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Cartographic aspects of WebGIS-software

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[Geospatial] *data sharing makes sense for the simple reason that there is only one Earth, and we share it.*

Kurt Buehler and Lance McKee
OGC Technical Committee

Foreword

As part of the Cartography curriculum, a specialisation of the study of Human Geography at the faculty of Geographical Sciences of Utrecht University, the student has to perform a final research project. A thesis has to be written based on a review of relevant scientific literature and individual research, and afterwards this thesis has to be presented. This thesis is submitted in partial fulfilment of the requirements to obtain the degree of Doctorandus (Drs.) from Utrecht University.

Contents at a glance

Table of contents

Chapter 1

Introduction

Distributed geographic information systems

ONE OF THE main assets of a society is its natural environment and physical environment. In order to make decisions about the environment, good geographical information is necessary. This geographic information is derived from geospatial data, data describing real-world phenomena directly or indirectly associated with a location relative to the surface of the Earth.

Geospatial data have been collected in digital form for more than 30 years. The overall rate of geospatial data collection increases rapidly with advances in technologies such as high-resolution satellite-borne imaging systems and global positioning systems (GPSs), and with the growing number of people and organisations that are collecting and using these geospatial data. That number will continue to increase with the growing awareness among information technologists that indexing data by location is a fundamental way to organise and use digital data.

The integration of various geospatial datasets is increasingly important because of growing environmental concerns, pressures on national governments and on businesses to perform more efficiently, and simply because of the existence of a rapidly growing body of useful geospatial data and of geo-processing tools. A Geospatial Data Infrastructure (GDI) enables this integration of geospatial data from various distributed resources. There is no straightforward, universal, concise definition of a GDI, for it may refer to different concepts. For the scope of this thesis the following definition is pursued:

- *A Geospatial Data Infrastructure (GDI) is a set of institutional,* **technical** *and economical arrangements to enhance the availability of correct, up-to-date, to-the-point and integrated geospatial data, timely and at an affordable price to support decision making processes*.

The technical arrangements of a GDI encompass amongst others geographic information systems, networks, and services: computers, software applications, and electronic communication facilities (networks). The Internet is such an electronic communication network. The Internet provides new challenges and opportunities for the integration, representation, dissemination, and communication of geographic information. These services that are provided via the Internet require geographic information systems that are able to deal with their networked computer environments: distributed geographic information technology (DGI):

- *Distributed Geographic Information (DGI) technology is technology distributed across a networked computer environment facilitating the integration, dissemination, and communication of geographic information.*

This is a general term for every kind of technology that is able to transfer geographic information across a computer network, as for example by means of the File Transfer Protocol (FTP). This thesis focuses on a specific type of DGI, WebGIS:

- *WebGIS is a Geographic Information System distributed across a networked computer environment to integrate, disseminate, and communicate geographic information* **visually** *on the World Wide Web over the Internet.*

In the next paragraph this specific type of Distributed Geographic Information technology, WebGIS, is further elaborated upon.

WebGIS

WEBGIS IS A Geographic Information System (GIS) distributed across a computer network to integrate, disseminate, and communicate geographic information visually on the World Wide Web. In performing the GIS analysis tasks, this service is similar to the client/server architecture of the Web. The geo-processing breaks down into a server-side and client-side task.

A client typically is a Web browser. The server-side consists of a Web server and a WebGIS software programme. The client requests for a map or some geo-processing over the Web to the remote server. The server translates the request into an internal code and invokes the GIS functions by passing on the request to the WebGIS software. The software returns the result that is reformatted for interpretation by the client browser application itself or with additional functionality from a plug-in or Java applet. The server then returns the result to the client for display, or sends data and analysis tools to the client for use on the client-side (Peng, 1997, URL; Plewe, 1997, p.5).

In the 1999 January issue of GeoWorld, J.D. Wilson provided a listing of the major leading GIS companies (Wilson, 1999, p.). Most of the companies have developed their own WebGIS software packages. In the scope of this thesis, four of these are examined: Environmental Systems Research Institute (ESRI) ArcView Internet Map Server 1.0, MapInfo Corporation MapXtreme 2.0, Autodesk MapGuide 4.0, and Intergraph Geomedia WebMap 3.0.

This particular selection from the host of WebGIS software available today is based on three grounds. In the first place, this selection covers the four major GIS vendors. In the second place, it covers the distinction between software from a geographic background (ESRI and MapInfo Corporation) and software from an engineering background (Autodesk and Intergraph). In the third place, the same selection of software packages has been the subject of review before (Limp, 1997b; Culpepper, 1998).

Research

WITH THE DIGITAL revolution in cartography during the 1980s, more and more the geo-processing became separated from geospatial database creation and -management. Now in the networked computer environment this is even more so: WebGIS facilitates the functionality of a GIS be distributed across the Web, spanning the whole globe. The maps generated by WebGIS, the so-called Webmaps, then become the interface between the client and the service of the Geospatial Data Infrastructure.

To give the client insight into the geospatial database, the design of Webmaps is important to communicate the contents of the geospatial database correctly. Several tools have become available to publish maps and other cartographic representations of geospatial data on the Web. To make sensible use of these Webmaps, cartographers have to take into account new issues in the design and construction of the Webmaps and the development of Webmapping applications. One of the issues is that the specific characteristics of the Web as visualisation medium ask for special cartographic design requirements. Second, cartographers should take into account the new ways of using maps, because the Web enables interaction and dynamics. Then the capabilities and drawbacks of Distributed Geographical Information (DGI) technology in general and WebGIS software in particular have to be considered as well.

Currently, there is little guidance available to cartographers on these new aspects of their profession. In WebGIS software, little attention is given to cartographic design. Surely, cartographic design is a difficult process. First, there are many different definitions of cartographic design. Second, it is mostly associated with art. Therefore, it is difficult to formalise. For this research project I turn to Wood who noted: "*The purpose of* [carto-] *graphic design is to facilitate human thought and communication. Success in graphic design is achieved when diverse design principles are manipulated and adapted to produce an image with a high degree of readability* (Wood, 1992)."

To overcome the second impediment I substitute "design principles" with "requirements for functionality". This takes cartographic design from the context of art into a broader context. These requirements for functionality should be derived from the functionality that is necessary for a map to cater for specific map use purposes, resulting in cartographic visualisation strategies.

Until recently, most texts about digital cartography have been about screen map display as the design phase for producing paper maps, for hard copy output. It tried to find ways to convert analogue map production into the digital environment. However, more and more attention should be directed to softcopy output; at present there are few guidelines for the design of maps specifically for computer displays (Green, 1993, p.93; Gooding & Forrest, 1990, p.15).

Especially now that the Web has become an important medium to reach a large audience, this lack is even more felt. There are thus several reasons to draw attention on cartographic map design for the Web. Firstly, the new Webmaps are different from the paper map. The human brain's perception of electronic images is not the same as that of traditional products (Gooding & Forrest, 1990; Taylor, 1994, 337). This difference of perception has to be taken into account during the design phase. Secondly, whereas the full range of cartographic language is available for the design of paper maps, the range available for digital maps is limited. The constraints of digital cartographic design also apply to Web cartography. However, the Internet imposes even further restrictions upon design. Only a limited sub-set of the cartographic language is available. This is acceptable if it supplies crucial information within the critical time scale (Roche, 1998, p.5-6). Thirdly, cartographic visualisation on screen displays and in Web browsers in particular offers design possibilities unavailable for paper maps, including animation, rotating, three-dimensional views, user interaction and integration in multimedia presentations. Finally, the nature of recent technological developments allows for dynamic interaction between clients and the map, which has never been possible before (Taylor, 1996, p.13). From now on the cartographer no longer has control over the map contents clients will see on their screen. The Web as medium for communication provides many unique design considerations cartographers may not accustomed to handling (Plewe, 1997, p.181). Therefore, the cartographer has to put much consideration into the design process to cater for all possible map views requested by clients and still achieving legibility.

Research question

Is current commercially available WebGIS software sufficient to generate Webmaps for Webmapping applications that facilitate the visual use of geospatial data sets across the Web?

Sub-questions

To make this research question more manageable, it is necessary to split up the main question into several sub-questions, each one covering a small area of the larger research.

- What requirements pose the characteristics of the Web as a visualisation environment for the cartographic visualisation of Webmaps to facilitate the use of geospatial datasets across the Web?

- What requirements pose the different types of use of Webmaps for the cartographic visualisation of Webmaps to facilitate the use of geospatial datasets across the Web?

- To what extend can these requirements be implemented by means of currently available commercial WebGIS software?

The first two sub-questions will be answered by means of a literature research. The last sub-question will be answered by means of a benchmark. Based on answers to the first two sub-questions, requirements are determined which have to be met by WebGIS software packages.

Research objectives

Based on the subquestions, several research objectives can be determined. The first two subquestions lead to the following research objective:

- Specify requirements for cartographic representation of Webmaps to facilitate the use of geographical data sets across the Web

The third subquestion leads to the following research objective:

- Make a judgement as unbiased as possible on the cartographic capabilities of different distributed geographic information systems with regard to cartographic representation

Relevance of research

The research described in this thesis has both scientific and practical relevance. The scientific relevance of this research is based on the literature review to give a comprehensive insight into the limitations and challenges for cartography on the Web. The practical relevance of this research stems from the benchmark results. The conclusions based on these results are helpful for those deciding on what WebGIS software to buy to fulfil their Webmapping requirements.

Methodology

Benchmarking

BENCHMARKING IS A term not unknown to the geosciences. In geodesy and land surveying, a benchmark is a surface point inscribed on a permanent monument to provide a fixed reference of elevation above the datum plane (Strahler & Strahler, 1992, p.591). The height of another point is evaluated or checked by comparison with this benchmark. This process of determining the height difference between a benchmark and a point of unknown elevation is termed “benchmarking”.

With the introduction of computers in cartography, the term "benchmarking" has taken on a whole different meaning. In this context, benchmarking is a practical test for a system (hardware or software) to test the operational use for a specific application (Bos *et al*., 1991, p.111). Benchmarking is an accepted methodology as part of the acquisition process within both private industry and government (Guptill, 1988, p.45).

To perform a benchmark of a computer programme, a context should be constructed as reference, the benchmark. This context is a description of the ideal performance of the computer programme. The input for the ideal performance results from analysing the user requirements, as a programme is only successful when it comprehensively and consistently meets the needs of the users (Guptill, 1988, chapter 3). A User Requirements Analysis (URA) is a detailed study of the needs of potential users of the programme. Based on this description, a problem is designed that the ideal computer programme should be able to deal with perfectly. This problem now also has to be solved by the programme to be benchmarked. The performance of this programme is compared to that of the ideal programme. The comparison of their performances provides a basis to evaluate the fitness for use of the benchmarked programme.

In this case, the benchmark test is formulated based on the description of a WebGIS software package that perfectly generates Webmaps. These Webmaps facilitate the use of geospatial data sets across the Web perfectly while taking into account both the characteristics of the Web as a visualisation environment for cartography and the different types of Webmap use. This description forms the basis of a benchmark test. This test is constructed by designing some Webmapping problems to be solved by the selected WebGIS software programmes. Then, these WebGIS software packages are evaluated by comparison of their problem-solving performance with that of the "benchmark".

Research operationalisation: structure of thesis

IN THIS THESIS, the benchmark test is formulated based on the description of a WebGIS software package that perfectly generates Webmaps. These Webmaps facilitate the use of geospatial data sets across the Web perfectly while taking into account both the characteristics of the Web as a visualisation environment for cartography and the different types of Web map use.

The next chapter, forms the scientific background for this research. At the same time, this chapter introduces the theory to structure the types of map use that have to be taken into account while designing maps. These types of map use are further elaborated upon in chapter four. The third chapter provides an extensive literature review addressing the characteristics of the Web as a visualisation environment for cartography. Introduced in chapter two, the theory structuring map use is described further in chapter four. This theory is then adjusted to the context of the Web, so the theory can be applied to types of Webmap use. Chapters three and four describe thus the conditions that have to be taken into account while designing Webmaps.

Based on the answers to these sub-questions the benchmark test can be constructed. In chapter five, the attention is once more drawn to the mapping constraints: the conditions of use, the geographic reality, and the available data. Then, structured by the mapping constraints, two ideal Webmapping applications are described. These descriptions serve as a substitute for a formal User Requirements Analysis (URA) that usually is the input for constructing a benchmark problem. Based on these descriptions, the benchmark test is constructed by designing some Webmapping problems to be solved by the selected WebGIS software programmes In chapter six these WebGIS software packages are evaluated by comparison of their problem-solving performance with that of the “benchmark”. This answers the third sub-question of this research, thus meeting the third objective of this research.

In the final chapter this comparison is evaluated so that conclusions can be drawn and recommendations can be made to further scientific research and to facilitate the choice Webmapping application developers and Web cartographers have to make to select the best WebGIS software package fulfilling their Webmapping requirements.