An Approach to Intelligent Maps: Context Awareness

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ABSTRACT
In this paper we regard the map on a mobile device as a type of a graphical user interface. Therefore the same usability issues that occur in other software development must also be involved in designing mobile map applications. In general, there has been an emergent need for more intelligent user interfaces and one approach to be considered is the context awareness of the systems. We think that this applies also to the screen maps, and propose, that embedding context awareness into the maps could also increase the usability of mobile map applications. We describe here the different mobile contexts from the map users' points of view, based on user tests of topographic maps in PDA. As expected, the most important context of use for mobile map services today, is location of the user. However, the users' needs to adapt maps in to other context elements too, appear obvious. Several other context elements relevant for topographic maps include purpose of use, time, physical surroundings, navigation history, user, and cultural and social elements. In this paper we list the contexts relevant for maps, and suggest that by adding some context awareness to maps in mobile devices we could be able to compile more intelligent map applications.

Keywords
Context awareness, topographic map, mobile device, usability, intelligent map

1. INTRODUCTION
When designing new products for users in general, it is essential to know beforehand what the real needs of the users are, to make the products usable and saleable. This also applies to maps in mobile devices. Users need various types of maps in different situations and when usability of maps is concerned, one of the main issues is that the user has the right type of map, at a suitable scale and with the symbology adapted for the specific usage situation. Originally, the responsibility for having on hand an appropriate map in each usage situation is part of the users' tasks. In turn, the responsibility of the map producer includes that the map is accurate, the information presented is up-to-date and the visualization of the map is of high quality.

During the first stage of map applications in mobile devices, typically the fastest way to provide maps was to use the same visualization as in desktop and Internet applications. However, the main problem turned out to be the presence of totally different usage situations. Maps in small displays of mobile devices are often used in outdoor situations, which means that their visualization should be totally different compared with indoor situations at office desktops. And not only the visualization, but also the information needed and used in the mobile environment, should be distinctly different [20].

As graphical user interfaces (GUIs) in software engineering, maps could also be regarded as user interfaces (UIs); e.g. Kraak and Ormeling [8] described maps as interfaces to geographical information systems (GISs). Kraak and Brown [9] stated that due to the multimedia nature of the Web, maps can be seen as interfaces or also as indices to additional information. Peterson [18] 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 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.

Intelligence in user interfaces could be described e.g. as a way to make the system more adaptive and flexible for each situation and user. Lieberman and Selker [12] stated that a considerable portion of artificial intelligence or good design in human-computer interaction (HCI) amounts to being sensitive to the context. In other words, intelligence could be implemented into UIs by making them aware of the context. In this study it is thought that this applies to the maps in mobile devices, too. We propose that embedding context awareness into topographic maps in mobile devices could increase the intelligence and the usability of mobile map services.

This paper is based on previous works by the authors (Nivala and Sarjakoski [15], [20]). The following Section 2 discusses about the former studies on context and context awareness in general. Contexts relevant for topographic maps in mobile devices are presented in Section 3. Finally, discussion and conclusions are given in Sections 4 and 5.

1. DEFINITIONS OF CONTEXT
In general, intelligence could be implemented into UIs e.g. by making them aware of the context. Before categorization of context awareness needs in mobile map environments, the previous studies of context definitions are examined in the following.

1.1 General Definitions of Context

Chen and Kotz [3] defined context as “the set of environmental states and settings that either determines an application’s behavior or in which an application event occurs and is interesting to the user”. Dey’s [4] definition for context is not far from the previous: “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 defined the system to be context-aware if it uses context to provide relevant information and/or services to the user, in which the relevancy depends on the user’s task.

1.1 Active and Passive Context Awareness

Sometimes the information about the context already exists (e.g. calendars) and in other situations it has to be gained by observing the user’s environment in real-time (e.g. location of the user). Chen and Kotz [3] defined two classes of context-aware computing: *active* and *passive*, in which the first influences the behaviours 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. Passive context awareness is also relevant, but not critical, to the application.

In mobile map applications, we believe that passive and active context awareness could also be approached from the point of view of the user’s activity of context input. Context information can be received passively, so that the computer ‘senses’ the specific context automatically. Another way of perceiving the context information is that the user provides it actively to the application, e.g. when he gives personalized information by typing it into the questionnaire offered by the application. This action can be thought to be active from the user’s point of view. Both approaches to active and passive context definitions are shown in Table 1. Passive user action can include situations in which the user only accepts or rejects the choices given by the application, or in an extreme case does not know of the context information that the application uses.

During map usage situations, it could be said that in some cases passive user action and active computing may be relevant 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 any active operations and context information inputs for the application. The situation may be different, e.g. when the user is planning a navigation trip at home, during which he might have time for making even complicated decisions and inputs to aid navigation in the field.

Table 1. Two different approaches for passive and active context awareness.

	Computer defines the contextual information (by Chen and Kotz [3])	**User defines the contextual information**
Active	Application automatically adapts to the discovered context by changing its behaviour.	User makes the application context-aware by inputting the information for the application (e.g. by personalization).
Passive	Application presents the new or updated context to an interested user or makes the context persistent for the user to retrieve later.	Applications’ context-aware information is shown to the user as a confirm-reject option.

1.2 Previous Classifications of Context Awareness

More specific context definitions were suggested, e.g. by Schilit et al. [22] 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 [3] proposed a fourth category, which is *time context* (such as time of day, week, month and season of the year). They also mentioned *context history*, which could be useful information in map applications.

The different context categories can also be grouped according to their complexity of functionality. Chen and Kotz [3] stated that low-level contexts consist of time, location, network bandwidth and orientation whereas high-level contexts consist of e.g. user’s current activity and complex social context.

In the following section the paper focuses on defining the contexts relevant for mobile map usage, which were identified during user tests.

2. CATEGORIZATION OF CONTEXT IN MOBILE MAP APPLICATIONS

The contexts relevant for the use of maps in mobile devices are examined here. The results are based on field test results from user tests with topographic maps in a Personal Digital Assistant (PDA) in Nuuksio National Park, Finland [16]. A group of appropriate test users was selected, including both genders, ranging in age from 24 to 60. In the Nuuksio National Park, users were asked to complete predefined test tasks using topographic maps shown in a PDA (Compaq’s Pocket PC). The navigation software used was Genimap®NavigatorLT, which supports raster maps and GPS receivers, and enables map-handling operations such as zooming and measuring distances. The maps used in the evaluation were derived from the Topographic Database of the National Land Survey of Finland. Two observers monitored the users during the evaluation, and interviewed them when the users were performing predefined tasks with the aid of mobile maps.

The user tests were part of the project “Geospatial Info-Mobility Service by Real-Time Data-Integration and Generalisation” (GiMoDig) [5]. The purpose of the GiMoDig research and development project is to improve accessibility and interoperability of national topographic databases [21]. To study the usability issues, pilot user tests were arranged in the GiMoDig project. User testing was carried out in cooperation with the KEN project (Key Usability and Ethical Issues), which was one of the horizontal support projects in the Finnish Personal Navigation (NAVI) research and development programme. User test results will be further used to develop principles for intelligent context-aware topographic maps and a suitable UI for the GiMoDig service.

Based on the field test results, the contexts were reclassified, compared to earlier research. In the following sections some mobile contexts, which can be used to create future intelligent maps for mobile devices, are described. Context descriptions also include examples of possible usage situations, in which the context awareness may give some additional intelligence from the users' points of view. The examples are actual demands and ideas figured out by users during the field tests.

The following descriptions do not focus on, and are not limited by, technical matters. Therefore we do not attempt to claim that all of the ideas that came up during the user tests could be realistically implemented with today's technology. However, some of the elements for context awareness listed here may be worthwhile to include in the map applications to make them more usable. The needs for context awareness presented here are specialized for use of topographic maps in field situations in forested areas. The needs may be totally different in various map usage situations (e.g. city navigation, road navigation). The contexts listed below are summarized at the end of this section.

2.1 Context – Location

During the field tests, the users clearly indicated that the most important advantage of digital mobile maps compared with traditional paper maps is the information of the user's current location. Users believed that without it there could be no critical difference between the benefits gained with traditional maps or screen maps. This result as such was not surprising, since several researchers have already pointed out the importance of location for future development [10], [11].

Information on the user's location can be used by itself or in combination with other context information. The basic use of location, however, is to show the user's position on the map in real-time. This is done currently by moving the cursor, which shows the location of the user, on the top of the map or by keeping the cursor in the centre of the display all the time and moving the map underneath according to the user's movement.

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, which may be the situation when the user decides to go off-route, e.g. when seeing a beautiful view nearby. The maps could take advantage of information on the user's location by providing different types of information according to the user's surrounding area (whether rural or urban) for navigational aid.

One example of how to bring context awareness to mobile applications was defined by Brown [2], who presented the stick-e document in which the users can place a message on their PDA in their current position, and whenever the user returns to the same place, the message is triggered and brought to the user's attention. In our field tests, a similar need for context awareness emerged when the users felt that they would like to save e.g. the location of a good blueberry patch or fishing site.

2.2 Context – System

The variety of mobile devices is growing and users expect to be able to use the same services on the various devices. It requires much work and abundant time and space in the databases to plan and store different maps suitable for various situations. One possible solution could be to use the same databases continuously, but the application would need to understand the hardware and software limits and also be aware of where the map will be used. By this we mean that the system providing the map should recognize the end-device from which the map request originates and should return the information in the right format so that the map would be suitable for the current device (e.g. with its display and functions).

Martikainen [13] stated that this also concerns the situation more generally, and the growing variety of Internet devices makes enterprises more reliant on user interface languages that are device-independent. By using these types of languages, the content could be delivered and transformed automatically from the single-user interface description into appropriate formats for the different types of devices.

The system properties that were considered to be the main issues, when the map is adapted to the different mobile devices, included differing sizes of the screens, function buttons and screen colours (colour or black-and-white screen). Other context awareness related to the system could include information on the processing power and memory capabilities of the device, so that the system could also take them into account when delivering the information for the mobile map.

One of the system properties, which may be highly relevant for map usage, is the input method. Some of the mobile devices are used with pens or touch panels, and some with function buttons. Rekimoto [19] suggested tilting of the device itself to be the input method. We think that the maps provided to the users should also be adapted to the input method of the device in some situations.

2.3 Context – Purpose of Use

One of the most challenging contexts to be considered is the user's purpose for using the map, in other words, what he intends to do with it. In using the application itself, it is probably very difficult to identify where the user may need the map and for what purpose. Most likely this context should be defined by the user. The problem here is that active personalization may not be very attractive from the user's point of view, although it may be useful in certain cases by providing the right maps for the usage situations. But in most cases, when using mobile devices, the surrounding context changes but the user remains the same for the device. So once given very specific and detailed personalization followed by only small amounts of information on the current context, it may be even worthwhile to use personalization in some situations.

In the field tests, the users came up with many different usage situations in which they may have needed specific maps. The maps that professional orienteerers may desire of the area, 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 thought that maps showing the good areas for picking cloudberries or mushrooms may be useful in some situations, as well as maps with good fishing locations in other situations. It would be useless to show all of this information on everybody's map; thus the maps could be adapted to each particular situation and purpose of use.

In some situations it was considered to be useful and interesting if the map could have information on the history of the user's personalization, e.g. 'in this area the user was earlier interested to see where good blueberry patches were; let's have that as a default this time'. But before making any assumptions on the user's current tasks, the system should probably ask the user to confirm the system's interpretation of the context.

2.4 Context – Time

There are at least two main categories included in the time context: time of day and time of year. Context 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 or where other information is enhanced, e.g. if the information service is open.

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 tracks could be different, because during the winter users are able to ski on the lakes and swamps, whereas information on swimming locations may not be as useful for many people during the winter months. Other points of interest (POIs) along the route may also differ greatly. In addition to information on the time, this part of context awareness knowledge could also incorporate information, e.g. from meteorological databases, such as thickness of the snow or ice in the area or the temperature of bodies of water used for swimming during summer.

2.5 Context – Physical Surroundings

The user's physical surroundings can vary widely during the use of maps in mobile devices. Kaasinen [7] divided physical context into illumination, background noise, temperature and weather. It is very likely that background noise information plays an important future role when using voice interfaces in mobile devices. Illumination and the brightness of light were found to be somewhat critical in certain situations. When using the mobile map during the day or at 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.

Some users desired to have maps suggesting several possible routes to the destination and also giving some additional information on the routes offered (e.g. suitability for different persons, how demanding it is, how long the track is, how long it would require a person to walk to some destination at the current speed, which POIs are along the route, how the terrain varies along the route etc.). Intelligent route suggestions in the field could also take account of the surrounding landscape (lakes, hills etc.).

2.6 Context – Navigation History

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 certain situations. This map could offer routes that have the most likely POIs and suitable routes for this user (e.g. if the user has been using cyclist route suggestions, the application could remember and use this information). Context-aware route suggestions could also use other context information, such as previous locations of the user to provide spatial diaries on the user's tracks during the day. Information on the user's navigational history, i.e. the location history, could be used for interpreting the navigational context; e.g. if the user is stationary, he may be having a break and the map could offer more information on the surrounding area.

2.7 Context – Orientation

When observing users during field tests, we noted, that most were rotating 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. The benefits of adding some orientation sensors to a PDA have been studied; e.g. by Schmidt et al. [23].

2.8 Context – Cultural and Social

Sometimes the usage situations of mobile maps can also differ, due to current cultural and social situations of the user. 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 accommodations left. One social context awareness application, implemented already, is in some car navigation system; the routes for drivers are suggested utilizing traffic information on traffic jams etc.

Ahonen et al. [1] grouped together some specific features that may vary between cultural areas when using navigational products and services. One of these is the recognizability and local conventions of navigational symbols, as well as the colours used. These can vary and have different meanings in various cultural areas. The names of places and streets and address formats can also be presented in many different languages, e.g. in Finland where in some areas all streets have Finnish as well as Swedish names. Shneiderman [24] listed other cultural issues: characters, left-to-right versus right-to-left versus vertical input, date and time formats, numeric and currency formats, weights and measures, telephone numbers, names and titles, social security, capitalization and punctuation, sorting sequences, icons, buttons, colours, grammar, spelling, policies, formality etc. An intelligent map should be able to recognize the context and give this information to the user in the right format.

2.9 Context – User

In addition to the purpose of use, one of the most difficult characteristics to be interpreted is the user context. Shneiderman [24] discussed the differences occurring among users: physical abilities (height, age, left-right handedness, speed of finger presses etc.), cognitive and perceptual abilities (memory, learning, problem-solving, decision-making etc.) and personality differences (gender, attitudes on computers, habits, personality types such as extroversion vs. introversion, emotional states etc.).

Although many of the variants listed above with Shneiderman cannot be used to advantage in mobile map applications, there is still some information on the user, which the application could use automatically. One of these may be interpretation of how the user knows the map symbols and how familiar he is with using the mobile device and the map on it.

2.10 Summary of Context Categorization

Table 2 summarises the context categorization described in this chapter. Categorization is divided into the general contexts (compiled from [22] and [3]) and those contexts that are relevant for the mobile map applications, based on our tests. A set of features belonging to each category is listed in the third column.

Table 2. Categorization of contexts and their features for mobile map services (Nivala and Sarjakoski [15])

General context categories	Context categories for mobile maps	Features
Computing	System	Size of a display Type of the 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	Tasks of the user 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

Defining the word context is a challenging task that can be approached from different levels and perspectives, as well as from various research fields. When, for example, mentioning the cultural context, we can either refer to the cultural surroundings of the user during the usage situation or to the user’s cultural background. The location can also be grouped under physical context, because it is one of the user’s surrounding variants, but it can be grouped under user context as well, because it is especially characteristic of the user in every situation.

3. DISCUSSION

During the product design process, usability issues are today one of the main approaches affecting the process. The developed UIs (including maps in this study) should be studied from the usability point of view throughout the application development project to make possible improvements at an early stage of the process.

The research presented here focuses on the fact that maps can be brought to the mobile environment, with portable computers and wireless communications. This leads to the situation where people want increasingly ‘intelligent’ systems that would be easy to use. We think that one way of compiling maps with more intelligence from the user’s viewpoint could be building context awareness on them. Adding context awareness into map applications would expand the traditional feasibilities for information presentation offered by traditional paper maps. Within the mobile map usage, context awareness could also aid in map reading and navigation.

When developing new context-aware applications, the main principles for usability must also work. The system may sometimes e.g. result in wrong interpretations of the contexts and acts on these, which can be very frustrating from the users’ point of view. Therefore it should be carefully ensured when bringing context awareness to map applications, that all usability heuristics and principles, e.g. consistency, feedback, simplicity etc. (e.g. [14], [17]), are still considered. Höök [6] suggested that system should also leave the user with a feeling of control, transparency, predictability, privacy and trust in the user’s hands.

There are several limitations to the results presented here. Firstly, it was beyond the scope of this study to examine the technical feasibility of how to bring the context awareness to the mobile applications. It is obvious that all the context awareness needs listed in this paper cannot actually be implemented in practice yet, but they might be possibly implemented in the future. Some needs may also be more useful than others, and some of the contexts are much more easily sensed than others. And even if information on some of the context variants may already be available for map applications in mobile environments (e.g. location), utilizing them is still far from being very effective and remains a challenging problem for mobile map application developers to solve.

Secondly, although it seems unlikely, it is possible, that because of the nature of the results (subjective comments by different users) all the contexts relevant are not listed here. And thirdly, it is not enough to know the context of the map use, but also to adapt the maps according to the context sensed. All these topics need further research in order to provide appropriate maps for different contexts of mobile map services.

4. CONCLUSION

Making the system aware of the contexts may increase the intelligence of the system in some cases. We think that this applies to maps in mobile devices too; by adding some context awareness to mobile map applications, the usability of the map may be improved. By using the context information, the map application could adapt the visualization for different situations and individual users. Today, the most important context of use for mobile map services is location of the user. However, several other context elements worthy of attention were identified in this study: system, purpose of use, time, physical surroundings, navigational history, orientation, user and cultural and social elements. The results presented in this paper were the actual needs identified and described by the users and it is obvious that the designers should be at least aware of these issues when designing future mobile map applications. The technical implementation of the context category remains for our future research. The more the map application knows of its usage context, the more intelligent support it is able to provide to the user, and the better the map can be adapted to the user's current context.

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