Adaptive maps for mobile applications

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Abstract

The rapid development in the field of mobile devices has led to high acceptance and an increase of its application. These devices, namely Personal Digital Assistants (PDAs) and Smartphones, are used in private as well as in business sectors. The applications range from simple organiser applications to navigation software for car drivers as well as for pedestrians. Additional hardware like GPS-modules can be connected to the devices and make them more flexible in use. Therefore, these devices should be taken into account as a basis for digital cartography as well. But their input and output options significantly differ from desktop-PCs and web-applications. They are subjected to limitations like limited memory capacity and small displays including low resolution. Therefore techniques and experiences of designing useful user interfaces as well as the design of readable maps can't be transferred easily from existing applications. The limitations mentioned have to be taken into account. In this paper we give a general overview of the status quo of mobile devices, their possibilities and restriction in terms of mobile cartography as well as their variations. We then describe an approach to address the restrictions of the small display and the limited memory capacity. As the amount of information the device can handle is limited, the load of information has to be reduced. For instance a clear map view can be kept by simplifying or leaving out unimportant information. To generate such a map, the system has to know, which information are relevant for the user and which are not. This decision is made by analysing the user's request and by exploiting user profiles stored in a database. Finally, to provide detailed and less detailed geometries for generating maps containing objects with different levels of details, online generalisation techniques must be available to simplify the shape of the less important objects. But generalising geometries is time consuming and can't be done online in all the cases. We propose an alternative way based on a Multiple Representation Database (MRDB). This kind of database includes several representations of the same real world objects. In our case it has objects of different levels of details derived by generalisation procedures. High resolution geometries will be used to visualise objects of interest, low resolution geometries reflect the other objects. Not only geometries but also attribute information can be accessed from the database with a flexible Level of detail (LoD).

1 Features and constraints of mobile devices and their impact on user interface design

Applications centred around mobile mapping have emerged as one of the most promising areas for the use of mobile computing and wireless communication technology. Because such applications are usually targeted at a diverse user population that will often employ them without previous training or reference to a manual a highly usable interface design is as critical for their success as the functionality itself. However, the devices as well as the mobile context of use differ significantly from the well established desktop PC environment, requiring special considerations of the specific user interface design aspects to ensure a pleasurable interaction experience for users. In the following section we provide a brief overview of the relevant user interface design aspects.

Visual presentation designs (e.g. maps, user interface, information presentation) for mobile devices are subject to a number of constraints compared to desktop applications. Relevant constraints include:

- Limited resolution: The limited resolution of the graphics display of mobile displays is a key constraint that must be addressed by interface designers. Typical resolutions range from 100*80 pixels for mobile phones to 640*480 for PDAs (compared to mega-pixel displays in desktop environments).

- Small display size: The small display size of mobile devices is another central constraint, especially for applications that are aimed at a divers user population, where possible vision problems must be considered. Other than resolution display size is unlikely to change significantly in the future.

- Limited number of available colours: Mobile devices are often limited to "several thousand colours" compared to "true-colour" displays in desktop applications that can display millions of colours. These limitations are relevant for visual presentation design because they limit the use of colour for information encoding and can limit the applicability of (semi-) transparency based techniques that could otherwise be used to stack several layers of information on small displays.

- Limited processing power: The limited processing power of mobile devices severely limits the use of interactive real-time animation and the generation of complex graphical displays. Especially the creation of interactive, animated 3D graphics is currently severely limited because existing mobile devices have no hardware support for 3D rendering. These constraints limit the applicability of several 3D based presentation techniques and the use of distortion based layouts.

Similarly, the interaction mechanisms and input devices offered by mobile devices differ significantly from the desktop computing domain. Key differences include:

- No standardisation: While desktop applications can typically rely on the presence of a number of standardised input devices (e.g. keyboard and 2D pointing device) the interaction facilities provided by mobile devices are often device specific, making skill-transfer between different devices difficult.

- No full keyboard: Few mobile devices provide a full alpha-numeric keyboard. Alphanumeric input is often implemented by indirect means (e.g. virtual keyboard, handwriting character recognition) that introduce additional problems and are far less usable than desktop keyboards. Only a limited number of function keys is usually provided.

- No mouse: Most graphical user interfaces for desktop devices rely on the use of a 2D pointing device (typically the mouse, but also track-pads, graphic tablets etc.) as the main interaction mechanism. Pointing devices on mobile devices often have significantly lower resolution (e.g. touch-screens) or require the use of additional hand-held components (e.g. pens on PDAs). Many mobile devices provide no 2D pointing mechanism at all (e.g. mobile phones, communicator).
- Specific interaction techniques: Most mobile devices provide additional input mechanisms that are not applicable in a static desktop setting (e.g. location sensing, camera-based input). Experience with these techniques is currently very limited, making their systematic use in user interfaces difficult.

Additional differences introduced by a mobile context of use relate to:

- Auditory environment: The use of sound can be limited if mobile devices are to be used in a public setting, either because environment noise can mask application sound output (e.g. outdoor applications) or because sound output from the application is undesirable (e.g. in a museum or library context or to protect privacy).
- Visual environment: While desktop applications are used under controlled lighting conditions, mobile devices can be used in a variety of contexts, ranging from total darkness to glaring sun in outdoor applications. These conditions can have a significant impact on the visibility of graphical presentations that must be considered in the user interface design.
- Level of attention: Because mobile applications can be used outside a classical work-environment the level of attention that a user can devote to the application may be limited (e.g. when using the device in parallel to other activities) or user interaction may be interrupted by the user's need to attend to some external events. It is therefore necessary to provide appropriate guidance information to enable use without high cognitive effort as well as sufficient status information to enable users to resume their activities after a break.

In our paper we present an approach based on MRDB representations that allows to address these special requirements for maps and can also serve as a model for more general information presentation requirements, based on different semantic levels of detail.

2 User dependent information

As mentioned in the previous sections the main disadvantages of mobile devices are the limited size of the display and the limited capacity of memory. Therefore they can't reach the same functionality as regular paper maps. In order to minimise the disadvantages introduced by these technical constraints and to exploit the advantages of these devices on the other hand, the information presented to the user should take preferences of each user into account, which leads to adaptive maps.

2.1 Adaptive maps

An adaptive map is adapted to the specific needs and requirements of the individual user and the mobile device she is using. Therefore the system has to decide about the relevance of information for each user and use case. To determine the user's preferences, she could asked to send as much information as possible along with the request. We would call this a kind of expert mode. But not every user is an expert knowing which information she needs or the client may not want to have to filter the amount of information. Therefore a sophisticated system has to decide automatically which information are relevant for a certain user in a certain situation.

Before developing a system adapting a map to a certain user, the adaptable elements have to be determined. Reichenbacher (2004) identifies four domains of adaptation

- Information domain
- User interface domain
- Presentation domain
- Technology domain

Linked to this Reichenbacher (2004) determines possible objects of adaptation. The following subset of items will be followed in our adjustment process:

- Geoinformation
  - Amount
  - Classification
  - Level of detail
  - Geographic area
- Visualisation
  - Map layout
  - Map section
  - Map scale
  - Map generalisation
  - Dimension
  - Graphical elements
- User interface

We aim at adapting the map content using multi-representation information, as an MRDB maintains several objects and furthermore several alternative representations of these objects. Two ways to adapt the map to the user's needs will be combined in our approach. The user or the usecases are categorised and each usecase is linked to a certain profile (cf. section 2.2). Furthermore these categories will be improved to match the needs of each individual user by observing and saving the user habits. This kind of strategy is used for instance by companies selling their products over the internet. Information are collected about the products the user has observed or bought. Depending on these information and also the behaviour of customers with similar preferences, certain products are offered to the buyer. This behaviour could be adapted for map users. To achieve this, first the request has to be analysed to collect as much information about the user as possible. The more information the user sends, the closer the system can match the preferences. The request contains information about the user, her ID and the designated use case. Furthermore the current position as well as the device in use can be requested. Dependent on their use case and also their current position the system can determine the information the user needs as well as his/her preferences on visualisation. Furthermore the serving system needs to know the information available from the database to serve the most adequate information. Knowing these needs, dispensable information can be left out and important information can be emphasised to keep a clear map view. In addition, the user should be able to adjust the settings herself. These changes will be detected and saved by the service to optimise the profile settings.

2.2 User categorisation

In the section above the need to categorise the mobile map users was described. In this section one possibility to categorise mobile map users will be proposed.

Peng & Tsou (2003) declare two categories of applications related to mobile GIS: Field workers and consumers. The first category is interesting for companies maintaining a large contingent of field workers where it is important for them to keep in touch with their corporation constantly to have up-to-date information. Peng & Tsou (2003) list potential applications including field data collection and validation, retrieving historical data, updating work orders etc. The field worker applications are further subdivided into the categories of

- Field data collection and validations
- Incident investigation and site analysis
- Real-time work order management and dispatch
- Real-time responses to customer service requests

Typical demands of the second category, the consumers, would be to have real-time information about where they are and what is around or how to get from point A to point B. This kind of application is also well known as Location based service (LBS).
Spiekermann (2004) categorises the users of LBS into three sections:

- Military and government industries
- Emergency services
- Commercial sector

These categories of course can be split into more detailed categories. For example possible categories in the commercial sector would be tourists, sportsmen, "find-a-friend-applications", etc. The user categorisation will not be described in more detail here.

Dependent on the user category, the individual preferences and also the content of the database linked to the service, the relevant information is gathered and presented to the user in an optimal way.

2.3 The level of detail concept

As mentioned in section 2.1 map adaptation means to reflect the necessary information in the map and to leave out unimportant information. This kind of adaptation is mainly dependent on the equipment. Because of the small display the channel to transfer information to the user is limited. That means only a certain amount of information is transferable. If this amount of information is exceeded the message to be communicated would be disturbed. To avoid this disturbance of the information flow, the number of information to be transferred has to be reduced according to the size of the display and other limitation (cf. section 1).

The amount of information communicated can be reduced by leaving out details. In other words the level of detail (LoD) is reduced by generalising the objects. The MRDB we are using offers exactly that kind of data. Depending on the importance of the object the MRDB offers alternative ways to visualise these objects. That leads to maps including different levels of detail. For instance if the display is too small to represent all the buildings with a high LoD, only the objects in close proximity to the user's position are shown using the original shape. The other objects are symbolised by alternative, generalised geometries. To determine the objects of interest the results of the analysing process described in the section above will be used. The approach to use multiscale information for visualisation on small displays is described in more detail in (Hampe, Harrie & Sester 2004).

But this concept of different LoDs is not limited to geometries. Our approach extends this principle to attribute information and the user interface. One example would be a routing functionality: The user with the PDA might be a pedestrian navigating from A to B. The map objects along this route like buildings and roads are represented by detailed geometries whereas the other objects are generalised geometries, both requested from an MRDB. Furthermore the user in a hurry would choose a low LoD regarding the route information whereas a tourist would like to get information with a high LoD. Also the routing information could be offered in different LoDs, as one user has no problems reading a map and does not need further rooting information whereas other user, e.g. car driver, need further routing information with a higher LoD. Finally different devices and also different use cases need different LoDs regarding the user interface, e.g. the car driver compared to the pedestrian. Following this concept the MRDB could be extended to offer not only different representations of the map objects but also different levels of attributes as well as for the user interface.

3 Standard based system architecture

The service described here will consist of elements based on Open Geospatial Consortium (OGC) standard definitions. The OGC offers a complete set of XML based specifications for setting up a standard based web map service. When software vendors implement their products in compliance with these specifications the user profits from interoperable web based tools for geodata access. The *OGC Web Service Architecture Specification* (Liebermann 2003) describes a common architectural framework for web-based geospatial services. The Web Feature Service Implementation Specification (WFS) (Vretanos 2005) defines interfaces for data access and manipulation operations on geographic features using HTTP as the distributed computing platform. The Web Map Service Implementation Specification (WMS) (de La Beaujardière 2005) specifies the behaviour of a service that produces georeferenced maps. This standard specifies operations to retrieve a description of the maps offered by a service instance, to retrieve a map, and to query a server about features displayed on a map. Additionally it is worth to mention here the Web Map Context Document (WMC) (Sonnet 2005). This specification states how a specific grouping of one or more maps from one or more map servers can be described in a portable, platform-independent format for storage in a repository or for transmission between clients. The Context Document can be used for example to save the state of a viewer client as the user navigates and modifies map layers. Therefore, this standard will be used to store the default data content and visualisation dependent on the user profile mentioned before. This Context Document can hold information about the layers included in the map, their status, i.e. if they are visible or not or the source-URL, the layer styles and also general information about the whole map. Therefore it can also store the status after the user has done some changes regarding to the map. Finally the Styled Layer Descriptor (SLD) (Lalonde 2002) is a styling language for the client to define styling rules. These rules can be used to portray the output of WMS, WFS or Web Coverage Service (WCS). When the user is not satisfied with the map proposed, she can request more information i.e. layers or can leave out information. The new context will be saved on the server and can be identified later as it contains an unique ID linked to the user or the user group.

4 Summary and Outlook

This paper described the state of the art of mobile devices, their limitations as well as possibilities to adjust to the constraints of the devices by adapting the information sent to the user. The modulation mechanism analyses the user's request and tries to serve custom-tailored amount and content of information. This information is extracted from an MRDB, which combines several representations of the real world phenomena. Furthermore, we adumbrate a system architecture which follows the OGC standards. The OGC proposes several service standards for implementing services like the one described above.

The service analysing the user's request, accessing an MRDB and serving an Scalable Vector Graphics (SVG) image has been realised already. The recent focus was on managing and accessing multi-representation data as well as analysing the user's request. Future effort in research and implementation will be focussed on investigating a more detailed categorisation of the users as well as in observing and storing the user's behaviour. Furthermore the LoD principle described above, including alternative user interfaces and levels of information will be realised. Such a system will help users to focus on their tasks with the help of a mobile device instead of being busy with a complicated and extensive handling of the system.

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