INTERACTIVE MAPS ON MOBILE, LOCATION-BASED SYSTEMS: DESIGN SOLUTIONS AND USABILITY TESTING

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ABSTRACT

Mobile systems help the user to use information in new contexts. If known to the system, the location of the user can be used to adapt information to these contexts. In the project SAiMotion (funded by the German Federal Ministry of Education and Research BMBF, Funding-Key 01AK900A) a mobile, location-aware fair guide is to be developed. A major requirement for such a system is the integration of spatial, context-related information and catalogue data like ontologies of exhibitors, or events. In many cases, the user has to has to read and integrate spatial and non-spatial information, e.g. when organizing his visit or short-termed parts of it, i.e. planning a tour. Interactive and location-aware maps presumably support this process. They can be used to visualize and manipulate the needed information like routes or single locations.

However, the display of detailed information on mobile devices is limited because of the small screens. Only few map objects can be visualised on a particular view, the usage of labels to describe the semantics of map objects is very restricted, and structural information like routes can only be displayed partly or in rough simplifications. The goal of our research was to find best design principles for interacting with map visualisations on small screen. The focus of this paper especially lies on the labelling of vast amounts of map objects like they are found on fair maps.

This paper describes the interface conception for a mobile, location-based map application, and the user-centred design approach used to validate design principles. We suggest design guidelines for interactive maps that were used for prototypes for a mobile fair guide. Abstract and simplified visualizations were combined with interactive linking to textual information, especially hidden labels for map objects that can be displayed in tooltips. Usability test results show this to be a promising strategy, if the hidden labels are combined with support of use cases that include search for known objects

1. INTRODUCTION

Mobile systems help the user to use information in new contexts. If known to the system, the location of the user can be used to adapt information to these contexts. In the project SAiMotion[1] a mobile, location-aware fair guide is to be developed. A major requirement for such a system is the integration of spatial, context-related information and catalogue data like ontologies of exhibitors, or events. In many cases, the user has to read and integrate spatial and non-spatial information, e.g. when organizing his visit or short-termed parts of it, i.e. planning a tour. Interactive and location-aware maps presumably support this process. They can be used to visualize and manipulate the needed information like routes or single locations.

However, the display of detailed information on mobile devices is limited because of the small screens. Only few map objects can be visualised on a particular view, the usage of labels to describe the semantics of map objects is very restricted, and structural information like routes can only be displayed partly or in rough simplifications. The goal of our research was to find best design principles for interacting with map visualisations on small screen. The focus of this paper especially lies on the labelling of vast amounts of map objects like they are found on fair maps. Furthermore, the approach of empirical validation of design concepts by user participation and -testing is stressed.

[1] SAiMotion is funded by the German Federal Ministry of Education and Research (BMBF, Funding-Key 01AK900A). The authors are responsible for the contents of this publication. The following Fraunhofer Institutes cooperate for SAiMotion: FIT (coordination), IAO, IGD, IIS, IPSI, IZM.

2. QUALITY DOESN'T HAPPEN BY ACCIDENT: ACHIEVING USABILITY THROUGH USER-PARTICIPATION

How to achieve intuitive handling and optimal usability for software appliances on mobile devices? For several reasons, it is not enough to know about ergonomic guidelines or heuristics: Generic heuristics remain imprecise and abstract, while concrete guidelines typically specify only some particular aspects but do not paint the whole picture of a complex user interface [1]. The selection of suitable guidelines for the particular design problem therefore is difficult. Furthermore, in new and dynamic fields like mobile cartography, existing guidelines typically do not represent a corpus of coherent, validated and knowledge collected in many years of ergonomic research and design practice.

2.1 User-Centred Design Process

The solution is to take a *user-centred design approach* [2,3] to guide the development process of applications, and user interfaces from the users perspective at any time in the development process. The key principle in user-centred design is to conduct an iterative process shown in Figure 1: a process of analysing and specifying the user´s requirements, designing interface prototype showing conception, visualization and interaction principles, and finally testing these prototypes with representative end-users to gain valid information about the usability. This results in redesigning based on the results of formative evaluation. This procedure serves the goal to detect and eliminate usability problems even in very early development stages and therefore to avoid irreversible design decisions.

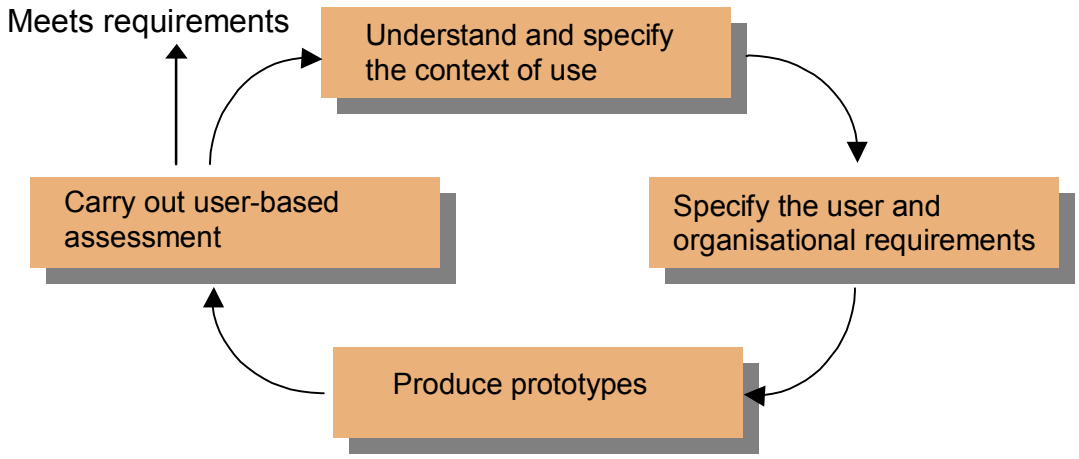

Figure 1. User-centred design activities (ISO 13407).

2.2 Usability Testing

In the course of an iterative user-centred design process, testing with users plays the key role. Usability testing can be seen as the most valuable method to gain valid data about usability problems; if used and conducted appropriately, it can guarantee a sufficient ergonomic quality of the system. In contrast to analytical or expert methods, tests with end-users provide a sound picture not only of inconsistencies with guidelines or ergonomical heuristics, but also give valid information about the severity of problems. Representative users performing typical tasks with the application in question are directly observed in a controlled laboratory setting. Grave deficiencies that will have negative impact on the interaction between the users and the application can be uncovered. In order to achieve valid data on the quality of use of the tested application, a testing environment is established which is as similar as possible to future domains and situations of use. The subjects are instructed to work on typical tasks. Test sessions are logged by verbal and video protocols which serve as a basis for further analysis. The evaluation phase consists of a quantitative evaluation (e.g., number of tasks and time needed for their solution, number of errors) and a qualitative evaluation (e.g., comprehension of wording, visualization, interaction paradigms). A post-test interview gives information about user satisfaction and acceptance as well as users' preferences and suggestions on optimisation. Finally, on the basis of all these data, recommendations for optimisation of system design are worked out.

3. USABILITY ENGINEERING FOR SAIMOTION MAP VISUALIZATIONS

For the SAiMotion map visualisations, we set up a user-centred design process, and the interface conception was strongly guided by usability engineering activities. The project started with a requirement analysis including empirical investigations with potential users. During the interface conception, GUI-prototypes were developed and tested in the usability lab.

3.1 Focus Group for User Requirements Analysis

In order to get first impressions on the probable acceptance of the planned system and requirements of the target group a focus group and interviews were conducted.

3.1.1 Method

Five potential users working as consultants and researchers in the IT field were invited to a focus group. First, the two moderators gave a brief overview over the project and the planned basic functionality. To illustrate the potentials of a mobile location-aware system, two short parts of the scenario were presented. Afterwards, the participants were asked to write down individually "ideas about useful functions" and "conditions for using and possibly buying such a system". This phase lasted about half an hour. In the next step, the participants presented their ideas and a discussion was initiated by the moderators. This discussion took 70 minutes and was recorded. The proposals written down individually or stated in the discussion were categorized and were used to specify functional and non-functional user requirements.

In addition, a semi-structured interview was made with three visitors of a German book fair. Similar to the focus-group, subjects were given a brief overview over the planned system and were asked about expectations, useful functions, and conditions for usage. The interviews lasted between 35 and 50 minutes.

3.1.2 Results – User Requirements for a context-aware mobile fair guide

In general, the participants were very positive about the planned system and generated a lot of ideas how to use the basic functionality for the scenario of visiting a business fair. The most significant features described were:

3.1.3 Information browsing and up-to-date information

Information typically included in a fair catalogue like lists of exhibitors and their products, events, facilities, services etc. should be available in the system. In order to browse these information and use them e.g. for planning, a decisive feature would be a topic ontology. To get or order brochures or product materials electronically from exhibitors was said to be helpful as well. The participants also stressed the advantage to have also up-to-date information that can be retrieved online.

3.1.4 Navigation and use of spatial information

One of the most valuable features for the users are spatial information. One should be able to display locations in order to get an overview and to be navigated by the system. The integration of spatial and attribute data like the catalogue information, e.g. to offer route planning and navigation to locations selected from the catalogue, was seen as a major strength of a mobile system, especially for visiting business fairs because of difficult locations, and great time pressure.

3.1.5 Activity planning and scheduling

The participants wanted to have a schedule for events, meetings, and other appointments that uses semantic data of the fair catalogue and spatial data. The system also should remind of important appointments and offer navigation to the location in question.

Furthermore, the system should be able to make proposals how to sequence activities, considering fixed dates as well as activities without temporal constraints like visiting stands. Ideally, an "intelligent scheduler" takes events and activities selected by the user and deduces an optimal sequence of activities using spatial and temporal information like distance, estimated walking time etc. It is noteworthy that some participants where quite enthusiastic about such a planning tool, whereas others (nearly one third) where sceptical about its usefulness.

3.1.6 Localization of persons and communication

An important insight from the focus group and the interviews concerned the importance of groups coming to a business fair together but walking jointly only in part. Nearly all participants claimed that to localize peers and to get navigated to them could be an advantage. However, the danger to be monitored e.g. by superiors was discussed extensively, and people described settings were social constraints would force to use such a service if it was available.

As a non-functional user requirement, the usability of the mobile application was discussed. Some participants were critical about the quality of displayed information, maps or routing information because of previous experience with mobile guides. Also to browse abundant content like lists of exhibitors, events, products etc. in order to plan activities was expected to be rather inconvenient. In this context, the issue of preparation at home was raised: About two third of the participants usually prepare a visit on a business fair in advance. Most of them stated that they would use catalogue data and location-data to plan at home on a PC and expected the mobile client mainly to support the execution of previously planned activities.

3.2 Scenarios and Use Case Model

To specify information on user requirements, we wrote usage scenarios [4] and the formalized them in a use case model. In order to get a basis for the task-oriented design of the user interface, *essential use cases* [5] were specified which not only describe the set of system functionality required to perform tasks but also the sequence of interactions between user and system. This turned out to be an important and systematic input for the user interface conception guiding the use of visual variables for symbolization and derived principles for the interaction design.

Based on this use case model, we specified the use of visual variables for symbolization and derived principles for the interaction design considering the restriction of the small screens of mobile devices and the usage of context information. The main design principles used for the map visualisations are described below, together with the usability testing results.

4. ITERATIVE PROTOTYPING AND USABILITY TESTING

To guide the interface conception for the interactive maps, an initial mock-up prototype was developed. It was based on HTML and comprised very limited functionality. However, it allowed to test most interaction sequences proposed in the interface conception: for all critical and interesting interaction sequences, screen flows showing example content were realised and linked. The mock-up prototype ran on an web-pad with stylus-interaction. The screen size was assimilated to a Compaq ipaq PDA.

In the first iteration, a laboratory test with 15 users was conducted. The participants were introduced in the general usage of the HTML-prototype. The participants had to solve several tasks focussing on navigating with different map views, changing displayed information, manipulating map objects, especially elements of a tour, reading and integrating information from list- and map-views. Specific tasks were given in order to test the usability of hidden labels (see below). To check the self-expressiveness of wording and iconic symbols, subjective and qualitative measures were recorded using the thinking-aloud method and semi-standardized interviews.

In the second iteration, the results of the first test were used to change the interface specification and to develop a second HTML-prototype. This prototype was also tested with 11 users. Again, they were introduced to the basic interaction with the web-pad, and had to solve tasks. The results of the second iteration cycle again was used to adapt the interface specification that finally will be used to develop the graphical user interface for SAiMotion.

5. DESIGN PRINCIPLES FOR INTERACTIVE MAPS ON MOBILE SYSTEMS AND RESULTS OF USABILITY TESTING

In the following, the design conception is described. Results from the two usability tests showing advantages and difficulties of the proposed design principles for maps on mobile systems are discussed.

5.1 Tooltips as hidden labels for map objects

The standard solution to display objects and labels on cluttered maps is to give only an abstracted overview in small scales and forcing the user to zoom into big scales to retrieve more detailed map objects and labels. However, this typically requires complex interactions (e.g. selecting a zoom mode, switching through several zoom levels). Furthermore, the user has to leave the overall small-scaled overview in order to retrieve labels in the bigger scales.

In contrast, labels can be hidden in tooltips that pop up when selecting a map object by clicking on it (see Figure 2 a, b). This leads to a very simple interaction and the user can retrieve object labels without leaving the small-scaled overview. In the case of a tour visualisation, not only names of tour elements, but also temporal information like starting times of fixed appointments can be presented in tooltips. This leads to much simpler map views that are more appropriate for small screens.

The results of our two usability tests show, that the tooltips itself are a very easy-to-use interaction style that was immediately adopted by the users. They could retrieve object labels without leaving the small-scaled overview. The results also indicate that hidden labels for map objects are sufficient for *some* tasks. In the usability tests, some tasks required to get a general overview of a spatial configuration, like identifying “problematic, unfavourable“ parts of a route, or learning the route in order to sketch it afterwards. Most subjects used tooltips to complete these tasks, even when other possibilities were available. It seems that users preferred not to leave the general view and to read additional information in the tooltips to build up a mental model of the spatial and temporal structure of the tour.

a) b) c)

Figure 2. Prototype views of SAiMotion interactive maps, showing hidden labels in tooltips a), tour elements and route together with additional information in a hidden label b), and an interactive legend c).

For other tasks, the majority of subjects did not use tooltips, like e.g. to identify the distance between two stands in the same hall. I.e., when the users had to search for a known label, the tooltips where quite inconvenient to use. Therefore we argue that hidden labels can be used to avoid cluttered screens. However, they must be augmented by interactive elements that prevent expensive search for known objects. One possibility is to provide a list of map objects displayed on a particular view that allows the user to select objects that should be highlighted and labelled. This solution was mentioned by several users in the second test. A text-based search may be used to find map objects. As search result, objects that match the search request should be highlighted and their labels should directly be displayed. In general, a design strategy could be to use the interaction history to decide which particular objects should directly be labelled on the map, and which labels could be hidden in tooltips. When it is likely that the user requested a map view to find the location of a set of objects the labels of these objects should directly be displayed. Examples are maps for exhibitors of a particular topic category, beginning and ending of routes, points of interests etc. Furthermore, important landmarks should be labelled directly.

5.2 Abstract and Simplified Visualization

To get a simple map visualization that can easily be displayed on a PDA, abstract objects must be used. An example is the abstract visualization of a tour path in a small scale that shows only the sequence of halls but not the detailed route within halls (see Figure 1 b). Instead, additional information of parts of the tour within the halls could be retrieved by clicking on a symbol representing parts of the tour in each hall. This type of abstraction was easily understood by the participants of the user testing. However, the users wished to have the direction of the tour visualized especially in the big scales where the start and end points were not visible. In general, the visualizations of the second prototype was rated as very obvious.

An important requirement in the fair context was, to use the colour coding of the exhibition map. This restricted the colour design heavily, especially the one of the fair overview. A problem of the map of the chosen German fair was that some colours were to similar to each other for PDA colour displays, so that the users could not distinguish between these colours.

5.3 Interactive Manipulation of Map Objects

The user should be able not only to display spatial data in order to get an overview but also to use map visualizations to browse and manipulate data, e.g., a user should be able to select an object like an exhibitor on the fair from a list, to get a map on which the location of this object is highlighted, and to assign new attributes to this objects like being element of the user's tour or a point of interest. This requires the generation of the map view from a geographical database and the possibility to access this database by actions on the map view. The interaction design must provide intuitive means to perform the relevant actions on objects and to switch between list and map views. In our prototypes, this was realized by a context menu which offered actions on particular objects, like taking an exhibitor to a tour or displaying more detailed information, e.g. product lists or events on exhibition stands. Especially the linking between map objects, texts, and listings was highly appreciated by the users in both tests. Also the general navigation by back- and forward-buttons to switch between map-, text- and list-views was seen as very valuable.

5.4 Interactive and Dynamic Legend

The first prototype distinguished between two different types of legends. The first one explained the coding of information, e.g. colours or symbols used for particular categories of map objects. This legend was adapted to the information currently displayed on the map view. The second type of legend was interactive, i.e. it allowed the user to add particular layers, e.g. to display a planned tour on the map. This interactive legend always showed the same set of items which were considered as important attributes that should be directly accessible on any map view. However, in the first usability test the difference between those two types of legends was not clear to the users; they searched in both legends in order to read out codes as well as for changing displayed objects. Therefore, in the second prototype these two types of legend items were integrated in one legend, including stable items that can be ticked interactively as well as temporary items, that explain what currently can be seen on the map (Figure 2 b).

5.5 Zooming by Clicking and Slider Control

Different solutions can be found for zooming: modes that are switched on by clicking on an icon, menu-commands, slider controls etc. We use two different types of basic maps: a map of the whole fair and maps for the halls. Within both maps, continuous zooming is possible and the two maps are linked. A horizontal slider control (Figure 3) can combine the continuous zooming within one map and the switch between both maps when slider was pulled over a marker in the middle of the track. We think that this combined interaction lead to a appropriate handling. However, this particular design decision was not tested empirically so far.

The slider was combined with the possibility to click on halls or other map objects in the fair overview. However, this produced an inconsistency in the effect of the user action “short click”: while it evoked a zoom-into on the overview map, in the hall maps tooltips were displayed when clicking on map objects. So, in the hall overview the users could not use direct clicks but was forced to take the slider control to get into the zoom further. Nevertheless, this inconsistency was accepted because it represents the most likely use cases in the different views: while no tooltip-information is necessary for recognizing the hall objects in the fair overview, the hidden labels are very important in the hall maps. This design decision was tested in the second user test, where no disadvantage could be observed because of the inconsistency. Most of the users immediately understood the zoom slider as well as zooming by clicking, and used both commands. Only two of the eleven users did not use the biggest zoom level because they neglected the zoom slider after using zooming by clicking.

Figure 3. Slider control in the prototype for SAiMotion interactive maps.

6. FURTHER STEPS

6.1 Field Trials and System Implementation

The experience with SAiMotion maps shows that abstraction and simplification are important design guidelines for interactive maps. The interactive linking of map objects with textual information, especially the usage of hidden labels, is a promising design solution for interactive maps on small displays in order to avoid cluttered screens. However, use cases like searching for known objects have to be supported. Our suggestion is to use the interaction history to select labels that probably are needed by the user. Furthermore, the user can search map objects by directly accessible lists of map objects for each single map view and with a text search for the whole set of map objects.

In the next step, an implementation of the map conception in the framework of the SAiMotion fair guide is realized. Important evaluation issues then are to test the proposed design guidelines in real usage settings including mobile situations on a business fair.

6.2 Design Pattern Language for Mobile Navigation Systems

The results of interface conception and usability testing are about to be transformed into a generic design pattern language [6] for overview and navigation maps on mobile systems. *Design patterns* are descriptions of typical design problems and possible solutions. The hierarchical structure of abstract to very concrete patterns – the design pattern *language* -- collect validated and empirically proved patterns and incorporate ergonomical knowledge how to use the patterns in a broadly applicable and easy-to-understand way. As our work on map visualisations yielded a number of empirical results concerning ergonomic design we aim at coining this knowledge into practical applicable design recommendations in the form of a generic pattern language.

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Biography

Fabian Hermann is a researcher and consultant at the Fraunhofer Institute for Industrial Engineering (Germany) in the field of human-computer interaction and usability engineering. In several research and industrial projects he works on interaction design, innovative user interfaces, and usability engineering for application on mobile devices. A particular research interest is the design of interactive maps for consumer applications on mobile devices, and design strategies for the problem of restricted screen real estate. Further working fields are the development of usability engineering and evaluation methodology, the approach of interaction design patterns for mobile devices, and socio-economic and organizational factors influencing the acceptance of new technologies. In industry consultancy he mainly works on usability evaluation and –design for end-consumer applications on mobile phones, industrial user interfaces, and web usability.

Fabian Hermann studied psychology with a focus on cognitive psychology and human-computer interaction, and did his PhD at the University of Freiburg on coordination patterns of computer-mediated communication and cooperation.