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The role of the map in a Web-GIS environment

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Abstract. The World Wide Web has changed the perspective on the role that maps can play. Their traditional function remains, e.g. to represent an abstraction of a selected part of reality to offer insight into geospatial patterns and relations. Additionally the map can be an important part of a search engine, especially in the context of geospatial data infrastructure. Maps can also function as an interface to other geographic and non-geographic information on the Web. The question 'What are the implications of this expanding role of maps for a WebGIS environment?' is addressed in this paper.

1 Introduction

Maps are recognised in their capacity to offer an overview of and insight into spatial patterns and relations. Maps can guide us from A to B, show the structure of the landscape, display the changes in population distributions, or show future urban plans. Maps do this because they represent abstractions and selections of reality. If well designed, the meaning of their symbology will give the user a link to a part of reality.

Geographical Information Systems (GIS) are characterised by the ability to integrate geospatial data from a wide variety of sources. The functionality of such systems allows different kinds of spatial analysis operations. The nature of these operations is often based on applications models, the current disciplinary approach to the problem at hand. Obviously, maps play an important role in GIS. Not only do they present the final results of the spatial analysis but they are also critical during the whole iterative process of geospatial data handling. The popularity of GIS has had a great impact on maps. Many maps have been created and used, but during the beginning of the GIS era map quality was not always acceptable. This was partly due to the fact that not all people involved in GIS-mapmaking were skilled in this process, and partly due to the limited resolution of screens and plotters.

The rise of the Internet, and in particular the World Wide Web, was another stimulant to map making and map use. However, the Web has also brought specific changes and opportunities due to the characteristics of this medium. These changes are related to the look and function of maps and their dissemination. As such, the use of the Web has had much wider implications than the rise of GIS. Today, millions of maps are being made and used by an audience that earlier on would not necessarily have thought of creating maps themselves.

Authorities that used GIS to run, for instance, a municipality or a state saw opportunities to use the Web to improve working processes and increase their service level to the public. Via the Web they started to offer their own employees better access to the wealth of geospatial data available, and at the same time they began to offer citizens more insight and aide them for public participation in local affairs. In the above process WebGIS will potentially play a prominent role since it offers GIS functionality in a Web environment. However, currently most WebGIS application in use is limited to (interactive) mapping applications.

This paper will discuss the role of the map in a WebGIS environment. To be able to understand this role, the next section will sketch the latest relevant developments in mapping, followed by a discussion of the role of maps, and conclude with comments on suggested future trends.

2 Trends in mapping

The opportunities offered by hard- and software developments have changed the scientific and societal needs for geo-referenced data and, as such, for maps. New media such as the Web not only allow for dynamic presentation but also for user interaction. Users expect immediate and real-time access to the data, which have become abundant in many sectors of the geoinformation world. This abundance of data, seen as a paradise by some sectors, is a major problem in other sectors. We lack the tools for user-friendly queries and retrieval when studying the massive amount of data for instance produced by sensors, now available via the Web (Cartwright et al. 1999; Kraak and Brown 2000; Peterson 2001).

Maps are no longer just a medium to display final results. Maps are used anywhere in the geospatial data handling process. Additionally, technological developments have brought mapping closer to other disciplines, which have influenced the approach to mapping. Interaction and dynamics became important keywords. In the 1990s, developments around scientific visualization (McCormick et al. 1987) have given the word visualization an enhanced meaning. These have linked visualization to more specific ways in which modern computer technology facilitates the process of "making data visible" in real time in order to strengthen knowledge. The relations between mapping and GIS on the one hand, and scientific visualization on the other have been discussed in depth by (Hearnshaw and Unwin 1994; Taylor 1994; MacEachren and Taylor 1994). In addition to scientific visualization, which deals mainly with medical imaging, process model visualization, and molecular chemistry, another branch of visualization that influenced mapping can be recognized. This is called information visualization (Card et al. 1999), and focuses on visualization of non-numerical information. In this field we see the map used as metaphor to access data. Other disciplines having had influence on the map are image analysis, exploratory data analysis (EDA), and of course methodological developments in GIS and cartography not to be forgotten.

The above developments in scientific visualisation stimulated (DiBiase 1990) to define a model for map-based scientific visualisation. It covers both the communication and thinking functions of the map. Communication is described as "public visual communication" since it concerns maps aimed at a wide audience. Thinking is defined as "private visual thinking" because it is often an individual playing with the geospatial data to determine its significance. On a more detailed level, different visualisation stages can be recognised, each requiring a different strategy from the perspective of map use. This ranges from presentation to exploration. The first fits into the traditional realm of cartography, where the cartographer works on known geospatial data and creates communicative maps. These maps are often created for multiple uses. Exploration often involves a discipline expert creating maps while dealing with unknown data. These maps are generally for a single purpose, expedient in the expert's attempt to solve a problem. While dealing with the data, the expert should be able to rely on cartographic expertise, provided by the software or some other means.

From the map perspective, a synthesis of all the above trends results in geovisualization. Geovisualization integrates approaches from scientific visualization, to provide theory, methods, and tools for visual exploration, analysis, synthesis, and presentation of geospatial data). This trend has been described by (MacEachren and Kraak 2001) for the Commission on Visualisation and Virtual Environments of the International Cartographic Association. More information can be found on the Commission's Website (URL1) or in the special issue of Cartographic and Geographic Information Sciences (2001) vol. 28, no 1.

In this context, it is obvious that cartographic design and research pay attention to human computer interaction – the interfaces, and revive the attention for the usability of their products. Additionally, one has to work on representation issues and the integration of geocomputing in the visualization process. As such maps and graphics are used to explore geospatial data, the exploration process can generate hypotheses, develop problem solutions, and ultimately construct knowledge.

In a geovisualization environment maps are used to stimulate (visual) thinking about geospatial patterns, relationships, and trends. One important approach here is to view geospatial data sets in a number of alternative ways, e.g., using multiple representations without constraints set by traditional techniques or rules. This should avoid the trap described by (Finke et al. 1992) who claim that "most researchers tend to rely on well-worn procedures and paradigms..." while they should realize that "…creative discoveries, in both art and science, often occur in unusual situations, where one is forced to think unconventionally." New, fresh, creative graphics might also offer different insights and would probably have more impact than traditional mapping methods. These arguments are valid in a WebGIS environment as well, but do require specific interactive functionality that is not always offered.

3 The function of the maps

The Web has changed the perspective on the role of maps. They can function as they have always done, as an abstraction of geographic reality, used to explain geospatial relations and patterns. This can be done by the presentation of a static map, or by offering an interactive framework for exploration (MacEachren and Kraak 1997; Kraak and MacEachren 1999). Interestingly the domain to be mapped has expanded as well; it now also includes the mapping of cyberspace (Dodge and Kitchen 2000).

One of the interesting and new functions of the map is its role in a search engine (see Fig. 1). This is especially relevant in the environment of a geospatial data infrastructure (GSDI). Users interested in, for instance, agricultural data from a particular geographical region for a specific time period can use the map to add the location part of the search criteria. In this process the user will access the search mechanism via a clearing house, while the actual search takes place based on metadata descriptions. The map can of course also be used as preview to geospatial data found during the search process to judge the data before the actual acquisition. In this context the visualisation of metadata is potentially an additional expansion of the realm of the map (Ahonen-Rainio and Kraak 2004).

Maps can also be used as a metaphor, and as such function as an index to other information. The hyper-linked nature of the Web allows this information to be of geographical or non-geographical nature. Particular map elements can be linked to other, more detailed maps, geospatial data sets, drawings, photographs, text, and videos or animations. The location of this additional information can be anywhere in cyberspace. The map metaphor is often used in information visualization, where the maps are called *spatializations* (Fabrikant 2000; Skupin and Buttenfield 1997).

In all these functions the map has to fulfil certain criteria to be successful. Providers of the map and data have to consider both new technological developments as well as the nature of the Web user. The technology is discussed in the dissemination section. In a Web environment users have specific expectations. From Web design literature it can be learned that

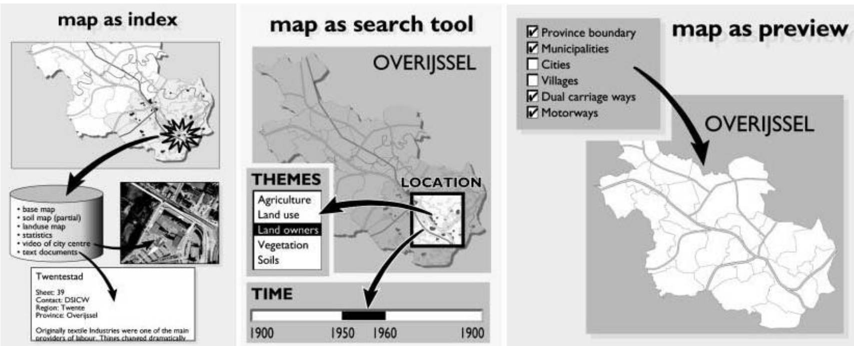

Fig. 1. Functions of the map on the Web. From left to right, the map as an index to other geographic and/or non-geographic data, as part of a search engine in a local geodata infrastructure, and as preview of data to be downloaded

surfers expect interactivity because if they can not interact with the Web page it will be considered dull, and it is very likely they will move on to the next Website. Here that translates into clickable maps. Surfers are also rather impatient. This means that maps to be displayed should load quickly and this puts constraints on the file sizes. Solutions to this problem are discussed later.

The Web map has some advantages that are shared with all digital maps. One can zoom-in or -out, it is possible to pan, while layers can be switched on or off. The map can also be queried. Clicking a symbol can give access to the database behind the map. Simple operation such as measuring distance or areas can be executed.

The disadvantages are related to practical usability aspects. Paper maps offer better usage in the field, although recent hardware such as advanced PDA or tablet PC's offers interesting alternatives. Additionally screen resolution of the often small devices will put extra demands on the design. Even more critical is that up-to-date information is expected. In the past, map provision was very much supply driven by cartographers who would consider user needs. Today, rightfully so, one has to consider a demand driven environment and some of the cartographic needs may be solved by algorithms used while creating the maps on demand.

4 Look of the maps

What makes Web maps unique? As seen in the previous section the Web as medium to display maps has many interesting advantages, but also some disadvantages. Just scanning paper maps or using default GIS maps and putting them on the Web is not a good alternative. However, in some situations there is no design alternative. Scanning historical maps and publishing them on the Web might be the only solution to make them available for a wider audience, and opening up our cultural and historical heritage. If the above is taken into consideration well-designed Web maps can be recognised as relatively "empty", i.e. they have a limited map content. This should not be considered as problematic since one can include lots of information behind the map image or individual symbols. Access to this hidden information can be obtained via mouse-over techniques or clicking on map symbols (Worm 2000). To ensure this approach one has to make sure the symbols have an appearance that invites clicking them (see Fig. 2). In the case of mouse-over techniques the appearance of a symbol will change or textual information appears on the map. Clicking the symbol might open new windows or activate other Web pages.

An advantage of those well designed Web maps is that they can be easily used in the world of mobile geocomputing. People will have portable devices such as mobile phones and/or personal digital assistants and call-in for location based information. Small maps with answers to questions such as how do I get to the railway station, or where is the nearest bookshop will appear on the small screen of these devices which often will have a GPS receiver built in to establish the owners position.

The possibilities offered by the Web have extended the traditional cartographic variables as proposed by (Bertin 1967). Web design software enables the application of new variables, like blur, focus, and transparency,

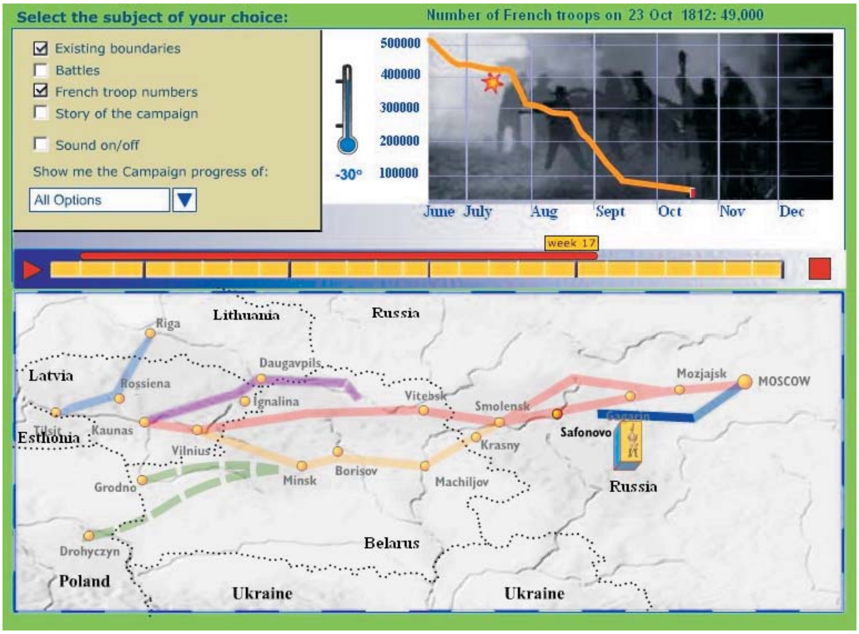

Fig. 2. Interactive map displaying Napoleon's Campaign into Russia design with Flash. The user can select the map content and run the animation. During the animation the map background will adapt to the season. See URL2 (Kraak 2003)

while shadow and shading play a prominent role as well. Blur gives symbols a fuzzy appearance and can for instance be applied to visualize uncertainty, while focus will introduce blinking symbols to attract attention (DiBiase et al. 1992). Both transparency and shading and/or shadow can be used to simulate a three-dimensional look. Transparency can be seen as a kind of fogginess, whereby part of the map content is obscured or faded in favour of other information. For example it can be applied to subdue the background in a map in order to enhance the main theme in the foreground (for instance a drape of geology over terrain features). In a three-dimensional "landscape" environment it can also be used as a depth cue. The use of shadow and shading increase the sense of depth. Shading is commonly used to increase the contrast between "figure" and "ground" or, for instance in relief maps to create a three-dimensional terrain impression. Shadow, also known as cast or drop shadow, can be applied to give the symbols a three-dimensional look. In Web maps this three-dimensional feel of the symbols invites the user to click on them to activate a hyperlink or mouse-over effects. The visual effect of shadow is casting a shadow of the symbol on the background. The origin of these new variables is partly to be found outside cartography (Spence 2001; Wilkinson 1999). The new variables have been fully accepted in cartography (Kraak and Brown 2000). However, further research on the new variables remains to be done, because despite all technological progress it remains important to make sure that the new representations and interfaces really work.

5 The dissemination of maps

The Web is currently the medium to present and disseminate geospatial data and maps. The Web allows one to offer the data and maps platform independently and a virtually unlimited number of users can access the map anywhere at all times. However, there are still many problems to be solved. The performance of working in a WebGIS environment depends on several technological factors. Among these are the internet connection, the traffic intensity, the data efficiency, and the capacity of the client and server machines. These days the nature of the task will decide if it will be executed at the client side (the user's machine) or at the server side (the provider's machine). Software vendors offer different solutions. Choosing a particular type of solution could tie the user to a particular environment. Another aspect of WebGIS and the current developments around the Geodata Infrastructure is that users can gather their data from almost any source (Green and Bossomaier 2002). This has all kind of implications, since data sets can be combined at will, even data that have never been collected of prepared with this intention. For instance data to be used to solve a particular geo-problem can originate from different providers, at different scales, and even at the same scale of different data density. They could be from different ages or collected by completely different sampling methods. What can be done to guarantee that data from different sources can be used together?

Currently, partners of the Open GIS Consortium (OGC - URL3) put a lot of effort in several projects to solve these problems. Interoperability is the keyword, aiming at a standard for the Web environment. Many efforts concentrate on the Geographic Markup Language (GML – URL4). This is a XML (eXtensible Markup Languague – URL5) based coding that allows the exchange of geospatial data.

XML can be described as the successor of the HTML code, however XML is a kind of umbrella for all kind of subject dependent languages such as GML. The Geographic Markup Language is not oriented toward the visualisation of the data. The organisation of the data and their use (here visualization) is strictly separated. The principles of the separation between the Digital Landscape Model (DLM) and the Digital Cartographic model (DCM) have been followed. Currently there are several geodata providers active with GML. The British Ordnance Survey is already offering its data in this new format, and several other national mapping organisations work hard toward this approach. See for instance URL6. Providers of GIS software have announced or realized GML import and export filters. To be able to provide the data in a GML-format one has to have well structured data. The Universal Modelling Language (UML – URL7) is a useful tool to realise this, establishing all relations among the database elements and their characteristics.

For the visualisation of the GML-files the Scalable Vector Graphics standard (SVG –URL8) is used. It encodes two-dimensional graphics and can be displayed in a Web browser. Currently a plug-in is required but it is expected that in the near future these will be incorporated in the browsers by default. From a visualization perspective the use of GML and SVG supports style sheets that give the maps their final look (URL9). Based on the same GML data one can create maps with a different (corporate) look.

Additionally style sheets offer the possibility to visualize the data according to predefined standards. These techniques allow one to incorporate standardisation and other rules into the data exchange process. In many situations this can be very helpful, because the increased functionality offered to the user in our demand driven environments also allow these users to create maps that will have a look that can not be imagined by the providers of the data.

6 Maps in WebGIS

Of the three topics discussed above, the function of maps, the dissemination of maps, and the look of maps. The last category gets limited attention in current WebGIS environments. Well design Web map can be found, but the typical Web map graphics are realized by specific dedicated graphics software (URL10). These programmes are often not integrated in the geospatial data handling chain. In other words most of these maps are 'hand-made'. A positive development is that the latest software versions are able to read from a database, which makes it possible to automatically up-date the maps.

Many maps used in a WebGIS environment are in fact Internet mapping solutions based on products offered by for instance ESRI (URL11 and URL12). These map environments can be customized such that functionality required for a particular task can be made available. Via the Geography Network, this approach is stimulated, and here data and tools are made freely available (URL13). One can zoom, pan, and query, and there is a set of basic GIS functions available. Examples are address matching, proximity searches, and routing. Interesting examples are found on the Website of the National Atlas of the United States where users can define their own maps (URL14). The Canadian atlas has similar options, and has been made part of the Canadian GeoData Infrastructure (URL15). Another example is the National Geographic Website (URL16) where users can also create their own interactive maps.

More advanced from a mapping perspective are certain academic non-commercial software developments. An interesting example is the Common-GIS project (Andrienko and Andrienko 1999). It encompasses a set of specific functions for the automatic generation of thematic maps (URL17). It allows the user to execute many different visually explorative analysis operations. User options to play with and change the parameters of the many function make it a strong map based solution. Another visually oriented approach is offered by Geovista Studio (Fig. 3) (Takatsuka and Gahegan 2002). It is a component based GIS and allows the user to select the GIS and visualization operations required (URL18).

The above examples are mainly desktop based. From a map perspective the last examples described are more sophisticated, but one should not forget it is the task at hand that should define the most suitable tools to be used. Recently the demand for mobile GIS solutions has been growing. Typical use scenarios are to access a database whilst in the field to download information to be able to solve a local problem or update the database because changes have been observed in the field (Ligtenberg et al. 2002). Typical tools to use are mobile phones, PDA and GPS equipment. The main limitations of the

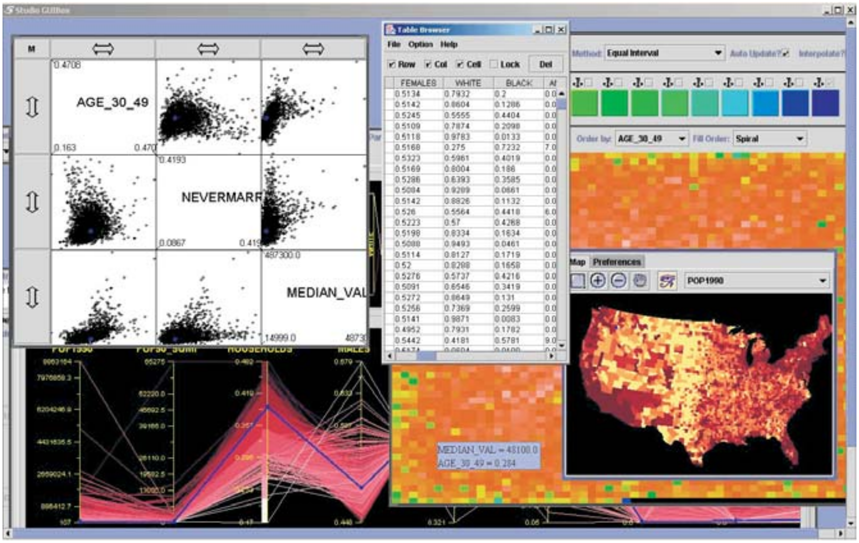

Fig. 3. Some of the GeoVista Studio tools for visual analysis operations. It offers a visual programming-free environment for rapid development and follows the component-oriented programming principle using JavaBeans as programming components (URL19)

graphics on these devices used in the field are due to small screens. The need for well designed 'empty' maps and a clever and efficient data transfer is required. When this is solved WebGIS will also be used on mobile GIS devices.

7 Conclusions

Maps have a definite role to play in a WebGIS environment. In their interactive and dynamic appearance they will guide and assist the user in solving geospatial analysis problems. They can do this in their traditional role, or even better in their new role as an exploratory tool that stimulates visual thinking. Additionally, they can function as an interface to the wealth of data available through the Web. With the currently increased availability of mobile devices, proper software and abundant data, maps can play these various roles anywhere and at any time.

8 URL's (all url's last visited October 1, 2003)

URL1 http://www.geovista.psu.edu/sites/icavis/
URL2 http://www.itc.nl/personal/kraak/1812/Nap000.swf
URL3 http://www.opengis.org/
URL4 http://opengis.net/gml/01-029/GML2.html
URL5 http://www.w3.org/XML/
URL6 http://kartoWeb.itc.nl/top10nl/index2.htm
URL7 http://www.rational.com/uml/index.jsp

URL8 http://www.w3.org/TR/SVG/
URL9 http://www.w3.org/Style/CSS/
URL10 http://www.macromedia.com/software/flash/
URL11 http://maps.esri.com/
URL12 http://www.esri.com/software/internetmaps/visit_sites.html
URL13 http://www.geographynetwork.com/index.html
URL14 http://nationalatlas.gov/
URL15 http://atlas.gc.ca/site/english/index.html
URL16 http://www.nationalgeographic.com/maps/
URL17 http://commongis.jrc.it/summary.html
URL18 http://www.geovistastudio.psu.edu/jsp/index.jsp
URL19 http://www.geovistastudio.psu.edu/GeoViz/images/all_beans.gif

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