Current trends in visualisation of geospatial data with special reference to cartography

(Invited Paper)

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Overview

1. Introduction

The title of this paper will immediately raise questions. Is the visualisation of geospatial data not cartography? The answer is both yes and no. Recent developments have changed the landscape of making and using maps considerably. For some of us the word cartography holds too much of the past, and when they communicate with others the image around cartography is felt uncomfortably old fashioned. Others built their activities on the long-standing tradition of cartography and cannot go without the public image of the discipline.

It is a fact that our world of maps is changing. Cartographers and others active in the geosciences witnessed highly dynamic and important developments in the fields of acquiring, managing, analysing, interacting with and visualising large amounts of geospatial data over the last two decades, and probably changes will come faster and more frequent in the future. However, it is assuring that the basic map concepts remain valid in this changing world. Next to static maps nowadays immersive and highly interactive virtual environments can be used to explore and present dynamic geospatial data, while the World Wide Web has developed into a prominent medium to disseminate geospatial data and maps.

All these changes can be traced back into various disciplines; among them are the fields of computer science, database design, statistics, geoinformatics, geography, cartography and other geosciences. Computer science has introduced the field of Visualisation in Scientific Computing (ViSC), database and statistics research provided new ways on data mining and knowledge discovery, geoinformatics introduced new approaches to spatially analyse datasets, where cartography and geography approaches led to geographical visualisation or geovisualisation.

This paper will first look into the characteristics of maps in more detail, and will discuss developments that have influenced the map and its environment most. Special attention will be given to the World Wide Web. The paper will end with a discussion on geovisualisation and a revisit to the word cartography.

2. Maps

Everyone accepts the usefulness of maps, irrespective of what purpose they are used for and to what professional level. In some non geo-disciplines the map is even used as a metaphor to access large amounts of non-geo referenced data. In the past, the time between production and use could be years, today it can be seconds. The environment in which maps have been produced and used has changed considerably. Technological trends have resulted in changes of both quantitative and qualitative nature. Quantitative in the sense that a wider range of map product is available, which can be produced much faster and with less expense than in the past; qualitative in the sense that those maps allow (real time) interaction with the display.

However, all maps deal with all questions/answers related to the basic components of spatial or geographic data: location, characteristics and time, and their combination.

As such maps are the most efficient and effective means to transfer spatial information. The map user can locate geographic objects, while the shape and colour of signs and symbols representing the objects inform about their characteristics. They reveal spatial relations and patterns, and offer the user an insight and overview of the distribution of a particular phenomena. Looking at maps one will notice an important quality of maps: the ability to offer an abstraction of reality. It simplifies by selection, but at the same time it puts, when well designed, the remaining information in a clear perspective. The Visualisation process is considered to be the translation or conversion of geospatial data from a database into map-like products. This process is guided by the saying "*How do I say what to whom, and is it effective?"* (Kraak and Ormeling, 2002).

Although people always tell us they like maps, the image that they have of those making maps has lacked behind these quite exciting developments. In the past only

cartographers were producing maps. Their skills and laborious activities were a guarantee that authoritative maps were produced. The rise of Geographical Information Systems has increased those involved in making maps. Today's revolution around the World Wide Web has even further increased the number of people involved in making maps. Did map making via GIS still involve geo-professionals? the WWW includes potentially everyone having access to this new medium to create maps. This has led to potential situations where the organisations offering maps via Internet will never know how their map products will look like, because the mapmakers on the other end have so much interactive symbolisation options (Kraak and Brown, 2000).

Maps are used for navigation, during planning, and to solve geo-problems. Before the era of geographical information systems (GIS) (the 1990s), paper maps and statistics were probably the most prominent tools for researchers to study their geospatial data. To work with those paper maps, analytical and map use techniques were developed, which can still be found in the commands of many GIS packages. Via GIS the same researchers have access to large and powerful sets of computerised tools like spreadsheets and databases, as well as graphic tools, to support their investigations (Longley *et al.*, 2001). The user can interact with the map and the data behind it. This capability adds a different perspective, as they become interactive tools for exploring the nature of the geospatial data at hand. The map should be seen as an interface to geospatial data that can support information access and exploratory activities, while it retains its traditional role as a presentation device. There is also a clear need for this since the magnitude and complexity of the available geospatial data sets pose a challenge as to how the data can be transformed into information and ultimately in knowledge.

Figure 1. Traditional and modern map image? Left a map by Pieter van der AA from around 1700; right a virtual reality view on Pudget Sound USA by Nick Hedley

3. Maps and visualisation

The opportunities offered by hardware and software developments have changed the scientific and societal needs for geo-referenced data and, as such, for maps. New media such as CD-ROMs and the WWW not only allow for dynamic presentation but also for user interaction. Another example is the rise of mobile GIS and related location based services. Users expect immediate and real-time access to the data; data that 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 produced by sensors, and now available via the WWW. However, other disciplines can offer help.

In the 1990s, scientific visualisation (McCormick, 1987) has given the word visualisation an enhanced meaning. These developments have linked the word to more specific ways in which modern computer technology can facilitate the process of "making data visible" in real time in order to strengthen knowledge. The relations between the fields of cartography and GIS, on the one hand, and scientific visualisation on the other have been discussed in depth by (Hearnshaw and Unwin, 1994, MacEachren and Taylor, 1994, Taylor, 1994). Next to scientific visualisation, which deals mainly with medical imaging, process model visualisation, and molecular chemistry, another branch of visualisation that influenced mapping can be recognised. This is called information visualisation (Card *et al.*, 1999), and focuses on visualisation of non-numerical information.

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 spatial data to determine its significance. On a more detailed level, different visualisation stages can be recognised: each requires a different strategy from the perspective of map use. These stages are exploration, analysis, synthesis and presentation.

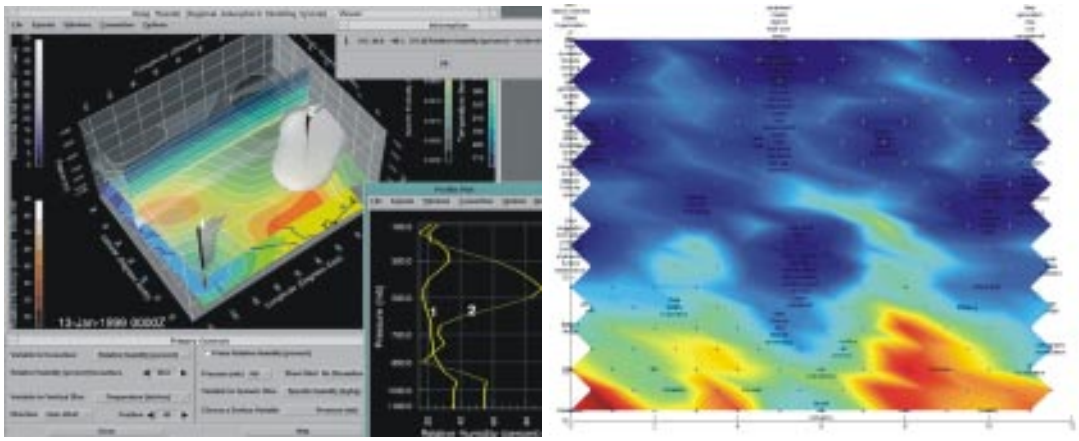

Figure 2. Scientific and Information visualisation: left weather forecast for Atlanta Olympics (Treinish, 1995); a self organising map of geoinformatics keywords (Koua, 2002).

The above developments have given the word *visualisation* an enhanced meaning. According to the dictionary, it means 'make visible' and it can be argued that, in the case of geospatial data, this has always been the business of cartographers. However, progress in other disciplines has linked the word to more specific ways in which modern computer technology can facilitate the process of 'making visible' in real time. This results in visualisation for presentation and exploration. Presentation 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, however, 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.

4. Maps and the WWW

The World Wide Web (WWW) is one of the latest new media to present and disseminate spatial data, especially in combination with multimedia elements. In this process the map plays a key role, and has multiple functions. Maps can play their traditional role, e.g. to provide insight in spatial patterns and relations. But because of the nature of the WWW the map can also function as an interface to additional information. Geographic locations on the map can be linked to, for instance, photographs, text, sound or other maps, somewhere out there in cyberspace. Maps can also be used as previews of spatial data products to be acquired.

Here we will not deal with the changing technology regarding client-server architecture, and recent and important trends related to OpenGIS, XML, GML and SVG, but with the design of the web maps. What makes web map design unique? The web as a medium to display maps has many interesting advantages, but of course also some disadvantages. When creating a web map one has to consider the physical design, both in file and display size. The first is important because people are not eager to wait for long downloads, and the second because the use of scrollbars to pan the map is also discouraged. Due to these characteristics the map design needs extra attention. Just scanning paper maps or using default GIS maps and put them on the web is not a good alternative. However, in some situation there is no design alternative. Scanning historical maps and publish them on the web might be the only solution to make them available for a wider audience. Well-designed web map can be, due to the above constraint, recognised as relatively "empty". This should not be considered problematic since one can include lots of information behind the map image or individual symbols. Access to this hidden information can be obtained via, for instance, mouse over techniques or clicking map symbols. To ensure this approach, one has to make sure the symbols have an appearance that invites clicking them. In 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 empty 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 information. Small maps with answers to questions such as how does one get to the railway station, or where is the nearest bookshop will appear on the small screens of these devices which often will have a GPS receiver included to establish the owners position. Those small screens require an economised map design.

The possibilities offered by the WWW 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, while shadow and shading play a prominent role as well. Blur give symbols a fuzzy appearance and can for instance be applied to visualise uncertainty, while focus will introduce blinking symbols to attract attention. Both transparency and shading/shadow can be used to simulate a three-dimensional look. Transparency can be seen as a kind of fogginess, by which a part of 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 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 to the background. Though the origin of these new variables is partly to be found outside cartography, it is interesting to note that the cartographic principles of Bertin and others have found their way in non-cartographic literature. Examples are the works of (Spence, 2001, Wilkinson, 1999). The new variables have been fully accepted in cartography (Kraak and Brown, 2000). However, further research on the new variables effectively remain to be done, because despite all technological progress it remains important to wonder if the new representations and interfaces really work.

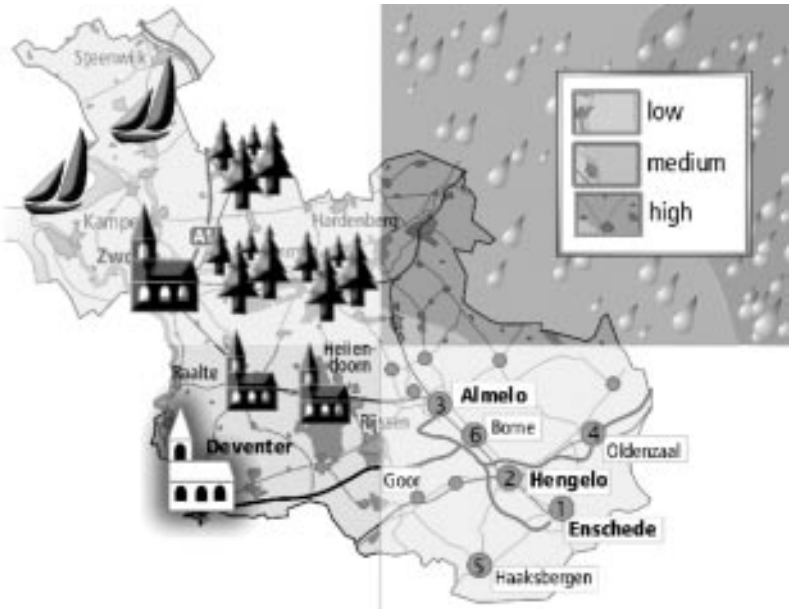

Figure 3. Web map design: additional graphical variables (clockwise from upper-left: shading, transparency, focus, and blur (from Kraak & Ormeling, 2002)

5. Maps and geovisualisation

From the map perspective, a synthesis of all the above trends results in geovisualisation. Geovisualisation integrates approaches from scientific visualisation, (exploratory) cartography, image analysis, information visualisation, exploratory data analysis (EDA), and GIS 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 Commission on Visualisation and Virtual Environments of the International Cartographic Association. More information can be found on the Commission's website (http://www.geovista.psu.edu/sites/icavis/) or in the special issue of Cartographic and Geographic Information Sciences (2001) vol. 28, no 1.

In this context, it is required 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 visualisation 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 geovisualisation 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 realise that "…creative discoveries, in both art and science, often occur in unusual situations, where one is forced to think unconventionally." This is well described by (Keller and Keller, 1992) who in their approach to the visualisation process suggest removing mental roadblocks and taking some distance from the discipline in order to reduce the effects of traditional constraints. Why not choose an alternative mapping method? For instance, show a video of the landscape next to a topographic map accompanied by a three-dimensional map, or use a cartogram instead of a choropleth map. New, fresh, creative graphics could be the result. They might also offer different insights and would probably have more impact than traditional mapping methods.

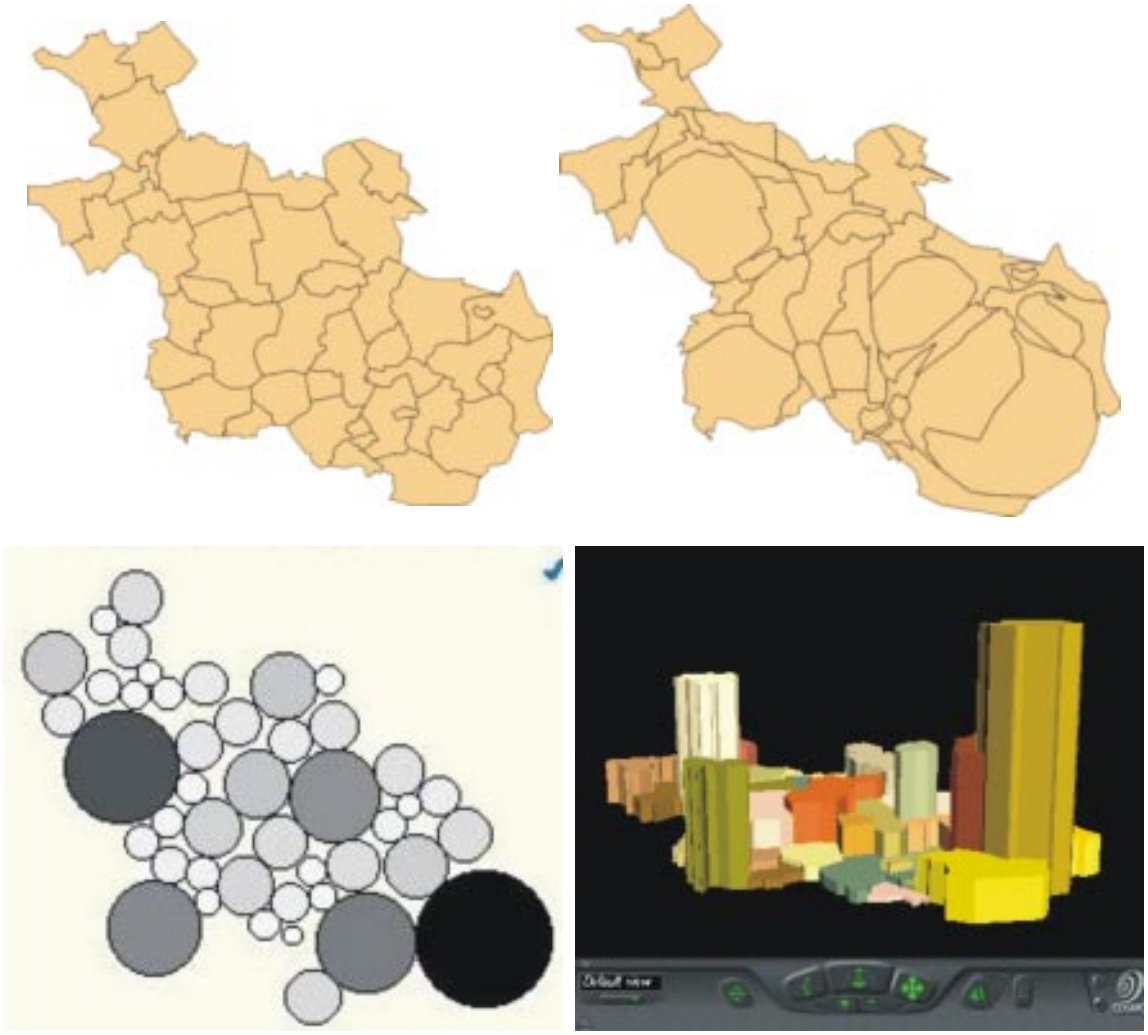

Figure 4. Alternative views: cartograms and interactive 3d views.

6. Again maps

Maps are certainly not boring. That must be obvious from the above. Many new challenges lie ahead, some even outside the traditional realm of geo-sciences. However, the term cartography somehow seems to have an unjustified, dusty image. What can be done about it? Can / should something be done? Personally I tend to use the term geovisualisation instead of cartography. Visualisation used not only to depict geospatial data in a presentation or an exploration environment, but also applied to a map processed behind the geospatial data handling process. Some of my cartographic colleagues do not always appreciate this approach. They argue, "What is wrong with cartography, and why use those trendy words?" From a certain perspective they might be right, but sometimes change is needed just to wake up and stop too much inward looking. Recent developments in our geo-world and around justify, no, even require change. If cartography raises a traditional view on maps it is justified to try something new.

Irrespective of this discussion it is still about maps, which remain the valuable products they used to be. Expertise is still required, but differently, since the role of maps has changed and expanded. In the past (paper) maps were

designed to be both database and presentation media. Digital cartography and GIS have split these tasks, but these days the link between the two tasks can even be better preserved. In modern on-screen environments one can store much more data behind the map, than on a single paper map. Linking multimedia elements to the map can enrich the maps even more, especially on the WWW with its hyperlink options. The new mapping environments can be characterised by two keywords: interaction and dynamics. Maps work.

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