CO-125

USABILITY TESTING OF A PROTOTYPE MOBILE NAVIGATION INTERFACE FOR PEDESTRIANS

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1. INTRODUCTION

Existing pedestrian navigation systems are in many aspects literal reproductions of vehicle navigation systems, although their contexts of use and users are clearly different. The amount of movement freedom of a pedestrian is much larger than a car driver and their strategies for orientation and navigation notably differ as well. To cope with this problem, a User-Centred Design (UCD) approach was followed to develop a prototype interface of a pedestrian navigation system for visitors to unfamiliar urban areas named “LandNavin” (LN, after Landmark-based Navigation interface). An interim report of the requirement analysis and prototype design stages of the UCD process was provided at LBS 2009 and ICC 2009 (Delikostidis & van Elzakker, 2009a, 2009c).

The requirement analysis provided the necessary information for the conceptual design of the prototype, the information requirements and the technological solutions needed. These solutions were a compass-based heading-up map, reverse overview+detail (or “dual”) map, global landmark visibility indication, multi-perspective landmark photo provision, landmark filtering based on the user’s orientation and position, and multi-path routing to the destination(s). Following these guidelines, LN was implemented on Google Android platform. After completing the development of the LN prototype, an evaluation of the design as part of the conducted UCD methodology was planned in the form of an empirical, field-based user testing. In this way, the applied technical solutions were evaluated and the extent to which the user requirements were met was investigated.

This paper begins with a brief description of the development procedure and decisions for LN. The aims, methodology and technical solutions for the usability evaluation of the prototype after it was completed are explained later on. Thereafter, the results are presented and analyzed and some conclusions drawn.

2. LANDNAVIN DEVELOPMENT

The first step for the development of LN was to convert the four identified use cases of the requirement analysis (Initial Geo-identification, Identification of Destination and Travel Decision, Route Confirmation / Route Control / Reorientation and Destination Confirmation) into sequence diagrams using UML. In this way, the conceptual design could be directly translated into software code for prototype development. Based on the information requirements established, a detailed description of the interface functionality and design was then made. Considering the need for a base map with smooth zooming capabilities, Google Maps was selected over other alternatives. Next to a base map of the whole world, the Google Maps Application Interface (API) provides the tools for building map-based interfaces for different software platforms. Additionally, that API natively supports smooth zooming, eliminating the need to develop a custom solution for that.

Making use of the results of the requirement analysis, the important landmarks to appear on LN were divided into 30 types and categorized as local and global (global when height>30 metres). For the local landmarks, everything except the noticeable monuments (e.g. outdoor art objects) was presented with distinct pictograms (Figure 1). For the global landmarks, but also the noticeable monuments, special drawings were made based on photos of the landmarks, in order to provide direct references to the landmarks’ visual characteristics. Pictograms were also used for representing some global landmarks, when the landmark could be easily recognized based on its type and functionality. To be able to calculate and indicate on the map the visibility of global landmarks at any point in Amsterdam, raster layers were used, showing the visibility of each landmark at pedestrian eye-levels from the ground (1.60m).

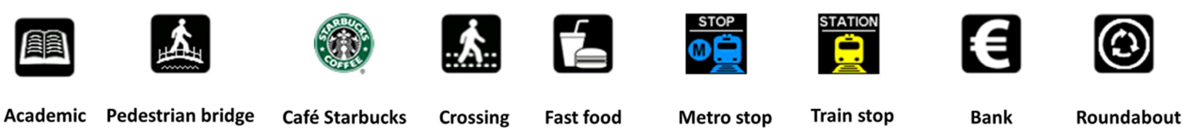

Figure 1: Examples of the pictogram landmark icons used.

To select a software and hardware platform for LN, a set of minimum hardware and software requirement were set, including amongst other things the integration of different sensors (GPS, digital compass), capability to run Google Maps API-based applications etc. As the most convenient platform, Google Android was then chosen. One of the main reasons for that decision was the Java-based Open Source, platform of Android which allows for easy cooperation of programmers and free code exchange. Besides, Eclipse Interface Development Environment (also Open Source) is well integrated with the Google Android Software Development Kit (SDK) making it very easy to create and debug new applications. Google Android is a multi-sensory platform, integrating many different sensors (e.g. GPS, accelerometer and compass) as part of the standard device architecture. An HTC Hero Android-based smartphone was used as the hardware basis for the software implementation of the prototype, later replaced by a Samsung Galaxy S for the aims of the usability testing.

During the development of LN, different issues were addressed while applying the proposed technological solutions of the conceptual design. A simple North-Up map was initially created, but at that time there was no direct support in Google API for map rotation, thus a custom solution was implemented for the heading-up map. For the implementation of the dual map, a second, individual map interface was created, which was called by LN and over imposed on the main map. To enable/disable the map rotation, the dual map but also a satellite view, three on-screen buttons were made, becoming green when pressed as an indication of their state. A moving scale bar and a rotating compass were also placed on the map (Figure 2a).

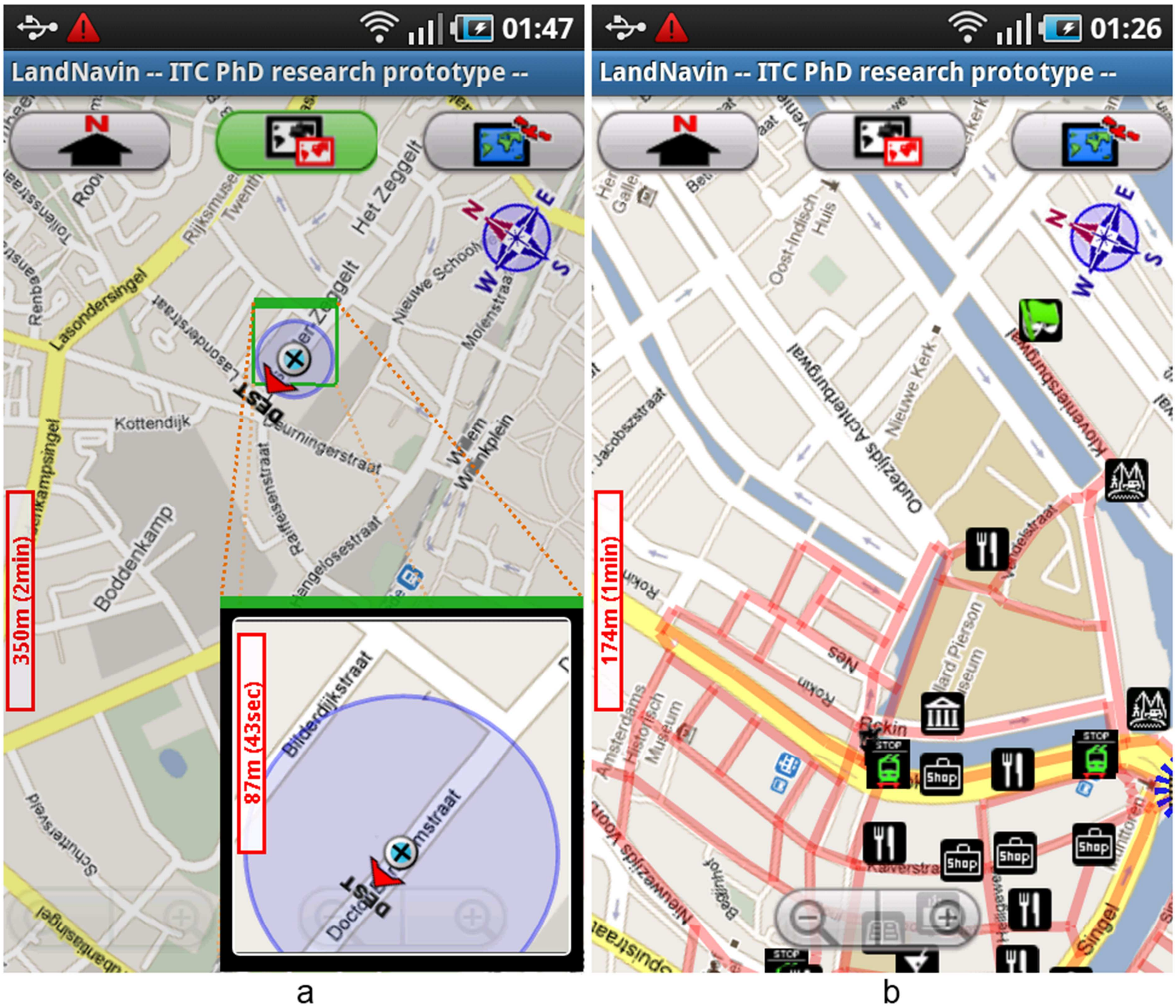

Figure 2: Actual appearance of the prototype interface: with dual map enabled (a) and showing a multipath accompanied by local landmarks (b).

As both local and global landmarks should be shown in the mobile interface and they should be differentiated, a dotted circle was put around the global landmarks to provide an additional reference to them. But this circle had also another important function: to inform the users about the visibility of global landmarks from current position through a change of colour (blue: visible and red: invisible). Landmark filtering was also implemented: in the heading map all the landmarks behind the user, local and global, were filtered based on his or her heading.

Multi-perspective landmark photo provision made use of four photos for each landmark, taken from its North, South, East and West perspectives. Depending on the user's position and bearing towards the landmark, one of them was selected and shown in a pop-up window along with information about the landmark.

Providing the users with automatic multi-path routing to their destination(s) proved to be not possible with the current version of Google Maps API. Alternatively, superimposing pre-made multi-paths in the form of multiple lines was a feasible solution (Figure 2b). Although the result was different than the "flow channel" idea, the multi-line solution was still a valuable way to demonstrate the users the multi-path idea and evaluate its usability.

3. USABILITY EVALUATION AIMS, QUESTIONS AND TASK SCENARIOS

The last part of UCD is usability testing of a developed prototype. Here, the aim of the testing was to identify possible usability problems and gather information regarding the performance of the test persons. Thus, a combination of objective (performance) and subjective (preference) metrics was applied, measuring the task completion times, the success and error rates on doing that and the satisfaction of using the prototype.

Central to this research were the links between reality, mobile maps and the users' mental maps. Doing the usability testing in the lab would exclude some of these links, as the real context of use would not be considered properly. Thus a field-based experiment was preferable, considering that content and presentation issues of the prototype could also be investigated in real usage conditions. A main problem of field-based testing, the high-resource demand, had already been successfully addressed during the requirement analysis experiment of this research by using special technical solutions (Delikostidis & van Elzakker, 2009b).

The initial development goal for LN was to help pedestrian visitors to orient themselves and navigate in unfamiliar urban areas through a usable mobile interface. Based on the conceptual design following the requirement analysis stage of this research, personal geo-identification (orientation) and navigation was broken down into 4 main tasks. Each of those embodies different questions that the users of a mobile navigation system are asking (themselves), and technical solutions to help answering those questions were proposed. The usability of these solutions had to be assessed by providing the users with real tasks in which the formulated questions should arise. Examples of such questions are: "Where am I?"; "Am I following the correct route?" and so on. Moreover, specific questions regarding the functionality of LN when used as an orientation and navigation aid were formulated. These questions were divided into 10 groups, according to the function that they were assessing:

1. Position of the user and map orientation
2. Reverse overview+detail map
3. Multi-path and time availability
4. Landmark visibility
5. Landmark pop-up information
6. Landmark symbology
7. Scale bar and on-map compass
8. Interface interactivity
9. Landmark filtering
10. General impressions, problems and areas for improvement

Navigating from a starting point to an unfamiliar destination was the basis of each user test session incorporating task scenarios which had to reflect real use and user contexts when there is a need for an electronic navigation tool. It was considered to be useful to compare the user's performance using another existing application interface as well. By doing so, the usability of LN could be measured against a different implementation (of the same concept). To make the results of this comparison valuable, both of the interfaces should share common characteristics regarding map style / colours / way of performing basic functions like zooming-in / out, etc. In this way, the possibility to get different results based on aspects other than the functionalities and available information on each of them was reduced. Considering that LN was implemented using the Google Maps API, Google Mobile Maps software (from now on referred to as

GM) was the best selection for this comparison. However, the user tasks had to be slightly adjusted so that they do not refer to functions that are only available for LN.

4. STUDY AREAS AND SELECTION OF TEST PERSONS

To investigate the usability of the prototype in different city settings, 2 test areas with 2 destinations each were selected to be used interchangeably with LN and GM for the same test person (TP), for comparison aims. The first area was in the greater centre of Amsterdam, starting at the Monument on the Dam (S1) with as selected destinations the Bijbels Museum (D1) and the Doelenzaal theatre (D2). The second was away from Amsterdam's centre, in a mostly residential and commercial area starting at Wibautstraat Metro Station (S2) and having as destinations the Krugerplein (D3) and Amstel Metro Station (D4). The reasons for that decision were first of all the data availability for 3D city modelling of Amsterdam, required for calculating landmark visibility. Second, travelling to Amsterdam is convenient for conducting user briefing sessions (Delikostidis & van Elzakker, 2009b). Third, Amsterdam is a very good example of a touristic city with a great structural diversity from the centre to the suburbs.

The TPs to participate in the test sessions should represent the potential user of the interface, a pedestrian visitor to an unfamiliar urban area who uses a navigation system in order to orient and navigate. The required number of TPs was 24, selected based on pre-selection questionnaires mainly distributed through academic channels (Faculty ITC, University of Twente). However, special effort was given to find (8) TPs outside that community (which has above average map skills) to increase the participants' diversity and control the background knowledge bias to the TPs.

The demographics and the individual characteristics of the 24 TPs are shown in Table 1. Their level of knowledge in particular fields of interest for this research is presented through numeric values (0 to 4). Thus 0 refers to "none", 1 to "poor", 2 to "fair", 3 to "good" and 4 to "excellent". The TPs had various country origins and their gender distribution was 10 males and 14 females. Their age was in the range of 18 to 60 years old; they were mostly between 18 and 40.

TP NUMBER	GENDER	AGE GROUP	COUNTRY OF ORIGIN	BACKGROUND	PAPER MAPS	DIGITAL MAPS	GPS	MOBILE NAVIGATION SYSTEMS	SMARTPHONES	MOBILE GOOGLE MAPS	ORIENTATION IN NEW PLACES
TP1	M	31-40	Bulgaria	Molecular Bioengineering	2	1	1	1	2	2	4
TP2	F	25-30	Bulgaria	GI Science	4	4	1	0	0	0	3
TP3	F	18-24	China	GI Science	3	3	2	1	2	3	3
TP4	F	25-30	China	GI Science	3	3	2	2	2	2	3
TP5	M	25-30	Nepal	Environmental Science	3	3	3	0	1	2	3
TP6	M	31-40	Mexico	Oceanography	3	3	3	3	2	3	3
TP7	F	31-40	Chile	Chemistry, Oceanography	3	3	3	3	3	3	3
TP8	F	31-40	Georgia	Cartography, GI Science	4	4	3	3	4	4	4
TP9	M	31-40	Sweden	Surveying	3	3	2	2	2	2	3
TP10	M	41-50	Spain	Rural Resource Management, GIS	3	3	3	2	2	2	2
TP11	F	18-24	Ukraine	Geodesy, GIS	3	2	3	2	2	1	3
TP12	M	25-30	Namibia	Geography, Information science	4	4	4	4	4	4	4
TP13	F	25-30	Zimbabwe	Environmental Studies	3	3	2	4	4	3	4
TP14	M	18-24	India	Information Science, Engineering	3	3	2	2	3	2	3
TP15	M	31-40	Colombia	Computer Science	3	4	4	3	3	4	4
TP16	F	31-40	Tanzania	Computer Science	2	2	2	2	2	3	2
TP17	F	31-40	Peru	Civil Engineer	2	3	1	0	0	0	3
TP18	M	41-50	Netherlands	Electronics, Computer Engineering	3	3	2	0	0	0	3
TP19	F	18-24	China	Interaction Design, Product Design	4	0	0	0	2	0	4
TP20	M	25-30	Netherlands	Security	3	2	2	1	2	2	3
TP21	F	18-24	Mexico	Industrial design	1	1	0	0	2	3	2
TP22	F	18-24	Mexico	Industrial design	1	1	2	2	4	2	2
TP23	F	25-30	Indonesia	Computer Science, HCI	3	3	0	0	3	0	4
TP24	F	51-60	The Netherlands	Management assistant, yoga teacher	1	1	1	1	1	0	2

Table 1: The demographics of the TPs and their individual characteristics. TP17 to TP24 have no background in Cartography or Geo-informatics.

5. TEST SET-UP AND METHODOLOGY

As the prototype shows different multi-paths to the destinations associated by particular local landmarks depending on two different time availabilities of the user ("you have plenty of time to reach your destination" / "you only have little time"), the performance of the TPs had to be tested with both of them. Half of the TPs were provided with the first option and the other half with the second one.

Each TP had to execute a test session in one of the two Amsterdam areas, divided into two parts. First, starting from the starting point he or she had to navigate to the first destination using one of the two application interfaces (LN or GM) and, thereafter, from that destination the second one had to be reached with the other application interface. The sequence of use of each interface was reversed for each new TP in order to investigate the results of the "learning effect".

The test parameters used to divide the TPs into groups for the experiment were two: the area of the test and the sequence of the interface used. Based on the two values each of these parameters can have, four groups (2 areas x 2 interfaces) of participants were constructed. Time availability was also considered as a test parameter but not for TP grouping, as GM does not offer different routing to the destination based on the available time of the user like LN does. The number of 6 participants in each of the four TP groups was regarded as suitable and feasible given the available resources. It is acknowledged that this number of TPs is too small to draw statistically strong conclusions, but, as said, enough to discover the main usability problems. The session structure for each TP is shown in Table 2, where the formation of the four TP groups is shown in four different colours. The TPs who were unfamiliar with both of the test areas were scheduled for testing in any of those, and the ones who were familiar with one of the areas were tested in the other one. In this way, any bias to the results due to previous experiences of the TPs was avoided.

PERSON	AREA	TIME	START	DEST.	INTERFACE	PARAMETERS	GROUP
TP1	CENTRE	P	S1	D1, D2	LN→GM	CPL	A
TP2	WIBAUTSTRAAT	P	S2	D3, D4	LN→GM	WPL	B
TP3	CENTRE	L	S1	D1, D2	LN→GM	CLL	A
TP4	WIBAUTSTRAAT	L	S2	D3, D4	LN→GM	WLL	B
TP5	CENTRE	P	S1	D1, D2	GM→LN	CPG	C
TP6	WIBAUTSTRAAT	P	S2	D3, D4	GM→LN	WPG	D
TP7	CENTRE	L	S1	D1, D2	GM→LN	CLG	C
TP8	WIBAUTSTRAAT	L	S2	D3, D4	GM→LN	WLG	D
TP9	CENTRE	P	S1	D1, D2	LN→GM	CPL	A
TP10	WIBAUTSTRAAT	P	S2	D3, D4	LN→GM	WPL	B
TP11	CENTRE	L	S1	D1, D2	LN→GM	CLL	A
TP12	WIBAUTSTRAAT	L	S2	D3, D4	LN→GM	WLL	B
TP13	CENTRE	P	S1	D1, D2	GM→LN	CPG	C
TP14	WIBAUTSTRAAT	P	S2	D3, D4	GM→LN	WPG	D
TP15	CENTRE	L	S1	D1, D2	GM→LN	CLG	C
TP16	WIBAUTSTRAAT	L	S2	D3, D4	GM→LN	WLG	D
TP17	CENTRE	P	S1	D1, D2	LN→GM	CPL	A
TP18	WIBAUTSTRAAT	P	S2	D3, D4	LN→GM	WPL	B
TP19	CENTRE	L	S1	D1, D2	LN→GM	CLL	A
TP20	WIBAUTSTRAAT	L	S2	D3, D4	LN→GM	WLL	B
TP21	CENTRE	P	S1	D1, D2	GM→LN	CPG	C
TP22	WIBAUTSTRAAT	P	S2	D3, D4	GM→LN	WPG	D
TP23	CENTRE	L	S1	D1, D2	GM→LN	CLG	C
TP24	WIBAUTSTRAAT	L	S2	D3, D4	GM→LN	WLG	D

Table 2: Structure of the test sessions for each TP.

The usability testing investigated the TPs' reactions and interactions with the prototype and measured their performance while carrying out their tasks. Every possible feedback from the TPs that could help improving the interface was also collected. It was particularly important to understand the users' feelings and mental processes behind their actions while using LN during the given tasks, especially when they got troubled or confused. For this aim, thinking aloud was applied. The TPs' satisfaction using the prototype and whether it met their expectations could also be inspected through thinking aloud. This sound was not only observed, but also captured and stored in a convenient medium so that it could be analyzed later on for extraction of usable information and provision of possible (re-) development directions. Moreover, video recording the TP from different view perspectives allowed for more accurate analysis of the research data, especially when these different views are synchronized and contain time information.

A technical system that supported synchronized multiple video and audio data collection in the field had already been implemented earlier in this research (Delikostidis & van Elzakker, 2009b). An improved version of that remote observation / recording system was developed for the execution of the usability testing of LN, offering less complexity, higher reliability, smaller size and weight and higher quality of collected data (Figure 3).

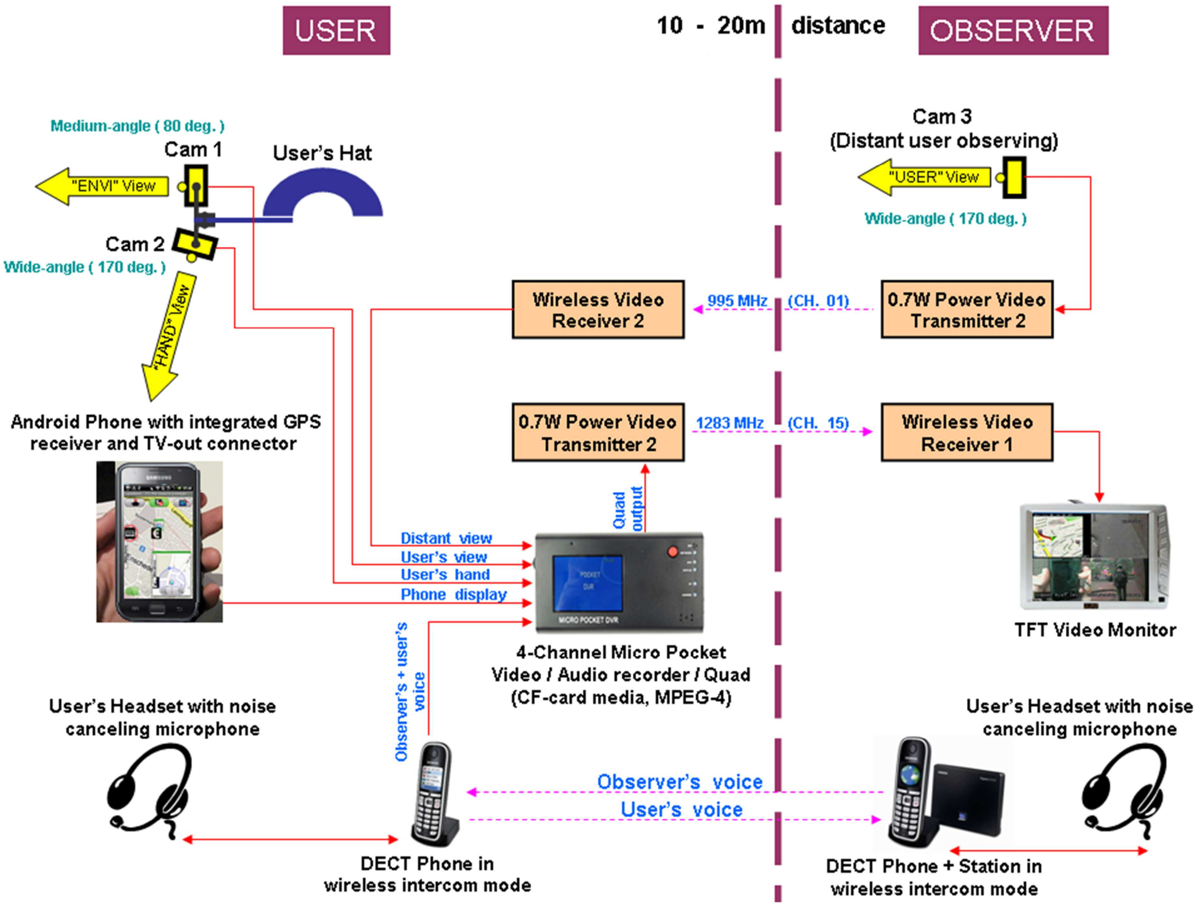

Figure 3: Diagram of the new field-based remote observation/recording system used.

6. TEST EXECUTION

Before the actual execution of the usability testing, two pilot tests in each of the two study areas were carried out, to examine the execution procedure and the correct operation of the technical tools. Through pilot testing, several problems were identified and addressed. Two of them were the interference produced by the video transceivers, solved by using a cable for video transmission (Figure 4) and the difficulty for continuous landmark scaling on the map, solved by using a pre-determined set of icon sizes for different map zoom levels.

Figure 4: Using a temporary video cable connection between the researcher and the TPs to overcome wireless video transfer problems.

The main test sessions were conducted between the 31st of July and the 12th of September 2010. In general, the tests were performed without significant problems in regards to the methodology. One researcher and one TP at a time was a convenient approach with low resource requirements. There were some technical issues, though, the most serious of them resulting from a defect CF-card of the video recorder which caused corruption of the video recording of three TPs.

7. RESULTING DATA

The research data acquired from the usability testing of LN comprised of 3 types of material: pre-test questionnaires, synchronized video / audio recordings of the test sessions and audio recordings of the post-session interviews. An example of the video recordings of the experiment is shown in Figure 5.

Figure 5: Example of the recorded video material (screenshot).

To analyze those data, first an interpretation of the results was done through verbatim transcription of the thinking aloud and screen and action logging from the recordings. In that way the data was transformed to an easily accessible form from which the problems, expectations, opinions and preferences of the TPs could be extracted. This was done by coding the different text segments of the transcript using Atlas.ti qualitative research software. Twelve codes were defined, each referring to a particular action or state of the TP (Table 3). The codes were accompanied by comments from the researcher, helping identify important usability issues and patterns in the research materials.

A: aborting task	P: positive comment
B: software / hardware bug	S: successful execution
C: confusion	U: usability problem
E: error / fail	V: verification
H: help needed	X: user stopped
N: negative comment	Z: doing zoom-in / out

Table 3: The codes which were used for the analysis of the transcript.

8. ANALYSIS OF THE RESULTS

a. Navigation performance

The 4 tasks of the usability testing experiment comprised of several sub-tasks that the TPs had to complete. Most of the sub-tasks comprised short assignments of orienting, locating landmarks, retrieving and verifying information, using interface functions and so on. However, to assess the performance of the TPs when navigating from a starting point to a destination, two longer-duration sub-tasks had been added at the end of the main tasks 2 and 3. During these sub-tasks the TPs were let free to use any available information and follow any path they decided to follow in order to find the given destination and go there. The outcomes of these sub-tasks were very important, as they provided an overall evaluation of the efficiency and effectiveness of the interfaces used for the tests.

As it comes to the navigation execution times, the number of TPs who performed faster with LN was larger than the number of the ones who did that with GM. At the same time, their performance using LN with little time available was exceptionally better (8 against 4) than using GM. Comparing the time results of the TPs who used LN first (half of them) to the ones who used it second, it appeared that the first group performed better in both of the test areas. A possible explanation for this result is that the TPs using LN first got used to its rotating map, thus could not perform as well when they had to execute similar tasks with the solely North-up map of GM. In many cases during the experiment, it was observed that those TPs were still expecting the map to rotate when using GM, having forgotten that this function was not available with it.

The number of stops of the TPs during navigation was an indirect indicator of the efficiency of the interfaces, although it also depends on the orientation and navigation capabilities of the TPs. The reported stops were only the ones made by the TPs and not induced by the researcher or other external triggers. As it comes to the average number of stops per group of TPs, 3 out of 4 groups (A, C and D) performed better with LN. The stops (LN against GM) for each of these groups were: 19 against 22 (group A), 11 against 8 (group B), 33 against 49 (group C) and 3 against 16 (group D). An interesting observation here is that the TPs of group D who had no background in Cartography or Geo-informatics produced noticeably better results using LN compared to the other groups.

b. Task completion effectiveness

During Task 1 (Initial Geo-identification), in the vast majority of the sub-tasks the task completion effectiveness was overall high with LN and better compared to GM. This was more noticeable for the sub-tasks 1e (landmark photo recognition), 1f (locating a near-by landmark) and 1g (walking towards the direction of a non-visible landmark). The main problem of the TPs with both the interfaces was their inability to recognize prominent landmarks in areas with low structural diversity. Most of the TPs preferred to use the compass-based rotated map of LN over a North-Up map and that helped 22 out of 24 TPs to correctly estimate the direction of near-by landmarks. With GM that number fell to 17. As it comes to moving towards a non-visible landmark, all the 24 TPs successfully completed the sub-task with LN. With GM 8 out of 24 TPs moved to the wrong direction and one TP refused to complete the task due to spatial confusion.

During Task 2 (Identification of Destination and Travel Decision), the task completion effectiveness using either LN or GM was very high for all the sub-tasks except sub-task 2e (walking towards the direction of destination for a few metres), where the average effectiveness using GM was very low.

During Task 3 (Route Confirmation / Route Confirmation / Reorientation), in all the 3 sub-tasks the task completion effectiveness was very high for LN and noticeably lower for GM, especially for the sub-tasks 3a (finding information about landmarks along the route and towards the destination) and 3c (walking towards the direction of destination). In the earlier, using LN the TPs were more able to complete the task, as a matter of easier recognition of landmarks on the map. In the latter, the better average performance of the four groups of TPs with LN indicates the usability of the compass-based rotated map when orienting.

During Task 4 (Destination Confirmation), the task completion effectiveness was very high with LN and noticeably lower with GM. Especially in sub-task 4a (verification of destination on the map while reaching it), all the groups had total success with LN. In sub task 4b (destination recognition through the provided text description and photo), besides the averagely better performance with LN, groups A and C performed better with both LN and GM than groups B and D. An explanation for this result could be that the destinations used in groups A and C (Wibautstraat area) were more distinct than the destinations used in groups B and D (Amsterdam Centre).

c. Assessing the technical solutions applied in LN

The assessment of the technical solutions applied in LN was based on the TP’s task performance, thinking aloud results and answers to the post-test interviews. In general, the TPs found LN less confusing, more helpful in orienting themselves, more accurate, responsive and easier to use with more and new useful functions.

The TPs found the rotating map more helpful for orienting and navigating themselves than a North-up map. However, half of them would like to have both options available. The dual map helped the TPs to orient themselves and connect reality to the mobile map and reduced their need for continuous zooming in and out. However, it was a bit complicated to use thus it needs some improvements. The multi-paths for different time availability were well accepted by the TPs and preferable over single paths. Slight (color) changes were proposed in the way these appear on the map. The majority of TPs also liked and used the landmark visibility indication. GPS and compass inaccuracies, though, affected its proper functioning and in several cases the TPs would need a little more time to get familiar with it. Therefore the solution should be slightly redesigned in order to make it more easily perceivable and thus more usable.

As it comes to landmark pop-up information, multi-perceptive photos and landmark symbology, the majority of the TPs used these solutions and found them useful. For a third of the TPs, online landmark-specific information should be provided as well. Most of the TPs could easily understand the meaning of landmark symbols; however, a third of them although they liked the icon scaling they would prefer smaller symbols. Using the moving, vertical scale bar was regarded as more useful than a standard, fixed-position horizontal one. The combination of distance and time needed on the scale bar was used and liked by most of the TPs. The rotating compass, on the other hand, was useful for only a third of them, implying that it should be enabled on demand.

For most of the TPs, the meaning and state of on-screen buttons was easily understood and the interface was in general very responsive. The landmark filtering was very helpful for the majority of them and it reduced their mental load. However, for almost one third of the TPs the function should be manually disabled. Disabling the landmark filtering when North-up map is enabled was a function not well understood by many TPs, thus a slight redesign is needed. Icon overlapping in particular zoom levels was one of the main problems that the TPs identified, and parameterization of landmark type presentation was one of the main functions proposed for future implementation.

9. CONCLUSION

This paper gives a detailed account of the methodology and execution of the usability evaluation of the LandNavin prototype and ends with a summary of the results. The analysis of the test results shows that the usability of LandNavin, alone and in comparison to Google Maps for the same context of use, is noticeably satisfying. The average number of spatial disorientations and stops is small and the technical solutions applied, such as map rotation, landmark visibility indication and dual map are well accepted and used by the TPs, with only slight improvements needed in some cases. Using LandNavin, the TPs were able to conceptualize space better and found their ways to destinations with more confidence and accuracy. At the same time, TPs provided valuable feedback for prototype improvements which can increase its usability further.

UCD proved to be a suitable methodology for building usable mobile interfaces where use and user contexts are important. Usability testing, as the last part of it, let us evaluate the designs through actual users and find possible problems. Future research projects could make use of the followed methodology in different contexts, trying alternative techniques such as remote usability testing done through internet-based observation and communication.

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