USABLE VISUALIZATION OF LANDMARKS ON MOBILE MAPS

ERIMINA MARKANU MASSAWE
March, 2011

SUPERVISORS:
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ABSTRACT

Currently the physical mobility of people is increasing and information technology is highly improving. Pedestrians, cyclists, car drivers, sailors, tourists and holiday makers can possibly travel from one place to another (familiar/unfamiliar areas). In orientation and navigation people tend to structure and recognize the space with the help of landmarks, therefore they need relevant landmark information in order to perform proper orientation and navigation. The need for proper landmark visualizations accelerated the growth of science in traffic behaviour, navigation systems and technology in various fields. Due to this it is important to represent these landmarks in an interactive manner, to enable individual users to decide which type of landmark visualization to be used during orientation and navigation. Landmarks are important physical, built, or culturally defined objects that stand out from their environment to help locating the geographic position. Best ways to visualize landmarks (being an essential part of both reality and mental maps of people) on the Mobile Maps (M2) to support users has been an active research topic of interest. However landmark visualizations are presented on M2 in a static way without considering individual user's needs. There are no options of selecting how to visualize the landmarks interactively based on user contexts, difficulties of linking landmarks as they appear in map displays with reality and their mental maps and the vast amount of landmark visualizations.

The design and test of an interactive prototype to adjust landmark visualizations to individual user needs has been done to allow users to decide on how to visualize the landmarks during orientation and navigation a geographic area. A User-Centred Design (UCD) approach, together with Google Maps JavaScript (JS) Application Programming Interface (API) were used to implement the prototype, including three proposed categories of landmark visualizations on M2 (Geometrics, Pictorials and Photos). Individual users are able to select the landmark visualizations of choice without limitations to solve problems.

To investigate whether the proposed visualization of landmarks on M2 at the prototype is working well, a usability evaluation was done using field-based methods and techniques to deeply investigate the interaction of real users with the developed prototype in the real environment. The results showed that the designed and tested prototype for interactive visualization of landmarks on M2 can be considered as a useful outcome of this research. The test users' landmark visualization preferences were obtained. Test users' preference if they were to plan a route themselves, the results showed that, 42% preferred to use Pictorial symbols, 33% preferred to use Photos and 25% preferred to use Geometric symbols. During overview of the route, test users preferences were, 58% use Geometric symbols, 25% preferred to use Pictorial symbols and 17% preferred to use Photos. During navigation test users preferences were, 33% preferred to use all types of landmark visualization interactively (Geometrics, Pictorials and Photos), 25% preferred to Pictorial symbols and Photos interactively, 17% preferred to use Geometrics and Photos interactively, 8% preferred to photos only, 8% preferred to use Pictorial symbols and 8% preferred to use Geometrics symbols.

Keywords
Landmark visualizations, orientation and navigation, mobile maps, UCD, user contexts, prototyping, Google Maps JS API, field-based testing, usability evaluation.

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1. INTRODUCTION

1.1. Overview

Currently the physical mobility of people is increasing and information technology is highly improving. Pedestrians, cyclists, car drivers, sailors, tourists and holiday makers can possibly travel from one place to another (familiar/unfamiliar areas). They need relevant landmark information in order to perform proper orientation and navigation. The need for proper landmarks accelerated the growth of science in traffic behaviour, navigation systems and technology in various fields. Technological advances in geo-information have played a great role in the development of science in navigation systems and methods and techniques of geo-spatial data processing and dissemination. Some aspects of the assessment of the technology which have been considered in geo-information and other disciplines are user and user demands and limitations of utilizing the technology. For a long time, there was no attention towards the individual user (pedestrian) and to how landmarks can best be visualized on M2 taking into account the dynamic contexts of use. Today, however, there is gradually more attention towards creating usable visualization landmarks on M2, by design, implement and testing an interactive prototype which contains different categories of landmark visualizations in order to allow users to select the landmark visualization categories for orientation and navigation. This prototype is expected to support people's geographical orientation and navigation using landmark visualizations. In addition, it will provide users with an option to decide on the type of landmark visualizations of choice when answering specific geographical questions. E.g. Where am I? (Orientations); Am I on the correct way? (Route confirmation); Is this the correct endpoint? (Destination confirmation) or before navigation, what are the landmarks I expect to base my navigation on my way? Is this the correct view at this particular point etc. (Delikostidis and van Elzakker, 2009a).

1.2. Motivation and problem definition

Society today is mainly motivated by technology, which has led to an increase in the availability and use of Mobile Devices (MDs), such as smartphones and PDAs. Their capabilities to serve users as a digital and interactive alternative to paper maps, has opened up an improved potential for mobile orientation and navigation aids, as well as location based services (Delikostidis and van Elzakker, 2009b). Comparative cheap prices of digital and electronic devices have made this new technology accessible to a wider public (Plesa and Cartwright, 2008). There is a significant increase of users relying on M2 for their orientation and navigation. It is forecasted by Malm (2007) that about 42 million users in Europe and North America will be using MDs for navigation in 2012. Typical complicated and simple geographic questions from users can be answered by MD having commercial applications for M2 (Kray et al., 2003; Rakkolainen & Vainio, 2001; Sarjakoski & Nivala, 2005; van Elzakker et al., 2004). Cartographers have comprised these trends, and digital maps are no longer restricted to stationary computers (Plesa and Cartwright, 2008). M2 address the important requirements of portability and accessibility. The application of real-time video, maps with satellite imagery, Global Positioning System (GPS) tracking and global database searches are now available in handheld devices that people carry with them in the field (Cisco, 2008).

Mobile navigation is one of the most popular applications for MD. In the past, the main focus of routing applications was on car navigation systems. However, an increase in availability of MDs influenced a new user group which is the pedestrian user. Different needs of both user groups and the demand for the development of usable landmark visualizations on M2 to improve the wayfinding process and its visualization are important to help users during orientation and navigation (Elias et al., 2005a).

In orientation and navigation people tend to structure and recognize geographical area with the help of landmarks. Thus it is important to represent these landmarks in an interactive manner, to enable individual users to decide which type of landmark visualizations to use during orientation and navigation. Landmarks are physical, built, or culturally defined objects that stand out from their environment and therefore help locating the geographic position. They act as reference points that connect the map displays with reality and the mental maps of the users. Landmarks may serve several distinct functions during navigation such as planning of a route, signalling where a crucial action should take place, locate another less visible landmark, or confirming to a pedestrian that s/he is still on the right way and verify his/her routes. It is thus not unforeseen, that the importance of landmarks for orientation and navigation has extensively been discussed in chapter two and several literatures (Deakin, 1996; Delikostidis and van Elzakker, 2009a; Delikostidis and van Elzakker, 2009b; Elias et al., 2005a; Elias and Paelke, 2008; Elias et al., 2005b; Gartner and Radoczky, 2006; Golledge, 1999; Hampe and Elias, 2004; Klippel, 2003; May et al., 2003; Michon and Denis, 2001; Millonig and Schechtner, 2005, 2007; Ross et al., 2004). The visualization of landmarks on M2 is subject to a number of restrictions implied by the mobile context of use. These restrictions include the form-factor of MDs (processing power, small size and resolution of displays), and the available communication channels (Chittaro, 2006; van Elzakker et al., 2008).

To this end there is an extensive research on different ways of representing landmarks on M2 (Deakin, 1996; Elias and Paelke, 2008; Elias et al., 2005b; Nivala and Sarjakoski, 2005). Elias & Paelke (2008) and Elias et al. (2005b) did a research on the visualization of landmarks and their impact on map perception. They conducted a user test on comparing different levels of abstraction symbols in terms of interpretation, size, style and proposed further investigating the understanding of the dependencies between users and preferred visualizations. Also the user test done by Nivala & Sarjakoski (2005) on landmark visualization for mobile users lead to the conclusion that more consideration and research is needed in order to provide the user with a presentation that will be attractive from a number of options.

Different ways of visualizing landmarks on M2 have been executed and a lot of research has been done by several authors. However, currently there is no report in the literature that provides a broad discussion on what is the best ways to visualize landmarks on M2 taking into account the dynamic contexts of use and user contexts (Deakin, 1996; Elias and Paelke, 2008; Elias et al., 2005b; Nivala and Sarjakoski, 2005).

Besides, most of the time landmark visualizations are presented on M2 in a static way without considering the individual user's needs. This research is based on the assumption that users may want to decide themselves which type of landmark visualizations they want to use during orientation and navigation, i.e. the research is focussing on interactive landmark visualization. In a static visualization of landmarks on M2, there are no options of selecting how to visualize the landmark types interactively based on user contexts (familiarity and time availability), difficulties with landmark visualization during orientation and navigation, difficulties of linking landmarks as they appear in map displays with reality and their mental map and vast amount of landmark visualization symbols. These problems may impose some difficulties with landmark visualizations to users during orientation and navigation considering their contexts such as:

i. Display overload on the user's map depending on the nature of the visualizations which may cause frustrations.
ii. Difficulties with landmark visualizations due to a lack of interactive ways of visualizing landmarks on M2.
iii. Visualizations may be only geometric symbols, hence difficulties of linking landmarks as they appear in map displays with reality and the mental maps of users.

iv. Vast amounts of landmark visualizations, for example when the map is overloaded with landmark symbols. A user may not understand the cartographic visualization of the map, the intending of the symbols or the aim of the map's contents, hence incorrect interpretations of the landmark visualizations may occur.

These problems may relate to user contexts, hence they may cause an interruption in the map reading process, and especially if this happens repeatedly, it can cause misleading of interpretations and improper orientation and navigation depending on type of visualization used (Nivala and Sarjakoski, 2005).

Landmark visualizations range from Abstract/Geometric symbols, Pictorial symbols, Stereotype sketches, Images/Photographs, 3D representations and other types which have not taken into vital by this research. Many of the visualizations/symbols are realistic when supporting pedestrian wayfinding in unfamiliar areas. Each of the landmark visualizations has specific merits and demerits that need to be taken into important when used to convey information to the user during navigation (Radoczky, 2007a). These visualizations with their properties and problems faced by users influence the idea "to design and test a prototype to allow adjustment of landmark visualizations to individual user needs (through interaction)". Individual users may decide on how to visualize the landmarks during navigation and orientation in a geographic area by selecting the landmark visualizations of their choice without limitations, such that to allow them to:

i. Select particular type of landmark visualizations of choice e.g. Geometric, Pictorial and Image/Photograph. This will be done interactively beforehand and for all landmark visualizations at the same time.
ii. Have a possibility of visualizing only one particular type of landmarks (e.g. church) after selecting a particular kind of visualizations. For example if a user is using pictorial landmark visualizations, there will be an option of viewing only existing churches in that particular route.
iii. Have a possibility of clicking a particular landmark symbol to change its way of visualization. For example if a particular user is using Geometric symbols during navigation, sometimes s/he may need to confirm it (e.g. church), there will be a possibility of clicking that particular symbol (church), and view other visualization options e.g. photo. It means now a user can confirm the church very clearly.

Thus, current existing landmark visualization problems faced by users during orientation and navigation to unfamiliar areas could be reduced. These problems have not yet been addressed by existing studies in landmark visualizations. When these problems are reduced, proper navigation and orientation could be attained (Deakin, 1996; Delikostidis and van Elzakker, 2009a; Elias et al., 2005a; Elias and Paelke, 2008; Elias et al., 2005b; Gartner and Radoczky, 2006; Hampe and Elias, 2004; Nivala and Sarjakoski, 2003a; Nivala and Sarjakoski, 2005).

1.3. Research objectives

1.3.1. Overall objective

The overall objective of this research is to design and test a prototype to allow adjustment of visualization of landmarks to specific individual user needs (through interaction). To achieve the main objectives the following specific objectives can be defined.

1.3.2. Specific objectives

i. To explore landmark visualizations and come up with different ways of representing them on M2
ii. To propose classifications/categorizations of existing landmark visualizations on M2
iii. To design and develop a prototype for interactive selection of landmark visualization types on M2 that will help the user in proper orientation and navigation.
iv. To validate the developed prototype by using individual users in the field to determine the usability of interactive and dynamic landmark visualizations on M2.

1.4. Research questions

i. What are the problems in existing research regarding the landmark visualizations on M2?
ii. What are the different existing ways of visualizing landmarks on M2, and what are the merits and demerits of each?
iii. What are the parameters that influence the visualization of landmarks on M2?
iv. What are the classifications of visualizing landmarks on M2 found to be better and why?
v. What distinctive solution could be developed to facilitate dynamic landmark visualizations during orientation and navigation in different use contexts (i.e. time availability and familiarity)?
vi. What are the suitable research methods and techniques to be used and what are their merits and demerits?
vii. Does the developed solution work well?
    - What type of landmark visualizations do user prefer, if they were to plan the route themselves?
    - What type of landmark visualizations do user prefer during overviewing of the route they are going to follow?
    - What type of landmark visualizations do user prefer to use during navigation.

1.5. Methodology adopted

The methodology adopted to this research is explained. In each four stages of the research execution (Literature Review, UCD, Prototyping and Analysis of Results), a brief discussion will be given to explain these stages as shown in the summary of methodology phases (figure 1-1).

1.5.1. Literature review

Exhaustive literature review will be carried out in details to reinforce the knowledge of different ways of visualizing landmarks on M2 so as to investigate ways to represent them in an application for personal orientation and navigation. The landmark visualizations will be systematically listed in increasing/decreasing order of abstraction suitable for M2 to come up with a respectable grouping of visualizations. This phase will help to discover the gaps in theories, methods, and practices about landmark visualizations that will then be implemented in this research. These will help to design and implement an interactive prototype representing different landmarks visualizations on M2.

The obtained levels of abstractions will be ordered in distinguished proposed categories to come up with classifications suitable for M2. These classifications will be incorporated during the design and implementation of the prototype which will help users better than before on landmark visualizations to reduce the problems faced by users.

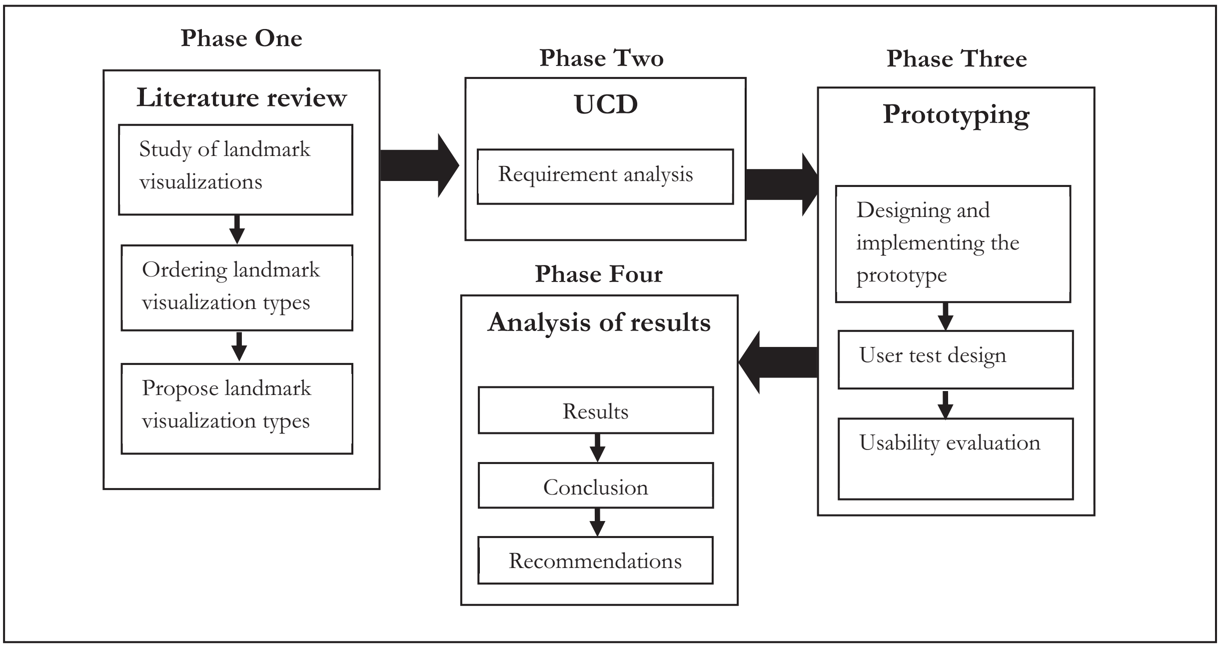


Figure 1-1. Summary of methodology phases adopted from (Hansen et al., 2006)

1.5.2. User Centered Design

The UCD approach will be adopted by this research. It is a concept originating from the theory of Human Computer Interactions (HCI), as a term to describe design processes in which end-users influence how a design takes shape. According to van Elzakker & Wealands (2007), UCD is an iterative process composed of the stages: requirement analysis, prototyping and usability evaluation. Its aim is to support the entire product development process with user-centred activities.

Requirement analysis

This stage of UCD will be used to discover the needs and interest of the users. In the requirement analysis stage, literature review will be used to explore and gather detailed information of the main users by understanding and specifying the context of use and tasks that will take place.

1.5.3. Prototyping

Throughout the design of the prototype the focus will be on Enschede case study data. A field study will be done in the central area of Enschede with the use of the landmarks which have been determined in an earlier user study (Razeghi, 2010). The obtained landmarks will then be visualized according to the procedures of classifying landmark visualization on M2. ArcGIS software will be used to develop shape files according to the the proposed categories of landmark visualizations. Later, shapefiles will be converted to Keyhole Markup Language (KML) files for easier accessibility with Google Maps JS API, which will be used to build the prototype, where byall required functionalities will be implemented.

Usability evaluation

This phase aims to attain the improvement of the product usability, involve real individual users in the testing, give the users real tasks to accomplish, enable testers to observe, listen, take notes, record the actions of the test users, analyze the data obtained and acquire the results. The objective of the usability evaluation is to determine the participant's satisfaction, efficiency and effectiveness with the product. The implemented prototype will be tested to examine if it can supports user during orientation and navigation with adjustable landmark visualizations by using field-based methodologies (questionnaire, semi-structured interviews, Thinking aloud (TA), video recording and observation). The interactively designed landmark visualizations implemented in the prototype will be tested to investigate if users can use them as navigation and orientation aid, in order to get views, insights and feedbacks from them. Feedbacks from usability evaluation will be used as recommendations for further research.

1.5.4. Analysis of results

This phase deals with the analysis of data generated during and after the performance of the usability evaluation. Strategies used during the execution of the task, the reasoning applied and the answers provided will be analyzed. Conclusions will be formulated by providing the answers to the research questions and further research on landmark visualization on M2 will be recommended.

1.6. Thesis structure

The main purpose of this research is to design and test a prototype to allow adjustment of visualizations of landmark to specific individual user needs (through interaction). To achieve this, four stages are established to contribute to the development of six chapters that present the outcome of this research (figure1-2).

Chapter two is about the visualization of landmarks on M2. It provides a general overview of landmarks, landmark functions, the cartographic presentation of landmarks, parameters that influence the visualization of landmarks on M2 and proposed categories of landmark visualizations on M2.

Chapter three covers the research methodology. It gives a general overview of UCD, the methods and techniques for requirement analysis, prototyping and usability evaluation for the research and it explains the application of literature review for a detailed analysis and justification of the selected research methodologies and techniques in each stage of UCD.

Chapter four outlines the design and implementation of a prototype to interactively select different landmark visualization types on M2. It explains the prototype design and implementation, it depicts the Google Maps JS API V3 for Android MD and clarifies the procedures used to upload the prototype into the Android MD and it also makes clear how users can use and interact with the prototype.

Chapter five discusses about the prototype testing. The user tests to fulfill the objectives of this research as initially stated to lead the research to the preferred results are explained by introducing the design stages of the user test which will be executed using a field-based methodology, adopted from chapter three. The usability of the developed prototype based on the efficiency, effectiveness and the satisfaction it grants to the users during orientation and navigation will be given. Also the results of the prototype testing will be discussed.

Chapter six outlines the main contributions and conclusion of this research with an emphasis on the analysis of data generated during and after the usability evaluation. The answers to the initial research questions are given according to the outcome of the previous chapters and the usability of the research objectives are examined. Strategies used during the execution of the task, the reasoning applied and the answers provided will be highlighted and further research on landmark visualization on the M2 will be recommended. Chapter two will discuss landmarks and their visualizations.

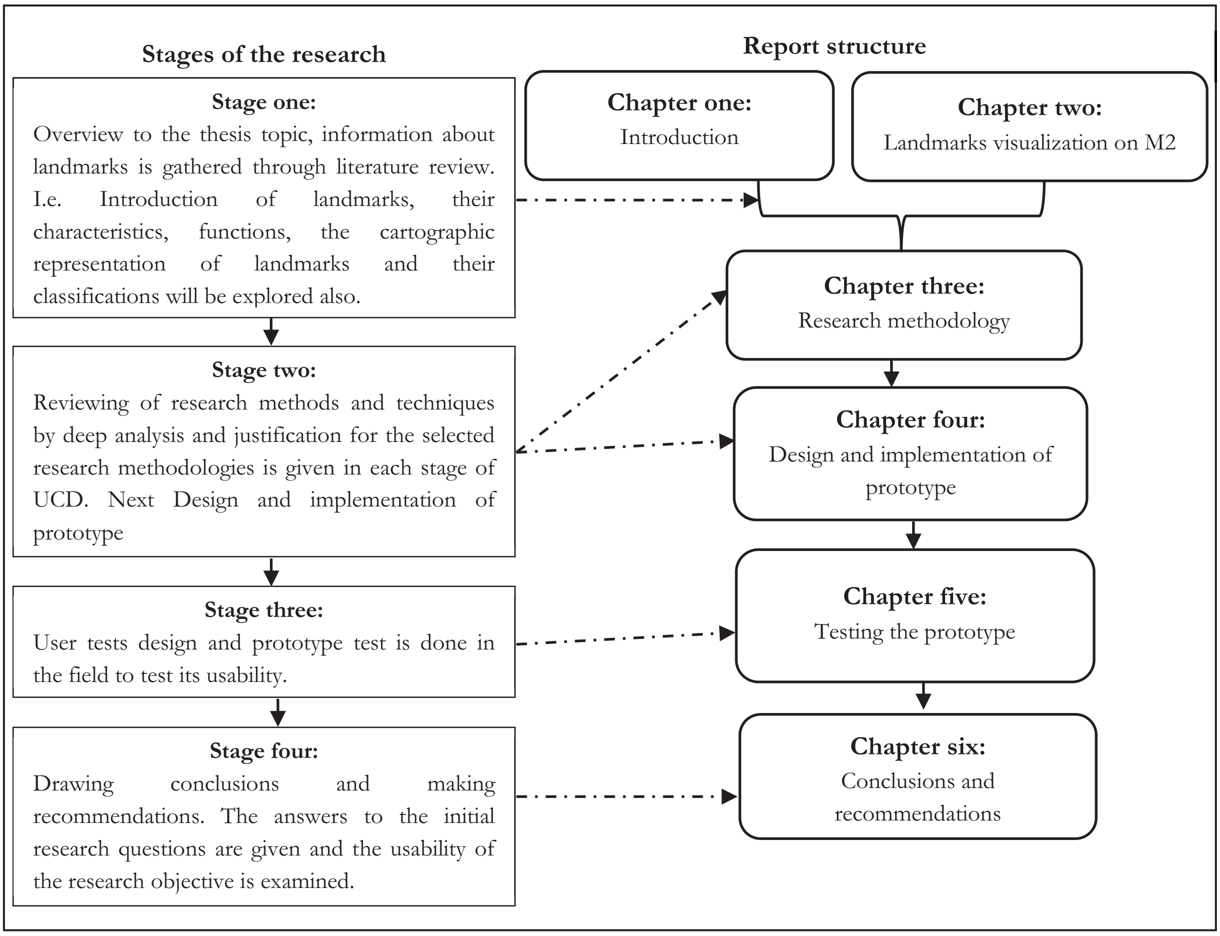


Figure 1-2. Adopted stages and structure

2. LANDMARKS AND THEIR VISUALIZATION ON MOBILE MAPS

2.1. Introduction

A comprehensive literature review is carried out in this chapter to reinforce the knowledge of different ways of visualizing landmarks on M2 and to explore ways to represent them in an application for personal orientation and navigation. A thorough overview of landmark visualization on M2 will be done to address the research questions: What are the problems in existing research regarding landmark visualizations on M2? What are the parameters that influence the visualization of landmarks on M2? What are the existing options of visualizing landmarks on M2, and what are the merits and demerits of each and What are the classification of visualizing landmarks on M2 found to be better and why?.

This chapter therefore intends to answer the research questions by providing a literature review in which information about the visualization of landmarks on M2 is discussed. Chapter two is composed of different sections as follows: 2.2 provides a general overview of landmarks, 2.3 enlightens landmark functions, 2.4 explains the cartographic presentation of landmarks, 2.5 presents parameters that influence the visualization of landmarks on M2, 2.6 proposes categories of landmark visualizations on M2 and 2.7 concludes the chapter.

2.2. Landmarks

Landmarks are important physical, built, or culturally defined objects such as parks, bridges, buildings and roundabouts that stand out from their environment. They are prominent for identifying features and therefore help locating the geographic position and establishing goals (Golledge, 1999; Michon and Denis, 2001). Landmarks are usually considered to be objects that have distinguishable features and a high contrast against other objects in the environment. They are often visible from long distances, sometimes allowing maintenance of orientation throughout entire navigation events (Evans et al., 1982; Klippel and Winter, 2005; Lynch, 1960; Vinson, 1999). Landmarks are significant elements in the communication of way finding directions and part of the mental representations of geographic area. They act as reference points that connect the map displays with reality and the mental maps of the users (figure 2-1). A multi-story building is normal in urban areas, but becomes a prominent landmark when being situated in a rural village (Millonig and Schechtner, 2007). According to Lovelace et al. (1999), landmarks are grouped into local (on-route) and global (off-route). Local landmarks are directly close to the route and global landmarks are in the far distance like a tower or mountain chain. Additionally, local landmarks are located between nodes, at decision points (a junction where a navigation decision is required) or at potential decision points (where a navigation decision is possible but the route goes straight on) Many authors talked about landmarks properties, (Appleyard, 1969; Deakin, 1996; Sefelin et al., 2005; Tom and Denis, 2003; Vinson, 1999).

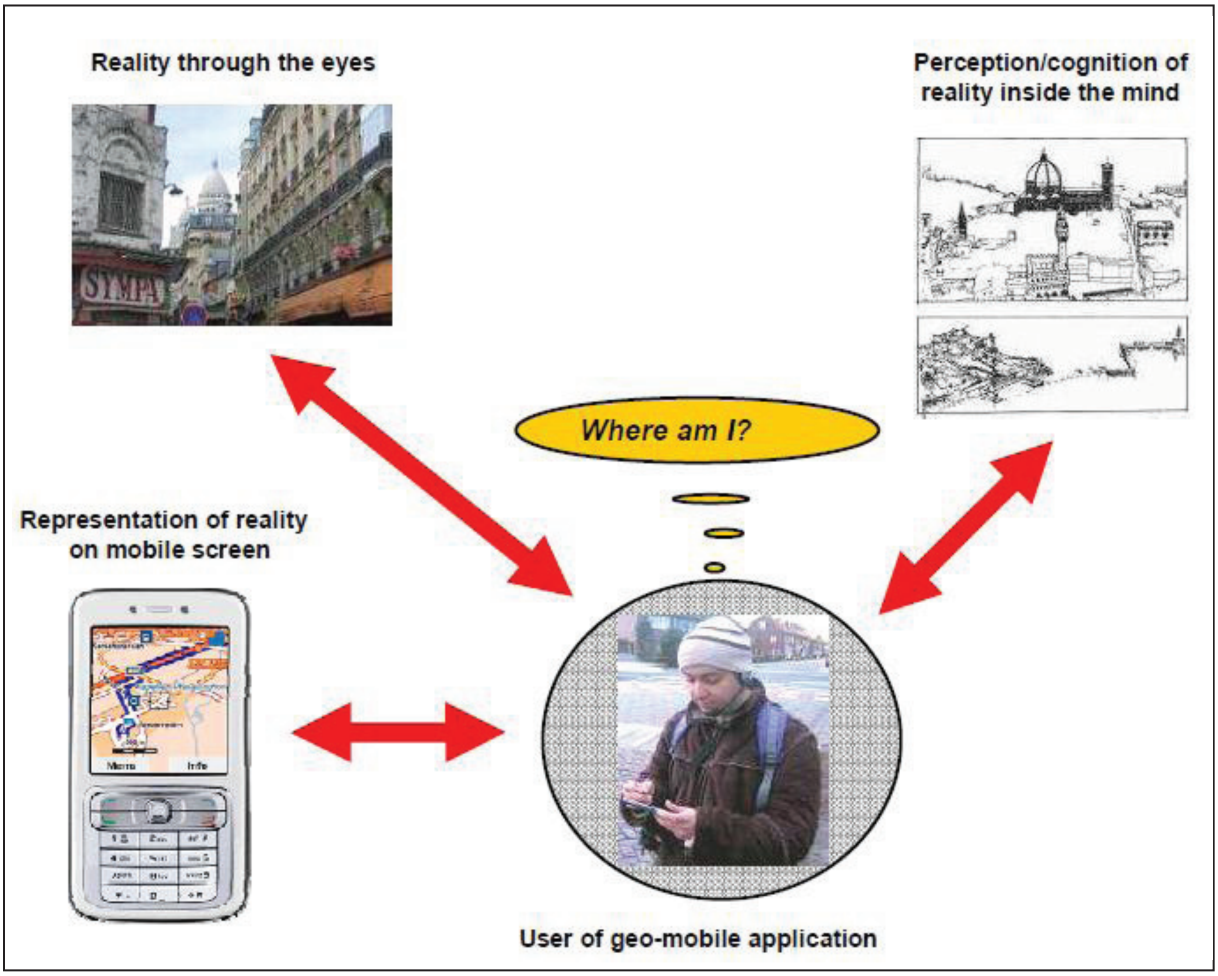


Figure 2-1. Landmark as reference points that connect the map displays with reality and the mental maps of the users (Delikostidis and van Elzakker, 2009b).

2.2.1. Procedures to classify landmark visualizations on M2

In order to classify landmarks obtained in a certain case study, procedures have to be followed. As stated in chapter one, Elias et al (2005b) and Elias & Paelke (2008) did a research on visualization of landmarks and their impact on map perception. They examined the different feature types that are useful as landmark based on guidelines, where 20 people were asked to describe two different pedestrian routes in the city of Hanover. The route descriptions were analyzed with regards to the landmarks used. All referenced objects were counted and divided into groups of object types. Five different groups were distinguished: buildings, monuments (statues), plazas (like market squares or big traffic junctions), references to public transport (underground stations, bus stops, tram tracks) and others (parks, bridges, pedestrian zones, stairs, and cemeteries) (table 2-1).

Object Type	Route 1 (University District)	Route 2 (City Center)
Buildings	20 (50%)	32 (55%)
Monuments	1 (2.5%)	6 (10%)
Plazas	3 (7.5%)	5 (8%)
Public Transport	6 (15%)	7 (12%)
Other	10 (25%)	9 (15%)
Total	**40 (100%)**	**59 (100%)**

Table 2-1. Distribution of object types in route description (Elias and Paelke, 2008; Elias et al., 2005b)

Although the routes differ significantly in their environment, in both routes they found that about 50% of all landmarks used in common way finding instructions are buildings. As most navigation aids are required in urban areas, an optimal representation of buildings as landmarks was a central issue. The buildings were divided into groups depending on the function or type of description of the building in the route instructions. For the purpose of their study they distinguished four categories: Shops and restaurants referenced by their trade name (e.g. McDonals, H&M), other businesses referenced by their type of function (e.g. hotel, pharmacy, hairdresser, butcher), buildings that are referenced by their general function (e.g. library, church, university building), buildings that are specified by their description of outstanding visual aspects (e.g. the large yellow house, the red clinker, brick building) (table 2-2). These procedures will be adopted in chapter four.

Building Type	**Route 1 (University District)**	**Route 2 (City Centre)**
Shop (referenced by name)	4 (20 %)	18 (56 %)
Shop (referenced by type)	3 (15 %)	8 (25 %)
Function / Name	7 (35 %)	6 (19 %)
Visual Aspect	6 (30 %)	0 (0 %)
Total	**20 (100%)**	**32 (100 %)**

Table 2-2. Distribution of different building types in route description (Elias and Paelke, 2008; Elias et al., 2005b)

The study showed that in the city centre the trade names of shops were preferred, whereas in areas where no trade chains were available other building descriptions using the function or the visual appearance of the object were given. The following section explains the procedures to follow when designing of landmark visualizations.

2.2.2. Designing of landmark visualizations

Once suitable landmarks have been selected the question of how this information can be communicated effectively to the user of the navigation system arises. The previous section shows effectively how to select the appropriate landmarks to be presented on M2. There is a need to investigate how this information can be presented appropriately to the user of the navigation system. According to Elias & Paelke (2008), this is a design issue that involves expertise from a wide range of the fields including navigation, visual design, cognitive psychology and MD programming. Elias & Paelke (2008) showed some important steps to follow which have been modified together with the user's context which has been considered in this research, in order to solve such design issues:

i. The task should be defined properly - for the aim of the orientation and navigation this means that a user has to match the landmark visualizations with the reality object when he encounters it.
ii. The parameters that influence the design solution should be identified and analyzed - for a landmark visualizations for pedestrian navigation system this includes various specifications:
    - the delivery device (e.g. MD/PDA)
    - the user's context (familiarity and time availability)
    - the area and context of use (laboratory/field)
iii. Potential design solutions should be generated and evaluated (usability evaluation). These parameters are discussed more in the section 2.5 and will be investigated in chapter five.

Elias & Paelke (2008) limited their study to the types of level of abstraction having a static visual representation of landmarks as the common denominator that can be implemented on all current devices. This particular study is limited to interactive visualization of landmarks that can be presented on MD as the implementation of one of their two proposed variations: employing animation and interactive visualizations.

Elias and Paelke followed the steps, design guidelines and evaluations proposed in the study of (Elias et al., 2005b; MacEachren, 1995) and come up with a proposed order of abstraction symbols (figure 2-2).

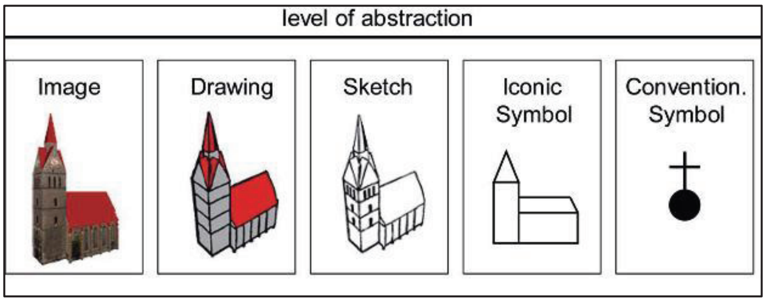


Figure 2-2. Levels of abstraction for visualization (Elias and Paelke, 2008; Elias et al., 2005b)

To converse about the different landmark characteristics appropriately, they proposed a systematic approach to base the visualization of landmarks on different levels of abstractions (figure 2-3). Due to the categories of the buildings, they come up with design proposal for landmarks which will be improved and adopted in this research.

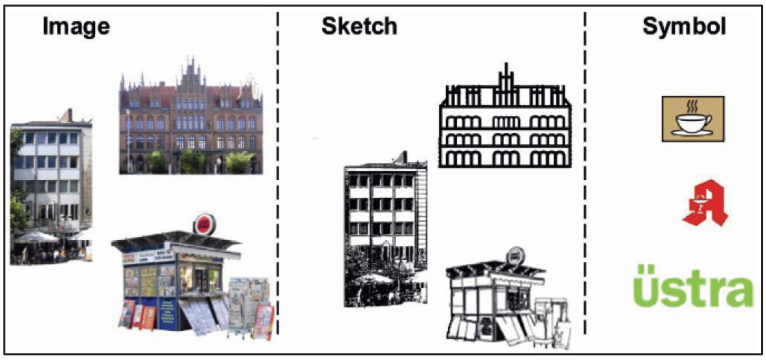


Figure 2-3. Final distinguished landmark categories used for executing the user test (Elias and Paelke, 2008)

These visualization drafts were formerly offered to test users to evaluate if they are distinguishable and able to convey the landmark information entirely. The results show the difference of the relative worth of different landmark visualizations and can serve as the basis to improve the visualization of building landmarks. The results propose different levels of abstractions as appropriate visualization for different categories of building landmarks. Also they propose further work to understand the dependencies between user and preferred visualizations, which this particular research is taking care off. All the procedures discussed from section 2.2.1 and 2.2.2 will be considered, during the designing and implementation of landmark categories in chapter four.

2.3. Function of landmarks

It is difficult to navigate to unfamiliar environments, we mainly navigate in environment that are quite familiar (Vinson, 1999). Orientation and navigation to unfamiliar environment can be aided by MD, encompass an interactive prototype with effective landmark visualization types, presented in different ways as suggested by different authors (Deakin, 1996; Elias and Paelke, 2008; Elias et al., 2005b; Nivala and Sarjakoski, 2005; Ross et al., 2004). Landmarks may serve several distinct functions, such as help the user cognitively to get through difficult or uncertain part of the environment through their construction of a mental representation of an unfamiliar area, signalling where a crucial action should be taken, memorizing and following a route (you know where you are and where you want to go), locating another less visible landmark or confirming (compare what is seen in the reality with what is on the map), increases user confidence and improves navigation performance (i.e. the number of correctly completed manoeuvres), they provide information about important manoeuvres to perform (or not to perform) at points in a route where changes in direction are likely to occur.

Landmarks also contribute to create a visual model of critical parts of an environment and they help to organize space, as observed from a route viewpoint, which prepares the moving agent (user) to react appropriately to situations involving a decision. They are used to communicate route knowledge verbally and graphically (Golledge, 1999; Klippel, 2003; May et al., 2003; Michon and Denis, 2001; Millonig and Schechtner, 2005, 2007).

During the navigation process, both mental and physical actions are involved in orientation and navigation. This process involves manoeuvring, performing a series of operations to achieve sub goals (Darken and Sibert, 1996; Nurminen and Oulasvirta, 2008). Direct experience, talking to others, studying a map or a combination of all three may be used to gain knowledge of an environment. Thorndyke & Hayes-Roth (1982) stated that, people when directly experiencing an unfamiliar environment, acquire knowledge about the route they are navigating, by associating a particular reaction (turn left, turn right, proceed straight ahead) with a particular landmark. Landmark knowledge can be called upon during subsequent navigation. The investigation of GÄRling et al. (1982) on the accuracy and precision of memory for the spatial layout of a town, supports the assumption of Thorndyke & Hayes-Roth (1982). GÄRling et al. (1982) discovered that subjects acquire memory for locations of landmarks relative to one another before a memory representation of routes.

During orientation and navigation, using landmarks encourage a pedestrian user to take the correct route, and confirm and verify whether s/he is still on the right route and at the right place. Landmarks increase pedestrian's accuracy when they are positioning themselves in the geographical area. If a pedestrian navigation system is used as a navigation aid, including landmarks could make users feel more confident when experiencing a new environment (Deakin, 1996).

For orientation purposes, landmarks are essential in establishing key locations in an environment (Vinson, 1999). Landmarks improve spatial learning for adults in new settings and for young children in familiar environments. It has now also been reported that specific building features can predict knowledge of spatial location (Evans et al., 1982).

Landmark information has been shown to be an important aid in way finding and it provides a background from which the environment may be learned (Deakin, 1996). Deakin (1996) discussed several issues on the integration of landmarks into graphic representations for way finding purposes. A user test conducted with street maps using geometrics and stereotype sketches indicated that landmarks improve pedestrian's navigation performance. Users of navigational systems benefit from way descriptions based on landmarks. Navigation information needed by pedestrians has been investigated and it was found that landmarks are the most popular cue type (May et al., 2003). Other studies have investigated the changes in navigation cues with age, gender, level of education, experience etc. and found that landmarks always form a key part of the cue set (Bradley and Dunlop, 2002; Elias et al., 2005a; Galea and Kimura, 1993; Zipf, 2002).

2.4. Cartographic representation of landmarks

A successful navigation system is the one that enables users to recognize the landmarks used in a real environment with minimal cognitive effort during orientation and navigation. During this process a user may have different geographical questions e.g. Where am I? (Orientations); Am I on the correct way? (Route confirmation); Is this the correct endpoint? (Destination confirmation) or before navigation, what are the landmarks I expect to base my navigation on my way? Is this the correct view at this particular point etc. (Delikostidis and van Elzakker, 2009a). All these questions raise the need for a particular type of landmark visualizations on M2. Landmark-based visualizations are easier to follow, shorten the navigation time, and reduce confusion by providing visual feedback on the correctness of a navigation decision. However, significant efforts are needed to explore how to effectively visualize landmarks on M2. To this end there is an extensive research on different ways of visualizing landmarks on M2 (Deakin, 1996; Elias and Paelke, 2008; Elias et al., 2005b; Nivala and Sarjakoski, 2005).

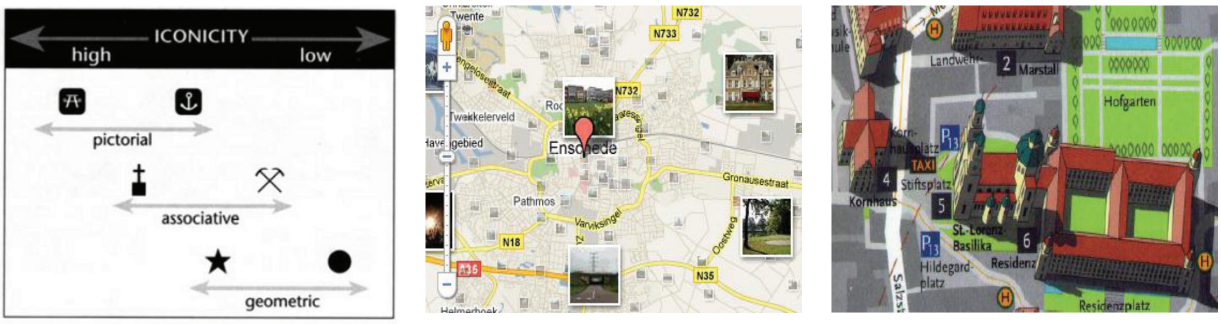
To optimize communication, a focus on the visualization of landmark information with cartographic instruments is highly necessary. In fact, knowledge on how user's perceives and interpret the visualization of landmarks is important to their effective use. The design of visual representations of landmarks should be based on this knowledge about the user's recognition and interpretation (Elias and Paelke, 2008; Elias et al., 2005b).

Landmarks features such as buildings, monuments, parks, bridges, roundabouts etc., can be represented at different levels of abstractions as discussed before. This is done in order to communicate different landmark characteristics information appropriately. If we are to improve visualization of landmarks on M2, it is crucial to understand different ways of visualizing landmarks on M2. These graphic representations of an object, action or attribute convey information to the user in terms of: Abstract/Geometric symbology, Pictorial symbols, Stereo type sketches, images/photograph and 3D representation. Many of the symbols are realistic when supporting pedestrian way finding in unfamiliar environments. Each of the landmark visualizations has specific merits and demerits that need to be taken into important when used by the user to enable them to navigate in a geographic area.

2.4.1. Abstract/Geometric symbols

Geometric symbols (circles, squares, spheres and cubes) have characteristics which do not mirror those of the phenomenon being mapped (figure 2-4-a). Generally, they have the following properties: they conserve map space compared to other kind of symbols e.g. Pictorial symbols and Image/Photograph, they are visually stable as they can produce attractive and eye catching graphic. Due to these merits, geometric symbols are mostly preferred by users and they are suitable for M2 (Deakin, 1996; Elias and Paelke, 2008; Elias et al., 2005b). The most frequently used geometric symbol is circle as this is the one which is mostly preferred by users (Slocum and ... 2009). Geometric symbols are the most commonly used symbols on maps because they can represent features of any size on a map of any scale (Muehrcke, 1986).

However unless the geometric symbol is labelled, a legend is required in order to identify the feature and convey the meaning that each symbol represents and removes the uncertainty (Bertin, 1983).



(a) (b) (c)

Figure 2-4. Different cartographic representations

(a) Abstract point symbols (MacEachren, 1995), pp.262, (b) Image/Photograph representation (Google Maps) and (c) Tourist map with 3D-tourist sights (taken from tourist map of city Kempten) (Elias and Paelke, 2008; Elias et al., 2005b) pp.43

2.4.2. Pictorial symbols

The pictorial messages communicate the reality of spatial location to the users. They are suitable for: international exchange as they overcome the language barrier; elders, visual impaired and young people and in the situation a particular user is under time constraints. Also they offers more efficient information than Abstract/Geometric symbols in the limited surface display of M2 due to their good visual presentation (Nivala and Sarjakoski, 2005). They can be recognized easily, due to the unnecessary requirement of graphics interpretation process. They match with the picture to the environment it represents. This requires that the symbol is not too exhaustive or confusing (Bruyas et al., 1998). They create attention and facilitate retention (Bertin, 1983). Well-designed pictorial symbols allow quick visual information processing in comparison with textual messages (figure 2-4-a).

Bruyas, et al (1998) performed a research on graphical representation of an object and stated that a pictorial representation should be quickly understood, with no ambiguity considering the users contexts. The recognition performance depends on the combination of essential, neutral and additional elements in the pictorial. Essential elements are the typical attributes that are necessary to recognize the object, and neutral element are the attributes which help the user to understand the symbol without doubt, however too much unnecessary details disturb the quick understanding of the symbol. Misunderstanding of the sign with similar objects may occur due to lack of user's knowledge with the typical attributes of the object.

While pictorial symbols are usually preferred by map users, they are seldom seen on maps because of the expense of designing them (Forrest and Castner, 1985). Pictorial symbols are difficult to make a distinction at smaller scales when that picture contains many details due to the small screen of MD (Deakin, 1996).

2.4.3. Stereotype sketches

Another way of symbolizing landmark is by stereotype sketches, which are used for communicating mental images. The results of Fitzsimons's (1973) study demonstrated the value of stereotype sketches for communicating mental images. They provoke a strong natural association for the map users. Stereotype sketches could prove to be more effective than pictorial symbols, (as it is possible to exclude details and can be well presented in small scale) means of representing landmarks on M2 and would be more practical than photographs at small map sizes. However stereotype sketches are hard to generate, take up large space compared to Abstract/Geometric symbols on the map and they are costly to create. (Deakin, 1996).

2.4.4. Images/Photographs

An image can be a supportive presentation type in a navigation system and it is more useful when the selected objects are unique. They are suitable to people who are: not familiar with the area; not in hurry and who have no map reading knowledge. Such kind of users can choose a photograph as an option to provide more information. Users need ample time to compare reality with the photograph that is why it is useful to use them when describing start point and end point of a particular destination only (Gartner and Radoczky, 2007; Radoczky, 2007b). Moreover, before including it in the guiding system the area should not underlie any seasonal changes. For example parks usually have another appearance in winter than in summer time, markets are sometimes only open at certain months and Christmas decorations could also extremely change the appearance of a place (Radoczky, 2007b).

Commercial developments e.g. Google maps, Google Earth and Bing maps have used the image/photograph for landmark visualizations (figure 2-4-b). Lee, et al.(2001) developed a prototype for visual navigation and stated that, photographic images are used to represent landmarks and they are matched directly on a perspective view of the map. The output from an evaluation done to the prototype showed that landmark photographs should be captured from the line of sight in which the object is appeared. Therefore, each landmark needs several images. Additionally, for a landmark, a photograph to be effective, visual clutter like neighbouring buildings should be removed so that the landmark can be displayed in itself. However, for the purpose of navigation it is more meaningful when the extent of the landmark image is matched with those on the reality.

2.4.5. 3D representation

3D representations are graphics which contain the feature's height, depth and width. Graphics tend to be more precise and realistic when presented using 3D. They are more informative and easy to be read by users who: are not familiar with the area; lack map reading knowledge and are not in hurry (Gartner and Radoczky, 2006, 2007; Radoczky, 2007b). They are very effective representations of space. One of the outcomes of user tests done by Delikostidis & van Elzakker (2009b) was that 3D representation on a map improve user's mental connection with the M2. They can give a remarkable feedback (good overview) and more directly recognizable visualizations of our environment by providing an interactive view and can contain more details. In principle, these characteristics should support ego-centric alignment: matching what is seen in the reality with the user's mental maps knowledge about an environment (Oulasvirta et al., 2009). With a 3D representation of an object, it is possible to rotate the object to gain more views, which will help to know the current position and easily navigation (figure 2-4-c).

However Burigat & Chittaro (2007) indicated that 3D users suffer from problems such as graphic occlusions and difficulties in comparing heights and sizes of graphical objects. Unfortunately another problem of 3D representation is the demand on display size as it requires more memory than Abstract/Geometric symbol representations (Radoczky, 2007b). Users of 3D representation spend more time travelling to a certain destination because movement is slow as it requires continuous rotation of the object (Oulasvirta et al., 2009). The mentioned cartographic representations of landmarks can be summarized in table 2-3 based on their merits and demerits.

Abstract level	Merit	Demerit
Geometric	Conserves map space compared to other symbols e.g. 3D, visually stable as they can produce attractive and eye catching graphic, preferred by users and they are suitable for M2 as they can represent features of any size on a map of any scale	Legend is required in order to identify the feature and convey the meaning that each symbol represents and removes the uncertainty
Pictorial	Converse the reality to the users, suitable for international exchange, relevant to users who are have limited time, offers efficient information than Abstract symbols, can be recognized easily	Expensive to design, requires user's knowledge to avoid misunderstanding of the symbol,
Sketch	Good for communicating mental images, more effective than pictorial symbols, more practical than photographs at small map sizes.	Hard and costly to generate, take up large space compared to Abstract symbols in the map
Photograph	Suitable to people who are: not familiar with the area, not in a hurry and who have no map reading knowledge, suitable for confirmation	Need more time to compare reality with the photograph, useful when describing start and end point
3D	Graphics tend to be more precise and realistic when presented using 3D, more informative and easy to be read by users who have: not familiar with the area, no map reading knowledge and not in hurry, improves user's mental connection with the M2, possible to rotate the object to gain more views	users suffer from problems such as graphic occlusions and difficulties in comparing heights and sizes of graphical objects, needs large display size and more memory than Abstract symbols, users spend more time during navigation

Table 2-3. Summary of the merits and demerits of each type of landmark visualizations

2.5. Parameters that influence the visualization of landmarks on M2

Substantial effort is needed to investigate how to visualize landmarks on M2 despite of the fact that, there are number of restrictions implied by the MD. All these restrictions must be reasoned when visualizing landmarks on M2. Different research approaches tried to identify the relevant impact factors of MD, context and personalization on landmark visualizations (Chittaro, 2006; Delikostidis and van Elzakker, 2009a; Elias et al., 2009; Galea and Kimura, 1993; Hampe and Elias, 2004; McGookin et al., 2010; Mulloni et al., 2007; Nivala and Sarjakoski, 2003a; Nivala and Sarjakoski, 2005). In this part, exhaustive discussions about parameters that influence the design and visualization of landmarks for pedestrian users are highlighted. This research is focused on user's context to fulfil its objectives.

2.5.1. Mobile devices

The MD such as PDA and smartphones are becoming more powerful, but indeed they have many restrictions with respect to desktop systems: the form-factor, performance and input peripherals among different MD models vary greatly compared to ordinary computer screen; displays are very restricted due to smaller size, poorer resolution, fewer colours and other factors; on-board hardware, including the CPU, memory, buses and graphic hardware is much less powerful; the available communication channels are less powerful; connectivity is slower affecting interactivity when a significant quantity of data is stored in remote databases. These limitations posed problems on how information should be designed and visualized on the M2. It is stated that the landmarks symbols developed for desktop computers do not scale well on MD because of its small size (Chittaro, 2006; Hampe and Elias, 2004; Mulloni et al., 2007; van Elzakker et al., 2008). Researchers have started to address these problems although some of them are unlikely to disappear in the near future because the MD must remain compact in size to be practical.

2.5.2. User's context

"Context is any information that can be used to characterize the situation of an entity, where entity means a person, place, or object, which is relevant to the interaction between a user and an application, including the user and the applications themselves" pp.304 (Abowd et al., 1999). The concept of differences in user context in visualizing landmarks on M2 has recently raised a lot of interest among authors in cartography. A map is always strongly related to the usage situation which help users' find the way in an unfamiliar environment. In terms of M2 the user's familiarity and time availability are the most important context information needed during landmark visualizations.

The problems faced by users when visualizing landmarks on M2 during the orientation and navigation are caused by the way landmarks are visualized currently in the MD. Landmarks are presented in a static way without considering individual user's needs. Context could be considered as a key concept to improve the landmark visualizations on M2 (Nivala and Sarjakoski, 2003a). The basic assumption is that if the map designers and cartographers know enough about the user's familiarity and time availability, they would be able to come up with an adjustable visualization tool whereby different landmark visualizations will be visualized interactively to individual users' context, to decide how to visualize the landmarks.

User's familiarity

As mentioned above a user's familiarity with an area is an influential factor on the landmark visualizations during orientation and navigation as it causes a user to use a certain type of landmark visualizations. Familiarity affects the user as it depends on the issue of having been there before or not. If s/he has been there (less familiar/more familiar), the type of landmark visualization to be used, the interaction with the environment and the speed of navigation to the destination differs with other users who have not been there. A user who is familiar to a particular area is probably positive in doing the above mentioned tasks. The user's mental maps and knowledge about an environment are improved as s/he navigates in geographical area, as a result orientation and navigation tasks should become easier although the following factors may influence the familiarity (Lovelace et al., 1999).

Internal factors such as: experienced with landmarks presented on maps (knowledge about environment, familiar to features of map, age, sex, health etc.). These are factors which are limited to the individual users. For example elderly people need clear presentation of symbols, e.g. photograph with a white background to improve the contrast of the symbol (Lynch, 1960; Sarjakoski and Nivala, 2005).

External factors are environmental factors such as rush hour, traffic jams, accidents, holidays, road restrictions daytime/night time (objects cannot be seen in the dark, special objects are illuminated at night) (Hampe and Elias, 2004). For example the user has more possibilities to interact and visualize the surroundings in the day-time compared to the night.(Elias et al., 2005a; Gartner and Radoczky, 2006; Hampe and Elias, 2004; Nivala and Sarjakoski, 2003a; Nivala and Sarjakoski, 2005). Elias & Paelke (2008) did a study and found out a significant impact of day or night time onto people's way to visualize landmarks on M2. According to Elias & Paelke (2008), prominent features are well seen during the day time. During night pictorial symbols are well seen compared to geometrical symbols. However at night a flashy banner of a small restaurant may make the place prominent.

User's time availability

Time availability context may make one type of visualization to be more suitable than another. It is expected that the time availability for a pedestrian enforces the need to use a certain type of landmark visualizations while performing orientation and navigation as it depends on the whether s/he is in hurry or not. When a particular user is in hurry (time pressure), s/he would not pay attention to the environment the same way as when s/he has ample time to reach the destination. Image/photograph and 3D visualizations are more suitable when users are not in hurry (Gartner and Radoczky, 2006, 2007; Radoczky, 2007b) and pictorial symbols visualization are suitable when users are in hurry (Bruyas et al., 1998).

User's familiarity and time availability will be taken into important in chapter five where the user test will be done to test the developed prototype, to find out whether they influence the users in selecting categories of landmark visualizations for orientation and navigation.

2.6. Proposed categories of landmark visualizations on M2

The discussion of the proposed categories of landmarks visualization on M2 is done to allow users to easily orientate, navigate and focus on their tasks of interest. Thus it is important to include objects intended to serve as landmarks on M2. However, it is vital that those objects are designed and visualized efficiently to aid users during orientation and navigation.

The decision, which type of landmark visualizations to use during orientation and navigation, is influenced by many different factors as aforementioned in previous sections, such as: the user's context for which landmark visualization are generated (familiarity, time availability and the geographical questions users want to answer). For example route confirmation is one of the geographical question user wants an answer to, as mentioned earlier. Image/photograph is indicated to be suitable for confirmation and navigation. The user test which will be done in chapter five will confirm this matter. Also commercial developments e.g. Google maps and Bing maps have used Image/photograph landmark visualizations (figure 2-4-b); the MD restrictions; the merits and demerits of each type of existing categories of landmark visualizations on M2 (see section 2.4) and problems faced by individual users (see section 1.2).

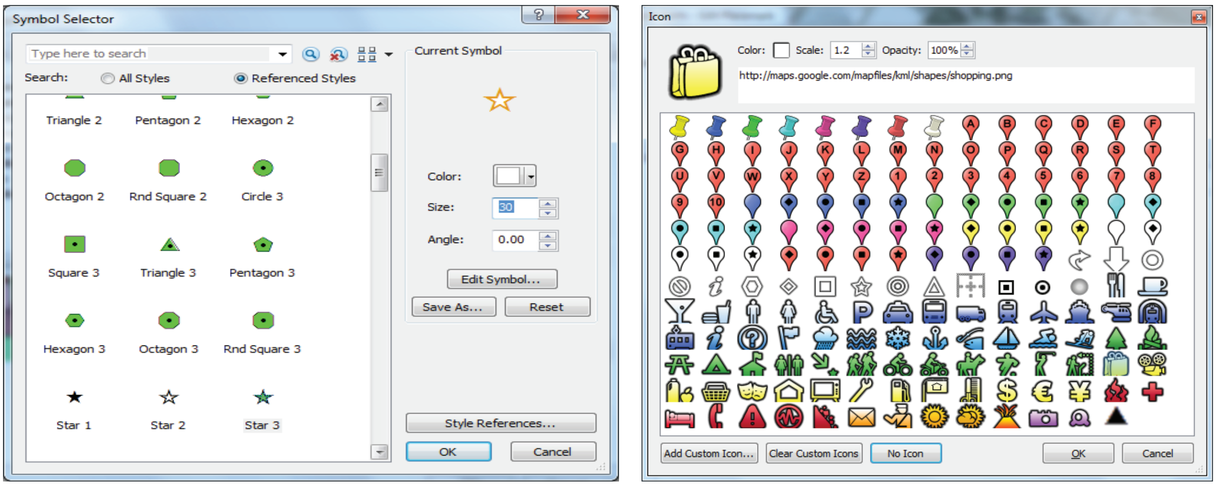
In addition, different studies have used and found that; Geometric symbols, Pictorial symbols and Image/Photograph are suitable for landmark visualizations. (Bruyas et al., 1998; Deakin, 1996; Elias and Paelke, 2008; Elias et al., 2005b; Muehrcke, 1986; Slocum and ... 2009). As discussed in (see section 2.4).

These factors are coupled towards a need for particular landmark visualizations. The reviewed information to these aspects has reinforced the knowledge and forms the criteria which motivate this particular research to adopt (take up) and improve the landmark visualization categories of Elias & Paelke (2008) for the design, development and testing of a prototype for interactive visualizations of landmarks on M2. These landmark visualizations will be implemented in a prototype and thereafter an investigation will be done in chapter five to explore if the prototype is working well based on individual user contexts. There is already studies as mentioned before which did user test and found all these categories are suitable for users (Deakin, 1996; Elias and Paelke, 2008; Elias et al., 2005b), some of them already exist in current applications like Google maps. Here are the proposed categories as also depicted in (figure 2-6).

i. Geometric symbols
ii. Pictorial symbols
iii. Image/photograph

2.6.1. Design of the selected categories of landmark visualizations

Visualization of three selected categories of landmarks was made to come up with visual presentation of each category. To create the category "Geometrics" ArcGIS ESRI Default Marker Symbols was used (figure 2-5-a), the category "Pictorials" was obtained by using the Google Earth library symbols (figure 2-5-b) and the category "Photos" was obtained by taking photos of the buildings which were identified as landmarks. There after these symbols were edited by using image software's such as Adobe Photoshop, Adobe Fireworks and Paintbrush before implementing into the prototype. Detailed information is discussed in section 3.4.2 and section 4.2.



(a) Geometric symbols (b) Pictorial symbols

Figure 2-5. Geometric and pictorial symbols used to obtain the proposed categories of landmark visualization

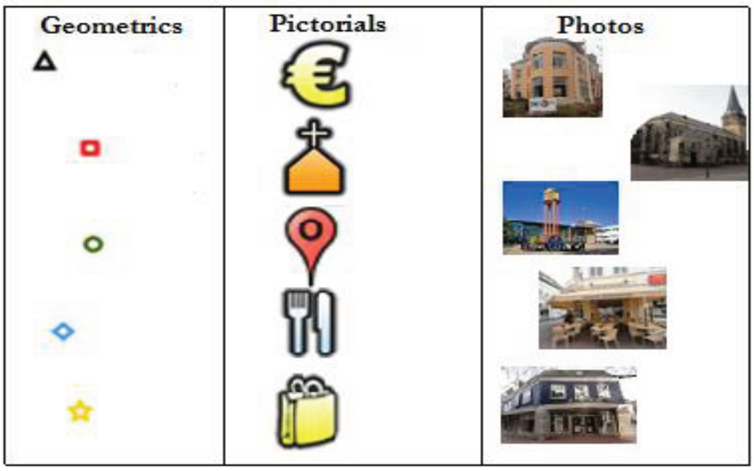


Figure 2-6. Proposed landmark categories to be implemented in the prototype

However based on literature review, it is difficult to come up with proposed categories of landmark visualization types which suits individual users, as each user has own suitable visualizations type depends on his/her context and also depending on the specific geographical questions the users want to find answers to. Therefore usability evaluation in real context of use, as it will be done in chapter five is required in order to come up with usable categories of landmark visualizations on M2 to reduce the current landmark visualization problems faced by individual users (Hampe and Elias, 2004; Nivala and Sarjakoski, 2003a; Nivala and Sarjakoski, 2005).

2.7. Conclusion

This chapter dealt with landmark visualizations on M2. Landmarks usually play an important role in supporting users during orientation and navigation into geographic area. General overview and functions of landmarks to pedestrian users which have been explained have given some highlights to cartographers/map designers, programmers and researcher on the procedures to follow during the process of landmarks identification, grouping and the way to design and visualize landmarks on the M2. Cartographic representation of landmarks, which have been described show the possibility of visualizing landmarks in different ways to individual users, considering the merits and demerits of each cartographic representation. Parameters which influence the visualization of landmarks on M2 have shown and emphasize the need for researcher to consider them when designing and proposing categories of landmark visualization on M2. Together with other mentioned parameters, they have been used to form the criteria's to the proposed categories of landmark visualizations on M2. Some of the categories of landmark visualization types were from Elias & Paelke (2008) which have been improved and adopted to be used in the prototype which will be designed and implemented in chapter four. It is claimed that there are different kinds of landmark visualizations presented on M2 currently, aimed at covering different user tasks in different context of use. But how can they successfully be visualized interactively so that a user can decide how to visualize the landmarks during the orientation and navigation? Interactive prototype and usability evaluation designed, implemented and tested in chapter four and chapter five, are among of the solutions regarding this issue. Chapter three will discuss research methodologies.

3. RESEARCH METHODOLOGY

3.1. Introduction

This chapter gives detailed analysis of various methodologies which will be applied in this research. For the purpose of this particular research, the UCD approach is employed to support the entire product development process with user-centered activities (Abras et al., 2001). Methods which will be applied in this research at each stage of UCD (requirement analysis, prototyping and usability evaluation) are explained and justification for the selected research methodologies is given. This relates to their merits and demerits in the context of this research. Literature review is used to give an overview of these methods and techniques among the existing ones based on their merits and demerits so that we can select suitable ones to be used at each stage of UCD. The research questions about what are the suitable methods and techniques to be used in user research and what are their merits and demerits will be answered to fulfil the research objectives. This means that the appropriate use and user research methods and techniques suitable for all stages of UCD will be proposed.

The chapter is composed of the following sections: 3.2 gives general overview of UCD, 3.3 enlightens on the methods and techniques for requirement analysis, prototyping and usability evaluation for this research project, 3.4 discusses the selected methods and techniques for each stage of UCD and finally 3.5 recaps the chapter.

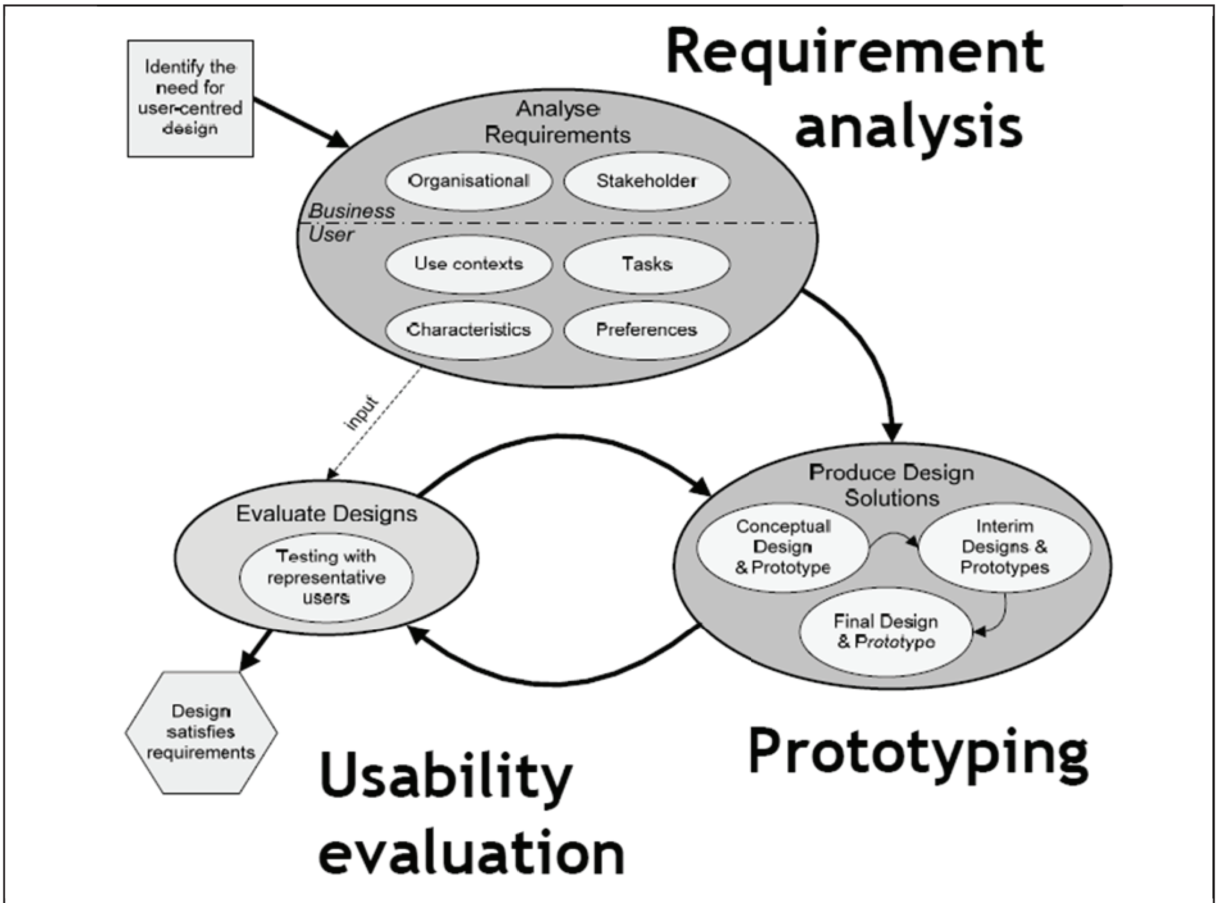


Figure 3-1. UCD project circle and development process (van Elzakker and Wealands, 2007)

3.2. UCD – approach

In product design, UCD is being taken into account increasingly. UCD approach is a concept originating from the theory of HCI, as a term to describe design processes in which end-users influence how a design takes shape. According to van Elzakker & Wealands (2007), UCD is an iterative process composed of the stages: requirement analysis, prototyping, and usability evaluation. Its aim is to support the entire product development process with user-centred activities. UCD is used in order to create applications that are simple to use and fulfil the needs of the planned user groups. This is exactly what a user's wishes to experience with a newly developed product.

There are two types of user participation in UCD. Real users may be involved in all, or in just one or two stages of the UCD-process (Abras et al., 2001). This research is following the second type. Current research reported that investing in UCD has a return of investment of about 50 days. (Meng et al., 2008; Nielsen, 1993; Nivala et al., 2005). Specifically UCD is attempted to this research to verify the usability of categories of landmark visualizations presented on the designed prototype by using MD considering its stages (figure3-1). A number of studies emphasize the necessity of applying UCD for the development of new applications. Elias & Paelke (2008) have used UCD in designing landmark visualizations. They examined different categories of landmark visualizations by comparing three abstraction levels (see section 2.2.3). Other studies are (Delikostidis, 2007; Delikostidis and van Elzakker, 2009a; Delikostidis and van Elzakker, 2009b; Meng et al., 2008; Nivala et al., 2005; van Elzakker et al., 2008; van Elzakker et al., 2004; van Elzakker and Wealands, 2007).

The following are the expected benefits of using UCD during the process of product design: products are more efficient, effective, and safe; users expectations and level of satisfaction with the product can be managed; the developed product require less modification and integrate into the environment more quickly; the iterative process generates more creative design solutions to problems. However there are some drawbacks of using UCD: It is more costly; it takes more time; it may require the involvement of usability professionals; data collected may be hard to translate; the product may be too specific for more general use (Preece et al., 2002).

The available resources determine the way that will be followed for the UCD implementation, taking into account the parameter of user research which is used, such as methods, test users, equipment and the stage of the project phase. Usability evaluation can be carried out using various usability methods (figure 3-1) (Nivala et al., 2005). Selecting of appropriate methods for data collection in UCD may depend on specific research questions and objectives, research financial, researcher capabilities, time resources as well as the needs to be evaluated considering merits and demerits of each method (Delikostidis, 2007; Delikostidis and van Elzakker, 2009b; Kumar, 2005; MacEachren and Kraak, 2001; Nivala et al., 2005; van Elzakker et al., 2008; van Elzakker and Wealands, 2007).

User research methods in geo domain are not applied in isolation. A couple of quantitative and qualitative methods are applied to collect qualitative and quantitative data (Kirakowski, 1996; Rohrer and Design, 2009). Such quantitative methods may still be applied to evaluate the effectiveness of landmark visualization on M2. Nevertheless, with the widening of scope in landmark visualizations on M2, the application of qualitative techniques is gaining more in its importance (Suchan and Brewer, 2000). The coming section discusses the stages of UCD.

3.2.1. Requirement analysis

This stage of UCD is used to discover the needs and interest of the users. To examine a particular product performance, only tests in which end users are involved are suitable (Nielsen, 1993; Preece et al., 2002). In requirement analysis stage, the detail explorations of the main users by understanding and specifying the context of use and tasks that take place are performed. The level of satisfaction and the problems of the users with the existing products are identified through user research and user's requirements from the new design are set. Several scenarios of use are formulated into use cases and later form the initial design of the interface which is task oriented, determining both system functionalities and the user-system interaction queue (Herman and Heidmann, 2002). More discussions are at section 3.4.1.

3.2.2. Prototyping

It is a strong consensus that, prototyping is an essential part of assessing design ideas. Ideas which have already been investigated in the requirement analysis stage of UCD will be transformed into something tangible and real, and thereafter will be tested (Sefelin et al., 2003). A prototype is often the best way to address the main goals of the project and try to collect feedback from users, to discover the weaknesses and drawbacks (Parvu and Kadirire, 2009). It is a quick way to find out if you are on the right track with your plans and the developed design. In addition Nielsen (2003) explains, "prototyping has 'Ten times the impact if you discover a needed design change early, and [it is] 100 times cheaper to make the change". Prototyping allows developers to quickly build a working model of their concepts with allocating resources early in a project, and a decision can be made as to whether or not the project is viable after testing. This is very important as the entire idea behind prototyping is to save the time and cost to develop something that can be tested with real users (Nielsen, 1993). Prototyping has the following merits: can improve the quality of requirements and specifications provided to developers i.e. the early understanding of what the user desires can result into faster and less expensive product; it improves and increases user involvement i.e. a prototype allows users to provide better and more complete feedback and specifications.

3.2.3. Usability evaluation

Geodata products when tested in a specified environment must meet specific purposes, individual information needs, utility, usability and user requirements. Utility implies whether the system can perform the function(s) required by the users to achieve their goals (Nielsen, 1993) and usability is the extent to which users can utilize the system to achieve their goals with effectiveness, efficiency and satisfaction in a specified context of use (ISO-9241-11, 1998). The success of products and services that are based on Information and Communication Technology is to a major extent determined by utility and usability. However there are various features that are used to measure the usability of developed systems. Based on the standard (ISO-9241-11, 1998), HCI handbooks, and existing studies on mobile application, there are nine generic usability measures (Nielsen, 1993; Nivala et al., 2005). *effectiveness:* the accuracy and completeness with which intended users can achieve specified goals in particular environments; *efficiency:* the resources used in relation to the accuracy and completeness of objectives attained by users; *satisfaction:* the pleasant and acceptability of the system to its users; *learnability:* How simple is it for users to achieve basic tasks the first time they encounter the design; *memorability:* when users go back to the design after a period of not using it, how simple can they reestablish proficiency; *errors:* the amount of errors rate the users do make, during the usage of the system, and how easily they can recover from them; *simplicity:* the degree of comfort with which users find a way to finish tasks; *comprehensibility:* The degree of easiness on how users can understand content presented on the system and *learning performance*: measurement of the learning effectiveness of users in mobile system.

Different usability measures may best be evaluated by different methods and variables. Selecting appropriate usability measures to evaluate a mobile system depends on the nature of the system and the objective of the study. Diverse of measures (e.g. time, speed etc.) has been used to evaluate different usability measures for specific mobile systems (Zhang and Adipat, 2005). The last 6 mentioned attributes measure the efficiency, effectiveness and the satisfaction of the system to users. Since the system can be effective, efficient and satisfy users when it is learnable, memorable, no errors and simple to use, comprehensive to users and good learning performance (Delikostidis, 2007).

For example, based on the usability measures, the designed prototype will be measured regarding the effciency, effectiveness and satisfactions it grants to users. Thus the prototype which will be designed and tested is expected to meet the user's needs in specific tasks hence the utility and usability will be readily accomplished.

The aims of usability evaluation is to attain the improvement of the product usability, involve real individual users in the testing, give the users real tasks to accomplish, enable testers to observe, listen, takes notes, record the actions of the test users, analyze the data obtained and acquire the results. The objective of the usability evaluation is to determine participant's satisfaction, efficiency and effectiveness with the product. (Abras et al., 2001; Dumas and Redish, 1993). Involvement of users in usability evaluation ensures that the product will be suitable for its intended purpose in the environment in which it will be used. To evaluate the usability of a product, usability testing methods and techniques are used to test it in a given area, with real representative users to strengthen in achieving project defined goals before being released to the commercial markets (Shneiderman, 1997). This is done by using the feedbacks from users during usability evaluation. Hence the design cost is reduced and usability problems of the product can be revealed and solved (Oztoprak and Erbug, 2006). The following explains the environments where usability evaluation can be performed.

Usability evaluation experiment can be done in laboratory and or in the field (for validation). In the field, individual users are used to test the usability of the developed system in the real environment based on the efficiency, the effectiveness and the satisfaction it grants to the users during task execution (Nivala and Sarjakoski, 2003b; Nivala et al., 2005; Sarjakoski and Nivala, 2005; Zhang and Adipat, 2005). Depending on the nature of the product, each environment of testing area (laboratory or field) has its own suitable methods for identifying how users actually interact with a prototype as discussed in the coming sections. Usability evaluation usually involves building prototypes of the system or of the user interface (often called mock-ups) and testing these early versions with representative users, performing representative tasks. The tasks are observed in order to discover the usability problems that users may counter with the system.

Usability evaluations are traditionally conducted in laboratories, consisting of e.g. a living room or office-like area connected to a monitoring area with a one-way mirror. In the laboratory testing human test users are required to accomplish specific tasks using a developed system in a controlled laboratory settings, feedbacks from testing can be used to improve the system and correct possible design mistakes, The laboratory environment is a peaceful space, where test users can concentrate on the given tasks. (Johnson, 1998). In laboratory testing, there is absence of interruptions, noise, movement, multitasking, different weather condition etc. that could affect the user's performance (Tamminen et al., 2004). Both environments are assumed to set special requirements for evaluations. Usability evaluation should take these requirements into account. Even if there seems to be a common concern about the adequateness of laboratory evaluations, field evaluations have been rather rare. A literature study by Kjeldskov & Stage (2004) revealed that most (71%) MD evaluations were done in laboratory settings. This may be caused by the data collection techniques such a video recording, observations or TA being hard in the field.

However conducting tests in the field has become easier due to the rapid development of mobile video recording systems like small video cameras during past few years. It is now potential to record the screen of the MD by attaching a small camera and collect that information for later evaluation (Delikostidis and van Elzakker, 2009b; Kjeldskov et al., 2004; Kjeldskov and Stage, 2004; Roto et al., 2004). This development permits similar test setting in the field as in the laboratory; it is possible for observer to follow what is happening on the screen and hear users' comments. This also lets the usage of TA protocol in usability evaluation in the field and gaining insight from the subject being tested by users. Despite the development of suitable tools testing in the field is still likely to be more time consuming than in laboratory testing (Kjeldskov and Stage, 2004). It may require extra effort from test users and the observer.

3.3. Methods and techniques for UCD

There exist common qualitative methods for data collection and recording that are used in usability testing, and each of them has different properties. Some of these data collection methods are: TA (or cooperative evaluation), questionnaires, interviews, observation and usability evaluations (both in laboratory settings and in the field). Data recording methods are video recording, data logging and voice recording (Delikostidis, 2007; Kumar, 2005; Solomon, 1995; Suchan and Brewer, 2000; van Elzakker et al., 2008; van Elzakker and Wealands, 2007).

Data collection methods and techniques

TA: The TA method can be combined with other methods like questionnaire to get rich verbal protocols and data about a cognitive process on reasoning and what problems users encounter while completing a given task (Jaspers et al., 2004). During this process an evaluator can: records the interaction and notes the problems; concentrate on knowing why and what the test users are actually doing at a given task (van Elzakker et al., 2004). This method is very useful as: it provides abundant data on cognitive process, delivers good performance and preferences; provides quick feedback and rich qualitative data; less expensive; suitable for exploratory design approaches; insights into the way users think and work with a given prototype can be provided that can be used to refine it later. However this method has the following demerits: Unnatural behaviour and conflict between task performance and communicating, time consuming nature, difficult and tediousness of analysis of the huge amount of data as no quantifiable measures are obtained, making it difficult to compare results between several alternatives, test users might face problems to express thoughts as it can be difficult to transform thoughts into words and might say somewhat different to the researchers side (van Elzakker, 1998, 1999).

Questionnaire: In addition this method is applied before or after the test sessions with the intention to collect user's demographic data and to organize homogeneous group of users regarding their background and experiences for getting views of different categories of landmark visualizations. It is used in combination with other evaluation approaches to study and collect user's opinion and thoughts towards the usability testing through question items, and can provide insights into preferred visualizations, preferences and other subjective usability ratings like satisfaction. Thus structured feedback on prototype usability and solutions can be generated. Due to its nature, questionnaires are fairly quick and inexpensive to create, fairly simple to perform and can provide feedback based on real user experience. They are less interfering than telephone or face to face surveys. They can be used throughout the design process. For example questionnaire was used together with other methods to test the projects: PALIO (Dolle, 2007), PARAMOUNT (GmbH, 2002) and TomTom (Nilsson, 1991) projects. However questionnaires do not identify specific problems of a design and that response rates are often poor.

Moreover, *semi-questionnaire* or a combination of questionnaire and interview is used to obtain extra user information regarding the test. The aim is to get more insight into user's recalled information after the test. During the interview users talks about experience while it is recorded by researcher (Delikostidis, 2007; Delikostidis and van Elzakker, 2009b; Elias and Paelke, 2008; Razeghi, 2010; van Elzakker et al., 2008; van Elzakker et al., 2004; van Elzakker and Wealands, 2007).

Interview involves a verbal interaction between the researcher and the test users for a specific purpose (Delikostidis, 2007). It can be carried out in a way which is flexible where a researcher has the freedom to formulate the questions at the instant the discussing issue is being investigated with the test users. It is inflexible as the questions are kept strictly when they are designed before the discussion. Interview questions have to be aligned with what is being looked for (Kumar, 2000). Interviews can be classified according to the degree of flexibility into the following categories:

Structured interviews: Researcher has to prepare a schedule that determines his/her set of already prepared questions using the same wording and order as specified in the interview schedule. The schedule is a written list of open or closed-ended questions prepared in advance to be used during the interview. Structured interviews provide uniform information which help to perform data comparison and it is most useful when looking for very specific information (Kumar, 2000).

Semi-structured interviews: Permits asking new questions based on what the test users said before in contrary to the structured interview. It is useful to investigate a topic that is very personal to the test users. Due to its flexibility the data obtained from this method is larger than the structured interviews. Its face-to-face interaction nature helps to avoid mistakes and misunderstandings. Complex and sensitive issues can be studied by elaborating multifaceted questions and preparing an appropriate respondent for such questions. Probing is also possible to obtain in-depth information. Interview data could easily be combined with other sources of information gathering techniques (Kumar, 2000). However interview data quality can be influenced by the experience, skill and commitment of the researcher and the quality of his/her interaction with the test users. It is also time-consuming and expensive method especially when the potential respondents are scattered over a wide geographic area (Kumar, 2000).

Observation: Furthermore this method is used to systematically selecting, watching and recording the behaviours and characteristics of the test users during the testing of the prototype, to capture user activities which help him/her during orientation and navigation. Specific issues that are not obtained from other methods, and especially in cases where the test users are not willing or it is difficult for them to express their opinions while they are interacting will be revealed (Salmon et al., 2006). However this method has a problem of causing disturbance, as the test users' performance may change if they are aware that they are observed. This factor makes this method not very convenient for field-based testing (Jordan et al., 1996). However the application of proper technical solutions where the observer stays somehow "invisible" to the test users can reduce his/her influence to them. Also this method cannot capture insights about what the person is really thinking or the reasons behind a particular behaviour or comment. Observation can be applied throughout the usability evaluation process (Delikostidis, 2007).

Data recording method and techniques

Video recording: This method is used to capture and record the test users' reaction and actions when using the prototype during usability evaluation, either in laboratory or in the field (Dumas and Redish, 1993). Also it reviews what the participant did, see where the problems are in the designed prototype and have efficient analysis of the tests user behaviours (Shneiderman, 1997). It is possible to capture the participant face expression and it has efficient analysis of the tests user behaviours. This method requires time procedure and camera alignment for best visibility of the participant's interaction and it is difficulty in analyzing the data (Delikostidis, 2007).

Voice recording: This comes automatically with video recording. This method used to document data on paper through jotting down the received information both by researcher and test users. This method can have two forms, first in the form of text which is useful during the course of TA and semi-or non-structured interviews. Graphical representation can be regarded as sketching or drawing which is easier to produce and conveying mental perceptions which are not possible through speaking or writing from the collected data.

Data logging: This method used to record the timing and the type of interaction of the user with the developed prototype, e.g. the time and number of times a user refers to a specific kind of landmark visualizations. It used to get good data analysis as it is reported that it can be up to eight times more efficient than other methods, depending on the context of use (Hammontree et al., 1992). Nevertheless this method has excessive amounts of data to be analyzed, possible violations of test users' security and privacy matters, and possible need for special logging software customization in order to be used by a particular system and this method cannot capture the participant's face expressions (Delikostidis, 2007).

Each method has its own merits and demerits. The combination of methods allow a deeply investigation of the test users thoughts and actions and at the same time records all the test activities. A proper combination of these methods can fill these gaps. It is good to combine methods when evaluating a particular prototype to get information that couldn't get with only one method. The following studies were done by using combination of methods like using TA with audio/visual observation and synchronous screen logging, questionnaire and a semi-structured interview. These combined methods are both easy to apply and effective at finding usability problems (Delikostidis, 2007; Delikostidis and van Elzakker, 2009b; Perlman, 1994; van Elzakker et al., 2008; Zhang and Adipat, 2005).

3.4. Selected methods and techniques

This part highlights the proposed methods and techniques suitable for each stage of UCD. However to say these are best methods and techniques for a certain research depends on the context of use, the special characteristics of the test users and what exactly the research wants to investigate. The reasons for choosing each of these methods based on their merits and demerits, as mentioned in section 3.3 is due to their importance hence they will be applied in the evaluation of the prototype in chapter five.

3.4.1. Methods for requirement analysis

The method which has been applied in the requirement analysis of this research is literature review. There exist common methods for conducting requirement analysis as started earlier (see section 3.3). To full fill the objective of this research, all these methods were not used; instead the literature review was adopted because there are already existing studies concerning landmark visualizations. These studies were used for investigation about landmark visualizations on M2 so as to discover the gaps in theories, methods, and practices about landmark visualizations that can be used to propose new usable categories of landmark visualization on M2, which later on will be used to design and implement the prototype. Literature review has been used to reinforce the knowledge of different ways of visualizing landmarks on M2. The findings of existing studies show that users are facing different problems in answering their specific geographic questions during orientation and navigation, due to the static way of landmark visualization on M2 (see section 1.2). Due to these problems, and the recommendations from previous studies lead to the outcome of categories of landmark visualization on M2, proposed in chapter two. Thus the proposed categories will be used to develop and implement the prototype as the outcome of requirement analysis.

Requirement analysis was emphasized by the outcome of chapter two (the proposed categories of landmark visualizations on M2), which are from the existing studies which have gone different tests about landmark visualizations (Deakin, 1996; Elias and Paelke, 2008; Elias et al., 2005b), some of them already exist in current applications like Google maps (see section 2.4.4 and 2.6).

3.4.2. Methods for prototyping

Throughout the design of the prototype the Enschede case study data will be used to design and implement the prototype. A field study will be done in central area of Enschede to investigate the landmarks which have been used in an earlier user study (Razeghi, 2010). The reasons to select this area are aligned with availability of the data, the need for test users, the relation of the executed research and the time available for this research. Suitable landmarks to be used among the mentioned ones, in terms of their pictures, and position will be collected (see section 4.2 and 5.3).

The obtained landmarks will then be categorized accordingly to the procedures of classifying landmark visualizations on M2 in terms of Banks, Churches, Restaurants, Shops and Others (see section 2.2.2). Spreadsheet will be used, to compile the data obtained from the field then ArcGIS software will be used to develop shape files according to the the categories of landmark visualization symbols proposed in chapter two, i.e. Geometric symbols, Pictorial symbols, and Image/Photograph. Later shape files will be converted to KML files for easier accessibility with Google Maps JS API which will be used to implement the prototype, thus all required functionalities will be implemented. KML is a file format used to present spartial information in an Earth browser, like Google Earth, Google Maps, and Google Maps for mobile. According to Open Geospatial Consortium (OGC), KML is complementary to most of the key existing OGC standards including Geography Markup Language (GML), Web Feature Service (WFS) and Web Map Service (WMS). KML files encourage broader implementation and greater interoperability and sharing of earth browser content and context. Currently, KML 2.2 utilizes certain geometry elements derived from GML 2.1.2. KML elements include point, line string, linear ring, and polygon.

Subsequently the Google Maps JS API Version 3 will be used to create the prototype based on created KML files which represents the landmark visualization categories proposed from chapter two, to design and implement a prototype to interactively select different landmark visualizations type on M2.

3.4.3. Methods for usability evaluation

The objective of this UCD stage is to use usability evaluation to gain views from individual users about the implemented prototype by doing the testing in the field, where the usability of the prototype will be determined by answering the user's specific questions. These activities will be achieved by using different research methods and techniques to collect and record the required information, as discussed and justified below: (Dumas and Redish, 1993).

Observation was chosen because it can provide qualitative assessment of the context of use, especially when it comes to the real environment in which the usability evaluation is taking place (Salmon et al., 2006). The *video recording* is used to capture test users interaction and give the validity and evidence to the conducted research (Shneiderman, 1997).

TA is selected because it can give qualitative assessment of problems, strategies and user expectations and identification while uncovers usability problems and the reasons why they happen. It is the most valuable of all usability evaluation methods (Nielsen, 1993), requires small number of test users, from 3-5 and little experience from the facilitator. Its small number of test users makes it very rich in obtaining qualitative output. The field testing which will be done in chapter five will explore this matter.

Questionnaire was selected because it provides extensive coverage and enables capture of abundantly of information about the cognitive process during problem solving without actual execution of a task (van Elzakker and Wealands, 2007). It is quick and inexpensive to create, fairly simple to perform and can provide feedback based on real user experience. It is relatively simple to conduct and can provide feedback based on real user experience. Less interfering than telephone or face to face surveys. It also discovers specific needs of various user groups and the difference between them in making use of the system (Nielsen, 1993). However, most questionnaires do not identify specific problems of a design and that response rates are often poor. Also they are rigid in structure and do not allow the respondents to qualify their answers. Especially when the problem is complex, questionnaires may not provide useful and comparable results (van Elzakker and Wealands, 2007).

The *semi-structured interviews* was chosen because its structure part allows a free interaction in its unstructured part between the researcher and test users by using the probing[1] technique. These kind of interaction help to discover new problems, ideas and sugestions and also help to uncover deeper thoughts of the test user. Through interview there may be misunderstanding concerning the reseachers questions, this can be resolved easily due to its face-to-face interaction nature something that is impossible with questionnaires unless the test users are filling them while they are next to the researcher. This method has a risk of biasness from the reseacher which can be infuenced by the experience, skill and commitment of the researcher to the test users, but its rich outcome do reduce this risk's significance. *Audio recording* is also used throught the interview for laiter confirmation of the result written on the paper notes by the researcher.

Due to the aforementioned studies, usability evaluation has shown to be a crucial part of the design and implementation of any prototype such as the M2 application. Elzakker et al.(2008) did a research to find out an appropriate field-based research methodology to evaluate the first prototype of the Usable (and Well-scaled) Mobile Maps for Consumers (UWSM2) project. They proposed suitable methods for field-based methodology considering their merits and demerits against the research objectives as follows: observation, TA, video/audio recording (including screen logging) and semi-structured interview. They found out that the combination of observation and video recordings, screen logging, synchronous audio recording of the TA and semi-structured interviewing with the developed remote field observation system, appeared to be the most encouraging methodology to be used for the evaluation of the UWSM2 project.

Similarly, Delikostidis & van Elzakker (2009b) did a field-based test to investigate the ways people navigate and orientate with the help of supporting tools with a cartographic interface in unfamiliar areas. The methodologies used (semi-structured interview, questionnaire, TA, observations, screen logging) result to have less resource and time needed for user data collection required for field-based studies and allow better analysis of the results.

This research will adopt the field-based approach to perform its experiment to assess and investigate the usability of the designed prototype regarding usable visualization of landmarks on M2. It will be based on a system that was already implemented during a previous investigation on methodologies for field-based usability evaluation of geo-mobile applications (Delikostidis, 2007; van Elzakker et al., 2008), and form a new improved methodology in order to offer higher reliability, simplicity and performance, This approach was used also in Geo-identification and pedestrian navigation with geo-mobile applications study (Delikostidis and van Elzakker, 2009b). This new field-based methodology utilizes an advanced technical solution to support the methodology proposed in the study of Delikostidis (2007) which is explained more in section 5.3. The reasons to adopt this methodology is that; the designed prototype will be tested with real users, performing their own tasks and goals, in an actual use context to reveals implicit the usability problems of the prototype as stated earlier. To investigate if the prototype is working well, the validation of the prototype using field-based approach has to be done. The visualization of landmarks is strongly related to usage situations in which the user tries to find his/her way in an unfamiliar environment. This is why we assumed that field-based evaluation would give us much richer feedback from the users than traditional laboratory evaluation. With field-based testing contextual usability information is gathered; cost are lower than laboratory tests and of higher quality; and appropriate usability data are collected using more representative sample of users (Oztoprak and Erbug, 2006); field-based is suitable for this research to fulfil its objectives, which is "to design and test a tool to adjust visualization of landmarks to specific individual user needs in real environment" (Oztoprak and Erbug, 2006). Moreover field-based testing

[1] Probing is a technique used by researcher during the investigation , to search into and explore very thoroughly from test users

gives a more realistic test setup as the tests users remain in their normal setting (Brush et al., 2004). In addition, mobile usage using while moving could be studied more naturally in a real environment. Field-based testing will help us to observe the prototype being used in their natural environment with real users (Nivala and Sarjakoski, 2003b; Nivala et al., 2005; Sarjakoski and Nivala, 2005; Zhang and Adipat, 2005).

In addition, the study of Elzakker et al.(2008) about the proposed methodology emphasizes that, using it complete information about the cognitive processes of the subjects during task execution will be obtained; Audio Video recordings allow for thorough and verifiable analysis of research outcomes afterwards; with direct observation researcher gets immediate impression of problems in task execution; observer can also immediately deal with technical problems occurring during test execution and may prompt subjects to TA.

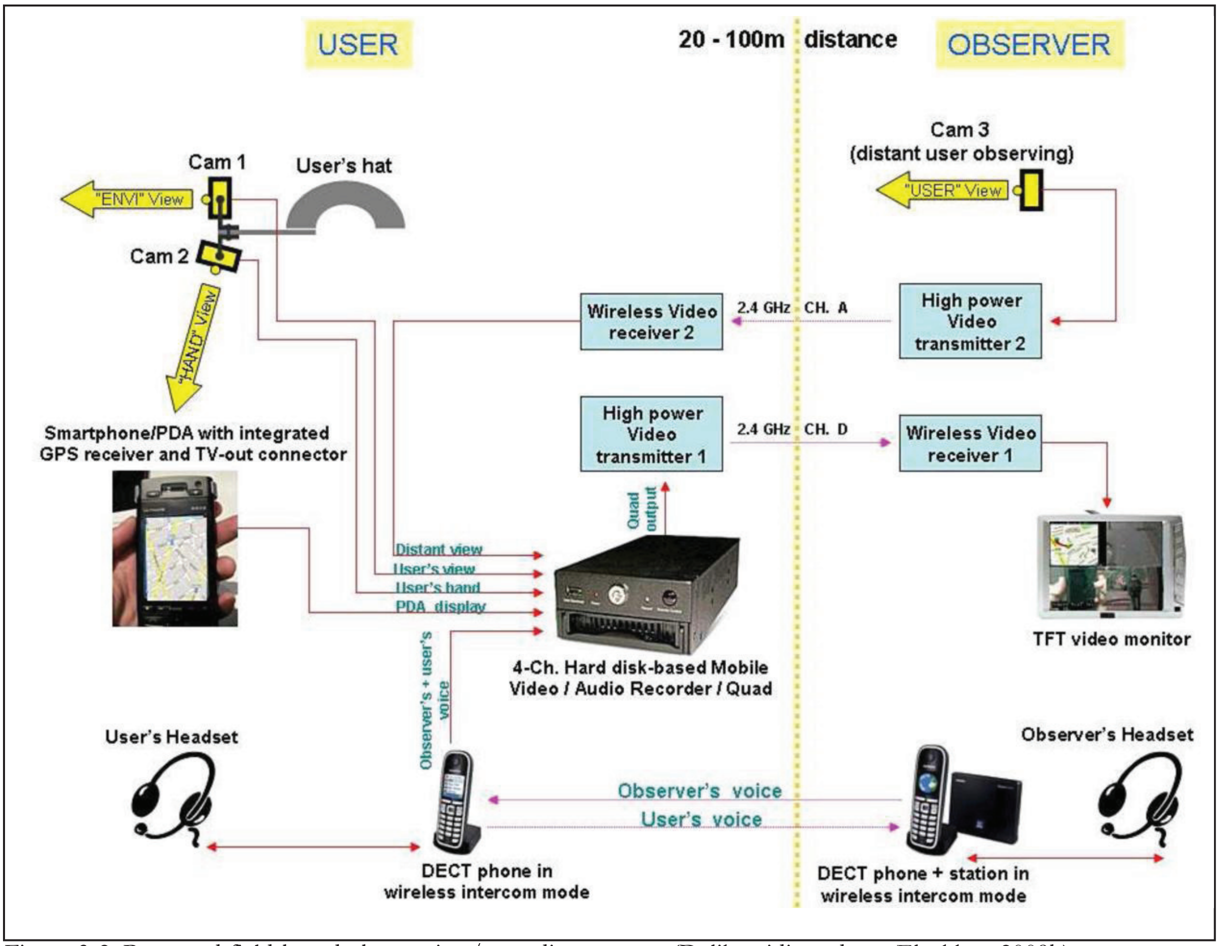


Figure 3-2. Proposed field-based observation/recording system (Delikostidis and van Elzakker, 2009b).

3.5. Conclusion

This chapter gives a broad overview of research methodologies. Methods and techniques for each stage of UCD (requirement analysis, prototyping and usability evaluation) are discussed and reasons of applying them considering their merits and demerits to fulfil the outcome of this research context were explained.

It has been highlighted two types of usability testing, laboratory and field-based testing. Depending on the nature of this research, field-based testing will be performed to fulfil the objective of this research, and to deeply investigate the interaction of real users with the prototype in the real environment. The different landmark visualization categories which will be implemented in the prototype will be evaluated to discover the usability of the prototype.Chapter four discuses about design and implementation of the prototype.

4. DESIGN AND IMPLEMENTATION OF THE PROTOTYPE

4.1. Introduction

Chapter four outlines the second phase of UCD: the design and implementation of a prototype to interactively select different landmark visualizations on M2. The research knowledge acquired from the literature study and from the requirement analysis is implemented together with new ideas. Proposed categories of landmark visualization on M2 for a pedestrian navigation system and the prototyping methodology proposed in chapter three are implemented. The research question "What distinctive solution could be developed to facilitate dynamic landmark visualizations during orientation and navigation in different use contexts?" is answered in this chapter.

This chapter consists of the following sections: 4.2 explains the prototype design, 4.3 describes the prototype implementation, 4.4 depicts the Google Maps API V3 for Android MDs, 4.5 clarifies the procedures used to upload the prototype into the Android MD, 4.6 makes clear on how users can use and interact with the prototype and finally 4.7 summarizes this chapter.

4.2. Prototype design

A prototype which gives its users a sense of control, hides its core codes from the users and performs most of work while requiring minimum information from them is called an effective prototype. A prototype should offer some ideals to its intended users in conjunction with design objectives like considering users problems (needs and wants) and supply that information to them. A good prototype should appeal the users awareness (Nielsen, 1994). When these ideals are combined with the research theme, the prototype is designed.

Throughout the design of the prototype, a field case study was done in central area of Enschede to investigate the landmarks which have been used in an earlier user study (Razeghi, 2010). Section 3.4.2 and section 5.3 describe more about the case study area. Considering the said properties of landmarks in section 2.2, it was discovered that, landmarks are grouped into local (on-route) and global (off-route) ones. Local landmarks are directly close to the route and global landmarks are in the far distance like a tower or mountain chain. Additionally, local landmarks are located between nodes, at decision points (a junction where a navigation decision is required) or at potential decision points (where a navigation decision is possible but the route goes straight on) (Lovelace et al., 1999). After considering these properties, suitable landmarks were selected, located and marked among the existing ones (figure 4-1). Within the 41 selected landmarks there were two new included landmarks, k1: Pool Cafe The Bridge and k2: Antique Boutique which make a total of 43 landmarks. These landmarks found to be important in the case of orientation and navigation. The earlier conducted user study of Rezeghi disclosed that the majority of the landmarks found were based on the buildings. This is due to the fact that the case study area is located in an urban area, where by an ideal representation of buildings as navigation aids is a fundamental concern (Elias and Paelke, 2008; Elias et al., 2005b). Considering the steps which has been highlighted in section 2.2.1, the procedures for classifying landmarks on M2 which has been discussed also in section 2.2.2 and the nature of the case study area, the 43 landmarks (buildings) obtained were then grouped/referenced according to their general function type, i.e. in terms of Banks, Churches, Restaurants, Shops and Others (buildings that are not in the groups of Banks, Churches, Restaurants or Shops). The group "Others" contains the landmarks which do not appear many times within the case study area. For example there is only one university, museum and music canter in the case study area (figure 4.2). From the study of Rezeghi, cafés and restaurants were separated as different groups. This particular research has combined these two groups to avoid having many categories of landmarks, since cafés and restaurants do the same work. Spreadsheet was used, to compile the data obtained from the field (table 4-1).

Figure 4-1. List of landmarks selected from the previous case study (Razeghi, 2010)

No	Id	Category	Name	Longitude	Latitude
1	e2	Bank	ATM Bank	6.8947010	52.2217610
2	e9	Bank	Elkebankkan Uvertellenover	6.8970190	52.2216400
3	b4	Bank	Fortis	6.8896290	52.2206570
4	b5	Bank	SNS Bank	6.8903950	52.2207950
5	b3	Bank	Staal Bankiers	6.8892480	52.2205830
6	f9	Church	De Grote Kerk	6.8964720	52.2208070
7	i9	Church	Geref Kerk	6.8992640	52.2208580
8	f3	Church	Revelation	6.8967260	52.2209510
9	b0	Others	De groote schuur	6.8875860	52.2201380
10	a4	Others	JPRAdvocation	6.8894040	52.2207800
11	a1	Others	Makelaarsbedrijf DTZ Zadelhoff	6.8890930	52.2204910
12	e5	Others	Muziekcentrum	6.8948520	52.2219720
13	b1	Others	Natuurmuseum	6.8879400	52.2202280
14	a0	Others	Saxion University	6.8875940	52.2202450

15	b7	Others	Snelder Zijlstra Makelaars	6.8911630	52.2207430
16	a9	Others	Tempo-team Uitzendbureau	6.8910780	52.2210420
17	b2	Others	Uitvaartcentrum Vredehof	6.8884490	52.2203710
18	c7	Restaurant	Bieren Café Het Bolwerk	6.8944950	52.2215200
19	i8	Restaurant	Brasserie Willemientje	6.8987350	52.2205400
20	d0	Restaurant	Chaplin	6.8932660	52.2210930
21	f4	Restaurant	De Buurvrouw	6.8969330	52.2212240
22	c9	Restaurant	Detropen	6.8946750	52.2217550
23	e0	Restaurant	FRED & DOUWE CITY LOUNGE	6.8946750	52.2215130
24	e3	Restaurant	Humphrays	6.8955110	52.2219720
25	d1	Restaurant	Los Ponchos	6.8931970	52.2211480
26	h3	Restaurant	Mix	6.8978830	52.2209120
27	g2	Restaurant	PINNOCIO	6.8967370	52.2208760
28	k1	Restaurant	Pool Cafe The Bridge	6.8955190	52.2214200
29	d6	Restaurant	Talamini	6.8942590	52.2210240
30	f0	Restaurant	The Edge	6.8973300	52.2216380
31	c3	Restaurant	Timeless	6.8944760	52.2215130
32	f2	Restaurant	Wijnhuys Jou & Mij	6.8972520	52.2212680
33	h5	Shop	Ad Heijne Schoenen	6.8972120	52.2208200
34	k2	Shop	Antique Boutique	6.8943610	52.2210680
35	h9	Shop	Avenue (Men´s Clothing)	6.8976060	52.2209710
36	c2	Shop	Boekhandel Broekhuis Libris	6.8938830	52.2210930
37	i4	Shop	BRITAIN	6.8978830	52.2209120
38	f5	Shop	Capelli Kappers	6.8973250	52.2216380
39	d3	Shop	Deslegte INKKOOP VAN BOEKEN	6.8938830	52.2209070
40	h2	Shop	G. Koelink Juwelier	6.8972120	52.2205850
41	d5	Shop	Mobile Action	6.8942590	52.2210000
42	j0	Shop	Sea-design B.V.	6.8987350	52.2208490
43	h4	Shop	Stolker	6.8972120	52.2205490

Table 4-1. Field data compiled in a Spreadsheet

Once appropriate landmarks were selected, the question of how this information could be communicated effectively, efficiently and with satisfaction to the user of the navigation system arose. This is a design issue that involves a wide range of fields including navigation, visual design, cognitive psychology and MD programming. The proposed landmark visualizations from section 2.6 were used. Also procedures for obtaining symbols to represent the proposed landmark visualization categories are explained and demonstrated below.

The category geometric symbol was obtained by using ArcGIS ESRI Default Marker Symbols. The entire proposed landmark categories proposed from chapter two were implemented, taking into account that the collected data were points, which need to have some size, shape and colour for visualization (see section 2.6.1). Each category were assigned different shape, size and colour for visualization to translate information (Bertin, 1983). Also it is depicted at appendix A. The statement made by different authors about geometric symbols: that they conserve map space compared to other kind of symbols e.g. pictorial symbols and image/photographs; they are visually stable as they can produce attractive and eye catching graphic; they are mostly preferred by users and that they are suitable for M2, was confirmed during the implementation and testing of the prototype (Deakin, 1996; Elias and Paelke, 2008; Elias et al., 2005b).

To attain the category pictorial symbols, a selection was made from Google Earth library symbols to represent the categories Banks, Churches, Others, Restaurants and Shops (see section 2.6.1 and appendix A). It is stated that, the pictorial symbols overcome the language barrier. To attain this property these symbols were found useful as they are internationally recognized. Therefore users can quickly identify them and process the information without limitations (see section 2.4.2).

Subsequently, ArcGIS software was used to develop shape files according to the categories of landmark visualizations proposed in chapter two, i.e. geometric symbols, pictorial symbols and image/photographs. As a result, the proposed landmark visualizations were formed (figure 4.2).

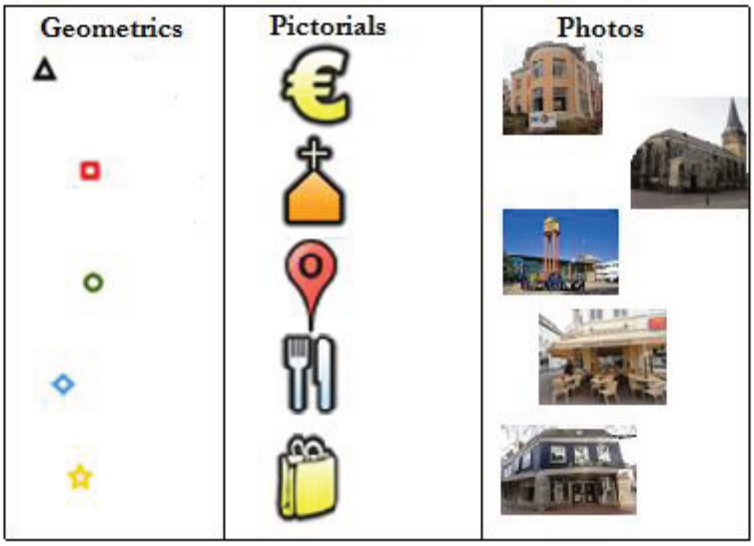


Figure 4-2. Landmark categories used in the prototype

Later, shape files developed from ArcGIS software were converted to KML files for easier accessibility with the Google Maps JS API which was used to implement the prototype by putting all the required functionalities of the prototype to enable individual users to:

i. Select particular type of landmark visualizations of choice e.g. Geometrics, Pictorials and Image/Photograph. This will be done interactively beforehand and for all landmark visualizations at the same time.
ii. Have a possibility of visualizing only one particular type of landmarks (e.g. church) after selecting a particular kind of visualizations. For example if a user is using pictorial landmark visualizations, there will be an option of viewing only existing churches in that particular route.
iii. Have a possibility of clicking a particular landmark symbol to change its way of visualization. For example if a particular user is using Geometric symbols during navigation, sometimes s/he may need to confirm it (e.g. church), there will be a possibility of clicking that particular symbol (church), and view other visualization options e.g. photo. It means now a user can confirm the church very clearly.

4.3. Implementing a prototype

The prototype is designed in such a way that all required functionalities are consistently employed to develop the user's productivity by reducing errors from which the user can predict what the system will do during the task execution and they can use their common senses when applying the new prototype. The smaller number of mistakes and shorter learning time a test user is taking usually leads to improved user satisfaction with the new prototype and fewer frustrations. Consistency strengthens the user's expectations with respect to being able to use the new prototype, leading to feelings of mastery and self-confidence (Nielsen, 1993).

Implementing a prototype efficiently requires that an organization has the proper tools and trained staff. Prototyping tools are diverse: from 4th generation programming languages used for rapid prototyping to complex integrated CASE tools. 4th generation visual programming languages for instance Visual Basic and Cold Fusion are frequently used since they are cheap, famous and relatively simple and prompt to use (Wales, 2001). Considering the nature of prototype to be developed, the objective of the research and the time limitation to execute this research, the Google Maps JS API Version 3 was used to create the prototype. Google Maps JS API Version 3 was found to be very handy to adopt and use as could be less time consuming compared to other prototyping tools mentioned before. Google Maps JS API V3 is a free service, available for any website that is free to consumers. It can run in the following platforms: IE 7.0+ (Windows), Firefox 3.0+ (Windows/Mac OS X/Linux), Safari 4+ (Mac OS X/iOS), Chrome (Windows/Mac OS X/Linux), Android, BlackBerry 6, Dolphin 2.0+ (Samsung Bada) (Chris, 2010). It has been designed to load fast, especially on mobile browsers such as Android-based devices and the iPhone. Special emphasis on enabling reliable and fast maps on mobile browsers has been integrated into this API. The Google Maps JS API lets its users embed the robust functionality and everyday usefulness of Google Maps into their own website and applications, and overlay data on top of them. Version 3 of this API is specially designed to be faster and more applicable to MDs, as well as traditional desktop browser applications. The API provides a number of utilities for manipulating maps (just like on the http://maps.google.com web page) and accumulating content to the map through different services, allowing the user to create robust maps applications on their websites.

The Google map was used as a base map for the prototype interface. Buildings as landmarks along the specified route in central area of Enschede have been presented in terms of different landmark visualizations as geometric symbols, pictorial symbols and photos, where it was accessed through the Internet connection. This map is stored on the Google Maps server, and every time requires internet connection to be viewed. The created KML files represents the landmark visualization categories proposed from chapter two together with a route were overlaid.

The implemented prototype is capable of helping users during orientation and navigation. The implemented route is predefined/fixed, hence it is not possible to plan a route using this prototype. The purpose of implementing this kind of prototype is to investigate if the landmarks along the route (red route) can be used as a guide to help users during orientation and navigation, so based on this purpose the prototype was implemented by using the predefined route to answer users' questions E.g. Where am I? (Orientations); Am I on the correct way? (Route confirmation); Is this the correct endpoint? (Destination confirmation) or after orientation, what are the landmarks I expect to base my navigation on my way? Is this the correct view at this particular point etc. Individual users have to use the presented landmarks together with the predefined route for orientation and navigation.

To solve the problems of display overload, the landmark visualizations presented in this particular prototype were grouped into categories based on their general function type, i.e. in terms of Banks, Churches, Restaurants, Shops and Others (figure 4.4-a). These help users to have a possibility of visualizing only one particular type of landmarks at a time (e.g. churches) (figure 4.4-b). For example if a user chooses to use pictorial landmark visualization, there is an option of viewing only existing churches in that particular route. Hence the display overload has reduced (figure 4.3-b).

4.4. Google Maps JS API V3 for Android mobile devices

The Google Maps JS API V3 has been created to load fast and work well on MDs such as the iPhone and smartphones running the Android operating system. Android is an operating system which runs on the MD that was available for this research. Currently only Android devices and iPhones can use the Google Maps API directly in the browser. This new API has minor delay and grants you with a growing variety of features. There are some restrictions of MDs compared to desktop computers (see section 2.5.1), for example small screen sizes, and they often have a particular behaviour specific to those devices such as "pinch to zoom" on the iPhone (Marks, 2009).

The following are the factors which empower this research to adopt Android MD for the implementation of the prototype: users on any MD that support HTML 5 and JS can find and load the application developed by using Android, the interactivity with an Android device is easier than iPhone as it is not dependent on having device specific native code[2], when user update their pages, the changes come automatically to the application, so there is no need to update the changes, Androids provide a built-in full web browser capable of rendering real web pages, not just the small mobile versions. Users can develop java-based application and deploy it on an Android device. This is the feature which sets the Android apart from other devices, like the iPhone. An application written for Android has the ability to be deployed on different operating systems (Chris, 2010; Hall and Anderson, 2009; Marks, 2009).

4.5. Uploading the prototype into the Android mobile device

The implemented prototype was developed on a notebook computer. Procedures were then taken to upload the prototype to the available MD: a Samsung Galaxy S I9000 Android MD which has the following specifications: CPU of 1 GHz, RAM512 MB, Display 4.0 in 480x800 pixels, Firmware version 2.2, Kernel version 2.6.32.9, External SD card 7.41GB, Internal SD card 5.78GB. All the processes of uploading and testing of the prototype were done and the results were as follows: Initially, the general page with the map opens on the Dolphin Browser installed on the MD. The zoom buttons drop-down map controls (map, satellite, hybrid and terrain) on the upper right corner content window and the panning button worked well. The following application problems were encountered:

i. The application page was very big and scrolling the screen was needed to see the whole page
ii. Page menus (Geometrics, Pictorials and Photos) were not working at all and returned wrong addresses because of incompatible path given during the running of the application on the notebook computer.
iii. The display at the content window could not be seen as the size of the user interface page was big; hence panning of the map was needed to view the landmark.

The following solutions were applied to solve the above mentioned problems:

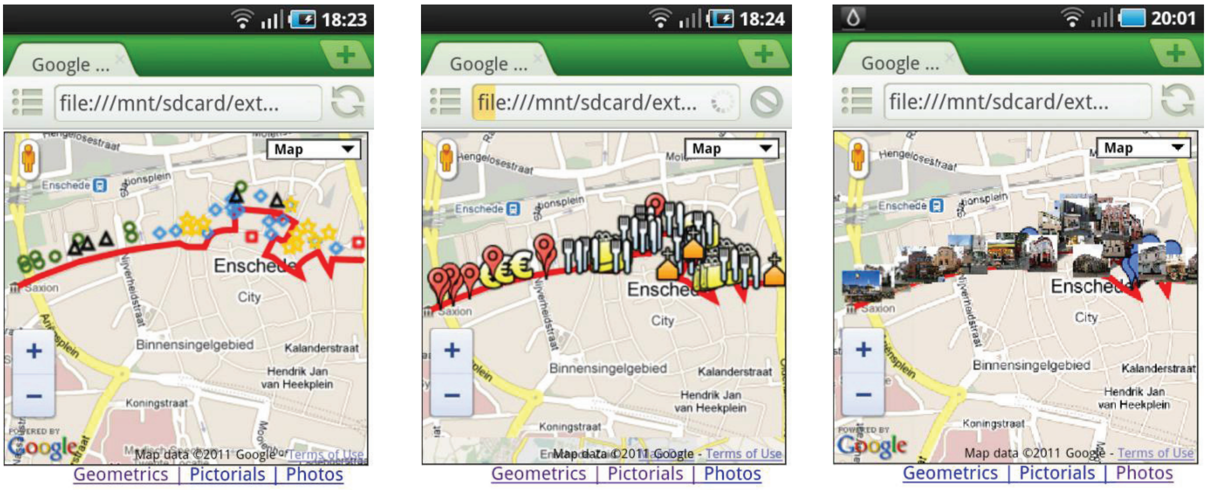
i. The size of the page was reset as per specifications of the MD size. Page dimensions were changed from width: 400px to 312px and height from: 400px to 285px to enable the display.
ii. To access the page menu, files paths were changed and replaced by the compatible paths. All files were kept on the working directory of the MD which is mnt/sdcard/external_sd/Erimina, the path which contains the entire required files, and it is a local path which is known to the MD.
iii. The content window was also reset by changing its position and removing some of the contents

4.6. The interface of the prototype

The prototype interface has been created so as to satisfy the overall research objective, "to design and test a prototype to adjust visualization of landmarks to specific individual user needs (through interaction)". Functionalities which have been implemented fronted to a user friendly interface with an adjustable landmark visualization categories presented interactively to individual users contexts (time availability and familiarity levels). Individual users are allowed to decide on how to visualize landmarks during orientation and navigation in the geographical area by selecting the visualization types of choice. These enable users to visualize the landmarks without limitations to attain proper orientation and navigation.

[2] Only one code base per application

The general functionality of the prototype is illustrated with screenshots and explained in detail on how to use the prototype. The prototype contains three page menus (category/button) such as: Geometrics, Pictorials and Photos. The figure 4-3-a shows the default display in which geometric symbols are used to present landmarks. The figure 4.3-b shows the pictorial symbols which appear when user clicks the page menu Pictorials and figure 4-3-c shows the Photos which appear when user clicks the page menu Photos.

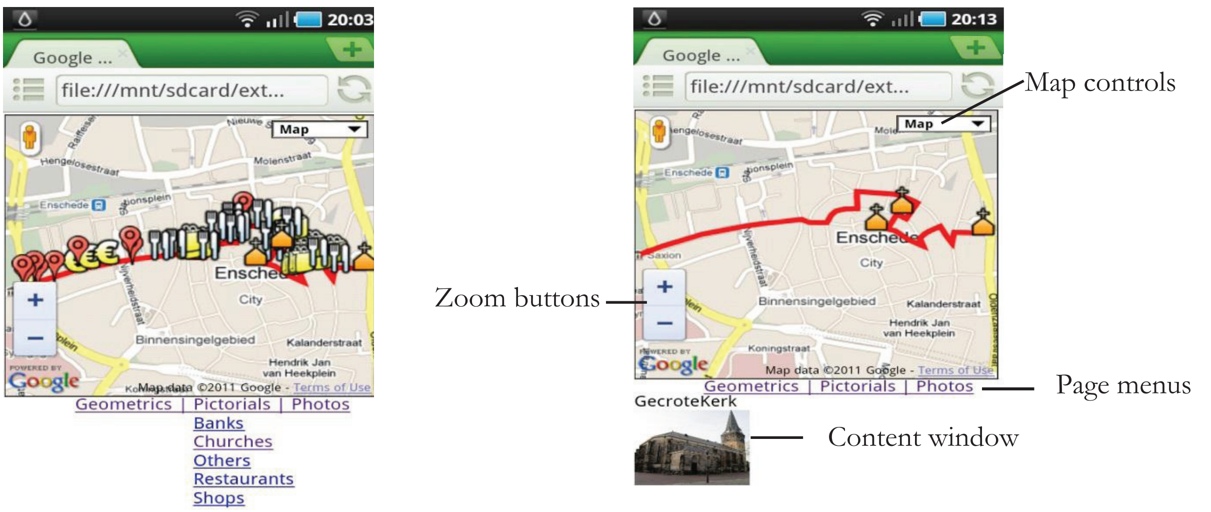


(a) The default category (Geometrics)

(b) Pictorials

(c) Photos

Figure 4-3. Interface showing different visualizations



(a) the drop down lists

(b) content window (with a photo and label) after clicking a landmark (No display overload)

Figure 4-4. Interface showing drop down menus (figure 4-4-a) and content window (figure 4-4-b)

In each button/control, there are drop down lists i.e. Banks, Churches, Others, Restaurants and Shops. These help users to have a possibility of visualizing only one particular type of landmarks at a time (e.g. churches) (figure 4-4-a). For example if a user chose to use pictorial landmark visualization, there is an option of viewing only existing churches in that particular route (figure 4-4-b).

Also a user has a possibility of clicking on a particular landmark visualization to confirm about that particular landmark. For example if a particular user is using Geometric symbols during navigation, sometimes s/he may need to confirm it (e.g. church), there is a possibility of clicking that particular symbol (church), and view other visualization options e.g. photo. It means now a user can confirm the church very clearly (figure 4-4-b). These are the functions which user can apply to interact with the prototype during the orientation and navigation.

4.7. Conclusion

The prototype design and implementation have been explained. In consort with the research basic idea the prototype has been created in such a way that the research goals may be investigated. The user's contexts (familiarity and time availability) have been considered as a key concept for improving the landmark visualizations on M2 during the implementation. The ways the functionalities have been implemented by using the Google Maps JS API fronted to a user friendly interface with an adjustable landmark visualization categories presented interactively to individual users contexts. Individual users are allowed to decide on how to visualize the landmarks during navigation in geographical area by selecting the visualization type of choice. These enable users of different contexts to visualize the landmarks without limitations so as to reduce the problems faced by users when visualizing landmarks on M2 during orientation and navigation such as, the display overload, frustrations and incorrect interpretation.

In addition the procedures taken to upload the prototype into the Android MD, the problems encountered and their solutions are explained. To demonstrate clearly how users interact with the application during orientation and navigation, screenshots representing the entire functionalities of the implemented prototype have been presented. Chapter five concentrates on testing the prototype.

5. TESTING THE PROTOTYPE

5.1. Introduction

In this chapter the emphasis is on the testing the prototype. The user tests to fulfill the objectives of this research to lead to usable results are explained by introducing the design stages of the test which was executed in Enschede, using the field-based methodology as discussed in chapter three. The goal was to examine the usability of landmark visualizations on M2, implemented on the prototype. This usability testing was done in the field with individual users in real contexts of use to test the designed prototype and give results regarding efficiency, effectiveness and the satisfaction it grants to them during orientation and navigation. The following research question was addressed: Does the developed solution works well?. To answer this question, three other questions were formulated: What type of landmark visualization do users prefer if they were to plan the route themselves? What type of landmark visualizations do user prefer during overviewing of the route they are going to follow? and What type of landmark visualization do users prefer during navigation?

The chapter introduces the study by providing the general overview of the following aspects: 5.2. the user tests design and setup of the user testing methodology and its application, 5.3 area where testing was done, the data used and specification of the test environment and equipment used, 5.4 characteristics of test users involved, 5.5 enlightens the user test procedures, 5.6. explains about pilot test, 5.7 prototype testing results and 5.8 conclusion.

5.2. User tests design and methodology

User testing with real users in real contexts of use provides direct feedbacks from respondents about the prototype. During the testing, it is the responsibility of the researcher to try to obtain reliable and valid test results. Reliability refers to whether one would get the same results if the tests were to be repeated and validity is the issue of whether the results reflect the usability concerns one wants to test. A high level of validity requires methodological understanding of the test methods and appropriate selections of test users. Selecting the wrong users or giving them the wrong tasks or not including time constraints and social influences are the typical problems against the validity (Nielsen, 1993). The user tests should be well planned and designed so that the outcome of the test can be desired. The purpose of the test should be clarified since it will have significant impact on the kind of testing to be done.

The field-based methodology proposed in chapter three is used. This methodology result to have less resource and time needed for user data collection required for field-based studies and allow better analysis of the results. These made it possible for the researcher to work independently without the supporting personnel. As depicted in figure 3-2, the system consisted of two sets of electronic devices: one for the user group and the other one for the researcher. Devices carried by test users were a hat with two colour cameras attached to it, a Samsung Galaxy S I9000 Android MD (with Third Generation (3G) technologies which comes with enhancements over previous wireless technologies, like high-speed transmission, advanced multimedia access and global roaming. 3G is mostly used with mobile phones and handsets as a means to connect the phone to the Internet or other Internet Protocol (IP) networks in order to make voice and video calls, to download and upload data and to surf the internet), a 2 channel hardisk-based mobile video/audio recorder/quad processor, a headset, and devices which were carried by the researcher were one colour camera, a high power video transmitter , two connected video receivers, a TFT video display, and a headset. This system was used to reduce the bias from the researcher physically being too close to the test users, to minimize the human resources required for carrying out the test sessions and to facilitate the analysis of the recorded research materials through synchronization. With this system, the results of the techniques which were used (TA, audio signals, video recording the environment and the respondent's interaction with the MD and the logging of the changes on the screen) were synchronically stored with a date/time stamp. The context of use and the test users' activities and expressed thoughts could thus be analyzed later with accuracy, speed and convenience. The test user wore a hat with two of the colour cameras attached on it. The first one captured the test user interaction with the MD and the second captured their actual viewpoint. A third camera was carried by the researcher, capturing the interaction of the test users with the environment from a distance of (20 to 20 meters) and sending this image to the user's video recorder (figure5-1). In addition to these inputs, a real-time screen capture of the MD display was provided through its integrated composite-type video receiver. All the four video signals together with the audio communication were recorded in the 2 channel hardisk-based mobile video/audio recorder/quad processor, which has enough storage space for many hours of continuous recording. The merits of using a 2 channel system is its comparatively higher quality of video per channel and synchronization between the video/audio channels and date/time stamping. The researcher could observe all the recorded video signals and simultaneously in a quad view (four images in one screen) on the TFT video colour display that he carried through a pair of video transmitter/receivers connected to the MD and the display. These synchronized recordings are the main research materials the researcher could view at the office for analysis purposes.

Figure 5-1. Parts of the research materials showing how a user is interacting with the prototype and the environment using the MD. From top left, User's Hand showing his interaction with the MD; Top right, the Environment user is navigating; Bottom left, the Prototype, Bottom right showing the interaction of the test Users with the environment and MD.

5.3. Test environment

The selection of the proper environment and equipment in a usability testing is an important factor that influences the possibility to collect the optimal possible amount of relevant data. There is also a relationship with the selection of correct methods and techniques for the test and the type of the product under investigation (Delikostidis, 2007; Delikostidis and van Elzakker, 2009a; Delikostidis and van Elzakker, 2009b; Dumas and Redish, 1999; Razeghi, 2010; van Elzakker et al., 2008). Usually the test environment in a usability evaluation is selected such that it is similar to the actual environment in which end users are going to use the product. There are important parameters of selecting an environment. These are test equipment to be used, the type of targeted end users, the stage of the product to be tested and the purpose of the test (Razeghi, 2010).

Enschede was selected as the case study area with a predefined route in order to investigate the usability of the developed prototype regarding the type of landmark visualization categories (figure 5-2). Referring to the previous study of Rezeghi, the case study area with the predefined route found to contain prominent landmarks. The earlier user study worked on identifying the prominent landmarks along the predefined route. Hence this research has saved time, instead of starting the work from the beginning; it has just proceeded where the earlier research ended. The aim was to investigate the landmark visualizations implemented interactively at the prototype, to explore the successfulness of these visualizations during orientation and navigation of test users from beginning to the end of the route. (Razeghi, 2010). Other details can be found in section 3.4.2.

An Enschede Google map has been used as a base map for the prototype interface. Buildings as landmarks along the specified route in central area of Enschede have been presented as Geometric symbols, Pictorial symbols and Photographs. Section 2.6.1 and section 4.2 explain clearly how these landmarks were obtained.

Figure 5-2. The study area with a predefined route (about 1km) (Razeghi, 2010)

The purpose of this study is to test if the developed prototype is usable, hence users will navigate along a predefined route from the beginning to the end, using a mobile application. There are dynamic parameters that can influence the output; these should be kept in mind with reasonable limits. In order to fulfil this, a descriptive definition of the testing environment should be made to limit the level of ambiguity that can influence the validity of the results. The testing was performed in an environment which satisfied the following parameters (Delikostidis, 2007).

i. Light: the test was done during the daytime by using the PDA's display light
ii. Period: The testing was executed between 9:00am and 16:30pm. The maximum practically possible number of user test sessions per day was found to be three, limited by the study area characteristics since some of the area contain cafes, which is not good to pass at the evening.

iii. Place: All test users performed their tasks in the central area of Enschede
iv. Weather: The test was done during sunny or cloudy days, with no rain or snow, and with a temperature above -2^{0C}. Weather was monitored through online forecasts and respondents were informed of weather changes. The results of user tests confirmed this.

To reflect these parameters during test session, a defined context of use has to be followed by considering the fact that the electronic devices used for the testing especially MD and video recorder are very sensitive to water and bad climate conditions.

5.4. Test users

Nielsen (1993) stated that the number of test users to be involved in qualitative research could be five. In UCD the number of test users can be different, depending on the stage and techniques used and the desired outcome (quantitative or qualitative). Normally, the number of test users in requirement analysis is smaller than the number of test users required in usability evaluation. This is because the testing done in requirement analysis is more often qualitative, while usability evaluations may also require quantitative results. The used test users were ITC students having different knowledge about landmark visualization on M2, paper maps, digital maps, GPS, navigation, use of smartphones, use of Google Maps on PDAs and orientation and navigation techniques, as it is stated that test users should be as representative as possible of the intended users of the developed prototype (Nielsen, 1993). The intended users of this prototype are normal pedestrian/tourist who wants to visit the central area of Enschede. Due to the characteristics of the used test users, they are not representative because due to the demographic information obtained through pre-test questionnaire (appendix B), more than average had geographic and map skills. But it was not possible to recruit other test users so quickly. With the field-based methodology the interaction of these test users with the developed prototype in the real context of use was investigated.

In the end, 12 test users within an age range of 20 to 40 years old were chosen. This large number ensured reliability of the data, as it is indicated that when designing usability evaluations, we should have enough user samples (Rosenbaum, 2002). Also time and resources which were available for this research have been taken into important. Likewise according to Nielsen(1993), the chosen number of test users is enough for the qualitative research. The test users were recruited as volunteers from the MSc students of the Faculty of Geo-information and Earth Observation (ITC), University of Twente, under the assumption that they may have more knowledge about geographic and maps skills and the fact that they are not very familiar with the study area because they are not originating from the Netherlands. These students were part of the actual intended users of the prototype and they were available, could be contacted easily and fast, and they easily formed the homogenous group for executing the test. These homogenous groups were needed to avoid biasness of the user test results since these groups were divided based on time availability (in hurry, ample time). The test users were attracted to participate in this experiment due to the developed system and test area characteristics. Among the incentives for the test users to participate was that they are considered to be potential users of the developed prototype. It is a new technology to the majority of them and so they would like to test it and make contributions. In addition, the case study area was only 250 meters away from the ITC.

The test users were invited through an invitation letter sent to 2009 MSc students, asking for their willingness to participate in the research (appendix B). The test users were allocated to two homogeneous groups, each with six members. Members of the first group were told they should behave as pedestrian users who are in a hurry, whereas the members of the second group should act as a tourist who navigates with ample time. The shaded area (gray colour) with tick in table 5-1 shows the time characteristics assigned to test users. The aim here was to find out whether the availability of time would influence the selection of landmark visualizations (appendix D). Test users were identified via codes User1, User2, User3 to User12 to indicate their position in the group for reasons of confidentiality. Any test user's demographic information and their actions during the test were kept confidential and they may only be exposed using the codes. The numbers of slashes from one to four determine the knowledge /experience level in different areas of expertise and their representation is none = No, poor = /, fair = //, good = /// and excellent = //// (table 5-2). This information was obtained by using the pre-test questionnaire (appendix C).

Test users	Time		Familiarity	
	In hurry	Ample time	Less Familiar	More Familiar
User1		✓	✓	
User2	✓			✓
User3	✓			✓
User4		✓	✓	
User5		✓		✓
User6		✓	✓	
User7	✓		✓	
User8		✓	✓	
User9		✓		✓
User10	✓			✓
User11	✓			✓
User12	✓		✓	

Table 5-1. Users' contexts "familiarity and time availability" used to form groups before navigation

Test users	Paper maps	Digital maps	GPS	Navigation	Smartphones	Google maps on PDA
User1	////	////	//	//	//	//
User2	///	///	///	/	/	/
User3	//	//	//	/	///	//
User4	////	///	//	/	///	//
User5	//	//	/	No	///	No
User6	///	///	///	/	/	/
User7	//	//	///	//	////	///
User8	///	///	//	//	No	No
User9	///	///	///	///	///	///
User10	////	////	/	//	//	/
User11	///	///	No	No	//	//
User12	///	///	///	//	//	/

Table 5-2. Test users' geospatial technology information

5.5. The user test procedures

In general, the basic rule for designing test tasks is that they should be selected to be as representative of the uses to which the application will finally be put in the field. Test tasks need to be representative of typical tasks conducted with the designed prototype. They can be designed based on a product identity statement listing the intended uses for the product. The tasks need to be small enough to be completed within the time limits of the user test, but they should not be so small that they become insignificant. The test tasks should specify what result the test user is being asked to produce since the process of using a new prototype to achieve an objective is considerably different from just using a prototype a user is familiar with. The test task should be given to the users in writing to allow them to refer to the task description during the experiment instead of having to remember all the details of the task. Also the tasks should be understandable in the user's language and related to the user's context (Nielsen, 1993).

A pre-defined task based scenario was prepared in which users were participating, so as to meet the research goals. In this scenario, the test users represented a normal pedestrian/tourist, who has limited or ample time during navigation and who was less or more familiar to the central area of Enschede and who wanted to follow a specific route. S/he was expecting to use a mobile geo-application running on his/her MD for navigating the route from the beginning to the end.

The following is a stepwise description of the test procedure: The execution of test took place from 23rd to 30th of January 2011, in the central area of Enschede, one kilometre of distance from ITC as it is already mentioned. The total numbers of the test users were 13 including 12 persons for the actual tests and one pilot user. The pilot testing was done on 20th of January to test the prototype if is working well and the equipment to be used during the test. More about pilot testing is explained in section 5.6.

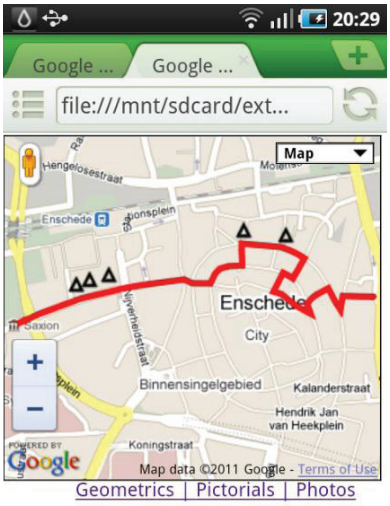
At the agreed day and time the researcher and the test users met at the ITC. Test users were first asked to complete the pre-test questionnaire (appendix C), to gather data on demographics and their background experience regarding maps, mobile navigation systems and preferences. Then a brief introduction to the study area, the newly designed prototype and the testing equipment used was provided. Furthermore, the task to be executed during the test was discussed with the help of printed screenshots of the newly designed prototype (figure 5-3).

Figure 5-3. Getting overview of the prototype based on printed screenshots before the test.

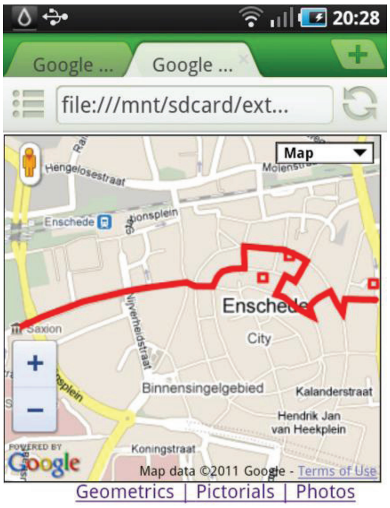
Figure 5-4. Reading the task before navigating

It was assumed beforehand that the 12 test users were either less or more familiar to the case study area. The respondents were tested on their familiarity in order to find out whether the familiarity level would influence the selection of landmark visualizations for navigation. Since the route was predefined, the test user was shown the route on the printed screenshots "This is the route you are going to follow. Try to get an overview of the route" (figure 5-3). Then, after this familiarization with the route, information about familiarity level was gathered through a pre-test semi-structured interview (appendix D). The interview helped the researcher to have planned information of the test users based on the following: the time characteristic pre-assigned to each the familiarity level (table 5-1), and the type of landmark visualization selected before navigation and as results to know test users preferences regarding category of landmark visualization during navigation (table 5-4). The test user was reminded about the familiarity level he choose through pre-test semi-structured interview (appendix D) by researcher, to make sure that this information is clear to him/her. Also training was given to each test user about the equipment to be used before the execution of their tasks. All these processes were done at ITC.

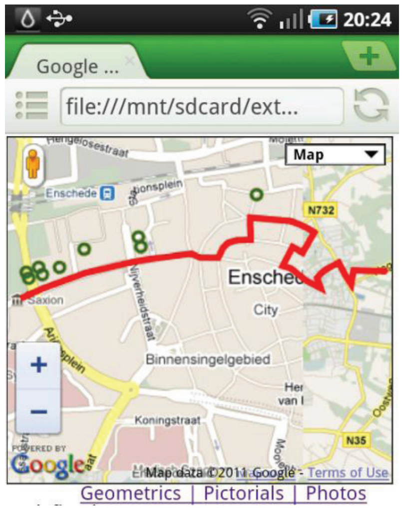
Then the researcher and the test users dressed up all the necessary equipment/devices and went to the testing environment, ready for navigation. Users were given the test task scenario to read, so as to understand the objective of the user test and to enable them to refer to the task description during the experiment (appendix E) and (figure 5-4). Then, at the starting-point of the route, the test users were asked to perform an individual orientation to know exactly which route/direction to take before task execution.



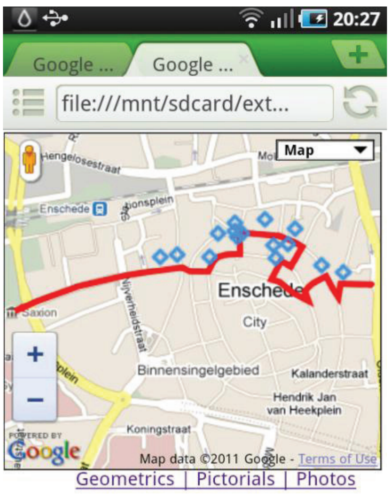
(a) Banks



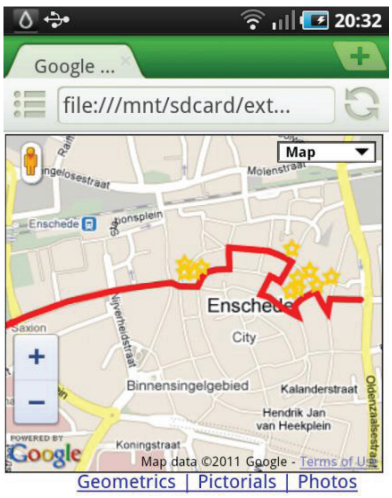
(b) Churches



(c) Others



(d) Restaurants



(e) Shops

Figure 5-5. Details of Geometric symbols

The researcher recorded the time of the following navigation aspects: starting of the route, when specific confirmation of particular landmark visualization is done, for all types of landmark visualizations categories (Geometrics, Pictorials and Photo). For Geometric symbols, there was extra elaborate information printed in a screenshot given to all test users about the category of the landmarks, which helped them to know the meaning of each symbol used (figure 5-5). For Pictorial symbols and Photos, there was no elaborate information since they tell themselves the meaning. Also during navigation test users were allowed to change the visualization types interactively at their convenience and these processes were observed by the researcher. During navigation the researcher walked all the time at a reasonable distance behind the test user in a distance of 10 to 20 meters, to avoid disturbance and to provide support in the case that the test user misses the correct path and makes mistakes in following the predefined route. The researcher also noted different reactions from each user about new insights related to the whole process of navigation.

At the destination point, the researcher recorded the total time used and turned off the test equipment. After that a post-test semi-structured interview was carried out to gather extra information from the test users regarding their experiences with the test (table5-4 and appendix F) before walking back to ITC. Therefore, new ideas and problems encountered were gathered. These allowed a better analysis of the results to measure the usability of the developed prototype based on the efficiency, effectiveness and satisfaction by the user.

5.6. Pilot test

To estimate the time needed for performing all activities during usability testing, a pilot test was executed with one of the supervisors in the same manner as the actual test to reveal any actual test problems, especially in the test scenario, such as the pre-test questionnaire session, introduction to the test, getting overview of the prototype, performance of the pre-test semi structured interviews, etc. (Dumas and Redish, 1999).This helped to reveal and solve problems related with the methodology used and the research activities as a whole to enable the real usability testing to be done without problems. The length of the route to be navigated was approximately 1,000 metres with a navigation time of at maximum 40 minutes. The pilot test revealed a problem with the microphone and was corrected thereafter. It also helped to allocate time limits for completing each activity to be done during the usability evaluation (table 5-3).

No	Activities performed during testing	Time needed
1	Pre-test questionnaire session	3
2	Test users are introduced to the task, the prototype and the testing equipment	4
3	Test users are getting overview to the route	3
4	Execution of the pre-test semi-structured interview	4
5	Preparation of testing equipment	4
6	Walking to the testing area	10
7	Test user is given the test scenario in a printed paper to get clear overview of the task to be performed	4
8	Execution of tasks	40
9	Unplugging the test equipment	4
10	Execution of the post-test semi-structured interview	4
11	Walking back	20
		100 Minutes

Table 5-3. Estimated time needed for each part of the test

5.7. Prototype testing results

5.7.1. User test execution

According to the test user's answers during the post-test semi-structured interview (appendix F), they were generally very satisfied with the whole setting of the field-based experiment and they found the research objective very remarkable and the methods and techniques used very encouraging. Due to weather constraints and battery charging problems, some of the test users had to be re-scheduled for testing sessions.

Regarding the landmark visualization categories implemented to the prototype, users were very satisfied with the dynamic way of visualizing the landmarks. Users were able to select the landmarks interactively according to their preferences. Before starting the task, users were able to orientate themselves on the basis of the landmarks and the predefined route provided. During navigation, users were able to change the type of landmark visualizations interactively and also they were able to confirm their current location. All users were able to navigate the route from the beginning to the end without problem, although some of them got lost on the way, and researcher had to help them by indicating the right direction.

Concerning the methods and techniques used for the tests, the test users' response on the field-based techniques, especially the TA, the observation and the semi-structured interview, was very positive. Some of the test users were very active to talk, and express each kind of activity done almost continuously without any necessary prompting by the researcher; while some test users had to be reminded through questions in order to express their thoughts as they were executing the task. Generally, the prototype tested was very much appreciated by users. During the post-test semi-structured interview they reported that it was very good as they were able to compare landmarks seen on the M2 with the ones seen in the reality, which helps them to avoid getting lost and reach their destinations fast. Some of test users (user1, user2, user7, user8 and user12) said this technology is very good and should be applied globally. User7 said that it was good for the researcher to see how pedestrians react in the field. If there were problems users faced during navigation, they could be fixed simply. User5 said that the methodology used was very good because each aspect of navigation was taken into account. Another test user indicated that it was good to walk in the field to see if the prototype was working well. User8 said that with this methodology you get a real feel of the prototype from test users during task execution. Users insisted that it was quite helpful and practical as the researcher was able to get direct feedbacks and insights from the test users through the thinking aloud and observation methodology, which could be used to modify the prototype later on or as recommendations for further studies.

5.7.2. Environmental issues

The environmental parameters were discussed in section 5.3. These conditions contributed to the scheduling and execution of the tests. Unpredictable weather in the Netherlands, a lot of rain and low temperatures during the winter season, led to delays in the usability evaluation. After finishing each test at the end point, the researcher had to walk back to ITC to meet the next test user. However, this maximum number of three users per day appeared to be comfortable, as it allowed for downloading of user data, charging the batteries and thoroughly checking of the functionality before each session. Low temperatures during some testing days posed some problems, although the users could still work with bare hands, except User9 whose hands could not tolerate a temperature below zero and he had to execute the test while wearing gloves during the last part of the route and making some stops to use the zoom and pan functionality (figure 5-6).

Figure 5-6. Test user wearing gloves on both hands due to outside temperature

Another problem that was faced during the usability evaluation was the disturbance from social environmental users to the researcher and test users. There were about four cases from local people who wanted to know the actual subject of the test and why we had to carry all these electronic devices. There was one test user who wanted to know if the task was related with Google Maps. Such two instances can be seen in figure 5-7, as recorded from the field observation system, where some of residences were asking the test user about the research and the researcher/test user explained it to him. Some of the local residents were very friendly and were just asking a few questions, while others were more curious and even doubtful sometimes and the researcher had to totally stop the experiment for some minutes in order to give them general facts about the experiment. The duration of particular tasks was influenced in such cases, and the researcher had to take notes for such time delays due to such disturbances, in order to correct the measured time for the completion of the task. These time delays were later confirmed and corrected through the analysis of the video and audio recordings.

Figure 5-7. Explaining the aim of the experiment to local residents

5.7.3. System and prototype issues

The methodology used offered reliability; simplicity and performance i.e. complete information about the cognitive processes of the subjects during task execution. The researcher was able to investigate the ways test users navigate and orientate with the help of the interactive landmark visualizations on the M2 of the developed prototype along a given predefined route in central area of Enschede. The video recordings and recorder allowed a thorough and verifiable analysis of the research outcomes and with direct observation the researcher was able to get an immediate impression of the problems during task execution. The researcher was also able to deal with problems which occurred during the testing. The TA session brought good results due to a good connection of audio signals of both researcher and test user. Although there was high environmental noise, during the analysis everything could be heard clearly.

The system was faced by a battery power break because it was used beyond its capacity and hence, an electronic boost was required. The electronic boost still did not help because the battery could not be recharged to its maximum capacity and therefore, the device could not be used for the complete task. Finally it was replaced with a new battery by the electronics expert (research technical advisor). This problem caused that the User5 data were not recorded. Another problem encountered during the task execution was that in one case the video recording suddenly stopped due to a power problem. There was a defect with a power cable and, as a result, the User7 data were not recorded. The expert cleared the defect again. These two problems caused the researcher to use 14 test users instead of 12 in order to replace the two data which were not recorded. The information of User5 and User7 test users were left out, and replaced by new test users information, hence information of test users which are included in table 5-1 and table 5-2 contains complete information of 12 test users.

The developed prototype was running well because the MD was connected to the Vodaphone internet service provider. The availability of 3G wireless technologies available on the Android mobile phone used in the research made the prototype run smoothly.

The problem with the prototype was the slow loading speed especially during the changing of landmark visualizations from one category to another and during confirmation. These problems are dependent on characteristics of MDs and the methodology used to implement the prototype. During these operations test users had to be patient and wait for the loading of the prototype. This problem happened most with Photo landmark visualizations. These are the problems which can be resolved by emerging of multifunctional PDAs and smartphones with improved capacity to process and execute commands and internet access speed as time goes (section 2.5.1).

5.7.4. Usability- Analysis of research material

This usability evaluation was aiming at checking whether the designed prototype is working well by using three measures of usability: efficiency, effectiveness and satisfaction. These measures were related to two user contexts: time availability and familiarity levels. The aim was to find out whether these contexts are of influence when selecting categories of landmark visualizations for navigation. The answers given in the synchronized recordings and research materials were used to this end.

The analysis of the research materials such as recordings, observation and TA was analysed based on the researcher notes written during and after task execution of each test user. The notes were taken in an organized way, for easier analysis later. Other research information from questionnaire was analysed based on the paper which test users filled before task execution, while pre/post semi-structured interview information was analysed from the recorder and from notes taken by researcher when the test user was answering the questions.

Efficiency and Effectiveness

The main research questions of this research is directed towards adjustable visualization of landmarks, hence efficiency and effectiveness of the different ways of visualization is very important.

Efficiency was measured by considering the time or effort used by test users to interact with the landmark visualizations implemented into the prototype during navigation. This was measured based on the task completion from the beginning to the end. A maximum time needed for completing the task was set to 40 minutes, based on the outcome of the pilot test. But the research wanted to verify if that time was enough for every test user. Also, the research wanted to investigate and note effects of time on test users in navigation depending on their context (time availability and familiarity levels).

Group	Test users	Familiarity	Visualization used	Time taken 40 min limit	Confidence rate	Satisfaction
Group1 (In hurry)	User2	More familiar	Geometrics and Photos	20	4	5
	User3	More familiar	Pictorials	28	3	4
	User7	Less familiar	Geometrics and Photos	38	3	4
	User10	More familiar	Pictorial and Photos	22	4	5
	User11	More familiar	Pictorial and Photos	21	3	5
	User12	Less familiar	Geometrics, Pictorials and Photos	24	4	5
Group2 (Ample time)	User1	Less familiar	Geometrics, Pictorials and Photos	29	4	5
	User4	Less familiar	Geometrics	34	4	5
	User5	More familiar	Geometrics, Pictorials and Photos	30	4	5
	User6	Less familiar	Geometrics, Pictorials and Photos	25	5	4
	User8	Less familiar	Pictorial and Photos	47	4	5
	User9	More familiar	Photos	37	5	5

Table 5-4. Group1 and Group2 information obtained during task execution for the user context "time availability"

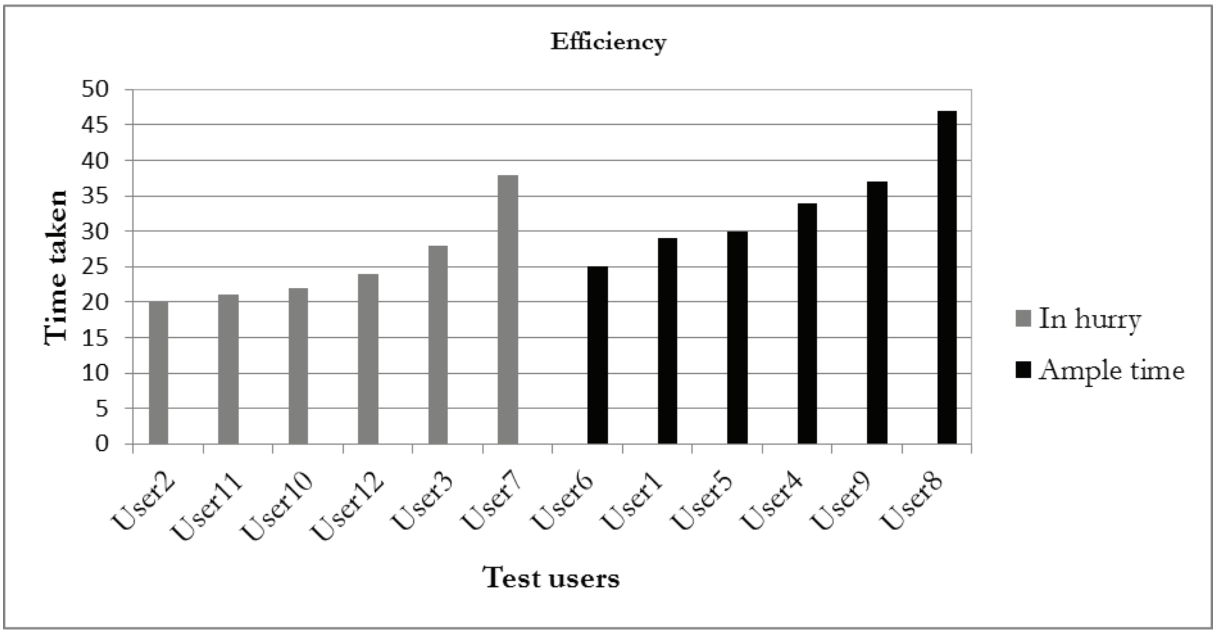


Figure 5-8. Eficiency based on time taken for the user context "time availability" (Group1 and Group2)

The analysis of the performance of Group1 (in a hurry) and Group2 (ample time) test users, depicted a significant difference in the time used during navigation (table 5-4 and figure 5-8). Test users who were assigned to navigate with the 'in a hurry' time characteristics used less time compared to Group2 users who navigated with the ample time characteristics. The lowest time used to navigate the route from the beginning to the end was 20minutes(50%) of the normal time to navigate from the beginning to the end (user2) while the highest time used was 38minutes(95%) of the normal time to navigate from the beginning to the end (user7).Other test users within Group1 used: 21minutes(53%), 22minutes(55%), 24minutes(60%) and 28 minutes(70%).It was discovered that the 'in a hurry' characteristic assigned to test users influenced the time they used for their navigation. These test users were observed from the video recordings and other research materials and it was found that they used fewer numbers of confirmations i.e. they click few time on a particular landmark to get detail information during navigation. Also it was observed that these test users, didn't pay attention to the environment the same as the test users who were assigned to navigate with an ample time. Observing deeply the background characteristics of both two test users, it was realized that user2 has fair characteristics in navigation, smartphone and Google Maps on PDA, while user7 has fair, excellent and good characteristics in navigation, smartphones and Google Maps on PDA (table 5-4). When familiarity levels were compared between these two test users it was found that both were less familiar with the area and they used the same visualizations (Geometric and Photos). When their ages were analysed, it was found that both are between 25 to 30 years old. User2 background is from Civil Engineering and has the ability to read and interpret maps, as he normally deals with topographic maps and user7 is from Information Technology (IT) and lacks the ability to read and interpret maps, hence this factor explains the time difference. Although all these test users were from a homogeneous group (the Geoinformatics course), still there were considerable differences noted in their navigation time.

Group2 users who were given the characteristic of navigating with an ample time indeed used more time than those in hurry. The lowest time used by a test user was 25minutes(63%) of the normal time to navigate from the beginning to the end (user6) while the highest time used was 47 minutes(118%) of the normal time to navigate from the beginning to the end (user8). This maximum time exceeded the time limit set to perform the test. Other test users within Group2 used: 29minutes(73%), 30minutes(75%), 34minutes(85%) and 37minutes(93%).The recorded video, TA information and observations show that these users looked a lot for confirmation during navigation and also they paid a lot of attention to the environment. Also, the researcher observed that the more confirmation a user sought for delayed the navigation compared to users who only looked for confirmation at the junctions. "This difference is also because of background information related to the use of smartphones, Google Maps and navigation on PDA. Numbers of confirmations one made depended on levels of familiarity with the area", suggested user8. The background information of this user towards navigation was fair (/) and experience with smartphones and Google Maps on PDA was nil (table 5-4). The overall comparison between Group1 and Group2, Group1 used 26 minutes (64%) while Group2 used 34minute (84%).

Group	Test users	Time availability	Visualization used	Time taken 40 min limit	Confidence rate	Satisfaction
Group3 (More familiar)	User2	Hurry	Geometrics and Photos	20	4	5
	User3	Hurry	Pictorials	28	3	4
	User10	Hurry	Pictorial and Photos	22	3	4
	User11	Hurry	Pictorial and Photos	21	4	5
	User5	Ample time	Geometrics, Pictorials and Photos	30	3	5
	User9	Ample time	Photos	37	4	5
Group4 (Less familiar)	User7	Hurry	Geometrics and Photos	38	4	5
	User12	Hurry	Geometrics, Pictorials and Photos	24	4	5
	User1	Ample time	Geometrics, Pictorials and Photos	29	4	5
	User4	Ample time	Geometrics	34	5	4
	User6	Ample time	Geometrics, Pictorials and Photos	25	4	5
	User8	Ample time	Pictorial and Photos	47	5	5

Table 5-5. Group3 and Group4 information obtained during task execution for the user context "familiarity levels"

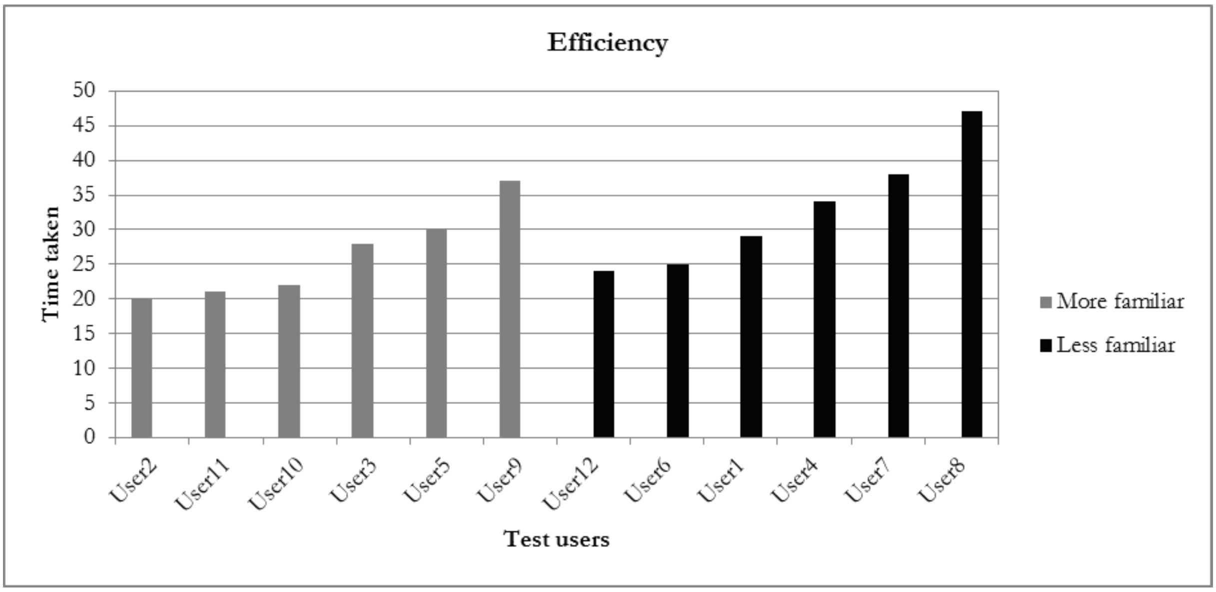


Figure 5-9. Eficiency based on time taken for the user context "familiarity levels" (Group3 and Group4)

The analysis of the familiarity levels between Group3 (more familiar) and Group4 (less familiar) test users also portrayed a significant difference in time used for navigation (table 5-5 and figure 5-9). Test users who said they were more familiar with the study area used less time to navigate compared to Group4 test users who said they were less familiar with the study area. The lowest time used to navigate the route from the beginning to the end was 20minutes(50%) of the normal time to navigate from the beginning to the end (user2) while the highest time used was 37 minutes(93%) of the normal time to navigate from the beginning to the end (user9). Other test users within Group3 used: 21minutes(53%), 22minutes(55%), 28minutes(70%) and 30minutes(75%). What has been discovered with these test users who were more familiar is their behaviour during navigation. They didn't pay attention with the environment, as they know it already. As in the time availability analysis these test users used fewer numbers of confirmations and they walked very fast during task execution. This made them to use less time during navigation. When comparisons are made between user2 and user9 (More familiar group of 6 test users), it can be found that they have a different background in map reading knowledge, mobile navigation experiences, smartphones and Google Maps on PDA. Observing deeply this background information of both two test users, it was recognized that it is not related with the time used frog navigation because user2 has fair characteristics in navigation, smartphones and Google Maps on PDA, while user9 has good characteristics in navigation, smartphones and Google Maps on PDA (table 5-4). When time availability is compared between these two test users it can be found that user2 was assigned to navigate while being "in a hurry", whereas user9 was assigned to navigate with ample time characteristics. User2 used the visualizations Geometric and Photos while user9 used Photos only. When their ages were analysed, it was found that the age of user2 was in between 25 to 30 years old while user9 was between 31 and 40. When their previous experience was analyzed it was found that the user2 background was from Civil Engineering and user9 from Geography, so both have the ability to read and interpret maps. User2 was from the Geoinformatics course, while user9 was from the Land administration course. As mentioned before, user9 was the one who did not tolerate a temperature below 0 degrees Celsius, which led him to use gloves on both hands during navigation in the last part of the route and to make some stops to use the zoom and pan functionality. This factor contributed to the time difference together with the mentioned other factors which differ from user2 and user9. (figure 5-9).

Group4 users who said they were less familiar with the study area used more time during navigation. The lowest time used by a test user was 24 minutes (60%) of the normal time to navigate from the beginning to the end (user12) while the highest used time was 47 minutes (118%) of the normal time to navigate from the beginning to the end (user8). Other test users within Group3 used: 25minutes(63%), 29minutes(73%), 34minutes(85%) and 38minutes(95%).The reasons for user8 to use more time than the limit of 40 minutes have been mentioned already in time availability discussion above. When user12 was asked what made him to navigate with less time compared to other test users within his group, he argued that he has an interest in navigation, and has experience with Real Time Kinematic GPS surveying and is well conversant with GPS and map reading. Also he has done a lot of works which relate to navigation by using paper maps. When his background information was analyzed, it was found that all these characteristics related to his academic and work experiences in Geomatics. All these factors contributed on using less time. In general Group3 test users used less time 20 minutes (50%) of the normal time to navigate from the beginning to the end, compared to Group4 test users who used 24 minutes (60%) of the normal time to navigate from the beginning to the end. The overall average comparison between Group3 and Group4, Group3 used 26 minutes (66%) and Group4 used 33minutes (82%).

With all this information regarding the efficiency of the prototype based on user contexts (time availability and familiarity levels), it can be concluded that users who were assigned to navigate with limited time (in a hurry) and who said that they were more familiar with the study area used less time for navigation compared to test users who were assigned to navigate with ample time and who said that they were less familiar with the study area. This was due to the convincing results obtained from the usability evaluation regarding the efficiency measure which was done to these groups of test users (figure 5-8 and figure 5-9).

Regarding the alternative visualizations of landmarks as this research is concern, the conclusions regarding efficiency in this respect is moderately high since among 12 test users, 11 test users were able to navigate from the beginning to the end of the route within the limited time given for the task and landmark visualizations were used interactively.

The designed prototype was also evaluated based on its effectiveness by considering the successfulness of test users on interaction with the different types of landmark visualizations implemented in the prototype. So the aim here was to check if the designed prototype worked well by producing the intended or expected results and to find out whether the time availability and familiarity levels influence the selection of landmark visualizations. Therefore, the analysis was done to investigate on how test users managed to interact with landmark visualizations interactively based on the total number of test users who used a particular/group of visualizations.

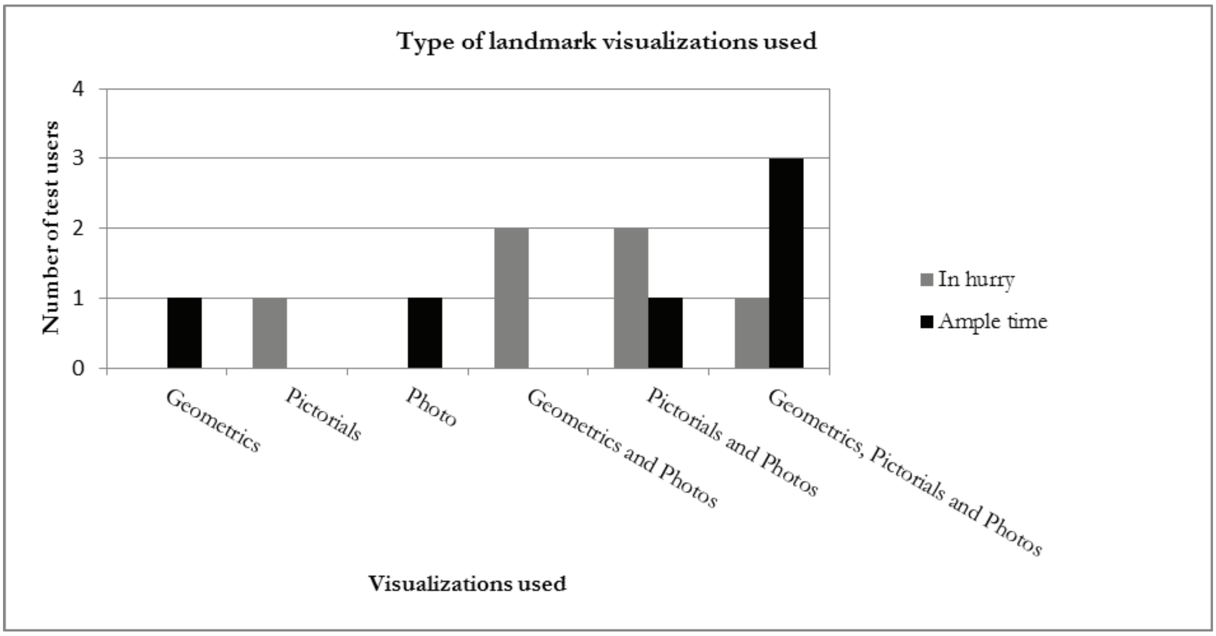


Figure 5-10. Ways of visualization based on number of test users for the user context "time availability" (Group1 and Group2)

Results showed significant difference between Group1 users who were assigned to navigate with limited time (in a hurry) compared to Group2 test users who were assigned to navigate with ample time (table 5-4 and figure 5-10). In Group1 there is only 1 test user (user12) who used all types of visualizations (Geometrics, Pictorials and Photos) compared to Group2 where 3 test users (user6, user1 and user5) used all types of landmark visualizations.

Regarding users who were navigating "in a hurry", 1 test user (17%)(user3) navigates by using pictorials only, 2 test users (33%)(user2 and user7) navigate with Geometric symbols and Photos and 2 test users (33%)(user10 and user11) navigate with Pictorials and Photos. In Group2 test users who were navigating "with ample time" 3 test users (50%)(user1, user5and user6) used all types of landmark visualization, 1 test user (17%)(user8) used Pictorial symbols and Photo interactively, 1 test user (17%) (user9) used Photos and 1 test user (17%) (user4) used Geometric symbols. It can be concluded that Group2 users who were assigned the time characteristics of ample time individually interacted with many types of landmark visualizations compared to Group1 test users. But it is difficult to say the time availability assigned to test users in this research has influenced test users to select a type of landmark visualizations during navigation as this depends on many other factors such as (health, traffic jams, accidents, holidays, road restrictions, night time etc. (see section 2.5.2).

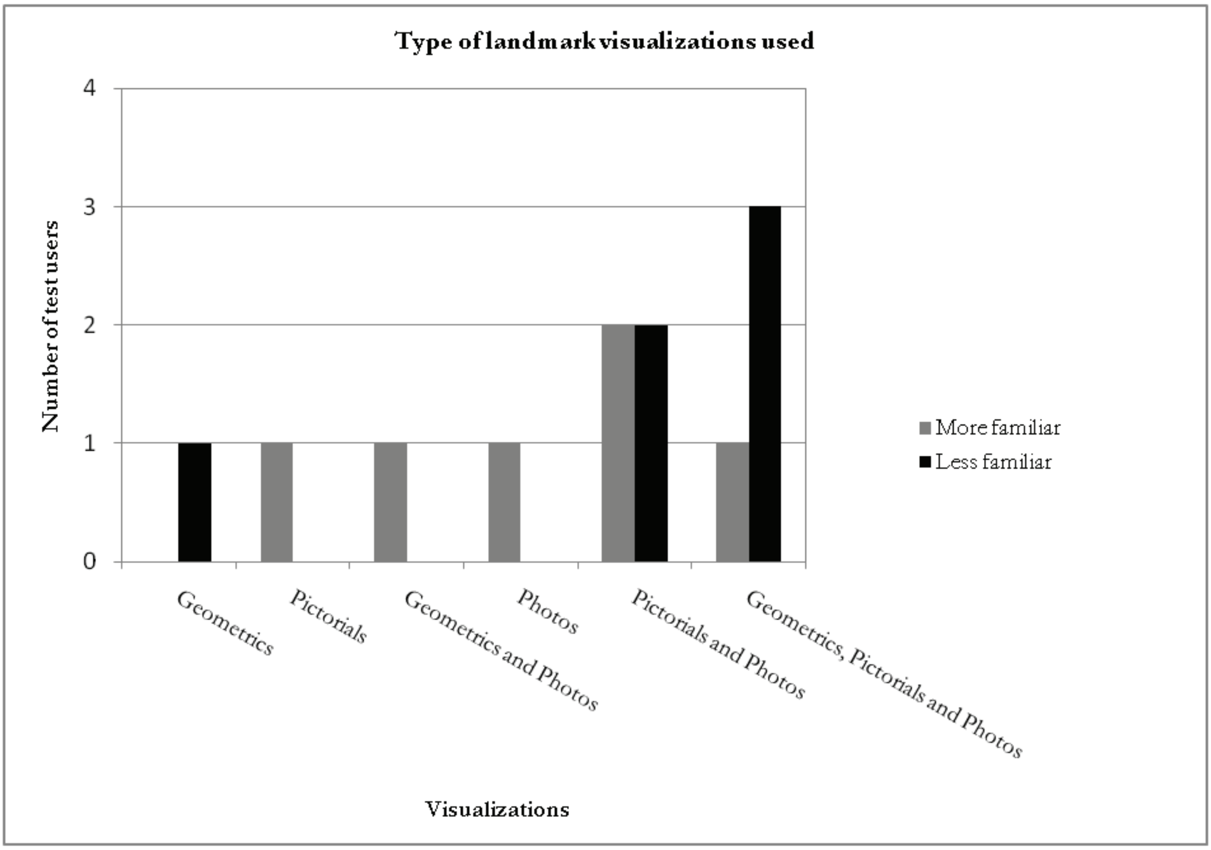


Figure 5-11. Ways of visualization based on number of test users for the user context “familiarity levels” (Group3 and Group4)

When the results were analyzed based on familiarity levels a significant difference was noted between Group3 (users who were less familiar) and Group4 (users who were more familiar) with the study area (table 5-5 and figure 5-11). Referring less familiar users, it was found that 3 test users (50%) (user2, user7 and user12) used all types of landmark visualizations 2 test users (33%) used Pictorial and Photos, 1 test user (17%) (user4) used Geometric symbols. The 3 test users who used all types of visualizations were asked during the interview why they used all these visualizations, user2 and user7 said that they used Photos and Pictorials to get confirmation on junctions to aid geometrics symbols. Geometric symbols are found too general and they could not differentiate objects which were close to each other, for example restaurants and shops. In this case users were using Pictorial symbols and Photos interchangeably. Also, user12 said that, he used both symbolizations as a matter of curiosity, to know exactly the performance of each category during navigation. Considering the test users who were more familiar with the study area 2 test users (33%)(user10 and user11) used Pictorials and Photos interactively, 1 test user (17%)(user3) used Pictorials only from the beginning to the end. 1 test user (17%)(user9) used Photos only, 1 test user (17%)(user2) used Geometrics and Photos interchangeably and 1 test user (17%)(user5) used both types of landmark visualizations. It can be observed that Group4 test users used fewer types of landmark visualizations interactively compared to Group3 test users.

The overall conclusion based on the results from both groups shows good results on the effectiveness of the prototype, since the proposed landmark visualizations were interactively used by test users, although it is difficult to say familiarity affected the way users selected the landmark visualizations because choice might have been influenced by many other factors out of the scope of this research such as health, traffic jams, accidents, holidays, road restrictions, night time etc. (section 2.5.2). This research considered only the user’s familiarity levels and time availability on evaluating the three categories of landmark visualizations implemented in the designed prototype. Rather it was observed that time availability and familiarity levels has influenced test users to interact with many/few types of landmark visualizations (figure 5-10) and (figure 5-11).

Satisfaction

This usability measure refers to the pleasance and acceptability of the prototype to its users. It is the consideration of the overall rate of working with the designed and implemented prototype and its usefulness to address the test users' tasks to be executed. This was measured by the feedbacks received from users with a thorough consideration of the confidence rate with the use of the prototype during navigation regarding different ways of visualizations. The test users were asked to choose a rate of satisfaction/confidence level among 1 to 5 in the semi-structured interview (table5-4) whereby 1=very poor (20%, 2= poor (40%), 3 = normal (60%), 4 = good (80%) and 5 =very good (100%). Rate 1 means test user was not comfortable in operating the prototype and 5 means the test user was very comfortable in operating the prototype.

Figure 5-12. Satisfaction regarding the dynamic of landmark visualizations implemented in the prototype regarding user context "time availability" (Group1 and Group2)

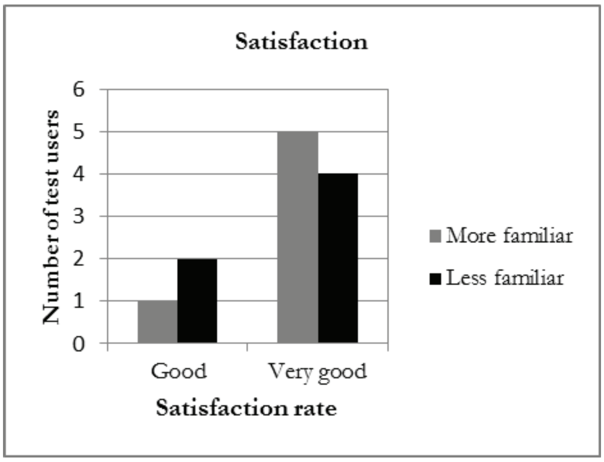


Figure 5-13. Satisfaction regarding the dynamic of landmark visualizations implemented in the prototype regarding user context "familiarity levels" (Group3 and Group4)

Satisfaction regarding the dynamic of landmark visualizations implemented in the prototype.

Generally test users were very satisfied regarding the dynamics of landmark visualizations implemented in the prototype. When Group1 and Group2 were compared based on the satisfaction with the way dynamic landmark visualizations are implemented in the prototype, there was no significant difference as in Group1, 2 users were satisfied with the rate of 4 (good) and 4 users were satisfied with the rate of 5 (very good) in Group2 only 1 test user was satisfied with the rate of 4 (good) and 5 test users were satisfied with the rate of 5 (very good) (figure 5-12). There is also no significant difference between the Group3 users and Group4 users because the Group3 users who navigated with ample time only 1 user was satisfied with the rate of 4 (good) and 5 test users were satisfied with the rate of 5 (very good). In Group4 the results showed that 2 users were satisfied with the rate of 4 (good) and 4 users were satisfied with the rate of 5 (very good) (figure 5-13). It is interesting to observe that, the rate of Group2 (ample time) test users was comparable with the rate of Group3 (more familiar) test users: 1 test user with rate 4 (good) and 5 test users with rate 5 (very good). Also the rates of Group1 (in a hurry) test users and Group4 (less familiar) was comparable. There was no test user who rated his satisfaction rate of 1=very poor, 2= poor, 3 = normal. Results show that the test users were very satisfied with landmark visualizations implemented at the prototype.

Confidence comparison rate for using the prototype.

There were small significant differences in the test users' confidence rate of using the prototype within the two groups of users. Group2 test users who were assigned to navigate with ample time characteristics showed a satisfaction rate from 4 (good) to 5 (very good), with a highest rate number of 4 test users who rated good, and 2 test users who rated very good (figure 5-14). In this group of test users, no one rated his confidence level of using the prototype as normal, while in Group1 users who were assigned to navigate with limited time (in a hurry) characteristics showed a satisfaction rate from 3 (normal) to 4 (good) where 3 test users rated their confidence level as 3 (normal) and 3 test users rated their confidence level as 4 (good). In this group there was no test user who rated his confidence level as very good. It can be concluded that Group2 test users who were assigned to navigate with ample time have higher confidence rate compared to Group1 test users who were assigned to navigate with less time.

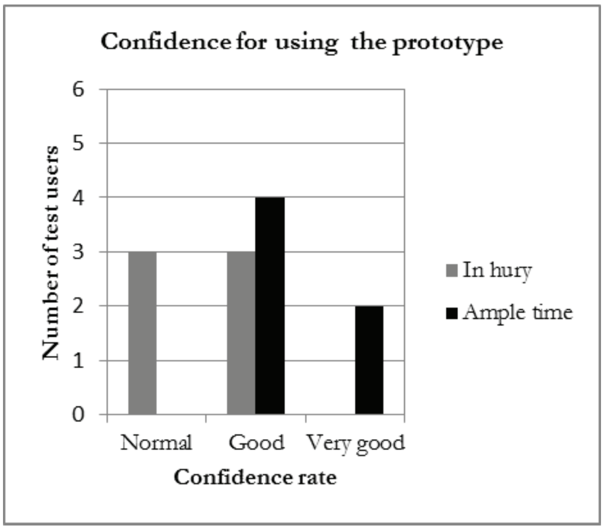


Figure 5-14. Confidence for using the prototype for the user context "time availability" (Group1 and Group2)

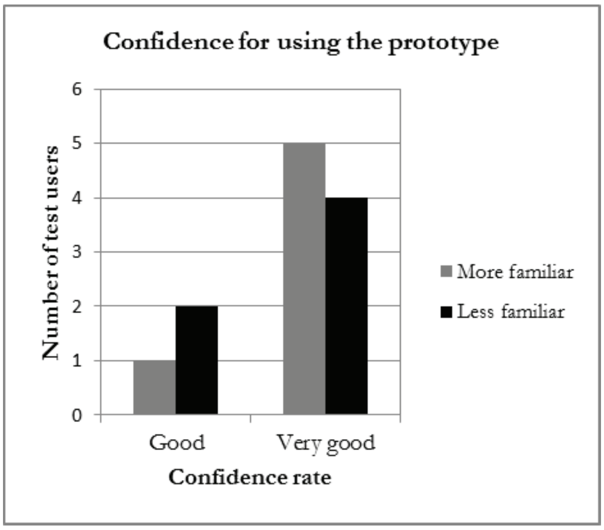


Figure 5-15. Confidence for using the prototype for the user context "familiarity levels" (Group3 and Group4)

There were no significant differences with the test user's confidence rate of using the prototype within the two groups of users distinguished on the basis of different familiarity levels. Group3 test users who said they were more familiar with the study area showed a satisfaction rate from 4 (good) to 5 (very good), with the highest rate number of five test users who rated very good, and one test user who rated good. The Group4 users who said they were less familiar with the study area showed a satisfaction rate from 4 (good) to 5 (very good) with the highest rate number of four test users who rated their confidence level as very good and two test users who rated their confidence level as good. Both groups had no test users who rated their confidence level as normal, poor or very poor. In researcher's opinion it can be concluded that Group3 test users who were more familiar with study area and Group4 who were less familiar with the study area showed no significant difference since the difference is only with one test user. (figure 5-15).

The overall conclusion regarding confidence when comparing user contexts (time availability and familiarity levels) without considering other factors is that users who were assigned to navigate with ample time and users who said they were more familiar with the study area have a higher confidence level, since users who assigned to navigate with ample time had many time to interact with the prototype, hence they had more time to interact with the functionalities implemented in the prototype, more time to compare what was seen in the M2 with what is seen in the reality and also they managed to reach at the destination point without problems as well as test users who were more familiar with the study area, since already the study area was known to them they interacted well with the prototype compared to other users. There was no test user who rated his satisfaction rate of 1=very poor, 2= poor.

The overall testing feedback given during the usability evaluation was very positive, as each test user indicated that it was a very interesting experience to navigate with a MD having the prototype which has been designed and implemented by one of their fellow student. The dynamic of landmark visualization provided was very interesting and useful to test users. They found the overall application very amazing, especially the way in which it was made possible to interactively/dynamically select the type of landmark visualizations to use during navigation. Many of the test users suggested this kind of application to be implemented widely so that pedestrian users can navigate smoothly from one place to another without limitations. Some of test users came from African countries where this kind of pedestrian navigation technology is not used at all, only car navigation systems are available. They suggested this kind of application to be implemented in their home countries as it is a very helpful application for navigation. Some of the test users suggested a pointer to be included on the application so that they can understand exactly their current position. But the researcher explained that the purpose of the test was to see if the landmark visualizations can be used as a guide to help users during navigation and also to understand test users preferences on landmark visualizations implemented at the prototype, therefore, there was no need to include the pointer in the application as there was a fixed route. Another user comment about the application was that it was very good the way it has been implemented as the visualizations provided with the predefined route were very helpful during navigation. However, the test users indicated that if many landmarks were included, the user might get confused during navigation.

Confirmation during orientation and navigation is the objective of a user, and can in principle, be obtained through photographic, pictorial or geometric symbols. Considering the observation of researcher, TA information and recorded video data, the results showed that, test users prefer most, Photos and Pictorial symbol for confirmation. This was done mainly by test users at the junction points where they don't know which way to take and also when they wanted to compare the landmark which was in the M2 and reality.

Also the prototype contains the confirmation function (appears in the content window when test users want to view details of a particular landmark) which was implemented in the prototype: The prototype implemented in such a way that, there is a possibility of retrieving the photo representing, each type of landmarks implemented. Every test user was able to use it, especially during navigation at junctions where users were not sure which way to take. Some test users said that sometimes when they were navigating by using Geometrics or Pictorials, it was difficult to differentiate between restaurants, as in some areas of the route the restaurants were very close to each other. So, they used this functionality to confirm these restaurants in order to differentiate between them. Another test user said that a photo of the landmark plus additional information was very useful, as you get to verify that you are at the correct path/route by using the confirmation function. The potentiality of this function was very high during navigation. It was observed by the researcher that confirmation was done by test users even when Photo was used as landmark visualizations (figure 5-6 and figure 5-16).

About the drop down menus which were implemented in the prototype: it was observed during task execution that it was very useful as test users were able to filter out the specific type of landmark visualizations to be used. Therefore the display overload was reduced in this way. In each button/control, there were drop down lists i.e. Banks, Churches, Others, Restaurants and Shops, to help users to have a possibility of visualizing only one particular type of landmarks at a time (e.g. churches) (figure 4-4-a). Test users were using the drop down menu especially when they wanted to confirm a particular location/destination. For example it was discovered that during navigation test users used this functionality to confirm the final destination which was a church. So they used the drop down menu to see only the list of available churches, to verify the last church (figure 5-17).

About the zooming functionality: some test users argued that it was very slow, especially when Photo visualizations were used. For those test users who used Photo during navigation, the researcher asked them to be patient during the zooming process as it may take a long time compared to the other visualizations.

Figure 5-16. Test user confirming the landmark before taking the junction

Figure 5-17. Test user confirming the final destination

5.7.5. Which types of landmark visualizations do users prefer for which purposes?

The aim of this section is to investigate the answers given in the research materials related to route planning and navigation. The aim is to come out with conclusions showing which categories of landmark visualizations were preferred by test users for which purposes and in which situations regarding the dynamic landmark visualizations implemented in the prototype during route planning and navigation.

Test users' landmark preferences, if they would have to plan the route themselves

Results from the pre-semi-structured interview showed a small significant difference when comparing two groups of users distinguished on the basis of time availability (figure 5-18). Comparing Group1 and Group2 test users it was found out that 4 test users who were assigned to navigate with limited time (in a hurry) and 3 test users who were assigned to navigate with ample time preferred to use Pictorial symbols compared to other test users (figure5-18).

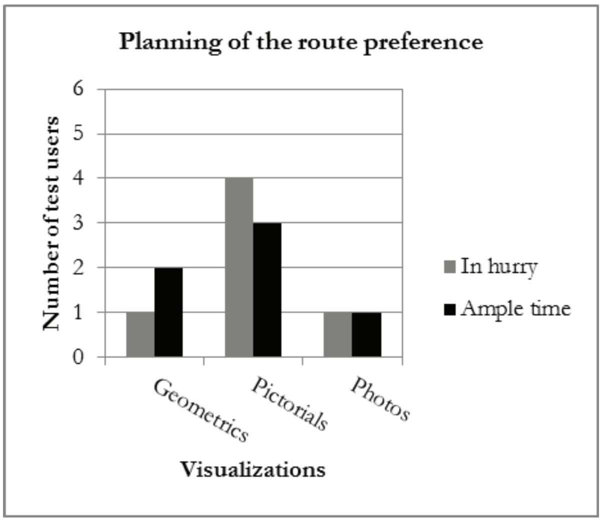


Figure 5-18. Landmark visualization preference for route planning based on user context "time availability" (Group1 and Group2)

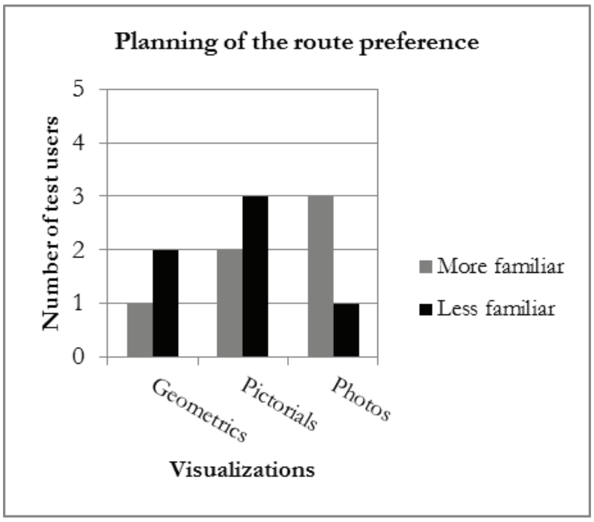


Figure 5-19. Landmark visualization preference for route planning based on user context "familiarity levels" (Group3 and Group4)

Also based on familiarity levels (figure 5-19), a large significant difference was found when comparing the results from the semi-structured interview. Comparing Group3 and Group4 test users it was found out that three test users who said they were familiar with the study area preferred to use Photos while three test users who said they were less familiar with the study area used Pictorial symbols (figure 5-19). This concludes with what has been said in the literature already about Photos and Pictorial symbols, that they are very useful for confirmation (see section 2.4.4).

The overall summary with respect to the preferences of the test users, regarding both time availability and familiarity levels (12 test users), when they want to plan the route themselves (figure 5-22), showed 5 (42%) test users preferred to use Pictorial symbols, 4 (33%) test users preferred to use Photos and 3 (25%) test users of preferred to use Geometric symbols.

Test users' landmark visualization preferences for over viewing the route to be followed

Results show a large significant difference between Group1 and Group2 test users (figure 5-20). All 6 test users (100%) who were assigned to navigate with ample time prefered to use Geometric symbols compared to other types of landmark visualizations. When these users were asked why they prefer this type for getting an overview of the route, they argued that this type of visualization does not overlap the route, so that they were able to see the whole route without limitations. This is due to the small size of the landmark symbols which occupy a small space on the M2. Test users who were assigned to navigate with limited time (in a hurry), 3 test users (50%) prefered to use Pictorial symbols, as it is clear to relate the landmark symbol with what is seen in the reality, and it is fast during visualization compared to photos. Section 2.4.2 explain in details about the merits and demerits of landmark visualizations.

Regarding the familiarity levels, results showed a large significant difference between Group3 and Group4 test users (figure 5-21). 5 test users (83%) who were less familiar with the study area preferred to use Geometric symbols compared to other types of landmark symbols, while 3 test users (50%) who were more familiar with the study area prefer to use Pictorial symbols (see section 2.4.2).

Preferences summary of getting an overview of the route(figure 5-23) based on both time availability and familiarity levels (12 test users), results showed that 7 test users (58%) preferred to use Geometric symbols, 3 test users (25%) preferred to use Pictorial symbols and 2 test users (17%) preferred to use Photos. This analysis has proved what has been discussed in literature already about Geometric symbols by showing large percentage of test users preference (see section 2.4.1 table 2-3 and figure 5-21).

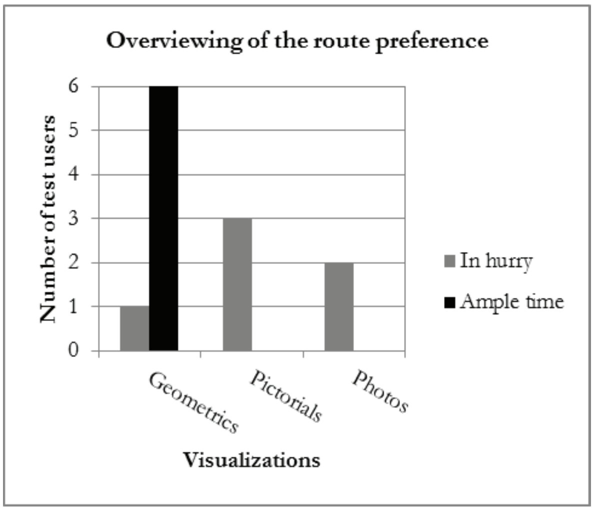


Figure 5-20. Landmark visualization preference on overviewing of the route based on user context "time availability" (Group1 and Group2)

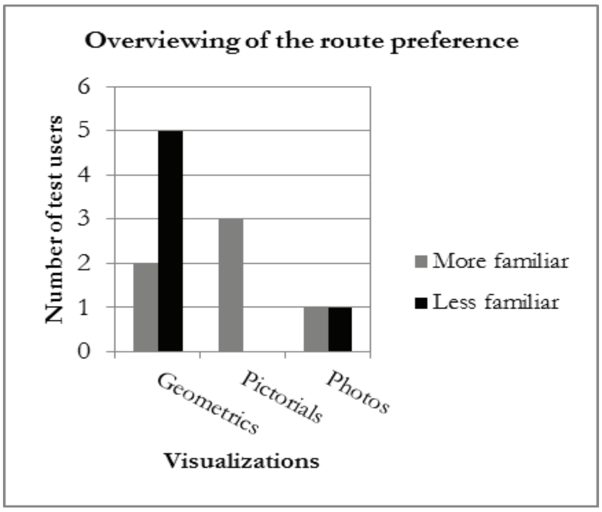


Figure 5-21. Landmark visualization preference on overviewing of the route based on user context "familiarity levels" (Group1 and Group2)

What type of landmark visualizations do users prefer to use during navigation.

During navigation (figure 5-24) based on both time availability and familiarity levels (12 test users), the analysis showed that 4 test users (33%) prefer to use all types of landmark visualization interactively (Geometrics, Pictorials and Photos), 3 test users (25%) preferred to use Pictorial symbols and Photos interactively, 2 test users (17%) preferred to use Geometrics and Photos interactively, 1 test user (8%) preferred to photos only, 1 test user (8%) preferred to use Pictorial symbols only, and 1 test user (8%) preferred to use Geometrics only (figure 5-24). The test users used Pictorial and Photos especially for confirmation and also other reason are as discussed before in this chapter.

Summary for all preferences based on time availability and familiarity levels (12 test users)

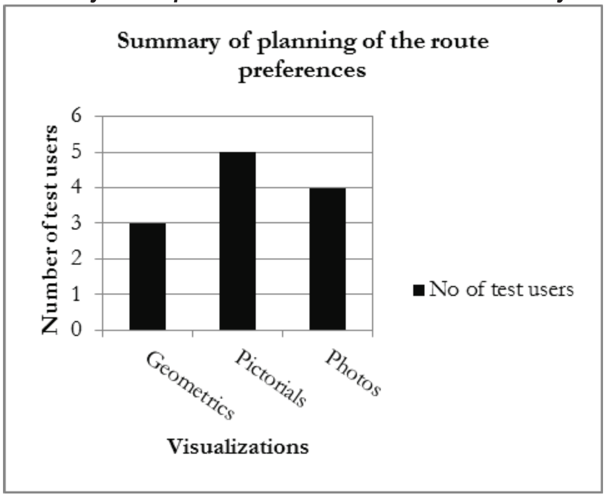


Figure 5-22. Summary of route planning preferences regarding user context "time availability and familiarity levels" (Group1,2,3 and Group4)

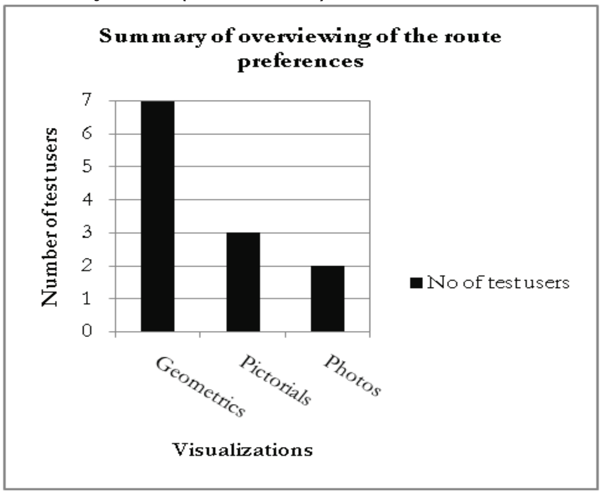


Figure 5-23. Summary overview of the route preferences regarding "time availability and familiarity levels" (Group1,2,3 and Group4)

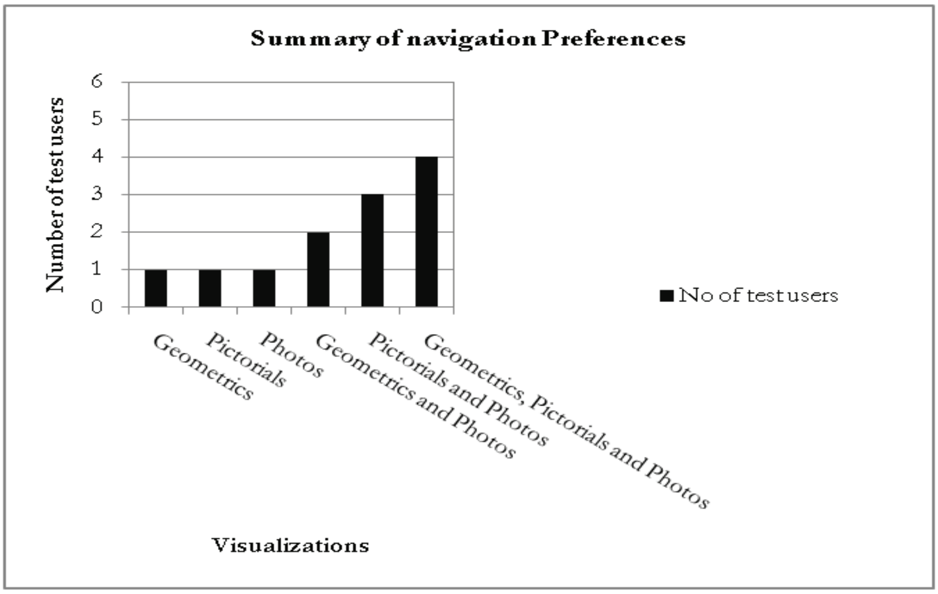


Figure 5-24. Summary of navigation preferences regarding user context "time availability and familiarity levels" (Group1,2,3 and Group4)

Considering the different users' preferences discussed, each category of landmark visualizations found to be potential since each group of test users used them during route planning, getting overview of the route and navigation. Discussion done in the literature and the output of this research confirmed this. During/before navigation, test users were able to answer their specific geographical questions such as: Where am I?, (Orientations), Before/During navigation, what are the landmarks I expect to base my navigation on my way? Is this the correct view at this particular point? Am I on the correct way? (Route confirmation) and Is this the correct endpoint? (Destination confirmation) were answered.

However during navigation test users gave some arguments regarding the landmark visualizations implemented in this research due to the immense potentiality of each based on their merits and demerits (table 5-6). These arguments look the same as the one which discussed in literature already (see section 2.4 and table 2-3).

Geometrics		Pictorials		Photos	
Merit	**Demerit**	**Merit**	**Demerits**	**Merit**	**Demerits**
Doesn't overlap each other compare to other visualizations, it is easier to see the whole route; they take small space on the map.	Complex to understand the meaning of the symbol without the legend; it is difficult to differentiate them especially when it appears more than one building which are near to each other.	Doesn't overlap each other; easier to be seen on the screen; helps the user to understand the meaning of the symbol.	Too detailed symbol may confuse users	Easier to compare the photo which is on the map with the one in the reality; easier to differentiate one building from another; good to represent landmarks which are unique	Small scale, they overlap the route; Difficult to be seen well; they take too long to load on the screen especially during zooming;

Table 5-6. Comparison of three categories of landmark visualizations regarding the test users' arguments

5.8. Conclusion

The prototype testing results are explained and the field-based user test methodology is given. The case study area and types of data used were highlighted. To this end, the environmental settings and documents used during testing and a description of the tasks given to the test users are shown.

The selection of test users and the justification behind using ITC students as test users and the process of how the test was executed using field-based testing methodology was given. The parameters which were assigned to users during the task execution concerning time availability and familiarity were shown. These parameters helped the researcher in the end to confirm whether the availability of time and familiarity level influence the selection of landmark visualizations as discussed later.

This usability evaluation aimed at checking if the designed prototype is working well by using three measures of usability evaluation (efficiency, effectiveness and satisfaction). These measures were used to evaluate two user contexts during task execution. The user preferences regarding the landmark visualizations implemented in the prototype were shown. Finally, the results of the usability evaluation regarding which types of landmark visualizations do users prefer for which purposes were given.

This research only considered the user's familiarity levels and time availability on measuring the three categories of landmark visualizations implemented in the designed prototype. The overall usability evaluation conclusion based on the results from both groups (Group1, Group2, Group3 and Group4) regarding the efficiency, effectiveness and satisfaction of the designed prototype with an option of selecting how to visualize the landmarks interactively based on user context were very encouraging. Each group interactively chose landmark visualizations during navigation, thus hopefully reduced the existing landmark visualization problems faced by pedestrian users during orientation and navigation to unfamiliar areas. These problems were display overload, frustrations, difficulties with landmark visualizations due to lack of an interactive ways of visualizing landmarks on M2, difficulties of linking landmarks as they appear in map displays with reality and their mental maps, vast amount of landmark visualizations, incorrect interpretations with the landmark visualizations and problems related to user profiles. Hence the prototype expected to worked well and proper navigation and orientation could be attained.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Summary

The visualization of landmarks on M2 and it's usability have been investigated and discussed by this thesis. For a long time, there was no attention towards the individual user (pedestrian) on how landmarks can best be visualized on M2 taking into account dynamic contexts of use and user contexts (familiarity and time availability). Today, however, there is gradually more attention towards creating usable visualization of landmarks on M2, by design, implement and testing an interactive prototype which contains different categories of landmark visualizations in order to allow users to select the landmark visualization categories for orientation and navigation. During this research different categories of landmark visualizations have been studied. The merits and demerits of these visualizations together with other factors were used to come up with a proposed classification of landmark visualizations to implement the prototype. Different methods and techniques, useful for each stage of UCD were studied and selected to be applied in this research. The usability evaluation methodology (field-based) was found to be very significant to investigate the individual user's contexts.

The interactively designed and implemented prototype with three categories of landmark visualizations (Geometrics, Pictorials and Photos) was tested in the field by using real user contexts. The functionalities which have been implemented fronted to a user friendly interface with adjustable landmark visualization categories presented interactively to individual user contexts. Individual users are allowed to decide how to visualize the landmark symbols during orientation and navigation in a geographic area by selecting the visualization type of choice. This enables users of different contexts to visualize the landmark symbols without limitations. Thus, problems faced by users when visualizing landmarks on M2, such as the display overload, frustrations and incorrect interpretation were hopefully reduced. Therefore, proper orientation and navigation could be attained.

Chapter two gave the information about the visualization of landmarks on M2. A general overview and functions of landmarks to pedestrian users have given some highlights to cartographers/map designers, programmers and researcher on the procedures to follow during the process of landmarks identification, grouping and the way to design and visualize landmarks on the M2. The described cartographic representation of landmarks showed the possibility of visualizing landmarks in different ways to individual users, considering the merits and demerits of each cartographic representation.

Chapter three gave a broad overview of research methodologies. Methods and techniques for each stage of UCD were discussed and reasons of selecting them considering their merits and demerits to fulfil the outcome of this research context. Two types of usability testing were highlighted, laboratory and field-based testing. Depending on the nature of this research, field-based testing was selected to be performed to fulfil the objective of this research, and to deeply investigate the interaction of real users with the prototype in the real environment.

Chapter four outlines the prototype design and implementation. In consort with the research basic idea the prototype was created to investigate the research goals. The user's contexts were considered as a key concept for improving the landmark visualizations on M2 during the implementation. The functionalities implemented by using the Google Maps JS API fronted to a user friendly interface with adjustable landmark visualization categories presented interactively to individual users contexts. Individual users were allowed to decide on how to visualize the landmarks during navigation in a geographical area by selecting the visualization type of choice. Therefore, users of different contexts were able to visualize the landmarks without limitation, hence the problem faced by users during orientation and navigation were expectantly reduced. In addition, the procedures taken to upload the prototype into the Android MD, the problems encountered and their solutions were explained. To demonstrate clearly how users use and interact with the application during orientation and navigation, screenshots representing the entire functionality of the implemented prototype was presented.

Chapter five describes the testing of the prototype. The field-based methodology used with important parameters was given. The case study area and types of data used were highlighted. To this end, environmental setting of documents used during testing and a description of tasks given to the test users were shown (in the Appendices). The selection of test users and the justification behind using ITC student as test users and the process of how the test was executed was given. The usability evaluation for the designed prototype with the results by using three measures of usability evaluation (efficiency, effectiveness and satisfaction) was given. These measures were used to evaluate two user contexts (time availability and familiarity levels) during task execution.

The research questions which have been highlighted in the first chapter will be answered to fulfil the results of this research

i. *What are the problems in existing research regarding the landmark visualizations on M2?*

Lack of best ways to visualize landmarks on M2 taking into account the dynamic contexts of use and user profiles. Currently landmark visualizations are presented on M2 in a static way without considering the individual user's needs. Therefore, there are no options of selecting how to visualize the landmark symbol types interactively based on user contexts (familiarity and time availability), difficulties with landmark visualization during orientation and navigation, difficulties of linking landmarks as they appear in map displays with reality and their mental maps and vast amount of landmark visualization symbols. These problems might impose some difficulties with landmark visualizations to users during orientation and navigation considering their contexts as described in details in chapter one. These problems might cause an interruption in the map reading process, and especially if this happens repeatedly, it can cause misleading of interpretations and improper orientation and navigation. The output of this research has hopefully reduced these problems.

ii. *What are the different existing ways of visualizing landmarks on M2, and what are the merits and demerits of each.*

In order to communicate different landmark characteristics information appropriately, landmark features such as buildings, monuments, parks, bridges, roundabouts etc. should be presented at different level of abstractions. To improve visualization of landmarks on M2, it is crucial to understand different ways of visualizing landmarks. These graphic representations of an object convey information to the user in terms of: abstract/geometric symbology, pictorial symbols, stereo type sketches, images/photograph and 3D representation. Each of the landmark visualizations has specific merits and demerits that need to be taken into important when used by the users to enable them to navigate in a geographic area. A summary of the merits and demerits of each type of landmark visualizations found in the literature is given (table 2-3). All discussions about these visualizations have been proven in chapter five where prototype testing results were discussed. During usability evaluation (task execution and data analysis) some of these merits and demerits have been experienced regarding the selection of landmark visualizations during navigation and confirmation of location.

iii. *What are the parameters that influence the visualization of landmarks on M2?*

The literature done in chapter two concentrated on some factors which influence the pedestrian users during landmark visualizations on M2. During the design and implementation of the landmark visualization on the M2 the following parameters were taken into important:

The delivery medium (e.g. MD/PDA)

This parameter was taken into vital due to its restrictions compared to desktop computers. The on-board hardware, including the CPU, memory, buses and graphic card is much less powerful and the landmark symbols developed for notebook computers do not scale well on MDs. The originally designed symbols were reduced to a small size of up to 3kb to meet these characteristics. The restrictions of MDs regarding the small size and speed were experienced during the usability evaluation and are explained in chapter five.

The user's context (familiarity and time availability)

To ome up with adjustable landmark visualizations on M2 in order to present them interactively, individual user context parameters were taken into vital to enable him/her to decide how to visualize the landmarks on M2.

User's familiarity

The user's familiarity with an area was found to be an influential factor on the process of landmark visualizations during orientation and navigation as it causes a user to use a certain type of landmark visualization .In this research it was found that, 3 test users (50%) of 6 users who were less familiar with the study area interacted with all types of landmark visualizations (Geometric symbols, Pictorials symbols and Photos) while 2 test users (33%) of 6 users who were more familiar with the study area. More details are shown in the results of chapter five.

User's time availability

Time availability context was found to influence one type of visualizations to be more suitable than another. It is expected that the time availability for a pedestrian enforces the need to use a certain type of landmark visualization while performing orientation and navigation. More details are in section 2.5.2. The overall average comparison between Group1 and Group2, Group1 used 26minutes(64%) and Group2 used 34minutes(84%). The overall average comparison between Group3 and Group4, Group3 used 26 minutes (66%) and Group4 used 33minutes (82%) (figure 5-10). The conclusion is that Group1 (in hurry) and Group3 (more familiar) used less time compared to Group2 and Group4. The detail analysis can be found in chapter five.

iv. *Which is the classification of visualizing landmarks on M2 found to be better and why?*

According to literature review (chapter two) there is no better landmark visualizations category among the ones implemented (Geometrics, Pictorials and Photos). Based on the output results and literature review it is difficult to mention which one is better. This depends on many factors such as context of use and user characteristics and what exactly the research wants to investigate. In this research it was shown that test user have preferences, taking into account the time availability and familiarity levels. When they want to plan the route themselves, many test users prefer to use Pictorial symbols 4 test users (67%), followed by Photos 3 test users (50%). When they were trying to get an overview of the route, irrespective of time availability and familiarity levels, most 6 test users (100%) prefer to use Geometric symbols, followed by 3 test users (50%) who prefered to use Pictorial symbols. This was influenced by the characteristics of the Geometric symbols (see section 2.4.1 and table 2-3).

Still it is difficult to conclude this in general terms, as the test users in this evaluation were ITC students who already have a good knowledge about maps. Maybe if we would use different test users with different backgrounds and experiences, the results might have been different. To find out which types of visualization are really better a deep investigation has to be done. However the adjustable landmark visualizations implemented in this research have shown potential based on the merits and demerits of each landmark visualization type and the output of this research.

v. *What distinctive solution could be developed to facilitate dynamic landmark visualizations during navigation and orientation in different use contexts?*

The satisfaction of the research goals was made by design; implement and testing of an interactive prototype .The user's contexts (familiarity and time availability) have been considered as a key concept to improve the landmark visualizations on M2. The functionalities which have been implemented fronted to a user friendly interface with adjustable landmark visualization categories presented interactively to individual users. Individual users were allowed to decide on how to visualize the landmarks during the process of orientation and navigation in a geographic area by selecting the visualization type of choice. Individual users were allowed to:

- Select particular type of landmark visualizations of choice e.g. Geometric, Pictorial and Image/Photograph. This will be done interactively beforehand and for all landmark visualizations at the same time.
- Have a possibility of visualizing only one particular type of landmarks (e.g. church) after selecting a particular kind of visualizations. For example if a user is using pictorial landmark visualizations, there will be an option of viewing only existing churches in that particular route.
- Have a possibility of clicking a particular landmark symbol to change its way of visualization. For example if a particular user is using Geometric symbols during navigation, sometimes s/he may need to confirm it (e.g. church), there will be a possibility of clicking that particular symbol (church), and view other visualization options e.g. photo. It means now a user can confirm the church very clearly.

These enable users of different contexts to visualize the landmarks without limitations to reduce the problems faced by users during landmark visualizations on M2 for orientation and navigation. Thus proper route planning and navigation has been attained.

vi. *What are the suitable methods and techniques to be used in usability testing and what are their merits and demerits?*

There are different methods and techniques that can be used in each stage of UCD. However to say these are the best methods and techniques for a certain research depends on the context of use, the special characteristics of the test users and what exactly the research wants to investigate. The following are methods and techniques that were found to be suitable in this research and the merits and demerits of each are summarized in table 6-1.

Method/ Technique	Advantages	Disadvantages
Think Aloud	Provides abundant data on cognitive process, performance and preferences, quick feedback and rich qualitative data, suitable for exploratory design approaches. Insights into the way users think and work with a given category of landmark visualizations can be provided.	Unnatural behaviour and conflict between task performance and communication, time consuming, difficult and tedious analysis of the huge amount of data.
Questionnaire	Quick and easy to create, fairly simple to perform and can provide feedback based on real user experience. Less interfering than telephone or face to face surveys.	The specific problems of a design and response rates are often low.
Semi-structured interview	Used to get more views from users after and before the test. Probing is possible to obtain in-depth information. Data can easily combined with other sources of information gathering techniques	Biasness may occur due to probing from the researcher, Time consuming and expensive method when the potential respondents are scattered over a wide geographic

		area.
Observations	It captures actual user behaviour, and not what she thinks that she is doing. It can later be compared with other collection methods for validity checks. Inexpensive method.	May cause disturbance to participants. Cannot capture insights about what the person is really thinking or the reasons behind a particular behaviour.
Video recording	Capture and record the participants' reaction and actions immediately, it is possible to capture the participant's face expression and it allows for an efficient analysis of the test's user behaviours.	Requires time procedure and camera alignment for best view and it is difficult to analyze the data.

Table 6-1. Methods and techniques that were found to be suitable in this research

vii. Does the developed solution works well?

The results of the usability testing showed the potential of the designed prototype. Each group interactively has selected landmark visualizations during navigation, and this reduces the current existing landmark visualization problems faced by pedestrian users during orientation and navigation to unfamiliar areas. These problems are display overload, frustrations, difficulties with landmark visualizations due to lack of an interactive ways of visualizing landmarks on M2, difficulties of linking landmarks as they appear in map displays with reality and their mental maps, vast amount of landmark visualizations, incorrect interpretations of the landmark visualizations and problems related to user profiles. Hence the prototype hopefully worked well and proper navigation and orientation has been attained as the implemented prototype aided the test users during orientation and navigation of a predefined route, from the beginning to the end without limitations. Therefore test users were able to answer their specific geographical questions such as Where am I. (Orientations); Am I on the correct way? (Route confirmation); Is this the correct endpoint? (Destination confirmation) or before navigation, what are the landmarks I expect to base my navigation on my way? On researchers opinion it can be concluded that, this research has moderate reduced these problems by designing, developing and testing a prototype by using field-based methodologies for interactive landmark visualizations on M2 that have helped users better than before in navigation and orientation.

However, the problem with the prototype was not running at reasonable speed especially during the changing of landmark visualizations from one category to another and during confirmation. These problems are dependent on characteristics of MDs and the methodology used to implement the prototype. During these operations test users had to be patient so as to wait for the loading of the prototype. This problem happened most with Photo landmark visualizations. These are problems which can be resolved by emerging multifunctional PDAs and smartphones with improved capacity to process and execute commands and internet access speed as time goes.

The following are the answers of the sub research question of question number seven as the output of chapter five concerned

- *What type of landmark visualizations do users prefer, if they were to plan the route themselves?*
  The overall summary with respect to the preferences of the test users, regarding both time availability and familiarity levels (12 test users), when they want to plan the route themselves (figure 5-22), showed 5 test users (42%) preferred to use Pictorial symbols, 4 test users (33%) preferred to use Photos and 3 test users (25%) of preferred to use Geometric symbols (figure 5-20).

- *What type of landmark visualizations do users prefer during overviewing of the route they are going to follow?*
  Preferences summary of getting an overview of the route(figure 5-23) based on both time availability and familiarity levels (12 test users), results showed that 7 test users equivalent to 58% preferred to use Geometric symbols, 3 test users equivalent to 25% preferred to use Pictorial symbols and 2 test users equivalent to 17% preferred to use Photos. This analysis has proved what has been discussed in literature already about Geometric symbols by showing large percentage of test users preference (see section 2.4.1 table 2-3 and figure 5-21)
- *What type of landmark visualizations do users prefer to use during navigation.*
  During navigation (figure 5-24) based on both time availability and familiarity levels (12 test users), the analysis showed that 4 test users, (33%) prefer to use all types of landmark visualization interactively (Geometrics, Pictorials and Photos), 3 test users (25%) preferred to use Pictorial symbols and Photos interactively, 2 test users, equivalent to 17% preferred to use Geometrics and Photos interactively, 1 test user (8%) preferred to photos only, 1 test user (8%) preferred to use Pictorial symbols only, and 1 test user (8%) preferred to use Geometrics only (figure 5-24).

6.2. Recommendations

In order to support these research findings and inspire new ideas, some aspects for further research are:

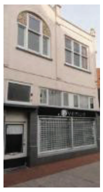
i. User testing for this research was performed with ITC students as test persons. Some of them have specific geographic knowledge. But would other categories of test users influence the outcomes of this research? As to the researcher's opinion the other categories of test users would result to different results as the ITC students, more than average were having knowledge about geographic and maps in general.
ii. The specific user context (familiarity and time availability, predetermined time of the day, weather condition, etc.) was considered during testing. How would other user contexts like, traffic jams, accidents, holidays, road restrictions, night time etc. vary the results?
iii. Field-based testing was used to perform the usability evaluation. If the usability evaluation could be performed with a combination of field-based and laboratory testing (another type of environment where usability evaluation can be done), would we reveal more usability problems related to landmark visualizations?
iv. The prototype was implemented using three categories of landmark visualizations (Geometrics, Pictorials and Photos). If we introduce more landmark visualization categories, would we reduce more current problems faced by users?
v. The implemented prototype had a predefined/fixed route. It meant that it was not possible to plan a route using this prototype. A GPS function was not enabled to allow users to locate their current position. For the purpose of this research, the landmarks along the predefined route were used to let the test persons locate their current position. If this GPS functionality would be employed, would the outcomes be the same?
vi. This research had limited its study to the different categories of landmark visualizations having interactive visualization of landmarks on M2 that can be implemented on all current devices, what if animation was employed to implement the landmark visualizations, would the outcome results be the same?
vii. This study was performed in the central area of Enschede, the Netherlands, where there are a lot of problems associated to weather conditions. What if the case study was in another country with different weather conditions? would the outcomes be the same?

LIST OF APPENDICES

Appendix A. Type of landmark visualizations implemented in the prototype

No	Category	Name	Visualizations		
			Geometrics	Pictorials	Photos
1	Bank	ATM Bank			
2	Bank	Elkebankkan Uvertellenover			
3	Bank	Fortis			
4	Bank	SNS Bank			
5	Bank	Staal Bankiers			
6	Church	De Grote Kerk			
7	Church	Geref Kerk			
8	Church	Revelation			
9	Others	De Groote Schuur			
10	Others	JPRAdvocation			
11	Others	Makelaarsbedrijf DTZ Zadelhoff			
12	Others	Muziekcentrum			
13	Others	Natuurmuseum			
14	Others	Saxion University			
15	Others	Snelder Zijlstra Makelaars			
16	Others	Tempo-team Uitzendbureau			

17	Others	Uitvaartcentrum Vredehof			
18	Restaurant	Bieren Café Het Bolwerk			
19	Restaurant	Brasserie Willemientje			
20	Restaurant	Chaplin			
21	Restaurant	De Buurvrouw			
22	Restaurant	De Tropen			
23	Restaurant	FRED & DOUWE CITY LOUNGE			
24	Restaurant	Humphreys			
25	Restaurant	Los Ponchos			
26	Restaurant	Mix			
27	Restaurant	PINNOCCIO			
28	Restaurant	Pool Cafe The Bridge			
29	Restaurant	Talamini			
30	Restaurant	The Edge			
31	Restaurant	Timeless			

32	Restaurant	Wijnhuys Jou & Mij			
33	Shop	Ad Heijne Schoenen			
34	Shop	Antique Boutique			
35	Shop	Avenue (Men´s Clothing)			
36	Shop	Boekhandel Broekhuis			
37	Shop	BRITAIN			
38	Shop	Capelli Kappers			
39	Shop	De Slegte bookshop			
40	Shop	G. Koelink Juwelier			
41	Shop	Mobile Action			
42	Shop	Sea-design B.V.			
43	Shop	Stolker			

Appendix B. Invitation letter

Dear Sir/Madam,

I am Erimina M. Massawe currently completing my MSc in Geo informatics at ITC, University of Twente. The subject of my research is "Usable visualization of landmarks on Mobile Maps" under the supervision of Dr. C.P.J.M van Elzakker and Dr. Connie A. Blok; both are assistant professors at the Geo Information Processing department - ITC. I am currently working on the usability evaluation part of my research, after the design and development of a prototype/mobile navigation interface for pedestrian navigation based on a User-Centered Design approach.

I am asking for your kind contribution to my usability evaluation which will provide me with valuable comments on identifying possible problems in my implementation and solutions to understand if the prototype is working well and suitable for its intended purpose in the environment in which it will be used.

I plan to use test users who are representative as possible of the intended users of the developed prototype. During testing you will be given a navigation task to complete in one of pre-selected areas in central area of Enschede with the help of a mobile navigation interface. The test area is at a walking distance from the ITC. Test users will walk to the case study area and they will participate only once. The whole testing process will take a maximum of 1 ½ hour. The briefing and training will take place in the ITC. To carry out the tests, a research methodology consisting of thinking aloud, observation together with audio/video recording, semi-structured interviews and a questionnaire will be used. All the information will be strictly kept private and any reference to the test users will be done later using codes only.

Kindly reply to me on your availability for this test

If you have any questions you can contact me at: massawe01895@itc.nl

Thank you for your time and consideration.

Your participation is highly appreciated.

Kind regards,

Erimina Massawe

Appendix C. Pre-test questionnaire

1. **What is your name and surname?**

   ____

2. **What is your occupation or subject of studies now?**

   ____

3. **What is your past studies field?**

   ____

4. **Which age group do you fit in?**

   □ 18-24 □ 25-30 □ 31-40 □ 41-50 □ 51-60

5. **What is your gender?**

   □ Male □ Female

6. **For how long have you been in Enschede?**

   □ Less than 1 year □ 1 year to 5 years □ more than 5 years

7. **How much are you familiar with central part of Enschede? Please indicate your familiarity rate**

   □ Less Familiar □ More Familiar

8. **What is your experience with paper maps?**

   □ None □ Poor □ Fair □ Good □ Excellent

9. **What is your experience with digital maps?**

   □ None □ Poor □ Fair □ Good □ Excellent

10. **Please rank your abilities to plan a route and navigate with the help of a map in places that you visit for the first time:**

    □ None □ Poor □ Fair □ Good □ Excellent

11. **Please rank your abilities to plan a route and navigate in places that you have visited before (recently):**

    □ poor □ fair □ good □ excellent

12. **What is your experience with GPS systems?**

    □ None □ Poor □ Fair □ Good □ Excellent

13. **What is your experience with mobile navigation systems?**

    □ None □ Poor □Fair □ Good □ Excellent

14. **What is your experience with smartphones (touch screen etc.)?**

    □ None □ Poor □ Fair □ Good □ Excellent

15. **What is your experience with Google Maps on mobile phones/PDAs?**

    □ None □ Poor □ Fair □Good □ Excellent

16. **Do you have any experience with any other navigation software for smartphones/PDAs? (I.e. other than Google Maps)?**

    □ No □ Yes

17. **If you answered yes in the previous question, please name the software:**

    ____

18. **How often do you use paper maps when you visit new places?**

    □ Never □ Sometimes □ Frequently □Always

19. **How often do you use mobile navigation systems when you visit new places?**

    □ Never □ Sometimes □Frequently □Always

Appendix D. Pre-test semi-structured interview

Route Planning

1. **You are exploring the route.**

   - **If you would have to plan a route now yourself, what type of landmark visualization would you prefer?**

     □ Geomatics □ Pictorials □ Photos

   - **When you want to have an overview of the route you are going to follow, what type of landmark visualization would you prefer?**

     □ Geometric □ Pictorial □ Photos

2. **Now having explored the route you are going to follow, how familiar are you with the area the route is going through?**

   □ Less Familiar □More Familiar

Navigation

3. **What type of landmark visualization would you prefer to use during navigation?**

   □ Geometrics □ Pictorials □ Photos

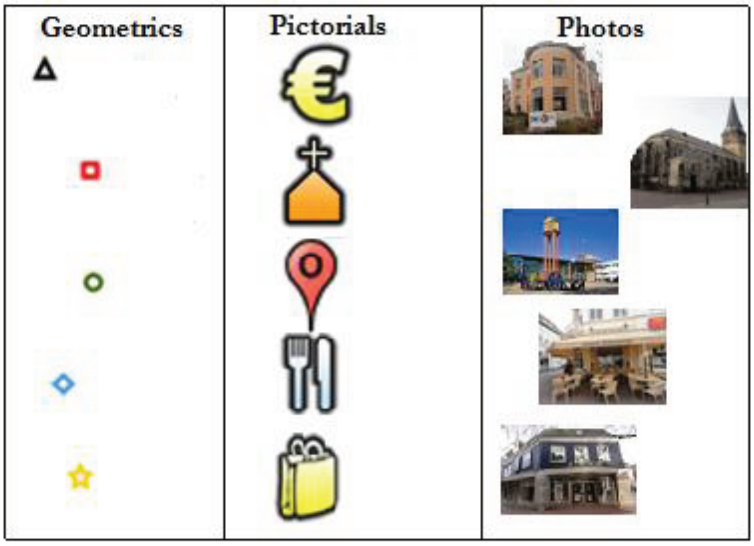
Appendix E. Tasks for field-based usability evaluation

Scenario

Imagine that you are either a normal pedestrian user or a tourist who wants to visit an interesting specified route area in the central area of Enschede, Netherlands. You are expecting to use a mobile geo-application running on your Mobile Device for navigation. Information about the existing route and type of landmark visualizations existing in the specified route is of significance. The designed prototype is capable of providing all this information. Now the pedestrian user/tourist required to navigate from the beginning to the end of the specified route with the given user context characteristics (familiarity and time availability).

Data

An Enschede Google map has been used as a base map for the prototype interface. Buildings as landmarks along the specified route in central area of Enschede have been presented in terms of different landmark visualizations as Geometric symbols, Pictorial symbols and Photos.



Tasks

You are a normal pedestrian/tourist. You are asked to follow a specified route from the beginning to the end, (Follow this route to reach the church which is located at the end) using the skilled developed during the overview of the given route. During navigation, you are required to think aloud to help the researcher to understand what type of landmark visualization category you are using (there are three types of landmark visualizations to choose from the mobile application). Also the reasons when and why you want to change the type of visualization and what you are doing generally along the route are solicited. **Remember, the aim of the test is to see if the landmark visualizations presented in the prototype interface will aid the user to navigate from the start to the end of the given route successfully.**
Navigate this route which started from Saxion University to GerefKerk Church which is located at the end of the route.

Appendix F. Post-test semi-structured interview to collect the test users' feedback

1. **Rate your confidence level of using the application**

   1 = very poor, 2 = poor, 3 = normal, 4 = good, 5 = very good)

   □ 1 □ 2 □ 3 □ 4 □ 5

2. **Are you satisfied with the dynamic of landmark visualization symbols provided**

   □ 1 □ 2 □ 3 □ 4 □ 5

3. **What type of landmark visualization do you prefer to use during navigation?**

   □ Geometrics □ Pictorials □ Photos

4. **Were you able to confirm your current locations during navigation?**

   ____

   ____

   ____

5. **Did you experience any limitations or drawbacks in the test, due to the landmark visualization category used (depending to the symbol group (Geometric, Pictorial, Photo)**

   ____

   ____

   ____

6. **Are there other types of visualizations, you would like to be included in the interface?**

   ____

   ____

   ____

7. **What other suggestions you have about the way the interface was implemented?**

   ____

   ____

   ____

8. **Describe your impression on using the field-based method (thinking aloud, observation together with audio/video recording and semi-structured interview for route planning and navigation.**

   ____

   ____

   ____

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