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7

Cartographic Limitations and Possibilities on Mobile Devices*

K Ram Mohan Rao, Rajinder Singh Nagi,
Milap Punia and Corné van Elzakker

The fields of geoinformation technology and cartography have seen dramatic changes in the last decade. The dissemination of digital geospatial data is no longer bound by desktop platform. It is now monitored on mobile devices such as Palmtops, Personal Digital Assistants (PDAs), and Smart phones. The map display on a handheld device is a challenge to cartography, due to the limiting factors of screen size, colours, resolution, processing power, memory and power supply. Though with technological advancements, these limiting factors are improving at a great pace, the small size display of devices still remains the same. Technological developments in the field of mobile computing are significant and more research is directed towards the use of mobile devices in geoinformation applications. However, new methods for location-based information, symbolization,

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data formats, context-based generalization and server-based real-time rendering are being explored for better cartographic visualization on the small display devices. Most of the present approaches are technology-driven, and have neglected the basic cartographic visualization aspects. This article aims to present the limitations, and possibilities of map design for mobile applications with design recommendations for improving visualization.

Introduction

Recent developments in cartography have shown that procedures of making and using maps have changed significantly. The fields of acquiring, managing, analyzing, interactivity and visualizing large amounts of geospatial data have witnessed highly vibrant and important development over the last two decades and these are continuing (Kraak, 2002). Cartographers have been modifying the design rules for screen maps using new technologies like multimedia, animation and anamorphosis, because the design rules for printed maps that deal with the map field, typography, colour management, piece composition, legend, title, margin decoration and back side, etc., are not suitable for screen reading anymore (Meng, 2003).

In this changing environment, the World Wide Web (WWW) is one of the latest new media to present and disseminate geospatial data (Kraak, 2002). The basic principles of map design do not change due to the new web environment, though it offers some new interesting possibilities like multimedia and animation, along with a few limitations (Kraak, 2002; and Kraak and Ormeling, 2003). While designing the Web maps, the physical design in terms of file size and display size (Kraak, 2002) also has to be considered. Web map design requires extra attention due to the constraints of media, resolution, and bandwidth problems. Just scanning paper maps or using default GIS maps for the web is not a good practice.

The popularity of handheld devices and mobile Internet gave a new platform to geoinformation. The cartographic display and design for these small devices

is a challenge due to their limitations. The growth of the Internet on mobile devices and the use of these devices as a tool for interacting with maps or distribution of digital cartographic forms offer new opportunities for cartographic communication and are hence seen as a major step in the digital revolution of cartography (Gartner, 2003).

The major difference in map presentation over the Internet and handheld devices is due to limited size, resolution, and colour display of current devices (Uhlirz, 2002). Though these are improving day by day due to technological advancements, at the moment, every graphical application still has to deal with these restrictions.

Evaluating Map Design Principles

Map design does not take place in a vacuum; rather, a number of factors or external forces influence the design process. These factors are the purpose of the map, reality, available data, map scale, audience, condition of use and technical limitations (Robinson *et al.,* 1995).

Factors involved in map design process include the analysis of geospatial data, the description of map content and requisite perception levels to depict the data based on the purpose of the map, the existence of map symbol association and standards, the scale and required accuracy. Most of these factors correlate and influence each other (Worm, 2001). In the past, the production of maps was with the realm of cartographers only. Their skills were a guarantee that authoritative maps were produced. The rise of geographic information systems has increased the number of those involved in making maps. The revolution around the World Wide Web has further increased their number (Kraak and Ormeling, 2003).

The basics of map design do not change because of the new web environment, although it does offer interesting extra opportunities. Similarly, map design principles remain the same for the latest mobile environments. As far as map display is concerned, the web as a medium, also poses some disadvantages. While creating a web map, the physical design has to be considered, in both file and display size. The first is important because people are not keen to wait for long downloads, and the second because the use of scrollbars to pan the map is also discouraging. Due to these characteristics, the design of web maps needs extra attention. Well-designed maps can be recognized, due to constraints as 'empty' because they have less information content and most of the information is behind the map image. This is not considered to be problematic, since a lot of information can be included behind the map image or at the back of individual symbols. The web environment gives option of interactive maps with possibilities such as mouse-over events, pull down menus, and hot spots. Access to this hidden information can be obtained *via* mouse-over technique, or by clicking on the map symbols. In case of the mouse over technique, the appearance of a symbol will change when covered by the cursor, or textual information will appear on the map. Clicking the symbol might open new windows or activate other web pages (Kraak and Ormeling, 2003).

Extra information could also become visible by using the so-called texture filters. Texture filters could have the shape of a magnifying glass and when this is moved over the map, the different levels can be shown. The possibilities offered by the web have extended the traditional cartographic variables as proposed by Bertin (1983) and opens the way to application of other "derived" graphic variables such as blur, focus and transparency, and shadow and shading (Kraak and Ormeling, 2003). Further, developments in the Internet have produced the possibility to disseminate three-dimensional virtual environments *via* the WWW using VRML (Virtual Reality Modeling Language). The WWW is an ideal platform to combine different multimedia (defined by interactive integration of sound, animations, text and (video) images) elements with maps (Kraak and Ormeling, 2003).

The graphic variables introduced by Bertin (1983) are widely used as guidelines for map design. He was mainly concerned with the monochrome maps, hence treated colour as single variable. Later, Robinson *et al.*, (1995) considered colour as three variables: hue, chroma (or saturation) and value (or lightness). In addition to splitting the colour into three variables, several authors have suggested additional variables or variations on existing variables (MacEachren, 1994 cited in Worm, 2001). For example, several variations of textures have been proposed based on directionality, size and density of patterns.

Overall, it can be stated that, the basic map design principles will remain the same, irrespective of the medium of display, while a new medium like web maps and latest mobile maps have brought plenty of new possibilities along with the limitations.

Limitations of Map Design for Mobile Applications

Map design principles are applicable to the mobile applications also, but the major problems are legibility and contrast in case of mobile devices. Everyday, consumers are generally less adept at understanding cartographic representation forms, a fact supported by the finding that about 64% of the general population has difficulty in reading maps (Streeter and Vitello 1986 cited in Urquhart *et al.*, 2003). Limitations of map design come from the limitation of mobile infrastructure. The limitations of mobile infrastructure can be divided into two categories i.e., Device and Network (Table 1).

Table 1: Limitations of Mobile Infrastructure

Display	Performance
Small screen size ^{D}	Slow connectedness ^{N}
Limited resolution ^{D}	High latencies ^{N}
Low (if any) color range ^{D}	Limited storage ^{D,N}
Interaction: Limited input opportunities ^{D}	Restricted processing power ^{D,N}
Restricted output capabilities ^{D}	
Note: D – Device, N – Network	
Source: Urquhart et al., 2004.	

Most of the technical limitations of mobile devices such as lack of processing power, low colour range, slow connectedness, limited storage, less bandwidth, are improving at a very fast pace with advancement in technology, but few limitations still prevail and will remain even in the future, such as the display size of the devices. User interface of a typical handheld computer has a resolution between 1200% and 400% lower than its desktop cousins, with mobile phones generally faring worse (Urquhart *et al.*, 2003).

The major limitation for map design is display size of the device. In a small display area, the details cannot be incorporated as in paper or digital maps.

The density of information should be less, thus putting great generalization pressure. Only generalization cannot solve the problem of map display because as a map designer, one has to communicate the message in an effective way, as per saying, "How do I say what to whom, and is it effective?" Hence, how can the message be communicated when less information content is a challenge?

Point, line and area are to be symbolized using the symbology principles and Bertin rules. In case of paper maps, digital and web maps, the user can understand the symbology by seeing the legend and other details on the map. The paper maps and digital maps generally use the geometric or abstract symbols to represent the ground features, which do not attempt to resemble the real feature represented. The same symbol can have different meanings in different maps. Therefore, they always require an exact explanation in the legend (Worm, 2001). Now, in case of mobile maps, there is no space for such legend and users do not have time to understand the symbols as well. Further, the user is mobile and consulting the legend to understand the map also interrupts the map reading process. These factors give another challenge to the map design. In case of paper maps and digital maps, generally, geometric symbols are used which acquire less space but need a legend or full description to understand the meaning of the symbols. These kinds of symbols cannot be used in mobile maps because, it intensifies the need for a legend. Hence, a map without a legend makes the map reading process more difficult.

Due to small display, the next limitation in map design is the legibility of the symbols and text. The minimum sizes of symbols defined in case of paper and digital maps cannot be applied to the mobile maps because of the typical characteristics of mobile devices such as small size, low resolution, and outdoor environment. A symbol should be large enough to understand its meaning, but as we have limited pixels, it is a great problem to optimally use the space and convey the appropriate meaning. Each and every feature cannot be labelled, because, it can make the map cluttered.

When designing maps for the screen, including web maps, new design possibilities arise, like, multimedia (sound and video), animation, and interactivity, because of the medium compared to paper maps (Worm, 2001). In case of

web maps or digital maps, the user is sitting in a relaxed environment and interactivity is high. But in case of mobile devices, the user is mobile and is in the outdoor environment, has less time and limited input facilities to interact with the map. This gives rise to a limitation to map design by ruling out much interactivity. Animation, which is quite common these days, cannot be used extensively in mobile map design because of the limiting processing capabilities of the device and low bandwidth.

However, various limiting technical factors come into play with respect to web maps because of the specific character of the web. One of the biggest limitations is the frequent need to keep file size small in order to facilitate downloading. This in turn leads to limit the amount of information on a map and take great care with generalization (Worm, 2001). The big file size of the map also causes the problem of functioning due to limited processing power of the systems. These limitations are even worse in the case of mobile environments.

Mobile devices have a low colour range varying from 8 bit (256 colours) to 16 bit (65,536 colours), as compared to desktop computers, which are having 16 million colours. When the maps are sent over the internet, the cartographers have little control over the viewing conditions at the user's end. Hence, while designing maps, it is safest to assume the user's configuration set to 256 colours. The web safe colours palette is used to guarantee 'non-dithered' images. The mobile maps are similar to web maps, which use 216 web safe colours due to the limited control on different viewing conditions at the user-end. The use of colours should be limited because the user will have a problem in identifying different colours due to the viewing conditions like sunlight. In case of mobile maps, visual contrast becomes more important considering the outdoor viewing conditions. This factor needs to be considered while designing the maps for mobile applications.

The speed of the mobile Internet is limited, as compared to the fixed Internet, since the processing power is less. Media such as animations, multimedia, etc., are useful web media, but these cannot be applied as such to mobile maps because of the limitations described above. Along with these limitations, mobile maps give the possibility of mobility. Hence, it combines the mobility of paper maps and accessibility and actuality of web maps (Van Elzakker, 2001). Mobility on the one hand provides the possibility of carrying the device everywhere, whereas, on the other hand, brought limitations for map design. As the user is involved in other activities being mobile, much interactivity with the maps cannot be had.

There are also other limitations like limited input, restricted output capabilities, high latencies and low storage. The environment in which the device will be used also brings limitations.

Possibilities of Map Design for Mobile Applications

Cartographic visualization on mobile devices causes a lot of problems due to limited capabilities of such devices. The major limitation is due to the display size and thus limits the information content presented in the device. This problem can be solved by first carefully selecting the information content required at a particular scale for a specific application, as in this case, the pedestrian tourist. The small display of devices limit the amount of information on a map, which can be solved by the most common solution—zooming and panning. The zooming option is available in three different ways as described by Worm (2001):

- Static linear zooming
- Static steeped zooming and
- Dynamic zooming (animated scaling).

Static Linear Zooming

The relation between zoom factor and map content is static. When zooming operation is applied to the map, the image is linearly enlarged without changing the content of the map. In this case, the map is simply stored as an image. Zooming option is most commonly applied in case of web maps (Worm, 2001) and even in the mobile maps. Most of the mobile applications use the scanned paper maps, which have static information. This will not give the effective information in case of mobile maps.

Static Stepped Zooming

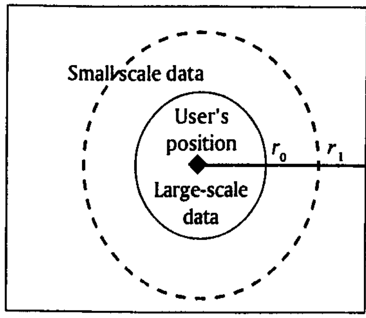
In this case, a series of maps of the same area is available, each one designed for a different scale or scale range. When the user requests 'zoom in' or 'zoom out', the software automatically chooses the most suitable maps for the desired scale. This is widely used in case of web maps and can be used in case of mobile maps. But it requires constant link with the server at high speed because, at each zoom in or zoom out activity, the data is retrieved from the server and rendered on the client device. The user generally has less patience and is mobile, hence, requires the map immediately. This problem can be solved with the upcoming Universal Mobile Telecommunications System (UMTS) network where, the device will always be available online.

Here, the approach of multiple representation databases can be used. According to Hampe *et al.*, (2004) a Multi Representation Database (MRDB) can be described as a spatial database, which can be used to store the same real world phenomena at different levels of precision, accuracy and resolution. To create the individual maps for a mobile device, real time generalization of data is often required. Despite the efficient methods developed in recent years, the available generalization process for going from large-scale to small-scale is very complex. Thus, to solve the problem of real time generalization, most of the studies have used the pre-generalized visualizations available at different scales.

Dynamic Zooming

In this case, there is direct relation between map scale and content. The larger the scale, the more detail is shown in the map. To achieve this, a direct link between map and some kind of database is necessary. The cartographic symbolization may change with change of scale (Worm, 2001). This may be possible ideally, if we have a database at each level of detail, and will thus solve the problem of generalization. At present, this situation is limited because, most of the countries do not even have a basic database to support such kind of activities. But in future, there could be the possibility to achieve better visualization at desired levels on mobile devices. In personal navigation, a user often needs both a detailed map of the area around his current position as well as an overview map. In cartographic terms, this means that the user requires both large- and small-scale data. To overcome this problem, a map can be created where the scale in the middle (close to the user's position) is larger than the scale in the border areas of display as shown in Figure 1.

Figure 1: Variable-Scale Map



Source: Harrie et al., 2002 taken from Hampe et al., 2004.

Now to show the information content in an effective way, the cartographer has to apply cartographic rules and grammar on point, line and area symbols to represent reality. As discussed in the previous section, symbology without legend is difficult to understand. The solution to this problem may be the use of pictographic symbols. Geometric symbols would not be preferred in case of mobile maps because, they cannot be understood without legend. On the other hand, pictorial symbols require large space to become legible. Thus the size of these symbols needs to be determined optimally so that, they give the messages in an effective way without hindering the other features of the map. The necessity of a legend can be overcome by designing the symbols in such a way that they are self-explanatory. But, this is an ideal case. Pop-up legends can be one option where a user based on his/her wish can turn it on or off. Viewing time for mobile maps is short, in comparison to web and paper maps. Further, Nivala (2004) emphasized in her study that a legend interrupts the users map reading process. Taken together, these lead to the use of simple, easily recognizable symbols and much of conventional map symbol associations such as blue for water, green for forest, etc., that are familiar to the users.

To make the symbols understandable, certain possibilities used in case of web maps such as mouse-over, tool tips, etc., can be used, which trigger the information in text form describing the object. One more possibility to increase the legibility of the symbol can be that while the user moves his/her pointer on the object, its size gets bigger and by clicking it, gives further information as shown in Figure 2.

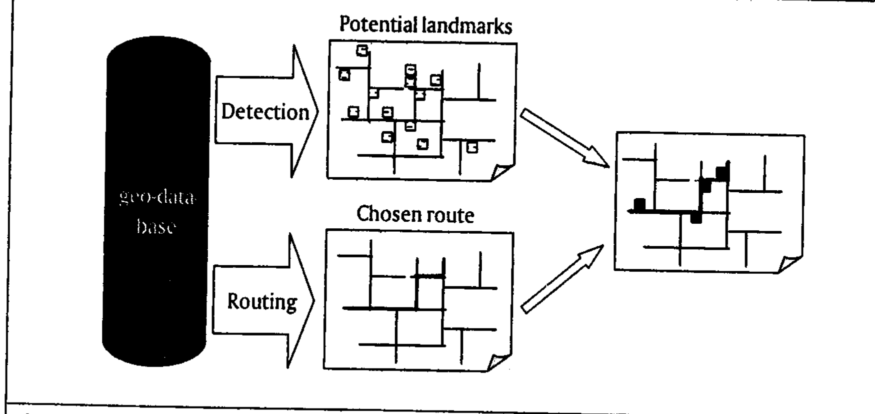
Figure 2: Mouse Over Effect

Maps on screen can also make use of graphic and symbol design options that, in the days of analogue paper map production, were not possible, or possible only with great effort (Worm, 2001). A lot of information cannot be placed in mobile maps due to the small display. Web maps introduced the concept of interactive web objects wherein, on clicking a particular object, the next level of hidden information can be triggered. In this way, a lot of information can be included behind the map images or individual symbols (Kraak, 2002). Due to this reason, Kraak and Ormeling (2003) termed web maps as 'empty maps'. This possibility can be available in case of mobile maps as well. Clickables can be used to access additional information on specific points or areas on the map that is not shown all the time and thus, help to reduce the overloading of the map presentation (Gartner and Uhlirz, 2001). Everything cannot be named in the map because, it will make it illegible to read and understand. Hence, the tool tip option can be used to make the map simple and easy to read. 'Tool tips' are used to show short written information as lettering and the advantage of this representation is as well not to overload the map graphics (Gartner and Uhlirz, 2001).

In cartography, the ordinary way to solve the problem of limited space while presenting spatial data is to generalize the data. The other option can be where the user gets the possibility to specify the information he needs for his purpose or specifies his purpose and the system selects the necessary data and leaves out unimportant details. As shown in Figure 3, a user wants to go from position X to Y, so, instead of giving all the irrelevant information, only selected information can be shown, based on his/her query. This can solve the problem of small display on the one hand while the problem of file size on the other.

The other option can be to only highlight the information specific to the user's needs along the route and dim all other objects. Because of this, the resulting map contains only the relevant information without any dispensable details. This helps the user to find these objects easily on the map and supports in recognizing the buildings in reality more easily. All the landmarks along the shortest path selected by the user can be labelled. Three-dimensional visualization is the possibility to gain an insight in the more complex data relations in the geospatial databases. The web offers an environment to create and distribute three-dimensional graphics rather easily. This can be an effective way of cartographic visualization because, we see the world in three dimensions but not two.

Figure 3: Presenting Route Specific Landmarks



Source: Hampe and Elias, 2004.

Most of the mobile map services used raster maps, thus, it is difficult to interact with them and require large space for storage and further the quality is poor. These kinds of problems can be solved by using vector approach. We can interact with vector approach easily. The downloading problem might be solved with advancement of technology and file size can be made smaller by using vector approach instead of raster approach. In vector approach also, Scalable Vector Graphics based on XML can be used which is text-based and contains very less file space as compared to the raster, thus making it easy to transfer large data through the narrow bandwidths.

As the maps in mobile devices would be frequently used in the bright sunlight, the contrast between features that would be suitable in the indoor environment may not be suitable in the sunlight. Thus, contrast between different features in the map need to be increased to enhance the visibility. During the night, the buildings or landmarks that are necessary to navigate may not be visible. To solve this

problem, the concept of active landmarks can be used. Active landmarks are the buildings that have sensors (using bluetooth technology) and when a user with the device moves near the building, it gives an alarm or highlights the building in the map, informing that the user is approaching the particular landmark.

Tourists moving in the city on Sundays try to find nearby restaurants, but since all the restaurants may not be open on Sundays, a visualization may be generated where all the open restaurants are shown as dark colour (raised symbols) and the closed ones in a dimmer shade. Further to enhance the visualization, the open restaurants may be defined as clickable objects.

The other case considered is where the user may not know the standard English language used in the map or he may be used to reading the local language. Hence, a visual to his needs can be created, showing the name of roads and features in the local language. These are some cartographic possibilities which can be used to make effective maps in the context of mobile environments.

Conclusions

Technological development in the field of mobile computing is significant and more and more research is directed to mobile usage of geographic information, numerous problems are yet to be solved and many gaps are to be bridged when it comes to developing solutions for mobile context (Reichenbacher, 2004):

- Geo-visualization for small displays of mobile devices is restricted by several technical limitations such as—the small display size and resolution, lack of processing power and memory, and most critical, the battery life. Furthermore, the mobile network bandwidth is considerably lesser than than in fixed networks.
- The usability of mobile geo-visualization solutions is hindered by inadequate geo-visualization. The causes are either the use of scanned paper maps designed for a medium with different characteristics or the production of illegible and cluttered maps that fit a large screen, but not the small mobile device screen with lower resolution.
- The geo-visualization on small displays is dominated by the constraint of small display sizes. This poses an immense generalization pressure. However,

the generalization alone cannot assure the fitness for use, required in mobile geographic information image situations. The lack of map space also implies that there is no room for auxiliary elements such as a map legend, which makes the map-reading process difficult.

Considering all these problems maps in the small screen require an economized map design, so that it may fulfil its role in the most effective and efficient manner.

(K Ram Mohan Rao, Scientist/Engineer 'SD', Geoinformatics Division, Indian Institute of Remote Sensing (NRSA), Dehradun, India. He can be reached at rammohan@iirs.gov.in

Rajinder Singh Nagi, Consultant, ESRI India, New Delhi, India. He can be reached at r.nagi@yahoo.com

Milap Punia, Associate Professor, Jawaharlal Nehru University, New Delhi, India. The author can be reached at punia@mail.jnu.ac.in

Corné van Elzakker, Assistant Professor, International Institute for Geo-Information Science and Earth Observation (ITC), Enschede, The Netherlands. The author can be reached at elzakker@itc.nl).

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