Geovisualization in Enterprise Institutions

PhD Project Outline — Alexander Salveson Nossum

There is currently a lack of methods and tools for knowledge construction from geospatial data in enterprise institutions, especially concerning visualization of spatial (including large, small, indoor and outdoor environments) and aspatial relationships. This project aims to develop, deploy, and test such methods and tools.

It is our belief that the design of computer-based methods and tools should be founded on a solid understanding of professional standards and practices within the domain of use, hence a user-centric design philosophy and a strongly multidisciplinary approach will be adopted.

Several research challenges are identified and presented, and collated with research agendas which are current in the GIS community.

A multidisciplinary cooperation involving the division of Geomatics, the COSTT[1] project, and the Department of Computer and Information Science has already been established, and will be an essential success factor for the project.

1 Problem statement

Cartography is traditionally the study and science of creating and using geographic maps. Extensive research has been carried out in the field of cartography, especially concerning map design. Technological advances have enabled new methods of creating and distributing maps, in contrast to the traditional paper version. Cartography as a science is forced to meet this change in the way maps are developed, disseminated and used.

The amount of data available is rapidly increasing in conjunction with technological advances. One driving force is the Internet. Available data is not necessarily of a geographic nature - however some research estimates that 80% of the digital data generated includes some sort of geospatial reference (MacEachren and Kraak 2001), such as geographical coordinates, textual addresses, place names, and so on.

[1]Cooperation Support Through Transparency

Technology additionally enables a radical change in the way maps are made. Maps are no longer bound to be static 2-dimensional representations. Highly interactive, dynamic and personalized maps are increasingly becoming the de-facto standard for representing geospatial information. Additionally, the availability of maps is no longer tied to a physical medium. Digital distribution through the Internet is providing a platform for an enormous potential in the availability of maps.

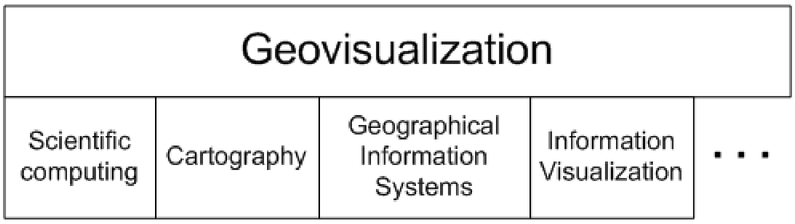

Figure 1: Geovisualization integrates several disciplines

In response to the changing nature of cartography, the field of geovisualization has emerged. Geovisualization integrates visualization methodologies from a range of different fields including visualization in scientific computing, cartography, information visualization and geographic information systems (GIS) as illustrated in figure 1. This integration is necessary to respond to the change in cartography.

1.1 Research challenges

The International Cartographic Association (ICA), Commission on Visualization and Virtual Environments, led the development of a comprehensive research agenda for geovisualization. The agenda is summarized in MacEachren and Kraak (2001) and has since been revised and extended, e.g. by Skupin and Fabrikant (2003) and Andrienko et al. (2007). This section will reproduce some of the main aspects of this research agenda which correspond to the project described in this document.

The agenda is categorized in four essential themes for geovisualization; representation, integrating visualization and computation, interfaces and cognitive/usability issues illustrated in figure 2. As the challenges in each theme was developed independently by different involved participants from different disciplines, there exists some overlap between themes. These overlaps are summarized in the crosscutting challenges section.

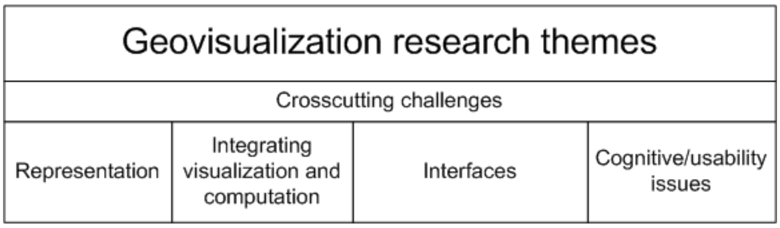

Figure 2: Research themes for geovisualization identified by ICA (MacEachren and Kraak 2001)

1.1.1 Representation

Representation deals primarily with the visual representation of data. However, the representation of the data itself, i.e. data structures, is inherently important to address. Visual representation is motivated by communicating with humans, cfr figure 3. One important goal of this communication is to allow and arrange for knowledge construction, i.e. to allow for the human user to apply intelligence and gain knowledge from the visual representation.

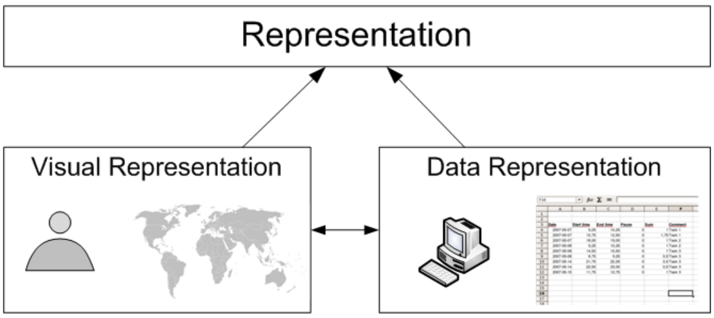

Figure 3: Representation comprises visual and data representation.

Mapping and general information visualization are related fields. Several new ways of representing both geographical data and non-geographical information have emerged recently, primarily through technological advances, but also through the increased amount of data with spatial attributes.

Traditional mapping techniques are increasingly applied on non-spatial data for non-spatial visualizations (Skupin 2000). On the other hand, the use of traditional non-spatial visualization techniques are also used for spatial information (Skupin and Fabrikant 2003). This indicates a trend towards merged hybrid representation techniques, where spatial and non-spatial visual representations are combined. This merging, and the need to address issues posed by it, was pointed out in recent work on integrating understanding of quality of maps and models (Nossum and Krogstie 2009, Nossum 2008).

Challenges in the representation theme of the agenda are focused on five central issues of representation. An extract of these five issues is given below.

Semiotics and meaning How visualization relates to underlying meaning. I.e. how the visual representation is linked to the data it represents.

Data How visualization relates to the structures and/or interpretations found in the data.

Map use How visualization relates to the desired use. Dealing with the intended/desired use of the visualization and the actual use of it.

Map users Relates to the users of the visualization and how they interact with it. Primarily a human-computer interaction issue.

Technology How visualization exploits or is able to exploit the technological advances.

Given these central issues, a set of specific categories were developed in the work by the ICA commission (MacEachren and Kraak 2001). In the following, a brief extract of the most relevant categories are reproduced.

- Develop methods for supporting navigation within complex representations and adapt representations to "intelligent" displays which react to context and user behaviour.

- Adapt representation methods to the various different kind of tasks that geovisualization can support. Specifically mentioned are the support of knowledge construction and decision making through visual representation. In its easiest form, an example of decision making support is the use of maps to illustrate suggested travel routes - frequently applied by web mapping services.

- Exploit the technological advances in hardware and data formats. Indicating a need to meet the increasing trend towards ubiquitous computing and cartography (Gartner et al. 2007). As examples, this could be to further enable representations with respect to wearable devices, multi-user environments and "smart" mobile devices.

1.1.2 Integrating visualization and computation

Visual representations are very useful for representing large amounts of data, with seeming lack of relationships, which can be explored through the visualization. However, the vast amount of data which is being generated and made available requires more comprehensive approaches than solely visual representations. Integrating computational methodologies with visual representation techniques is one means of success in supporting for instance knowledge creation *through* spatial data. Figure 4 illustrates the essential idea of integration of visualization and computation, specifically for a data mining task. Complex tasks of exploring and finding structure in seemingly unstructured data can be leveraged through a tighter collaboration between human and machine - enabled through visualization.

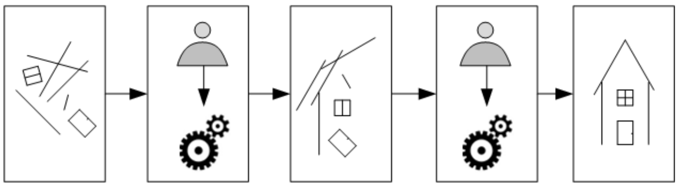

Figure 4: Abstract illustration of visual data mining, enabling visual communication and collaboration between human and machine

Efforts in visual data mining, visual support for computational knowledge construction methods and database models for supporting this are recognized in the research agenda (MacEachren and Kraak 2001). As for the other themes of the agenda, identified challenges are developed according to the theme's topics. Below are the challenges thought to be of greatest importance to the project described here.

- Human-machine *collaboration* through visually facilitated tools. Neither human nor machine alone is capable of solving complex problems comprising large amounts of data and requiring a high level of intelligence. One approach to overcome this barrier is to facilitate the collaboration of human and machine for joint efforts in solving such problems, illustrated in figure 4.

- Develop visual approaches to geospatial data mining. Data mining is, roughly said, the task of extracting structure, relationships and meaning from large sets of data automatically. Figure 4 illustrates this. Traditionally, this is a task performed automatically by machines, more or less in isolation. A visual approach to this calls for humans to be more involved in the process - thus uncovering patterns and structures in concert with data mining methodologies currently applied.

1.1.3 Interfaces

Interfaces are essential for success in geovisualization. The more advanced and integrated the use of geovisualization becomes - the greater the need for more advanced interfaces. Especially to gain success beyond usage solely by experts. MacEachren and Kraak (2001) argues that:

> "New interface paradigms are needed that support interaction with advanced forms of representation and analysis [...]"

An immediate concrete challenge of interfaces is constructing high quality interfaces for different kinds of devices, such as mobile devices vs. desktop devices, large vs. small screens et cetera. Techniques for one may not produce high quality results for the other. Research on cartography for mobile devices abounds in the literature (Dillemuth 2005), but there are still many challenges in the field of interfaces for geovisualization.

The research agenda recognizes themes including; Interfaces and representation of geography, interaction, universal access and practical implementation of interfaces (MacEachren and Kraak 2001). Specifically, several categories are related to these themes. The following will highlight the ones thought to be of greatest importance to the present project.

- Develop mechanisms to enable creative thinking through visual interfaces. Specifically mentioned is the need to identify how computers enable humans to determine answers, and how to exploit this through geovisualization.

- Develop a more complete understanding of how non-geographic and geographic visualization approaches differ in cognitive and usability aspects. The intention here is to construct precise methods for selection of appropriate metaphors. The work on integrated quality (Nossum and Krogstie 2009) is believed to be directly relevant with respect to this challenge.

- Focus on developing comprehensive user-centric design approaches to geovisualization usability. In the advent of mobile technological advances, this challenge is of increasing importance. Availability and accessibility of data and visual representations of data is increasing. Combined, this poses an increased need for high quality interfaces. Geovisualization will be an important asset in meeting this need. The science of cartography in general and geovisualization specifically needs to meet these increased demands by scientific development of suitable methods and techniques.

1.1.4 Cognitive/Usability challenges

The use and users of geovisualization are essential to the field of traditional cartography and the newer approach of geovisualization. Increased adoption of using "maps" as metaphors for non-geographic visualizations introduces several new aspects related to use and usage (Skupin 2000).

Challenges that are specifically mentioned in relation to the project outlined are:

- Understand differences in group usage and individual usage of geovisualizations. Groups and individual users often have distinctly different requirements of visualization in general and geovisualization specifically. These different requirements of usage need to be met by developing a precise understanding of the differences and thus develop methods for adaptable geovisualization with respect to group/user differences.
- Determine where and when geovisualization is useful. Claims and beliefs that geovisualization is useful are ubiquitous. However, little effort has been put into determining if geovisualizations actually are useful, and especially when and where they are.

1.1.5 Crosscutting challenges

This section has briefly introduced some of the research challenges for geovisualization and thus cartography. The challenges were developed by the ICA commission, summarized by MacEachren and Kraak (2001), and elaborated by e.g. Skupin and Fabrikant (2003) and Andrienko et al. (2007). Several of the challenges overlap in the themes they relate to. Crosscutting challenges are of great importance but also of a particularly challenging nature. In order to meet these challenges, it is believed that strong multidisciplinary efforts are needed, thus aligning the inherently multidisciplinary nature that cartography and geovisualization has become.

Several crosscutting challenges were identified by the research agenda teams. Related to the project outlined, one is of particular interest:

- Develop user-centric approaches to geovisualization. It is recognized that this challenge is of increasing importance, powered by technological advances but also powered by the increased needs and requirements put forward by the users and makers of geovisualizations. Modern information systems finds great success in emphasizing and focusing on personalization specifically towards the user. Geovisualization needs to meet this increased trend.

1.2 SPIRIT project

SPIRIT (Spatially-Aware Information Retrieval on the Internet) was an EU-funded project through the EC Fifth Framework Programme (Jones et al. 2002). Essentially, the project contributed to the development of the Semantic Web[2] in general and the exploitation of geographical referenced information in particular. The project relates to themes in the research challenges previously mentioned.

Interfaces for both querying and presenting the results are of great importance to a search engine. Research on different interfaces relating to geovisualization was carried out in the project and results are available (Purves and Yang 2005).

The current project will build upon and extend the knowledge gained in the SPIRIT project, especially the work carried out on interface design.

1.3 Enterprise application of geovisualization

Collaboration in large enterprises is a complex task of team problem solving. In the health care domain, the complexity of collaboration and coordination is particularly great. Efforts to support the planning and monitoring of this activity by ICT[3] is regarded as difficult, but potentially highly beneficiary. Traditional workflow-oriented approaches are insufficient in meeting the dynamic and sometimes improvised work practises found in hospitals.

The COSTT [4] project aims at investigating properties of the challenge of collaboration and coordination in hospitals and is currently funded by the VERDIKT programme of the Norwegian Research Council. One means of leveraging the complexity of collaboration and coordination tasks is thought to increase information transparency of the process of health care work. The information can be gathered by tapping into the already established information base, such as electronic patient records and existing information systems. One important segment of the health care information is the spatial information. Spatial information is believed to ease coordination tasks in large

[2] "Next generation Internet, incorporating machine interpretable meaning in web pages"
[3] Information and Communication Technologies
[4] Cooperation Support Through Transparency

hospitals (Marjamaa et al. 2006). But spatial information is not necessarily explicitly present in the already existing infrastructure. However, indoor real time location systems (RTLS) is an attractive novelty. One of the most promising technologies for accurate and precise positioning indoors is the use of ultrasound technology, primarily provided by the Sonitor company. Information transparency of spatial attributes requires effective communication with the user, similar to what geovisualization requires. Hospitals are slowly beginning to convert to digital formats for their information, however, this information is often communicated in a textual, "digital-paper" form, reminiscent of the beginning of digital cartography. It is strongly believed that more effective forms of communicating this information is needed. Thus the application of methods and techniques within geovisualization is important. Applying geovisualization techniques in the health care domain, in collaboration with the COSTT project, will gain deeper understanding in the challenges of geovisualization previously discussed as well as improving the knowledge of how spatial information can support collaboration and coordination.

2 Research method

The primary focus of this project will be to investigate and gain deeper understanding of applying geovisualization, on geographical as well as non-geographical information. This will be undertaken by strong multidisciplinary efforts primarily among the Department of Civil and Transport Engineering division of Geomatics, the COSTT project and the Department of Computer and Information Science. The tight collaboration with the COSTT project is mutually desirable and efficient, as previous collaboration has shown. A multidisciplinary effort is of great importance to the success of this project.

The goals of the project are:

- Survey and gain comprehensive knowledge of the state-of-the-art in geovisualization in general, and possible applications of geovisualization in large scale enterprises.
- Gain a comprehensive understanding of the results from the SPIRIT project and deduce the applicability of the results to this project.
- Extend and adapt methods and techniques in geovisualizations to the health care domain.

- Implement several prototypes of the most promising geovisualizations methods and techniques.
- Empirically test the prototypes in as close to real-life situations as possible. The tight collaboration with the COSTT project will enable easier real-life testing. If applicable, empirical experimentation can be performed in a usability laboratory.

It is firmly believed that the project will contribute to the research challenges put forward by the geovisualization community. Dissemination of the research will be a main priority, and extensive efforts will be put into publishing the results in scientific publications and through conferences and similar channels.

3 Expected results

Results from the project will primarily be increased knowledge of applied geovisualization. It will support information transparency of integrated data in general and health care institutions specifically.

Additionally, the project is expected to contribute new insights into how best to visualize information which is of an integrated nature, combining spatial and aspatial information. The project will result in new scientifically founded methods and techniques for specialized geovisualization, adapted to user-centric, enterprise applications.

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