Accessible User Interfaces in a Mobile Logistics System

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Abstract. In this paper, we focus on ICTs for young people attending occupational rehabilitation and training. An important goal is to develop ICTs that decrease the need for reading and writing dramatically. The UNIMOD-prototype demonstrates how mobile phones can be used as the main and only ICT-device by truck drivers who deliver mats from the laundry to a large number of companies and public places. The mobile phone can be used in the truck for navigation according to traffic situation and geography, and for handling the customer and delivery information. The test sessions show that mobile phones offer an excellent point of departure for the development of simple and intuitive services that support users with cognitive declines.

Keywords: Accessibility, Cognitive disabilities, GIS, Mobile solutions.

1 Introduction

The influx of people registered as unfit for work is steady, if not increasing in Europe. In particular, incapacity for work amongst young employees increases continuously. There are also large numbers of so-called drop-outs, i.e. young people who drop out of school for various reasons. One of the reasons for not completing basic or occupational education is learning disabilities, such as dyslexia. According to an OECD-study [6], approximately 30 % of adults have difficulties in reading and writing, to such an extent that it is difficult for them to handle daily activities at study or work. Other cognitive declines [14], such as concentration problems are also rather common among young people.

In many European countries, different occupational training and rehabilitation policies and programmes have been established to combat unemployment due to occupational disability. In Norway, there is a large number of enterprises that are dedicated to and specialized in occupational rehabilitation [1]. Such enterprises are organized as shareholder companies where the main shareholder usually is the local municipality. The services provided for occupationally disabled persons include assessment of the potential work and educational capacity of the individual and qualification of the

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individual through individually adapted job training and guidance. The enterprises qualify occupationally disabled persons in real work environments.

In this paper we focus on ICTs for young people attending occupational rehabilitation and training. An important goal is to develop ICTs which decrease the need for reading and writing dramatically. In connection with the R&D-work of the UNIMOD-project, the authors have collaborated with the rehabilitation enterprise ÅstvedtGruppen and their logistics team [2] on specifying and testing the prototype.

1.1 The UNIMOD-Project

The main objective of the UNIMOD-project [12] is to develop new knowledge of multimodal, personalized user interfaces, and thus to improve the accessibility and use of electronic services. The UNIMOD-prototypes are based on real cases, and show how to increase the accessibility of the user interface on the mobile phone.

The project presented in this paper addresses users with different kinds of cognitive declines in such areas as memory, problem-solving, orientation, attention/concentration, reading/writing, learning and verbal/visual/mathematical comprehension [4]. These areas are crucial to support in order to achieve an inclusive HCI-design for ICTs [1], such as mobile phones [14].

The so-called Åstvedt-prototype of the UNIMOD-project demonstrates how mobile phones can be used as the main and only ICT-device by truck drivers who deliver mats from the laundry to a large number of companies and public places in the Bergen area in Norway. The mobile phone will be used in the truck for navigation according to traffic situation and geography, and for handling the customer and delivery information. The Åstvedt-prototype results from software development collaboration between three UNIMOD-partners: Norkart Geoservice [9] delivers GIS, Tellu [11] develops applications for mobile phones, and ÅstvedtGruppen [2], a large rehabilitation enterprise (cf. Chapter 1). Researchers from Karde [5] and Norwegian Computing Center [8] have performed user requirements analyses and usability tests.

1.2 The UNIMOD-Prototype in a Nutshell

Based on field studies, i.e. empirical observations of (a) the collaboration between the truck driver and the co-driver, (b) available documents (driving instructions, delivery information etc.), (c) the variety of different mats and other “deliverables”, (d) concrete traffic situations and actual navigation, (e) the architecture of public places and buildings, and (e) customer behaviour and preferences, the UNIMOD-team has developed a two-dimensional model for the mobile user interaction.

The first dimension of the model handles **geographic and navigational information** in a user-centered way. The solution suggests a route, but the truck driver makes the concrete navigation decisions depending on the work situation. This dimension also handles the delivery information (i.e. delivering clean mats and picking up dirty ones). It is possible to change the order of delivery stops, and to switch between different representations of the route.

The second dimension **manages the presentation**. The presentation is based on a multimodal user interface, and a “minimal information model”. Interactive forms of information input follow design guidelines developed in earlier projects [4]

Multimodality enables alternative presentations of the very same information (e.g. points of delivery on a map instead of a list of addresses). The minimal information model shows just the necessary information, until the user asks for more. The users require that the user interface introduces the lowest possible cognitive load, and that it must be possible to operate the application multi-modally, depending on personal preferences. In all modalities, the progress of the working day is shown to the user. This is considered an important motivating factor for both the truck driver and the co-driver.

In the remainder of this paper, the R&D-work concerning the prototype will be presented. We approach the presentation by discussing the opportunities and limitations of GIS on mobile phones. Second, we will make some remarks about mobile phone technology and the challenges it poses to developers. Finally, we will present the HCI of the prototype.

2 Challenges and Opportunities for Mobile GIS

In general, it is fair to say that navigating with the use of a map is not a trivial task. Even a simple map is saturated with topographical data, road data, buildings and landmarks. When constructing a good map, it is always important to have good idea of what information it should convey, what it is will used for, in what context it will be used, and it is certainly important to have a notion about the end user.

The mobile digital map differs from its analogue counterpart in some important ways. A traditional printed map is static in its nature; it has a set scale and gives no option of filtering any information in the map. It is mobile in the sense that you can bring it with you, but offers no context sensitive help or guidance (GPS, nearby points of interests, turn-by-turn navigation etc.). However, it often provides detailed, high resolution data, and a well defined cartography. Therefore, it is common that printed maps have a specific theme, and if you need other information you go out and buy a new separate map.

A digital map, on the other hand, has the ability to present dynamic data. Also, depending on the hardware and software platform, it can assist the user in simple tasks like knowing his or her position, calculating route and distance to a destination, gathering context information (speed, bearing etc.), and communicating with similar devices or other users. This makes the digital map a very flexible tool, which can be tailored to match the user's abilities and the use context.

2.1 Technical Constraints Pertaining to Mobile Maps

While mobile digital maps excel at providing dynamic, context-based information, they are less good at displaying complex cartography. This has a lot to do with the relatively small screen-sizes associated with such devices, but also with the resolution of the screens. A typical mobile phone has a resolution of 240x320 pixels on a 2.8 inch display, which gives little room for detail. Moreover, mobile screens often render colours in disparate ways, which constricts the map to a small colour space.

Mobile devices have numerous technical constraints in addition to the screen limitations which do not affect the map directly. They often have cumbersome interfaces, lack the inclusion of a decent “qwerty-keyboard”, they rely on battery power, and they have unreliable and low data connections (at least in comparison to an ordinary PC). Such limitations play an important role when mobile systems are designed for professional use at work.

2.2 Mobile Cartography

Mobile cartography is a concept described by Reichenbacher as follows [10]: “*Mobile cartography deals with theories and technologies of dynamic cartographic visualization of spatial data and its interactive use on portable devices anywhere and anytime under special consideration of the actual context and user characteristics.”*

While the prototype application did not use a client side vector map rendering engine, we could make small server-side adjustments to enhance readability on small screens. One of the things we encountered through user feedback during the project was the lack of road names at certain spots on the map. A given map which may work well in a desktop solution will lack essential information because of the limitations connected with the small screen. The map engine uses pre-rendered map tiles from a WMS-source (Web Map Service), so in this case the rules pertaining to road names had to be changed. We changed text to occur more frequently in vector and hybrid maps, resulting in a more informative map for our mobile users (Fig. 1).

Fig. 1. Text changes in maps for mobile users: more frequent information

2.3 Aerial Photos, Hybrid Maps and Waypoint-Based Navigation

It is a well known fact that landmark navigation is a simple and intuitive method of getting from one place to another, given some knowledge about the route. It is, for example, common to use landmarks when explaining a route to another person. On a vector-based map, these objects are often hard to spot, as the features that characterize a building or structure, often is lacking from the dataset. In these cases the use of ortophotos, which are terrestrial images that have been geometrically corrected in such a way that they can be used as maps, may be useful.

Hybrid maps can be used as an addition to the vector map. These pictures provide extra details pertaining to the user's surroundings and allow for landmark based navigation. Hybrid maps, which are ortophotos with vector data layered on top of them is also a good alternative. Fig. 2 illustrates the three types of maps. Our user tests showed that a number of users preferred ortophotos instead of vector maps.

Fig. 2. Vector map, orthophoto and hybrid map of same point of interest. Different end users may prefer different presentations.

2.4 Delivery List and Its Map Representation

The delivery list (Fig. 3) is a central artifact connected to the work process of the truck drivers. It tells them where to drive and what to deliver.

One of the early objectives of the UNIMOD-prototype project was to facilitate multiple ways of viewing the delivery list. We wanted a simple model that could be viewed as a geographically ordered list or as waypoints along a route in a map, depending on the user's cognitive abilities and preferences. One alternative was to create a simplified route-view, which had a loose connection to the actual geographical locations, much like a modern subway map.

The map representation of the list has the same interface mechanisms for going back and forth between waypoints, or selecting delivery spots, as the normal list. Either view contains the same amount of information, so the user should not need to change display to access another kind of data.

The map view was intended for users with limited or no knowledge of the route, and the list view was intended for users who were familiar with the locations, and only needed to know the name of the next stop.

2.5 Challenges of Mobile Computing

The prototype client for the UNIMOD-project was developed for mobile phones. As pervasive computing comes with a lot of additional challenges, this is most notable on cell phones. According to Forman et al. [3], the main challenges in mobile computing can be divided into three fields. These are wireless communication, mobility and portability. The concrete problems, in addition to wireless communication, are related to disconnection, low bandwidth, high bandwidth variability, heterogeneous networks and security risks.

For the UNIMOD-prototype, the **wirelessness** is a *real* challenge. The problem with wireless communication is that there is no guarantee that the device is connected to the network. As the mobile client is developed for use in a truck delivering goods, there might be environmental issues that block both GPS and GPRS communication, such as tall buildings. Hence the application can not rely on communication at all times. For instance, the mobile client can use GPS-positions to provide relevant user interface and activate the current views. However, it is necessary to allow the user to override application navigation to avoid a deadlock when the GPS-signal is lost.

02 Test Sjåførliste

Tirsdag 29.01.2008

BIL 4 FONNES

Klient 0021 - Total Tekstil AS

Tlf: 55 53 80 40 / Fax: 55 53 80 60

Ivar Aasgardsvei

Postboks 94 Ytre Arna

5265 YTRE ARNA

10 BIL 4 FONNES

44445455	Dekk 1 Minde, Conrad Mohrsvei 11, Conrad Mohrsvei 11, BERGEN			
Stopp nr : 1				
1	INNGANG	MATTE MILJØ PLUSS 85*150	1	**FS :176483**
2	INNGANG	MATTE MILJØ PLUSS 115*200	1	**FS :176483**
15221001	Elgrossisten Bergen As, Kanalveien 107, C/O Berggård Amundsen & Co As, OSLO			
Stopp nr : 2				
1		MATTE IRON HORSE BM 200	1	**FS :176513**
44444775	Jæger Automobil As / Kanalveien 111, Kanalveien 111, ,			
Stopp nr : 3				
1	HOVEDINNG.3 ETG	MATTE IRON HORSE BM 200	2	**FS :176656**
2	INNENF.SKYVEDØR BRUKTB	MATTE MILJØ 300	2	**FS :176656**
3	KUNDEMOTTAK VERKSTED	MATTE MILJØ 150	1	**FS :176656**
4	DØRER TIL KONT.BRUKT	MATTE MILJØ 150	1	**FS :176656**
5	KUNDEMOTTAK 1.ETG U	MATTE MILJØ 150	1	**FS :176656**
6	KUNDEMOTTAK 1.ETG	MATTE MILJØ 150	1	**FS :176656**
7	KONTOR/SALGSLOKALE	MATTE MILJØ 150	1	**FS :176656**
8	DØR TIL KONT. BRUKT	MATTE MILJØ 200	1	**FS :176656**
29301522	Steen-Hansen Maling As C.Mohrs, Conrad Mohrsvei 7, Ulsmågv. 24 Avd. 830/930, BERGEN			
Stopp nr : 4				
1	KUNDE KVITTERE!!!	MATTE IRON HORSE BM 150	2	**FS :176514**
2	MARIUS/RAGNAR	MATTE IRON HORSE BM 200	1	**FS :176514**
11313027	Mb Auto As, Kanalv. 19, Kanalv. 19, BERGEN			
Stopp nr : 7				
1		MATTE IRON HORSE BM 200	4	**FS :176515**
39282903	Wergeland Bofellesskap, Elvebakken 24, Ressursnr. 35101, BERGEN			
Stopp nr : 8				
1		MATTE IRON HORSE BM 200	1	**FS :161265**
44445267	Kværneland Bil Bergen As, Fjøsangerv. 68 B, Postboks 294 Forus, STAVANGER			
Stopp nr : 16				
1	HOVEDINNG.VERKSTED	MATTE MILJØ 200	1	**FS :176463**
2	FOCUS/S.MAX MATTE	MATTE LOGO	1	**FS :176463**
3	DISSE SKAL GÅ ANNEN HV	MATTE LOGO	1	**FS :176463**
29302531	Kontor Varehuset, Minde Alle 35, , BERGEN			
Stopp nr : 17				
1		MOPPER -Abonnement	10	**FS :176518**

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Fig. 3. A paper-based delivery list. Exceptions are written on it etc. At the end of the day, it may not look like this at all, with comments and coffee stains on it. Perhaps a bit of the sheet is torn off, because the co-driver needed something to write a phone number on…

Another reason why mobile computing relies on wireless connection is that it is necessary to reduce the amount of computation and processing executed on the mobile device to maintain battery capacity. Wireless communication allows the client to delegate computational work to a central server, by sending some parameters and receiving the outcome of the computation from the server.

In fact, we experienced some problems with the prototype as a consequence of congestion when sending much data during a short time interval. The map service used by the client sends a grid of nine images of 250x250 pixels. This would not be a problem for stationary devices, as TCP has mechanisms that deal with congestion. For the UNIMOD-prototype, this caused the application to crash. We solved this by using a proxy on the application server. This assured that just one image is sent at a time. For the end-users in real working situations, such mechanisms are vital.

The next challenge of mobile computing is **portability**. This challenge includes such aspects as the lack of standardisation on mobile devices with respect to screen sizes, input interface, communication features (such as Bluetooth, GPS, Wi-Fi etc.) and other hardware constraints. Other concrete constraints are battery capacity, small and different user interfaces and relatively small storage capacity. Fortunately, the latter is not a great issue anymore, as new devices ship with at least 40 megabytes of RAM with the possibility to increase this by inserting memory cards. However, the constrained application memory (heap) is still an issue, and we experienced problems with it during the prototype development.

There are three main concerns regarding portability on mobile devices. It is important to reduce the amount of heap to an absolute minimum, to reduce the processing needed in order to preserve battery and to make generic interfaces with respect to both screen and user input.

One of the factors that make it difficult to achieve processing and memory heap economy is that the API used on the relevant devices is Java. Java is an intuitive programming language, and it is easy to implement it on all systems. Unfortunately it is not efficient with respect to memory management and economic processing. The reason for this is that Java is an interpreted language, meaning that it is a high level that requires a lot of redundant processing and large structures to fit in the memory. Solutions to reduce processing are distributed processing by external server for heavy computations, use of native functionality to avoid processing overhead whenever possible and keeping data structures at an absolute minimum.

The features in the prototype that are the largest threat to heap consumption are the images used by the navigation module and the paths between destinations. To solve this we had to implement mechanisms that assured that only visible images were in the memory, and persistent storage of all the other images to reduce communication latency and potential charge for bandwidth usage. As for paths we have reduced the number of points needed to draw the path.

With regard to external processing, this is implemented on the paths between destinations. All paths are calculated on the server. The client requests the path with the start and the destination coordinates as parameters, and the server responds with the shortest path to the destination.

2.6 The Development Framework

The UNIMOD-partner Tellu has developed a framework that solves most of the issues connected with wireless communication. This framework is called ActorFrame [7]. It is an open framework that connects devices to a message bus. The framework can operate on most of the protocols and connections used in mobile computing. ActorFrame divides the application into a number of Actors. An actor is a module that serves a responsibility (called "role" in ActorFrame) in the application. One actor may consist of several inner actors. Seen from the outside the application consist of one actor, usually with multiple inner actors. ActorFrame assures that there is a connection between all peers comprising the application at all times, using a message bus.

The prototype consists of tree actors on the server side and two actors on the client side. These actors are in addition to standard actors that are part of the framework, such as resource manager, name server etc. The actors used by the server are:

- MapServer handles map tile requests and transformation and visual representation of navigation.
- UnimodServer handles handshake with the client, and routes the other messages to their respective actors.
- UnimodFileedge parses the delivery lists and prepares initial data, such as default spider paths and initial images, persistent delivery objects etc.

The client consists of the following actors, in addition to framework actors:

- MapClient handles map requests, path requests and mapping to the client view. This actor handles all interaction with the map view, including the module assuring persistent storing of map images.
- UnimodClient handles the more application specific logic, such as sorting delivery lists, handling progress, user interaction etc.

ActorFrame maintains a connection between the client and server at all times using a router that allows the message bus to communicate over GPRS. ActorFrame provides a persistent connection between the server and the client, and so it is adequate for continuous communication. This is convenient in terms of dynamic route updates from base, or reporting back to base about schedule changes etc. ActorFrame will also allow communication between clients. This may be convenient in case of obstacles in the road, or when a truck lacks delivery objects. The client can simply broadcast a message about this, or send directly to another client, and this car might make the delivery instead.

3 The Prototype

Using a hierarchical ordering of screens, and having the intended user in mind (i.e. users with potential cognitive declines), the prototype was kept as simple as possible. The end user should only need to see information pertaining to the task at hand, while also maintaining an overview of the delivery process and the route.

The UNIMOD-prototype has six levels of screens. (Fig. 4). The first two levels are used as preliminary steps to the actual delivery. Level one lets the user choose which truck (carrier) should be used. Level two has a list of deliverables pertaining to the chosen truck. When the carrier has finished loading the truck he is presented with one of the level three screens, depending on a user setting. This level holds all supernodes in the route, and the carrier can choose between list mode or map mode.

When the carrier has arrived at a supernode, he can expand it to see which subnodes (actual delivery spots) it contains. In this particular case the deliverables were doormats, and for each supernode (building) there could be multiple subnodes (entrances). While at the level four screen, the carrier can choose to recursively check the subnode with its products as delivered. This is to avoid unnecessary interface navigation, but the user can – if necessary – dig one step further, to level five. If the user is not sure about what kind of goods to deliver, or what number of goods to deliver, or if there is a mismatch for some reason, the user is given the option to check off single deliveries at the level five screen.

When finished with all deliveries, the user is presented with a message box, indicating a job well done. At all times during the delivery, a status bar is shown in the upper portion of the screen. This is to give the carrier a quick overview of the delivery route progress, even while at low levels in the interface.

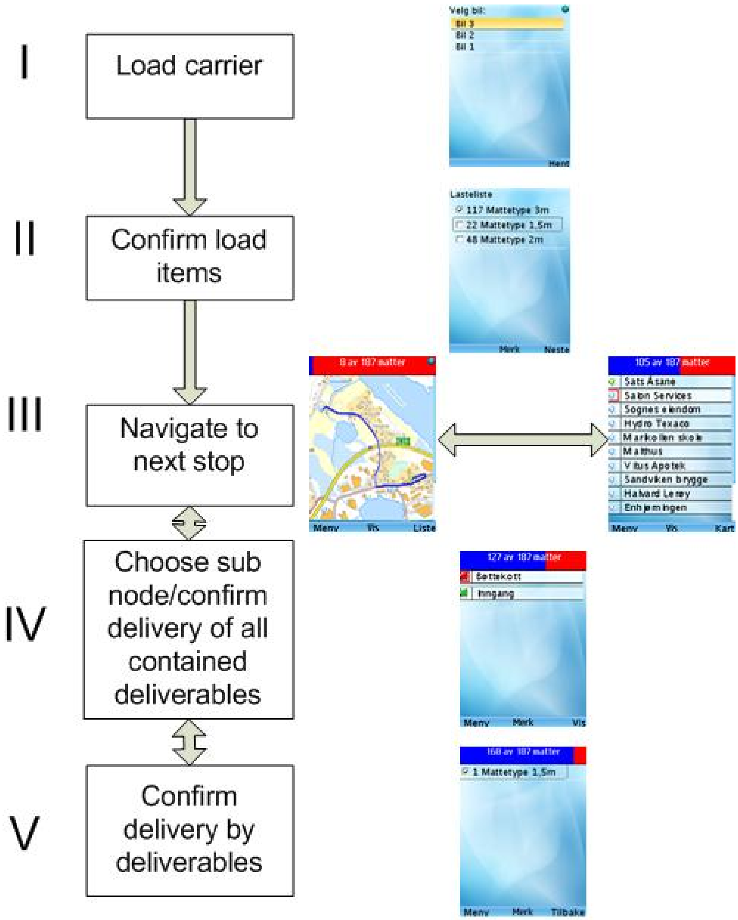

Fig. 4. The UNIMOD-prototype and the work flow. The bar that indicates the progress is shown at the top of the screens. The blue colour indicates the degree of completion.

4 Conclusion

In this paper we have presented our R&D-work to increase the usability and accessibility of applications on mobile phones. Walkthroughs were applied as the main test methodology, allowing the designers and developers to communicate on the prototype. Feedback from the expert users concerned more intuitive navigation, the need to increase the visual clarity of map symbols and the possibility to use multimodal input when registering exceptions on the delivery route. The overall impression from the test sessions is that mobile phones offer an excellent point of departure for the development of simple and understandable services which support users with cognitive declines, such as people with dyslexia.

It is, however, necessary to continue increasing the accessibility requirements connected to physically small screens and interactivity designs that apply to mobile devices. It is also necessary to address the constraints of multimodality.

The flexibility afforded by multimodality raises considerable challenges for the users who interact with their systems, services and devices. This concern is connected to the overload that may be generated by the introduction of several modalities, such as combinations of visual and audio information, and the opportunity to *choose*. Finally, there is the question of suitable use contexts for the mobile phone. The UNIMOD-prototype clearly shows the potential of mobile phones in professional use contexts.

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