USER-CENTRED MOBILE NAVIGATION SYSTEM INTERFACE DEVELOPMENT FOR IMPROVED PERSONAL GEO-IDENTIFICATION AND NAVIGATION

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Abstract

Introduction

Orientating and navigating with the use of mobile navigation systems involves interaction with different sources of information. Landmarks are very important into linking these sources. However, outcomes of user research projects in such fields are not yet fully implemented in the mobile navigation systems that are currently available.

Objectives

The objectives of this paper are the presentation and explanation of a conceptual model of the interactions between the users of a geo-mobile application, their mental maps, reality and the mobile map displays. This model is used to create a series of guidelines for a usable mobile (carto-) graphic interface which contributes to the implementation of a prototype design solution.

Methodology

In order to meet the objectives of the research, two main sources of information are used: already existing research literature and the results of the analysis of two of our experiments with real users. The aim of the first experiment was to compare different methodologies for field-based usability testing of geo-mobile applications. Investigating the behaviour of pedestrian visitors to unfamiliar cities while orientating and navigating with the use of already existing geo-mobile applications was the aim of the latter.

Results

A conceptual design of a user interaction model as well as user interface prototype design solutions for personal geo-identification and navigation can be considered as the concrete outcomes of the research described in this paper. The results also demonstrate the importance of landmarks in the geo-identification and navigation processes of the users.

Conclusions

Following User-Centred Design in order to develop a more usable mobile cartographic interface for pedestrian navigation can reveal a lot of information regarding the user-environment-system interactions. Several design aspects can be extracted from modeling these interactions that could be used for the prototype development. However, usability testing is needed to determine the success of the followed approach.

1. Introduction

Geo-identification and navigation of pedestrians with the use of a geo-mobile application involves their interaction with three sources of information: the environment, the users' mental maps and the (map) representation of reality on a small display screen. One of the problems during this interaction are the missing links between the information sources, which, combined with frequent disruptions of GPS signals along urban canyons can lead to disorientation and confusion of the user. Landmarks are evidently instrumental in binding together the three sources of information.

However, outcomes of user research projects are not yet fully implemented in the mobile navigation systems that are currently available on the market. It also appears that those systems are more frequently the outcomes of finding technical solutions to problems of wireless geo-data transmission to portable devices than the result of user-centred design (UCD) approaches. Besides, most of the available mobile navigation systems are dedicated to vehicle navigation which involves contexts of use that sensibly differ from the ones of pedestrian users.

Therefore, we have reserved a more central position for the prospective users in the development of a usable mobile cartographic interface for personal geo-identification ("where am I?") and pedestrian navigation. The main purpose of this paper is the presentation of a conceptual design of a prototype interface, based on a requirement analysis carried out through literature review and two field-based experiments in the Netherlands.

The paper starts with an identification of the problems of mobile navigation applications for pedestrians considering the special contexts of these users. Then the role of landmarks is described in helping the users to orientate and navigate by linking different sources. Afterwards, the need for UCD-approaches for developing more usable mobile navigation systems for pedestrians is justified. Two research studies, one done as part of the UCD stage of requirement analysis and an earlier one comparing different usability testing methodologies are presented. Based on their findings and in combination with related research results, a conceptual model of user interactions during orientation and navigation is proposed, and the technical design aspects of this model are described.

2. Personal geo-identification of pedestrian users and related issues

Interacting with different sources of information when orientating and navigating can be difficult and confusing for mobile navigation system users, restraining them from finding decent answers to any spatial questions that they may have. For instance, using such a system can distract the attention of the users from collecting information about the environment that can help them to develop or update their cognitive maps (Krueger et al., 2004; Ishikawa et al., 2008; Delikostidis & van Elzakker, 2009). Besides, most of the current systems are dedicated to vehicle navigation, lacking information and functionalities necessary to pedestrian users navigating in different contexts (lower speed, larger scales, larger movement freedom degrees and so on).

Maps are very efficient ways of geo-communication and the most operative media available (van Elzakker, 2003), helping to spatially localize objects and retrieve information regarding sizes, distances, directions, spatial relationships and patterns (Kraak & Ormeling, 2002). The same holds for mobile maps. However, the limitations of mobile devices complicate map use and exploration especially under time pressure.

Scaling maps for small mobile displays requires special techniques in order to avoid graphical overload and cluttering. For instance, overview maps, needed by the users to perceive a global spatial context, omit a lot of information which can make screens virtually unreadable. On the other hand, detailed views become map fractions that seem disjoined from the overall understanding (Yammiyavar et al., 2007). Although zooming and panning are widely used as an easy way to fill the gap between overview and detailed maps, they can often lead to loss of contact between mobile maps, users' cognitive maps and reality. Step-wise, redraw-based transitions between different zoom (scale) levels instead of animated transformations worsen the situation further. Hence, the users can become spatially confused and disoriented, continuously using zooming and panning to keep a mental connection with the map (Dilo & van Oosterom, 2006).

In an effort to address the map scaling problem on mobile displays, several solutions have been tested by different researchers, such as local fish-eye views (Chittaro, 2006); overview+detail (Burigat et al., 2008), vario-scale maps (Harrie et al., 2002) and off-screen object visualization (Baudisch & Rosenholtz, 2003). But still, proper scaling of mobile maps remains a major issue especially in view of their usability.

Being another crucial information source for mobile navigation system users, cognitive maps are mental representations that help effective interpretation and comprehension of the environment and developing spatial knowledge (Garcia-Mira & Real, 2005). They are for this reason essential for spatial behaviour and decision support. Lynch (1960) argued that mental (or cognitive) maps are comprised of landmarks, edges, districts, paths and nodes that resemble reality. Cognitive maps are actually dynamic, encompassing various types of information rather than being just a replication of graphical, static maps (Hannes et al., 2006). In fact, inside the mind a reshaping of the natural environment is taking place. Thus there, for instance, distances do not follow the well established rules of cartography, as scale appears to be non-uniform. The often visited places, for example, are subjectively perceived as being closer compared to unfamiliar ones regardless of their real proximity (Letenyei, 2007).

Mobile and cognitive maps share information about reality but, at the same time, represent it in different forms that are sometimes incompatible to each other. Finding sound ways of linking them in order to support personal geo-identification and navigation would thereby help develop more usable pedestrian navigation systems.

3. The role of landmarks

There have been many efforts to incorporate mental mapping in the development of mapping applications. Look & Shrobe (2007), for example, investigated the mental models that citizens of Boston city have about it. Based on that, they formulated directions for the development of mapping applications easier to be perceived and used. The role of prominent features (landmarks) inside mental maps proved significant as they help humans to specify and conceptualize unfamiliar places. The final conclusion of Look & Shrobe (2007) was that understanding mental mapping, and the core objects around which they are formed, enables the development of map-based applications that, besides helping navigation through the presentation of landmarks, also support the upgrading and expansion of current mental maps with new useful information.

Landmarks help forming structural knowledge, acting as spatial reference points in both reality and cognitive maps. Around landmarks, the initially empty cognitive spaces are filled up with information acquired through actual experience in reality (Ishikawa & Montello, 2006) and allow confirmation of decision points and route directions (Siegel & White 1975). People favour orientating based on observable landmarks instead of synopsizing the general geometrical structure of an area (Davies & Peebles, 2007).

Because of the importance of landmarks, mobile navigation systems development has paid interest to the proper selection and presentation of landmarks that sufficiently support orientation, navigation route direction provision. Structural taxonomies, for instance, have been developed based on landmarks' saliency (Klippel & Winter, 2005), dividing them into different groups and levels, such as local/distant landmarks, so that they can be selected and presented to the user in particular parts of a route. Hereof, distant landmarks are fundamental in direction provision and they help people to orientate and acquire global spatial understanding (Sorrows & Hirtle, 1999). In this respect distant landmark visibility is an important aspect to be taken into account.

Providing mobile navigation system users with cartographic interfaces based on landmarks has been a promising approach. Obtaining a deeper understanding, though, of the types of landmarks and other structural elements that users refer to in real contexts in order to make spatial decisions and carry out spatial tasks would further support the development of more usable mobile navigation systems.

4. Requirement analysis and experimental findings

The stage of UCD requirement analysis in this research was completed based on two field-based user studies involving spatial task execution and the findings of other published research. Both the field-based studies were based on scenarios developed after real context use cases, where the user represented a tourist-visitor arriving to an unfamiliar city, trying to understand where she or he is and navigate towards different targets with the use of a mobile navigation application. The main aim of the first study (Delikostidis, 2007; van Elzakker et al., 2008) was the comparison between different methods and techniques for field-based usability testing of geo-mobile (navigation) applications. However, many findings about personal geo-identification and navigation could be extracted from the analysis of the results as well. 18 test persons participated in that experiment which was held in the village of Lonneker in the Netherlands.

A combination of different research methods and techniques was used for that study, comprised of questionnaires, observation, thinking aloud, audio/video recording, and semi-structured interviews. Implementing a unique field observation/recording system allowed for synchronized capture of different video and audio sources, reduced bias to the test persons and easier analysis of research material. The audio signal of user's thinking aloud together with observations of the user, the environment, the mobile display and the user's interactions with the mobile interface were recorded simultaneously together with date/time information. In this way, analyzing the users' actions, expressed thoughts and the context of use could be done precisely and quickly.

The second study (Delikostidis & van Elzakker, 2009) investigated the behaviour of the users of geo-mobile applications when geo-identifying themselves and navigating with the help of landmarks, identifying the reasons for spatial confusion and disorientation. The test persons carried out predefined wayfinding tasks in two structurally different areas of Amsterdam, using two different commercial mobile navigation applications. The latter were selected in the basis of criteria, such as provision of 3D landmarks and smooth zooming capability. The research methodology was the same as in the first study, involving now GPS tracking and mental map drawing as well. Additionally, an improved version of the field observation system used in the first study was employed.

Asking the test persons to draw a map of the route they followed during the experiment including anything remembered, gave us a useful indication of the landmarks used in their mental maps. These drawings together with their behaviour during the experiment suggested that the important landmarks (considering the test areas' specific characteristics) were transportation stations, street names, road patterns and sizes, pedestrian paths and crossings, railroads, tall and/or important buildings, churches, squares and parks, supermarkets and big shops, city centers, rivers / canals and bridges (Delikostidis & van Elzakker, 2009).

From the two studies we could conclude that continuous and accurate automatic rotation of the mobile map towards the user's viewpoint is very important. Besides, the map should be simple, following a straightforward colour coding and it should not be overloaded with many symbols or 3D buildings. The street sizes and patterns should reflect these parameters of reality. Landmark photos that pop-up when clicking them are more preferable than 3D models. Frequent zooming and panning is needed to maintain the reality-mental map-mobile map connection, something that could be avoided by preserving landmark visibility in successive scales. Information on the map should be presented in a way that allows the user to spend more time observing the surroundings and developing his or her mental maps rather than interacting with the mobile map time and again.

5. Conceptual model of user interactions and prototype design aspects

The findings of the requirement analysis stage of this research helped us outline the parts of current mobile cartographic interfaces for pedestrian navigation that could benefit from particular design approaches. In the design solutions production stage of our UCD-approach, a conceptual model of user interactions with the mobile map, reality and the underlying mental maps was formed, based on the usual user tasks during orientation and navigation in new areas and the questions related to these tasks. As a response to these questions, the mobile navigation system interface should provide the user with answers in terms of visualized information and system operations (Figure 1).

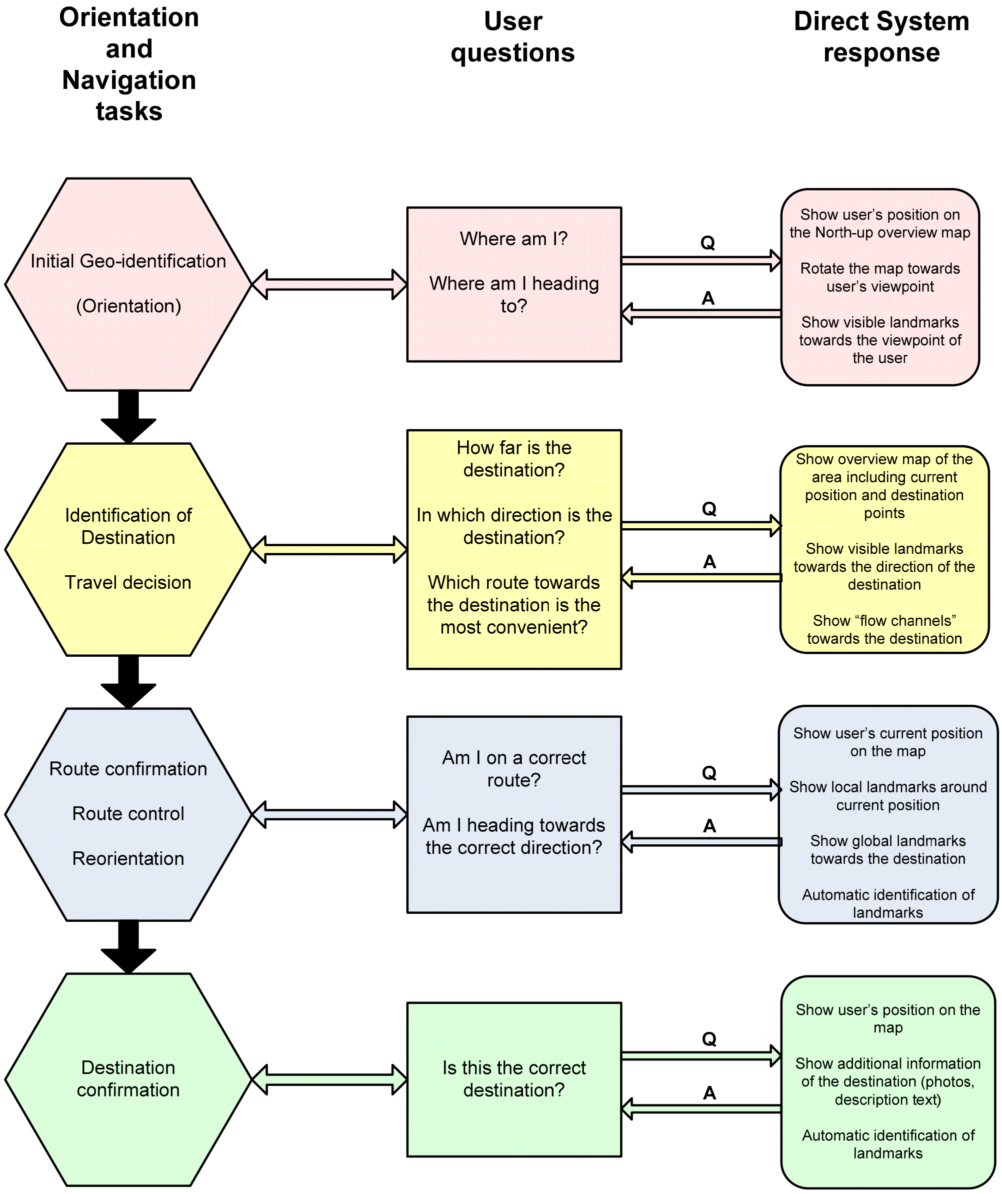
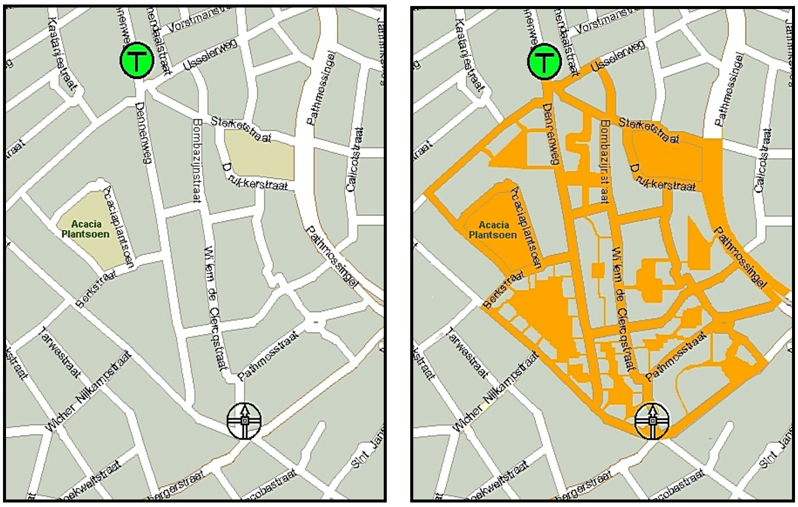


Figure 1: User interactions during orientation and navigation.

Although there are several differences between particular users in the way they interact with the environment, their mental maps and the mobile application while orientating and navigating, there still is a large pool of similarities in these cognitive processes and their components. These similarities allow for the successful application of the results for specific groups of users, where at the same time a carefully designed individual parameterization can increase particular user's satisfaction and requirement achievement. In this regard, an additional user research is currently carried out at ITC into meeting individual needs for landmarks through context aware pedestrian navigation systems. During ICC 2009, the first results of that research will be reported.

The proposed system response is based on five main design aspects formulated:

I. Pedestrians should not be forced to follow particular paths or streets in terms of car navigation system-like route directions as their degree of movement freedom is considerably larger. They should thus be let free to select any possible route (inside a predefined range window) that leads to their destination. We introduce here the concept of pedestrian “flow channels”, representing any possible walkable space between buildings, highways, canals or other non-accessible features that pedestrians can cross in any possible trajectory as metaphor of water flowing inside ditches (Figure 2).



(a) (b)

Figure 2: Typical city map (a) and the same map with “flow channels” visible (b). User’s position and heading (cross+arrow) and target point (T) are shown.

II. Considering the importance of landmarks as reference points linking reality, mental maps and mobile maps, they should remain visible on the mobile map in any scale used. Further, providing the users of mobile navigation systems with visibility information regarding landmarks in the environment would help them determine and confirm their position, heading and route at any particular moment.
Using 3D city data together with an algorithm calculating landmark visibility at consecutive map points (that occur inside “flow channels”) it would be possible to create such maps. This information could then be used to determine whether a landmark should be visible on the map depending on its visibility in reality or change its colour, size or shape accordingly (Figure 3).

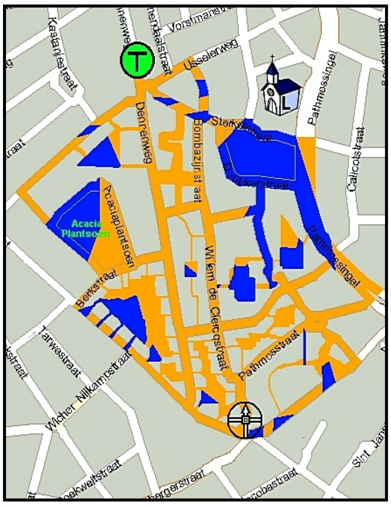


Figure 3: A landmark visibility map with areas where a landmark is visible in a darker (blue) colour.

III. The performance of mobile navigation system users during spatial task execution is strongly affected by the map orientation (Darken & Cevik, 1999; Winter & Tomko, 2004; Smets et al., 2008). In general, and despite some individual differences, North-up maps enhance global awareness, and heading-up maps help wayfinding tasks by reducing the mental effort needed for map rotations and alignment to the user's viewpoint (Winter & Tomko, 2004; Smets et al., 2008). Heading-up maps should then rotate at any moment automatically towards the user's viewpoint following his or her body rotation even when she or he is not walking (digital compass) to further support user's spatial task execution. A North-up map would be useful when provided at the beginning of any navigation task, automatically transformed by animation into heading-up during navigation in order to help the user keep the connection between the two views. Manual transformation from one to the other view should be possible as well, while the type of orientation should be clearly indicated on the display.

IV. Providing the users with a tool for automatic recognition-identification of landmarks, would promote the development of their mental maps and enhance their global spatial understanding. Using the integrated digital camera of the mobile device and the user's GPS position and heading information in combination with the landmark visibility map data, an image recognition algorithm (example: Zhang & Kosecka, 2005) could carry out this task.

V. One of the biggest issues in mobile navigation systems is the impossibility of having an overview and detail map concurrently as, for instance, with paper maps. Overview+detail maps, adopted from desktop systems, did not provide any benefits as well. However, a reverse version of that method has not been tested yet. In that case, an overview map would be the main display and a "viewport" window could show the area around the current user position in larger detail. The part of the overview map displayed in detail should be highlighted and distinctly related to the freely movable viewport window (Figure 4). At any moment the viewport could transform into full screen view through an animated transition. Using animated transitions between zoom levels would allow us to test this approach during user testing, evaluating a method that seems promising but still lacks experimental evaluations.

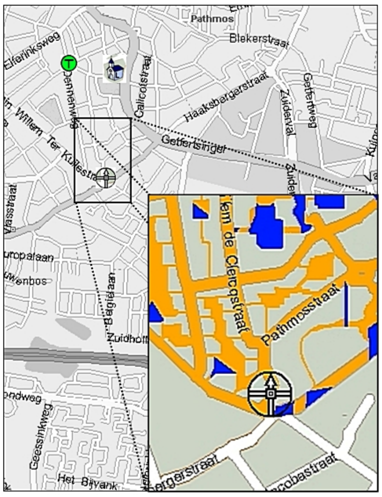


Figure 4: A reverse overview+detail map.

6. Conclusion

This paper presented the evolution of a UCD-based research project, aiming at the development of a more usable mobile cartographic interface for pedestrian geo-identification and navigation. The reasons for carrying out such a research were explained and the already completed stages of requirement analysis and conceptual design were described. Carefully modeling user interactions with the environment, mental maps and the (map) representation of reality on a small display screen, based on theoretical and experimental studies, can reveal several ways to support personal geo-identification and navigation of pedestrian users through geo-mobile applications. The main outcome of this paper, was the conceptual design of a of a prototype mobile navigation interface of improved usability. However, the success of the followed approach is something to be evaluated through user testing when the prototype is developed.

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