THE WORLD IN YOUR POCKET – TOWARDS A MOBILE CARTOGRAPHY

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Abstract

The dawn of new technologies on the horizon, such as telecommunication, mobile internet, and handheld computing devices, offers new chances to the discipline of cartography. However, existing approaches to mobile cartography mostly have a commercial background and are rather technology centred. This quite narrow view ignores many relevant problems and does not fully profit from the new possibilities a mobile cartography could provide.

Hence, we will sketch a general conceptual framework for cartography in a mobile environment. After the identification of specific user tasks and requests in a mobile environment suitable models of context and user's interests or preferences are highlighted.

The process of adaptive and dynamic generation of visualisations for mobile users is illustrated and the key research fields involved are pointed out.

An example demonstrates the benefits of dynamic visualisation of geoinformation on mobile devices. It should illustrate the basic ideas of mobile cartography and prove the flexibility of vector data (e.g. SVG) as an efficient and useful means of visualisation in a mobile context.

Introduction

After the tremendous success of the Internet and the cellular telephone in the last decade the next technological wave seems to be the convergence of the two: the *wireless Internet*. To better understand the chances of this technology for cartography, we will first consider the pros and cons of paper maps and digital maps.

Printed maps have according to (Goodchild 1999) the following characteristics: visual, flat, exhaustive, uniform in level of detail, static, generic, precise, and slow. However, paper maps are also mobile and in certain aspects flexible, but not adaptable in terms of the user's preferences and his context.

In the nineties *web maps* and *digital maps* on CD-ROM became popular basically due to the success of the Personal Computer and the Internet used in many households. These mapping technologies allow personalisation and adaptation, are easily deliverable, revised in shorter time, can incorporate multimedia, and may be interactive; however, they are *not* mobile.

The emergence of *mobile computing and wireless devices* has brought about a whole palette of new possibilities for cartography. New mobile information devices (MID) such as PDAs, Smartphones and the like put forward several advantages for personal assistance during mobility: they can present up to date spatial/nonspatial information in a very individual, dynamic, and flexible way – and the user being *mobile*. They can provide and run many other services/applications (appointment scheduler, address book, e-mail, etc). The vision is to present the user always the right information in the right moment at the right place. The versatility of these mobile devices though is only possible under certain conditions: screen size, colours, and resolution are limited compared to analogue and stationary digital visualisations. Size, weight, robustness, and power supply of the MIDs account for further limiting factors.

Taking into account all these drawbacks, the focus must be put on several new possibilities such

devices can offer: context integration, adaptability, personalisation, true dynamism, and flexibility.
It should be noted that most of the previously mentioned attributes are not new to the discipline of cartography. But, unfortunately neither paper nor web maps possess only positive attributes.
The goal is therefore to integrate these positive characteristics of both concepts in a conceptual framework of *mobile cartography* and use them efficiently to balance the overall benefit. This will also allow co-existence of paper, web, and "mobile" maps, each in their application spaces, where they exceed. The aim of this paper is to introduce this new concept and to highlight some of the core building blocks and arising research questions as an overview in the following sections.

A conceptual framework of mobile cartography

Although different concepts of IT, GIS and web mapping introduced some substantial innovative issues to cartography, none of them fully covers the scope of cartography in a mobile context. These fields have all their own point of view (market, technical issues) and follow their own rules. A comprehension of the concept of mobile cartography and its scope is still missing. It is therefore time to bring these divergent views into one coherent and convergent concept. We will therefore put forward a new concept called mobile cartography.
Mobile cartography deals with theories and technologies of dynamic cartographic visualisation of spatial data and its interactive use on portable devices anywhere and anytime under special consideration of the actual context and user characteristics.
On the one hand we use the term *mobile* since it reflects the user's mobility. Attributes like wireless are too narrow and put the emphasis rather on technology. On the other hand we use the term *cartography* to distinguish our concept from mobile mapping or mobile GIS, where the focus is on real-time graphic rendering or analysis in the field without design.
Figure 1 shows the basic framework of mobile cartography. The key components are information, context, user, visualisation, and technology. This introduction will briefly discuss these core elements. The following chapters will cover context, user models, and adaptive visualisation in more detail.

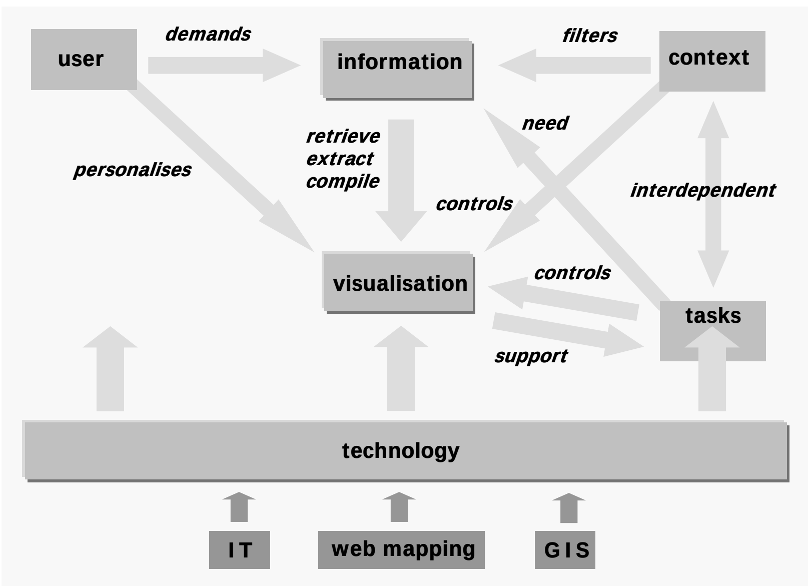

Figure 1: Conceptual framework of mobile cartography

information:
Spatial information useful for mobile cartography is hold in the Internet as a huge information pool (other buzzwords and concepts are *Infoverse*, *distributed geolibraries*, and *Digital Earth*). This information is distributed, very heterogeneous and differs in scale, quality, underlying data types, price, and availability. It can be maps, images, geographic features or other resources. It can be either explicitly or implicitly geocoded. In the latter case automated *geo-referencing* mechanisms are needed. Furthermore, extraction procedures and spatial data fusion techniques have to be developed in order to make efficient use of this information pool. For a successful search and extraction process metadata play an important role.

context:
The most important context element for mobile cartography is of course location. However, there are many more facets of context, which can partly be derived from location. Other examples of context parameters are time, weather or medium of transport.
The context, in which a user is performing his tasks, has a strong connection to his information needs and controls the content and the visualisation mode of the information. There are also technological context elements, such as network quality, device characteristics and many more.

user:
The user plays an important role in mobile cartography. His knowledge, preferences, abilities, and personality are the major parameters for a more personalised information extraction and visualisation. The user's privacy is a significant issue in mobile cartography.
As mentioned above, there are many different tasks a user can fulfil in a mobile environment and for which appropriate information visualisation techniques have to be developed.

tasks:
The tasks a user wants to accomplish during mobility are very much dependent from context and vice versa. The task performance needs information and can be supported by visualisations for better efficiency, but at the same time the tasks also control the visualisation mode of the information.

visualisation:
Mobile cartography is primarily a very flexible and dynamic way of presenting spatial data to a mobile user based on his context and his profile. A user profile includes the elements discussed above.
The visualisation in a mobile context raises many requirements associated with graphics and generalisation. Furthermore it becomes necessary to visualise new types of information as positions within a certain tolerance range etc. MIDs together with appropriate software build up a mobile viewer for the spatial *Infoverse*.

technology:
There are a lot of technical issues involved in mobile cartography. Many of them are already known from GI technology and web mapping. Critical – to cartography – are the characteristics and limitations of portable, mobile devices (e.g. screen size), wireless data transmission networks, and new data types and formats (WML, SVG, etc.)
The technical prerequisites for a mobile cartography are:

- mobile, handheld consumer **devices**
- high resolution **displays**; weather resistant; readable in daylight and at darkness
- **positioning** (GPS, cellular network) and orienteering techniques (digital compass, gyroscope)
- higher **bandwidth** (e.g. UMTS up to 2Mbit/s); *always-on*

In the framework both parts of information handling, searching/retrieving and presentation/visualisation, are sketched. However, in the remainder of this paper the focus will be on the latter.
The concept of mobile cartography reflects a system of high adaptability. To enable this adaptability at least two models must be at hand: the user and the context model. In the following sections we will discuss these models in more detail.

Related approaches

There are just a few research projects or groups dealing with cartographic issues in mobility, e.g. the GUIDE project (Cheverst et al. 2000) and DeepMap (Malakka 2000). However these projects put the emphasis either on IT or GI technology. The cartographic, or more general, the visualisation issues involved are not addressed.
As an effort to overcome proprietary and incompatible solutions in the GI business the Open GIS Consortium (OGC) started two major initiatives: the *OGC Web Map Server* (WMS) specification and the *Open Location Services* (OpenLS).

To date two major technologies for the wireless Internet are in use: services based on WAP are common mainly in Europe; in Japan another technique called I-mode is in use. Both systems are based on second generation mobile communication networks reaching data rates of 9.6 kbits/s. For increasingly dynamic Internet content not to speak of multimedia content, this is not enough. However, third generation (3G) standards are just now being implemented in USA and Europe. 3G spectrum will allow a theoretic bandwidth (depending on velocity and area) up to 2Mbit/s. For video streams this might still be insufficient, though for the purposes of mobile cartography it seems to be a major improvement especially with regard to vector transmission instead of the currently fashionable raster map downloads.
To revenue the high investment costs of 3G communication networks, telecommunication network operators are still looking for a "killer application" for the new technology. Such a candidate is location based services (LBS). "A location service, in the broadest sense, is any service or application that extends spatial information processing, or GIS capabilities, to end users via the Internet and/or wireless network." (Koeppel 2000) The OGC defines location services as follows: " … location (application) services are any application software services that access, provide or otherwise act upon location information." (OGC 2000)

In contrast to conventional cartographic media the new tools available with mobile cartography incorporate an additional element: the knowledge of the user's exact position. The position of a mobile user, i.e. the mobile device position, can be determined by either a network based or a handset based positioning technology. (Swedberg 1999) gives a comprehensive overview of the different positioning methods.
The thus obtained location simultaneously defines the context in which the user moves around. This allows context-based information rendering, whereby the filter function results not only in a reduced information amount, but a more relevant, detailed, accurate and hence appropriate information content to meet the user's needs. This adaptability is a concern of mobile cartography and technologies like LBS.
We can distinguish three levels of LBS: first generation LBS enable the user to obtain information around his location after having explicitly supplied his location to the service. Second generation LBS are able to retrieve location information based on the network without the need of user entries. The third generation LBS will proactively initiate actions invoked by triggers. A trigger is just a condition coupled to a location.

The acceptance of LBS will depend on the following criteria (Geake 2000):

- speed of delivery
- completeness of delivered information
- compactness or clarity of delivered information
- currency of delivered information
- relevance of delivered information
- simplicity of use

Seeing this list, we can point out some unsolved problems and shortcomings of current LBS:

- they are mostly commercial and therefore mainly operate with precompiled and edited content
- they might serve marketing and advertisement purposes not necessarily desired by the user
- they often are not compatible with other services and solutions due to proprietary formats and technology
- though location is an important context parameter, it is not the only context element. For an effective mobile cartography other context elements have to be derived from location and must be included
- they do not necessarily take account of different users in the same location
- they need to handle the variable dispersion of location data
- predicting the next location of a user is quite difficult
- do not put focus on graphical quality and clarity (*anything goes approach* …)

LBS do not cover all intrinsic tasks involved in a mobile environment. In the next section we try to elaborate tasks for mobile users. Furthermore enhanced and sophisticated spatial services for MIDs (like orientation) are outlined.

User tasks in a mobile environment

Geoinformation tasks and needs during mobility differ from those in a stationary environment. Basically we can distinguish four main groups of user tasks in a mobile environment:

1) locators
2) proximity
3) navigation
4) events

These tasks represent high level tasks which can be refined and split up to several low level tasks. Locator tasks are questions such as *where am I*, *where is … ?* Proximity tasks are for instance finding the next bus stop or news agent. An example of a navigation task is routing. Tasks concerning events are finding out what is happening or what the conditions are at a location. Not all of these user tasks necessarily afford a visual information representation. For some of them even a visual presentation does not make any sense, is inefficient or can cause danger. Just think of the distraction potential of visual stimuli.

The usage of visual information display is mainly controlled by the context. In a car, route directions in speech form might be more appropriate than graphical presentation. On foot, where stops are easier, directions drawn on a map make more sense. Further research has to be done to evaluate which type of information presentation is appropriate for which tasks in which contexts.

It is important to separate goals and plans of a user (e.g. navigation: get from here to point A) from the tasks needed to achieve them (direction following, translation of position on the display to the real world environment, etc.). A goal task mapping will help to structure the domain of mobile cartography and find suitable visualisation techniques and modes for specific tasks.

New tasks or enhanced services in a mobile environment could be:

- multi-modal assistance for navigation: the device and consequently you know where you are and in which direction you look, the direction to follow is displayed on a map; you get voice direction commands; your actual and your supposed path is displayed on the map; furthermore you get an acoustic signal, if you are too far from your supposed route

- multimedia information (text, voice, images, video, detailed plans) of objects around your current position (*what is this around me?*)
- getting more information for features at your position through *Geolinks* (“a *Geolink* is a spatial hyperlink that links features, i.e., location elements, to other features, or links features to other Web resources that represent properties of features … an example of a feature being linked to a graphical ‘property’, a house feature might have a *Geolink* to a floor plan of the house.” (OGC 2000)
- tracking; digital, spatially enabled diary (*where have I been today?*)

Low level tasks are selection of spatial data; change scale (zooming); etc. Even though these tasks are not only valid for mobile cartography the user interface for these tasks has to be carefully designed for the mobile environment.

User modelling

User and context modelling are actually very much connected and not separable. Often the user and his interests and preferences are seen as one part of context. As shown in Figure 1 the user is the target for adaptation, but also the source of information needed for this adaptation. To enable this adaptive functionality user model (UM) is essential. For (Orwant 1996) user modelling is “… nothing more than a fancy term for automated personalisation.” The aim of a UM is to deliver a better knowledge of the user to a computer system in order to come up with more appropriate services, answers and functionality. This results in the ability to predict a user’s behaviour and intent. According to (Orwant 1996) an ideal UM includes what the user looks like, what he sounds like, what the user knows, his interests, and his habits. Moreover these user characteristics include skills, experiences, proficiency, function/social position, tasks history, usage scenarios, etc.
The elicitation of the UM is a knowledge acquisition process in the sense that knowledge about the user is gained. There is no universal method, indeed there are many different techniques: Bayesian (probabilistic), logic based, ML techniques, clustering, stereotype-based, inference rules. A common way to store and handle user information are *profiles*.
A user model for the purpose of mobile cartography can at the most generic stage include all characteristics intrinsic to the mobile environment and be applied to a mobile user stereotype. From this stereotype further subcategories can be derived and different users will be attached to different categories. For a start the categorisation could be based on the user’s information requests or action sequencing learning.
In the realm of mobile cartography the user modelling has the following goals:

- prediction of next location; this allows for pre-fetching information of this location, re-centring the map display; adjusting the visualisation to the context of this location, checking for events happening at this location and finding suitable representation forms for them
- prediction of next information requests; pre-fetching, compilation of an information choice, structuring the information content
- prediction of next information visualisation method/style; pre-rendering of map data; buffering
- taking into account the user’s cognition of space; delivering and presenting spatial information in a mode easily perceivable for the user

Although user modelling is very important, many questions of privacy arise. Could it be harmful letting a system constantly predict where you will be next? Where is this user data stored and for how long? Who will have access to this user data?
As long as there are no satisfactory answers to these issues, most users probably will not accept the kind of intelligent services mentioned above – however useful they may be!

Context modelling

As mentioned above, location is not the only context parameter. Other elements of context are time (day, year), time account (in a hurry, having a whole day left …), weather, device characteristics, network status, transportation medium, culture (own and at current location), language, being alone or in a group, etc.
For mobile cartography it is important to build a sound model of context. Hence, the development of methods to derive other relevant context elements from a given location is crucial for the success of mobile cartography.
Most important are geo engines that search the web for relevant information to a position. In a way it is the opposite process of geocoding, often called *reverse geocoding*. Starting with a location – a point with x and y, possibly z coordinates – an address or other information having the same coordinates or being within a distance from this point is sought. This process can involve spatial functions such as overlaying layers.

Adaptive map rendering

Using the concepts mentioned in the previous sections, a new way of visualisation of spatial information for mobile users can be accomplished. This visualisation offers many new possibilities like adaptability, user focus, dynamism, and context awareness. This builds the core of mobile cartography. Figure 2 shows the basic principles of adaptive mapping.

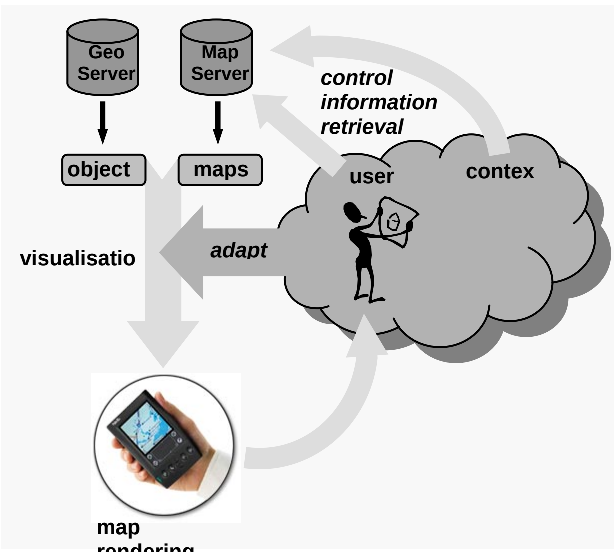

Figure 2: Process of adaptive map rendering

By adaptive map rendering we mean the ability of the visualisation technique to adapt to a specific user and his current context. The context influences the information demand of a user. This demand can be expressed by explicit queries to map and geodata servers, or push and pull technology. However, user and context also define the amount and detail of information extracted from these servers and the way this information is visualised. Symbolisation is generated dynamically, generalisations will have to occur on the fly. This means that for the same location, different visualisations can be generated for different users. And for the same user different maps could be rendered according to different contexts.

Our adaptive map rendering approach is similar to the *portrayal services* proposed by the OGC: "… these services provide for the customisation, tailoring, and understanding of the display geospatial information." (OGC 2000) This is much different from current web mapping technology where mostly previously generated maps with fixed symbolisation are hold in databases to be downloaded. Often these maps are simply scans of paper maps and do not allow many adjustments since they are in a raster format. We plan to use vector files for our mobile visualisation process. Scalable Vector Graphics (SVG) seems to be very promising for this task. (Neumann and Winter 2000) describe the features of SVG that can be applied to cartography.

The challenges in adaptive map rendering are:

level of detail (LOD)

The display size of a MID is very small. This constitutes serious problems to a legible presentation of geodata. The data have to be strongly generalised, but must still transfer meanings. We need to know which level of detail is appropriate for which tasks.
To make it more difficult, generalisation should occur just in time of request. This issue is studied by (Cecconi and Weibel 2000). Our goal is to find methods how the context and the users preferences can be used to select and generalise data before visualisation.

access speed

In order to achieve reasonable response times spatial data will have to be differently structured for the purpose of mobile cartography.

rendering speed

The speed of information is a crucial factor in the acceptance of new kinds of services. It must be studied how data can be progressively transmitted to the device. Approaches to progressive transmission are described in (Buttenfield 1999) and (Bertolotto and Egenhofer 1999).

interaction

As mentioned above, raster maps do not offer a lot of interaction possibilities. Vector graphics have to be used to enable the user to interact with displayed data.

The examples below show two maps of the city of Munich for mobile information devices. The map on the left is designed for the desktop platform. The map on the right is adapted for the mobile environment and in this case for a user interested in beer (*Hofbräuhaus*) and shopping (*Kaufhof*). His task is to find his way home to the hotel after a few beers at the *Hofbräuhaus*. Note the different orientation of the adapted map.

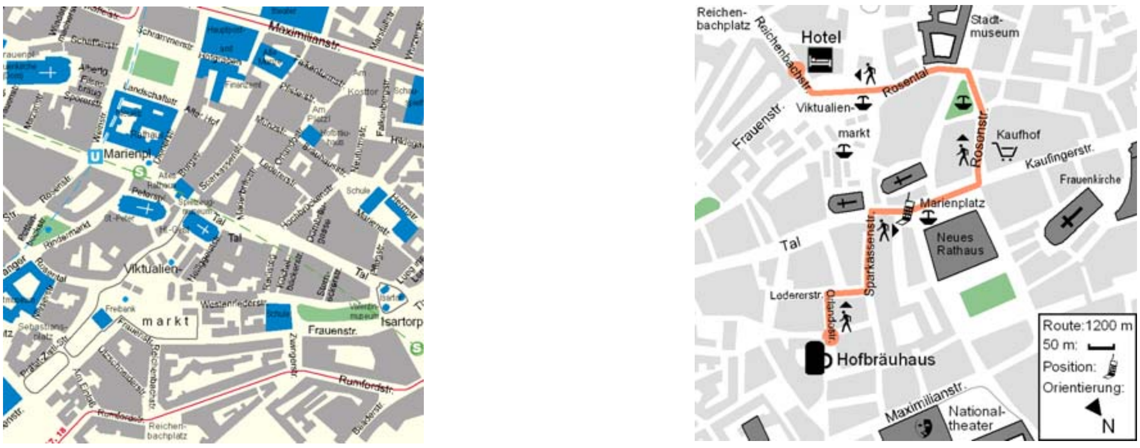

Figure3: map designed for desktop (left) and adapted map (right); © base data: Städtisches Vermessungsamt München

Outlook

Based on the conceptual framework proposed in this paper we will concentrate on categorising users and contexts in order to simplify the problem in an initial stage. On this base we try to develop some sample visualisation scenarios, linking user, context, information, and tasks.
To prove the feasibility of the proposed approach we will develop a prototype application for a

MID. The main focus will be on encoding geoinformation for mobile devices with GML and the transformation to SVG; other high priority issues are handling dynamic symbolisation and maintaining quality standards for the map rendering.
Future research in mobile cartography includes the tasks of automatic information search and retrieval supported by mobile *intelligent agents*. These agents could cooperate with other agents in a multi agent system. Being aware of the user's position, such agents could also assist navigating through the physical space. If the user needs new, different, additional or tailored information, the content could be dynamically adapted.

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