

## Web cartography

### Cartographic design for the Web

GROWING AWARENESS OF the importance of the natural and physical environment has led to an increasing availability of geographical information derived from geospatial data, data describing the geographic reality. The World Wide Web has enabled the integration of geospatial data from various distributed resources, resulting in a Geospatial Data Infrastructure (GDI).

Since the digital revolution in cartography, geospatial database creation and -management, geo-processing, and visualisation became more and more separated. The Web boosted this practice: WebGIS now provide Webmapping applications facilitating the functionality of a GIS be distributed across the Web, spanning the whole globe. The interface between the client and the service of the Geospatial Data Infrastructure is provided by Webmaps generated by WebGIS software. To make sensible use of these Webmaps the Webmapping application has to take into account the specific characteristics of the Web as visualisation environment, the expected mode of use and the capabilities and drawbacks of WebGIS software.

Chapter three provided an extensive literature review, addressing the characteristics of the Web as a visualisation environment for cartography that impose various mapping constraints. This chapter served as a partial introduction to the establishment of requirements for the cartographic design of Webmapping applications.

The introduction of the theory structuring map use in chapter two and several mapping constraints not discussed in the previous chapter aid in adjusting the theory to the context of the Web, so the theory can be applied to types of Webmap use. This provides a theoretical background for the definition of different Webmap use goals, each requiring specific visualisation strategies: requirements for cartographic visualisation. These visualisation strategies provide additional requirements to enhance the description of the functionality of an ideal WebGIS software package, as the mapping constraint posed by the purpose for which the map is used is the overriding determinant of a map's final character (Muehrcke & Muehrcke, 1994, p.15). This description forms the basis for the design of the problem that is used to benchmark several commercially available WebGIS software packages.

### Using Webmaps

ANYONE WITH A computer and an Internet connection is able to access the Web. The Web has enabled the Geospatial Data Infrastructure (GDI) to disseminate geospatial data across the globe. Anyone with a computer and an Internet connection can access the Web to retrieve geospatial data to cater for their own requirements of geographic information.

The enormous amount of geospatial data provided on the Web poses a major problem. Therefore, the lack of available data as a mapping constraint is not valid anymore on the Web, but the opposite holds true now: the abundance of data has become a mapping

constraint. Developing Webmapping applications has to take this mapping constraint into consideration by providing tools for user-friendly queries and retrieval when studying the massive amount of geospatial data. A new scientific discipline has evolved to solve the problem of data abundance: *scientific visualisation*.

Developments in scientific visualisation are having a major impact on cartography as well. Applied in cartography, it offers clients the possibility of instantaneously changing the appearance of the map. Interacting with the map will stimulate the client's thinking and will add a new function to the map. As well as communication, it will prompt thinking and decision making. These developments stimulated DiBiase to define a model for map-based scientific visualisation (Kraak, 1998, p.48).

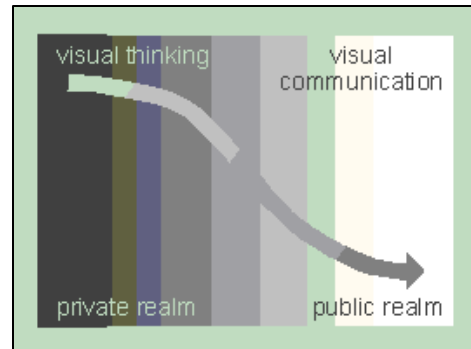


Figure 6. Visualisation in scientific research.

This model covers both the communication and thinking functions of the map. From the perspective of map use, each function of the map requires a different visualisation strategy based on audience, data relations, and the need for interaction (MacEachren & Kraak, 1997, p.337; Schlimm, 1998, p.5). From this description it becomes clear, that usually the requirements for cartographic visualisation result from the interplay of mapping constraints: the availability of data caters for the various purposes of a diverse audience. This interplay of the mapping constraints is looked further into in the following paragraphs.

## Public visual communication

The communication function in the model of DiBiase is described as “public visual communication”, because it concerns maps aimed at a wide audience. It is obvious that this fits into the traditional realm of cartography, where the cartographer works on known geospatial data and creates communicative maps.

Most people accessing the Web are not used to reading maps, yet geographic information could be vital in their daily decisions (Huber, 1994, p.51; Plewe, 1997, p.39). They may just be surfing the Web, looking for something interesting and stumble upon a Webmap. In this case, the Webmap is used as final presentation, with a low level of interaction (Brown, 1993, p.132). The Webmap as interface to the Webmapping application must be intuitive and easy to learn. Users should be able to carry out some trivial GIS and mapping functions and to immediately grasp essential information.

## Private visual thinking

The model for map-based scientific visualisation defines the thinking function of maps as “private visual thinking”. This 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. Experts are consciously accessing, querying, and processing a particular geospatial database across a corporate Intranet. Therefore, the Webmap becomes an interactive working document and plays an important role in supporting geospatial decision-making (Brown, 1993, p.132). To reach the appropriate decisions, the design of the Webmap has to facilitate private visual thinking about the geospatial data sets displayed in the Webmap.

The link between the Webmap and the geospatial data set as well as access to GIS tools to describe and manipulate the data are of major importance. Interaction between the user and the geospatial data set facilitates these processes (Kraak, 1999, p.163). This interaction

requires more powerful computer capabilities on the client-side. Furthermore, users should have substantial knowledge of the geographic phenomena and of the appropriate analytical processes, as the relation between the geospatial data under analysis is not always clear. The audience of Webmapping applications for private visual thinking thus mainly consists of geoscientists and GIS-experts.

## Demand and supply

This paragraph discussed the specific purposes of Webmap use: public visual communication and private visual thinking. Each purpose results from the interplay of other mapping constraints like the availability of data and the audience. The different purposes gave rise to a distinction in interaction that is necessary between users and the Webmap to meet their mapping purpose. In the next paragraph an overview of Webmaps is presented. This overview gives insight into how the Web is able to cater for the ways that Webmaps are used for a specific purpose. A comparison of the demand for certain Webmaps to facilitate a specific purpose and the supply of Webmaps available provides a basis to formulate requirements for the production of Webmapping applications with regard to the needs of the user. These requirements then can be added to the process of designing the benchmark.

## Maps on the Web

Webmaps are very effective for the transfer of geographical information derived from geospatial data that can be accessed via the Geospatial Data Infrastructure on the Web, as they provide insight and overview that cannot be provided with other means of communication enabled on the Web. The previous chapter provided a technology-driven approach to Webmapping, as it discussed the various ways Web technology enables the generation of Webmaps, the inclusion of Webmaps in hypertext-documents, and their display in the Web browser.

This paragraph, however, presents a user-oriented approach to Webmapping as it discusses the display of Webmaps based on the level of interaction between users and Webmaps. The previous paragraph already highlighted this interaction as a crucial element determining the usefulness of Webmaps for a certain purpose. It is also this interactive character that makes the Web an interesting visualisation environment. Furthermore, it is expected that especially interaction awaits future developments (Elzakker & Koussoulakou, 1997, p.10).

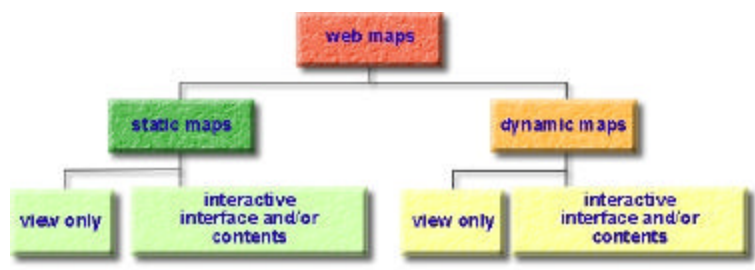


Figure 7. Classification of Webmaps

Kraak presents a classification of Webmaps giving an overview of current possibilities (Kraak, in press). This overview is only a snapshot in time, since the Web evolves tremendously fast. The classification distinguishes between static and dynamic Webmaps. Static maps are a familiar view on geographic reality. They represent a slice in time and give the impression of a stable, immobile environment. These maps are usually displayed in other visualisation environments, e.g. on paper. They can also be easily created by computer mapping and GIS software and incorporated into a hypertext document (Peterson, 1997, p.1639). Web technology allows also for display of dynamic processes via animation. Dynamic maps are about change; change in one or more of the components of the geospatial

data. The most common examples of animated maps on the Internet are those of weather patterns (Beddoe, 1997, p.2171; Peterson, 1997, p. 1639).

However, for the scope of this thesis dynamic maps are left out of the discussion. Though for some Webmapping applications the WebGIS software generates Webmaps based on a geospatial database through a live link (as the contents of the database are updated automatically, the Webmap contents is changed accordingly) and therefore may be classified as dynamic, it still results in a static Webmap. The limitation to focus on static Web maps only emphasises the interaction between users and Webmaps once more. In the next discussion, the reference to “static” is dropped, because this attribute is already apparent from the exclusion of dynamic maps.

## View-only Webmaps

Static maps that do not allow any type of interaction are the most common types of maps available through the Internet. The most prevalent view-only Webmaps are those that have been scanned from paper maps and stored in a GIF or JPEG format (Peterson, 1997, p.1639). However, the use of conventional maps presented on screen produces a lower level of performance in simple map reading tasks when compared to their use in paper form (Gooding & Forrest, 1990, p.19). A second form of view-only Webmaps are those that have been specifically designed for display in a Web browser. A last form of view-only Webmaps, is the PDF-format. By means of the Adobe Acrobat plug-in these maps can be viewed online, but they can also be printed, allowing for higher print resolution.

## Interactive Webmaps

Webmaps may offer more than view-only functionality. They might for example offer an interactive view to the user by offering zooming, panning, or hyperlinking to other information resources elsewhere on the Web. The much-used “clickable maps” are examples of the latter and they can be very useful to have the map act as an interface to the geospatial data. Clicking on geographic object could lead the user to quantitative data, photographs, sound or video or other information sources on the Web. It is also possible to have the user interactively determine the contents of the maps, by choosing data layers, and even the visualisation of the information, by choosing symbology and colours. Among the different forms of Webmapping applications, the interactive sites have gained the most interest and financing (Peterson, 1997, p.1639). The most popular of the interactive sites have been those that generate street or road maps (Beddoe, 1997, p.2171).

## Visualisation strategies

The second paragraph of this chapter discussed the specific purposes of Webmap use: public visual communication and private visual thinking. Each purpose results from the interplay of other mapping constraints like the availability of data and the audience. The different purposes gave rise to distinguishing levels of interaction necessary between users and the Webmap to meet their mapping purpose. Based on the level of interaction, the previous paragraph presented an overview of Webmaps, giving insight into how the Web is able to cater for the ways that Webmaps are used for a specific purpose.

**E**ach purpose of map use requires a different visualisation strategy based on audience, data relations, and the need for interaction (MacEachren & Kraak, 1997, p.337; Schlimm, 1998, p.5). This paragraph draws attention to the requirements for cartographic visualisation, visualisation strategies, to cater for the different purposes of map use, as the mapping constraint posed by the purpose for which the map is used is the overriding determinant of a map’s final character (Muehrcke & Muehrcke, 1994, p.15).

## General visualisation strategy for the Web

Though there is a need for specific visualisation strategies for the different purposes of Webmap use, there are common requirements to be kept in mind when developing Webmapping applications. As the general mapping constraints posed by the Web are already discussed in the previous chapter, the constraints brought forward here are the geographic reality and the conditions of use: the generation of map types and interface design.

### Map types

Developing Webmapping applications, the WebGIS software must be able to process both thematic maps and reference maps. The geospatial data is stored per category in layers. The thematic maps have to be able to display both quantitative and qualitative data, e.g. by means of choropleth maps and chorochromatic maps (Ormeling & Kraak, 1999, chapter 8). Each map type has its own characteristics making the map type especially suitable for the display of a specific geographic reality (Muehrcke & Muehrcke, 1992, p.15). As the WebGIS software provides a life link to the data, updates can be easily produced from the server-side, or the user may manipulate the data from the client-side.

### Web interface design

The circumstances of map use vary greatly, especially on the Web. Cartographers have no control whatsoever on the configuration of the client-side, user-defined Web browser preferences and screen settings. Nevertheless, the interface has to be designed such that the Webmapping application is able to cater for a specific purpose of Webmap use. On paper maps, marginal information used to provide the user with background knowledge on the data represented on the map and the purpose of the map (Ormeling & van der Schans, 1997, p.101). On the Web, the marginal information can be located near the Webmap itself if there is space available. Otherwise, it can be located near the bottom of the page (Plewe, 1997, p.214). They can also be made available on request by means of pop-ups, saving even more space in the interface (Ormeling & Kraak, 1999, p.186).

When designing the interface of the Webmapping application, the location of the tools to interact with the Webmaps relative to the graphics display is important (Plewe, 1997, p.212). The relative location is based on the importance of the tool for interaction to the audience. These tools are described in further detail in the next paragraphs.

Apart from the interface design of the Webmapping application in the Web browser, the application should allow for printing a specific view of the Webmap (Ormeling & van der Schans, 1997, p.102). This functionality is necessary, because especially the general public does not always have access to a Webmapping application at home. For example, they use Internet facilities at the local library and generate a Webmap that they want to keep for later reference. This requires control on the layout of this document. The layout can be pre-defined from the server-side, or the user can select which elements of the Webmap view and which marginal information to display for printing.

## Public visual communication: view-only Webmaps

In the model of DiBiase, “public visual communication” is about the transfer of geospatial knowledge presented in maps aimed at a wide audience. This purpose of using Webmaps can therefore best be equated with cartographic communication. For this purpose, the cartographic discipline provides a comprehensive cartographic language with associated rules, strategies and conventions that may serve as a visualisation strategy so the Web may provide a visualisation environment to support this public visual thinking. Derived from the previous paragraph, it can be concluded that this purpose for map use requires little interaction. Therefore, view-only Webmaps serve this purpose best. Nevertheless, some interaction is necessary anyway. The levels of interaction as presented in the previous paragraph should therefore be considered as a sliding scale, not as a strict dichotomy.

In order to evaluate the applicability of the rules, strategies and conventions for designing Webmaps supporting public visual communication, it is useful to consider the semiotic approach adopted by Bertin (Bertin, 1983) and many others since. By breaking cartographic design into the graphic variables, it is possible to isolate the various mapping constraints imposed on the contents of Webmaps for public visual communication (Stynes et al., 1996, URL).

### **Graphic variables with a spatial component**

Not generally treated as a graphic variable, location may be considered the variable most central to cartography. As HTML and CSS do not have a browser-independent way to specify the exact placement of screen elements, the location of all geo-referenced elements has to be stored in one screen element (Kuunders, 1998b, p.14; Meyer, 1998, URL), either in raster or vector. However, there is no standard for explicit geo-referencing of raster or vector data in Web document (Stynes *et al.*, 1996, URL).

Size is another graphic variable with a spatial component. This aspect has been treated in the previous chapter already where area features were concerned. Due to differences in client-side configuration of screen size and addressability, the actual display area varies by a factor of 9 (Stynes *et al.*, 1996, URL). With regard to lines on the Webmap, one has to keep in mind, that the smallest line width is one pixel, about four times the width of a printed hairline on a paper map (Roche, 1998, p.4)! As the pixel size is the only measure for line width and this measure has but a interval measurement level, the angular separation (Bertin, 1985, p.178), the difference in width between lines which is discernible on screen, has to be kept in mind.

The quality of lines is best at an angle of 0, 45 and 90 degrees (Ditz, 1997, p.574). Lines not orientated vertically or horizontally may be systematically distorted both spatially when re-sampled to the orthogonal grid of Web graphics, and spectrally if subject to anti-aliasing. The variability in the way different Web browsers resample images can make this problem more acute, certainly less predictable. A very bright colour of lines tempers this effect because of irradiation but causes problems in distinctiveness. A black underground would improve the contrast but it is not useable for the representation of black line elements. As cartographic images are only a representation of reality, the author can not influence the orientation of line elements. However, the cartographer should pay attention when introducing “artificial” lines, e.g. graticule lines or grid lines. For example, only orthogonal grids are not subject to distortion.

When applying the graphic variable of size to point elements, it should be borne in mind, that the most significant change in relative size occurs at scales approaching the pixel resolution of the graphic. Point symbols should not be too small. As point symbols are often represented by special typefaces as Symbol and Carta or native fonts as MapInfo Real Estate or ESRI Oil, Gas & Water, their size often has to be defined by type size. This is discussed later with other considerations on text. In the context of Web delivery, the other graphic variables with a spatial component, orientation, and shape, are subject to the same constraints imposed on size and location. For example, minor variations in shape at almost pixel-level may not be noticed.

### **Graphic variables with a spectral component**

Each of the three components of the HSV colour model are considered separate graphic variables. While there is a huge body of literature on colour selection and matching in digital cartography, there are several problems that are exacerbated on the Web (Stynes *et. al.*, 1996, URL). Some of these have been discussed previously with regard to the Web-safe colour palette.

It has to be kept in mind, that the application that surrounds the Webmap also uses some colours. Whereas there is almost an unlimited choice available for the printed map, the choice for Webmaps is limited to about 130 (Roche, 1998, p.4). In extreme cases, where for example safety is dependent on the correct identification of colours under all circumstances, as on

electronic charts, the number of different colours used may be no more than about 5 to 8 (Brown, 1993, p.131)!

Although the cartographer has no control over value and saturation, these graphic variables are more important than hue as by finding the optimum balance, the differences in display of hue are less important (Weinman, 1998, p.35). The gamma-setting of the screen display is important, for it defines the value and contrast of the display. Especially the contrast value is important. The representation on a Mac is usually lighter than on a Windows PC. Even when using the Web-safe palette, one must avoid saturated colours. While value is the most widely used of the colour variables for representing ordered data it can be significantly altered when rendered by a Web browser (Stynes et al., 1996, URL).

### **Combined spatial and spectral graphic variables**

The issues discussed previously are equally relevant to the graphic variable of texture, as this variable is controlled by both spatial and spectral factors. The problems associated with hue have interesting implications for texture since dithering results in texture that has not been deliberately introduced by the cartographer. This could cause problems if similar textures have been explicitly designed elsewhere in the Webmap. This focuses the attention once more on thoughtful colour selection from the Web-safe colour palette. Though, texture design may not be too big a problem, for this graphic variable is hardly used in paper maps as well.

### **Graphic variables and text**

As with the graphic elements of points, lines and polygons, the graphic variables of Bertin may also be applied to text. As one letter is considered to be a point, a line of text as a line and a page as an polygon all the implantations of the two-dimensional space are catered for.

The graphic variable of form can be applied to text as typeface. The issue of typeface selection has been discussed already in detail in the previous chapter. Only sans-serif typefaces should be considered on Webmaps, but even in this case, some typefaces are more suitable than others (Ditz, 1997, p.575). Though texture is not a powerful variable when applied to graphic elements, when applied to text it becomes all the more persuasive as texture applied to text elements can be thought of as type size. As pointed at in the previous chapter, selecting type size for the display of text is also limited. Applied to text, orientation can be thought of as slant: the distinction between roman and italics. It is important to notice that type size is already covered by the graphic variable texture. The graphic variable size, when applied to text, refers to the distinction between regular and bold text. Font style offers few possibilities to prepare text for screen display (Ditz, 1997, p.575). Besides the options "normal" and "bold", the other possibilities cannot be used for display in Web browsers. When using italics some characters cannot be discriminated. The use of italic text, which served for distinction on printed maps might be compensated with the use of colour.

Alignment of text common for lettering hydrology and street names cannot be realised on screen when aiming at high cartographic image quality. The raster display of the Web browser introduces systematic distortion both spatially when re-sampled to the orthogonal raster grid, and spectrally if subject to anti-aliasing similar as for lines (Ditz, 1997, p.575). The use of special Web characteristics should compensate for this lack of cartographic design e.g. dynamic labelling when the mouse pointer moves over or clicks on a particular map object.

In general, text should be used scarcely on the map, because of huge space consumption supported with a short-time utilisation of lettering on screen. For example, the display of text can be limited to when users move the mouse cursor over an element they want to get information from (Ditz, 1997, p.575). As the user creates each new map view, the features must be dynamically labelled, starting with those features of high priority and then continuing with features of minor importance. The labelling must avoid collision and clutter, especially at the map border (Roche, 1998, p.4).

## **Graphic variables on the Web: constraints and challenges**

The Web provides a visualisation environment for Webmaps supporting public visual communication. From the discussing the various graphic variables for the implantations of space and for text presented here, it becomes clear that not all of them are equally useful on the Web. Some variables may not even be useful at all in this visualisation environment, whereas they were valid in an analogue environment and vice versa. Summarising the remarks made in this paragraph, it can be said that the Web as visualisation environment poses severe constraints on the graphic representation of geospatial data, whereas at the same time these constraints can be surpassed by the new challenges of the Web.

## **Private visual thinking: interactive Webmaps**

The emphasis in private visual thinking is more on the development of ideas, rather than, as in traditional cartography, on presentation (Fisher *et al.*, 1993, p.136; Lee, 1995, p.37; Marks, 1998, p.25). Reflecting the position of private visual thinking in the model of map-based scientific visualisation of DiBiase, there is only limited design input. Since the Webmap is often temporarily displayed, the time put into a thoughtful cartographic design is not worth the effort. Furthermore, the audience of a Webmapping application for private visual thinking is often limited to few GIS-analysts, requiring less attention to the established principles of cartographic design, as they are familiar with the geographic phenomena displayed. Nevertheless, any transfer of geospatial information benefits from an appropriate cartographic visualisation strategy. Thus, even in visualisation environments to private visual thinking, cartographic design principles developed for public visual communication should be available (Kuunders, 1998b, p.16). The emphasis when developing a Webmapping application for private visual thinking turns more towards the interactive functionality. Therefore, interactive Webmaps serve this purpose best.

## **General visualisation considerations for interactive Webmaps**

Interactive visualisation introduces new challenges and considerations for classic cartographic visualisation strategies (Fisher *et al.*, 1993, p.141). Caution must be exercised, when applying the cartographic rules developed for communicating view-only maps to the design of visualisation environments intended for highly interactive map use for private visual thinking (Dykes, 1997, p.1365; MacEachren & Kraak, 1997, p.340). The prime objective of the cartographic visualisation strategy for private visual thinking should be to display clearly where the interaction takes place in the Webmap and what the results of interaction are (Brown, 1993, p.133).

When geo-processing very large spatial data sets, the cartographic visualisation strategy must not overly complicate or slow down operations as scrolling, panning and zooming, because the time users spend looking at Webmaps is already much shorter than that for analogue maps (Brown, 1993, p.133; Kuunders, 1998b, p.16; Schlimm, 1998, p.2). One means for reduction can be the display of scanned analogue maps as a background on which to perform vector type operations (Kraak, 1998, p.50).

## **Interaction tools for private visual thinking**

Private visual thinking about geospatial data is a three-step process. In the first step, the visualisation goal is identified. This is covered in the paragraph dealing with presentation as map use goal. The second step in exploration is the removal of mental roadblocks: new ways of data-expression are used. Here, the new challenges of the Web provide interesting tools. The final step in this process is the detailed design of the map display (Kraak, 1999, p.166). Interaction and multimedia are the keywords in describing functionality for this step.

- **Basic display**

Since only a small part of the underlying geospatial dataset is displayed, users should be able to move to their area of interest by means of panning and zooming (Plewe, 1997, p.187). These geometric tools should always be available.

- **Navigation and orientation**

These tools involve the keys to the Webmap. At any time, users should be able to know where the view is located and what the symbols mean by means of overview maps, scale indicators and legends. The legend as key to the objects in the map should not contain more than eight themes visible at the same time, for it will make the map illegible (Plewe, 1997, p.195). Users should therefore be able to select which layers to display at one time.

- **Query data**

During private visual thinking, users should have access to the geospatial database to query the data. This requires tools for not only simple questions on location, attributes or time, but also to construct more elaborate questions and search requests. The queries can be constructed by form input, or can be map-based queries by selecting objects or defining areas of interest by buffering (Plewe, 1997, p.205). For example, the clickable map discussed in the previous chapter provides a tool for querying geospatial objects represented in the map to interactively access the geospatial database.

- **Multi-scale**

Combining different geospatial data sets is a common operation during private visual thinking. For some aspects analytical operations are required, but sometimes just a visual comparison reveals interesting geospatial patterns. The chance that these sets will have different scales and levels of generalisation. For geometric comparison, generalisation operators help solving these multi-scale problems.

- **Re-expression**

As not all types of thematic maps are suitable for making thematic comparisons, multiple options of visualisation, re-expression of the same thematic attribute should be enabled. As the map is linked to the database, the cartographic visualisation can be altered easily, resulting in a new map type. Tools are required to manipulate the geospatial data behind the Webmap, because thematic maps often have a different classification.

- **Multiple dynamically linked views**

These tools represent a combination of multimedia and brushing techniques. Tools should enable users to view and interact with the geospatial data in different windows, all representing related aspects of the data. These views do not necessarily contain maps; video, sound, text, etc. can all be included. Clicking an object in a particular view will show its geospatial relations to other objects or representations in all the other views. This requires links to be added to objects in the Webmap. Vice versa, it should be possible to bookmark or even to store a particular view on the Webmap, so linking to the Webmapping application from another data view immediately produces the appropriate view on the Webmap.

### **Spatial data access**

These tools have no function, if users cannot directly access a geospatial database or, more likely, multiple databases. Under ideal circumstances, users have access to them on the corporate Intranet. However, exploring spatial data nearly always involves accessing different types of data from different sources: the key to data access will be the Web. "Access" in this context stands for finding and retrieving. In the case of WebGIS software, retrieving the geospatial data is most important. The visualisation environment for private visual thinking should include not only the tools described previously, but they should also be integrated with Web-retrieval tools so users may add layers themselves to the Webmap (Plewe, 1997, p.199). In such an environment, the user is indeed able to interact with the Webmapping application for private visual thinking.

## Cartographic visualisation strategies for Webmaps: a summary

To make sensible use of these Webmaps the Webmapping application has to take into account the specific characteristics of the Web as visualisation environment, the expected mode of use and the capabilities and drawbacks of WebGIS software. Whereas chapter three addressed the characteristics of the Web as a visualisation environment, this chapter provided a theoretical background for the definition of different Webmap use goals, each requiring specific visualisation strategies: requirements for cartographic visualisation. These visualisation strategies provided additional requirements for the development of Webmapping applications

In the next chapter, these requirements and the ones formulated in the previous chapter serve as input for the description of the functionality of two Webmapping applications, one for each Webmap use goal, that should be developed by the ideal WebGIS software package. This description forms the basis for the design of the problem that is used to benchmark several commercially available WebGIS software packages to evaluate the capabilities and drawbacks of each WebGIS software package.

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## Benchmark problem design

### Introduction

THE WEB ENABLES integration of geospatial data from various distributed resources, resulting in a Geospatial Data Infrastructure (GDI) to disseminate and gather geographic information. Since the late 1990s, many players in the field of the geosciences have recognised the necessity to become part of the GDI. Through Webmapping applications they provide their customers with services to view, gather, analyse, and explore geographical information via the Web.

To develop these Webmapping applications, almost all major leading GIS vendors do WebGIS software. For organisations to make sensible decisions on which WebGIS software to choose, they often execute a benchmark test. This benchmark is a practical experiment to assess the operational use of specific software for a certain task. Benchmarking software implies several steps. A problem is designed that the ideal software should be able to deal with perfectly, based on a description of the ideal performance of the computer programme to execute a certain task according to the requirements set by the organisational duties. 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 software package.

As benchmarking implies performing a practical experiment to assess the operational use of specific software for a certain task, a real-life case serves as a context for the benchmark. In this set-up, a formal User Requirements Analysis (URA) that usually is the input for constructing a benchmark problem cannot take place as a real-life organisation is not available. To overcome this drawback, the regional government for the province of Overijssel in the Netherlands serves an imaginary context from which organisational requirements can be drawn. Another source of input for requirements is the literature review about cartography and the Internet. An important aspect when selecting a specific WebGIS software package, is the ability to generate Webmaps that are suitable from a cartographic point of view for a specific mapping purpose, because these Webmaps are the main interface between the client and the service of the GDI: the Webmapping application. From this cartographic perspective, the selection has to take into account the specific characteristics of the Web as visualisation environment, the expected mode of use and the capabilities and drawbacks of WebGIS software.

Chapter three addressed these characteristics of the Web as a visualisation environment for cartography based on an extensive literature review, structured by the mapping constraints imposed by the Web. The theory structuring the expected mode of using Webmap that was introduced in the chapter two was taken further in chapter four, adjusted to the context of the Web. This description served as theoretical background for the definition of different Webmap use goals, each requiring specific visualisation strategies: requirements for cartographic visualisation. These strategies were input for the formulation of additional requirements, enhancing the description of the functionality of an ideal WebGIS software package.

In this chapter, the organisational context of the imaginary government office of the Dutch province of Overijssel and the requirements for cartographic visualisation on the Web that have been derived from literature review are used as an input for the description of the benchmark. These smaller tasks can be taken apart further into test items. The performance of each WebGIS software package is evaluated based on these individual test items. The score for the test item is context-sensitive and can only be applied to the situation described in this thesis. Nevertheless, these values give a guideline for the performance in other situations.

Taking the organisational context of the imaginary government office of the Dutch province of Overijssel, two different requirements for Webmapping applications can be distinguished. First, there is the requirement for the officials themselves to analyse and explore geospatial data over an Intranet. Second, the office needs to communicate geographic information to the general public over the Internet. These requirements define specific Webmap use goals. Each of them requires a particular visualisation strategy: a specific set of requirements for cartographic visualisation. These two requirements for the dissemination of geospatial data can be mapped to the model for map-based scientific visualisation that distinguishes public visual communication and private visual thinking as Webmap use goals. Different sets of requirements have to be met by the WebGIS software to test their capabilities to generate Webmapping applications for a specific Webmap use goal.

However, this distinction should not be interpreted as a strict dichotomy. First, there are certain aspects which have to be taken into account that do not stem from the Webmap use goal directly, but need attention because of the characteristics of the Web as a visualisation environment. Second, there is a sliding scale from the one Webmap use goal to the other especially with regard to the level of interaction between the user and the Webmap as mentioned earlier. Finally, the Webmap should always be able to communicate the message even for private visual thinking.

In the context of this thesis, three different aspects are tested. First, WebGIS software must be able to handle the available geospatial datasets and it must be able to produce softcopy and hardcopy maps of the geospatial datasets. This aspect can be summarised as the input and output task. Second, WebGIS software must be able to generate a Webmapping application for public visual communication, addressing a large audience of people interested in the province of Overijssel. Finally, the WebGIS software must be able to generate a Webmapping application for private visual thinking. This application enables GIS professionals to analyse and explore the geospatial available about the province of Overijssel. In the following paragraphs these three aspects of WebGIS software are described to establish a basis for the benchmark.

## Input and output of geospatial data

TO COMPARE THE WebGIS software packages fairly in this benchmark, the same input data about the Dutch province of Overijssel is used. There are two reasons for this standardisation of the input data. First, the government office of the province of Overijssel mainly needs to have geographic information only about the region itself. Second, the standardisation of the input data is necessary, because the comparison of the capabilities of the software under study should not be flawed by the geography of different regions and the available geospatial data about these regions.

Since each situation requires a particular cartographic visualisation strategy, the varying character of the geography and the available geospatial data themselves may lead to contrasting appearances of maps of different regions. This heterogeneity may flaw the observation of differences that exist between the WebGIS software packages. In reality however, data sources may differ and each software package may behave differently.

## Task 1: Handling geospatial data

### File formats

The geospatial data about the province of Overijssel is available as ArcView themes in the ArcView shape-file format. This is a simple, non-topological format to store both the geometric location and attribute information of geographic features. This format defines their geometry and attributes in five different files. The most important files are the .SHP and .DBF files. The former stores the feature geometry, the latter stores the attribute information of features. However, only one of the WebGIS software packages that are being benchmarked, namely ArcView IMS, is developed by ESRI and can native support the ArcView file format. The other packages need to have some functionality to handle foreign file formats. This is a viable requirement, because ArcView GIS is almost the de facto standard for government GIS in the Netherlands.

One of the available themes contains detailed information of the forest areas in the province of Overijssel. Because of this detail, the size of this file is 3.37 MB, guaranteeing a long downloading time when the file is being transferred over the Web. This is frustrating for users. The file is converted into the TIFF raster file format to reduce its size. The TIFF file comes together with a TFW file containing the world co-ordinates for geo-referencing the image. Since the theme is included only as a background for reference and it is unlikely the theme will serve as input for geo-processing, this conversion does not reduce the usability of the file. In general, the raster data structure is useful for storing land use data. This conversion led to a size reduction to only 214 KB, making it more useful for transfer over the Web. The TIFF file is a bi-tonal file in which the attributes only indicate the (non-) existence of forest areas within the grid cell. The existence of forest areas is indicated by a coloured grid cell using a Web-safe colour (RGB=102/153/51). The WebGIS software must not only be able to handle vector data structures, but also raster data structures, in this case the TIFF raster graphics file format.

The strength of GIS is the combination of spatial and thematic data. Geographical objects are represented as map features on the map. These map features have specific attributes that can be accessed by users to derive more information from the map. Every ArcView theme has an attribute table, the .DBF file. This table can be joined with other thematic tables.

Thematic data can be loaded into ArcView GIS directly as a table (e.g. dBASE). As the organisational context is a large government office, it is more likely that the data is stored in a database server (e.g. Oracle). To connect to a database server, ArcView GIS has a SQL connection feature. To retrieve records from it, an SQL query is run. The records that are accessed become a table in the ArcView project. This table is like any other ArcView table. The PC version of ArcView performs SQL connections using Microsoft's Open DataBase Connectivity (ODBC). To handle thematic data, the WebGIS software packages must be able to access ODBC drivers.

### Map projection, co-ordinate system and unit of measurement

Displaying geospatial data on map requires a projection from a three-dimensional sphere to a plane. The map projection in the Netherlands is an oblique stereographic projection. The plane of projection intersects the reference ellipsoid (Bessel ellipsoid). This (circular) plane of intersection has a 122-kilometre radius and its centre is the projection of the benchmark located on the spire of the O.L.V.-kerk in Amersfoort on this plane of intersection (Ormeling & Kraak, 1999, p. 42). Every country has its own geodetic control network. This network is the foundation for the national co-ordinate system used for topographic mapping. In the Netherlands, this co-ordinate system is referred to as the National Triangulation System (*Rijksdriehoeksstelsel* = RD). The unit of measurement is the metre.

For the WebGIS software packages to handle the available geospatial datasets of Overijssel, cartographers must be able to define the map projection, the co-ordinate system, and the unit of measurement. The WebGIS software packages must at least enable cartographers to define a custom map projection and reference system. Even better, these should be provided as standard options.

Before cartographers can design the Webmaps to be generated by the WebGIS software, the software packages first have to be able to deal with the various data sources. The following benchmark items can be discerned to cope with this requirement.

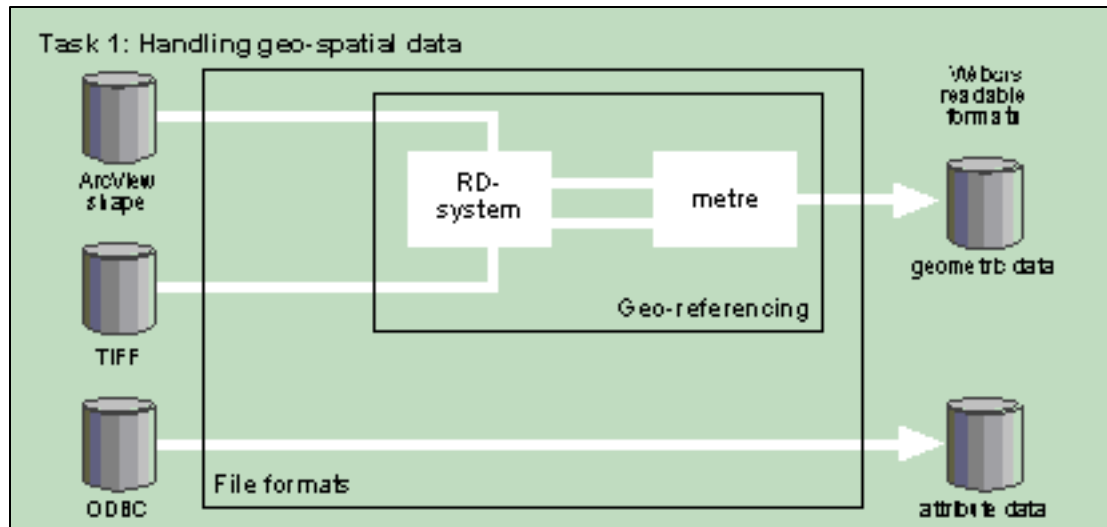


Figure 8. Flow diagram task 1

The WebGIS software must be able to access ArcView Shape files, TIFF files and ODBC data sources. For geo-referencing, the Webgis software must have options to define the reference system (rd-system) and the unit of measurement (metre).

## Task 2: Displaying the topographic map of Overijssel

The most important aspect of a Webmapping application is the cartographic visualisation of the Webmaps themselves. The WebGIS software must be able to generate various map types as part of the Webmapping application. In the first place, the geospatial datasets can be used to generate a topographic map. The ArcView themes contain geographical objects that can be represented by map features on the Webmap. Each theme has specific requirements for cartographic visualisation.

### Municipalities and built-up area

The first theme to be included into the topographic map contains the municipal boundaries. These administrative entities are an important aspect of the Webmaps. Most users will use them as the main cue for orientation. Another theme that is recognisable for users on the Webmap is the built-up area within every municipality. In the province of Overijssel, the built-up area per municipality differs. The different sizes of settlements can be grouped into five classes. Each class of settlements must have a different cartographic visualisation. Both themes contain geographic information about regions. These must be represented, especially at larger scales, by polygon map features. Polygon map features that represent the municipalities must have a stroke to emphasise their territory. This stroke must have a patterned form to distinguish the boundaries from other linear map features. A fill represents the actual municipality. Polygon map features that only have a fill can best represent the built-up areas. The fills of these settlements must be different. One of the municipalities, Ootmarsum, is fully surrounded by Denekamp. To differentiate between the administrative area of Ootmarsum and the built-up area of Denekamp, the map features that represent the built-up area must not only have a colour fill, but also a hatch pattern.

In order to represent these themes the WebGIS software packages must be able to generate polygon map features. Cartographers must specify a colour fill, a hatched pattern, and a patterned stroke for these map features. With regard to the colour fill, cartographers must select only from the “Web-safe” colour palette. The specific RGB values should be visible to the cartographers for individual identification of the colour. In this way, they can be sure the right colour is chosen from the palette.

At the larger scales, polygon map features represent the built-up areas. However, on smaller scales, these irregularly formed polygon map features make the Webmap illegible and require too long downloading time. The smaller built-up areas must be represented as point map features at a small-scale display. This change of cartographic visualisation can be interpreted as generalisation by collapsing the map feature’s geometry from polygon to point. The style definition must not render these point symbols too small. Since special typefaces or native fonts often represent point symbols, the size of point symbols is defined by type size.

### **Road network**

Another available ArcView theme contains the road network within the province of Overijssel from the ones maintained by the state government down to those maintained by the municipal government. For reasons of scale this layer is split into three separate layers, each distinguished by the governmental body responsible for its maintenance: a nominal classification. When displaying the road network, it has to be kept in mind, that the smallest line width is one pixel. For differences in line width between different road classes to be discernible on screen, the definition of line width has to be sufficiently robust. The difference can be emphasised by means of difference in colour of the line as well. Also for the road network there is a necessity for scale-dependent display. WebGIS software packages must be able to generate linear map features with different size (line widths) and different colours.

### **Static lettering**

Most users are not familiar with the geographical area that is represented in the Webmap. To help users finding their way around the Webmap, toponyms are an effective tool. Cartography makes use of lettering to put these toponyms of the associate map objects on the map.

With WebGIS software, it must be possible to label map objects in the Webmap according to cartographic theory of positioning. Positioning ensures the correct association of toponyms and map objects. Overlapping of labels must be avoided.

The labels must not scale when the Webmap’s scale is changed. In Webmapping applications, users frequently change scales, but they always want to see the labels for identification. For example, if a map object is labelled with its toponym, this toponym will remain the same size next to the map object irrespective of how closely users zoom in on the map object or how far they zoom out. Furthermore, this avoids cluttering the view and overlapping other important map features.

The WebGIS software must also provide cartographers with control over the typeface itself, type size, and type colour: common sans-serif typefaces in 10pt. Type colour compensates for the lack of other possibilities apart from “normal” and “bold” type to discriminate lettering as e.g. italic type. To have the lettering stand out from the Webmap, it must be possible to set a halo around the labels.

### **Generalisation**

The basic display tools facilitate interaction with an extensive geospatial database, despite the small size of the Webmap. Zooming out renders small map features illegible. Generalisation ensures legibility of the Webmap and correct visual communication of the geographic information at every scale of display. Furthermore, generalisation gives the impression that

the map features resemble the actual dimensions of the geographic objects they represent on the Earth. Finally, generalisation helps emphasising important map features.

There are several options to mimic generalisation. In ArcView GIS, the different categories of data are stored into different themes. Setting scale-dependent layer visibility, the themes that are less important can be switched off or new themes, intentionally designed for small-scale display, may be shown as scale is reduced. Another option is setting scale-dependent cartographic visualisation. In this case, the same geospatial data set is displayed at all scales, but depending on the scale, the cartographic visualisation changes to optimise legibility.

This generalisation is important for representing the topographic map. First, the smaller settlements have to be represented as polygon map features only at larger scales. At smaller scales, point map features represent the smaller settlements. When representing the road network, generalisation is important. The highways are displayed in the Webmap at all scales. With increasing scale, the smaller roads have to become visible. To give the impression that the map features represent that actual dimensions of the road network, the width of the lines has to increase also as scale increases.

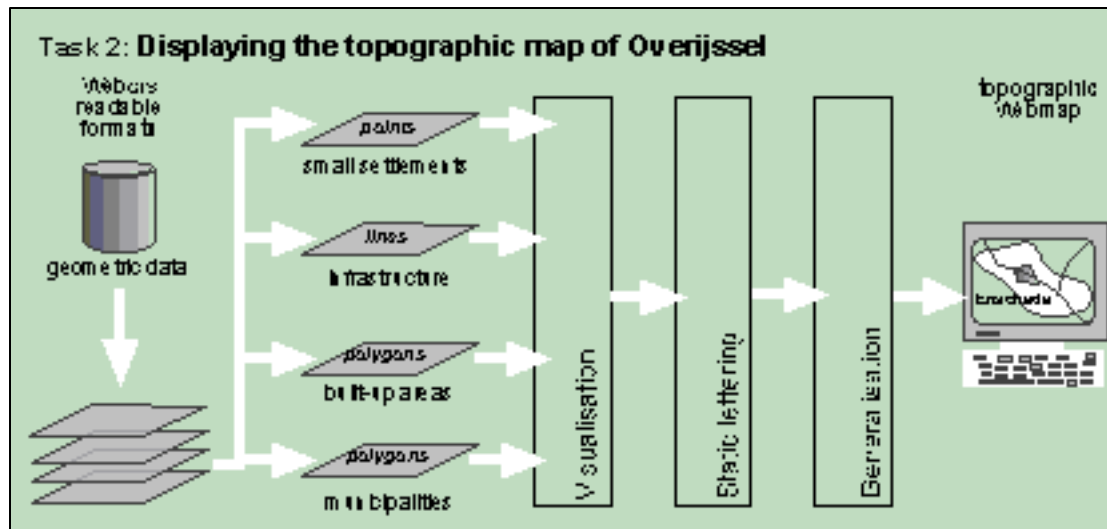


Figure 9. Flow diagram task 2

### Task 3: Displaying thematic data about Overijssel

Developing a Webmapping application, the WebGIS software must not only be able to generate topographic maps of the province of Overijssel, but also thematic maps. To be able to test the WebGIS software on their abilities to generate various map types, it is necessary to have different thematic data sets available that can be displayed using the different map types. Each map type has its own characteristics making a particular map type especially suitable for the display of a specific geographic reality that is captured in the thematic data sets (Muehrcke & Muehrcke, 1992, p.15).

First, WebGIS software must be able to generate chorochromatic maps. On the topographic map, the municipalities have the same colour fill. To distinguish better, each municipality must have its own colour fill. The chorochromatic map can be generated for the municipalities, based on the nominal classification of a unique variable, e.g. its toponym or key variable.

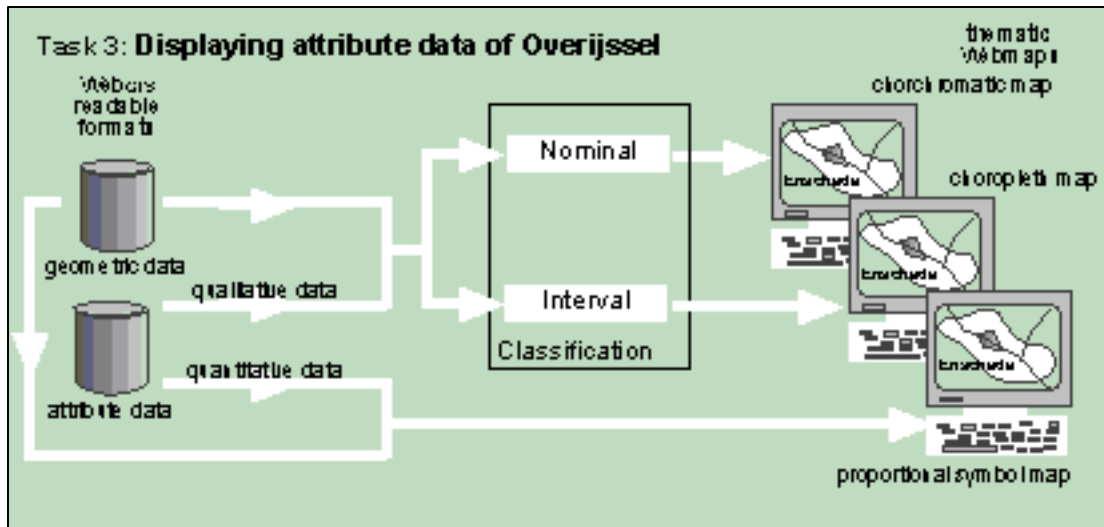


Figure 10. Flow diagram task 3

Apart from the topographic themes, there are several thematic datasets available containing statistics about the physical environment, the population, and economics. Some data sets provide relative values other data sets give absolute values. This requires different map types to display the data sets. Since the available datasets contain some statistics giving both relative and absolute values, the WebGIS software should at least be able to generate proportional symbol maps to represent the absolute values and to generate choropleth maps to represent the relative values correctly. As the choropleth map is the map type most often used for the display of statistical data, the priority for WebGIS software to generate this map type is very high.

Furthermore, the WebGIS software must provide different ways to classify the geospatial data. When generating these Webmaps, the graphic variables should be taken into account; e.g. the cartographer must be able to select appropriate colours to represent the values.

### Task 4: Output of hardcopy maps

Apart from generating Webmaps, the WebGIS software must allow for generating functionality in the Webmapping application for printing a specific view of the Webmap, together with the marginal information. This requires server-side control over the layout of the document, so users can print maps according to a pre-defined layout that assures cartographically correct hardcopy map output.

### Summary

These paragraphs described the various tasks that have to be performed by the WebGIS software with regard to the input and output of geospatial data. First, the software must be able to access the available data sources. Based on the data, the software must be able to generate both topographical and thematic Webmaps. This requires a correct application of the graphical variables and the ability to generate various map types adapted to the characteristics of the Web as a visualisation environment. However, the software must not only be able to generate softcopy output, but is must also enable users to print the maps.

These Webmaps are served on the Web to the users as part of a Webmapping application. Not only the Webmaps make up this Webmapping application, but the interaction tools are an important aspect as well. Users require different interaction tools to perform a specific map use task. In the next two parts of this chapter, the two map use goals are treated separately. One Webmapping application has to be developed for each map use goal, each having its own Web interface. The difference stems from the different interaction tools the users require and from the different ways in which these interaction tools have to be provided to the users.

## Communicating geospatial data to the public

THE MODEL FOR map-based scientific visualisation distinguishes two mapping purposes or functions: a communication function and a thinking function. Public visual communication addresses the former function. In the context of Web cartography, this function is concerned with Webmaps aimed at a wide audience. It fits into the traditional realm of cartography, where cartographers work on known geospatial data and create communicative maps. Since most people accessing the Web are not used to reading maps, yet geographic information could be vital in their daily decisions, the Webmap must be intuitive and easy to learn. Users should be able to carry out some trivial GIS and mapping functions and to immediately grasp essential information. These Webmapping applications have been designed for a general purpose.

In this paragraph, a Webmapping application is described from which to derive benchmark items for which the WebGIS software packages have to be tested. This Webmapping application provides a service through which the provincial office communicates geographical information about the province of Overijssel to a general audience.

### Task 5: Webmapping application interface for communication

Developing Webmapping applications for communicating geographic information over the Web, still the circumstances of Webmap use vary greatly. Cartographers have no control over the configuration of the client-side, user-defined Web browser preferences and screen settings. To ensure optimal visual communication, cartographers still must have some factors over which they have control. The design of the Webmapping application interface is one of these. After the Webmap has been transferred over the Web, the interface of the Webmapping application is responsible for its display and for providing a GUI for the interaction tools.

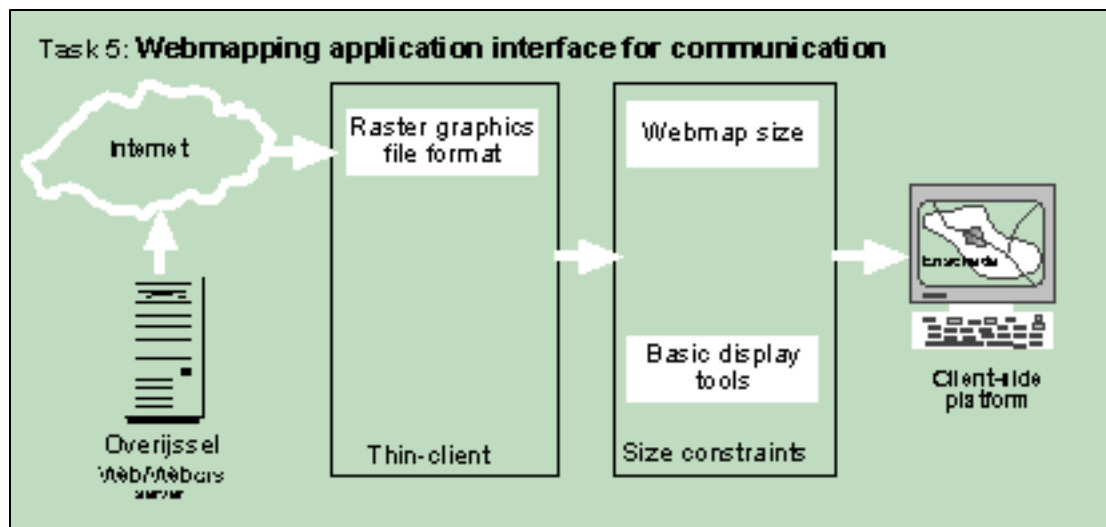


Figure 11. Flow diagram task 5

### Raster graphics file formats

Cartographers control the technology that is used to embed the Webmap into the Web document that is being displayed in the Web browser. For developing a Webmapping application targeted at a wide audience, the starting-point for the provincial office is to implement a thin client configuration: a Web browser that displays Webmaps as GIF images embedded into a Web document. This configuration entails a lot of data transmission, but

there is only little need for intensive server-side geo-processing as users only carry out some trivial GIS and mapping functions.

### Webmap size and basic display tools

Cartographers must be able to control the size of the Webmap. The Webmap provides the main interface for the Webmapping application. However, the size of the Webmap must not be too large, because this slows downloading time. For every new view of the Webmap, a new raster graphics file has to be transmitted. Since the Webmap only gives a small view on the geospatial data set, graphics-based basic display interaction tools have to be added to the Webmapping application to change the view of the Webmap by panning, scrolling, and zooming.

### Task 6: Transferring geographical knowledge

When developing Webmapping applications for the general audience, the interface should not only hold the Webmap itself and some basic display tools to change the view of the Webmap on the underlying geospatial database. It is likely, that most of the audience needs to have more tools to grasp the geographic information embedded in the Webmap. These tools are the navigation and orientation tools. These tools provide information about the Webmap, not about the map features. The map legend and lettering are standard cartographic means to inform the audience about the map features themselves.

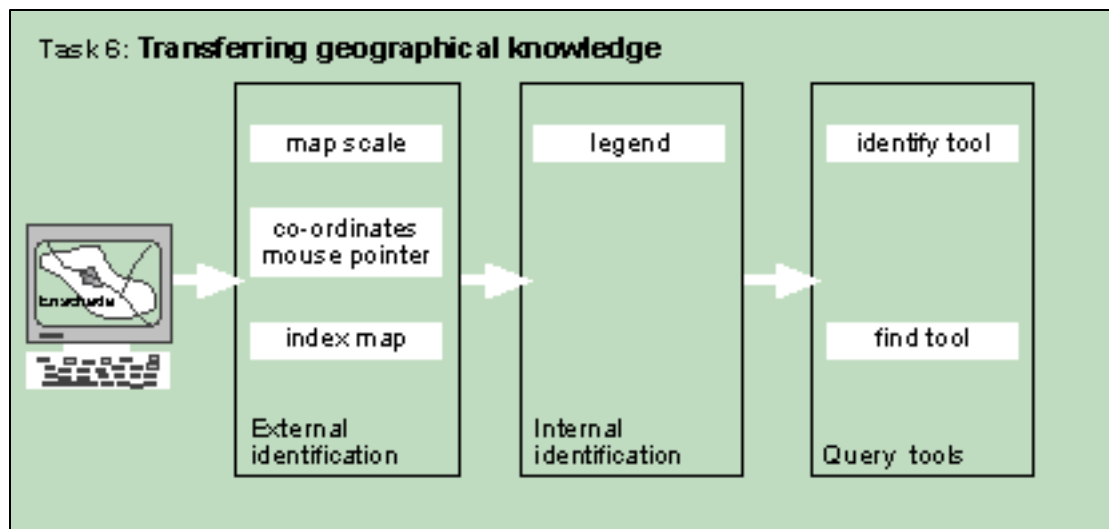


Figure 12. Flow diagram task 6

#### External identification: scale, co-ordinates, and index map

The limited size of the Webmap makes it necessary to incorporate some basic display tools to facilitate the disclosure of the entire geospatial database behind the Webmap. While changing the Webmap view by zooming, scrolling and panning, users need to know their location in the geospatial database and where to go. For their orientation and navigation users need to be provided with special tools.

The display of the mouse pointer's location in map co-ordinates easily communicates the exact location to the users. In order to reference this location to the location of other map features in the same user's view, the scale bar is a familiar tool. These tools transfer the location of the Webmaps in the geospatial database to the user. When users have established their location, they want to navigate through the geospatial database. The index map is an important tool for navigation as it shows the position of the map view in the geospatial database.

### **Internal identification: the map legend**

Apart from the Webmap itself and the basic display tools, the legend is the most important interface of the Webmapping application. The legend lists the names of the themes in the Webmap and their cartographic visualisation. Since the legend is such an important tool in the Webmapping application, it needs to be displayed at all times. However, not all themes must be included into the legend to avoid confusing users. Furthermore, hiding these themes from the legend avoids cluttering it up, while still having them drawn on the Webmap.

There must not be any interaction with the users to assure optimum communication of the contents of the Webmap. For, example, users should not be able to hide the legend as a whole from the interface, nor should they be able to hide particular themes. The legend must be automatically generated based on the contents of the Webmap as moderated by the cartographer. Since there is no client-side interaction required, a raster image of the legend is sufficient.

### **Query tools**

Webmapping applications for public visual communication must also provide a query tool. There are several reasons to provide this interaction tool already at this level of Webmap use. First, users must be able to carry out some trivial GIS and mapping functions to immediately grasp essential information. Second, these tools allow users to directly move to their area of interest, because the basic display tools sometimes take too long to move around the Webmap. Third, the Web as visualisation environment almost entices users to interact, especially when the geographic reality displayed in the Webmap is familiar to them. This evokes questions as “He, what is the value for this variable in my village?” Another case is, when they want to learn more about the geography by asking questions as “Hmm, what is this line here on the map?” These questions refer to the idea of the image map that already is an established tool for interaction between the user and the Web document.

## **Webmapping application for private visual thinking**

THE OTHER MAP function distinguished in the model for map-based scientific visualisation is the thinking function. Public visual communication addresses this function. In the context of this research, this function is concerned with Webmaps aimed at a discipline specialist, e.g. a geo-scientist or a GIS-expert. The emphasis is more on the development of ideas, rather than, as in traditional cartography, on presentation. Users should have substantial knowledge of the geographic phenomena and of the appropriate analytical processes, because they are consciously accessing, querying, and processing a particular geospatial database across a corporate Intranet. The link between the Webmap and the geospatial data set as well as access to GIS tools to describe and manipulate the data are of major importance. Interaction between users and the geospatial database facilitates these processes.

### **Task 7: Webmapping application interface for exploration**

Developing Webmapping applications for exploring geospatial databases over an Intranet, cartographers have more control over the configuration of the client-side than for a Webmapping application targeted at the Web. Furthermore, the user characteristics of the audience are better known. The interface can be more sophisticated and trivial information does not need to be provided at first.

### **Plug-ins**

To allow Webmapping applications to support services for private visual thinking, the client-side capabilities have to be extended by means of plug-ins or ActiveX controls. This ensures a high degree of rapid interaction as less data is needed to be transmitted for server-side geo-processing and the new map view is being created much faster. Simple operations as panning

and zooming can be handled on the client-side, whereas in a set-up without plug-ins, a new raster graphics file has to be transmitted over the Web for every new view of the Webmap. This rapid interaction is important, because the time users spend looking at Webmaps is already much shorter than that for analogue maps.

The disadvantages discussed earlier do not count so much anymore. In corporate network environments, the network administrators themselves may install this plug-in technology, to ensure that these added browser capabilities are supported corporation-wide.

### Basic display tools

The Webmap provides the main interface for the Webmapping application. Because of size limitations, the Webmap only gives a small view on the geospatial data set. Basic display interaction tools have to be added to the Webmapping application to change the view of the Webmap by panning, scrolling, and zooming. These tools must be available at will: their inclusion into the Webmapping application must be user-driven, preferably as part of a pop-up menu.

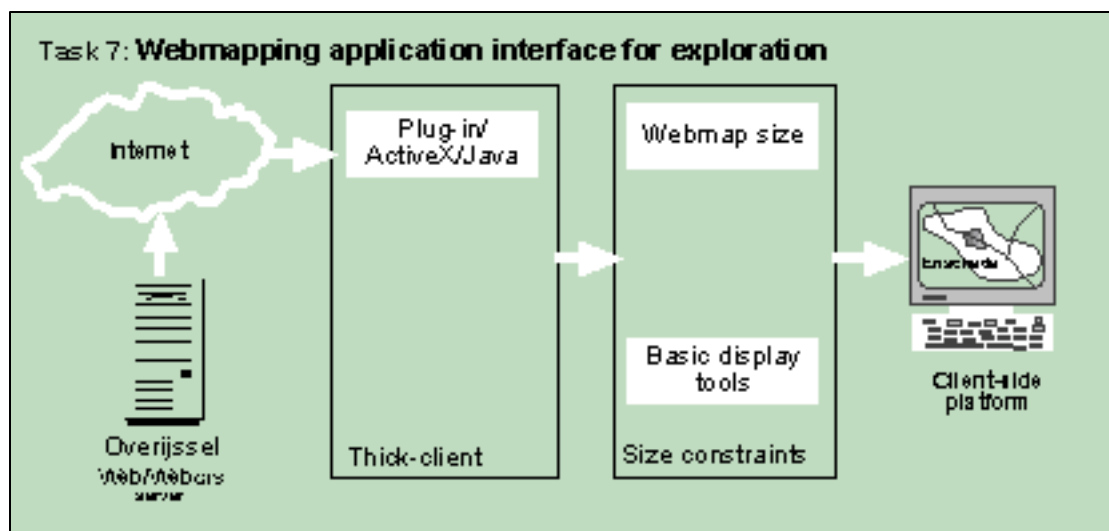


Figure 13. Flow diagram task 7

### Task 8: Background information: available on demand

It can be assumed that the GIS specialists at the provincial office of Overijssel are familiar with the area. There is no need to include the information provided by the orientation and navigation tools as standard interface elements. This group of users already knows where the view is located and what the symbols represent. They do not need an overview map, an indication of the scale of display, and a legend. Nevertheless, sometimes these tools might be very helpful. Therefore, the WebGIS software generated Webmapping applications should be able to have these tools available only on demand.

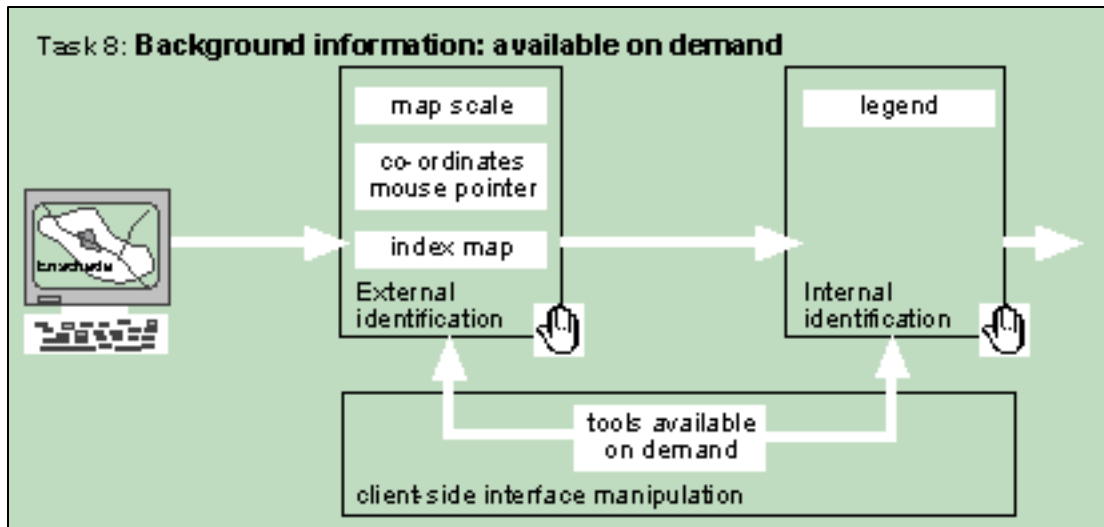


Figure 14. Flow diagram task 8

### Map legend

Some WebGIS software packages automatically generate a map legend with the Webmap to embed into the Webmapping application based on the themes that are included into the Webmap. Cartographers must be able to moderate the inclusion of themes into the map legend, but have them still appear in the Webmap. This is necessary if the Webmap contains themes that might confuse users if they were exposed in the legend. For example, the Webmap may contain themes that represent labels that are only drawn at particular scales. Hiding these themes from the map legend, avoids cluttering it up, while still having them draw on the Webmap.

### Task 9: Map legend theme control

Now that the cartographic visualisation of the themes can be made available to the users in the map legend, they want to control the display of the themes in the Webmap. The legend becomes a selection tool. This selection of themes to include in the Webmap is a process of conceptual or semantic generalisation. Users can focus on exactly the map features they want to see. Selection of relevant information from a geospatial database implies powers of abstraction that depend upon an understanding of geographical concepts (Jones, 1997, p.271). The GIS professionals at the provincial office can be viably assumed to have this necessary understanding.

Since users themselves control the display of themes in the Webmap, cartographers must be able to specify which themes are displayed in the Webmap by default when users log onto the Webmapping application and which themes are displayed in the Webmap only when users require this. Setting the default display properties for the themes, cartographers always have control over how users see the Webmap when they first log onto the Webmapping application, regardless of which themes were visible when the Webmap was generated.

Further user control on the Webmap is to change the order in which the themes display on the Webmap. This enables users to see certain map features more closely which might have been hidden in the default order of display. Furthermore, changing the display order of themes allows users to obtain better insight into the topology of map features.

For users to be able to focus even more on a specific theme, they might want to change the cartographic visualisation. This enables the users to emphasise particular theme in the Webmap.

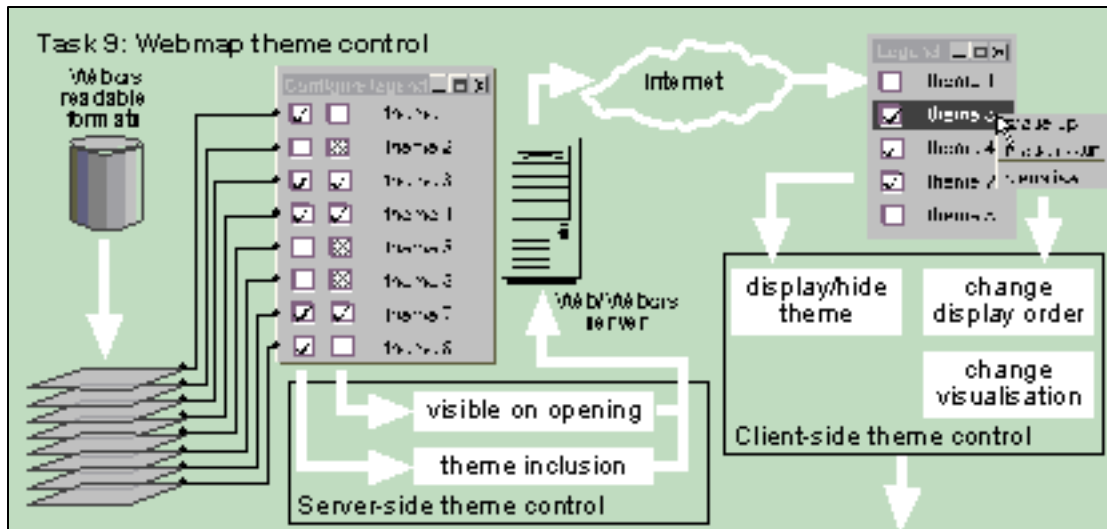


Figure 15. Flow diagram task 9

## Task 10: Information on single map features

### Dynamic lettering

Since the orientation and navigation tools are not readily available to the users, they should be able to find their way around the Webmap easily nevertheless. The inclusion of toponyms is a viable solution when aiming at a general audience. However, in the case of GIS professionals, superfluous lettering must be prevented: lettering should be used scarcely on Webmap because of huge space consumption. The labels might overlap other map features that are more important to the GIS professionals. Lettering of the Webmap should be implemented using dynamic labelling of map features when the mouse pointer moves over or clicks on it.

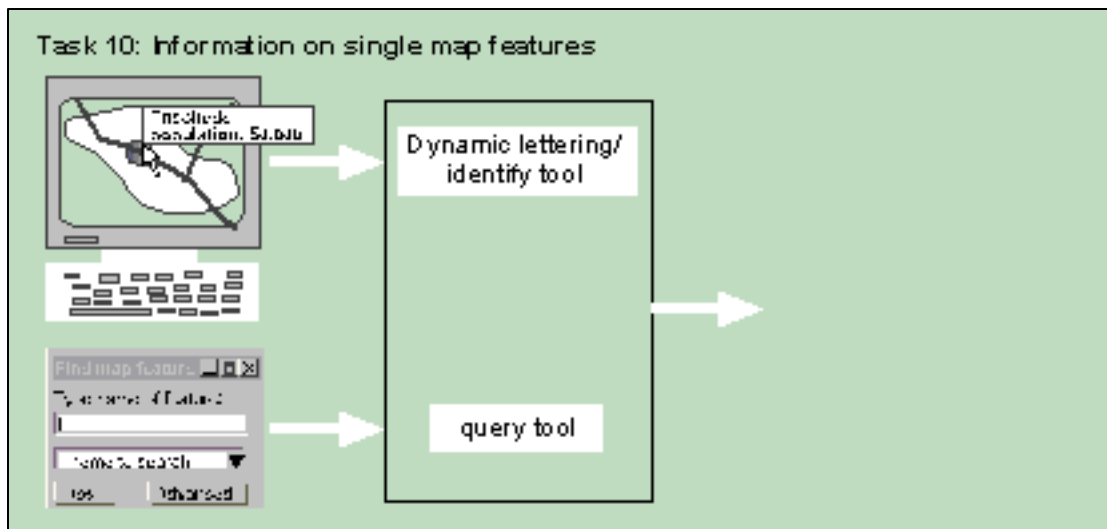


Figure 16. Flow diagram task 10

### Querying map features

Users must have a tool to quickly go to their area of interest. Especially in the case of GIS professionals, they should not spend too much time on panning and zooming around the Webmap before they are at the appropriate spot. A simple query tool facilitates this quick movement through the Webmap's geospatial database. Users must be able to control their availability. This can be achieved by implementing the tool as part of the pop-up window.

## Task 11: Geometric map comparison

The thematic datasets that are available contain statistics about various topics. Based on the available datasets, the following question serves as an example for the queries that the Webmapping application for private visual thinking must be able to deal with:

- How many people live in the built-up area of a particular municipality and are within 500 meters of a particular national highway assuming that 80% of the population of a municipality lives within the built-up area and assuming that the population is equally distributed within this area?

This question can be answered by these smaller questions that are put to the WebGIS software

- What is the name of the particular municipality/national highway that is on the Webmap?
- How large is the distance of 500 meters in the Webmap?
- Make a buffer of 500 meters around the national highway?
- What is the area of this buffering surrounding a particular national highway up to 500 meters on both sides?
- What part of a built-up area within a particular municipality coincides with this area?
- How many people live within this area?

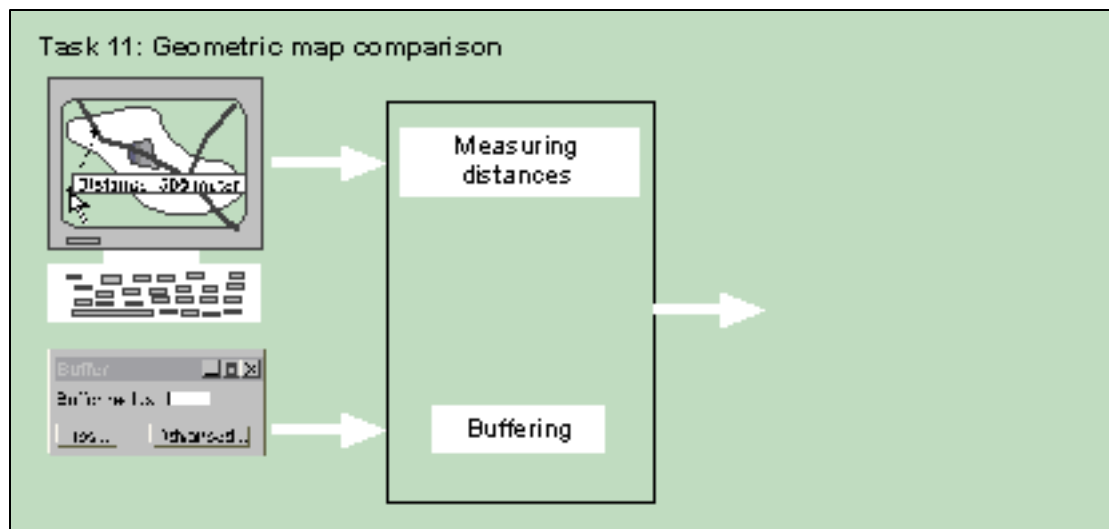


Figure 17. Flow diagram task 11

Since this benchmark focuses on the cartographic aspects of WebGIS software, its database management capabilities are not tested. From the previous list of questions, only two have a geographic nature. First, users must be able to measure a distance in the Webmap between map features. Furthermore, users must be able to make buffers around map features.

## Task 12: Integrating the Web

The Webmapping application addressing the GIS professionals of the provincial office, emphasises the development of ideas when dealing with unknown datasets. The Webmaps function as interactive working document and play an important role in supporting geospatial decision-making. To reach the appropriate decisions, the Webmapping application has to facilitate private visual thinking about the geospatial data sets. Combining different geospatial data sets is a common operation during private visual thinking.

- As the total amount of houses per square kilometre per municipality in the province of Overijssel is smaller, the higher is the average expendable income per inhabitant per municipality in the province of Overijssel.

- As the total population in the age category of 65 and up per municipality in the province of Overijssel is smaller, the higher is the average expendable income per inhabitant per municipality in the province of Overijssel.

As not all types of thematic maps are suitable for making thematic comparisons between the available datasets, multiple options of visualisation of the same thematic attribute must be enabled by the Webmapping application by means of “re-expression”-tools. As the map is linked to the database, the cartographic visualisation is altered easily, resulting in a new map type. The “re-expression”-tools must facilitate the visualisation of both relative and absolute values of the available datasets to provide correct images of the datasets. For comparison these tools must enable classification of these datasets according to various classification schemes. In the context of WebGIS software, these tools can be implemented easily by sending parameters over the Web as part of a URL, or by means of HTML forms, to the Web server. This is not really a requirement for the WebGIS software itself.

Users can compare the geospatial dataset easily, when Webmaps are displayed in different windows. The Webmapping application must provide “multiple dynamically linked views”-tools. These windows contain Webmaps (to allow for direct visual comparison) and multimedia. Clicking an object in a particular view shows its geospatial relations to other objects and representations in all the other views. WebGIS software must be able to add links to map features in the Webmap. Vice versa, it must be possible to bookmark a particular view on the Webmap, so linking to the Webmapping application from another data view immediately produces the appropriate view on the Webmap. The Web provides this multi-window environment itself. Therefore this is not a requirement for benchmarking the WebGIS software.

These tools have no function if users do not have access to a geospatial database. In the case of WebGIS software, retrieving the geospatial data is most important. The Webmapping application includes the tools described previously, and is integrated with Web-retrieval tools so users may add layers themselves to the Webmap. This allows them to test their hypotheses by taking more relevant datasets from the Web for analysis. However, not all datasets have the same necessity for access. From the server-side their access is restricted, e.g. for means of privacy or copyright. These exploration tools enable users to interact with the Webmapping application for private visual thinking.

### **Hyperlinks**

In short, the WebGIS software must be able to add hyperlinks to map features and to bookmark a specific view of the Webmap. This enables users to derive even more information from the Webmapping application. Users can hyperlink from one Web document to the other each containing another method of transferring information, e.g. text, tables, images, and video films, opening up the Web as an additional source for information.

### **Clickability**

Since users must be able to interact freely with the Webmapping application, the hyperlinks must be available at all times. This allows users to follow the hyperlink immediately by clicking on the map feature. Users must be sure they click on the right map feature and that a map feature is clickable at all. Therefore, clickable map features must have an alternative cartographic visualisation from non-clickable map features in the same theme and the mouse pointer icon must change as it is over a clickable map feature. These are familiar visual cues to Web browser users. Furthermore, the cartographic visualisation of map features must change on the moment the mouse pointer is over the particular map feature, corresponding to the image-rollover paradigm. This change indicates to the users on which map feature they click. Another means to indicate on which map feature the users click is to display the name of the map feature in the Webmap, as the **ALT** attribute value of the HTML <IMG> tag, and to display the URL in the status bar.

## Bookmarking

One can think of a Web browser as a book full of millions of Web documents. When users are looking at a particular Web document and want to be able to quickly get back to it later, they can create a bookmark for it. Using a Web browser, a bookmark is a saved URL-link to a Web document that has been added to a list of saved links.

Along this line of thought, the Webmap can be thought of as an interface to various views on a geospatial database. Users can pan and zoom to get a certain view of this geospatial database displayed in the Webmap. To save the current view in the Webmap, users must be able to add a bookmark. When they want to get to this view again, they simply choose the bookmark instead of panning and zooming all over again. This can save lots of time and effort.

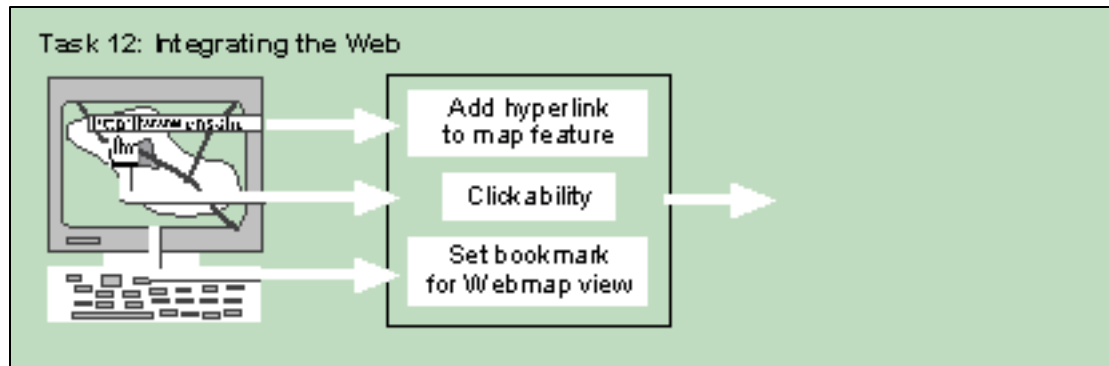


Figure 18. Flow diagram task 12

## Benchmark environment: client/server set-up

IN ORDER TO test the WebGIS software, it is necessary to limit as much as possible external factors that influence their performance. Otherwise, the conclusions drawn from the benchmark test results do not apply to the cartographic design capabilities of the particular software under study, but to the performance of the computer network configuration as a whole including the WebGIS software. Furthermore, the conclusions drawn would only apply to a specific case and cannot be universal. This requires an elimination of differences in the conditions of use enforced by the computer network environment. This configuration requires standardisation in such a way that only a particular WebGIS software packages has to be mounted onto the server-side. The standardisation of the computer network configuration is described here, taking into account the issues described in chapter 3.

**W**ebGIS is a Geographic Information System (GIS) distributed across a computer network providing a Webmapping application that integrates, disseminates, and communicates geographic information visually on the Web. 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.

### Server-side

To standardise the server-side of the computer network configuration, the system requirements of the four WebGIS software packages have to be compared with regard to their operating system (OS) dependency and the server software dependency. From this comparison, one OS and one server software is chosen on which all software packages run.

	AVIMS	MapXtreme	MapGuide	GMW
<b>OPERATING SYSTEM</b>				
<b>Microsoft Windows</b>	x			
- Windows 95/98	x	X		
- Windows NT	x	X	x	x
<b>UNIX</b>	x			
- Digital UNIX	x	X		
- Hewlett-Packard 700 / 800	x	X		
- IBM RS/6000	x	X		
- SGI	x	X		
- Sun	x	X		
<b>SERVER-SOFTWARE</b>				
<b>Microsoft</b>				
- Internet Information Server	x	X	x	x
- Personal Web Server		X		x
<b>Netscape</b>				
- FastTrack	x	X	x	
- Enterprise Server	x	X	x	
<b>Apache</b>		X		
<b>APPLICATION INTERFACE</b>				
CGI	x	X	x	x
ISAPI	x	X	x	x
NSAPI	x	X	x	

#### **Platform: Windows NT Workstation 4.0**

Windows NT is the most advanced version of Windows OS. Windows NT is a 32-bit operating system that supports pre-emptive multitasking. There are two versions of Windows NT: Windows NT Server, specifically designed to act as a server in networks, and Windows NT Workstation for stand-alone or client workstations. In networking, workstation refers to any computer connected to a local-area network. Nevertheless, the Workstation version of Windows NT can also be used as an operating system for a server platform. This OS is cheaper than the Server version and it is even said to be a more stable OS than the Windows NT Server.

Windows NT Workstation 4.0 has the Windows 95 interface, enhancing usability and efficiency. As mentioned before, this OS has the advantage of proven stability. With pre-emptive multitasking, users can work faster and run multiple applications simultaneously with increased responsiveness: e.g. users can work in other applications while lengthy Internet downloads occur in the background. The OS also provides easy Internet access, as the MSIE browser is included and TCP/IP networking support is already in place.

#### **Server software: Microsoft Internet Information Server 4.0**

Microsoft Internet Information Server (IIS) is an Internet file and application server included with Microsoft Windows NT. IIS can be used alone as a Web server, or in conjunction with compatible technologies, for example to build Web applications that take advantage of server script and component code to deliver client/server functionality.

The Microsoft Management Console (MMC) provides an administrator utility to manage the network environment. One tool of MMC is the Internet Service Manager. This tool gives administrators the ability to create Web and FTP sites, start and stop sites, and perform all other administrative tasks for the Web server or servers. Another feature of IIS is its application development platform. Active Server Pages (ASP) technology, server components, search and index features, and new transaction-processing capabilities are making development of server-intensive Web applications a growing component of Web development. Adding multiple components extends the capabilities of the Web server. For

example, the Data Access Components consist of ActiveX Data Objects (ADO) and Remote Data Service (RDS) - the Microsoft OLE DB Provider for Open Database Connectivity (ODBC) - and ODBC allowing programmatic access to multiple types of data

In addition to this example, third parties are developing solutions that work with Windows NT and IIS. They provide a multitude of services that expand the capability of the Web server environment. In this context, these solutions can be thought of as WebGIS software server components providing Webmapping applications.

### **WebGIS and server software: single computer configuration**

The server-side of a Webmapping application consists of a Web server and a WebGIS software programme. The server translates the client's 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 WebGIS software contains two parts. The first part is for developing the Webmapping application and is sometimes regarded to be a client to the Web server as well, although from a user's point of view it resides on the server-side (e.g. MapGuide Author). The second part takes care of the communication between the Web server and the part for application development. It is technically possible for the Web server to interface with the communication part of the WebGIS software between computers over a network. In most cases, these two programmes reside on the same computer. First, the two programmes are tightly integrated. Second, the current server interface architectures require the WebGIS software to be on the same computer as the Web server (Plewe, 1997, p.155).

Most WebGIS software provides several configuration options for the different parts of the WebGIS software. The single computer configuration contains all parts of the WebGIS software and the Web server on the same computer. The distributed computer configuration puts the communication part of the WebGIS on one computer together with the Web server, while the development part runs on another computer. Mostly, the development part of the WebGIS software resides on a separate computer, because different people have responsibility over each part of the WebGIS software. The server administrator is responsible for the communication part, while the cartographer has responsibility over the development part. In this research the single computer configuration is used for benchmarking the several WebGIS software packages. First, the server administrator and the cartographer in this research are one and the same person. Second, this reduces the influence of data traffic over the network between the different parts on the performance of the WebGIS software

## **Client-side**

### **Platform: Windows NT Workstation 4.0**

In a client/server architecture a client computer application requests services from a supplying application, the server. It is mentioned before, that an important feature of this computing architecture is that a client in some cases becomes a server and vice versa. This characteristic is used in the set-up of the client-side of the benchmark as the single computer configuration discussed in the previous paragraph is pursued. Putting the client and the server sides of the Webmapping application on the same computer further reduces the influence of data traffic over the network between the different parts on the performance of the WebGIS software. Therefore, the client-side OS is the same as on the server-side: the Windows NT Workstation 4.0.

Although this benchmark set-up does not cater for cross-platform testing, the multiple issues involved in operating system heterogeneity are borne in mind nevertheless when setting the requirements for cartographic visualisation of Webmaps.

Another source of heterogeneity on the Web is the variation of both the screen size and the addressability at the client-side, resulting in differences of the actual display area. To limit the influence of map size as a mapping constraint, a 15-inch monitor and an addressability of 800 x 600 have been selected as a standard for developing the Webmapping applications.

#### **Client software: Netscape Communicator 4.7 and Microsoft Internet Explorer 4.0**

The client of a Webmapping application typically is a Web browser, putting requests for a Webmap or some geo-processing over the Web to the remote server. Since the NCSA Mosaic graphical point-and-click hypertext browser of the early 1990s, a lot of different Web browsers have been developed over the years, among which Netscape Communicator (NC) and Microsoft Internet Explorer (MSIE) are best known. Of each browser several versions are in use simultaneously. For this research, these two major competitors in the “browser-war” have been selected as client-side software.

## **Summary**

Chapter three addressed the characteristics of the Web as a visualisation environment and the previous chapter provided a theoretical background for the definition of different Webmap use goals, each requiring specific visualisation strategies: requirements for cartographic visualisation. These visualisation strategies provided additional requirements for the development of Webmapping applications. In this chapter, these requirements served as input for the description of the functionality of two Webmapping applications that the ideal WebGIS software package should be able to develop. This description formed the basis for the design of the test items to benchmark several commercially available WebGIS software packages: to evaluate the capabilities and drawbacks of each WebGIS software package. This testing is described in the next chapter.