8 Adaptation to Context – A Way to Improve the Usability of Mobile Maps

L. Tiina SARJAKOSKI, Annu-Maaria NIVALA

Department of Geoinformatics and Cartography, Finnish Geodetic Institute

Abstract. This chapter examines the usability of topographic maps on mobile devices. To evaluate this usability, field tests in a national park were arranged with a group of test users as a part of the GiMoDig project[5]. The purpose of the evaluation was to identify preliminary design principles for maps on small displays, as well as the main benefits and obstacles in using topographic maps on mobile devices. As a result of the user test, the mobile contexts relevant for topographic mobile maps were identified. Regarding mobile map services, the most important context of use is currently the location of a user. However, several other contexts worthy of attention were: system, purpose of use, time, physical surroundings, navigational history, orientation, user, and cultural and social contexts. How some of these contexts were considered for the implementation of adaptive maps, is also described. As is normally seen in the iterative process of user-centred design, the implementations presented here will also be evaluated, and the experiences gained will be used in the second round of user-centred design cycle.

8.1 Introduction

Mobile cell phones have become commonplace tools and multimedia phones are also emerging. There are already a couple of commercial applications for maps on mobile devices, in which the maps are displayed on the screen of a personal digital assistant (PDA), or a cell phone. Most of the applications are for car navigation purposes, but there are also products for off-road navigation for cyclists or walkers (*Navman GPS 3300 Terrain* 2004; *Outdoor Navigator* 2004; *TomTom CityMaps* 2004; *Falk City Guide* 2004; *MapWay* 2004). In general, most of the services so far provide the maps in raster format, but vector formats are also emerging, mainly because of the higher quality visualisation and interaction possibilities available.

Usability is defined as "the effectiveness, efficiency, and satisfaction with which specified users achieve specified goals in particular environments" by the ISO 9241 standard (1997). Another definition according to ISO standard 9126 describes usability as "the capability of the software product to be understood, learned, used and at-

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tractive to the user, when used under specified conditions". The standard was updated later on and the ISO 9126-1 (2000) now uses the term 'quality in use', which means the capability of the software product to enable specified users to achieve specified goals with effectiveness, productivity, safety and satisfaction within specified contexts of use.

The ISO 13407 standard (1999) provides guidance on human-centred design activities throughout the life cycle of interactive computer-based systems. User-centred design is seen as an iterative process that starts by recognising the potential users of the system, and continues by identifying their specific user requirements. This information is used in the design of the usability goals for the product and construction of the first prototypes. The next step is to illustrate the design for the users and, based on the user feedback, to evaluate the design against the goals that were set earlier. By doing this, user requirements may be refined or new requirements may be identified. The feedback may also lead to changes in implementation. The iterative process continues until the usability goals are achieved.

Kraak and Ormeling (1996) described maps as interfaces to geographic information systems (GISs). Kraak and Brown (2001) stated that because of the multimedia nature of the Web, maps can be seen as interfaces or also as indices to additional information. Peterson (1995) also suggested that the word interface can be related to maps in two ways: maps are firstly interfaces to the world and secondly are composed of user interface (UI) elements. The layout of the map, the legend, its colours, sectioning and folding are all aspects of the map's UI and there is interaction between map and user when the map is used. Therefore a map on a mobile device can be treated as a graphical user interface (GUI), from which it follows that the methods used in human computer interaction (HCI) can also be brought to cartography.

During the first stage of map applications on mobile devices, the fastest way to provide maps was typically to use the same visualisation as for desktop and internet applications. However, the main problem turned out to be the presence of totally different usage situations. Maps on mobile devices are often used in outdoor situations, which means that their visualisation and information contents should be totally different compared with indoor situations at office desktops. Like in designing new products in general, it is essential to know beforehand what the real needs of the mobile map users are. Users need right types of maps, on a suitable scale, and with the symbolisation adapted for the specific usage situation.

So far few results have been published on the usability evaluation of topographic maps on mobile devices; existing studies are mainly focused on tourist and route maps. Some cartographic research, however, is being undertaken on mobile guides that consider the usability issues in their product development. The IST programme (*IST* 2004) is strongly oriented towards the concept of user-centredness, and as a consequence the projects involved are also oriented to user-centred design, e.g. GiMoDig (*Sarjakoski et al.* 2002), WebPark (*Edwardes et al.* 2003) and LOL@ (*Pospischil et al.* 2002). Usability evaluation of mobile maps can be done in many ways, either by the project developers or by bringing the users into contact with the product (*Bornträger et al.* 2003; *Heidmann et al.* 2003; *Melchior* 2003; *Schmidt-Belz and Poslad* 2003).

'Intelligence' in UIs could be described e.g. as a way to make the system more adaptive and flexible for each situation and user. Lieberman and Selker (2000) stated that a considerable portion of artificial intelligence or good design in HCI amounts to being sensitive to the context. In other words, intelligence could be implemented into UIs by making them aware of the context. Cheverst et al. (2000) have studied how context awareness can be utilised in a tourist information system, although maps play a minor role in their study. Baus et al. (2002) describe a system that determines the location of the user and adapts the presentation of route directions according to the characteristics of the user's mobile device as well as to the cognitive resources expected of the user. Reichenbacher (2001) studied the process of adaptive and dynamic generation of map visualisations for mobile users.

Here the usability issues concerning topographic maps on mobile devices are examined. This chapter is based on previous works by the authors, which point out that by adapting the visualisation and information content of maps to the different contexts, more intelligent and usable maps can be offered to the users of maps on mobile devices (*Sarjakoski and Nivala* 2003; *Nivala and Sarjakoski* 2003a,b; *Nivala et al.* 2003). The following Section 2, Preliminary User Requirements Based on Field Testing, describes the information collected by arranging usability evaluation field tests in Nuuksio National Park, Finland, to determine user requirements. The evaluation results were used to examine context awareness from the mobile map point of view and to develop design principles for adaptive maps. Contexts relevant for topographic maps on mobile devices are listed in Section 3. Examples of the maps that are adapted to some of the contexts are shown in Section 4, and finally, suggestions for further development of context-aware adaptive maps are given in Section 5.

8.2 Preliminary User Requirements Based on Field Testing

Direct user feedback is widely recognised as a necessary element in a human-centred design process. At the time of preliminary field testing the GiMoDig project did not yet have any real prototypes to test. Therefore, it was decided that the maps available with already existing hardware and software would be used in the test to identify at an early stage of the development the most problematic issues concerning topographic maps on mobile devices. The evaluation was conducted in cooperation with the KEN project (Key Usability and Ethical Issues), one of the horizontal support projects in the Finnish Personal Navigation (*NAVI* 2003) research and development programme.

A group of appropriate test users was brought to Nuuksio National Park in Espoo, southern Finland, and asked to complete predefined test tasks using topographic maps shown on a PDA. Nuuksio National Park is an area well known for hiking and camping. The test is briefly described in the following paragraphs, a detailed report can be found in Nivala et al. (2003).

8.2.1 Aim of the field study and test method

The main goal of the field testing was to examine the usability of topographic maps currently available, to derive preliminary user requirements for the GiMoDig service (*Jakobsson* 2002), and to identify the design principles for adaptive maps to be implemented on mobile devices. Some examples of the questions for which we wanted answers were: What are the deficiencies of the maps? Are the symbols and feature types easily understood? Can the user recognise the map symbols?

The tasks that the users were asked to perform were based on the following user scenario:

Hiker in Nuuksio National Park

A hiker goes on a camping trip in Nuuksio National Park. She uses topographic maps on a mobile device (PDA) that are provided by a map service. With the aid of maps of different scales she finds the nearest campsites, is able to determine her position, navigate to other locations and obtain information on restricted areas and different features on the map, etc. She is also interested in skiing, so she wants to know if it's possible to do that there in wintertime, and if so, where?

A controlled, experimental field-testing method was chosen, one that would allow for the same conditions and tasks for each user. The field test was a compilation of the three usability methods: thinking aloud, observation and interviews.

The users were informed of the Nuuksio scenario and were asked to complete predefined tasks using topographic maps on a PDA. Two observers monitored the users during the test and interviewed them in the usage situations. The users were asked to think aloud, especially in situations where they believed they were having problems. The tests were recorded on minidisk and videotape. One pilot test was conducted to practise identifying any problems that might arise in field situations and to determine test duration.

8.2.2 Test users, material and equipment

Since our concern was to gather preliminary qualitative data and elicit the thoughts of the users, the study's user group was relatively small. We had one pilot test user and six actual test persons. The test users were selected to represent the average users of map services and included both genders and were from 24 to 60 years of age, both novice, and expert map users. Each testing procedure required a relatively long time period, about three hours.

The mobile maps used for the test were derived from the Topographic Database (TDB) of the National Land Survey of Finland (1:10 000). Raster maps on four different scales were derived from the TDB, to simulate a 'zooming function' on the map display. The cartographic presentation on the maps used in the test was partly the same as in the present topographic map (1:20 000), and partly altered (e.g. colour of the paths). Some improvements were made to the information content, e.g. symbols of campsites and routes were manually added on the maps in the Adobe Illustrator program (Figure 8.1).

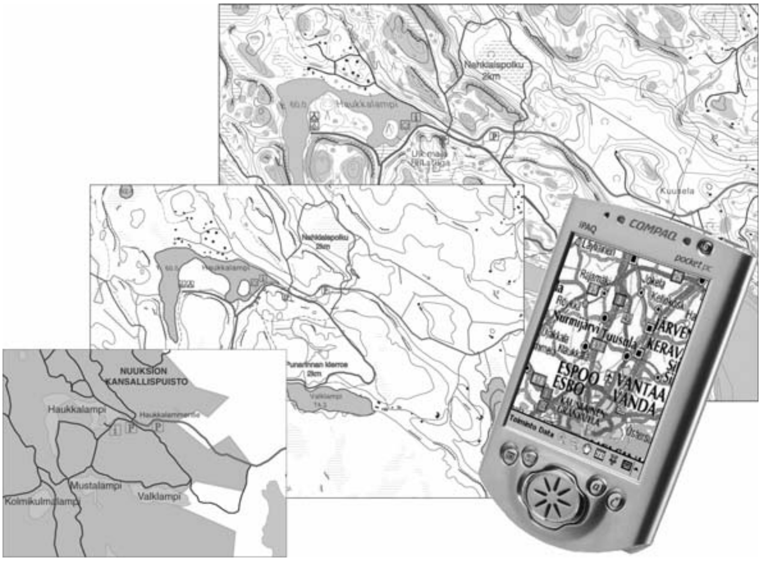


Fig. 8.1. PDA with navigation software and examples of maps used in the Nuuksio field tests.

The mobile device used in the field evaluation was a PDA (Compaq's Pocket PC), with a 64-colour image, 240 x 320 resolution display, and a keyboard, stylus and touch screen input methods. The navigation software used for showing the test maps was Genimap® Navigator LT, which supports raster maps and Global Positioning System (GPS) receivers, and enables map-handling operations such as zooming and measuring distances.

8.2.3 Pre-defined tasks

Users were given two 'orienteering' tasks, the first of which was to find a suitable campsite for a tent. They were asked to describe their impression of the campsite they planned to visit, based on information from the map. After planning the route they were asked to estimate the distance to the chosen campsite and then calculate it with a measuring tool. Other questions related to the information content and cartographic design of the map were also asked. Finally, the users were asked to navigate to the chosen site. During this first task the GPS was not connected to the PDA.

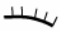
While hiking, the users were asked several times to establish their location and show it on the map. They were asked about the landmarks they used for locating themselves. The use of different map scales was also observed during the test. After arriving at the campsite, they were asked how well their earlier impression of the map corresponded to the real situation.

The second 'orienteering' task was performed with the use of the location information received from the GPS module. The users were asked to return to the parking area where the test began, using a route different from the outward route. They were asked to evaluate the topography of the area. At the end of the field test the users were asked questions on matters such as the symbols of the maps and users' desires for improvement.

8.2.4 Results

Since our concern here is how the usability of the topographic mobile maps could be improved, we mostly focus here on map-related results. For the other results of technical issues and experiences on testing, the readers are referred to Nivala et al. (2003). The main results on map symbols are summarized in Table 8.1.

Tab. 8.1. Examples on map symbols that users commented on or had problems with during the Nuuksio tests (*Nivala et al.* 2003).

Symbol	Meaning of the symbol	Feature type	Colour	Users' comments
	Deciduous tree	Point symbol	Black	Believed to be a small contour line.
	Coniferous tree			Tree symbols should be more illustrative or displayed as a coloured area.
	Boulder	Point symbol	Black	Symbol unknown to all the users, not descriptive enough.
	Precipice	Line	Black	Symbol unknown to some users.
	Outcrop	Area	Light grey	Symbol unknown, not seen very well in bright sunlight.
	Contour lines	Line	Brown	Indistinct from the path symbols. Should be more descriptive: several users suggested shadowing of the slopes.
	Weir	Point symbol	Black	The symbol for the weir was unknown to all of the users. Suggestions for more picturesque symbols for the human-made structures (e.g. houses, bridges) were made.
	Residential building			
	Outbuilding			

The users found it difficult to understand some of the map symbols, most of which were either unfamiliar or not clearly and distinctively different from the other symbols. Examples of such symbols included those for outcrop, contour lines, paths and hiking trails. The link in these misunderstandings seems to be the colour of the symbols, since the contour lines and path markings were both brown and the hiking trails and main roads were both presented in red. When using the same colours as paper maps, the symbols may become unclear, especially on a small display.

The fact that mobile maps are mostly used outdoors, and in our case in bright sunlight, can make it more difficult for users to recognise the different colours. Light colours were also difficult to recognise, e.g. yellow and light grey. This means that the symbols' colours should be even more distinct from each other, compared with paper maps.

The legend is an important issue when maps on small displays are being scrutinized. The users suggested that there should be a choice over whether or not to display the legend. Some of the users commented that the information pertaining to map symbols and their meaning could be displayed as interactive links. Some users believed that more descriptive symbols would make maps more comprehensible and the question of the legend could be avoided. One suggested the idea that maps could be like drawings in fairytale books, where visualisation would describe the surrounding environment to make them look like 3-D maps.

The users believed that the greatest advantage of mobile map services (in addition to the GPS) would be the possibility of combining information from different sources and presenting it as an overlay on the topographic map data. This demand for additional information shows that there is a clear need for data integration. From the users' point of view, topographic datasets in different scales are not enough.

The users also believed that one of the main advantages was also the possibility of zooming between different map scales. The users wanted the step between the scales to be smooth enough so that no one would lose his sense of being in the area, implying that this step should not show the user a totally different-looking view. Visual representation should be consistent between the scales, but users also believed that this step was not needed unless the information content changed.

It was also noted, quite naturally, that the small-scale maps were used for planning a route and the larger-scales once for walking along the route. The overview map should contain general information on the terrain, routes and services in the area. With larger-scale maps people were interested in seeing more specific information on nearby areas and also on the available services. The large-scale maps were also expected to provide detailed information on the landmarks in the area.

The scale should be indicated in a way that would make it immediately usable to everyone. The users could not easily interpret the traditional number scale (e.g. 1:20 000) on the maps. A more suitable way would have been some type of scale bar. A light grey grid was also believed to be a possible way of helping the users to understand distances on the map.

While compiling the test, we did not intend to focus on the hardware or software, because the main interest was in the mobile maps and the usability testing itself. However, during the test the users raised several problems and usability issues concerning the technical aspects. The most severe ones were thoroughly documented by Nivala et al. (2003).

The most interesting test result was identification of the different context elements around the user during this mobile usage situation. It was observed that the actual environment surrounding the user essentially affects the use of maps. The map is strongly related to situations in which the user tries to find his/her way in an unfamiliar environment, and the adaptation of map presentation and contents within the usage context greatly improves the usability of mobile topographic maps.

8.3 Categorisation of Contexts in Mobile Map Applications

In general, 'intelligence' could be implemented into UIs e.g. by making them aware of the context. We suggest here that this also applies to mobile map applications. In the following we first examine the meaning of context awareness and how it is classified. This is followed by the categorisation of context awareness needs in mobile map environments, based on the field tests.

8.3.1 Definitions of context

Chen and Kotz (2000) defined context as "the set of environmental states and settings that either determines an application's behaviour or in which an application event occurs and is interesting to the user". Dey's (2001) definition of context is not much different: "context is any information that can be used to characterize the situation of an entity, where entity means a person, place, or object, which is relevant to the interaction between a user and an application, including the user and the applications themselves". Dey also classified the system as being context-aware if it uses context to provide relevant information and/or services to the user, in which the relevancy is dependent on the user's task.

Chen and Kotz (2000) defined two classes of context-aware computing: active and passive, in which the first influences the behaviour of an application by automatically adapting to the discovered context. By passive context awareness they mean that an application presents new or updated contexts to an interested user or makes the context persistent, enabling the user to retrieve and use it later.

During map usage situations, active computing may be relevant in some cases due to the mobility of the map usage situation. When navigating and moving at the same time, the user may not be willing to perform extensive operations and input context information for the application. The situation may be different, e.g. when the user is planning a navigational trip at home, during which he may have time for making even complicated decisions and inputs (e.g. personalisations) to aid navigation in the field.

More specific context definitions were suggested, e.g. by Schilit et al. (1994), who stated that context could be divided into three categories. The first is computing context (such as network connectivity, communication bandwidth and nearby resources such as printers and displays). The second category is user context (such as the user's profile, location, people nearby and the current social situation) and the last category is physical context (lighting, noise levels, traffic conditions and temperature). Chen and Kotz (2000) proposed a fourth category consisting of time context (such as time of day, week, month and season of the year), and they also mentioned context history.

8.3.2 Contexts relevant for mobile map usage situation

Based on the field test results, the contexts relevant to mobile map usage situations were reclassified by Nivala and Sarjakoski (2003a). When a map is used in the field, the surrounding contexts define the type of map the user needs, see Figure 8.2. The centre of everything is the user and the purpose of the use: Who is he? Is he hiking or going fishing? The location and orientation of the user are also relevant information: In which direction is he moving? Time may also play important role: Is it day or night, winter or summer? The physical, social and cultural surroundings may also affect the map: Are there many hills around or many rivers to cross? In which country is he? Is he alone or with the group of people? And finally, what type of mobile device does he have?

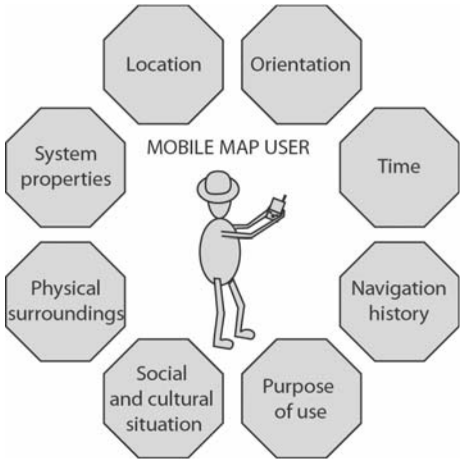


Fig. 8.2. The surrounding context of the mobile map user is composed of different elements.

The following describes some mobile contexts that can be used to create future intelligent maps for mobile devices. The examples are actual recommendations and ideas for improvement suggested by users during the Nuuksio field tests.

Context – Location

During the field tests, the users clearly indicated that the most important advantage of mobile maps compared with traditional paper maps is the real-time information on the user's current location. Users believed that without it there could be no critical difference between the benefits gained with traditional maps or mobile maps.

Information on the user's location could also be used when the user is navigating along the planned route. The system could offer a new route if the user wanders further from the originally planned course. The maps could also take advantage of information on the user's location by providing different types of information on to the user's surrounding area for navigational aid.

Context – System

The variety of mobile devices is growing and users expect to be able to use the same services on the various devices. The system properties of the devices vary, though, which means that the service providing the map should recognise the end-device from which the map request originates and should return the information in the right format so that the map is suitable for the current device. When a map is being adapted to different mobile devices relevant system properties also include the size of the screen, function buttons, input method and screen colours.

Context – Purpose of use

One of the most challenging contexts to be considered is the user's purpose for using the map. In the field tests, the user suggested many different usage situations in which they could have needed specific maps. The maps that professional orienteerers may desire, would probably need abundant detailed topographic information (on rocks, waterways etc.), whereas a family with four children may only need information on the main tracks, campsites and beaches in the area. Some users also believed that maps showing the best areas for picking cloudberries or mushrooms might be sometimes useful, as would maps with good fishing places. It would be useless to show all this information on each person's map; thus the maps could be adapted to every particular situation and purpose of use.

Context – Time

There are at least two main categories included in the time context: time of day and time of year. The awareness of the time of day could affect the map, e.g. in situations where the map would only show the cafeterias open at that time.

The time of year may also constitute important information from the user's point of view. Maps from areas such as Nuuksio National Park could be totally different during summer and winter seasons. The points of interest (POI) along the route may also differ greatly.

Context – Physical surroundings

The user's physical surroundings can vary widely when maps are used on mobile devices. Whether by day or night, the map colours and background illumination should be adapted to the surrounding brightness. Information on the weather was also found to be useful, with integration of user location and local weather forecasts possibly being one way of presenting the map. Intelligent route suggestions in the field could also take account of the surrounding landscape (lakes, hills etc.).

Context – Navigation history

Clearly, the most important requirement for navigating is to know your own location on the planned route. Optional routes to the destination and more detailed information on the services and POIs available along the routes, as well as at the destination, may also be of interest to the user. The map application, which takes account of the users' previous navigational targets and other previous requirements for the route, may be useful in some usage situations.

Context – Orientation

When users were being observed during field tests, it was noticed that most rotated the map while walking, so that the actual view in front of them corresponded to the map view on the mobile device. One of the most useful context awareness themes may be information on the user's orientation. The map could then be displayed in the right position with respect to the user's line/direction of movement.

Context – Cultural and social

Sometimes the usage situations of mobile maps can also differ, due to user's current cultural and social situations. The social situation appears to be very difficult to measure or sense, but some needs concerning social context awareness were revealed. When people were searching for a peaceful campsite, they often commented that the map could also show all the other mobile devices in the area, enabling the user to choose the site with the fewest campers. In a different situation the map could show only those cottages with sleeping accommodation left.

Context – User

In addition to the purpose of use, one of the most difficult characteristics to interpret is user context. The differences occurring among users may include: physical abilities (e.g. height, age, left-, right-handedness, speed at which the keys are pressed), cognitive and perceptual abilities (e.g. memory, learning, problem-solving, decision-making) and personality differences (e.g. gender, attitudes towards computers, habits, personality types such as extroversion vs. introversion, emotional states).

8.3.3 Summary of context categorisation

Table 8.2 summarizes the context categorisation described in this section. Categorisation is divided into general contexts (compiled from *Chen and Kotz* 2000 and *Schilit et al.* 1994) and those contexts that are relevant to the mobile map applications, based on our tests. A set of features belonging to each category is listed in the third column.

Tab. 8.2. Categorisation of contexts and their features for mobile map services (*Nivala and Sarjakoski* 2003a)

General context categories	**Context categories for mobile map**	**Features**
Computing	System	Size of display Type of display (colour etc.) Input method (touch panels, buttons) Network connectivity Communication costs and bandwidth Nearby resources (printers, displays)

User	Purpose of use User Social Cultural	User's tasks User's profile (experience etc.) People nearby Characters, date and time formats
Physical	Physical surroundings Location Orientation	Lighting, temperature, weather conditions, noise levels Surrounding landscape User's direction of movement
Time	Time	Time of day Week, month Season of the year
History	Navigation history	Previous locations Former requirements and points of interest

8.4. Implementation of the GUI and Adaptive Maps

In this section the results of the user test are elaborated further and reflected in the implementation of the GiMoDig UI and adaptive maps.

8.4.1 Personalisation of the service

Based on the results of field testing the GiMoDig PDA UI implementation includes personalisation of the following features: identity, activities, time, place and device. These features correspond to the studies on mobile contexts described in Table 8.2. However, the user is not forced to define the user preferences if she/he so wishes, in which case the application sets the default parameters automatically.

Identity

The methods of personalising the service according to the identity of the user include: choice of language and a user's age group. The choice of language reflects the language of the UI itself; in our case the languages of the countries participating in the GiMoDig project are included in addition to English. The choice of age group, in turn, reflects the requested map's content and layout.

Activities

Activities here refer to the service's implemented use cases that are hierarchically organized. After the user has made her/his selection, the Activity-menu is automatically personalized according the user's favours and shows only her/his own preferred activities. In the GiModig service the following use cases are implemented: Outdoors, Cyckling, Emergency and Expert use.
The user may define the season and time of day (day/night), according to which map information she/he is interested in displaying. If no specific user preferences are given here, the default time is always the current time.

Place

The user's location at the centre of the delivered map is used as the default location for the displayed map. However, other areas may also be of interest to the user and may be selected by using an overview map. Additionally, an expert map user may define the coordinates for the area of interest.

Device

For demonstration purposes the user is able to choose from among the PDA and PC devices. However, the type of device could be set by the system automatically in the final client application.

8.4.2 Adaptive seasonal maps

Following the story line for a 'Hiker in Nuuksio National Park' given in Section 2, some examples for implemented adaptive mobile maps are shown below. The general service architecture and the funtionality of the GiMoDig map service is described in the Chapter by Lehto and Sarjakoski (2004). For implementing the preliminary client UI and the adaptive maps on a PDA Scalable Vector Graphics (SVG) was used. Our implementations on a PDA, as earlier described by Sarjakoski et al. (2004), were carried out with a Mobile SVG viewer called Embedded Scalable Vector Graphics, eSVG (2004) from Embedding.net, belonging to EXOR International Inc.

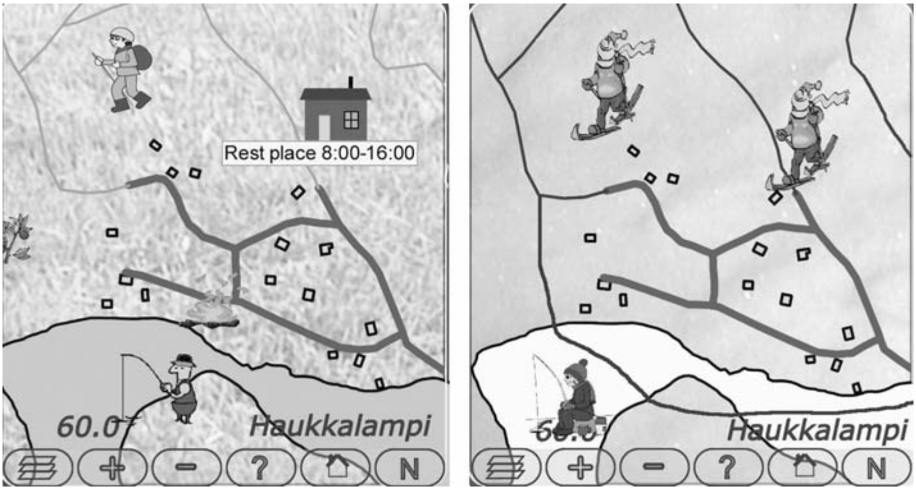


Fig. 8.3. Adaptive seasonal hiking and skiing maps for a user in the 11-17 yr. age-group shown as screen shots.

Studies of small-display cartography were conducted in the first phase of the GiMoDig project (*Nissen et al.* 2002). Further development and studies for the seasonal maps regarding the map layout were performed. In Figure 8.3 the user has received in real-time adapted seasonal maps on the PDA responding to the user preference 'Time'. The options 'Summer' and 'Winter' with the current time are used, as well as the ‘Activity’/’Outdoors’. When the user clicks the symbol for cottage, he obtains additional information for the current moment: ‘Rest place open 8-16’.

The topographic map data received from the GiMoDig server are displayed in vector format (SVG), together with the POI symbols on top of it. As was observed during the Nuuksio field tests, the users were occasionally very unsure of the map symbols. The layout here takes into account our desires for more illustrative and drawing-like map symbols. For example, the important café-house is displayed on the map enhanced compared with the other buildings. The skiing routes are also believed to be better understood if there is a picture of a skier by the route. The background of the map also adapts to the season; during wintertime it is displayed with a snow texture and during summer with grass. Since the GUI was personalized in our example for a user group between 11-17 years, we have used a kind of photo-realistic presentation style, familiar from the game world.

It can also be seen how the information on the outdoor map changes while the season changes. Hiking tracks are displayed in the summer map on the left, while in winter the user is only interested in the skiing tracks on the right. The tracks for hiking and skiing differ partly from each other. The map is adapted for the time of the year – fishing in winter is also possible on the ice, as is skiing, shown by the tracks that can naturally also be found on the ice.

In Figure 8.4 the outdoor maps are adapted for the user groups between 18-44 and 45-64. The symbols in the latter group have white backgrounds to improve the contrast.

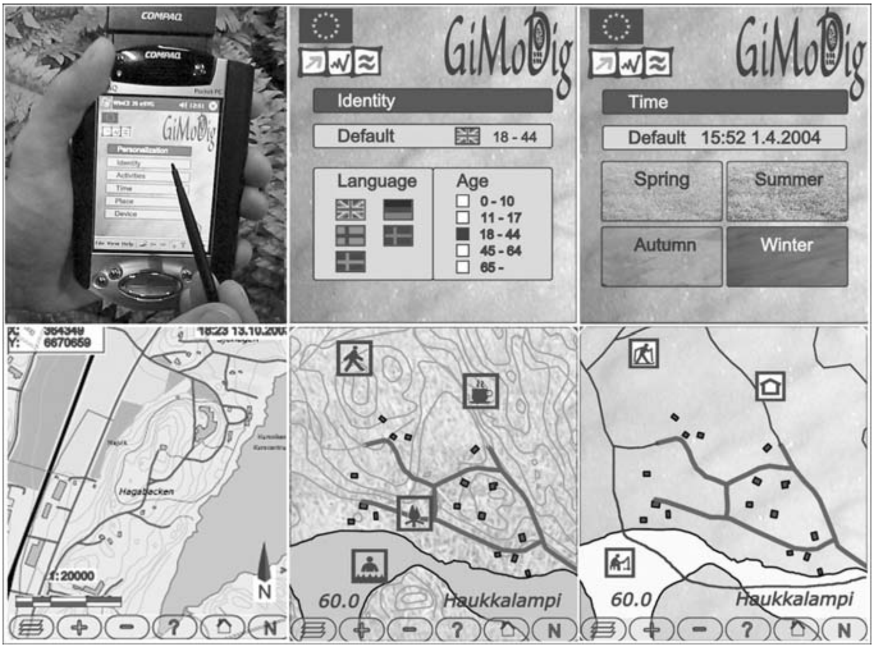


Fig. 8.4. The GiMoDig- service deliveres maps in real-time to the mobile devices. After personalisation of the service, the maps are automatically adapted to the different users in different usage situations.

8.5. Further Development of Context-Aware Adaptive Maps

Mobile users desire increasingly 'intelligent' systems that are easy to use. Since the IST programme is strongly oriented towards the concept of user-centredness, the UIs developed within it should be evaluated from the usability point of view throughout the application development projects to make possible improvements at an early stage of the process. In the project presented we try to follow this concept, although the GiMoDig service will be a prototype system resulting from a research and development project. Therefore, many of the context-related features currently implemented aim only at demonstrating the capability of a mobile map service.

We suggest that one way to compile intelligent maps from the user's viewpoint could be to embed context awareness in them. As shown in this chapter, adding context awareness to map applications would expand the traditional possibilities for presenting and using information, compared with traditional topographic maps. Within mobile map usage, context awareness could also aid in map reading and navigation, and the usability of the map may be improved.

There are several limitations in the results presented here. Firstly, although a relevant issue, it was beyond the scope of this study to examine the technical feasibility of how to bring context awareness to mobile applications. We have made some preliminary implementations that take account some of context elements. But it is clear that all the context awareness needs listed here cannot yet be implemented in practice, but they might be implemented in the future. The examples given also showed that topographic datasets alone will not bring satisfaction to users. Much more enriched information (POIs, additional information, linked information sources) related to our surrounding world is needed in addition to the topographic map data to meet the demands from users. Even if information on some of the contexts may already be available for map applications in mobile environments (e.g. location), utilising them is still far from being very effective and remains a challenging problem for mobile map application developers to solve.

By using the context information available, the map service could adapt the visualisation for different usage situations and individual user needs. The results presented here were the actual needs identified and described by users and it is obvious that the designers should at least be aware of these issues when designing future mobile map applications. As usual with the iterative process of user-centred design, further implementations will also be evaluated, and the experience that has been gained will be used in the second round of the user-centred design cycle.

References

Baus, J., Krüger, A., and Wahlster, W. (2002): Resource-adaptive Mobile Navigation System. *Proceedings of the 7th International Conference on Intelligent User Interfaces*, San Francisco, California, USA, pp. 15-22.

Bornträger, C., Cheverst, K., Davies, N., Dix, A., Friday, A., and Seitz, J. (2003): Experiments with Multi-Modal Interfaces in a Context-Aware City Guide. In L. Chittaro (ed.), *Proceedings of MobileHCI'03*, Udine, Italy, pp. 116-129.

Chen, G., and Kotz, D.A. (2000): Survey of Context-Aware Mobile Computing Research. Technical Report, Dept. of Computer Science, Dartmouth College.

Cheverst, K., Davies, N., Mitchell, K., Friday, A., and Efstratiou, C. (2000): Developing a Context-aware Electronic Tourist Guide: Some Issues and Experiences. *Proceedings of the SIGCHI conference on Human factors in computing systems*, The Hague, The Netherlands, pp. 17-24.

Dey, A.K. (2001): Understanding and Using Context. *Personal and Ubiquitous Computing,* Vol 5, No. 1, pp. 4-7.

Edwardes, A., Burghardt, D., and Weibel, R. (2003): WebPark – Location Based Services for Species Search in Recreation Area. *Proceedings of the 21st International Cartographic Conference* (ICC), Cartographic Renaissance, Durban, South Africa, pp. 1012-1021, CD-ROM.

eSVG (2004/01): Embedded Scalable Vector Graphics. At http://www.embedding.net/eSVG/.

Falk City Guide (2004/01): At http://www.falk.de/cityguide/.

GiMoDig (2004/01): Geospatial info-mobility service by real-time data-integration and generalisation. IST-2000-30090. At http://gimodig.fgi.fi/.

Heidmann, F., Hermann, F., and Peissner, M. (2003): Interactive Maps on Mobile Location Based Systems: Design Solutions and Usability Testing. *Proceedings of the 21st International Cartographic Conference* (ICC), Cartographic Renaissance, August 10-16, 2003, Durban, South Africa, pp. 1299-1305, CD-ROM.

ISO 13407 (1999): Human Centered Design for Interactive Systems. International Organization for Standardization, Geneva, Switzerland.

ISO 9126-1 (2000): Software Engineering - Product quality - Part 1: Quality Model. International Organization for Standardization, Geneva, Switzerland.

ISO 9241-1 (1997): Ergonomic Requirements for Office Work with Visual Display Terminals (VDTS) - Part 1: General Introduction. International Organization for Standardization, Geneva, Switzerland.

IST (2004/01): Information Society Technologies. At http://www.cordis.lu/ist/home.html.

Jakobsson, A. (2002): User Requirements for Mobile Topographic Maps. GiMoDig-project, IST-2000-30090, Deliverable D2.1.1, Public EC report, 93 p. An electronic version available at http://gimodig.fgi.fi/deliverables.

Kraak, M-J. and Brown, A. (2001): *Web Cartography, Developments and prospects*. Taylor & Francis Inc, London, 208 p.

Kraak, M-J., and Ormeling, F.J. (1996): *Cartography, Visualization of spatial data*. Longman Ltd, 222 p.

Lehto, L. and Sarjakoski, T. (2004): XML in Service Architectures for Mobile Cartographic Applications. In this book, chapter 12

Lieberman, H., and Selker, T. (2000): Out of Context: Computer Systems That Adapt to, and Learn from, Context. *IBM Systems Journal*, Vol. 39, Nos. 3 & 4, pp. 617-632.

MapWay (2004/01): M-spatial products. At http://www.m-spatial.com/mapway.htm.

Melchior, E-M. (2003): User-Centred Creation of Mobile Guides. In Schmidt-Belz, B. and K. Cheverst (eds), *Proceedings of the Workshop W1 "HCI in Mobile Guides 2003"*, in conjunction with Mobile HCI'03, Udine, Italy, pp. 40-44.

NAVI Programme (2003): Final report of Personal Navigation NAVI Programme. Ministry of Transport and Communications, Edita Plc, Helsinki, in Finnish, 104 p.

Navman GPS 3300 Terrain (2004/01): Navman products. At http://www.navman-mobile.co.uk/.

Nissen, F., Hvas, A., Münster-Swendsen, J., and Brodersen, L. (2002): Small-Display Cartography. GiMoDig-project, IST-2000-30090, Deliverable D3.1.1, Public EC report, 66 p. An electronic version available at http://gimodig.fgi.fi/deliverables.php.

Nivala, A-M., and Sarjakoski, L.T. (2003a): Need for Context-Aware Topographic Maps in Mobile Devices. In *ScanGIS'2003 -Proceedings of the 9th Scandinavian Research Conference on Geographical Information Science*, June 4-6, Espoo, Finland, K.Virrantaus and H. Tveite, Eds. pp. 15-29. Available at http://www.scangis.org/ scangis2003/papers/.

Nivala, A-M., and Sarjakoski, L.T. (2003b): An Approach to Intelligent Maps: Context Awareness. In *Proceedings of the Workshop W1 "HCI in Mobile Guides 2003"*. In conjunction with Mobile HCI'03, September 8-11, 2003, Udine, Italy, B. Schmidt-Belz and K. Cheverst, Eds. pp. 45-50. Available at http://www.mguides.info/.

Nivala, A-M., Sarjakoski, L.T., Jakobsson, A., and Kaasinen, E. (2003): Usability Evaluation of Topographic Maps in Mobile Devices. *Proceedings of the 21st International Cartographic Conference* (ICC), Cartographic Renaissance, August 10-16, 2003, Durban, South Africa, pp. 1903-1913, CD-ROM.

Outdoor Navigator (2004/01): At http://www.maptech.com/products/outdoornavigator/.

Peterson, M.P. (1995): *Interactive and Animated Cartography.* Prentice Hall, Englewood Cliffs, New Jersey, 257 p.

Pospischil, G., Umlauft, M., and Michlmayr, E. (2002): Designing LOL@, A Mobile Tourist Guide for UMTS. In F. Paterno (ed.), *Proceedings of Mobile HCI'02*, Pisa, Italy, pp. 140-154.

Reichenbacher, T. (2001): The World in Your Pocket – Towards a Mobile Cartography. *Proceedings of the 20th International Cartographic Conference*, Beijing, China, pp. 2514-2521.

Sarjakoski, L.T., and Nivala, A-M. (2003): Context-Aware Maps in Mobile Devices. In *Perspectives on intelligent user interfaces*, Helsinki University of Technology Software Business and Engineering Institute, Technical Reports 1, HUT-SoberIT-C1, Espoo, A. Salovaara, H. Kuoppala, and M. Nieminen, Eds. pp. 112-133. An electronic version available at http://www.soberit.hut.fi/publications/ReportSeries.

Sarjakoski, L.T., Nivala, A-M., and Hämäläinen, M. (2004): Improving the Usability of Mobile Maps by Means of Adaption. In *Location Based Services & TeleCartography, Proceedings of the Symposium 2004*, Vienna University of Technology, January 28-29, Vienna, G. Gartner, Ed. pp. 79-84.

Sarjakoski, T., Sarjakoski, L.T., Lehto, L., Sester, M., Illert, A., Nissen, F., Rystedt, B., and Ruotsalainen, R. (2002): Geospatial Info-Mobility Services - A Challenge for National Mapping Agencies. *Proceedings of the Joint International Symposium on GeoSpatial Theory*, Processing and Applications, Ottawa, Canada, 5 p, CD-ROM.

Schilit, B., Adams, N., and Want, R. (1994): Context-aware Computing Applications. *Proceedings of IEEE Workshop on Mobile Computing Systems and Applications*, Santa Cruz, California, pp. 85-90.

Schmidt-Belz, B., and Poslad, S. (2003): User Validation of a Mobile Tourism Service. In *Proceedings of the Workshop W1 "HCI in Mobile Guides 2003"*, in conjunction with Mobile HCI'03, Udine, Italy, B. Schmidt-Belz and K. Cheverst, Eds. pp. 57-62.

TomTom CityMaps (2004): TomTom products. At http://www.tomtom.com/, 2004/01.