Geovisualization in Enterprise Institutions

PhD Project Outline — Alexander Salveson Nossum

There is currently a lack of methods and tools for knowledge construction from and communication of 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

[1] Cooperation Support Through Transparency

(MacEachren and Kraak 2001), such as geographical coordinates, textual addresses, place names, and so on.

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.

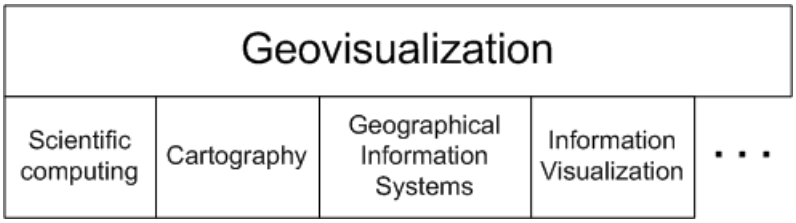

Figure 1: Geovisualization integrates several disciplines

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.

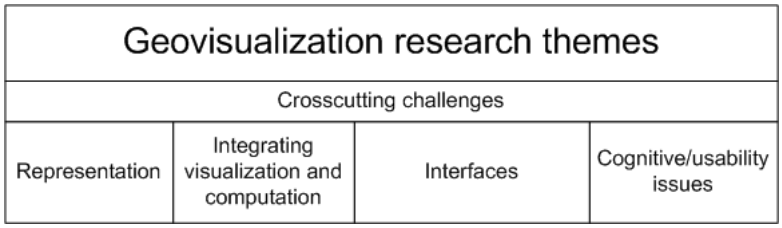

Figure 2: Research themes for geovisualization identified by ICA (MacEachren and Kraak 2001)

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.

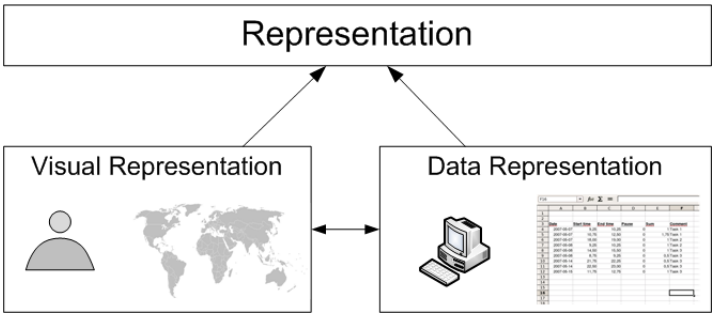

Figure 3: Representation comprises visual and data representation.

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.

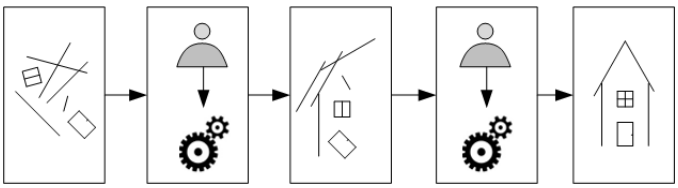

Figure 4: Abstract illustration of visual data mining, enabling visual communication and collaboration between human and machine

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 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[2] 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 [3] 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 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

[2]Information and Communication Technologies

[3]Cooperation Support Through Transparency

coordination.

This project identifies several different challenges related specifically to the issues of collaboration and cooperation, illustrated in figure 5. Awareness and communication are highlighted as core challenges directly affecting collaboration and cooperation. Awareness can be looked upon from different viewpoints. This project will focus on and differentiate between; Social awareness, spatial awareness and information awareness. The challenge of communication is similarly divided in different means of communication. One way communication of information to actors. Two way communication between different actors. And the specific case of one way communication between a machine actor and a human actor. These challenges needs to be addressed, one means of addressing them is by introducing the concept of information transparency. However great care should be taken in identifying and properly address the sub-challenges mentioned above. These sub-challenges may prove to demand solely different solutions although contributing to the same overall challenge. The following section will present the chosen approach for addressing these challenges - as well as propose initial high level themes which is considered beneficiary in order to succeed in attaining information transparency in an enterprise.

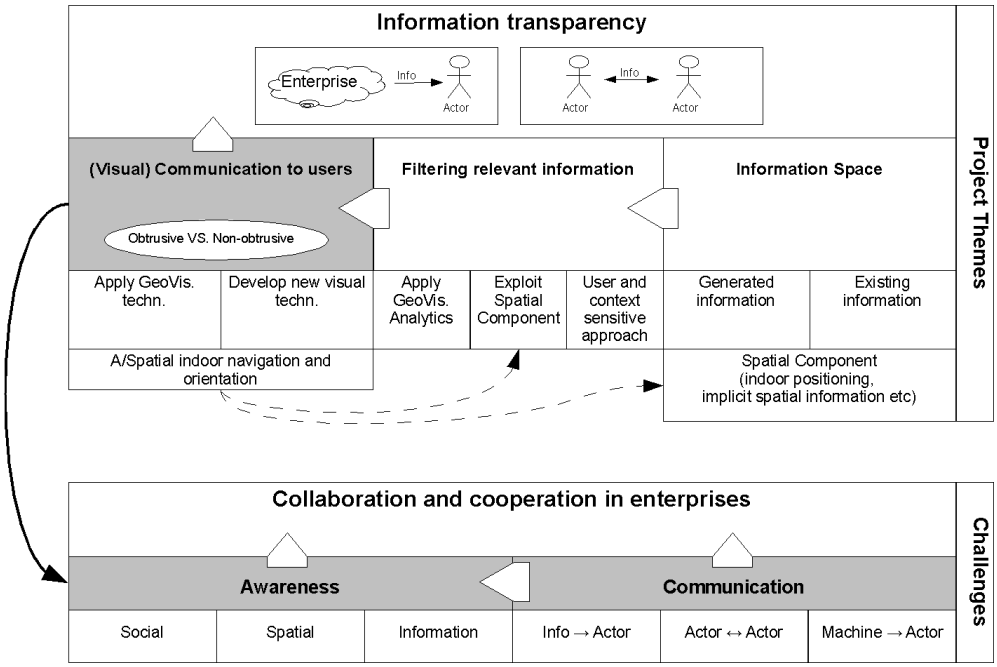

Figure 5: Project themes and approach relating to challenges in enterprise environments

2 Research method

This section will present the overall methodology chosen for the project. For presentation the methodology is divided into two different viewpoints. One concentrating on the overall approach of meeting the previously presented challenges and one on the concrete project methodology. The research approach is aimed primarily at the concrete challenges faced by collaboration and cooperation in enterprises. Thus, the approach aims at contributing to the high-level research challenges by means of application in a concrete domain.

2.1 Research approach

Figure 5 illustrates the research approach as project themes, challenges and the relation among them. This section will present the project themes - and discuss their internal relevance.

The overall approach is driven by the concept of information transparency. Information transparency is, as defined by this project, primarily driven by the communication of information to human actors. Communication is separated in two distinctly different concepts; one focusing on one-way communication of information from the enterprise/organization to the actors. For instance broadcasting existing schedule information for actors and similar. On the other hand, is communication between actors. The information communicated may be existing information and ad-hoc information, such as questions between human actors and similar.

In order to enable information transparency the concept is divided into three main parts; *Information space*, *filtering relevant information* and *(Visual) communication to users*. The project approaches these parts as sequentially dependant. Information space considers only the data and information. Information may be already existing as part of the enterprise or generated. The generated information is believed to be mainly ad-hoc information with a short life-span, for instance a question from one actor, answered immediately by another actor. Common to both generated and existing information is the spatial component, which will be of primary focus for the project. Considering the information space is an essential part of the concept of information transparency as it is the information which is to be made transparent.

Filtering relevant information focus on the mechanisms to manipulate the information space in order to retrieve only *the* best information relative to the actors, context and intended usage. Existing methods from the field of information retrieval is believed to support this. As well, the exploitation of the spatial component, driven primarily by existing geovisual analytics tech-

niques, will be further investigated. Combined, this is envisaged to provide new techniques in user and context centric information retrieval especially in the light of supporting information transparency.

Visual communication to users is the primary theme of the project. The theme is dependant on the previous mentioned themes by obvious reasons. Communication of relevant information will be approached both by means of visual methods, but also by means of non-visual methods (text, sound etc). A separation between obtrusive and non-obtrusive methods is made to better examine the properties of them in different environments and application areas. The theme will be driven by integrating and applying techniques from the field of geovisualization as well as possibly develop new techniques based on existing knowledge in (visual) communication. The spatial component will primarily be in an indoor environment. Thus, navigation and orientation in indoor environments will be addressed specifically. The metaphor of navigation and orientation will span not only spatial information, but also aspatial information such as documents and similar in order to enable innovative integration of geovisual techniques.

2.2 Project driven methodology

As highlighted earlier, the project will rely on multidisciplinary efforts.The COSTT project being and essential collaborating partner, and also other relevant actors such as other enterprise institutions and other fields of science. The research approach is divided in several different themes, each contributing to the overall project theme while maintaining the possibilities to be investigated in more or less isolation. Combined, the research approach and the multidisciplinary efforts suggest that the research project should be divided into several sub-projects each targeting specific themes. Thus, the research will adopt a project driven methodology. This is believed to be highly beneficiary for the sustained progress of the project.

Benefits from this methodology includes the possibility of parallel sub-projects with different collaborating partners. Each sub-project may benefit by the possibility of defining concrete goals as well as targeting concrete themes for the project.

The contribution from each sub-project to the overall project theme will be emphasized to ensure overall consistency of the project.

The methodology and approach chosen for each sub-project will vary according to what best suits the goals and theme of the sub-project. However, the primary method of investigation will be: to gain sufficient knowledge on the relevant theme, elicitate research challenges for the relevant theme, develop necessary and relevant prototypes of the solution and empirically

evaluate the performance of these either by experiments and/or in usability laboratories. Exceptions from this methodology is expected where appropriate.

3 Expected results

Results from the project will consist of a collection of results from the sub-projects conducted. In addition to these results there will be produced aggregated results which combines and extracts results contributing specifically to the overall goal of information transparency by means of geovisualization. The aggregated results will emphasize the contribution to the field of geovisualization in relation to the application domain.

Dissemination of results will be on the form of scientific papers - preferably published or accepted in international scientific journals appropriate for the project conducted. Additionally, effort will be put into dissemination of results in non-scientific channels - such as through the internet, popular science magazines and similar. Attendance and presentations on conferences and similar scientific gatherings will be essential to both the dissemination but also for the possibilities of attracting new collaborating partners. It is expected that each sub-project will result in at least one paper ready for publishing in one or more of the above mentioned channels.

The primary contribution from this project is expected to be an extended insight and knowledge to the field of Geographic Information Science, specifically in the area of geovisualization. Integration and application of geovisualization in enterprises is of great importance to the project and will be reflected in the results. Extending and adapting existing techniques from geovisualization in enterprise environments will inherently lead to new insight in indoor cartograhy as well as user-centric cartography. Ubiquitous cartography is additionally expected to be touched upon. In addition to new insight in the above mentioned areas, it is also emphasized that the results will reflect and present the evaluation and performance of integrating and applying geovisualization techniques in enterprise environments. This is an important asset for potential further work on the field and will be of priority.

Secondarily the project is expected to provide additional insight in the health-care domain. Specifically on the issues of awareness and communication, how these properties affect information transparency and the effect information transparency has on leveraging the complexity of coordination and collaboration.

Date: September 15, 2009

Sign:	_____	Sign:	_____
	Prof. Terje Midtbø		Alexander Salveson Nossum
	Thesis supervisor		Applicant

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