal GIS in modeling and management of dynamic processes

Temporal GIS would become a powerful tool for geographic data modeling and dynamic geographic processes and phenomena's management and analysis. The potential temporal GIS capabilities and functions according to [2] are:

- Inventory - Store a complete description of a study area and accounts for changes in both the physical real world and computer storage.
- Retrieval - Issue queries and retrieves information according to various spatial, temporal or thematic criteria, via spatiotemporal query language.
- Updates - Supersede outdated information with current information including retroactive, pro-active and real-time updates.
- Analysis - Explain, exploit or forecast the features contained by and dynamic processes at work in a geographic space.
- Quality control - Evaluate whether new data are logically consistent with previous versions and states.
- Scheduling - Identify or anticipate threshold database states, which trigger predefined system responses.
- Display - Generate a static or dynamic map, or tabular summary of temporal processes at work in a geographic space.

All these capabilities have great impacts on performing efficient spatiotemporal analysis, dynamic modeling and visualization. Whatever the dynamic geographic process or phenomena under scrutiny, the organization of the appropriate spatiotemporal data representing the process and involved changes on the basis of time is essential. Thus, the one of the major portion of temporal GIS is the spatial database consist of spatial, thematic and temporal information about geographic entities, built on an efficient spatiotemporal data model. Spatiotemporal database must include appropriate modeling of time in order to be capable of serving the inventory, retrieval and analysis that may be demanded by the scientific studies of dynamic geographic processes. The analysis engine is the "mind" of GIS, including functions for analyzing temporal relationships of events and geographic entities.. These functions are based on spatiotemporal data extracted from the database and mainly depends on the organization and quality of spatiotemporal database. The testing of cause and effect relationships as well as the development of general process models requires scheduling and simulation of alternative future realities. The most obvious and visible temporal GIS capability is to visualize and display spatiotemporal data in order to suitably represent dynamic geographic processes. In last years there is an increasing interest in geographic visualization and animation, which can be achieved in three ways: as a single static map with symbols and annotations representing changes in time, as series of static maps displaying different states of dynamic geographic phenomena (map strips), or as animated maps as the most powerful and effective way. All these characteristics have the potential of opening a new understanding of the physical world, possibly resulting in new models and knowledge about world surrounding us.

4. GinisNT system and its temporal extension

GinisNT is scaleable, object-oriented GIS framework developed at the Computer Graphics & GIS Lab at the University of Niš [11]. The basic concepts of GinisNT include object-oriented data model, an object-oriented application development methodology and extensible class library. GinisNT data model supports all important concepts found in object-oriented theory and paradigm, and is used at the application level, while the underlying database is actually stored and maintained by the RDBMS. The relational implementation level is transparent for the developer of GIS by existence of intermediary software components in the system that automatically performs mappings between the two data models [12]. GinisNT consists of four components: Object Wizard, Mediator, Spatial Data Manager (SDM) and user interface. Object Wizard is a CASE tool that implements GinisNT object-oriented methodology by supporting schema definition. It enables the user to create an application by defining its object-oriented model and corresponding classes on the basis of the predefined class hierarchy. Object Wizard maps the application object-oriented model into relational schema, creates relations and stores the definition of the application in the meta-data repository. Mediator serves as an intermediary between object-oriented application and the relational database providing run-time application support. Mediator uses services of the Spatial Data Manager, which provides spatial data storage and retrieval in a RDBMS using abstract data types and appropriate spatial indexing. GinisNT user interface is a collection of user interaction tools that can be adapted to suit the needs of a specific GIS application.

In order to suitable perform tasks of developing GIS applications that need temporal dimension of spatial data to be maintained and managed, GinisNT must be extended with temporal capabilities. The extensible class library is the starting point in developing temporal GinisNT extension. GinisNT provides definitions of feature classes' hierarchy representing the primitive, raster and vector, spatial objects such as point, line, area, point-array, point-matrix, etc., and node, chain, polygon and DEM topological ones. These classes contain a description of geometry and attributes related to corresponding spatial abstraction, and a set of appropriate geometrical and topological operations for processing of this data. Feature hierarchy is extensible, thus enabling the user to specify application specific classes with inherited geometry and related operations, and defined special properties and behavior of the real world entity.

GinisNT temporal extension is based on temporal hierarchy with class Temporal_feature as top-level class, and multiple inheritance as one of the core concepts of the object-oriented paradigm. Temporal classes for time instant, time period, time duration, and complex time object are specialized from the base. The class definitions include appropriate temporal data such as year, month, day, hour, minute, second, etc., temporal reference system, as well as temporal topology operators and general purpose temporal functions. The class of particular spatiotemporal object (for example hail cloud, oil spill, navigated vehicle) is specified via multiple inheritance from appropriate feature class describing its spatial properties and the temporal class describing its temporal characteristics. Thus, according to mechanism of object-oriented inheritance, the spatial and temporal dimensions are integrated within single class abstraction in addition to concrete thematic attributes and operations specified for that class of spatiotemporal objects. On the figure 3, this concept is schematically shown for the class of navigated vehicle objects.

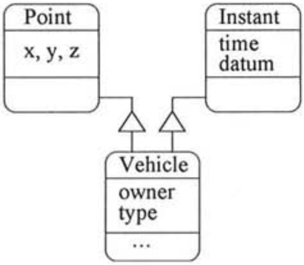


Fig 3. Specification of a class for navigated vehicle objects

The class Temporal_change is defined for every specified class of spatiotemporal objects in order to evidence changes, previous and next versions of objects, the versions belonging to the current time slice, with support for efficient making of queries relating to the temporal relationships. This spatiotemporal object-oriented model is tested and further refined in the implementation of hail suppression information system, developed for the purpose of modeling and management of dynamic atmospheric processes.

5. HASIS - the hail suppression information system

Hail suppression information system (HASIS) has been developed in order to increase efficiency of a radar center applying automation process starting from radar information about clouds to launching rockets with seeding material [13]. This specialized information system is based on GIS technology, object-oriented paradigm and GinisNT object-oriented framework. Its primary purpose is hail suppression, but the system can be efficiently used in meteorological research and short term weather forecast. Basic purpose of the radar center is to detect cumulo nimbus clouds with high probability, to perform accurate measurements of all relevant parameters of hail cells in clouds, to determine launching elements (azimuth, elevation, timing) for rockets with seeding material and to determine suitable hail suppression stations with the great degree of efficiency and command them. Hardware configuration consists of PC-based workstations connected in LAN Ethernet, with main workstation equipped with two additional cards: radar log-video signal digitalization card (A/D converter) and specialized DSP card. The main workstation performs a lot of tasks in real time for processing, displaying and analyzing of radar signal data, among all are:

- Digitalization, integration, conditioning of a radar signal, signal comparison with threshold and dBm to dBz conversion.
- Transforming of the volume polar coordinates into Cartesian coordinates and calculation of the particular address of RAM location.

deep-water or seaward side to guarantee the safety of sailing and other marine activities which concern the depth of water. This rule means that only the segments representing concave areas(gaps, small bays, valleys, etc.) can be deleted from the chart; the segments for raised areas(shoals, capes, ridges, etc.) should be reserved. As a result, the segments of depth-contour lines, coastlines and contours will only move in the direction from the high- or shallow-side to the low- or deep-side of the lines. Obviously the original Douglas-Peucker algorithm cannot carry out the processing tasks under this restriction.

Refinement

Main Idea

Douglas-Peucker algorithm has to be refined. to satisfy the special requirement of simplification of depth-contours and some other lines in nautical chart generalization. The main idea to fit this problem is to add a protecting step to the basic operation cycle of Douglas-Peucker algorithm.

The protecting step is that in the original processing course of Douglas-Peucker algorithm, when having found out a point to be deleted but having not executed the actual deleting, the program checks whether or not this point(and the segment it stands for) represents a hollow area on the earth's surface according to the state of the segment's convexity. If yes, it will be deleted; otherwise the point should not be removed from the data set of this line.

This step will definitely ensure the reservation of those points (and segments) standing for a raised terrain, thus have the segments move toward only one side of the line. As to the points for hollow regions, logically this additional step does not affect their saving or deleting--for them the decision depends on the examining result of original Douglas-Peucker algorithm.

Method

Baseline

In the following paragraph, word ***baseline*** will be used to help our discussion. This term refers to the line connecting the two neighbor points of the concerned point (Pi in Figure 1) which, as the basic Douglas-Peucker algorithm decides, should be deleted from the stored point-set of the line. The baseline can play a reference's role in judging the state of convexity of the terrain that the concerned point suggests.

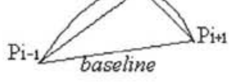


Figure 1

Mathematical Judgment

There are two problems to solve in the protecting step. The first one is how to judge the state of convexity, from a mathematical point of view, of the segment which the concerned point suggests. That is to say, to tell on which side of the baseline the point Pi locates. The second problem is how to determine the spatial and geographical relationship of deep-side and shallow-side of the processed curve, or to find out which side of the baseline is deeper. When these two problems being settled down, the question about whether the concerned point should be deleted or reserved has been answered.

Table 1: State of Convexity

Baseline Dx	Dy	F(x,y)	Convexity	F(x,y)	Convexity
		F= 0	Straight		
>0	>0	F< 0	Concave	F>0	Convex
<0	<0	F< 0	Convex	F>0	Concave
>0	<0	F< 0	Concave	F>0	Convex
<0	>0	F< 0	Convex	F>0	Concave
=0	>0	xi<xi-1	Convex	xi>xi-1	Concave
=0	>0	xi>xi-1	Convex	xi<xi-1	Concave
>0	=0	yi>yi-1	Convex	yi<yi-1	Concave
<0	=0	yi<yi-1	Convex	yi>yi-1	Concave

The first problem can be solved by using a mathematical criterion, namely signalized area. The course is:

- build a triangle with the points P_i, P_{i-1} and P_{i+1} (Figure 1), where P_i is the point which is to be removed by the decision of preliminary judgment by original Douglas-Peucker algorithm, P_{i-1} and P_{i+1} are the fore- and back- neighbor points of P_i in the point string of processed curve. The edge $P_{i-1}P_{i+1}$ is the so-called baseline;
- set up a judgment function F(x,y):

  $F(x,y)=y-ax+b$; where *a* and *b* can be determined by the equation of baseline;
- calculate the value $F(x_i,y_i)$ of judgment function for P_i:

  $F(x_i,y_i)=y_i-a*x_i+b$

  where (x_i,y_i) could be the screen coordinate of point P_i;
- based on $F(x_i,y_i)$ and Table 1, judge and decide the mathematical convexity of arc $P_{i-1}P_iP_{i+1}$.

Geographical Judgment

The next problem, to determine the geographical relationship of deep-side and shallow-side of the processed curve, can be solved by several methods. In our experiment a comparatively simple one is employed. We assign a **direction** to the processed curve by appropriate construction of datafile structure of those curves. With this attribute of depth-contour's datafile, the geographical convexity of segment keeps in accordance with the mathematical convexity so that we can judge whether the concerned point stands for a higher or deeper relief.

In this system the positive direction of curve is the one that keeps the higher area on its left and the lower area on its right side when navigating from the first through the last point of the curve. There could be two ways to accomplish it.

- when building datafile by digitizing, the curve lines should be digitized in the positive direction, keeping the shallow region on left side and deep region on the right. If a contour line closes itself and surrounds a higher area, it should be digitized counterclockwise; otherwise digitize it clockwise.

• when creating the datafile with a scanner or from chart databases, the storage sequence of points in datafile should be adjusted after determining the positive direction by comparing the soundings on both sides of the curve.

Results

New cycle of refined algorithm

The cycle of Douglas-Peucker algorithm under this restriction consists of the steps below(Figure 2):

① picking up a curve line of positive direction, setting up the threshold ***e***;

② connecting the start and end points A, B, the two point set a line;

③ calculating the distances of intermediate points to Line AB, finding out the largest distance ***h***;

④ if $h \geq e$, then ⑤; otherwise ⑥ and ⑦;

⑤ separating the curve into two parts at point C; repeating steps ② to ④;

⑥ all the intermediate points being labeled the *would-delete* points;

⑦ protection judgment: to reserve the points for positive reliefs and delete the other points;

⑧ repeating from ①.

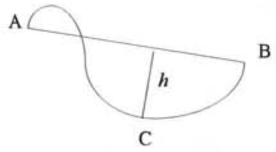


Figure 2

Sample Experiments

Figure 3 through 5 show a set of experimental results of line simplification. Figure 3 is the basic chart sheet. Figure 4 shows the generalization result using basic Douglas-Peucker algorithm. Figure 5 gives the line simplification of refined Douglas-Peucker algorithm. The two experiments run upon a same pre-set threshold value of 10. Dotted lines in Figure 4 and 5 indicate the original depth-contour lines. Notice the different graphics between the two result pictures at the neighbouring areas of the **points a**, **b** and **c**. The refined algorithm for simplification of Figure 5 seems more satisfactory to process depth-contours. This refinement may also applys to the simplification of contours and other lins which only moves toward a specific side.

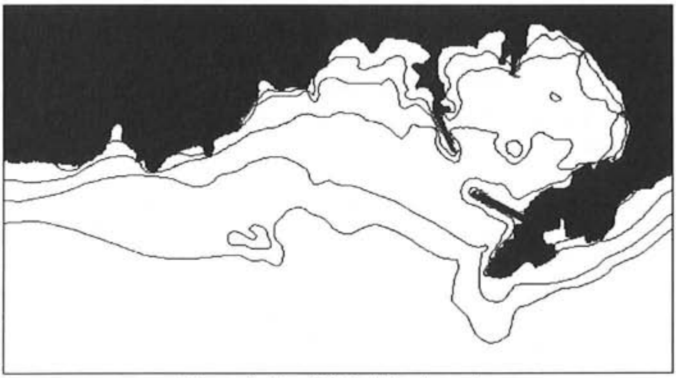


Figure 3: The Original Depth-contours

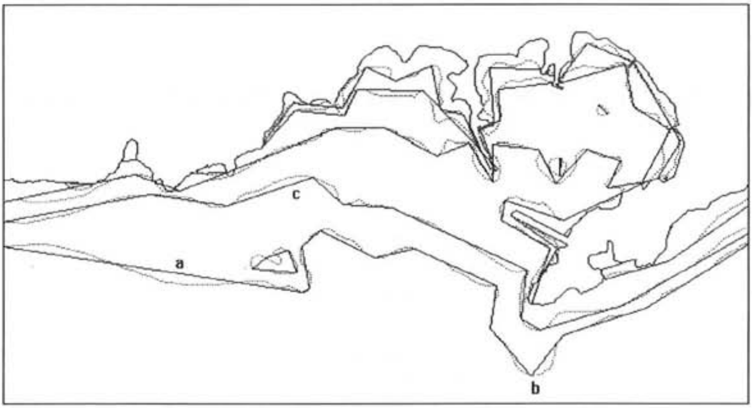


Figure 4: Sample of D-P Algorithm

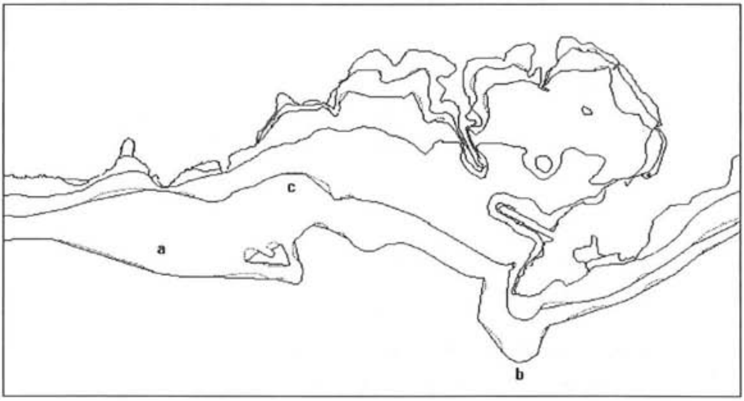


Figure 5: Sample of Refined D-P Algorithm

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THE SPECIFICATION AND EVALUATION OF SPATIAL DATA QUALITY

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1. Abstract

Standards for the specification of spatial data quality and quality assurance routines are currently being developed by the international standardisation organisations CEN and ISO. One problem in developing and evaluating these standards is the lack of documented experiences.

The Commission of Spatial Data Quality of the ICA have performed a world-wide questionnaire, aiming at an increased knowledge concerning the quality specifications and quality assurance routines being used today. The purpose of this paper is to describe the result of this survey.

The results shows that

* the quality measures proposed by the CEN corresponds fairly well to the measures currently being used in practice.
* improved quality assurance routines are needed, especially concerning completeness, but also concerning positional and thematic accuracy.
* there is a large need for standards and guidelines but also for education and R&D efforts.
* there is a clear mismatch between the requirements of the users and what is currently being offered by the data producers in terms of data quality specifications.

2. Introduction

One of the major international activities in our current GI society is the standardisation of spatial data. This type of work is carried out as well within international standardisation bodies as within national organisations and other interest groups such as the Open GIS Consortium (OGC). On the international level, both the European Committee for Standardisation (CEN) and the International Standardisation Organisation (ISO) are working on standards for spatial data quality. Although they are separate organisations, the members of the working groups are partly the same. Due to earlier start, the proposal from CEN (CEN, 1996) is the first one reaching a stage of a formal proposal. This draft preliminary European standard is now under consideration by the CEN members and formal voting is expected during 1998.

One aim of developing spatial data quality standards is that every set of spatial data will have uniform quality descriptions. Using this specification, a potential user will then be able to decide, whether the data set fit his or her needs or not. A data producer must as a consequence have production routines that ensure that the data being produced are of specified quality. In traditional mapping industry, several methods for quality checking and quality control have been developed. They have however usually been tailored for cartographic production and not for spatial databases and GIS. The production of topographic maps for instance, usually has well developed methods for checking and controlling the positional accuracy and the completeness of the map. As data to an increasing extent now are stored in spatial databases, there is a need for an extended set of data quality assurance routines. It is believed that several organisations already have considered this problem, while others, for different reasons, have not. This problem have also been considered by the ISO and a working group have been established, aiming at standards for quality assurance routines.

One problem concerning standards for spatial data quality is the lack of documented experiences. As a consequence, the content of such a standard is to a large degree depending on experiences and opinions as expressed by the organisations participating in the development of the standard. Currently, these organisations are mostly major data producers, for instance national mapping authorities. To what degree are their experiences and opinions also valid for other data producers, data vendors and data users?

Considering the lack of documented experiences in this field, the Commission on Spatial Data Quality of the ICA have made a world-wide questionnaire to producers of spatial data. The purpose of the survey is to obtain an overview of data quality specifications and quality assurance routines being used. One question of interest is to investigate if the set of quality elements and measures currently being proposed by the CEN is complete. Another question of interest concerns which quality assurance routines are being used today. A third group of questions concerns the relationships between producers and clients and if there are any further actions that can be made to improve the use of spatial data.

3. General information

The questionnaire was sent to 288 National Mapping Agencies, the last two weeks in December 1996. The deadline for submission of answers was set to 31 January 1997, although later responses were accepted. In total, 56 organisations responded to our questionnaire, corresponding to a response rate of around 19 %. Most answers were received from Europe (59 %), followed by Asia (19 %) and Africa (7 %). The contribution from North America (excluding Central America) was only 6 %, mainly because the number of mapping organisations here is small. The reason for not sending the questionnaire to data vendors and data users were mainly due to practical considerations.

There has also been an email version of the questionnaire. Although some technical problems with this approach have been reported, resulting in some manual work, around 24 % of the answers were received this way.

In total, 83 different databases are covered by the survey. Their main themes are topography (58 %) and hydrography (37 %). Themes such as Land Cover and Parcels are included in around 17 % of the databases. Less than 4 % of the answers concerns soil or geological databases. Note that many databases covers more than one theme. As a result, the sum of percentages exceeds 100. Nearly all databases have a national coverage (81 %).

80 % of the databases have their quality specified. Of those, 74 % claims to have a homogenous quality. The specifications being used are mainly based on in-house standards (46 %) while 26 % are based on national standards. But on the other hand, the clients don't request this information that often. Only 42 % of the data producers claims that the clients often request their quality specifications.

4. Data quality specifications and assurance routines

The term quality can be defined as the "totality of characteristics of a product that bear on its ability to satisfy stated and implied needs" (CEN , 1996). To describe data quality, a set of quality elements are used. In the CEN proposal for quality standards, the quality elements are lineage, usage and quality parameters such as positional accuracy, thematic accuracy, temporal accuracy, logical consistency and completeness. CEN also proposes textual fidelity as a secondary quality parameter (CEN, 1996), which is not covered by this survey. To describe the quality elements, quality indicators are being used. An example of a quality indicator is absolute accuracy, which may be quantified by the root mean square error (RMSE).

The Commission of Spatial Data Quality of the ICA have recently published a textbook describing the elements of spatial data quality in more detail (Guptil, Morrison , eds. 1995). Here elements such as lineage, positional and attribute accuracy, completeness, logical consistency, semantic accuracy and questions related to temporal information are discussed.

4.1 Positional accuracy

Accuracy may be defined as "closeness of observation to true values or values accepted to be true" (CEN, 1996). Positional accuracy may then be defined as a quality parameter indicating the accuracy of geographic positions.

The quality measures being used for describing the positional accuracy are shown in Table 1. The most common quality measure is, as perhaps expected, the RMSE (Root

Mean Square Error) value. This measure is used by 58 % of the data producers. Another observation is that 15 % of the data producers states that they are also using other measures for positional accuracy.

Table 1. Use of quality measures for positional accuracy. The total number of answers is 66. Since a single organisation can use several measures, the sum of percentages is larger than 100%.

Quality Measure	Number of organisations	Percentage
RMSE (Root mean Square Error)	38	58 %
Maximum Error	15	23 %
Error ellipse	4	6 %
Error of distance	10	15 %
Other	10	15 %
None	3	4 %

For quality assurance three methods are dominating, see Table 2. The use of independent measurements, for instance field checks, are most commonly used (44 %). Also subjective evaluation is commonly used (41 %) as well as results from adjustments (34 %). Nearly all organisations have however some sort of quality assurance. Only 2 % state that they don't use any methods for assuring the positional accuracy.

Table 2. Quality assurance routines used for checking the positional accuracy. The total number of answers is 82. Since a single organisation can use several methods, the sum of percentages is larger than 100%.

Assurance routine	Number of organisations	Percentage
Results from adjustments	28	34 %
Repeated measurements	12	15 %
Independent measurements	36	44 %
Subjective evaluation	34	41 %
Unknown	1	1 %
Other	10	12 %
None	2	2 %

4.2 Thematic accuracy

A thematic map is a map showing the spatial distribution of a certain property or attribute, for instance population densities. The attributes can be of quantitative or qualitative nature. For quantitative attributes, the accuracy may be expressed in traditional statistical terms such as RMSE. In cases where the attributes are of qualitative nature, errors and uncertainties occurs when the wrong class is assigned.

Measures for misclassification may then be used. The actual use of quality measures for thematic accuracy is summarised in Table 3.

Table 3. Use of quality measures for thematic accuracy. The total number of answers is 56. Since a single organisation can use several measures, the sum of percentages is larger than 100%.

Quality Measure	Number of organisations	Percentage
RMSE (Root mean Square Error)	7	12 %
Maximum Error	5	9 %
Percentage correctly classified	20	36 %
Misclassification matrix	1	2 %
Other	12	21 %
None	17	30 %

Table 4. Quality assurance routines used for checking the thematic accuracy. The total number of answers is 79. Since a single organisation can use several methods, the sum of percentages is larger than 100%.

Assurance routine	Number of organisations	Percentage
Results from adjustments / classifications	20	25 %
Repeated measurements	8	10 %
Independent measurements	15	19 %
Subjective evaluation	25	32 %
Unknown	0	0 %
Other	8	10 %
None	13	16 %

4.3 Temporal accuracy

As mentioned above, accuracy may be defined as closeness of observations to true values or values accepted to be true. If we follow this definition strictly, temporal accuracy should then describe the accuracy of temporal observations. If such observations are stored as dates, temporal accuracy is then the accuracy of these dates. Such an accuracy may be described by mean time error or other statistical measures.

In the CEN proposal for data quality standards, the meaning of temporal accuracy has been extended (CEN, 1996). It is realised that the temporal dimension is "a qualitative aspect of the geographic subset as a whole". As a consequence, the quality indicators for temporal accuracy also covers aspects related to the temporal effects on the spatial data quality. Examples of such quality indicators are updateness (date of last update), rate of change and temporal lapse (time between a change in the real world and the updating of the database). Since this survey follows the structure of the CEN proposal, this extended view of temporal accuracy have been adopted. The results are summarised in Tables 5 and 6.

Table 5. Use of quality measures for temporal accuracy. The total number of answers is 63. Since a single organisation can use several measures, the sum of percentages is larger than 100%.

Quality Measure	Number of organisations	Percentage
Date of latest update	47	75 %
Number of units change per unit of time	1	2 %
Mean time error	0	0 %
Other	8	24 %
None	11	17 %

Table 6. Quality assurance routines used for checking the temporal accuracy. The total number of answers is 78. Since a single organisation can use several methods, the sum of percentages is larger than 100%.

Assurance routine	Number of organisations	Percentage
Repeated measurements	12	15 %
Independent measurements	7	9 %
Subjective evaluation	28	36 %
Unknown	3	4 %
Other	8	10 %
None	25	32 %

4.4 Completeness

The term completeness may be defined as the degree of conformance of a geographic dataset compared to its nominal ground with respect to the presence of objects, association instances and property instances (CEN, 1996). The term nominal ground is here used to define a certain aspect of the real world, not the real world itself. The nominal ground can be expressed as an ideal database, that is a database which is fully complete and have no observation errors. In this sense, the term completeness describes how much information is missing or should not be present. The term can be applied on feature level as well as on attribute level. When applied on feature level, the term indicates whether all features that should be present in the database are present or not. When applied on an attribute level, the term indicates to what degree a certain attribute is known. Although the definition by CEN includes all these aspects, the examples given in the CEN proposal only relates to completeness on a feature level.

Table 7. Use of quality measures for completeness. The total number of answers is 59. Since a single organisation can use several measures, the sum of percentages is larger than 100%.

Quality Measure	Number of organisations	Percentage
Percentage of objects missing	25	42 %
Percentage of objects erroneously being present	10	17 %
Other	19	32 %
None	15	25 %

Table 8. Quality assurance routines used for checking the completeness. The total number of answers is 79. Since a single organisation can use several methods, the sum of percentages is larger than 100%.

Assurance routine	Number of organisations	Percentage
Repeated measurements	11	14 %
Independent measurements	30	38 %
Subjective evaluation	34	43 %
Unknown	1	1 %
Other	8	10 %
None	10	13 %

4.5 Logical Consistency

The term logical consistency may be defined as the degree of conformance of a geographical dataset compared with its nominal ground with respect to the constraints defined in the application schema (CEN, 1996). The constraints being defined in the application schema may for instance concern constraints on certain attribute values (domain consistency), constraints on relationships among tables (referential consistency) and constraints on spatial relations (topological consistency).

Table 9. Use of quality measures for logical consistency. The total number of answers is 65. Since a single organisation can use several measures, the sum of percentages is larger than 100%.

Quality Measure	Number of organisations	Percentage
Topological consistency checks	56	86 %
Data value validation checks	33	51 %
File structure checks	31	48 %
Other	4	6 %
None	4	6 %

Table 10. Quality assurance routines used for checking the logical consistency. The total number of answers is 81. Since a single organisation can use several methods, the sum of percentages is larger than 100%.

Assurance routine	Number of organisations	Percentage
Checking printouts of consistency checks	64	79 %
Subjective evaluation	21	26 %
Unknown	1	1 %
Other	11	14 %
None	5	6 %

4.6 Lineage

Lineage is a quality element that describes the history of a geographical dataset. According to the CEN proposal (CEN, 1996), lineage information is mandatory for describing the quality of geographical information, while usage (4.7) and the quality parameters described in 4.1-4.5 are optional. Within the lineage part, information about the production of the data is mandatory (name of the organisation, purpose of production and date of production), while other lineage information such as source material is optional.

Table 11. Use of descriptors for lineage. The total number of answers is 61. Since a single organisation can use several descriptors, the sum of percentages is larger than 100%.

Lineage information	Number of organisations	Percentage
Producer organisation	32	52 %
Purpose of production	24	39 %
Date of production	37	61 %
Source material / process history	43	70 %
Other	9	15 %
None	1	2 %

Table 12. Use of descriptors for usage. The total number of answers is 62. Since a single organisation can use several descriptors, the sum of percentages is larger than 100%.

Usage Information	Number of organisations	Percentage
Usage organisation	20	32 %
Usage purpose	20	32 %
Usage constraints	17	27 %
Other	6	10 %
None	18	29 %

4.7 Usage

The term usage may here be defined as a quality element describing applications for which a geographic dataset has been used (CEN, 1996). As mentioned above, this information is not mandatory in the CEN proposal, but such information certainly gives valuable information about possible additional uses of the dataset. The use of usage as a quality element is summarised in table 12.

5. Attitudes

The attitudes of data quality specifications and quality assurance routines are very important when formulating a strategy for further work. It should be stressed that the opinions expressed in this survey reflects the personal opinion of the person filling out the questionnaire, not any eventual official declarations of each organisations. The responders were asked to state their agreement with 9 different statements. Their answers were ranked along a scale from 1 to 5, where 5 = strongly agree, 3 = partly true and 1 = strongly disagree. The answers are summarised in table 13.

Table 13. Summary of attitudes.

Statement	Agree (4,5)	Partly true (3)	Disagree (1,2)
My organisation has recognised the needs of a proper data quality spec.	94 %	4 %	2 %
Our current clients always require a data quality specification	27 %	52 %	21 %
The current quality specification of the database fulfils the needs of our clients	57 %	34 %	9 %
Our organisation needs standards and guidelines concerning the specification of data quality	86 %	12 %	2 %
Our clients need standards and guidelines concerning the use of data quality specifications	66 %	34 %	0 %
The requirements of our clients have a large impact on the design of our quality assurance routines	46 %	34 %	20 %
There is a great need for educational material concerning the specification of data quality and assurance routines	79 %	19 %	2 %
Our current quality assurance routines are sufficient for a proper specification of the data quality	41 %	36 %	23 %
There is a strong need for better tools and working procedures in the area of quality assurance routines	80 %	18 %	2 %

The second last question in table 13 concerns whether the current quality assurance routines are sufficient or not. Here a large number of responses feel that these routines are not sufficient. By analysing the data further, a correlation was found with the question whether the quality of the database was known and specified or not. Grouping the answers into these two groups it was found that 15 % of the databases with known and specified data quality have insufficient quality assurance routines while 67 % of the databases with unknown quality have insufficient quality assurance routines.

6. Discussion

One important point to consider when evaluating this survey, is the low response rate. It is clear that a response rate of 19 % is too low to be used for detailed analysis. There are many possible reasons to the low response rate. One reason could be that the time frame between receiving the questionnaire and the deadline for its submission was too tight. Another reason could be that the mailing lists being used were not suitable for this type of surveys. A third reason may be that the questions related to spatial data quality are not considered to be of importance, resulting in a unwillingness to respond. A fourth response might be that the routines are not developed or commonly known, resulting in difficulties in filling out the questionnaire. A fifth reason finally, may be that several organisations are more concerned with map production and have not yet established data bases.

Considering the responses that were received, the conclusions that are drawn below mainly applies to topographic and hydrographic databases in Europe and North America.

The measures and elements used for data quality specification, agrees fairly well with the measures and elements being proposed by the CEN. The answer "other measures" are generally below 15 %. Exceptions from this are the quality measures for thematic accuracy (other = 21%), temporal accuracy (other = 24%) and completeness (other = 32%). The responders have not indicated which other measures they are using. Further investigations may be required in this field.

Considering quality assurance routines, subjective evaluation seems to be a very common method (26% - 43%). Subjective evaluation could indicate visual inspections or the use of "rules of thumb". The fulfil requirements for more robust quality assurance routines, more rigorous methods have to be applied. If we assume that the use of "subjective evaluation" or "no method" indicates a need for enhanced quality assurance routines, R&D efforts should then mainly be spend on assurance routines for completeness, but also to thematic and positional accuracy (Table 14). The high need for improved assurance routines concerning temporal accuracy should not be stressed to far. The reason for this is that the major quality measure being used is date of last update. The need for quality assurance routines could in this case be questioned.

The attitudes presented in section 5 shows some very clear results that needs to be pointed out. First of all, an overwhelming majority of the data producers have recognised the needs of an proper data quality specification. As a conclusion, there is no need for any action aiming at raising the awareness among the data producers.

Table 14. Percentage of answers indicating subjective evaluation or no evaluation as quality assurance routine.

Quality Parameters	Percentage
Positional accuracy	43 %
Thematic accuracy	48 %
Temporal accuracy	68 %
Completeness	56 %
Logical consistency	32 %

There is however some strong needs for enhancing the current situation. Several responses (86 %) have pointed out the need for standards and guidelines. There is also a large need for educational material and improved tools and routines (79 %). There is also a strong feeling that the current routines for quality assurance are not sufficient. Only 41 % of the respondents consider their assurance routines to be sufficient. A strategy where the development of standards is combined with educational and R&D activities is therefore justified.

If we then consider the relation with the clients, the situation is somewhat more diffuse. First of all, the needs of the clients have only a limited impact on the quality assurance routines. Secondly, only 57 % of the quality specifications fulfil the clients needs. But on the other hand, the quality specifications are not that often required by the clients. Why this situation? Why this mismatch between the clients needs and what is being offered by the data producers?

Let us first assume that the clients are very interested in receiving data with specified quality. Considering their limited interest in the current specifications, it seems not that they are suited to the needs of the client. If so, the proposed standards will also be of limited use. If we on the other hand assume that the clients are not interested in quality specifications at all, at least two possible reasons may be formulated. One reason may be that the quality specifications as such are of less importance to the clients. If so, the quality standards from CEN and ISO will mainly be of use for data producer when enhancing their production capabilities. A second reason might be that the low interest from the clients is a matter of awareness and set of available tools for handling the data quality elements. If so, we should pay more attention to education and R&D specifically based on client perspectives.

It should be stressed that this questionnaire have been responded by data producers, not the data users themselves.

7. Conclusions

The conclusions can be summarised as follows

* Due to limited response to the questionnaire, the conclusions presented below mainly concerns topographic and hydrographic databases in Europe and North America.
* The quality elements and measures being proposed by the CEN corresponds fairly well to the elements and measures currently being used by the data producers. Additional quality measures for completeness, temporal accuracy and thematic accuracy are however also being used. Further studies in this field may be justified.
* Methods for quality assurance needs to be improved. This concerns especially methods for assuring the completeness, but also thematical and positional accuracy.
* There is less need for actions aiming at raising the awareness of data quality issues among the data producers.
* There is a large need for standards and guidelines for data producers. There is also a large need for educational material and improved tools and routines.
* It seems to be a mismatch between the requirements that the clients have on data quality specifications and what is currently being offered by the data producers. This question needs to be investigated further. If not, there is a risk that the standards currently being discussed will mainly for suited for the data producers and not for their clients.

8. Acknowledgements

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APPLICATION OF ISO-9000 IN MAP DIGITIZING

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ABSTRACT

Early in the U.S. Geological Survey (USGS) program to contract for the production of digital line graphs (DLG), quality was found to be inconsistent, often not meeting requirements. The USGS developed a strategy to eliminate quality problems, which included the requirement that the contractor implement an ISO-9000 quality system that would create the necessary quality environment and could be easily adopted in cartographic production. The ISO-9000 system is in fact a philosophy that defines a total quality environment by identifying 19 key issues, covering all major facets of production, that must be addressed to reliably and consistently produce a quality product. The principal advantages of the ISO-9000 system are its generic applicability in industry, universal acceptance, and simplicity. The ISO-9000 has strong potential for success because it clearly defines what needs to be done to produce quality products, including cartographic products. The ISO-9000 alone cannot guarantee quality, but it does establish the building blocks that can place a mapping firm in excellent position to meet demanding requirements such as those established by the USGS. The USGS experience in working with industry has proven that the ISO-9000 is beneficial to map digitizing and to customer-supplier partnerships.

DIGITAL LINE GRAPH CONTRACTING

The standard vector product used by the U.S. Geological Survey (USGS) to convert its published maps to digital form is the digital line graph (DLG). The production of DLG's was initially accomplished using in-house resources at various production centers. In 1988, the USGS began to contract for DLG production in an effort to increase production capacity. Now production has shifted firmly toward contracting

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Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

as the USGS commercializes those operations that are well developed in the private sector. The USGS spends about $2,000,000 per year procuring DLG's.

The Quality Problem

The DLG is defined by the USGS Standards for Digital Line Graphs, a comprehensive set of specifications to convert USGS published topographic maps to DLG data. Initially, the USGS and the contractors thought that merely following the specifications would produce suitable results. The specifications are generally straightforward, identifying all of the rules and formats required of the product. However, map digitizing of general topographic maps, such as the USGS produces, is enormously complex because of the vast amount of data, symbols, and rules for converting the symbology to digital form. The complex production environment for DLG's presented new challenges. Vendors launched production programs with quality control measures relying on inspection, but without establishing a comprehensive quality program.

The contractors and the Government found that they were faced with unexpected quality problems in the early stages of contracting. The problems were not always severe and varied in magnitude from contractor to contractor, but the overall volume diminished the effectiveness of contracting. Solving quality problems on a case-by-case basis yielded minimal gain over a mounting issue. Although much progress was made, to make contracting truly effective, an initiative was needed to resolve the core of the quality problem. Contractors needed a quality system as a foundation of quality.

The Application of ISO-9000

Rather than invent a new quality system, the USGS looked closely at the International Standards Organization quality standards known as ISO-9000. These standards, first published in 1987, were developed by a consortium of quality experts from around the world and represented a global consensus of thought on the definition of quality. The emphasis was on defining the fundamental building blocks of quality systems. The ISO-9000 standards defined the source of quality and required that all production operations be firmly rooted in sound quality principles. ISO-9000 is not a complex encyclopedia of quality, but rather a simple outline breaking quality operations into individual components that can be systematically addressed. With the components of quality soundly developed and these building blocks pieced together, a comprehensive foundation to quality is created. By not only building, but also continually maintaining the ISO-9000 principles, the manufacturer is well positioned to make huge strides forward in achieving quality.

In analyzing the elements of ISO-9000, the USGS found that these elements pertained perfectly well to map digitizing. This is not surprising because the goal of the ISO-9000 standards was to be applicable to all industry, and the standards were based on the theory that regardless of what is manufactured, the same basic processes are used. The USGS found that the ISO-9000 version known as ISO-9002 (published in the United States as the ANSI/ASQC Q-9002-1994 standard, American Society for Quality organization, including public and private enterprise. Even guideline documents are generic and are insufficient for determining how to actually apply the defined elements. It is left to individual organizations to implement the standard in ways that make sense to their operation.

Learning From Others

The best "how to's" often come from other organizations. Most organizations that have committed to the path of ISO-9000, no matter what stage they are at in their journey, are willing to share ideas about how they have implemented elements of their quality system to be compliant with the standard. Organizations do not have to be in the same business in order to share useful ways of implementing the ISO-9000 standards. In fact, cross-business disciplines are often helpful in understanding the scope of the standards from different perspectives.

Businesses in Pacer Infotec's hometown of Portland, Oregon are fortunate to have an active ISO-9000 Users Group that meets monthly. Each meeting focuses on applying specific elements of the standard, and the guest speakers and attendees include registrars and members of companies who have successfully implemented ISO-9000. They provide very helpful interpretations. There is also a "mentorship program" sponsored by the Oregon Quality Initiative. Any organization that requests help will be matched with another organization of similar size that has successfully implemented ISO-9000.

An Approach for Implementation

An unwavering commitment from top management is essential to undertake implementation. Management must believe that it is a good business decision and commit to participating and providing resources. Pacer Infotec approaches ISO-9002 as a business model. It is not a total business model because some elements, such as accounting, and some human resource functions are not included. But the standard provides most of the elements necessary for running an effective business.

No element of the standard can be effectively applied alone. For example, quality system documentation relates to every aspect of quality system implementation. Corrective and preventive action is linked to training, process control, control of nonconforming product, and internal quality audits. Quality planning is inseparable from contract review, inspection and testing, identification and traceability, training, and process control .

All elements of ISO 9002 are interrelated to varying degrees. We will look at how Pacer Infotec implements just a few of the individual elements, always keeping in mind that these are only a few of the components that make up a larger business system. We will look more in depth at how Pacer Infotec implements three of the 19 elements of the standard: training, corrective and preventive action, and process control.

Training (Element 18) Pacer Infotec recognizes that training is essential to ensure that all personnel have the knowledge needed to perform their jobs and understand how they fit into the organization. The importance of, and the company's commitment to, this element is demonstrated by the fact that a full- time position is devoted to training. The training coordinator ensures that every member of Pacer Infotec receives the training required for his or her job, that the training is effective, and that it is documented. She personally provides key training and coordinates with other members of the organization, as well as with outside experts, to provide specialized training. All newly hired data technicians are required to participate in a week-long class focusing on the actual data conversion processes used at Pacer Infotec.

Following are examples of some of the in-house training: (1) "Getting The Most From Meetings," 1 hr; (2) "Continuous Improvement - Processes & Tools," 2 1/2 days; (3) "Corrective Action System Training," 40 min; (4) "Final Header Check Training," 30 min; (5) "Hypsography Training," 1 day; (6) "Introduction To Digital Line Graph Data Conversion," 1 week; (7) "Introduction To Pacer Infotec's Quality System," 40 min; (8) "LT4X (Internal Software) For Digital Elevation Model Production," 1 day; (9) "Public Land Survey System," 3 hrs.

This list is not complete, but it illustrates the range of training and the skills required by Pacer Infotec employees to perform their jobs effectively. The task lists and skills required for every position are identified and documented. This helps the employees, supervisors, and managers to have a realistic view of expectations and how each new employee can achieve them.

The training coordinator maintains copies of all current training materials; doing so provides verification of the content and consistency of the material presented and ensures that others can fill in as trainers. Records are maintained of all employees' attendance in classes. In the spirit of continuous improvement, participants are asked to complete evaluations on the courses so that the instructors can improve both delivery and content on the basis of feedback. Some of the training needs are identified through the corrective action process.

Corrective and Preventive Action (element 14) Corrective action includes both remedial action and action taken to prevent recurrence of a nonconformance. It concerns both system and product nonconformances. Organizations that do not truly understand root cause analysis typically take corrective action by adding more inspection. At best, inspection only catches 80 percent of the errors made. As the late Dr. Edward Deming, one of the fathers of the modern quality movement, often stated, when you rely on inspection, you are paying someone to produce errors, then you are paying someone else to catch them, and finally, you are paying for the work to be done over again!

All Pacer Infotec employees are provided with training specifically designed to promote understanding of what a process is and how to identify the causes of variation inherent in all processes. Variation causes nonconformances. There is an assumption that any nonconformance has a root cause and this root cause can be determined and prevented. The focus is on understanding why and how to prevent errors, rather than on blaming or punishing individuals. This is not to suggest that individuals are not accountable for their performance. Individual- performance feedback is an essential part of systems improvement. However, employees look at how they can redesign processes in ways to "error-proof" them. Any process that relies on word-of-mouth communication and memory is one that will inevitably yield great variation!

The following conditions require that a formal, documented corrective action request (CAR) be initiated: (1) Any report from a customer of nonconformances or problems with the product. (2) Problems or deviations in system procedures as noted in the internal audit process or through other observations. (3) Any occurrence that results in 2 or more hours of lost production time. (4) Any occurrence where more than 20 percent of a project must be reworked before it is sent to the customer. All members of Pacer Infotec are trained in the use of the corrective action procedure and are held responsible for initiating a CAR when one of the above conditions is observed or discovered. The quality assurance director administers the CAR's and coaches individuals in the processes used to determine root cause and corrective action.

Managers, staff, and project coordinators have been trained in the use of various tools that can be used in root cause analysis and preventive action. Following are three examples of such tools: (1) Process Mapping, The "Three Actual Rule" (Go to the actual place of the problem. See the actual problem. Talk to those directly involved and get the actual facts). (2) The "5 Whys" ("Why did the nonconformance or problem take place?" "Why?" "Why?" "Why?" "Why?"). (3) Cause and Effect Diagrams, also known as Fishbone or Ishikawa Diagrams. These and many more tools that are useful for root cause analysis and process improvement can be found in the references appended.

Corrective action items with due dates are assigned to individuals. These become part of the open CAR status report, which is reviewed at the weekly staff meeting until the corrective action is completed. The staff review involves the entire management team of Pacer Infotec, so all levels of management are informed and involved. It also serves to identify whether a problem on a specific project is actually a system-wide problem that needs to be corrected. Corrective actions often include revising work instructions or adding a work instruction to define a process that had previously been undocumented and so open to individual interpretation. This leads us to the element of process control.

<u>Process Control (element 9)</u> There is no single procedure for process control. Instead, every work instruction exists for the purpose of ensuring that work is always done repeatably, accurately, and in the best way known every time. Each work instruction is based on the assumption that there is a "best way" to perform any task and, paradoxically, that best way can always be improved upon. In most cases, the best way today will be replaced by a better way in the future.

Currently, approximately 45 work instructions incorporate detailed procedures guiding employees in their day-to-day tasks. Work instructions are written for every process that affects the product delivered to Pacer Infotec's customers. Work instructions are used during training, then serve as reference for those performing the work. There are more than 15 work instructions related to the USGS digital line graph data conversion process. These include instructions for each type of data category, as well as inventory control, edgemapping, digitizing, in-process and final inspection and product delivery instructions. While working on a given project, data technicians keep an open copy at their work stations of the current revised work instruction for the data category being corrected.

For ease of use, all quality documents should have the same look. Documenting instructions for software usage required that the Pacer Infotec technical staff all agree on a format for identifying commands and variables, and on how to describe using the cursor versus how to execute keyboard commands. Because of this consistency, the work instructions are exceptionally easy to use.

Work instructions are controlled documents, each one identified by a unique document number and revision numbers. They are "living" documents that are always being revised and improved. The production staff are permitted to use only the most recent revisions. A revision history is shown at the end of each work instruction to indicate revision date, description of changes, reason for the change, and who authored the change. Changes must be reviewed and approved by designated members of the management team.

Work instructions define when and how in-process and final quality checks are performed. Even though Pacer Infotec emphasizes "doing it right the first time," verification that it is, indeed, done right is still required. Errors are documented and corrected; feedback is given immediately to the data technician who performed the work. Documenting this information helps maintain individual and organizational performance records. These data provide the basis for complying with the statistical techniques element of ISO-9002.

CONCLUSION

The DLG's delivered to the USGS from Pacer Infotec are accepted at a rate of 98.5 percent. Of the 1.5 percent returned for rework, most have problems that involve digitizing style and interpretations and are not critical errors. This quality record is a substantial accomplishment considering the potential for error, the strict quality requirements of the USGS, and the extensive array of checks performed on the data in the acceptance process. This is the result of many quality program initiatives at Pacer Infotec, but central to this effort has been the foundation of quality presented by the ISO-9002 requirement. The success is also attributed to Pacer Infotec's adoption of ISO-9002 as a working quideline and not as a regulatory burden. The USGS sees additional benefit in the assurance that a quality program is in place at the contractor site and, when combined with sample results, allows the USGS to reduce the cost of its quality checking program.

A VIRTUAL TOUR IN THE 3D MODEL OF THE TOWN OF LECCO

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Abstract

This article describes a teaching experience carried on with forty students of the Surveying Course at Politecnico di Milano (Lecco Branch Office), Faculty of Engineering. The work aim was to involve the students in real and practical planning problems in order to organize and to realize topography and photogrammetric surveies. The students get practice with GPS antenna methodologies, with traditional surveying and photogrammetry methods, and with computer use too, reaching, as final result, an example of 3D virtual tour in the town of Lecco.

1. Introduction

The planning work was preceded by some lessons about computer use as the greater part of the students was impractical with it. These lessons had the only goal to give the students some practical knowledge of computer for beginning their work (use of standard CAD systems and worksheet software).

The work done by the students regards the following topics:
1. learning the use of G.P.S. technology;
2. learning to survey using traditional methods (total stations);
3. learning to survey using digital photogrammetry method;
4. learning to work with CAD systems starting from numeric cartography.

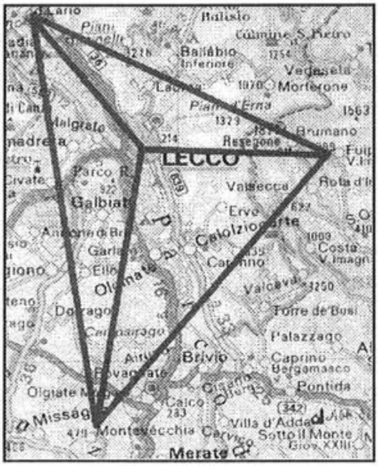
The students were following the third or the fourth year of their five years studies at the Faculty of Civil Engineering. This is the only course on surveying and photogrammetry sciences they have planned in their engineering studies. All the students have been working at the first two phases; only five of them have been working, after the end of the course, to the final two steps.

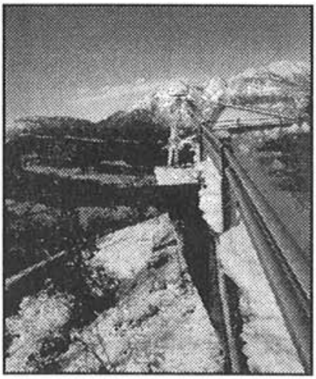
2. Surveying with GPS system

2.1 The GPS network Project

The first experience carried on by the students has been the project, the measure and the adjustment of a GPS network. It was planned to measure a network composed by eight points; five of them were placed inside and three outside the town of Lecco. The vertices outside the town were chosen in correspondence of the IGM95 monuments (Italian zero order network known either in WGS84 and RM40 systems). These vertices were placed in a range of 20 Km around Lecco and allowed to evaluate the WGS84 coordinates of the network.

The students had to propose a network scheme to connect the five points in Lecco to the reference points IGM95 outside the town placed in Mandello Lario, Fuipiano Valle Imagna and Montevecchia (picture 1 and picture 2).





Pictures 1, 2: The GPS network planned by the students and a GPS antenna placed at Valle Imagna IGM95 point.

The students had to evaluate the approximate values of the X, Y, Z coordinates, starting from the map coordinates obtained from 1:2.000 or 1:10.000 scale maps. To make the coordinates transformations they had to create the following *Microsoft Excel* worksheets:

1. TRASF1.XLS to move from East, West, h map coordinates to φ, λ, h referred to the Hayford ellipsoid (without here considering ondulation problems);
2. TRASF2.XLS to move from φ, λ, h to X, Y, Z geocentric coordinates;

The so obtained approximate coordinates have been later used to make a least squares a priori analysis to estimate the networek a priori accuracy. The analysis has been made using the software *CALGE* from Politecnico di Milano; the students had to make, by themselves, an a priori analysis on a smaller network (at least 3 point and 3 baselines) creating the *Microsoft Excel* worksheet SIMU.XLS.

2.2 The network measurements

The GPS measurements have been made in two days of work. The work planning has been chosen between one proposed by the students, that were organized in groups of 4-5 people. Three double frequency GPS receivers *(Geotronix Geotracer System 2000 L1/L2)*, free given by *AGEOS*, were used (picture 3). The acquisition was made in static mode with 40 minutes of acquisition and a cut off angle of 15°.
The students had one day time to learn at the University the practical use of the receivers and they could study at home the user manual of the instrument. During the measuring operations only few baselines were lost for mistakes on using the receivers.

Picture 3: Student measuring the slope instruments height of the GPS antenna.

2.3 The network adjustment

The network adjustment was not made by the students themselves. In fact the University could use just one copy of the baselines evaluation software *Geotracer* of *Geotronix*. The baselines values (ΔX, ΔY, ΔZ and the full matrix 3x3 of correlation) were used as input for software *NETGPS* (Politecnico di Milano) to evaluate the WGS84 coordinates of the network. The least squares adjustment used of only one constrained point and the accuracy reached was of about ± 4 cm. The students had to project an *Excel* worksheet to transform, using a 7 parameters least squares approach, the network X, Y, Z WGS84 coordinates to the X, Y, Z coordinates of the Hayford ellipsoid oriented in Monte Mario. With an iterative approach (Bencini formulas) the students had to evaluate φ, λ, h coordinates and, using the HIRVONEN formulas, they finally evaluated the map Gauss-Boaga RM40 coordinates. Having both the ellypsoidic and the orthometric heights of some points it was also possible to evaluate the ondulation values and to compare them with the Italian geoid ITALGEO95.

3 Surveying with traditional methodologies

The students have planned a 3D network in Lecco historical city in order to measure the necessary control points for the photogrammetric survey of some buildings in XX Settembre square (one of the most representative in Lecco). The planned network contains four vertices placed in the square and twenty-six points placed on the buildings façades. The four monuments in the square were special nails, hammered on purpose in the ground, while the points on the façades were natural details like window edges, cornice edges, building edges, etc.
During the lessons the students have learned in the University court how to use a total station and so, they became skilled enough in taking measures for surveying the network points (picture 4).

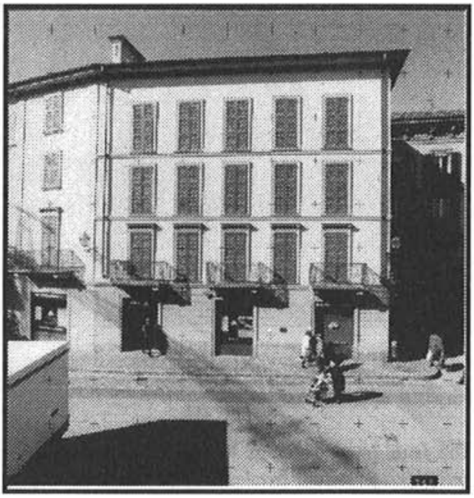
Picture **4:** Student working at the total station

The coordinates of the four points placed in the square have been measured, using a polygonal scheme having as first and final vertices two GPS points. In this way it was possible to move all the coordinates in Gauss-Boaga RM40 (Italian cartographic reference system), the same used in the numeric cartography files.

Later the students have learnt how to process measures with a least square adjustment approach. They have made a first least squares adjustment of the polygonal scheme using a *Microsoft Excel* worksheet, for the matrix calculus, and they have balanced all the surveyed network using the software *CALGE* from Politecnico di Milano. In this way they obtained the 3D coordinates of the twenty-six control points, with a standard deviation lower then 2.0 mm.
The coordinates values of some buildings edges, linked to the above described GPS survey, have been compared with their values in the numeric cartography. The comparison have shown a different of few centimeters in East and West coordinates.

4. Surveying with digital photogrammetry method

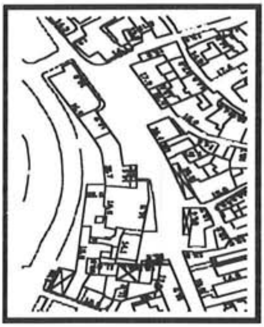
After the end of the course, some students have applied the concepts of digital photogrammetry to survey some architectural façades. They have studied about control points, interior orientation, exterior orientation, relative orientation, picture plane. Using a *Rollei 6006* semimetric-camera, with a 11x11 reseau, they have taken pictures of three old façades in the XX Settembre square (picture 5). The printouts have been later scanned using a *HP 4C Scanjet* for the digital elaboration. Before doing the restitutions the pictures were cleaned by the students from troubling elements using suitable software such as *Corel Photo-paint, Adobe, Phoshop, Aldus Photostyler,*
The interior and the spatial resections were obtained using the *Nikon RealView (NRV)* software. *NRV* is a monoscopic *Autocad 13* add-in ,which works both with raster and vector data realizing scaled pictures-plane. Every picture-plane was obtained using at least 5-6 control points measured on the façades.

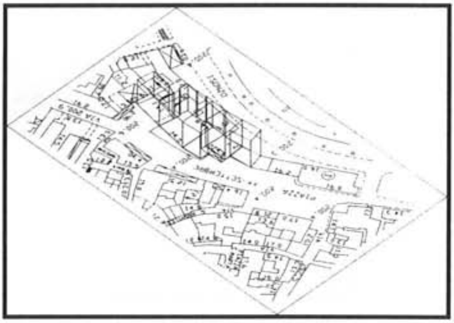


Picture 5 Printout example of a *Rollei* 60mm x 60mm photogram

5. Working on the numeric cartography with 3D CAD systems

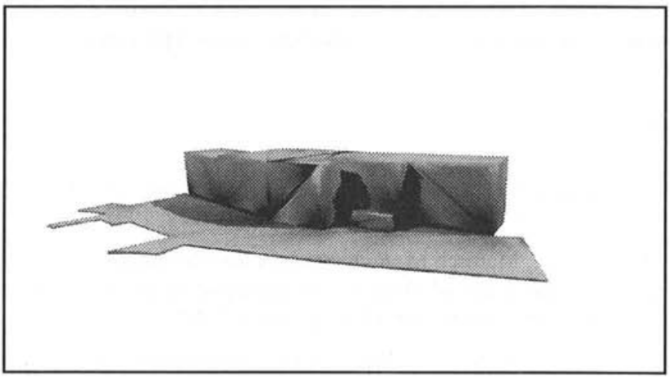
The students worked on the Lecco numeric cartography in order to create a 3D model of the square. The aim of this work was to obtain an example of a realistic 3D model of the photographed buildings. The students, with the help of an expert in CAD systems, individuated and cut the area around XX Settembre square (picture 6) from the files containing the whole town cartography and modeled in a CAD system, the buildings shapes, using for the polylines extrusions the roof gutters heights given by the numeric cartography (picture 7). The adopted CAD system was *AutoCAD for Windows Release13*.





Picture 6,7: The selected area in the Lecco numeric cartography and the building shapes created with the CAD software

Later they created, using *Autodesk 3D Studio Max* software, a schematic model containing the square ground shape and the 3D models of the surveyed buildings (picture 8).



Picture 8: The 3D model created with *3D Studio* Software

SATELLITE IMAGE INTERPRETATION IN CARTOGRAPHIC UPDATING AND IN THE MANAGEMENT AND MONITORING OF AGROFORESTRY AREAS

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Abstract

The following paper describes a research study on the potential applications of digital image classification as an integral part of land coverage up-dating of the Army Geographic Institute's (IGeoE) map production chain.
Detailed on-site field work analysis was carried out so as to obtain an accurate assessment of the digital image classification and the results obtained therein. A more efficient classification of the digital image was made possible by applying different methods as well as the combination of a variety of methods, which resulted in the production of the final map.
Some indications which allow for better results in the classification of digital satellite images are also provided. These indications result from conclusions drawn on the basis of experience gleaned during the course of this lengthy project.

1. Introduction

Over the last decade enormous developments have been witnessed in the field of new technologies and with a view to a more efficient and effective application of remote sensing systems on high altitude platforms (satellites), many and varied research projects have been carried out on the use of satellite images as a means of identifying, managing and quantifying some of the characteristics representing the earth's surface.
Thus, with the aforementioned aims in mind, the IGeoE also carried out a research project on the potential of classification of digital satellite images in providing information on land coverage and soil stratification as a contribution to the different map series produced at this Institute. The following is a detailed, although brief, description of the work plan followed, the methodology applied and the results obtained. Some guidelines for future projects of this nature are also provided with the hope of contributing towards obtaining increasingly better and more accurate results.

2. Characteristics of the Area of Study

The selected area of study where the classification of digital satellite images was applied was located in the North of Continental Portugal between the Barroso Mountain Range, Mondim de Basto, Guimarães and the Caniçada Lagoon, an area covering 12 map sheets of the M588 Series at a scale of 1:25 000 and part of the maps produced by IGeoE.

The altitudes in this area cover a range varying from 371 to 1285 metres approximately, with an irregular relief and slopes which may either be sunny and shady at the moment when the passing satellite obtains its images. This will naturally have some consequences in the classification of digital images.

Land parcelling and intensified grouping of a variety of cultures within the same parcelled areas, the wide variety in vegetation as well as the existence of microclimates which influence vegetation differing growth rates, make this area very heterogeneous and one of the most complex in Continental Portugal. For all the above reasons this area is an ideal focus for a study of this type.

3. The Preparation Phase

The preparation phase began in 1995 and involved gathering information on the results of the growth of the different species, during such periods as foliation, flowering and fruit-bearing. The aim was to identify the development of the fundamental vegetation species in this area of interest to the study project in hand, as well as their differing growth in light of their geographical location, the diversity of the relief and the characteristics of the region.

The following tasks were carried out during this initial phase:

- random selection of the test areas (approximately 20% of the total area of the image) with the aim of obtaining independent gathering of information and non-correlation data;
- acquisition of aerial photographs of the selected areas so that soils and dividing lines of the vegetation types could be more easily and accurately identified;
- acquisition of the SPOT XS satellite image of 30 May 1995. Geocoding of the corresponding test area is then carried out from well-identified landmarks plotted on the digital cartography. The image of the area destined for field work is then plotted and printed out at a 1:25 000 scale;
- non-supervised classification of digital image is then carried out with a view to obtaining generic information on the distribution of the vegetation in the test area.

It must be stressed that work carried out on the image was brief and rapid so as to avoid delays in initiating the fieldwork, making sure that no significant alterations in soil occupation would take place between the time when the satellite image was obtained and the moment when the on-site fieldwork was carried out.

4. On-site Field Work

The on-site field work was divided into two phases so as to gather sufficient information deemed necessary for determining the spectral (identification) signatures of the vegetation species for later supervised digital image classification and for the validation of the results obtained.

It should be pointed out that, among other aspects, the test areas covered involve a great variety of situations as to geographical location, the development stages of the vegetation and the density and grouping of species.

The first phase of the field work was carried out between 19 June and 3 July 1995 with the aim of gathering data, both in the designated test areas and easily identifiable surrounding areas.

The second phase was carried out from 18 to 28 July 1995 with the following objectives:

- to monitor the results of the supervised digital classification previously carried out;
- to identify the areas of spectral conflict;
- to gather additional information in, for example, conflict areas.

The second phase proved to be very useful for redefinition of the selection process of spectral classes and served as a warning of the importance of recourse to precise statistical parameters when establishing test areas.

5. Digital Image Classification

Digital Image Classification was carried out in three fundamental stages. Classification work was subject to precise monitoring thus allowing for the perfecting of methodologies both in the on-site field work and information gathering on classes. This allied to methods used throughout the process of classification of digital image. The three stages of the work were as follows:

a. Non-supervised Classification

This stage was carried out during the planning phases so as to permit identification, although generic, of a number of classes, and their respective distribution which could possibly be represented in the image.

b. Supervised Classification - 1st phase

The supervised classification of digital image was carried out between the two stages of the field work so as to produce an initial analysis of the species found in the area. The aim, however, was not to delay the on-site identification for validation. Classification of digital images played an important role in the verification of the field identification work carried out both in the test areas and in areas of spectral conflict.

The resulting classification played a decisive role in redefining methodologies, identification processes and fundamentally, in redefining of test classes as well as in the individualisation of areas of spectral conflict.

c. Supervised Classification - 2nd phase

The following tasks, carried out during this phase, played a determinant role in the presentation of results:

- orthoretification of the original image bands (SPOT XS) using a Digital Terrain Model with a 20-metre grid width;
- additional bands produced by manipulation and linear combinations of originals, with special emphasis on ratios, main components and NDVI. By means of an analysis of test class divergence, the most suitable set of bands was identified;
- classes were selected using different methods and standard deviations so as to guarantee the purity of each class, Gaussian distribution and statistic consistency. This reduced conflict between classes in turn reducing classification errors;
- based on the information obtained from on-site field work, two training sets were established thus permitting statistical validation of the data obtained by creating a confusion matrix;
- analysis and study of the divergence values produced as a statistical measurement of seperability and discrimination among the classes, keeping in mind the diversity of classes and spectral bands involved in the process as well as results obtained by use of different methods;
- overlap masks produced from pre-classification of digital images and visual interpretation and its subsequent inclusion in the final classification of digital images;
- digital image classification was obtained by using parametric, non-parametric and combined methods based on a variety of parameters and confidence levels. The results obtained were rendered more efficient by interactive methods from visual interpretation based on the field work carried out.

6. Analysis and Validation of Results

a. Analysis of Results

Final classification was obtained through the application of combined methods and considering the various supervised digital classifications. Different classification algorithms were combined among themselves and tested, while the parameters were simultaneously rendered more efficient and accurate. Final classification of digital image resulted from a combination of one non-parametric method (parallelepiped classifier), followed by a parametric method (maximum likelihood classifier), the latter being taken as the deciding rule. This form of classification served as a basis for plotting the different areas of vegetation was carried out under the following conditions and with the following characteristics:

- the classes covered in the training sets were acquired with standard deviation which varies from 1.25 to 2.75 depending on the spectral characteristics of each class;
- by using a mask for specific areas within the image;
- classification obtained from 7 bands, of which 5 were obtained from a linear combination of the three original bands;

- use of 58 spectral classes distributed among 11 thematic classes;
- digital classification obtained proved to have an 89.23% degree of average precision and a global precision of 91.63%.

In view of the diversity and reflectivity levels of species in conflict areas, a variety of thematic subclasses were taken into consideration so as to reduce the margin of error and increase classification precision, as table 1 shows:

Table 1

CLASSES	TRAINING FILE FOR CLASSIFICATION (Nbr of classes)	TRAINING FILE FOR VALIDATION (Nbr of classes)
Pine tree	14 (11)	14 (10)
Eucalyptus	7 (6)	11 (7)
Brush		
-furze and ferne	6 (5)	11 (8)
-shrubs (furze and gorse)	11 (7)	7 (3)
-vegetation w/ rocks	6 (6)	8 (8)
Oak	8 (6)	6 (6)
Rock	4 (3)	3 (3)
Quarries (scraped land)	3 (1)	3 (2)
Burnt areas	8 (8)	6 (6)
Water	4 (4)	2 (2)
Vineyards(*)	5 (0)	4 (0)

(N) The numbers in brackets indicate the number of classes used in classification.
(*) The range of the spectral sample is very small and not taken into consideration in the final digital classification as it would have resulted in rather inconsistent statistical parameters.

It must be pointed out that data on cultivated land, specifically vineyards and corn fields, was also gathered. However this data was not taken into consideration in the digital classification as the classes represented provided a highly diversified spectral behaviour pattern because of their geographical location, the small parcels of land involved and the association of cultures. Even with variation in deviation standards it was not possible to gather data for the production of consistent statistical results to make digital classification possible.

b. Validation of the Classification Produced

(1) *From the Confusion Matrix*

Table 2 shows the analysis of the Confusion Matrix, showing precision levels acquired in the validation carried out, based on two training sets groups gathered and the fundamental class types.

Table 2

CLASSES	CALCULATED PRECISION (%)	
	User`s Accuracy	Producer`s Accuracy
Pine tree	83 (88) (**)	90 (91) (**)
Eucalyptus	89 (91) (**)	84 (87) (**)
Oak	94	92
Fern	100 (*)	100 (*)
Woodwaxen and gorse	63	93
Brush (furze etc.)	92	90
Vegetation w/ rock	97	95
Rock	100	96
Stone Quarries	100	99
Burnt Areas	96	100
Water	100	100

(*) One class only;
(**) The level of precision obtained is presented in brackets and does not take into account the confusion between pine trees and eucalyptus in areas of dense and disperse vegetation.

From the values shown in the table above it was concluded that the reduction in calculated precision was the result of some overlapping of classes such as pine trees and eucalyptus, pine trees and brush, eucalyptus and woodwaxen and furze and even eucalyptus and oak. The characteristics of the test area were a decisive factor for this event when analysing the various spectral confusions, specially in view of the great diversity in the relief forms, as well as the presence of large shady areas at the time of the acquisition of the image. Another factor was the association of species which results in the same thematic class having a differing spectral behaviour pattern thus constantly entering into conflict with other classes.

(2) *From On-site Field Work*

(a) *Carried out by the Remote Sensing Department*

The classification obtained shows good global results, although one must stress the confusion occurring between pinetrees and eucalyptus (mainly in shady areas), oaks and eucalyptus, woodwaxen/furze and eucalyptus and pines, and pines and brush. Difficulty was encountered in identifying areas of brush during the global monitoring work carried out. In addition to the above, there are also some areas where the error occur as a result of overlapping of spectral classes making it impossible to provide an accurate definition of the frontiers or dividing lines between the types of land coverage within the required precision levels.
This classification satisfies the precision requirements as pertains the areas of vegetation for scales of 1:100 000 or smaller.

(b) *Carried out by the Survey Department*

The monitoring work carried out by the Survey Department focused on an area of 110Km2 which was selected because of the enormous degree of difficulty it represented. From this monitoring work one concludes than only 1km2, divided into 5 areas of approximately 200m2, was left unclassified; the pine and chestnut tree species had been well classified and the confusion area of the classification arose between the eucalyptus and chestnut trees.
It must be highlighted that, based on the assessment carried out as to method, the green areas corresponded to the reality in the field.

7. Conclusions

The search for new methods and means of monitoring and updating the green areas and agroforestry management has led to satellite images becoming an excellent instrument for this type of inventory. However, some limitations still exist both at the level of spatial resolution as well as the identification of area boundaries, features which are obviously conditioned by the scale at which one is working and by the precision parameters of the up-date.
Notwithstanding the limitations inherent to this type of information, it must be stressed that, as an instrument for updating cartography the digital classification produced demonstrates high levels of precision both for the producer and for the end user, although it must be validated by the appropriate field work. The following aspects were deemed of great importance when obtaining the results:

- the introduction of bands allowed for a divergence analysis according to the selection of the different groups of bands. From these originated the resulting group of bands which led to the final classification and showed the widest average divergence of groups;
- the study of the seperability of classes proved to be decisive for the classification process through the JM-Distance analysis, allowing for improvement in the process and speed of classification;
- the use of a mask based on visual pre-classification and encompassing urban and some agricultural areas (characterised by a vast land parcelling division) also played a decisive role in the production of better results from the areas of spectral confusion;
- the classification of cultivated areas proved to be inapplicable because of the characteristics of the area with small land parcels and association of cultures, resulting a high number of confusion pixels;
- the combination of a non-parametric method followed by one parametric method as the decisive rule, proved to be the most appropriate methodology used in digital classification.

Although this project did not involve the use of masks based on the Digital Terrain Model, it must be said that these are of great use and would have reduced the confusion between species by improving the levels of precision in classification.

Perspectives for managment and agroforestry monitoring are optimistic, although in the field of agriculture no faithful results were obtained.

In the form of a general conclusion it must be said that, although the precision level obtained in this study may be deemed good within the context of the methodology applied, the limitations of the image and the area of work conditioned the use of the digital classification used. It is thus concluded that this method of classification should not be used as a means of up-dating IGeoE's 1:25000 scale cartography in view of the precision parameters which characterise this map series. However, this type of classification is appropriate for 1: 100 000 scale maps or smaller.

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PRODUCTION OF MILITARY GEOGRAPHIC INFORMATION WITHIN THE ARMY GEOGRAPHIC INSTITUTE THE VECTOR SMART MAP PROJECT

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ABSTRACT

The Army Geographic Institute (IGeoE) has been working on a project involving several NATO countries within the field of military GIS. Its main goal is the production of digital cartographic information of the world using a 1/250 000 scale and an associated alphanumeric data base.

This project, Vector Smart Map (VMap), operates under specific rules (DIGEST) and must be produced using the Vector Product Format (VPF). The knowledge of these standards will enable all nations involved in its production to work in the same data pattern and all potential users to have easy access to this information.

Within this context, we propose to present some of the VMap characteristics along with some more technical features of the IGeoE production.

1. INTRODUCTION

Cartography-related activity has a long tradition in Portugal and the military have always had a vigorous and determining role in the country's cartographic production. Their preponderance in the carrying out of the basic triangular division of the country is well known. It was begun in 1778 and resulted in the 37 sheets of the Chorographic Map of Portugal to a scale of 1/100,000, awarded a prize by the International Congress of Geographical Sciences in 1875. They also played a prominent role in work carried out in Portuguese overseas territories, which made such a great contribution to the development of cartographic techniques and to the spreading of geographical knowledge of remote, hitherto unknown lands.

The Army Geographic Institute (IGeoE) inherited all of this long cartographic tradition, and is still responsible for producing maps, plans and other geographic

information needed by the various branches of the Armed Forces. The various centres and departments which make up the Institute are organised to fulfil this mission.
The Military Geographic Documentation Centre is the IGeoE body responsible for compiling alphanumeric data to complement drawn cartography, searching and acquiring geographic information, exploiting, filing and divulging this information and research in the area of Geographic Information Systems. Thus, within the context of military geographic information, and by using its Geographic Information System, this Centre is participating in a project which by involving several countries is intended to obtain the cartography of the globe in digital format, to a scale of 1/250,000, together with an alphanumeric database. This project, entitled Vector Smart Map - Level 1 (VMap), seeks to provide the nations involved with geographic data, produced in accordance with a set of pre-established norms. It is these norms which will ensure that the information is produced homogeneously, and allow for the data later to be made compatible and usable.

2. THE VECTOR SMART MAP PROJECT

The VMap was conceived with a view to providing the military organisations involved in its production with quickly accessible rigorous digital geographic information on the whole globe, when and as needed.
The purpose of Vector Smart Map Level 1 as stated in the Concept of Operations «is to ensure military defense readiness for worldwide operations with digital geographic information product in a standard format. Specific objectives of this program ... are:

a) Establishment of a worldwide medium resolution (1:250,000 scale equivalent) database, based on the VMap Level 1 Military Specification, to support Geographic Information System (GIS) applications.
b) To use Vector Product Format (VPF) implementation of DIGEST Annex C for the final product.
c) To ensure the final product is available to all coproducing and participating nations' Defense Agencies in accordance with the provisions stated in the General Principles for the Cooperative Production and Exchange of VMap Level 1.
d) To complete worldwide VMap coverage at medium resolution in calendar year (CY) 2000.
e) To share the production burden among the coproducing and participating nations.»

The information which should be contained in the database may largely be taken from JOG (Joint Operation Graphics), i.e., 1:250,000 scale analogue cartography with information on topography, the road network and other information at medium resolution scale.
The VMap uses one or more reference libraries which cover the whole world: eurnasia (Europe and North Asia), soamafr (South America and Africa), sasaus (South Asia and Australia) and noamer (North America). Each CD-ROM of one of these regions must contain a reference library and at least one data library. The data library must include layers arranged by reference and theme.

Given that the VMap may be used for very different purposes, the themes contained in the database should also cover a wide range. For this reason, 10 themes have been chosen: elevation, boundaries, hydrography, industry, physiography, population, transportation, utilities, vegetation and data quality. The thematic information contained at the level of each layer is divided in such a way as to ensure that the large volume of date generally contained in them can be easily handled. The primitive files are stored in a hierarchy of tiles in each directory of layers.

One of the fundamental aspects ensuring compatibility in the exchange of digital geographic information between several countries or between different organisations is the definition of a model for data with a common design and which at the same time ensures that it is possible to operate in different systems. The Vector Product Format (VPF) is intended to do this, and is therefore a standard which defines the structure, format and organisation of large geographic databases. The VMap is a VPF Product, which is why it uses this data model.

3. VMAP PRODUCTION METHODOLOGY IN THE IGEOE

3.1 Data Capture and Database Loading

The gathering of data and its conversion into digital, in this case, vector format is the first step in the VMap production process, indeed as it is for the majority of processes involving the use of Geographic Information Systems.

The information sources that IGeoE uses for this work are, as already mentioned, JOG sheets in analogue format. The digitalisation of the maps presupposes, in this case, that cartographic information is represented by points, lines or areas (vector format) and that they are duly geo-referenced. This is the most time-consuming part of the work and requires a high degree of precision, since it is at this stage that all the information to be used in the various applications of the VMap is gathered.

The following methodology was used to vector the cartographic information: in first place, it was decided to create a graphic file for each theme layer (elevation, hydrography, population ...) for each 1° x 1° or 1° x 1° 15' tile, in the case of an area of the country above 40° latitude[1] (Figure 1). By way of example, we have Mainland Portugal with 20 tiles and the respective 10 theme layers, in other words, a total of 200 graphic files.

The next stage, raster images geo-referenced with each element reproduced from the JOG sheets[2] were made for the various tiles. This way, it proved possible to attribute to each operator responsibility for gathering all of the features contained in a particular

[1] The specifications define the division of the project into tiles: "The VMap Level 1 data base will contain data in variable sized tiles based on the GEOREF reference system... Typically, 1° by 1° tiles will be used; however, the tiling scheme will change by library in the northern and southern latitudinal parts of the world." (MIL-V-89033)

[2] Each JOG sheet is obtained by superimposing the reproduction elements which the various cartographic entities contain separated by colour. Therefore, 5 different raster are used, each corresponding to reproduction elements in blue, green, sepia, purple and black.

tile, which allowed each operator to become familiarised with the specific contents of the tile, as well as making it possible to concentrate on a small range of information each time, since the screen only shows the raster for the colour which contains the data being digitised at a given moment. Thus, when it is vectoring level curves, there is no need for the screen to show the hydrography of that particular tile. However, if, when digitising roads, the operator realises that it is important to see how they are related with hydrography, which is in a different colour, it is always possible to overlay the two images.

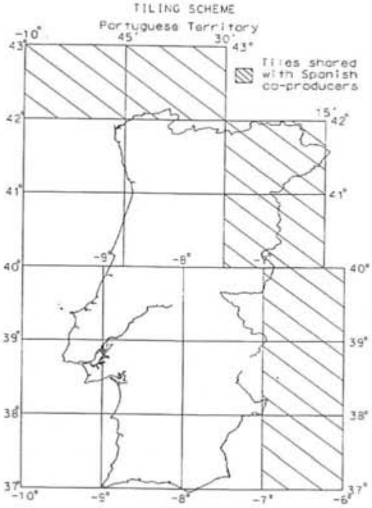

Figure 1
Coordinate System: Geographic - WGS84

The geo-referencing of the raster leads to the first problem in data capture. It has been seen that the various methods which could be used in this situation bring in an error which, although it is only a few fractions of a millimetre, on a 1/250,000 scale represents a few metres in reality. From the point of view of the scale of analysis in question, an error of up to 50 m is negligible (a graphical error of 0.2 mm on the scale of the map is commonly considered acceptable), however, to make it easier to vector the different features, zooms are normally made of the raster. These zooms normally show up less coherent aspects resulting from insufficient precision: areas of vegetation which "invade" other areas with different characteristics, the positioning of dams in relation to reservoirs and contour lines in relation to the hydrographic network, etc. (Figure 2).

Various experiments were carried out in order to find the method which would produce the least error. The results indicated as sufficient a Warp with Affine 1st order transformation, at four control points of equal weighting, scattered throughout the graphical area of the reproduction elements with known UTM WGS84 coordinates.

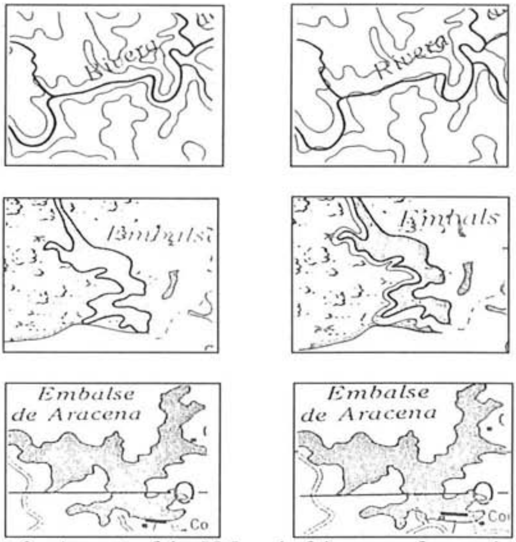

Figure 2 - Aspects of the JQG and of the geo-referenced raster

Before the Warp process, the raster of the reproduction elements, in Run-Length Encoding (RLE), were overlaid using rotation and translation operations. The intention was that the Warp should be applied to all images in similar conditions, since it was proved that this procedure leads to less error than if the process had been carried out using initial positions.

The rotation and translation operations, intended to overlay the raster, brought to light a number of errors, such as the ones in the following example: (Figure 3):

BLUE		BLACK		PURPLE		SEPIA		GREEN	
+ 0m	0m +	+ 52m	0m +	+ 19m	0m +	+ 16m	0m +	+ 38m	0m +
+ 0m	0m +	+ 40m	44m +	+ 53m	57m +	+ 52m	58m +	+ 38m	56m +

Figure 3 - Errors detected after overlaying by rotation and translation of the top right hand corner of the various raster on the blue raster, before transformation of the coordinates

These errors very probably result from deformation of the raster, caused by the movement through the scanner, the incorrect placing of the crosses for the control points and prior transformation of UTM ED50 coordinates into UTM WGS84.

After the geo-referencing of the raster using transformation parameters calculated by the minimum squares method (Warp Affine 1st Order), errors of up to 60 m were detected.

In order to overcome the practical problem of vectoring features with errors of this size, priorities were set for the digitalisation of themes, i.e., vectoring began with the vegetation theme, then went on to transportation, etc., and, on the other hand, whenever feature edges were known to coincide (when, for example, the coastline partially coincides with the edge of an area of vegetation), copies were made of these common lines.

In tandem with the process of vectoring cartographic features, and since we intend that they be linked with a database of attributes, alphanumeric data describing the various cartographic features was collected.

VMap Level 1 includes a wide variety of cartographic features (around 169) which, although it is envisaged that other sources be used to obtain this data, are taken exclusively from the JOG, since IGeoE has a complete set of this series for all Portuguese territory. If, on the one hand, using other types of source might in this case fill some gaps in terms of the accuracy and quantity of descriptive information, on the other, a guide on the extraction of features would have to be drawn up and distributed for each of these situations, existing in parallel with the JOG extraction guide.

Since, even when using JOG as the only source of information, these features appear under different names, in different languages (when the sheets cover international borders) and even different symbols (on sheets published at different times), it is necessary to make such anomalies uniform. For this very purpose the Feature Attribute Coding Catalogue[3] sets out the codes to be attributed to each of these features so that they can be recognised by users, quickly identified in the database and thus standardised.

The question of the standardisation of information has a crucial role in this research, since the end aim is to exchange information between countries and map-making organisations. It is also of the greatest interest to IGeoE. Since this institution is involved in the production of the VMap, in addition to structuring geographic features in line with the norms set out in the project specifications, it needs to adjust its geographic terminology in line with DGWIG. This will ensure that, when information is exchanged and analysed, there will be no doubt as to its meaning. To this end, the listing of features with codes and attributes has been translated and published in a single work - Glossário de Termos Geográficos (Glossary of Geographic Terms) - a considerable volume of information on the majority of features likely to be represented cartographically in the IGeoE series.

As has already been mentioned, there is a document produced by the Defense Mapping Agency (now known as the National Imagery and Mapping Agency), the Extraction Guide for the Capture of VMap 1 Features, which indicates which features should be gathered from JOG, as well as the values these attributes may assume. The IGeoE team involved in coordinating the information gathering process has simplified this exhaustive extraction guide and has produced a card for each tile. The card includes all of the information on the tile which is to be vectored, the codes and values which these attributes may assume with their respective JOG symbols. The operator will use this

[3] In addition to establishing the rules for the structure and format of data, the Digital Geographic Information Working Group (DGIWG) has drawn up a list of codes for various geographic features, as well as their definition and translation into the languages of several participating countries - the Feature Attribute Coding Catalogue FACC).

card to know which feature(s) he should gather, which attributes to give to them by looking at the symbol represented and in which thematic area they should be included.
Finally, once the cartographic features have been vectored and the tables of attributes filled in, all of the information constituting VMap Level 1 must be loaded into the database. IGeoE opted to vector and fill the alphanumeric data tables using purpose-designed software. The information would be loaded into the database at a later stage. This made it possible to rationalise costs (relatively lower price for the software for vectoring and it does not require powerful graphic stations) and time (this way operators gather information in a simpler, therefore quicker, way).

3.2 Digital Product Finishing

The second stage in the process of producing the VMap follows a methodology set out in a series of software steps specifically designed to achieve the final product in VPF.
It begins with checking the data loaded into the database. Errors are often detected at this point, both in terms of graphic data (duplicated lines and points, unclosed areas, etc.) and attributes (untagged features, missing attributes, features loaded on wrong thematic layer, etc.).
The transformation of data, which is represented with UTM coordinates, to the geographic coordinates system in order to ensure it is in accordance with VMap specifications can now be carried out, since no more operations involving measurements will be done at this stage.
The next step is to put the features into object-space, using a data dictionary which contains a description of the structure of the data and a set of parameters which makes this transfer possible. The thematic layers with the data in object space are then integrated vertically, and the topology of the features as a whole is defined. This process does not include the elevation layer, since it is a file with a large amount of topological information, which, were it included, would result in a final file so large that it would be difficult to handle.
At this point, it is necessary to undertake geometric and topological validation, since normally a number of errors appear which will have to be eliminated in the graphic file prior to the creation of the object-space and the repetition of the vertical integration process.
The aim is also that the new object-space file, with the quality of the data already assured, should contain only VMap Level 1 features. For this, a data dictionary with the required scheme already defined is used.
Once vertical integration combining the various themes of a tile on a topologically organised file has been carried out, it is possible to perform operations involving all of the information. It is now no longer necessary to repeat these operations for all 10 themes.
Horizontal integration is one of the operations which benefits from the fact that the themes are all in a single file and takes place when, for instance, a tile is shared by two raster. Each tile always has 8 other tiles adjacent to it containing the continuation of the features represented on it. Edge match ensures this (graphic and topological)

continuity, which might otherwise have been broken due to the fact that work has been done on separate tiles or parts of tiles. Any errors detected must be corrected, of course.

The themes which formerly had been part of a single file to facilitate certain operations must now be separated and put into the data library. At this point, it is possible to transform the data into VPF format and then proceed to validate it.

One of the most important characteristics of the VPF data model is the possibility of having metadata (data describing data), since it informs the user on how to access and explore the data, as well as the sources and quality of the data. Practically at the end of this production process, the tables containing metadata information are filled in.

From this point onwards, the CD-ROM with data in VPF format may be distributed and used by all coproducers.

4. CONCLUSIONS

Since its involvement in the production of VMap 1, IGeoE has developed its own methodology, based on a Concept of Operations defined by NIMA and supported by a range of material and human resources at its disposal to achieve the required digital product.

Of the various steps in the process leading to the production of the VMap, it was seen that information gathering is the longest phase, but also the phase which allows for most freedom in terms of methodology. It is also at this stage that problems of accuracy and optimisation appear, such as those we have already pointed out.

IGeoE participation in this project led to a deeper awareness of the need to normalise geographic information and helped us develop data vectoring techniques using raster. Above all, we were part of a multinational team, which is always an enriching experience, and this will provide Portugal with digital geographic information at medium resolution scale covering the entire globe.

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VISUALIZING SPATIAL RELATIONSHIPS AMONG HEALTH, ENVIRONMENTAL, AND DEMOGRAPHIC STATISTICS: INTERFACE DESIGN ISSUES

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Mapping of georeferenced health statistics has, in the past, led to insights concerning various health-environment-behavior interactions. Insights have derived from the identification of clusters of deaths on static maps (Mason et al., 1975; Pickle et al., 1987; Pickle et al., 1990) followed by comparison of the cluster locations to the mapped distribution of potential etiologic agents (Croner et al., 1992). Spatial associations identified have prompted hypotheses about the causal relations, some of which have been verified. Examples include identification of "hot spots" of esophagal cancer in China and oral cancer in the U.S. state of North Carolina (Winn et al., 1981). Static paper maps, while somewhat successful in prompting epidemiological hypotheses, impose constraints on exploration of spatial characteristics of health-environment-behavior interactions.

Dynamic visualization methods offer the potential to dramatically extend the role of maps in health analysis. This paper reports on the design and implementation of a prototype dynamic interface to georeferenced health, environmental, and demographic data, with the prototype sponsored by and developed for the U.S. National Center for health Statistics, Centers for Disease Control and Prevention (NCHS). Two specific objectives have been delineated for the initial prototype: (1) to design alternative methods for displaying dynamic maps of death rate and risk factor data in a user-friendly computer system, and (2) to test these designs in an experiment where users attempt to draw inferences about changing death rate patterns and their relationship to risk factor patterns.

Background

While the primary objectives of the research are directed to particular issues of health data analysis, the representation and interface problems are more general ones associated with a range of quantitative spatio-temporal data. In designing a system to allow analysts to interact with data of the sort identified, we draw particularly upon two areas of research: (1) map animation (and its use for representing quantities aggregated to contiguous geographic units), and (2) representation methods for multivariate display. Each is represented by a growing body of research within cartography/geography and complementary research efforts in a range of disciplines from which Geographic Visualization (GVis) developers have borrowed ideas and approaches. A brief overview of key developments in each area is provided below.

Map Animation

Although animated cartography has been the focus of sporadic attention within the field since the late 1950s (Campbell, 1990), it is microcomputer-based animation of the past decade that has stimulated a focused effort to address the fundamental questions raised by a shift from static to dynamic maps. The research literature has expanded quickly and here we emphasize that research directed to animated mapping of enumerated data (a term used here to include derived quantities, such as death rates, calculcated for counties or other contiguous units). This research can be grouped into time series and non-time series animation.

Depicting a time series is, perhaps, the most obvious use of map animation. Animations of the disease AIDS by Gould and his colleagues (1990) are prototypical of time series animation applied to enumerated data. These animations have captured attention within and beyond cartography — with coverage in *Time, Playboy,* and other non-academic publications. In addition to demonstrating the power of animation as a rhetorical tool, these animations raise a variety of conceptual issues related to symbolization, data classification, and color schemes (MacEachren and DiBiase, 1991). In relation to symbolization, MacEachren and DiBiase advocate a hybrid method (chorodot maps) as more appropriate than either choropleth or isopleth maps. More generally, Dorling (1992) has argued against choropleth maps (either static or animated time series) for demographic statistics of any kind. Instead, he advocates population cartograms as a base to which choropleth-style depiction of other variables can be added. Whatever the symbolization form used, time series animations of classified enumerated data are often choppy and discontinuous. This problem is exacerbated if classification is applied independently to each time step (Monmonier, 1994).

With non-temporal animation of enumerated data, display order is matched to a non-temporal ordered attribute. Three sub-categories are apparent. The first uses order to signify level of attribute generalization, with the map sequentially built up from one class through several classes (Peterson, 1995). A second sub-category matches scene order to order of categories on a map having a fixed number of classes, thus highlighting spatial locations having similar attribute values (Slocum et al., 1990; Monmonier, 1992). The third sub-category involves reordering maps from a time series according to some attribute of each time period, what DiBiase, et al., (1992) term "reexpression." One example that they describe involves reordering of a presidential election time series based on the magnitude of landslide voting percentages.

For any animation of enumerated data, an additional consideration is the use of exploratory data analysis (EDA) methods of linked views (two or more views that change together) and focusing (highlighting subsets of data). Monmonier (1992), for example, has generated both attribute and time series choropleth animations linked to corresponding histograms and has implemented temporal brushes that aggregate data across time periods. Both linking and brushing are most useful in a dynamic multivariate environment and are, therefore, discussed in more detail below.

Multivariate Representation

Like animation, multivariate representation has a long history in cartography prior to the advent of dynamic computer systems (or computers in general). DiBiase et al. (1994) provide a comprehensive review of multivariate representation methods emphasizing those for three or more variables. Here, as above, we restrict attention to representation of quantitative data aggregated to enumeration units.

Several authors have addressed color schemes for multivariate maps. Trumbo (1981) proposes (but does not test) color guidelines designed to highlight positive associations or to make variables separable. Building from empirical evaluation of U.S. Census bivariate color schemes by Olson (1981), Brewer (1994) has developed a more comprehensive color syntactics (system of color logic) for multivariate maps in which she distinguishes among several kinds of bivariate situations. Focusing specifically on correlation between variables, Eyton (1984) proposes a unique solution to bivariate data classification and a matching color scheme. The scheme uses a white-grey-black continuum to depict values along the regression line (that describes the relationship between variables) and complementary colors (red and cyan) to signify outliers. This approach appears to be very effective in displaying positive bivariate relationships. The most widely studied alternative to color for depicting bivariate enumerated data is texture (in the form of cross-line shading). Carstensen has demonstrated that crossed-line shading can be as effective as color (Carstensen, 1984) and that this representation method facilitates hypothesis generation about the relationships between variables mapped (Carstensen, 1986).

An important cognitive-perceptual issue that should be considered when choosing symbols for a multivariate map (whether color, texture, or other visual variables are used) involves a distinction between visually integral and visually separable visual dimensions (Shortridge, 1982). Integral variables (sign-vehicle components) are seen as wholes rather than as independent components — making selective attention to their individual components difficult. Separable variables, on the other hand, are seen individually — making divided attention (a focus on the conjunction of sign-vehicles as a whole) difficult. MacEachren and Brewer (1995) compared a coincident visually separable display (a bivariate map in which color attributes represented one variable and a texture overlay represented reliability of those data) with a coincident visually integral display (a similar map in which both data and reliability were depicted by attributes of color). The visually separable display proved effective in allowing the map users to recognize unreliable data without impeding their ability to notice clusters and characterize patterns in the data. A coincident visually integral depiction made it difficult for users to consider data and reliability independently.

Many dynamic graphical approaches to exploring multivariate data have their roots in EDA concepts of linking and focusing (Becker et al., 1988; Buja et al., 1991). Linking can occur in time (when views that are adjacent in display time share some attribute that provides the conceptual "link"). Linking is also used to relate simultaneously visible views (the first application being with a matrix of scatterplots). With simultaneous views, linking is usually combined with the EDA focusing technique of "brushing," where interactively selecting data in one view results in automatic selection of the corresponding data locations in all other views (Becker and Cleveland, 1987; Carr et al., 1987). Linking has been adapted to cartography in the form of scatterplot-to-map links (Monmonier, 1989), links among maps, scatterplots, and temporal legends (Monmonier, 1990) and links between standard maps and cartograms (Dykes, in press).

In addition to linked brushing, the EDA concept of focusing extends to single-view manipulations of data segment highlighting, such as dynamic data classification (Ferreia and Wiggins, 1990). A related kind of focusing is implemented in Calico, a system for dynamically adjusting the balance between two variables displayed on a bivariate map (Rheingans and Tebbs, 1990).

Prototype Development

The research highlighted above is directed primarily to representational and cognitive issues of implementing mapping/GVis systems. Designing and building a system also requires attention to issues prior to implementation. System and interface design should be approached at multiple levels in an effort to prevent particular hardware and software characteristics from dictating system goals or what a system is actually designed to do. A typical multi-level strategy is to direct separate attention to what the system is for, what it needs to be able to do, and how it works. Howard and MacEachren (1996) review literature relevant to these issues and propose a hierarchical approach to GVis system and interface design. Their approach has been used to guide our prototype design process. The stages of this approach are defined specifically as *conceptual* (the level at which what and who the system is for are considered), *operational* (the level at which conceptual goals are sub-divided into a set of discrete operations applicable to the data), and *implementational* (the level at which methods for achieving the operational goals are addressed — within particular, hardware, software, and problem context constraints).

As noted above, the research contract that prompted this project defined quite narrow objectives related to design and testing of an environment for display of time series mortality data and associated risk factors. The broader objective of research on mapping sponsored by the NCHS, however, is to facilitate incorporation of geographically referenced representations at various stages of health research. Thus, we approach the task of identifying conceptual level goals and associated operational level "operations" with these broader objectives in mind. This results in a prototype capable not only of meeting the specified goals but also of evolving to address anticipated demands of future analysts more aware of dynamic mapping's potential for facilitating visual thinking.

Conceptual level

At the conceptual level, several categories of goals can be defined for GVis. These range from domain-independent use goals, through domain-specific reasons for a system, to narrow task objectives within a particular application context. In relation to GVis use, MacEachren and Kraak (in press), building on earlier work in statistics by Tukey (1980) and in geography by DiBiase (1990), propose four goals: exploration, analysis, synthesis, and presentation. The project reported here emphasizes exploratory visualization. Within the project's application domain of health statistics analysis, the most general goal is one that underlies all uses of mapping and GIS for health data analysis — to understand the spatially varying factors that lead to mortality and disease and the variation in those factors for different at-risk groups in the population. Together this domain goal plus the emphasis on exploratory stages of research leads to a practical goal for the environment being designed — to develop dynamic GVis methods and tools that enhance the ability of health/statistics specialists to recognize (and draw inferences about) mortality rate patterns, risk factor patterns, relations between risk factors and mortality, and change in both mortality and risk factors (and their relations) over time.

Within these general goals, a set of application-specific sub-goals can be identified that relate to specific aspects of exploratory analysis. At this stage, these conceptual-level sub-goals can be characterized as ones that (a) emphasize spatial pattern analysis (for points in time), (b) facilitate an understanding of spatio-temporal processes, (c) support analysis at multiple spatial, attribute, and temporal scales and (d) address the implications of data characteristics and data processing methods for apparent spatial and spatio-temporal patterns. This "typology" of conceptual goals is a tentative one that we expect to modify and expand as the project develops.

In relation to spatial pattern analysis, the key goals identified thus far are: (1) identify "hot spots" (clusters in geographic space) of mortality and sort real from false hot spots; (2) facilitate the search for relationships between mortality clusters and potential risk factors. For spatio-temporal analysis, goals identified include: (1) explore spatial diffusion of mortality (due to various causes, and for various at-risk groups); (2) facilitate the search for change in geographic co-variation (between mortality and risk factors) over time. Conceptual goals dealing with "scale" relate to aggregation and disaggregation of attribute, geographic, and temporal aspects of information, and include: (1) facilitate exploration of data as a whole as well as data parsed into constituent groups (by gender, age, race, etc.); (2) facilitate multiresolution analysis (spatially and temporally). In an effort to minimize visualization errors (seeing false patterns and missing real patterns), we have identified a set of conceptual goals addressing the data characteristics and the methods for representing these data, as well as the background of the users for whom the system is being designed. These include: (1) build upon specialized expertise of potential users (e.g., in statistical analysis) to introduce methods for exploratory geo-visualization with which they may be unfamiliar; (2) facilitate an understanding of data reliability.

Operational level

As noted above, achieving a specific conceptual level goal generally requires subdividing the goal into a series of sub-goals, each of which can be met by applying a particular operation to particular information. The task at the operational level of system/interface analysis is to identify these operations. While it is never possible to completely disentangle operations as concepts from their possible implementation given available tools, the intent at this stage is to determine what procedures should be available for application to information, not how to implement them. Following from the categories of conceptual goals delineated above, operations can be grouped into those related to:

1. spatial pattern analysis and comparison (dynamic data classification, manipulation of the "mapping" between data categories and their visual representation, overlay, correlation, linked brushing of attribute and geographic displays, zooming)
2. spatio-temporal analysis (time series generation, sequential display of time steps, animation, temporal brushing, change and rate-of-change representation).
3. aggregation, disaggregation (hierarchical aggregation of geographic units, temporal aggregation, attribute disaggregation into constituent groups, spatio-temporal smoothing),
4. metadata and methods representation (representing data reliability, representing the implications of other operators — such as those for dynamic classification)

As above, this "typology" of operations is a tentative one that is intended simply to facilitate discussion of the operations that have been identified for initial implementation. As the process of building/refining the prototype discussed here evolves, we are concurrently working toward delineation of a more comprehensive typology of spatio-temporal operations.

Implementational level[1]

At the implementational level of prototype development, our first step was to examine existing software environments to determine whether any one environment was

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[1] Page limits preclude figures to illustrate the prototype. Interested readers can, however, find figures illustrating various interface components, along with updates about the project on the WWW at: http://www.gis.psu.edu/MacEachren/MacEachrenHTML/NCHS.html. This site includes static samples of ArcView interface components and dynamic depictions of the Director component (viewing the latter requires the shockwave plugin and compatible browser).

suitable for prototype design and testing (and perhaps for future system development beyond the prototype). The full range of conceptual and operational goals identified above played a role in selecting a development environment. The most important criteria, however, were the initial client (NCHS) objectives of (a) designing alternative methods for displaying dynamic interactive maps of death rate and risk factor data and (b) testing these designs in an experiment where users attempt to draw inferences about changing death rate patterns and their relationship to risk factor patterns. Thus the goals of the prototype were less comprehensive and somewhat different than for the full system the prototype and its testing are expected to produce. The need was for an environment that facilitated rapid prototyping and experimental testing of the representation and interface options developed, not necessarily an environment that was ideal for full system implementation.

Characteristics of the NCHS data were also a factor in selecting our rapid prototyping environment. Data available for the project consist primarily of mortality rates and related demographic statistics aggregated to the 798 Health Service Areas (HSAs) for the conterminous U.S. The mortality rates are available for five time steps. The geographic component of the data (HSA boundaries) was provided in a standard desktop GIS format (ArcView shapefiles).

A review of several potential development environments found none that would allow us to implement easily all of the operations identified thus far and allow us to alter quickly the form in which operations were implemented. As a result, we opted for a development environment that combines ArcView (with its Avenue scripting language) and Macromedia Director (with its Lingo scripting language). Operations associated with pattern analysis and pattern comparison (of multiple variables at one time) are being implemented in ArcView. Operations associated with spatio-temporal analysis are being implemented in Director. At this stage, we have not yet implemented operations dealing with either aggregation/disaggregation or the representation of metadata and methods.

We are implementing several exploratory spatial data analysis operation within ArcView. Since relationships between mortality rates and potential risk factors (both reported as aggregate rates, or other derived measures, per HSA) are of primary importance, linked geographic brushing has been implemented. For each time step, users can highlight any points of a scatter plot to determine their location in geographic space or highlight any HSAs on a map to determine their location in bivariate (or multivariate) attribute space. As a complement to these linked views, users can select among various bivariate map depictions of the two variables displayed on any scatter plot. These depictions include representation forms designed to yield visually integral representation and others designed to yield visually separable representation (MacEachren et al., 1995). In addition, the scatterplot can be used as a dynamic legend for the maps, allowing users to interactively manipulate data category breaks. We plan to also implement a dynamic version of Eyton's (1984) equiprobability ellipse legend to facilitate the exploration of patterns of data anomalies.

Aspects of the interface that require animation are being prototyped in Director. Map sets that include mortality rates at each of five time periods along with various potential risk factors are being generated in ArcView and exported as PICT files for import as Director Cast members. In Director, an interface template has been designed that includes a map window with a temporal legend/control widget (see (Kraak et al., 1997) for discussion of temporal legends). Controls being assessed include simple start-stop buttons that control whether a time series animation is running or not, an animation pace control, a frame-by-frame advance and reverse control, push buttons that access particular time slices directly, and a temporal brush that allows users to scroll through time slices. In addition to the map window and temporal controls, additional controls are included in the basic display template for selecting the mortality cause to be displayed and the suspected risk factor to compare with it. There is also a control area through which users can manipulate whether or not the risk factor is visible and (if visible) manipulate risk factor thresholds dynamically. This focusing tool allows a user to specify that only HSAs with a value in the top X% for that risk factor (by 10% increments) will have the risk factor depicted. Various control styles implementing this tool are being compared.

Summary

The research described here is continuing. Using the three-level approach to system design outlined above, we have established system/interface goals, identified operations on data that facilitate addressing those goals, and are in the process of implementing those operations in a prototype. Once implemented, we plan to use the prototype to experimentally investigate several issues related to representation of multivariate spatio-temporal information. In particular, we will address issues related to dynamic classification, linked brushing, direct manipulation of color schemes for bivariate maps, smoothness of animation, user control of animation direction and pacing, and the depiction of relationships between two georeferenced variables as they both change over time.

Acknowledgment & author order

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CAN ETHNIC MAPS BE OBJECTIVE? POSSIBILITIES AND LIMITATIONS OF ETHNIC CARTOGRAPHY

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1 Introduction

Due to a revival of ethnic consciousness that sometimes culminates in nationalism in large parts of Europe, ethnic and linguistic maps are regaining importance. They are now being more frequently published in school, popular and scientific atlasses. New nation states in Eastern Europe are investing great efforts into documenting and informing about their ethnic and linguistic structure by cartographic means. Some of these activities may be regarded as being attempts to underline and justify political measures and claims. But even publications of a purely scientific nature are - because of their new political relevance - intensively discussed and frequently called into question by representatives of other ethnic groups or from other countries.

Apart from the validity of ethnic and linguistic data (which is another wide field), questions regarding the validity and correctness of ethno-cartographic representation are again on the agenda;- What criteria must the cartographic representation of ethnic and linguistic topics comply to in order to be called scientifically correct? What are the strengths and shortcomings of individual ethnic mapping methods? What criteria determine the choice of ethnic mapping methods, with respect to a given ethnic structure? Do certain methods necessarily favour ethnic majorities or minorities? Which methods are most suitable for portraying urban minorities? Which methods are more adequate for representing spatially concentrated, which the diaspora of ethnic groups? What has to be taken into account when statistical reference areas are selected? And, finally, can ethnic maps be objective?

2 Advantages and disadvantages of the basic ethnocartographic methods

The basic methods of ethnic and also linguistic mapping are the areal, the dot and the diagram methods. They admit a variety of combinations and modifications as well. The areal method represents ethnic groups by areal symbols (colours, screens) that refer to plots that coincide with statistical and (often) administrative units or are topographically defined. The dot method poses dots of equal or different size, colour and value according to statistical and (as a rule) administrative reference units. The diagram method links circles or other shapes of diagrams, which are subdivided by colours or screens according to the ratio of ethnic groups in the overall population figure, to statistical and (as a rule) administrative units.

2.1 Can they render the actual distribution of ethnic groups in absolute numbers ?

The absolute numbers of ethnic groups can only be communicated to the reader by means of the dot and diagram methods and not by the areal method.
The areal method actually conveys only an impression of the territory, over which an ethnic group is spread or in which it forms the majority. It merely informs the reader about the conditions one has to reckon with when moving to a certain region, i.e. about land reclamation by ethnic groups. Densely populated urban regions are thematically treated in the same way as high mountain regions or swamps and marshes. It favours ethnic groups which form a majority in rural or thinly populated areas.
In order to give at least a rough indication of the real population distribution, one could exclude thinly or unpopulated areas from thematic representation, introduce diagrams for larger cities and urban agglomerations and introduce different colour intensities for different grades of population density.
The diagram method is certainly the precisest in respect to information on absolute figures. Within the limits of treshholds and the possibilities of visual estimation and measuring the size and value of circle sectors, divisions of squares or columns, the numerical strength of ethnic groups can be precisely conveyed.
The greatest advantage of the dot method is to offer easily countable symbols of equal size or only a few grades of sizes. The gradation of symbols slightly hinders the precise representation of numerical information. A continuous symbol scale without gradation would eliminate this disadvantage, but would at the same time compromise the method´s greatest comparative advantage, i.e. countability at one glance.

For these reasons the dot and especially diagram methods favour ethnic groups with majorities in densely populated, urbanized and urban regions.

2.2 Can they render the actual numerical proportions of ethnic groups ?

The comparative merits of the three methods are self-evident. The diagram method is the best, since it represents the overall population number of a certain areal unit by the outlines of the diagram and shows the proportion of ethnic groups as well as their absolute numbers by sectors or divisions. Thus it is the only method that provides the reader with information about the absolute numbers as well as the proportion of ethnic groups within a certain reference unit at a glance.

The dot method ranks second, since it does not offer an instant information on proportions, but leaves it to the reader to find out the proportion between the ethnic groups in a certain region by counting the relevant dots. Again, the precise numerical issue is veiled by the gradation of symbols.

The areal method cannot communicate absolute population figures, and is also incapable of rendering the proportion between ethnic majority groups. This method nevertheless offers the opportunity of representing the proportion between a majority and one or several minority groups. The most common method is to indicate the proportion of ethnic groups within a multiethnic reference unit by means of bars, the size of which corresponds to the relative numbers of the ethnic minority. But this indication is valid only in relation to the individual reference unit. No conclusions can be drawn about the absolute numbers of minorities, neither within the reference unit, nor across the whole area of the map. Thus, in absolute numbers much larger minorities in large cities look small in relation to small rural minorities in absolute terms. Furthermore the reader remains uninformed about the statistical reference unit and its areal extension, to which this method is applied. Because of this and the limits of visual perception, even the numerical proportion between ethnic groups within a reference unit can only be roughly estimated.

Another way to show the numerical proportion between ethnic groups in a multiethnic region (in combination with the areal method), is to represent minorities by graded dot symbols, e.g. circles. They convey a clear impression of the relative importance of minorities within a specific statistical reference unit - and this is an essential political, social and cultural issue. But it distorts the real numerical distribution of an ethnic group over a region composed of a multitude of such units. Only if all reference units were equal in population numbers, no distortion would occur. The distortion is especially strong if, for instance, statistical reference units on either side of a country border have very different population numbers.

Other ways of showing minorities combined with the areal representation of majorities, such as dot symbols of equal size, are not much more than qualitative indicators for the existence of a minority, suitable only for small-scale and popular maps.

2.3 Can they render land reclamation by ethnic groups ?

While the symbols used by the dot and diagram methods refer to geometric points and leave it to the reader to interprete the areas in between (to attribute them to the one or other ethnic group or to regard them as thinly or unpopulated), the areal method interprets this itself by creating "ethnic territories". This interpretation may be based on facts (administrative subdivision, land ownership, etc.), but it opens a wide field for subjective procedures. It also supports the traditional view that an ethnic group "owns" a distinct territory, where it should have privileges or exclusive rights. In reality, due to migration and the dissolution of closed rural societies we meet an increasing number of spatial ethnic networks interfering with each other.

2.4 Can they reflect small and dispersed minorities ?

Small ethnic groups or in total larger ethnic groups dispersed over a wider region pose a difficult problem to all methods. But the dot method, using dots of equal or graded size, offers a practicable solution for minorities in thinly populated rural regions as well as in urban centres. As soon as a minority surpasses a minimum absolute number, it will at least be represented by the smallest dot size, irrespective of the overall population density.

The areal method allows every small ethnic group in thinly populated rural regions to be portrayed, but suppresses even larger minorities in urban regions, as long as one sticks to its principles. Frequently, however, the principles of this method are not observed so strictly, to allow at least some hints at urban minorities.

The diagram method requires a minority to form a minimum portion of the overall population to be represented, irrespective of whether a thinly or a densely populated region is concerned. This portion cannot be much smaller than 3%, if the colour to be filled into the circle sector or into the bar of a rectangular shape is to remain visible. Thus, the diagram method is the least capable of portraying small minorities. The definition of treshholds offers some opportunities for manipulation. They may be defined unnecessarily high to hide minorities and make major ethnic groups looking more substantial (by adding the sector or bar for the minority to the sector or bar of a major group). Strongly manipulative is a procedure, which adds several smaller minority groups, not surpassing the treshhold indivually, to one or several major groups, although the cumulated share of these smaller groups is higher than the treshhold.

2.5 Can they render the actual spatial distribution of ethnic groups ?

Both areal and dot method are predestined to portray the spatial distribution of ethnic groups in an almost topographic way. They use statistical data that refer to statistical units just as the diagram method does. But by adapting thematic contours (areal method) or dots (dot method) to the features of the topography or to the real distribution of members of an ethnic group known from other than statistical sources, the areal and dot methods are capable of representing almost a "topography of ethnic structures".

This is not feasible by the diagram method, in which the diagram symbolizing the overall population of a reference unit is either bound to the geometrical centre of this unit or to its population focus.

2.6 Can they illustrate a wider variety of ethnic groups ?

Confronted with the requirement of rendering a wider variety of ethnic groups, the dot method mostly proves inadequate. At least the smallest size of dots will not allow the reader to distinguish between much more than 5 colours. The variation in colours may be combined with a variation in shapes to enlarge the possibilities of portraying a variety of ethnic groups. But human vision is not particularly sensitive to variation in shapes. They are much more difficult than colours to distinguish at a glance. Thus, the dot method is practically confined to the representation of smaller regions in larger scales with a rather limited number of different ethnic groups.

By introducing variations in colour and in screens, both the diagram and the areal methods can portray well up to 100 ethnic groups, especially when simple and distinct symbols are applied to the smallest ethnic groups and a redundant numbering ensures clear distinction of the symbols. The areal method has even capacities to widen the range by adding point symbols (varied in shapes, colours and screens) for minorities.

2.7 Scales, spatial resolution and generalisation

The dot method has no problems in showing the highest spatial resolution in very large scales, while for reasons of qualitative distinction it soon reaches its limits when a larger region with a wider variety of ethnic groups is to be represented.

The diagram method may be applied to large scales with a high spatial resolution as well as to the smallest scales depending just on data availability and map purpose.
The areal method always suggests a high spatial resolution, which may in many cases not be justified by the data on which it is based. While in smaller scales the reader takes generalisation for granted, in larger scales a critical divergence between visual impression (which always suggests preciseness) and actual data may arise. The limits between ethnic groups are not always as distinct as the line dividing two colours suggests. The method is therefore frequently used to "round up" ethnic territories on the basis of absolute or even just relative majorities, irrespective of how numerous ethnic minorities might be. In this way it was easy even before the Bosnian war to evoke the impression of a Bosnia properly dividable into homogeneous "ethnic territories", although at the time almost every single commune of Bosnia was actually composed of several ethnic groups.

2.8 Can the ensure legibility and visual effect, for which groups of users are they suitable ?

The areal method is visually by far the most effective in presenting the main issues at the first glance. It is therefore no surprise that it is prefered for popular and political purposes and has always been the main method of ethnic cartography.
Dot and diagram method reveal their issues only after some investigation and depend on a scientific or a least very interested audience to get evaluated properly. Since they do refer ethnicity to the relevant reference criterion, i.e. population number, and not to area, as the areal method does, they are strictly speaking the only scientific methods from the cartographic point of view.

3 Use of colours

The use of colours in ethnic (as well linguistic) maps opens a wide field for manipulation. But there are only a few methods, which may be called definite offenses against cartographic objectiveness. One is the habit of attributing the brighter colour to one´s own ethnic group, provided it is not a small minority (then it should be symbolized by a bright colour). A second is to "incorporate" other ethnic groups, which declare themselves differently, by using the same colour, perhaps using just a screen or the name of the people for distinction.
Less obvious offenses are the "downgrading" of minorities by attributing to them less intensive colours than to the majority group; the attribution of "dark" and "dirty" colours to rivalling groups.

4 Conclusion

So, can ethnic maps be objective? They can, if the methods of ethnic mapping are not applied in a manipulative way. But that is frequently done. Already the choice of a certain method may be governed by manipulative attitudes (e.g., when the areal method is taken to favourably portray an ethnic group with majorities in thinly populated regions). Dot and diagram methods are always strictly bound to statistical data and statistical reference units. They offer opportunities to manipulate only with the definition of treshholds and grades (the last only with the dot method), and when this is done, the reader can easily discover this. Also the areal method might be applied with strict statistical reference (by portraying the limits of reference units) and thus be superviseable. Mostly, however, and especially in smaller scales the method is applied without any reference to statistical units and therefore open to a wide range of hardly discernable manipulation. Apart from this, this method cannot reflect the actual numerical distribution of ethnic groups and is scientifically valid only as a means of expressing land reclamation by ethnic groups.

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Comparative Advantages of Ethnocartographic Methods

Advantage of the method in respect to	Methods		
	Areal	Dot	Diagram
distribution of ethnic groups by absolute numbers	3	2	1
land reclamation by ethnic groups	1	2	3
numerical proportion of ethnic groups	3	2	1
small and dispersed minorities	2	1	3
spatial distribution of ethnic groups	1	1	3
a wider variety of ethnic groups	1	3	2
large scales, high spatial resolution	3	1	2
small scales, high generalisation	1	3	2
visual effect	1	2	3

1 = best, 2 = second, 3 = third

UNDERSTANDING OF CHILDREN'S ABILITY TO WAYFIND AROUND AN UNFAMILIAR ENVIRONMENT USING A LARGE SCALE MAP

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Introduction

The study of children's performance in reading and using maps is of interest to cartographical educators for three distinctive reasons. Firstly, map work is a basic part of the geography curriculum in almost all primary and secondary schools (Department of Education, Queensland, 1994; IGU, 1992; Riding & Boardman, 1983). Secondly, maps are often encountered in everyday life and hence is an essential life skill for children to master (Gerber, 1993; Kwan, 1996). Thirdly, using a map and its performance are related to children's spatial visual ability (Witkin *et al*, 1977) to disembedding a geometrical shape from within a more complex pattern (Riding & Boardman, 1983).

Children have been found to be able to use maps to find their way around familiar environments such as their home and school area (Gerber & Kwan, 1994 & 1995) before they begin to receive formal map education in school (Blades & Spencer, 1988; Kwan, 1996). Such an ability is related to the intuitive experience of the children in a familiar environment which is addressed as environmental cognition. The reliance upon the use of maps by children is particularly made obvious if they were asked to be involved in the actual route walking in a real environment. They are seen to be able to make sense and meaning out of the abstract information embedded in the map more readily than from working on maps in an indoor hypothetical manner. It is hence of great interest to see how children may find map information useful to them when wayfinding in an unfamiliar environment. This also demonstrates the educational objective of using maps as a life skill to enhance spatial communication and exploration.

With increasing research into how children work with maps, there are increasing outcomes to contradict the conventional Piagetian school of thought that children cannot learn and handle map skills until much later in life. Sowden *et al.*,(1996) showed that children as young as four-years-old have significant untaught mapping abilities. Kwan (1996) worked with three children at the age of 10 and 11 years also revealed their ability to understand and use maps, based very much on their intuitive experience of their familiar environment, before they began their formal map lessons in secondary school. Both results suggested that children upon entering school may already be able to benefit from much a richer geographical learning experience than are at present provided.

Yet most of the earlier studies (Kwan, 1996; Sowden *et al*, 1996; Spencer, Blades & Morsely, 1989) and many others were conducted in an in-house, hypothetical or experimental manner. Very few research and studies have been conducted to the actual use of maps in the environment. Children were found to depend heavily on their individual's memory for the familiar environment that they were asked to wayfind (Blades & Spencer, 1988; Gerber & Kwan, 1994 & 1995). On the contrary, if asked to wayfind in an unfamiliar environment, children have to rely heavily on external aids such as maps, landmarks, signage, verbal and/or written instructions to help them explore such an unfamiliar environment. However, there has been little research actually conducted into children's ability to find their way through unfamiliar areas. This study takes a step further to find out how children use their intuitive mapping ability to wayfind themselves in an unfamiliar environment. The outcome will further strengthen the claim that children do have significant untaught mapping abilities before entering school.

Blades & Spencer (1988) described "wayfinding" as the ability to navigate successfully through different environments - both familiar and unfamiliar. In discussing various research studies conducted on wayfinding, Gommel (1995) revealed that orientation is the first step in successful wayfinding which was first suggested by Downs and Stea in 1977. Other sequential and interrelated steps in wayfinding are choice of the route, keeping on the right track and discovery of the objective. Arthur & Passini (1992) noted that to understand wayfinding is to understand how people use the information that the (unfamiliar) environment provides. Through the way people see and feel about the environment, and register the signage information of a place, the concept of a sense of place can be grasped and hence eventually they can find their way around. Gommel (1995) suggested six elements of an effective wayfinding system which include: spaces that are visually distinctive, points of references, a building layout that is easy to remember and recognised, memorable and distinctive landmarks, the provision of information in maps and well trained staff to provide instructions if needed. However, once people cannot 'find their way', they feel uncertain and stressed and can cause disorientation which will result in a total loss of direction (Gommel, 1995:387).

Gauvain (1991) on the other hand discussed the role of activity theory in the study of the development of spatial cognition. Activity theory states that human behaviour and thinking occur within meaningful contexts as people conduct purposeful goal directed activity. Knowledge about large-scale space is embedded within a rich context of meaning. Such contextual frame encourages understanding and the use of spatial knowledge in naturalistic contexts and problem solving activities. The results of a study by Riding & Boardman (1983) also suggested that map reading performance depends on the children's learning style. The verbal-imagery dimension of learning style exerts influence upon map task performance of children. Each person (child) has a preferred mode of representation which is habitually and involuntarily used when using and analysing information that is seen or heard (Riding & Dyer, 1980).

This paper aims to report a small scale study of 10 children in Queensland how they wayfound themselves in an unfamiliar environment using both map and textual instructional information. The outcomes of the children's strategies and behaviours observed in their process of wayfinding were reported and discussed. The lived experience of exploring in a realistic environment helps to illuminate the qualitative characteristics of the children.

Subjects

The subjects were a group of 10 Australian children (six boys and four girls), aged 8 years 5 months to 14 years 6 months old, in their upper primary and junior secondary schooling. They were selected because one of their parents was studying with the author in the university at the time when the wayfinding exercise was conducted in October 1996. All the children were escorted to the university campus by their parents or guardians to participate in this wayfinding exercise. Eight children visited the university campus for their first time while two other children had been to the canteen before with their parents. But they did not regard themselves to have any clear overall knowledge about the campus.

Material

The children were given a large scale map (1:2000) of the university campus with all the building blocks represented in black, main roads in thick solid black line and minor path and track in the campus as thin black line. Open spaces are represented as clear patches on the map. Textual information was printed on the reverse side of the map giving instruction to the children how to go from one station to another. Towards the end of the wayfinding exercise, the children were asked whether they have been used maps before to wayfind in a new environment. They were also asked whether they have enjoyed this wayfinding exercise. The A3 size of the map and instruction sheets were laminated to facilitate convenient reading by the children in the open.

Method

The children were asked individually to show the way they used map and instructional information to 'hunt' around a university campus that they have not been to before. Instead of being shown around an unfamiliar place by adults, each child was given a large scale map of the campus with instructional information to guide the walk from one station to another station. The round-campus-circuit was about 1.2 kilometres covering 14 stations. During the process of wayfinding, each child was accompanied by a research assistant for the purposes of safety, observation and note-taking. There was no time limit for the child to complete the circuit route. The child had to make his/her decision how to complete the route. The research assistant would only offer advice if the child requested it or he/she had gone to a very wrong direction without noticing him/herself. A reflective interview using phenomenological principles (Kvale, 1983) was conducted upon the completion of the wayfinding exercise. This is to encourage the child to describe in fuller detail his/her experience in using a map to pursue this wayfinding in the unfamiliar campus.

Results

Table 1 shows the categorization of the 10 children into three subgroups according to their knowledge of the campus ground and their experience of using maps. In general, all the children spent about 25 to 30 minutes to complete the wayfinding route and returned back to the starting point. Only one child from subgroup C spent 65 minutes to complete the route and prompts were given to bring her back on track.

Table 1 : Categorization of the children

	Some knowledge of the campus	**No knowledge of the campus**	total
used map before	Subgroup A: 2 children (C1 & C5)	Subgroup B : 4 children (C4, C8, C9 & C10)	6
not used map before	nil	Subgroup C : 4 children (C2, C3, C6 & C7)	4
total	2	8	10

Wayfinding approaches

Four approaches of using maps in a wayfinding exercise were identified with a group of Australian pre-adolescents near their familiar school environment (Gerber & Kwan, 1994). These are (1) a neophytic restricted approach, (2) a careful step-by-step sequential approach, (3) a deductive and familiarized approach, and (4) a visualized co-ordinated spatial approach. In this study, children were observed to be using the neophytic and many sequential approaches. There was a total absence of the two more advanced approaches of deductive familiarized one and the visualized co-ordinated spatial one. It was very distinctive that all the children planned to work from one station to another station which is a typical characteristic of the step-by-step sequential approach. None of them actually settled down to study the map of the campus as a whole to gain a spatial conception of the area first. They purely completed the route by going from station to station.

Step-by-Step Sequential Approach

Among the use of the careful step-by-step sequential approach, it was observed that the children relied on:

- mainly written instructions
  walk uphill, go upstairs, a narrow bridge, a wooden Queenslander house
- a number of the environmental stimuli and signage
  C1 *"Carpark, so there must be cars around. I have to look for cars."*
  C5 *"It says there is a bridge walk around. So I was looking for a such pathway to Block L."*
- mainly map information
  C5 *"When I came out of Block L, I was standing on top of the stairs of L Block. That triangle flower bed in front of me is this triangle on the map. S Block is over there. So I should be here (*pointing to a correct spot on map*)."*

Despite the fact that there are three subgroups, the outcomes showed that the limited knowledge that the two children had upon the campus played no significant difference to their wayfinding behaviours. Rather, it was the previous experience that they had used maps before played a substantial difference in the way they conducted the step-by-step sequential approach of wayfinding in the unfamiliar environment.

It was noted that children in both Subgroups A and B used more of the environmental signage, landmark features and written instructions to help them to determine the walking route between two stations. When they arrived at the target station, they would check from the map to confirm if they had come to the right location. Other than this, they seldom referred to the map. This kind of behaviour was typical with children of C4, C8 and C9.

On the other hand, two children from Subgroup C (C2 and C7), who claimed that they had never used maps before, used the map more heavily and sensibly to determine the walking route. They adopted a very systematical way of:

- reading the written instructions;
- referring to surrounding landmarks; and
- comparing information on maps

between the current station and the next. This is regarded as the most sophisticated approach observed among this group of children. However, the constant turning of map at each station by pointing to the incoming direction indicates that they are not up to anywhere close to the visualized co-ordinated spatial approach. The following dialogues indicated these characteristics clearly:

C7 At station M, he said: *"Well, I have already been to L, so that way* (the left) *can't be the way. This should be M* (point to the right and aligning map with the incoming direction of Ring Road)".

C2 *"S" is here* (point to the map) *and we came from "J", so "M" is this way (point to the right). And if we just follow along the road, it* ("O") *should be next door. "P" is down here, so we'll follow this road along to the carpark.*

C2 When he was outside the canteen, he said: *"Well A is there* (pointing to the A block in front of him) *and I need to turn the map so that A is in the right place on the map. Then we can walk along this way."*

Despite relying heavily on map information, the children made quite a few mistakes especially when they were at the road intersection. When a mistake was made, the map became the device they sought help. They seldom needed prompting and could justify when they made the mistake and how they would go about correcting it.

C9 *I came out from here* (Block L) *and turned right onto Ring Road. I walked along it but probably went too far to Victoria. I checked the map and realized I must have missed the small turn. I went back and the words "wooden house" helped me to find J.*

Neophytic Restricted Approach

Two children from Subgroup C performed their wayfinding exercise with a lot of the characteristics of a neophytic restricted approach. Though they had the idea of locating themselves on the map, they were constantly disorientated and unable to orient map correctly. Hence, they were prompted a number of times by the research assistant to bring them back onto the 'right' track. Because of this disorientation, both children spent much longer time to complete the circuit route. The main difference between these two children with children from Subgroup B was that they were seen to read the map more often than those others who preferred to read the written instructions and use the surrounding environmental landmark information to help with their wayfinding decision.

<u>**Understanding of map concepts**</u>

The children have shown some understanding the following map concepts of

- symbolization
  - *C1* To look for the S carpark, he said: "*Black ones are blocks. White ones aren't. This is the carpark (pointing to the outline of carpark).*"
  - *C5* "*Buildings are in black. Carparks are open space. They are not black. The big roads are those thick black lines. They are all different on the map.*"

- direction and orientation
  - *C5* She turned the map so that Ring Road is pointing in the same direction. All the Blocks of S, M and O are on her right. She stopped in front of each block and check the Block sign of the building to confirm she was on track.
  - *C2* When he was outside the Canteen, he said: "*Well A is there (pointing to the A block in front of him) and I need to turn the map so that A is in the right place on the map. Then we can walk along this way.*"

  They demonstrated an ordinary conceptual understanding of direction using languages such as "to the right", "to the left", "in front of" or "behind" etc. However, it was noted that none of the children ever mentioned the north point on the map.

- distance
  - *C8* When he came out of the rainforest, he knew he had to go to S. He read from the map and realized that S was just very close to the forest exit. So he took the shortcut by going through S to bring him back to the Ring Road. He said: "*This is quicker to get back onto Ring Road*".

With regard to locating where they stood on the map, they made good use of various environmental objects that they had come across, such as

- the shape of the flower bed
  - *C5* "*When I came out of Block L, I was standing on top of the stairs of L Block.*

That triangle flower bed in front of me is this triangle on the map. S Block is over there. So I should be here (pointing to a correct spot on map)."

C8 *"We have just come out at that fork (the flower bed) and so we have to walk along this road and then go left to J."*

- the shape of building

  C5 *"I looked at the shape of the buildings on the map and checked it with the building in front of me. I can pick out the correct building."*

  C9 *"When I came out from the Rainforest, the building next to the forest should be S. The long shape tells."*

- the shape of car park

  C9 After reading the instructions, he checked the map for "K" and "bk" and said*: "Oh, that's (referring to K Block) just across the road. Next to it should be this carpark."*

Conclusion

Overall, the children had been observed to have used the map in four different ways to wayfind themselves in this unfamiliar environment.

- don't use map much but mainly relying upon the written instructions;
- use map as the main devoice to wayfind every station;
- use map to confirm the location upon reaching a station; and
- use map to check information and location when a mistake was made.

The map became a particular prominent device to sustain a correct wayfinding decision especially when they were 'lost' in an unfamiliar environment. It was at this point that the children demonstrated a much higher level of using map information, written instructions and the environmental information to crosscheck each other to come up with a correct decision. Even children who appeared to be at a loss at the beginning of the route demonstrated a much more competent way of using the map to wayfind themselves in the latter part of the route. The constant turning of map to orientate their position agrees well with Downs & Stea (1977) and Gommel (1995). Children were seen to be capable to wayfind the section between two stations of the route using a lot of the earlier found landmarks or features to act as new points of reference. But they were still not able to gather an overall conceptual picture of the whole environment. As a result, the more advanced approaches as indicated by Gerber & Kwan (1994 & 1995) were not found with this group of children. Yet, there was indiction of a preferred mode of information such as textual or symbolic map information among this group of children. Children who have used maps before tend to rely more on textual information and used the map mainly to confirm they have reached the right station. Those children who claimed to have used map for the first time were seen to work with the map information more intensively before they started to walk to the next station.

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CREATING BUILDING STONES FOR CARTOGRAPHIC VISUALISATION BY LINKING CARTOGRAPHIC VARIABLES

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Summary

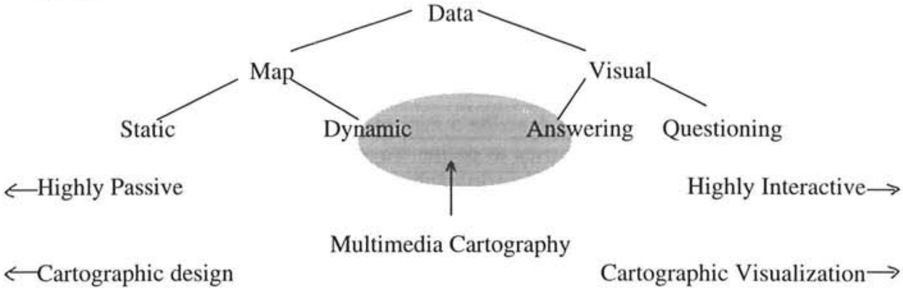
In this paper the author's research approach into multimedia cartography is described. The creation of similar cartographic map objects with the use of different cartographic elements and cartographic variables is described. By user testing these objects an attempt is made to describe the perceptive properties of the different techniques used. This knowledge can be used to aid the construction of multimedia maps either by hand or by linking the cartographic attributes of one map object to another, similar, map object.

Art or Technology

The art of cartography is the efficient and aesthetically pleasant transfer of geographical data to the map-reader. Computer technology and other electronic devices and possibilities, often called new technologies, have introduced new cartography, computer assisted cartography and cartographic visualisation as terms for the use of these techniques in cartography (*8;*9). Also the wish for intelligent systems that can create maps on the fly without interference of a cartographer does exist. A distinction can be made between two types of geographical data transfer, cartography and cartographic visualisation. The presentation form that is created can either be a map or a cartographic visual. A further distinction can be made between static maps and dynamic maps and for the cartographic visual between question answering and question posing visuals. From the static map to the question posing visual an increase in interaction takes place. A static map can be regarded as highly passive while a question posing visual 'asks' for reaction and interaction.

Multimedia Cartography

The use of multiple digital presentation techniques in a single cartographic display is called multimedia. While multimedia is the combination of techniques (sound, video, communication, graph etc.) to present information, multimodal is the perception of these techniques by the map reader or map user (*2). The field of multimedia cartography deals with the creation of dynamic maps and the question answering visual. The communication of geographical information to the user is an important issue, hence the term dynamic map. However, the great number of possible techniques that can be used makes it difficult to control the communication, hence the connection with a cartographic visual. The relations between cartographic visualisation and cartography described in the terms knows and unknowns, interaction and public versus private are presented by MacEachren's Map Use Cube and adopted by the commission on visualisation of the ICA/ACI (*1). Instead of using the Cube, the position of multimedia cartography is sketched in the diagram below.



From this one can conclude that multimedia maps are always:

- dynamic
- digital and
- most likely hyperlinked

The use of colour cycling techniques, video and sound makes a map dynamic. Without digital technology these effects cannot be realised. A very interesting and challenging aspect is the possible linking of map elements to remote data sources. A great advantage of this is the possibility to have updated elements in the map without having to change the maps itself, and the limitation in size of the map display. Most people know examples of hyperlinking from the World Wide Web. The problem of hyperlinking is the progression through time. If the attribute data of a map element changes, its presentation characteristics might have to change as well. A possible solution to this problem might be the development of a geographical SGML(Standard Generalized Markup Language) or HyTime (Hypermedia/Time-based Document Structuring Language) (*x) instead of the document based HTML(The Hypertext Markup Language) used on the World Wide Web.

The design and construction of maps has been subject of cartographic research for decades. The full understanding of the 'how' of creating a 'good' map that communicates its geographical message in an efficient way seems impossible. Good cartography can still be regarded as an art, which asks for talent, insight and great skills. But, since maps have to be created by a great number of people researches have focussed on the determination of maps into elements that make a map communicate. Bertin (*3) was the founder of the concept of using variables to describe the construction of maps, or cartographic grammar. These graphical variables have been succeeded with three-dimensional aspects by Kraak (*5) and with dynamics and sound by MacEachren, DiBiase, Krigier (*1) and Cassetari (*4). Confusingly they describe as well as constructional elements as perceptive properties of elements, for example texture and frequency. This makes the use of these variables as guides to create maps and visuals more complex. Another approach has been the description of possible map types (*7). While this approach for traditional cartography seems feasible, with multimedia cartography this seems almost impossible. Both approaches are combined in an effort to describe multimedia map objects.

<u>Elements of Multimedia Map Objects</u>

This approach does not attempt to describe a map as a whole (where does a digital map end in space and time?) but tries to define ways of constructing map objects and the process of communicating cartographic attributes from one object to another. Before the suggested approach can take place a framework has to exist of the types of multimedia maps that can be created. Any dynamic map is created with the elements:

- space
- dot
- line
- area and
- change

With these elements the construction and perceptive properties of map objects can be described. With all elements a distinction can be made between construction and perception. Since space is such a basic map feature is can never be left out any map or visual. The introduction of change (either in attribute or time) makes the perceptive characteristics of map objects change from moment to moment.

'perceived' Spaces	'described' Spaces	Elements	Variable Sets
2D(t)	2D(t)	Dot	Graphical
3D(t)	2½D(t)	Line	Dynamical
	3D(t)	Area	Sound
	nD(t)	Change (time or attribute)	

Communication or Visualisation

Next to the determination of the possible elements to create multimedia map objects two different goals exist to create multimedia maps. Either the communication of a geographical message is important or the visualisation (exploration) of geographical information. When communication is important the approach is taken to user-test different map constructions to create insight into the communicative properties of different multimedia map compositions. When visualisation is the issue it is important to offer alternative displays of the same geographical data to the user. This will prevent the user of drawing conclusions too early.

The construction of multimedia maps can take place at three levels of complexity. With each level a shift is made from a map towards a visual. The three levels are:

- basic level: at the basic level only instances of a set of variables are used, for example states in colour, shape or noise
- the second level deals with equal situations. An example could be a static point symbol with a fuzzy border next to a vibrating point symbol. The perception of both symbols could be that of an attribute at a location with a not exactly known value
- the third level deals with complex combinations of elements and variables. At this level a more complex visualisation is created and the result cannot be realised with the use of only one set of variables. Interaction plays a higher role. An example could be the movement of armed forces through Europe in the last two centuries, so the user gets a perception of time and place, and query the map. At this level results could be described with terms like 'perceive', 'trigger' and 'handle'.

The basic level deals with known cartography and could be typified as traditional cartography. The second level is the level where multimedia cartography is introduced and the research of map objects as described in this paper takes place. The third level is where cartographic visualisation takes place. User interaction with cartographic visualisation is still a complex and hard to predict subject of research.

Cartographic Style Sheets or Building Blocks

The creation of user-tests can be with the aid of style sheets of building blocks. Both metaphors are taken from computing experiences. Style sheets are known in word processing and desk-top-publishing software and deal with the concept of the complete end product. Building blocks are present in computer-aided design like doors and windows in an architectural design software package. In the tests the metaphor of building blocks is used. This resembles much more with the use of map objects. The characteristics of the building blocks are described like cartographic variables.

- the measurement scale of the data
- applicable variables

- perceptive characteristics
- behavioural aspects

Testing can take place by creating multimedia map objects that theoretically should have equal perceptive characteristics, or make equal impressions to a map-reader. With this setting, hypotheses can be formed and the perceptive characteristics of the different building blocks can be compared. The results of these tests will create more insight into the usability of multimedia techniques in cartography and set ranges for the use of the different dynamic variables. The latter can be illustrated with the following question: 'when is display time of a map(object) perceived as belonging to the same map or as a 'new' map(object)?'

Conclusion

In this paper a framework is presented to create cartographic building blocks or map objects to construct multimedia maps. The perceptive characteristics of these map objects are tested. The resulting knowledge will aid future multimedia map design and provides a way to created dynamic hypermaps that partly construct themselves though exchange of attributes from one element to another.

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*x http://www2.echo.lu/impact/oii/oiiold/moving.html#HyTime