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Diploma Thesis in Computer Science

Evaluation of a Push-Based Location-Aware System In-Field

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I, Hogir Habasch, hereby declare that I have created this work completely on my own and used no other sources or tools than the ones listed, and that I have marked any citations accordingly.

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Bonn, April 2010
Hogir Habasch

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Abstract

Over the years technology-driven society continuously developed more sophisticated electronic devices. Computers became personal computers, increasingly powerful and smaller. This development is the origin of a variety of successors. Nowadays computers and their descendants have taken a big role in people's everyday life. They and their provided services are ubiquitous, creating a novel interaction space. User-behavior in this new technological space prompts new research questions which have to be investigated in-situ. However, Computer Science's techniques lack the capability to investigate user-behavior in their natural environment with state-of-the-art devices. Methodologies of different research areas, especially of sociology and psychology, have to be transferred to Computer Science. This diploma thesis will exploit such methods to find answers to open research questions. Therefore a task-oriented experiment will be conducted where participants interact with a mobile Location-Based System (LBS) in a natural environment. In the in-field experiment participants have to fulfill different tasks each with one of eight alternatives of presenting spatial data on the mobile LBS. The goal of the experiment is: A) to evaluate their behavior, B) to identify serious usability issues which occur in-field and C) to determine the best presentation style. Their behavior and the task performance will be monitored and interpreted to derive new answers to open research questions. The findings of the experiment will push research forward. To assure a certain research quality User-Centered Design is used as the main methodology. User-Centered Design is a design philosophy that puts the user into the focus of the design process. This work involves potential users and experts in the design process of the experiment throughout all stages of this thesis. The diploma thesis originated from a cooperation between the University of Bonn, department Computer Science III, and the Fraunhofer Institute for Applied Information Technology FIT, department Information in Context.

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Last but not least I thank my family and my friends, for their great support throughout my studies, especially in difficult times they support me through.

Conventions

Throughout this thesis we use the following conventions.

Text conventions
Technical or important terms are put into italics.

Definitions of technical terms are set off in boxes.

Excursus:

Excursus are detailed discussions of a particular point in a book, usually in an appendix, or digressions in a written text.

Definition: *Excursus*

The whole thesis is written in American English.

Chapter 1

Introduction

This chapter opens the diploma thesis with the motivation for this work. It is followed by the focus of the thesis. The last section describes its structure.

1.1 Motivation

> *"Human-computer interaction (HCI) is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them."*
>
> *—ACM SIGCHI Curricula for Human-Computer Interaction*

When the first computers were developed, in the mid 1930s (Zuse Z1 computer), HCI as a technical term still had many until it was coined. Computers were big "things" that needed great ministration from their operators[1] [Sha97].
The move from vacuum tubes to transistors made it possible to minimize computers. This change decreased the interaction with the computer from many-to-one to one-to-one. Operators slowly became users. At this point researchers started to think about how to increase the functionalities of computers.

In 1965 Bonnie Huddart, D.C. Engelbert and W.K. England introduced the mouse as a computer input device, and in a study compared it with other input devices (light pen, grafacon, and joystick) [WE65]. From the experiment's findings the combination of mouse & keyboard arose as the best input device.

[1] An operator's responsibility was to monitor the computer and make sure that the computer fulfilled its tasks. You could say that operators were the ancestors of the user.

Over the years technology-driven society continuously developed more sophisticated electronic devices. Computers became increasingly powerful and smaller. This development is the origin of a variety of successors. Nowadays computers and their descendants have taken a big role in people's everyday life. New scenarios have arisen in which people use these devices in situations outside the office environment. Mark Weiser realized this development and summarized it in his article *The Computer for the 21st Century* [Wei99], where he defined the technical term *ubiquitous computing*. Computers take a part in people's natural life with new ways of interaction and services.
User-behavior in this new technological space has to be investigated, so that the interaction with ubiquitous services and human beings becomes more natural. Research in this area is being carried out from two sides from which researchers began to investigate user-behavior:

Two perspectives on research

Techno-centric:
Technical achievements made it possible to investigate new more intuitive ways on how to interact with computers. New ideas have been created to substitute the mouse & keyboard as the negotiator between human beings and computers.

Human-centric:
People started to use computers not only in their offices, but also outside the desktop environment. Researchers from different disciplines, especially from sociology and psychology, started to exploit non-computer science methodologies to understand why users behave the way they do.

From HCI's perspective this development raises new challenges. Important questions have to be answered such as:

1. How can a user be supported to retrieve relevant information in different situations?
2. How do users interact with state-of-the-art devices outside the office environment?
3. What is a convenient way to present the information efficiently on these devices?

New paradigms in HCI have been defined to classify these questions. In mobile HCI the notion of the user's context was introduced to overcome these challenges. The user's situation is interpreted with the objective to derive relevant information. The intention is to make the devices more intelligent, to make them aware of the user's context.

1.2 Focus of the Thesis

The goal of this thesis is to find new answers to the aforementioned questions. This work will examine user-behavior with a mobile context-aware application in a real case scenario.

This diploma thesis will exploit the most important part of a user's context, his location, and conduct an experiment with a mobile location-based system (LBS). Although much research has gone into the improvement of mobile LBS, the focus was rarely on push-based LBSs. No studies have investigated a fully implemented push-based LBS in-field as it will be designed in this thesis. The intention of the experiment is to discover novel usability problems from which new guidelines can be defined for the research community. This diploma thesis wants to answer the following question:

Thesis Question: *How do users of a mobile push-based LBS behave in a task-oriented in-field experiment with different presentation styles?*

On the path to achieve this goal an in-field experiment with a focus group will be conducted. In the experiment the participants will execute different tasks with a state-of-the-art prototype in a natural environment. Their behavior and the task performance will be monitored and interpreted to derive new answers to open research questions.

In-field study will be conducted

Throughout this work potential users and experts are involved in the design process of the experiment. This approach assures that the experiment fulfills the users' requirements and its results are valuable for the research community.

To follow a specific research methodology is important for the diploma thesis, especially when an in-field experiment with user-involvement is conducted. Otherwise the work may come to a misleading end. To avoid this kind of failure a User-Centered Design (UCD) is used as the main methodology in this thesis. User-Centered Design is a design philosophy that puts the user into the focus of the design process.

UCD main design philosophy

This work exploits six well-established methods of HCI to assure a certain level of research quality. The following research methods are used:

Interviews Interviews will be conducted to receive the users' feedback on mobile LBSs and as an instrument to gather initial requirements for the first prototype.

Scenarios The scenarios will describe the interaction between users and devices in a short story. They will help to understand users better in certain situations. The goal is to give a short and clear description of a use case.

Use cases The use cases will help to define the functional requirements for the LBSs which will developed in this thesis.

Prototyping The development of a high-fidelity prototype is part of the design process. It is used to control if the defined requirements fulfill the goals of the experiment.

Expert review/workshop Reviews and workshops with experts are efficient methods for the identification of design flaws of the in-field experiment.

In-field evaluation The in-field evaluation is the last and most important part of this thesis. It is conducted to observe new findings of user-behavior in a real case scenario.

1.3 Outline of the Thesis

The outline of the thesis is as follows:

Chapter 2: Fundamentals and State of the Art
The second chapter gives an overview of the research area this work is based on. It explains important technical terms so that the reader can familiarize himself with the topic. Moreover on it discusses related work and denominates open research questions these studies have left.

Chapter 3: Conceptual Approach of the Push-Based LBS
Chapter 3 presents the design concept of the thesis and how specific steps are conducted.

Chapter 4: Planning and Implementation of the Experiment
In chapter 4 the design of the final experiment and the implementation of the customized push-based LBS is documented.

Chapter 5: Conducting the User-Study
The fifth chapter presents the design of the study, the statistical results and the user behavior attained from it.

Chapter 6: Result Discussion
Chapter 6 discusses the results of the experiment and concludes important findings.

Chapter 7: Conclusion & Future Work

The final chapter 7 summarizes the work conducted in this thesis and suggests possible future development based on the findings.

Chapter 2

Fundamentals and State of the Art

This chapter introduces the fundamentals on which the research of this thesis is grounded and points out challenges which remain unresolved by the state of the art. It explains important technical terms and provides a discussion about the different perspectives of different research areas.

2.1 Mobile Human-Computer-Interaction

This section gives a overview on the development of mobile HCI. It explains the technical terms *Usability* and *User Experience* and describes the characteristics of mobile HCI .

2.1.1 High-Level View of HCI

The change of interaction was driven by the idea to make the communication between human-beings and computers more natural, while examining every aspect of humans' daily life. Therefore methodologies from different research areas have to be taken into account. This movement in HCI was identified and summarized in Harrison et al.'s paper "The paradigms of HCI" [HTS07]. Harrison et al. define three paradigms in HCI and classify the research in HCI into this three paradigms (Table 2.1). 3 paradigms of HCI

The first paradigm encompasses methods that try to improve the usage of devices for the user. The second paradigm focuses on techniques to reduce the cognitive workload while interacting with computer systems.
The third paradigm, *Situated Perspective*, unites different approaches. In their core they reflect on human interaction with computer systems in specific situations. Their objective is to understand the action of human beings

in a better way. Section 2.3 discusses important methods belonging to the third paradigm in more detail.
This thesis is classified as belonging to the third paradigm *Situated Perspective*. The interaction of human beings with state-of-the-art technology will be observed in a real environment.

2.1.2 Usability and User Experience

After the introduction of HCI which has placed this thesis into its thematic context, two important technical terms, *Usability* and *User Experience* will be discussed. For this thesis, it's significant to comprehend both terms and the differences between them.

Usability

Usability reviews the characteristics of applications and devices. For both classes, usability demands an intuitive or easy-to-learn user-access. The workload for users should be kept low, so that the user can fulfill his tasks in an efficient way. Usability for the devices falls under the term *Hardware-ergonomics*, which means to say that devices have to meet criteria like the haptics or the natural and healthy position in relation to the device. For applications the according term is *Software-ergonomics*, which deals with the cognitive and physical capabilities of human beings.

The ISO 13407 (Version 2.3) standard on *Human-Centered Design Processes for Interactive Systems* defines usability as:

Usability (ISO 13407:1999: 2.3):

Definition: *Usability (ISO 13407:1999: 2.3)*

Extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.

User Experience

By its definition usability is measurable, and focuses on improving task-oriented systems. To discover the contentedness of the user beyond the task-oriented milieu, the user experience (UX) has to be examined. Researchers do not only ask how efficient a task was performed, they also ask questions about the subjective experience of the user. It is more important how users sense the system during the interaction with it. Figure 2.1 summarizes all levels which influence the entire user experience from a user's perspective.

Table 2.1: Three paradigms of HCI compared

	Paradigm 1: Human Factors/ Engineering	**Paradigm 2: Cognitive Revolution**	**Paradigm 3: Situated Perspective**
Metaphor of interaction	Interaction as man-machine coupling	Interaction as information communication	Interaction as phenomenologically situated
Central goal for interaction	Optimizing fit between man and machine	Optimizing accuracy and efficiency of information transfer	Support for situated action in the world
Typical questions of interest	How can we fix specific problems that arise in interaction?	What mismatches come up in communication between computers and people? How can we accurately model what people do? How can we improve the efficiency of computer use?	What existing situated activities in the world should we support? How do users appropriate technologies, and how can we support those appropriations? How can we support interaction without constraining it too strongly by what a computer can do or understand? What are the politics and values at the site of interaction, and how can we support those in design?

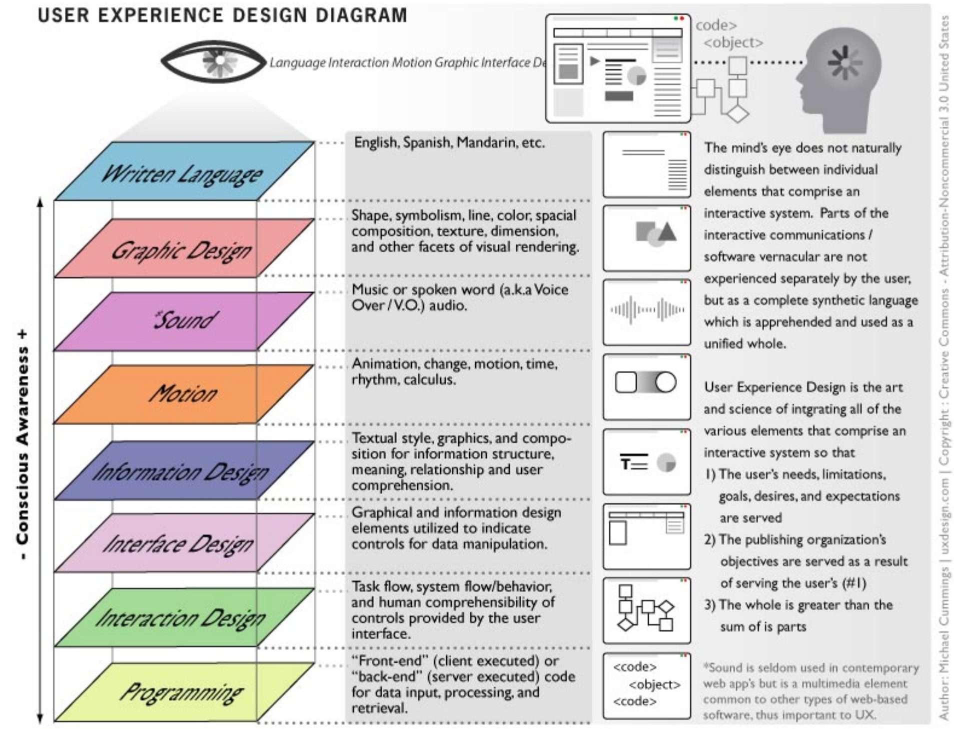


Figure 2.1: User experience from the user's perspective (by Michael Cummings, uxdesign.com)

Definition:
User Experience (Nielsen Norman Group)

User Experience (Nielsen Norman Group):

"User experience" encompasses all aspects of the end-user's interaction with the company, its services, and its products. The first requirement for an exemplary user experience is to meet the exact needs of the customer, without fuss or bother. Next comes simplicity and elegance that produce products that are a joy to own, a joy to use. True user experience goes far beyond giving customers what they say they want, or providing checklist features. In order to achieve high-quality user experience in a company's offerings there must be a seamless merging of the services of multiple disciplines, including engineering, marketing, graphical and industrial design, and interface design.

2.1.3 Characteristics of Mobile HCI

Interaction in the mobile context raises additional usability challenges researchers have to conquer. There are several aspects to consider in mobile HCI. Mobile devices are smaller, resulting in smaller input and output interfaces. Mobile devices are less powerful, therefore resources have to be

handled efficiently.
On the other side of the spectrum is the human being in the mobile context, who uses the mobile device during work and after work to fulfill a variety of tasks. In short, mobile devices are becoming an intrinsic entity in human life.

Evaluation in mobile context is challenging

Due to the usage complexity of mobile devices, established usability methods are not applicable one-to-one to the Mobile HCI. Therefore research that examines special features of mobile devices is necessary. Duh et al. [DTC06] e.g. investigated the difference of usability of mobile devices in the lab and in-field.
Research can tackle these challenges from two different sides. Firstly, looking at it the techno-centric perspective, which seeks for answers to the question "How can we improve the usability of small computer devices?" (Paradigm II). Secondly, from a human-centric view, with the question "How can we support the user in different situations with mobile devices" (Paradigm III).

From the usability perspective, designing interfaces has matured, high-quality guidelines are provided by many technology companies, e.g. Apple Inc.[1] or for Windows Mobile[2].
Research has been investigating new ways in making devices more intelligent. A vivid research topic in Mobile HCI has become the direct interaction of mobile devices with the physical world and smart environments, see e.g. [RLC+06] or Fahim Kawsar's PhD-thesis [Kaw09].

2.2 Context and Context-Awareness

This part of the thesis introduces the terms context and context-awareness and explains why they are important for the UX in Mobile HCI.
The purpose of context-awareness in HCI is to provide the user with relevant information to overcome the increasing information and service overload he has to handle nowadays. The additional feature increases the user experience, because a) the user only receives information which is important in his situation, b) it minimizes the workload and c) it minimizes the user-interaction.
The challenge is to define what *relevant* means in general for a context-aware system.

In this work users will interact with a mobile context-aware system. Hence

[1] http://www.developer.apple.com/MobileHIG
[2] http://msdn.microsoft.com/en-us/library/bb158602.aspx

it is significant to define the terms in relation to the thesis.

2.2.1 Context

Why is context important for mobile computing?
When computers began to leave the desktop environment, systems needed to acquire additional information about the user's physical environment, about his situation. This is a contrast to traditional computer interaction, where interaction and the physical environment share a common ground. This makes context in mobile computing important and hence is a highly investigated research topic (Figure 2.2).
It basically carries out Weiser's idea of ubiquitous computing: Intelligent devices understand the user's intention without direct interaction with the user.

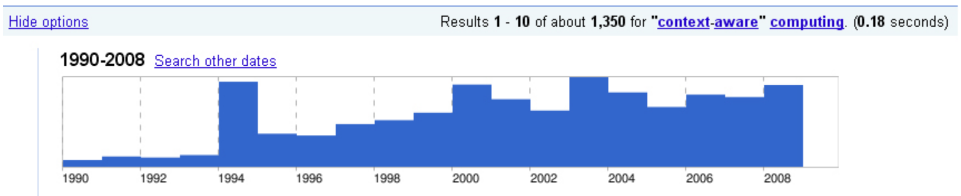


Figure 2.2: Research of context-aware computing in the recent years

The most cited definition of context[3] is from Anind Dey [Dey00] defined in his PhD-thesis:

Definition:
Context (Dey, 2000)

Context (Dey, 2000):

Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.

For the course of this thesis Dey's meaning of *context* will be used. Its definition reflects how context is understood.

Alternative views on
context

However, several works defined their own meaning of context and challenged Dey's definition, giving reasons why his definition is not appropriate. Two important papers are discussed here:

[3] 1277 citations. Source: scholar.google.com, 01-14-2010

Intelligibility and Accountability Bellotti and Edwards [BE01] advise against blind trust in context-aware systems. They take a human-centric stance. From their point-of-view the human being has the final arbitrament. They point out two human factors for this argument:
Firstly, humans do improvise, in contrast to systems. Secondly, humans are lazy on updating their current state, so that the system cannot rely on the user. Therefore, context-aware systems should not hide relevant information from the user. In general, Bellotti and Edwards claim transparency for the user, which contradicts Dey's idea of the hidden computer.

Dourish's approach Dourish [Dou04] does not criticize specific definitions of prior research, he questions the conceptual work prior research has done, where context takes a representational position. He understands that those definitions derive from sociological investigations of real-world practices, but the conclusion drawn lead to a model that does not explain what context is.
He considers context as an interactional problem rather than a representational problem. Instead of asking *"what is context and how can it be encoded?"*, he sees the central concern of context in the question *"how and why, in the course of their interactions, do people achieve and maintain a mutual understanding of the context for their action?"*.

The discussion about the different definitions of *context* points out that there are alternative perspectives on *context* in HCI, each having its entitlement depending on the objective of the research.

2.2.2 Context-Awareness

Context-awareness refers to systems which exploit users' context to improve usability. The notion of context-awareness in mobile computing was first mentioned in Schilit's et al. [SAW94] work. In their sense, a context-aware application *"adapts according to its location of use, the collection of nearby people and objects, as well as changes to those objects over time"*. Context-awareness is subject to the same discussion as context. There are several approaches to define context-awareness.
Dey's definition of context-awareness [Dey01] is used in this thesis:

Context-aware (Dey, 2001):

A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task.

Definition:
Context-aware (Dey, 2001)

The intention of context-aware computing is to make the interaction with applications more seamless and less distracting. These are factors which are very important in mobile computing, where users are confronted with continuously available services.

2.3 Methodologies and Methods in HCI

The ongoing research in computer science let computers emerge in people's life outside the office environment. To understand people in this situations (the combination of emerging technologies and unexamined environments) scientist adapted established methodologies from different research areas, especially from sociology and psychology to computer science, and to be more exact, to HCI.

Influences of different research areas to HCI

The first part of this section highlights rising methodologies in HCI. They have emerged because computers are becoming a more and more important part of people's daily life, and researchers need to understand the new interaction spaces between human beings and computers.
The second part presents important research methods in (Mobile) HCI. It points out their characteristics and explains when they should be executed.

User-Centered Design is used as the basic design philosophy. Throughout this work certain methods are executed to follow this path. All of these well-established methods which are presented in this thesis are carried out to fulfill the requirements for the in-field experiment and to raise its quality.

2.3.1 Methodologies in HCI

In the last 20 years a rising movement from in-lab to in-field studies can be monitored [HTS07], almost every one belongs to Paradigm III (see Table 2.1) of HCI.
Recent studies focused not only on task-oriented quantitative analysis of a user's interaction with devices, but also on user's behavior outside this task-milieu [Gav02, GBPW05]. Technomethodology and the design for the homo ludens[4] are important methodologies, which have emerged in HCI. They give another perspective on human behavior in contact with novel technology.

[4] Describes the human-being who acquires his skills in a playful way. See Johan Huizinga's "Homo Ludens" for further reading

User-Centered Design

User-Centered Design (UCD) is a design philosophy that puts the user into the focus of the design process. It takes mental and physical human characteristics (human factors) into account and improves interactive systems for human beings regarding the mental workload and efficiency on the one side, and the emotional experience on the other side.
The ISO 13407 (2.3) standard on *Human-Centered Design Processes for Interactive Systems* characterize UCD by the following four features:

1. the active involvement of users and a clear understanding of user and task requirements;
2. an appropriate allocation of functions between users and technology;
3. the iteration of design solutions;
4. multi-disciplinary design.

Technomethodology

Technomethodology = HCI + Sociology

The term Technomethodology was introduced by Paul Dourish and Graham Button [DB98] in 1998. Both wanted to highlight the influence of sociology to system design in HCI, in this case the influence of Ethnomethodology. Ethnomethodology is a branch in sociology, introduced by Harold Garfinkel. Ethnomethodology's main target is the investigation of everyday social actions of human beings in specific situations. In contrast to prior work in sociology, it does not assume social order as the basis for social actions. Ethnomethodology focuses its analytic attention on how social actions are achieved. That is why Ethnomethodology has raised interest in HCI, it allows a different view on the user's action. The purpose to get a better understanding on occurring technology-gaps between a user and a system.

This approach was first used in HCI in the workplace environment, but more as a critique of system design, to perceive requirements, than as an integral part of the system design.
Dourish and Button see the need to define Technomethodology (Figure 2.3), a symbiosis of system design and ethnomethodology, because Technomethodology is more than a *practical matter*, it is a analytic orientation in design context.

Crabtree [Cra04] articulates the conversion of this hybrid approach by an practical example. Can You See Me Now? (CYSMN) is a location-based mobile outdoor game, where two teams chase and catch each other in a physical environment. Crabtree describes how observing users with new technologies within their actual context of usage can drive innovation. The study improved the game through three constitutive experiments. User-interaction with the technology and the communication between the players was observed. One interesting observation was how the players overcame technological weaknesses of the system to improve the performance of their own team. The players e.g. communicated with each other in zones, where GPS was unable to localize players. In these zones players could hide and avoid to be caught.

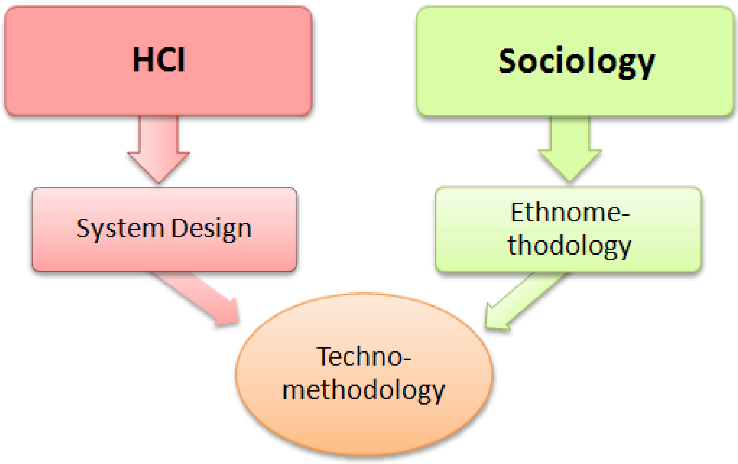


Figure 2.3: Influences of Technomethodology

Introducing the Homo Ludens to HCI

Derive theory from practice based research

This section discusses studies which push the boundaries of HCI and move the in-field studies away from the task-oriented milieu. One main driver is William Gaver from the Goldsmith University of London. His approach is to confront the user with new technology without explicit explanation of it. His work is based on concepts of the homo ludens.
Gaver describes his design-vision for the homo ludens, exemplifies it [Gav02], and observes the changes to his vision [Gav08]. He explains how theory can be derived from practice-based research [Gav06] by exploiting these principles.

One of his first works that derived from this idea [GDP99], was used in the Presence Project[5], funded by the European Commission. The goal of the project was to increase the presence of the elderly in their local communities in three different cities, Oslo, Amsterdam and Pisa. For each one of the three communities the researches prepared a package for the participants of

[5]http://www.hookerandkitchen.com/presence/

the experiment. These packages, named cultural probes, contained maps, postcards and other utensils, the participants had to utilize during the experiment phase. The purpose of the materials was to perceive requirements for the individual communities with the help of these cultural probes.
This work is important for the HCI-community because it shows a different way of requirements engineering, contrasting the task-oriented approach.

2.3.2 Techniques to Understand People in Mobile Computing

This section describes methods for identifying requirements and for increasing the usability and user experience in mobile computing. A fraction of the presented methods are conducted to improve the design of the in-field experiment in this thesis.

Surveys

Surveys encompass different methods to receive participants' answers to specific questions. These can be research questions or questions asked for a marketing company. Depending on the exploited techniques participants' answers lead to specific conclusions.
We differentiate three techniques to ask for a user's opinion.

Reception of user feedback

Observation The goal of participant observation is to monitor participants in their natural environment so that realistic conclusions are drawn from their behavior. Researchers watch the user's behavior in general or in dependence to the observation's objective. In an observation participants take a passive role.

Questionnaire Questionnaires can be used in the beginning of a development process, used as a tool to identify requirements, or during an evaluation to support its findings. Questionnaires can be structured, semi-structured or unstructured. The differentiation depends on if only open or closed questions are asked in the questionnaire, or a combination of both.

Interview In an interview, the researcher asks the participants face-to-face, which is the main difference between an interview and a questionnaire. You can distinguish between informal and formal interviews. An informal interview more resembles a conversation where open questions are asked and the interview does not always follow the same path in contrast to formal interviews. Interviews are helpful when the interviewee is not familiar with the interview topic. In this case the interviewer has the possibility to guide the participant through the interview.

Scenarios

Short stories of use cases

Scenarios are short stories, that describe the interaction between users and devices in specific situations. Their general goal is to give a short and clear description of a use-case. Carroll [Car00] lists the following features a scenario should contain. They can be used as a template for an easier creation process:

Setting *This is the starting circumstances for the story. Remember the fables you heard when a child; they always started 'Once upon a time ...' and went on to tell you where the action was set. Just as these opening words in the story above help place yourself in Little Red Riding Hood's[6] world and moment, so should the setting of the scenarios you write.*

Actors *The extract from Little Red Riding Hood, above, also lays out the key players. Scenarios can be written without reference to specific personas[7], but it is better to include them.*

Goals or objectives *What do the personas want to achieve in the situation?*

Action or events *Here, you detail the steps the persona takes in trying to achieve their objectives.*

Scenarios are a lightweight method in user-centered design, they allow easy definition of features and point out possible hurdles for new systems. Therefore they are popular among HCI-designers. They are to be distinguished between "As-Is Scenarios" and "Visionary Scenarios". The type of scenarios one describes a situation as it is, whereas the other type describes a situation as it could be.
There are also guidelines on how to enforce scenarios through the whole development process of a system [RC07].

Prototypes

The main goal of a prototype is to give the user an overview about the device's main functionalities and to identify usability problems. Prototypes are divided into two areas, in low-fidelity prototypes and high-fidelity prototypes. Both types can be tested earlier and later in the development cycle. The classification is blurred, not all prototypes fall into one category or the other. It is more like a range which starts with basic paper prototypes and ends with beta systems.

[6] Rotkäppchen for German natives.
[7] Personas are models of persons with concrete characteristics and/or user-behavior

Low-fidelity prototype The main benefit of low-fidelity prototypes is that they're easy and fast to sketch. Low-fidelity prototypes are very useful at the beginning of a development cycle for receiving first responses about an idea and also because basic UI design is used without writing any code [KK05]. They avoid needless waisting of resources for not elaborated ideas. The prototypes can range from one-paper prototypes with only one interface to prototypes which represent the whole menu with its sub-menus.
The main disadvantage of those prototypes is that the user may have difficulties to see the benefits of the new device, especially in mobile usage, where devices are used in a different context.

High-fidelity prototype The main benefit of high-fidelity prototypes is that they can be examined in near-real case scenarios. This gives the user a better understanding on how and when the prototype will be used and will lead to a higher probability of discovering usability issues, especially in the mobile context. It is easy to understand that e.g. an evaluation of the usability of a Location-Based System (LBS) will be much more accessible for a participant with a high-fidelity prototype than with a low-fidelity prototype [RKH08]. During the evaluation only certain features of the prototype are tested, depending on the predefined evaluation goals. The goal can be to evaluate as much features as possible, without any implemented functions. This method is classified as *horizontal prototyping*. A *vertical prototype* on the other hand, implements a particular part of the functionality of the prototype and this will be tested.

Important for evaluating a LBS

Matt Jones and Gary Marsden summarize the advantages and disadvantages of both kind of prototypes [JM06] based on Rettig's work [Ret94].

Think-Aloud Protocol

The think-aloud protocol is an often used method in usability testing. In this method participants comment on what they're thinking while performing certain tasks. Research in cognitive psychology found out that letting a user talk while performing a specific task resulted in more reliable results than querying the user after the task. This is due to the minimal capacity of the short-term memory of human beings [ES80, ES84].
However, users may be embarrassed to verbalize their thoughts in an unfamiliar environment and they also tend to stop talking, which is another risk in a think-aloud protocol. To face these hurdles Nielsen presented an other form of think-aloud protocol, the so called *constructive instruction* [NM94].

Self-Report Diary

A self-report diary is an established method to monitor participants in a passive way during an evaluation phase. It is used if a study should be conducted over a longer period of time and/or evaluators cannot accompany the participants because of lack of resources or privacy concerns.

Monitors participants passively

Participants document their interaction with the evaluated system in a predetermined way. This can be done with a form of diary e.g. see [BSO00], questionnaires or video recording. It is important that participants don't have to carry recording devices that are too heavy. They should be lightweight so that the experiment represents a natural interaction between the participant and the tested system. The evaluators have to think about the length of the evaluation period, what kind of observation is needed and how often participants should make an entry into the diary.

The main disadvantage of this method is that the evaluators loose control over their experiment by not monitoring the participants in-situ and by relying on the subjective comments of the participants.

Wizard-of-Oz

Simulation of a system

The Wizard-of-Oz method [GCH83] simulates a fully functional system to participants in an experiment. But in fact there is a researcher acting as the "Wizard" in the background, and responding to participants' input as does the system. Participants are unaware about the simulation, it seems to them as if they are interacting with a fully functional application. The advantage of this method is that it allows rapid prototyping without worrying about the total implementation of the system. Results have proven that Wizard-of-Oz is a good method if resources do not allow the implementation of a fully functional prototype.

Heuristic Walkthrough

Heuristic walkthrough, introduced by Sears [Sea97], a usability inspection method, has it seeds in other usability inspection methods, namely heuristic evaluation [NM94], cognitive walkthrough [WRLP94] and usability walkthrough [KCF92]. Heuristic walkthroughs incorporate a list of user tasks and a list of questions that highlight important parts of the interaction process.

Sears defined the heuristic walkthrough as a two-step process. In the first step evaluators execute tasks from the priority list of user tasks. The evaluators are allowed to complete the task in an arbitrary order without any time constraint. In the second step the evaluators have to fulfill predefined tasks against a list of usability heuristics. In this case the evaluators have the chance to examine any part of the system in order to look for usability problems. Heuristic walkthroughs are often used as a usability inspection method. They are less expensive than user-tests and deliver respectable results with few experts.

Ethnography in HCI

Ethnography is a research method to observe, describe and analyze interaction of people with each other or with the environment, it is usually conducted in long-time studies. Ethnography has its seeds in anthropology and has established itself as a research method in Mobile HCI because it allows observing the interaction of people with new technologies in their natural environment in qualitative experiments.

Conducted in long-time studies

Ethnography focuses on how people do something, and allows conclusions for the improvement of the usability of mobile devices. Ethnographers utilize observing methods, like detailed description, voice or film recordings. The main challenge is to preserve the observations made from peoples' interaction with emerging technologies. Ethnographers can only be at one place at the same time, but experiments with ubiquitous systems confront researchers with the problem to gather all the information. This makes objective examination difficult. Crabtree et al. [CBG+06] suggests guidelines to improve ethnographic studies in-field, but also points out that these guidelines have not yet matured and further investigation is essential.

The findings of ethnographic studies are important for Mobile HCI because they allow the discovery of important usability problems in real case environments. However, ethnographic studies are laid out for long-time observation, making them laborious. Researcher have to decide whether resources allow the procedure of an ethnography.

2.4 Related Work

After the two terms context and context-awareness have been defined, specific research that examines context-awareness in Mobile HCI will be presented. The importance of context-awareness in the mobile environment has been discussed. To substantiate its significance related research which deals with context-aware mobile systems is documented.
Hereby research will be dissected into the following two approaches: Techno- and Human-centric research.

Table 2.2: Comparison of research methods

Research method	When to use	Result type	Complexity
Observation	At the beginning of a project	Qualitative	low - middle
Questionnaire	At the beginning to receive user opinion or after an experiment	(Mainly) Quantitative	low
Interview	At the beginning to receive user opinion or after an experiment	Qualitative & Quantitative	middle
Low-fidelity prototype	At the beginning to receive early user-feedback about the design	Qualitative & Quantitative	low
High-fidelity prototype	Later in the project phase, when users test a prototype in near-real case scenarios	Qualitative & Quantitative	middle - high
Think-aloud protocol	During experiment	Evaluation of device by users	middle
Self-report diary	During experiment	Diary notes from user	middle - high
Wizard-of-Oz	At the end to evaluate almost final design	Qualitative & Quantitative	middle - high
Heuristic walkthrough	After first design concepts have been developed	Quantitative	middle
Ethnography	Anytime	Qualitative	high

2.4.1 Techno-Centric Research

Gellersen et al. [GSB02] derived context from a collection of diverse simple sensors. They were integrated into small devices. The research was conducted under the custody of the European research project TEA[8]. The objectives of the research were on the one hand to exploit the data of novel multi-sensor devices to create context-awareness, and on the other hand to use technology that is relatively cheap. In several experiments [STL01] they exploited sensors in mobile phones to identify callers who were assigned a specific profile. The mobile phone was exposed to different situations (in-hand, on-table, in-pocket, and outdoors), and the TEA phone recognized these situations with a certainty of 87%. But the recognitation had a delay of up to 30 secconds.

Another techno-centric initiative was the Place Lab project[9]. The idea of Place Lab was to develop an ubiquitous positioning system. One of the main requirements was, that the system should also work within buildings, – an advantage over the Global Positioning System (GPS).
In Place Lab Wi-Fi and Global System for Mobile Communications (GSM) cells are fingerprinted. Fingerprinting is a process which saves access points with their geographic coordinates, signal propagation and strength in a database. The positioning error in Place Lab can reach a value between 15 and 20 meters in very dense urban areas [HLS06], but can increase to a value way above 100 meters in less covered areas. Although Wi-Fi and GSM beacons are more likely to work inside buildings because of their greater signal strength compared to GPS-satellites. GPS can operate almost all over the world, whereas Wi-Fi and GSM positioning can only be done if a database like the Place Lab contains entries to the associated location. The problem of fingerprinting is that it is a laborious method, hence Place Lab focused on a community approach, where it benefits from volunteers. However, compared to GPS worldwide coverage the Place Lab database is still very fragmentary.

Evaluation of Wi-Fi positioning system

Hightower et al. [HCL+05] used their positioning system to conduct several technology evaluations. One evaluation focused on determining people's whereabouts through the help of Place Lab and their developed algorithm *BeaconPrint*. BeaconPrint's goal is to support the task of automatically assigning names to positions. In a month-long evaluation phase, BeaconPrint identified and learned about 64% of people's whereabouts with only one visit, the accuracy increased up to 80% with two visits.

[8] Technology for Enabling Awareness, http://www.teco.edu/tea/
[9] http://www.placelab.org/

Both projects are good examples on how to evaluate user behavior in a mobile context-aware environment with a techno-centric approach, first creating the novel technology and then confronting the user with it.

2.4.2 Human-Centric Research

The human-centric view observes human interaction, alone or in a group, with the support of mobile devices. The main goal is to understand humans' behavior in different situations, within the context of mobile computing.
However, this investigation exceeds the borders of Computer Science. An example for a human-centric research is Dearman et al.'s comparison of humans on their rendezvous behavior with and without location-aware devices [DHI05]. The main objective of the experiment was to investigate how location-awareness influences rendezvous behavior. Results where documented in a qualitative analysis. This approach indicates how a typical human activity, rendezvous behavior, can be examined with a novel technology, location-awareness. Findings of these types of experiments lead to better understanding on how to integrate new technologies into people's daily activities, in short to increase the user experience.

Methodologies from other fields of research like cognitive psychology, sociology and anthropology have to be involved to make this research valuable. Section 2.3 takes a deeper look at this discussion.
In general, the human-centric approach is still lacking of research. Most of the research concentrates on novel system design. In Mobile HCI and context-aware systems there is only little focus on humans first and then on system design.
The GUIDE Project [CDM+00] is one of the important works in this area, which examined extensively human behavior with a mobile context-aware tourist guide. Section *2.4* will take a detailed look into the GUIDE Project.

In-field research is important to find usability issues

Garzonis reviews research in this field [Gar05] and concludes that though in-lab experiments have their entitlement, in-field research put mobile context-aware systems into realistic situations of usage. They yield to real usability problems related to real context of use. That makes in-field studies so important in this research area.
This is the exact basis of the thesis, the investigation of serious usability problems. They are mainly identified in actual use cases, therefore a state-of-the-art in-field experiment is conducted.

The conjunction of new technologies in real context of use lead to a discussion in the research community on how to incorporate methodologies from different research areas into HCI. That is what basically is encompassed in Paradigm III (see Section 2.1.1).

2.5 State of the Art

This section examines significant research for this thesis. It will be denominated, discussed and the open questions on which this thesis will investigate will be accentuated.

2.5.1 Levels of Interactivity (LOI) of a Context-Aware System

The question on how to deliver information of context-aware systems (CAS) to users was investigated in different projects. The work will be analyzed and the points in which this thesis differs from the state of the art will be highlighted.

Interactive and Proactive Context-Aware Retrieval (University of Exeter, UK)

Brown and Jones [BJ01] define the information retrieval of a CAS as context-aware retrieval (CAR). They divide the retrieval of CAS into *interactive* and *proactive*. In an interactive CAR the user issues a request to retrieve relevant information. A proactive CAR presents relevant information automatically.

The GUIDE Project (Lancaster University, UK)

Cheverest et al. [CMD01] compare information push versus information pull in their GUIDE Project [CDM^{+}00]. Both terms describe methods how information-updates can be triggered in a CAS.

A push-based CAS updates data through *implicit-input* [Sch02] of the user, e.g. the movement of a user. In contrast, the user has full control over data updates in a pull-based CAS, by manually requesting data.
The goal of the GUIDE Project was to examine user behavior with a mobile CAS. Therefore the researcher built a tourist-guide infrastructure in Lancaster. Users of the in-field study were provided with mobile location-aware clients. The study itself was not task-oriented, so that participants used the mobile tourist-guide at will. The results of the experiment were obtained through direct observation with the think-aloud method and gathering statistical data through direct user interaction with the mobile device.

Information Pull	Information Push
+ Stimulus for information comes from the user; the user is already focused on using application.	+ Users show great acceptance for push-based approach.
+ Fits the browser metaphor better, which is provided by GUIDE, e.g. the refresh button.	- Content currently read may disappear in case of a simultaneous update[10]
- Information can become inconsistent to user's current context.	
- Users may forget to pull information or may get tired of pulling information.	
- Field trial showed that users were unsure when to push the update-button.	

Table 2.3: Information pull vs. information push

The system independent findings of the two different levels of interactivity are listed in table 2.3.

Low positioning granularity

Although the GUIDE Project had a big impact on the research community, it left some open questions, especially for the push-based study [CMD02]. For the localization, WLAN-triangulation was exploited, but only a few reference points for the localization were used, which led to a low granularity for the localization itself. During the study two different clients were utilized, a big one (Fujitsu TeamPad 7600) and a small one (Compaq iPAQ). However, the small client was only evaluated with a mock-up interface, it was not really tested in the study and users had to imagine how the interaction with the small client would be. There was no actual examination of the study with a smartphone-like device. However, participants still preferred the small client.

No evaluation with smartphone.

PUSH imitated through Wizard-of-Oz

For the push-based study the Wizard-of-Oz [Hö6] method was used. This means that the actual localization for the push-based Tourist-Guide was not implemented, instead it was manually triggered with a remote device. Anyways the participants revealed enthusiasm for the push-based concept.

[10]Cheverst et al. changed the immediate updates to an interactive update in later studies

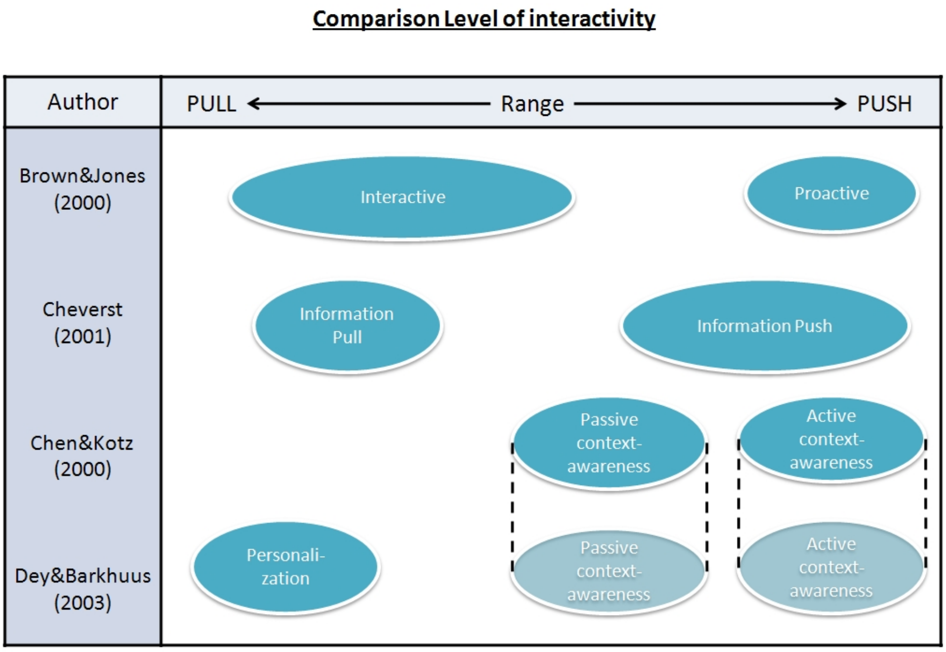


Figure 2.4: Level of Interactivity

Active and Passive Context-Awareness (Dartmouth College, USA)

Chen and Kotz [CK00] define *context* from their point-of-view and from this derive the definition of the terms *active context-awareness* and *passive context awareness*. Figure 2.4 illustrates the meaning of both terms and puts them in context to related work. Chen and Kotz discussed related context-aware applications and categorized them into these two groups.

Three Levels of Interactivity (LOI) (The IT University of Copenhagen, DK and Intel Research Berkeley, USA)

Louise Barkhuus and Anind Dey [BD03] exploited both levels of interactivity (LOI) of Chen and Kotz and an additional interaction type, which they named *personalization*, in an experimental user-study.
In their study a between-subjects design was chosen. This design separates participants in groups for each of the different conditions in the experiment. Each participant is tested once only.
In the study every participant had to test six services:

A Private ringing profiles
B Public ringing profiles
C Lunch service

D Class slides
E Location tracking
F Activity tracking

These were examined with one of the three conditions (levels of interactivity):

1. Personalization
2. Passive Context-Awareness
3. Active Context-Awareness

Barkhuus and Dey made the presumption that participants would prefer personalization over the other two LOIs. But results of the experiment showed something else. People tended more towards the other two LOIs than to personalization.

Participants were not monitored.

Not all services implemented

Regarding the experiment there are two main reasons why more investigation is needed. Firstly, the experiment was based on a self-report diary. Thus, participants were not monitored during the experiment. Secondly, not all services were implemented within each LOI, participants had to more or less imagine that the service is working and had to write their self-report based on assumptions.
Hence it is difficult to measure how reliable the answers of the participants were, especially for the not implemented services.

2.5.2 In-field Evaluation in the Mobile Context

Studies focused not only on task-oriented quantitative analysis of the user's interaction with devices, but also on the user's behavior outside this task-oriented milieu [Gav02, GBPW05] or like in the GUIDE-Project described in detail.

TIP, a mobile tourist information system (University of Waikato, NZ and University College London, UK)

No in-field evaluation of presentation style.

A. Hinze and G. Buchanan [HB05] discuss the user-related challenges with a context-aware mobile tourist information system. They propose different possibilities on how data should be filtered and represented on a list-based UI.However, no in-field experiment has been conducted to verify their hypothesis.

Evaluating the Usability of a Mobile Guide (Aalborg University, DK and University of Melbourne, AUS)

The findings of Kjeldskov et al. [KGP+05] indicate that in-field studies have the greatest probability of discovering critical and serious usability problems in real world context among four evaluation methods: 1. Field evaluation, 2. Lab evaluation, 3. Heuristic walkthrough, 4. Rapid reflection. These results give an additional motivation to conduct in-field study with the goal to suggest novel user-guidelines for the usability of mobile context-aware systems.

High probability of finding critical and serious usability problems

2.5.3 Adaptive Interfaces

An important aspect in mobile computing is the adaption of the UI of mobile devices'. The works of Kane et al. [KWS08] and Yamabe et al. [YT07] have investigated this usability issue. They have evaluated approaches to improve the UI for walking users.

Walking User Interface (WUI), (University of Seattle and Intel Research Seattle, USA)

Kane et al. conducted an in-field experiment which evaluated the feasibility of a walking user interface (WUI). They have developed an music player whose UI adapts to users' walking speed. In their study participants performed a set of tasks in two different conditions, walking and standing, with the adaptive UI. The UI switched between two interface sizes: a *complex* (small-button) size and a *simple* (large-button) size. In the study the adaptive UI was tested against two static interfaces. The main finding of the study was that the WUI did not perform better than the static interfaces. The result was caused by the design of the WUI. The buttons of the *complex* interface were too small to be comfortably pressed. Therefore it has to be investigated if the general concept of the WUI does not increase the usability or if the specific design of this work was flawed.

UI Design flaws

In this study the adaption of the WUI was imitated with the Wizard-of-Oz 2.3.2 method.

UI Adaption for Walking Users, (University of Waseda and University of Tokyo, Japan)

This work evaluated an adaptive UI with three sizes, small, middle and big. In their feasibility study they tested two different applications, the *TextViewer* and *ImageViewer*. Both adapt the content in the interface to users' walking speed within the three pre-defined sizes. The results of the

Issues with UI adaption

TextViewer showed no improved usability for the adaptive UI compared to static UIs. The *TextViewer* performed worst in the study.
In this study the *TextViewer*'s UI had flaws in the adaption process. It has to investigated how users behave with a different developed UI adaption.

2.5.4 Open Research Questions

Classification into 2 types of problems

The discussion of the state-of-the-art research has unfolded a set of open research questions that this thesis will focus on. They are classified into usability and methodical problems. Usability problems are issues that refer to the design or features of the applications. Whereas the methodical problems relate to technical issues which the mentioned context-aware systems could not solve:

I. Usability problems

a) **No evaluation of the presentation style**
A. Hinze and G. Buchanan [HB05] discuss different ways of presenting information on a spatial LBS. However, they have not evaluated their hypotheses. The works of Kane et al. [KWS08] and Yamabe et al. [YT07] have evaluated their hypotheses with participants but their prototypes had design flaws. Therefore it has still to investigated:
What is a efficient and user-accepted way to present spatial data on mobile LBS?

b) **Low configurability**
The presented LBSs did not allow high configurability [CDM+00] or the configuration was not actual implemented [BD03]. It has still to be investigated how much of the features of a context-aware system should be processed by the system itself or by the user [BE01].
How much much control should be assigned to the user of a context-aware system?

c) **Content Adaption**
Participants liked the push-based LBS [CDM+00], but it was not examined how participants react when the spatial content is overwritten. Participants of a push-based LBS control the system implicitly by their movement [Sch02]. This approach can create situations where currently read information by the user can be overwritten because the system is updated with new information.
How would participants react to content overwriting after location updates of a fully implemented LBS?

II. Methodical problems

a) **Location Granularity**
The LBSs that had been evaluated had low position granularity [CDM+00]. The technology of mobile LBSs as vastly evolved, hence new investigation is needed to observe the effect of improved position technology with potential users.
How is user-behavior influenced by a LBS with higher position granularity?

b) **No evaluation with smartphones**
The presented LBSs [CDM+00] [HB05] did not evaluate a fully implemented systems with state-of-the-art smartphones. It is important to evaluate todays state-of-the-art smartphones in real case scenarios. They express a more exact image of the reality and therefore reveal serious usability problems [KGP+05].
Which kind of usability problems does the evaluation of a fully implemented LBS reveal in a in-field experiment?

c) **Implementation of different LOIs**
The presented push-based Levels of Interactivity (LOI) were not implemented, they were imitated by the Wizard of OZ method [CDM+00] and [KWS08]. Therefore it would be interesting to evaluate how users interact with a push-based LBS in comparison to prior research.
How do users behave with a fully implemented push-based LBS?

The six listed open research questions can be formulated in one question which expresses the general goal of this thesis.

Thesis Question: *How do users of a mobile LBS behave in a task-oriented in-field experiment with different presentation styles?*

The objective of this work is to give answers to the listed questions. The answers will help to understand user-behavior in their actual environment and therefore it will push the research forward.

6 open research questions

The mentioned problems create the basis for the development phases of the thesis.

2.6 Summary

This chapter provided the basis for development of the diploma thesis. The thesis was put into its research context.

The first part of the chapter gave an overview about the development of mobile HCI. It explained the technical terms Usability and User Experience and described the characteristics of mobile HCI. The three paradigms of HCI were explained. This work was classified to the third paradigm *Situated Perspective*.

The next section introduced the terms context and context-awareness and explained why they are important for the UX in Mobile HCI. The purpose of context-awareness in HCI is to provide the user with relevant information to overcome the increasing information and service overload.

Important Methodologies and methods of HCI were discussed. They have emerged because computers are becoming a more and more important part of people's daily life, and researchers need to understand the new interaction spaces between human-beings and computers. In this thesis User-Centered Design is used as the basic design philosophy. Throughout this work certain methods are conducted which follow this design philosophy. A set of well-established methods were reviewed. Some of them are carried out in this work to receive the requirements for the in-field experiment and to raise its quality.

The next section presented related work which examined context-awareness in Mobile HCI. Hereby research was dissected into the two approaches: Techno- and Human-centric research. The last section focused on significant research for this thesis. Open research question were discussed. They were divided into usability and methodical problems.

The goal of this work is to find answer to the identified problems. The next chapter presents the concept of how the answers to the open research questions will be delivered.

Chapter 3

Conceptual Approach of the Push-Based LBS

The six open research questions identified in subsection 2.5 established the ground structure for the in-field user study that will be conducted in this work. The quality of the user study will be raised through User-Centered-Design. Potential users will be involved into the design process by using techniques discussed in subsection 2.3.

The standard does not prescribe specific methods to achieve these goals; they are to be chosen according to what the state of the art is and what is appropriate under the individual research. Based on the methods used in the related work (Section 2.4) and in the state of the art (Section 2.5) this work devises a scenario-based approach for mastering requirements, combined with user interviews, use cases and expert analysis, based on the structure proposed by Robertson et al. [RR06].

This chapter discusses the path from the idea of the thesis to the final requirements of the prototype and the structure of the final experiment. In the initial step, users' opinion is gathered by semi-structured interviews. These results will lead to scenarios which describe possible features of the prototype and its exploitation. The interviews, the scenarios and the use case will define the requirements for the prototype. The selection of different methods to receive requirements assure a certain level of quality. All three techniques were explained explicitly in Section 2.3.2.

The whole development process of the thesis is illustrated in Figure 3.1, it describes the individual steps that will be proceeded.

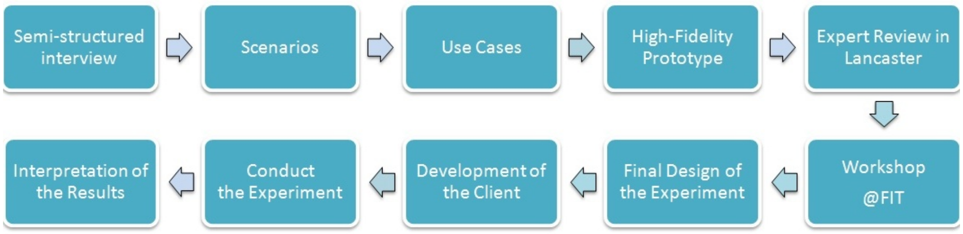


Figure 3.1: Planned development phases for the thesis

3.1 Requirements Analysis

This section introduces methods which ask for the users' interests of a mobile LBS. Potential users will be interviewed to derive user requirements. Scenarios and use cases, two additional techniques, are conducted to define requirements. The final requirements are documented in Volere *Requirement Sheets* .

3.1.1 Interviews

Subsection 2.3.2 described different ways to ask for users' opinion. This thesis chose semi-structured interviews as the best possibility to perceive requirements for the prototype. This type of interview gives the interviewer the chance to guide the interviewee through the questions and to drift away from the pre-planned structure if an interesting discussion arises. Although semi-structured interviews consume more time and effort than questionnaires, it was more important to discuss the user's opinion face-to-face.

Goal of the Interview

The main goal of the interviews is to perceive the user's point of view on mobile LBSs. The interview should give answers to three questions that are of special interest:

- *Where does the user see the greatest benefits or drawbacks of a location-aware application?*
- *How much control is the user willing to hand over to the application?*
- *How should the location updates of a LBS be executed?*

The set of total 14 questions for the interview can be divided in two parts (Appendix A). The first half gathers information about the user and his mobile phone usage, the other half focuses on the three key points mentioned before.

Interview Results

The interview was conducted in a face-to-face conversation, where the questionnaire provided a basis for the interview flow. 16 participants were interviewed, with an average duration of 39 minutes. The following part displays the result of the interviews.
During the interview participants were asked to give their own definition of a LBS. Five people gave an appropriate definition of a LBS and six had a basic idea about what a LBS is. So 69% of the interviewees had at least a basic knowledge of what a LBS system is. After that, the interviewer explained how a LBS works with the help of an example. The participants then were asked about their general interest in using a LBS.

69 % know what a LBS is.

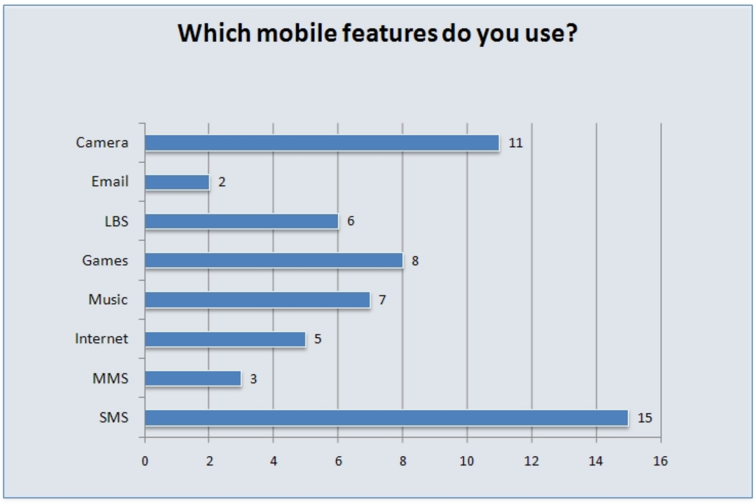


Figure 3.2: Features used by the interviewees

Although 88% were at least interested in using LBSs, only six of them had used LBS with their mobile device (Figure 3.2). The reason was that the mobile devices of the other participants did not have the features to exploit LBS or the service was to expensive to use.
The next part of the interview focused on the kind of features users of a LBS would want. The interviewer asked participants how much control they want to have over the LBS and how the updates should be performed.

Interpretation of the Results

81% of the interviewees want to have much control over the LBS, meaning that the application should allow high configurability. Regarding the update-type, answers were more diverse (Figure 3.3), which lead to the interpretation that different update-types should be provided. On the question in which cases the interviews would like to use a LBS, 81% said that

81% want high configurability.

Implement different update types!

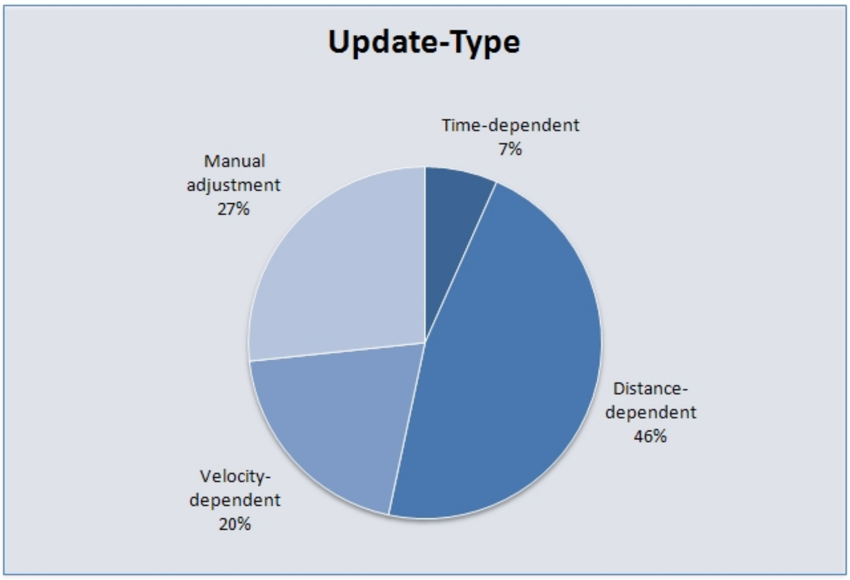


Figure 3.3: Demanded update-types for a LBS

they would like to receive interesting information in unknown places. The conclusion from the interviews are summarized by the following points:

- The participants have a high demand for LBSs.
- The participants want a high configurability for LBSs.
- The participants ask for different ways for updating the information.

3.1.2 Scenarios

The results of the interviews were discussed in a brainstorming session, which led to the classification into three main categories of functionalities for the LBS. 1. High configurability, 2. Automatic content-adaption and 3. Adaptive update-rate. Three visionary scenarios illustrate the categories. The scenarios describe mobile systems that exploit additional information about user's situation and his context, other than his location. The additional context-awareness indicates to-be-developed features for the high-fidelity prototype.

3 scenarios describe requirements

Scenarios are short stories which describe use cases, subsection 2.3.2 explains the usage of scenarios in detail.
The first scenario shows that the prototype requires the provision of high configurability. The second scenario focused on the adaption of the user's context information; download size is adapted to the device's current

download speed. The last scenario exemplifies the adaption of the number of location updates to user's velocity. With the help of these scenarios the requirements for the prototype will be acquired.

Scenario I: Change configuration *Andreas, a German citizen, plans to spend his holiday in USA. Staying in New York the first days of his holiday, he wants to try out his new application WikiNearYou. WikiNearYou is a location-aware application for mobile devices which displays Wikipedia Sites depending on the geographic position.*
So walking by the Empire State Building, his mobile phone indicates that there is Wikipedia information available. It's Andreas' choice whether he wants to read the information from the German Wikipedia site or not. Knowing that the English Wikipedia site has far more entries than the German one, he switches the language attribute in WikiNearYou from German to English. After that, the application shows more information about the current position.

Scenario II: Smooth Changes *Barney is an enthusiastic user of ImageLocator. So whenever he utilizes ImageLocator on his 3G-mobile phone images of nearby locations are downloaded to his mobile device.*
One of ImageLocator's features is the ability to adjust the downloaded data automatically, so in the cases when Barney is outside a 3G network or Wi-Fi-Spot, ImageLocator notices that the mobile device is using the GSM-Network. Within the GSM-Network ImageLocator reduces the amount of media data downloaded or the resolution of the images or both, depending on the pre-defined configuration determined by the user. With this feature the user-experience is increased because Barney never need to bother about with long waiting period while using ImageLocator.

Scenario III: Velocity *Samaire uses her smartphone on her business trips for all kinds of needs, especially GeoLocator, a context-aware application for mobile devices. The application allows Samaire to receive information depending on her current location and velocity. So when she walks through the city center to reach her next meeting, GeoLocator sets the update rate to a maximum. Realizing she would not make it in time to her appointment, Samaire decides to catch a cab, in the cab GeoLocator decreases the update rate because of the higher velocity. At her destination she enters the office building, where she attends to a meeting, GeoLocator recognizes that a building has been entered, so no more updates are made until the building is left. After the meeting Samaire takes the train home, in the train GeoLocator switches automatically to train mode.*

These three scenarios are the basis for the use cases to be discussed in the next subsection.

3.1.3 Use Cases

A use case diagram displays a relationship between actors and use cases [Oes01]. They will help to define the functional requirements for the prototype. The use case diagram has been terminated:
GeoBrowser Usage

Use case diagram: Geobrowser Usage

Update location list : The user or system initiates a location list update.

Load current list : Loads current location list.

Back : Jump one page back in the history.

Next : Jump one page ahead in the history.

Change Settings : The user can configure the settings to his personal preferences.

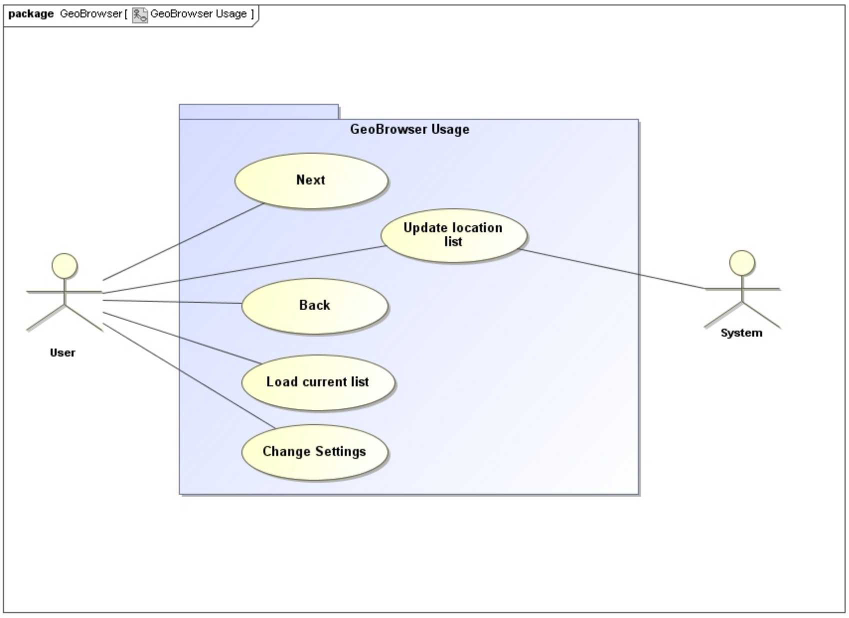


Figure 3.4: Use case diagram of *Geobrowser Usage*

3.1.4 Requirements of the Prototype

This work has gathered its requirements through user-centered design by interviewing potential users, creating visionary scenarios and from use

cases.
Robertson and Robertson [RR06] recommend the Volere process to ensure that all important aspects of requirements are carefully addressed. The philosophy of Robertson and Robertson is very much in line with ISO 13407 "Human-centered design processes for interactive systems" (see Section 2.1.2) and allows a structured processing of the requirements assuring that they remain always applicable and testable. The Volere methodology[1] has been chosen as suitable work which fits into the user-centered approach.

Volere process fits into design of the thesis

The Volere methodology uses a structured set of components for the specification of the requirements. The requirements are written in *Requirement Shells*, also called *Snow Cards*, as atomic components. The Requirement Shell is a template which contains obligatory and optional fields. The complete list of Requirement Shells is illustrated in Appendix B.

The functional and non-functional requirements were derived from three independent sources. They were gathered through the combination of semi-structured interviews, use cases and scenarios. The selection of different methods to receive requirements assures a certain level of quality.

Functional Requirements

1. **Increase the positioning quality**
   The mobile LBS requires exploiting different positioning techniques to increase the positioning quality of the application. The position quality has to be higher than higher than of prior research (see Section 2.5)

2. **Adapt location update intervals to the user's velocity**
   The mobile LBS requires implementing an algorithm to adapt to the user's velocity. Adaption of position update to user's velocity increases the user experience because users are disturbed by too few updates or are under-informed by too few updates.

3. **Adapt content to network speed**
   The mobile LBS requires to adapt the data volume to the current network speed. The adaption decreases latency and therefore increases the user-experience.

4. **Adapt content to the user's movement**
   The Content's presentation style adapts to the user's movement. The user's speed is interpreted as different use cases in which an adaption of the content will increase the usability.

[1] http://www.volere.co.uk/

5. **Assure spatial data quality**
   Geo-referenced content requires to be available in wide inner-city area where the study can be conducted. It also important that the spatial data has certain density.

6. **The application needs high configurability**
   The application requires to provide a high configurability. Users want to have the control over the LBS so that they can match the settings to their preferences.

Non-Functional Requirements

1. **Ease of use**
   The application has to be easy to use for the participants of the evaluation.

2. **Fast response time**
   The application must have a user-accepted response time so that the participants are not disturbed with dead time during the experiment.

3. **Assure high system reliability**
   The application has to have a high system reliability. This is a requirement which is very important for an experiment in the mobile context.

4. **Comply iPhone Standards**
   The application requires to fulfill the iPhone Human Interface Guidelines[2]. They assure the application's usability quality.

3.2 Development of the High-Fidelity Prototype

High-fidelity prototype

The pre-processed steps gathered sufficient information for the development of the high-fidelity prototype. The development of a high-fidelity prototype was essential. High-fidelity prototypes have the advantage that they can be tested in real case scenarios, and hence they have a high-probability for the identification of serious usability problems [KK05], especially for a context-aware application [RKH08].

Development of prototype mandatory

The omission of the evaluation of a high-fidelity prototype would increase the risk of running into usability problems while conducting the in-field experiment. This would be an unacceptable condition and it would put the work of the whole thesis in danger of failing. Therefore the development of the high-fidelity prototype is mandatory.

[2] http://developer.apple.com/iphone/library/navigation/index.html/

The objective of the high-fidelity prototype is to test it against the requirements which have been identified in the previous section. The application will be a context-aware Wikipedia-Browser. It provides spatial Wikipedia content with the help of an LBS.

3.2.1 The System Architecture

A Three-Tier-Architecture establishes the system design. It consists of the parts shown in Figure 3.5. This architecture separates the different conceptual parts (the tiers) physically.

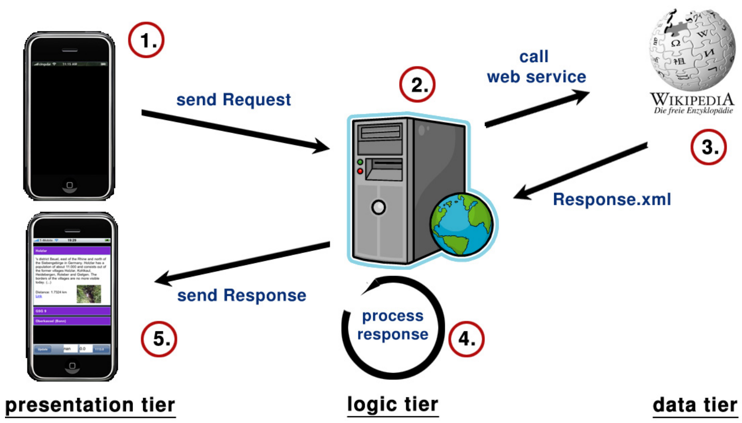


Figure 3.5: Design of the Three-Tier-Model

Presentation tier In this architecture the client is taking a passive role by acting as a data viewer (presentation tier). Its job is to send the application's parameters, the user input and sensory data, to the logic tier and to display the response from the logic tier within the application's user-interface.

Data tier The data tier is responsible for providing the content. The web service from geonames.org[3] will deliver the geo-referenced Wikipedia data. It provides a database of currently 610,000 geolocated Wikipedia entries[4]. The exploitation of this web service fulfills requirement #5 (see Appendix B).

Logic tier The logic tier is realized within an Apache Tomcat Servlet Container (Version 6.0.20), forwarding the client's request to the data tier and processing its response.

[3]http://www.geonames.org/about.html
[4]As of 10/01/2010

3.2.2 The Apple iPhone

Participants will interact with the iPhone during the user study. It is the key element for the participants and the user-study. The iPhone 3G will monitor participants' movement and gestures. Therefore it is important to give an insight over the device itself and its components.

The device

Given the requirements mentioned in subsection 3.1.4, the Apple iPhone 3G[5] will be chosen as the development platform. Its key features are:

- Multi-functional location service based on a combination of GSM cell recognition, WiFi SSID detection and Assisted-GPS, which fulfills requirement *#1*.
- Multi-Touch Display
- Sensors: Accelerometer, Proximity sensor, Ambient light sensor

The Cocoa framework

Cocoa is an application environment for the iPhone, it consists of an object-oriented frameworks that allows to run applications on the iPhone. Another part of Cocoa is the development environment with all its tools. It enables developers to create applications for the iPhone (or Mac OS).

Objective-C, a superset of ANSI C, is the main programming language for developing iPhone applications. It has been enriched with some syntactical and semantic features for object-oriented programming. More detailed information about the Cocoa framework can be found in the Cocoa Fundamentals Guide[6].
Figure 3.6 shows the Cocoa architecture stack with its different frameworks. The Core OS grounds the fundamental layer, it contains low-level functionalities that includes the kernel, the file system and network management. The frameworks in the Cocoa Touch level specifically support the iPhone OS.

Xcode and Interface Builder

Xcode and Interface Builder are two important components for the development of iPhone applications used for this thesis. The release version 3.2

[5] http://www.apple.com/iphone/iphone-3g/
[6] http://developer.apple.com/iphone/library/navigation/index.html

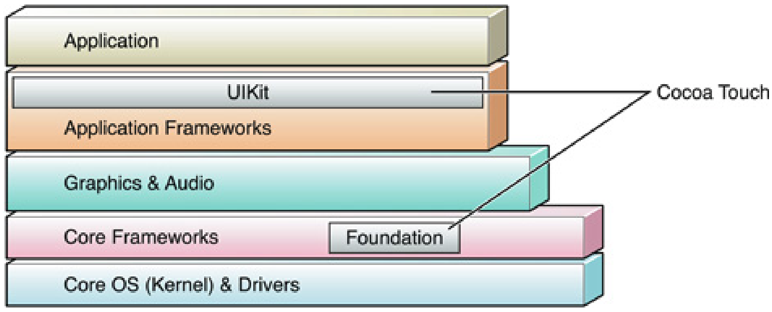


Figure 3.6: The Cocao architecture stack for the iPhone OS

of both of them will be discussed in this section.
Xcode is a state-of the art integrated development environment (IDE). Its main features are syntax coloring and automatic indenting for the editor, providing specific project and class templates, debugging the project on the iPhone OS simulator or on a remote device. The 3.2 release of Xcode also allows to perform a static code analysis.
Integrated into Xcode are two performance test applications, *Instruments* and *Shark*. The Instruments application monitors different measurements like memory allocation, CPU usage and other. Shark traces the execution of a program, e.g. specific function calls and memory allocations.

Interface Builder is an application for creating user-interfaces (UI). The UIs can be designed solely with Interface Builder or in conjunction with Xcode. The main advantage of using both applications together is that in Interface Builder a basic layout of the UI can be created and then programmatically manipulated in Xcode. Both components work well in cooperation.

3.2.3 The Context-Aware Wikipedia-Browser

This subsection explains the implementation of the Wikipedia-Browser. The features of the Wikipedia-Browser are set by the requirements provided by the interviews and scenarios. They were specified in subsection 3.1.4.

The Application

The application consists of two views, the first view is the presentation interface (Figure 3.7). The interface has three areas. Starting from the top, the first area is the statusbar. The statusbar's task is to deliver useful information to the user. It illustrates the a) positioning accuracy, b) current speed, c) average speed and d) download speed.

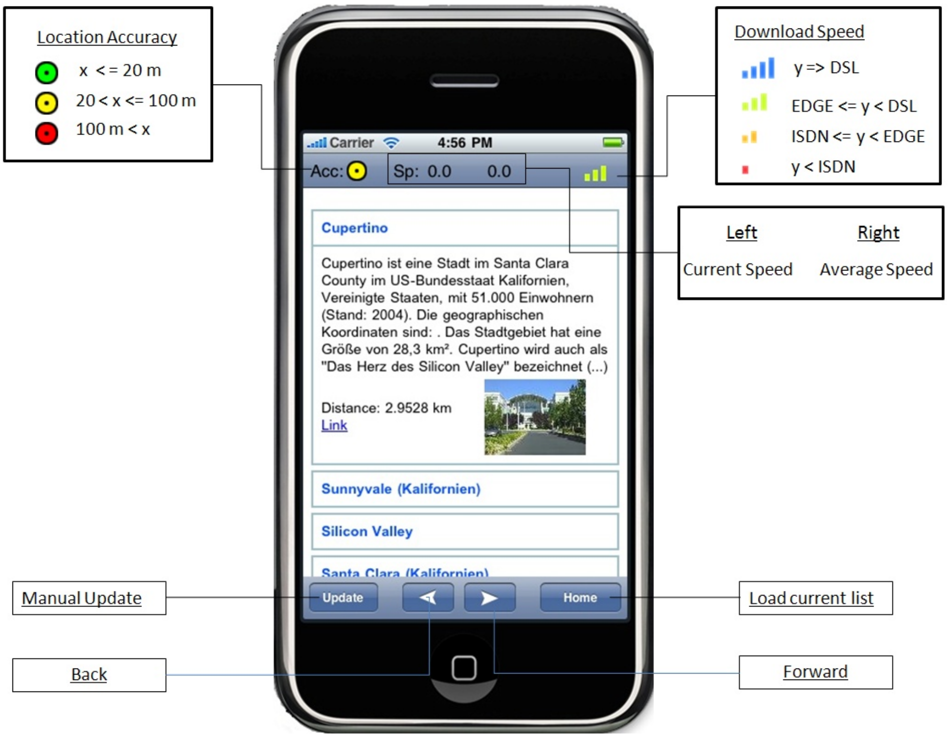


Figure 3.7: UI of Wikipedia-Browser

The main part of the presentation is reserved for an instance of the UIWebView class. The UIWebView is used to embed web content into a view. This view contains the Wikipedia entries which are sent from the logic tier to the iPhone. The content is composed with a combination of HTML and JavaScript. This approach has the advantage that the content can be displayed on different smartphones e.g. any Android[7] mobile device because the iPhone OS and Android's web browser is based on the same web layout engine (WebKit).
The bottom layer gives the user control over the application. He can control location updates by the far left button, if the button is pushed a new location update is initiated. If new data is available, the button text changes from "Update" to "New". On the opposite side is the "Home"-Button, if this button is pushed, the current location list with its Wikipedia entries is loaded. Both buttons in the middle help the user to navigate backwards and forwards through the Wikipedia content.

Features fulfill requirements

The second view is the settings view (Figure 3.8), which allows the user to adjust the application as specified by requirement #6.

[7] Android is Google's mobile software platform.

Vibration Notifies the user with a vibration if a new location update is available.

Update-Type The user can choose between three ways to initialize location updates.

- **Intelligent** The system monitors the user's speed and adaptively adjusts the update-rate *(Requirement #2)* and the content-type *(Requirement #4)*. It also measures the download rate and filters out the images if the download rate falls below a certain threshold *(Requirement #2)*.
- **Distance** Location updates are only executed after the chosen distance in the Update-Interval menu exceeds the distance to the position of the phone at the last update.
- **Manual** Location updates are only initiated by the user and not the system.

Update-Interval The user can choose between the distance interval values 50 meter, 200 meter, 500 meter and 1000 meter.

Content-Type The user can choose the type of content which he wants to receive. 1. Only text, 2. Only images, 3. Both.

Language The user can choose between four different language, in which the information is illustrated: 1. English, 2. German, 3. French, 4. Spanish.

The features of the context-aware Wikipedia-Browser fulfill all functional requirements #1 - #6 listed in Appendix B.

3.3 Expert Review/Workshop

The next two steps in the development phase (Figure 3.1) have been the expert review at the University of Lancaster and a workshop at the Fraunhofer FIT institute. The goal of the first part was the analysis of the context-aware Wikipedia-Browser. The results of the analysis were integrated into the workshop at FIT for the determination of the final requirements for the user-study.

The evaluation with experts has the benefit that it identifies usability problem faster and it consumes less resources in comparison to an evaluation with users. This approach was used to refine the requirements for the prototype and determine the design strategy of the in-field experiment.

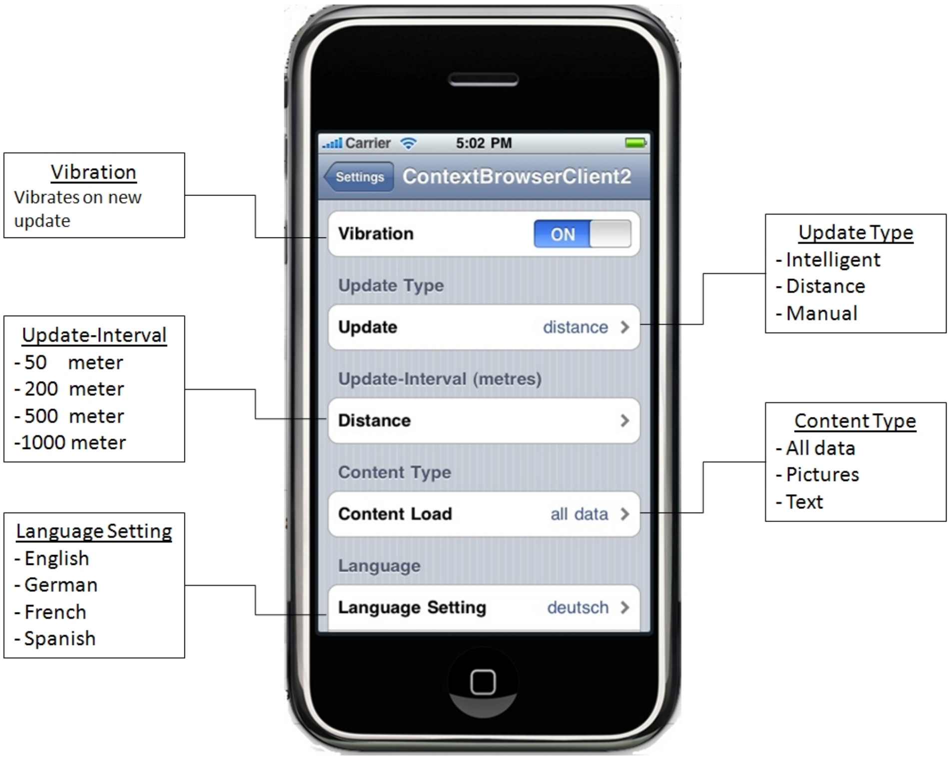


Figure 3.8: Settings view of the Wikipedia-Browser

3.3.1 Expert Review in Lancaster

Expert review in Lancaster

The expert review took place at the Computing Department InfoLab21 under the supervision of Dr. Enrico Rukzio and was preassigned for two weeks.

The plan for the visit in Lancaster was to examine the context-aware Wikipedia-Browser and then to determine which features of the application can be exploited for a user-study or how they may be extended.
The expert review started with a presentation of the Wikipedia-Browser and the goal of the thesis. After the presentation six experts, PhD-Students in Computer Science, tested the application individually. After the evaluation the experts were interviewed. The results of the interviews were gathered and summarized.

System issues identified

The findings of the expert review was that the existing features of the Wikipedia-Browser would not satisfy the standards for a state of the art user study.
Four main flaws of the application were identified:

1. **Wikipedia content not dense enough**

Since the study should be evaluated in Bonn or its surrounding, the Wikipedia location-based content is not sufficiently dense.

2. **Information cannot be categorized**
   The categorization of the data provided by the web service of geonames.org is too coarsely grained.

3. **Evaluation of different levels of interactivity in field too expensive**
   Examining the user behavior with three levels of interactivity (Subsection 2.5.1) demands too many resources which would exceed the scope of a diploma thesis.

4. **Evaluation of content adaptation to velocity difficult**
   It is questionable if the costs for monitoring participants during context switches, e.g. change from walking to driving, would outweigh the benefits.

As a consequence requirements for the application had to be refined within the workshop at FIT.

3.3.2 Workshop at FIT

Workshop @FIT

The findings of Lancaster were the basis for the workshop at the FIT Institute. The workshop dealt with two topics, the design of the in-field experiment and the flaws of the Wikipedia Browser. The four flaws of the led to five refinements of the functional requirements within the workshop. They are listed in Volere Requirement Sheets (see Appendix B.5). They mark the general layout for the user-study:

Refinements for the in-field experiment

1. **Create own geo-referenced data set**
   Produce an own set of geo-referenced data in a controlled environment in Bonn. This gives full control over the data quality and allows to distribute the data uniformly over a certain area.

2. **Data must be divided into categories**
   Every geo-referenced information should belong to a category. So it is recognizable that the size of the data set decreases when filtered by category.

3. **Only focus on push-based LBS**
   Only few studies have focused on the pure push-based LBSs, and the

majority of them imitate push-based technique with the Wizard-of-Oz[8] method.

4. **Examine different presentation and ordering styles**
   Let the participants of the study walk through the controlled environment. Give them several tasks where they have to identify specific objects. For every task the participants have to use a different presentation or ordering style to identify the objects. The presentation the information will be based on the concept of the mobile tourist information system, TIP, [HB05], where location based information is displayed in a list.

Refinement of experiment design

5. **Gather quantitative and qualitative data**
   Gather statistical data for the study from the iPhone and questionnaires. The data which should be logged is: the completion time per task, the number of touches per task, the participant's position. Qualitative data will be collected through a researcher who will accompany the participants during the study.

The design refinements of the final experiment require that the **Thesis Question** defined in Section 2.5 has to be stated more precisely:

Thesis Question (Version B): *How do users of a mobile push-based LBS behave in a task-oriented in-field experiment with different presentation styles?*

3.4 Summary

The first section introduced methods of the user-centered design to gather requirements. Potential users' were interviewed to derive user requirements. Scenarios and use cases were conducted to define requirements with two additionally techniques. The final requirements were listed in Volere *Requirement Shells*.

The pre-defined requirements were integrated into the development of the high-fidelity prototype. The development of a high-fidelity prototype, the Wikipedia-Browser, was essential. It had the advantage that it could be tested in real case scenarios. The omission of the evaluation of the Wikipedia-Browser would have increased the risk of running into usability and design problems while conducting the in-field experiment. This would be an unacceptable condition and it would put the work of the whole thesis in danger of failing. Therefore the development of the Wikipedia-Browser was mandatory. It was tested against the requirements which have been

[8] see Subsection 2.3.2

identified in the previous section.

The next two steps in the development phase (Figure 3.1) were the expert review at the University of Lancaster and a workshop at the Fraunhofer FIT institute. The goal of the first part was the analysis of the context-aware Wikipedia-Browser. The analysis revealed the flaws of the application. This result approves the assumption made in the previous section, that expert reviews have a high probability for identifying serious design issues. The results of the expert review were discussed in a workshop session at FIT. The discussion led to refinements of the requirements for the high-fidelity prototype and the determination of the design strategy of the in-field experiment.

Chapter 4

Planning and Implementation of the Experiment

This chapter documents three software engineering phases, software design, software development and software testing. The defined Volere Requirement Shells from the preceding chapter built the basic framework for the implementation of the experiment. They will be used as a metric to determine if the requirement specification have been met.
The goal of this chapter is to present a controlled environment in the city center of Bonn, where a fully working system can be used to conduct the pre-defined experiment.

4.1 Final Design of the Experiment

Final Design of the Experiment

An in-field experiment will be conducted to test different presentation styles for a mobile push-based LBS. The objective is to measure with which presentation style the participants cope best. Another important aspect of the experiment is to observe the participants' behavior to identify serious usability problems in a real case scenario. Therefore a tourist guide application will be developed for the mobile push-based LBS. Useful components of the Wikipedia-Browser are transferred into the development of the tourist guide application.

Development of a mobile tourist guide

A mobile LBS's most important feature is to provide a user with useful information in an unknown environment. This feature is exploited to test the different presentation styles. The different presentation styles all have in common that they use a list to display the location–based information. In the experiment variations of list views will be examined, which will be used to compare the works from [HB05] and [KWS08], discussed in the state of the art section 2.5.

Diverse presentation styles will be examined in an especially developed spatial information space. Therefore an environment in the city center of Bonn will be created where the experiment can be conducted. The spatial data in the information space will be separated into five categories. Table 4.1 lists the five elected categories available for the experiment with their associated colors.

Color	Category
	Tourist
	Shop
	Eat&Drink
	Freetime
	Service

Table 4.1: Categories in the controlled environment

The experiment will be conducted in a scavenger hunt[1]. The participants receive tasks where they have to find certain spatial objects in the information space. Each spatial object will be searched for with a different presentation style by the participants. At the end of the experiment all presentation styles will be compared by their performance.

4.2 Defining the Experiment Environment

A mobile LBS's most important feature is to provide the user with useful information in an unknown environment. To support this feature, the experiment zone was enhanced with touristic information in different areas. Each area provided five point of interests (POI) , each classified to one category of a specific country.

This section explains the decision-making for the right type of geo-referenced data. The question to be answered is: what kind of data is needed for the experiment and is it possible to create a uniformly distributed data set in the experiment zone?

[1]In German: Schnitzeljagd

4.2.1 The Experiment Zone

The Requirement #*12* for the experiment was to conduct it in an inner-city environment. The zone required to have a high distribution of buildings on which the virtual data could be mapped. A specific area in Bonn's city-center was chosen.

Testing the Zone

Before any data was distributed over the experiment zone, it had to be tested against the iPhone's localization and network quality. The test checks the iPhone's reliability in the experiment zone regarding the two parameters.

Test environment fulfills requirements

It would be challenging to interpret the participants' performance in the experiment if the results of the test were not acceptable, because it would be difficult to distinguish if the participants' behavior relies on the experiment itself or the iPhone's bad performance regarding the two parameters.

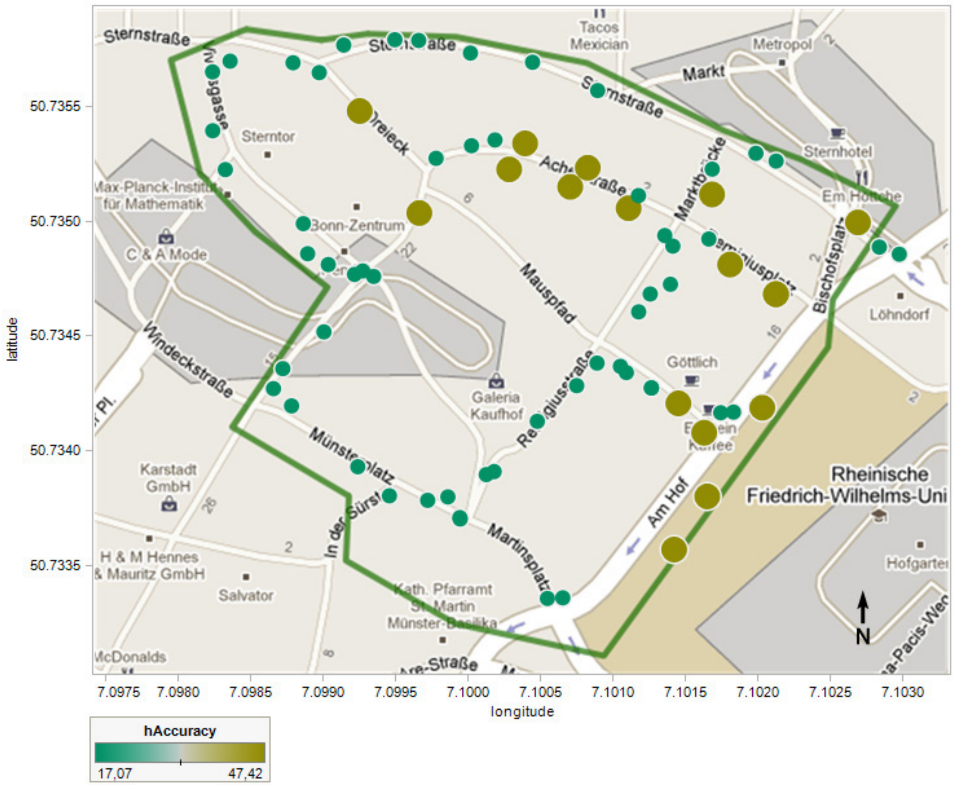


Figure 4.1: Result of localization quality of the iPhone in the experiment zone

Figure 4.1 depicts the experiment zone, an area with a size of 67.865 m^2. The test results indicate an acceptable localization accuracy in the experiment zone. 77% of the location points had a maximum inaccuracy of 17.07 meters, the rest had a maximum inaccuracy of 47.42 meters. The 3G[2] network was available in the complete zone, which provides a more than acceptable download rate.

4.2.2 The Comparison of the Three Approaches

Three distribution alternatives of the spatial data will be discussed. The three alternatives are named as 1. *Sparse data*, 2. *Dense data* and 3. *Virtual data*.
The data is required to be uniformly distributed over the experiment zone. Additionally it has to be assigned to one of five categories to assure a variety of the geo-referenced information.

Sparse Data

This approach allocates a certain amount of geo-referenced objects within the controlled environment, with the goal of the categories being uniformly distributed. Each geo-referenced entry refers to a physical object. Figure 4.2 shows the distribution of the geo-referenced data.
The map reveals that a uniform distribution of the five categories is not provided in the controlled environment. Moreover, there are too many "blind spots" where no data is available. Although this approach provides an efficient way of creating an experiment zone, it is discarded because of the two named disadvantages.

Dense Data

The idea behind the *dense data* was to provide a consistent experience for the participants during the experiment, in a sense that every physical building in the controlled environment is geo-referenced.
Figure 4.3 depicts an excerpt of the controlled environment with 88 geo-referenced objects alone. The map reveals no uniform distribution between the categories. The west locates mainly shops and the east mostly service providers. Beside that, it would be too elaborate to extend this approach to a wider region, if a uniform distribution would exist. The region of Figure 4.3 has 88 geo-referenced objects alone.

[2] 3rd generation network, which incorporates as set of network standards like UMTS and EDGE.

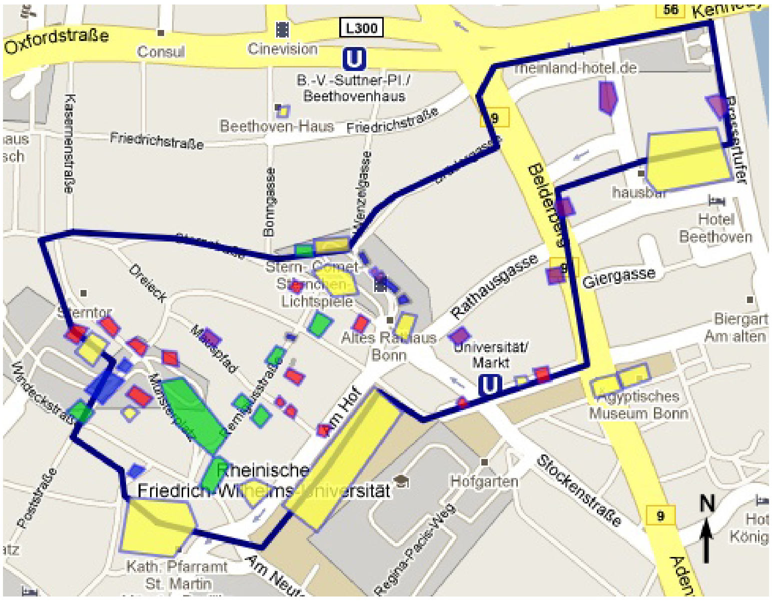


Figure 4.2: Sparse data

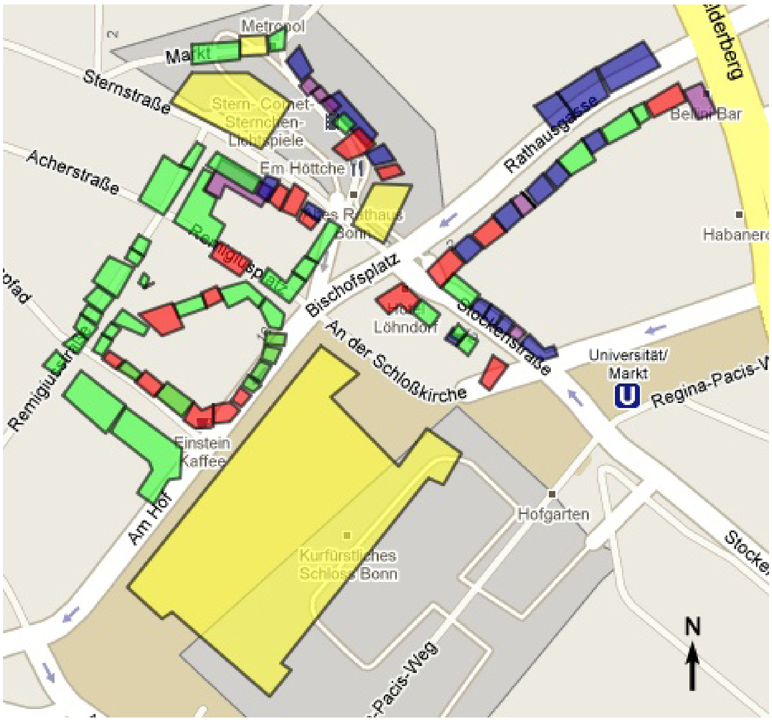


Figure 4.3: Dense data

Virtual Data

The notion behind the virtual data approach is to create an environment where anybody who is not involved in its development finds himself in an unfamiliar environment. The spatial information is detached from the physical landmark.

Detach spatial information from physical landmarks

The main benefit of mapping virtual data onto physical objects is that it allows to distribute the virtual data uniformly within the controlled environment. Beside this, it achieves equal chances for all participants. It assures that the iPhone is the only source for the geo-referenced data. All participants start with the same knowledge over the experiment zone, which eliminates benefits for participants more familiar with the real environment. This is important for the reliability of the measured task performance. The other two approaches would treat participants with a higher knowledge of the city better.
The third advantage of this method is that it allows to place any kind of information in the experiment zone. The virtual data is not bound to actual physical objects. In this thesis e.g. information of three continents will be used for the conduction of the experiment.

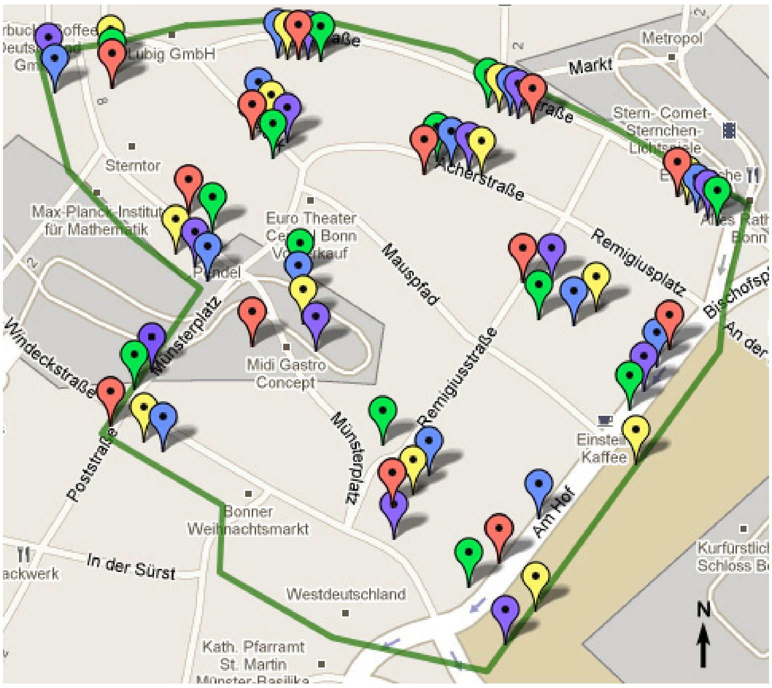


Figure 4.4: Virtual data

Figure 4.4 displays the experiment zone with the distributed touristic data. 65 POIs are placed in the area with a medium distance of 157 meter (Standard Deviation (SD): 25,7). There is information available on 13 countries.

A downside of this method could be that the participants may have difficulties to associate the virtual information with the physical object. The creation of a training zone would reduce this problem.

Chosen approach

The comparison of the three approaches revealed the virtual data approach is the most adequate solution for this experiment. It allows to distribute the geo-referenced data uniformly over the controlled environment. It also gives control over the data-quality, regarding the content and availability. Another important factor is that this approach equalizes the variances in the city environment-knowledge between the participants.
Table 4.2 summarizes the advantages and disadvantages of all three approaches and lists the category frequency within the examined areas.

Virtual data approach chosen

Categories	**Sparse data**	**Dense data**	**Virtual data**
Tourist	8	4	13
Shop	8	38	13
Eat&Drink	13	38	13
Freetime	13	17	13
Service	8	21	13
No "blind" spots		✓	✓
Efficient approach	✓		✓
Uniform distribution			✓
Equal chances for participants			✓
Easy to associate with physical object	✓	✓	

Table 4.2: Summary of three data approaches

4.3 Cooperation of Development Tools

This part gives a brief overview over the system architecture. It had to be adapted to fulfill the new requirements.

4.3.1 System Architecture

Data tier is exchanged

The system architecture will remain a three-tier architecture, but the data tier component will be exchanged compared to the Wikipedia-Browser (see Section 3.2.3). Instead of retrieving data from an external web service the geo-referenced data will be provided from a pre-defined, made-up set. Therefore a geo-database system has to be elected where the data can be inserted and manipulated. The communication between the logic tier and the new data tier had to be modified, too.

4.3.2 The Components

The *presentation tier* and *logic tier* will be the same as the elected components presented in chapter 3. But the additional defined requirement shells *#12 - #16* ask for new functionalities which have to be implemented.

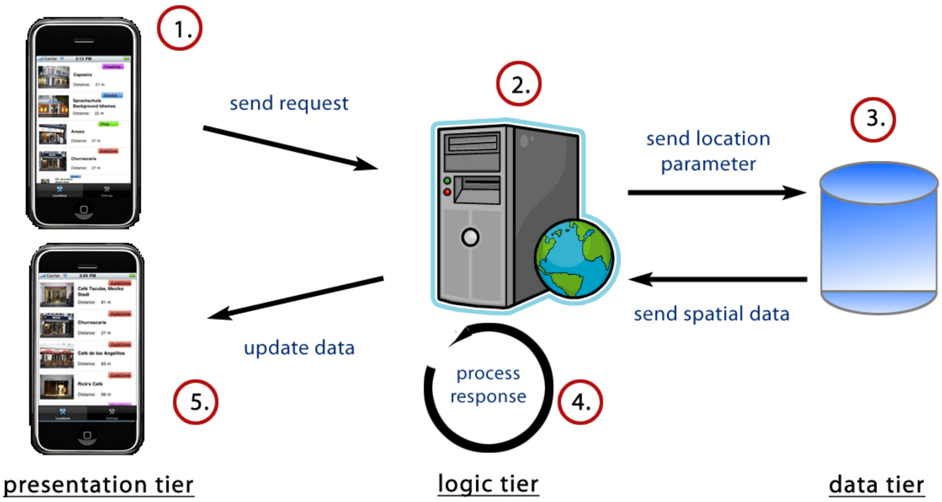


Figure 4.5: The updated system architecture

For the *data tier* a new component has to be integrated. A database (DB) which can operate on spatial data is required. The relational database management system (RDBMS) PostgreSQL[3] (Version 8.4.1) will be used for the

[3]http://www.postgresql.org/

data tier. It will be extended with PostGIS[4] (Version 1.4.1). The addition of PostGIS enables PostgreSQL to add spatial data types to the database and to perform spatial operations on them. Both software products are open source, and hence no licensing of the software is necessary. Figure 4.5 illustrates the system architecture with the new data tier.

4.3.3 DB-Design

The goal of the DB-Design was to have a clear and extendable structure for the spatial data so that it would be easy to add new content to the DB.
The DB contains five tables, the table *POIs* saves the information for every geo-referenced POI. Every entry is assigned to a groupID (ID for a country) and the zone it belongs to. The table *zones* lists the specific zones which the countries are assigned to. In this work two zones will be created, an experiment zone, where the actual study will be conducted, and a test zone, where the participants will be prepared for the experiment. For other studies additional zones could be created.

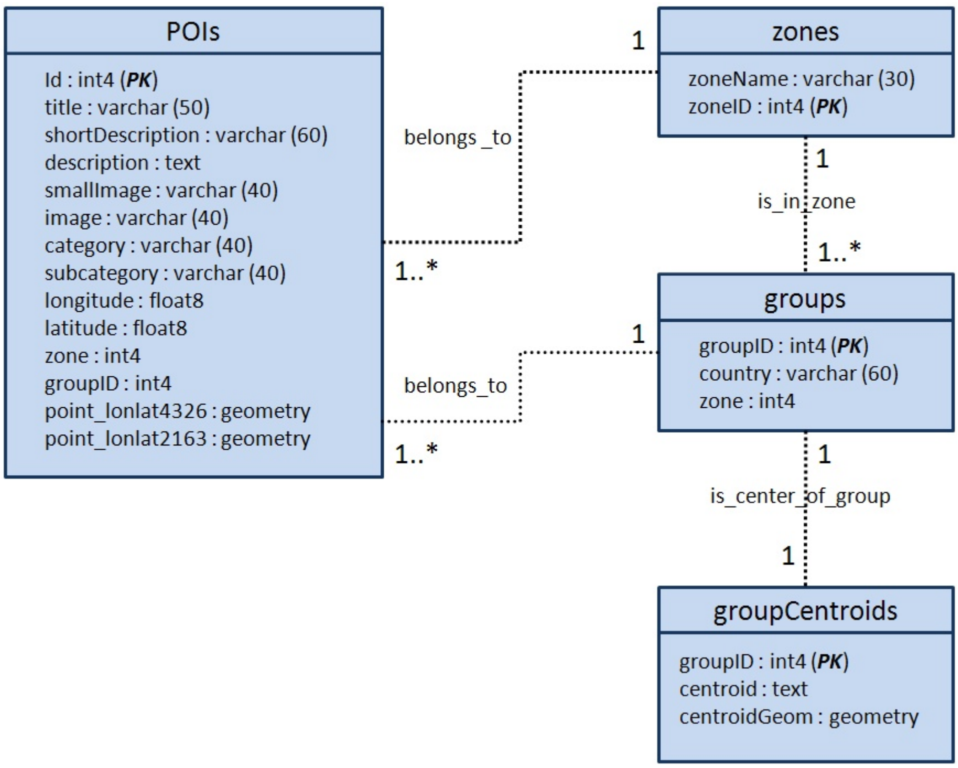


Figure 4.6: The database design of the data tier

The table *groups* contains 15 groups, 13 for the countries in the experiment

[4]http://www.postgis.org/

zone, and two for the ones in the test zone. The centroid of each group is saved in the table *groupCentroids*. It is used to calculate the medium distance between each pair of groups.

4.4 Implementation of the Client

Creation of experiment environment

This section documents the development of the client, the *Virtual Tour Guide* (VTG) . It begins with a presentation of VTG, so that a overview of its structure and features is given at first sight. The following part focuses on VTG's internal class structure and important procedures. It describes the relationships between the important classes and the collaboration between them. To assure that VTG fulfills the requirements, VTG underwent different test techniques.

4.4.1 Design of the Client

The functional Volere Requirements # *14* (Implement push-based LBS) and # *15* (Implement different presentation styles) defined the main features of the client. The push functionality already has been developed for the Wikipedia-Browser (Subsection 3.2.3). So this module could be transferred to the VTG, only small modifications had to be added.

The different presentation styles all have in common that they use a list to display the location based information. In the experiment variations of list views will be examined, which will be used to compare the works from [HB05] and [KWS08], discussed in the related work section 2.5.
For the implementation of the VTG-application the same development tools as for the Wikipedia Browser were used. Xcode 3.2 for programming the application and Interface Builder 3.2 for creating the UI. In the development process the MVC-Model was used to encapsulate the logical program units from each other. It is an architectural design pattern [GHJV94] that is incorporated into the UIKit framework (Subsection 3.2.2).

4.4.2 The Application

Design of VTG

The application consists of three views. In contrast to the Wikipedia-Browser (Section 3.2.3) the content in the main view (1) is not generated through HTML. It is created by an instance of the class *UITableView* of the Cocoa Touch framework. This class provides features to display and edit hierarchical lists of data.
The main view consists of two parts. The *location list* holds a list of geo-referenced entries in a specific order. Figure 4.7 depicts the location list

where the entries are ordered by their category. Within each category they are ordered and scaled by distance.

If the user clicks on an entry the *detail view* pops up (2). It shows detailed information about the entry. In this example the entry informs the user about the souk in Marrakech, a traditional Moroccan market. It is associated with a Swarovski[5] shop in the experiment zone.

Figure 4.7: Main view of the client

At the bottom of the main view are two buttons, *Locations* and *Settings*. They control the views of the application.
The *settings view* allows to manipulate the parameters which determine the presentation style of the *location list* (Figure 4.7).
The "Radius filter" sets the distance in which the spatial information is allocated. The "Category" section allows to filter only the selected categories. The last section "Order Style" gives different options on how the entries are ordered in the *location list*.
The first settings option "Distance filter" adjusts the distance (in meters) between two location updates of VTG.

Main classes

The two main classes of VTG are the *LocationViewController* and the *SettingsViewController*.
Figure 4.9 illustrates the class diagram of the main classes. The central class in the application is *LocationViewController*. *LocationViewController* is responsible for processing the location updates and sending them to the

[5]http://www.swarovski.com/

Figure 4.8: Settings view of the client

VTG's internal structure

logic tier. It handles the response and converts it to the presentation style defined by the current settings.
It inherits from the *UITableViewController* class, a class in the iPhone SDK which manages a table view. The interface[6] *MyLocationDelegate* is realized by *LocationViewController*. As the name denotes it supports, the delegation design pattern[7]. On specific events, instances of the interface defer tasks to a customized method in the *LocationViewController* class.

A singleton[8] of *MyLocation* delegates new location updates to the *Location-ViewController* where the parameters are further processed.
MyLocation realizes the interface *CLLocationManagerDelegate*, which sends positioning information to the implemented class. The main task of *MyLocation* is to evaluate the location data received from *CLLocationManagerDelegate*. If certain criteria are fulfilled, the location data is delegated to *LocationViewController* where it is further processed.

The class *SettingsViewController* is responsible for managing the settings of the application. It handles the update distance at which location updates are called, the control over the radius, the category filter and the type of presentation style.
SettingsViewController notifies *LocationViewController* if settings have been

[6]Protocols in Objective-C.
[7]A fundamental design pattern within the Cocao Touch framework. A method's work is delegated to another method.
[8]A creational design pattern which ensures the creation of one only instance of a class.

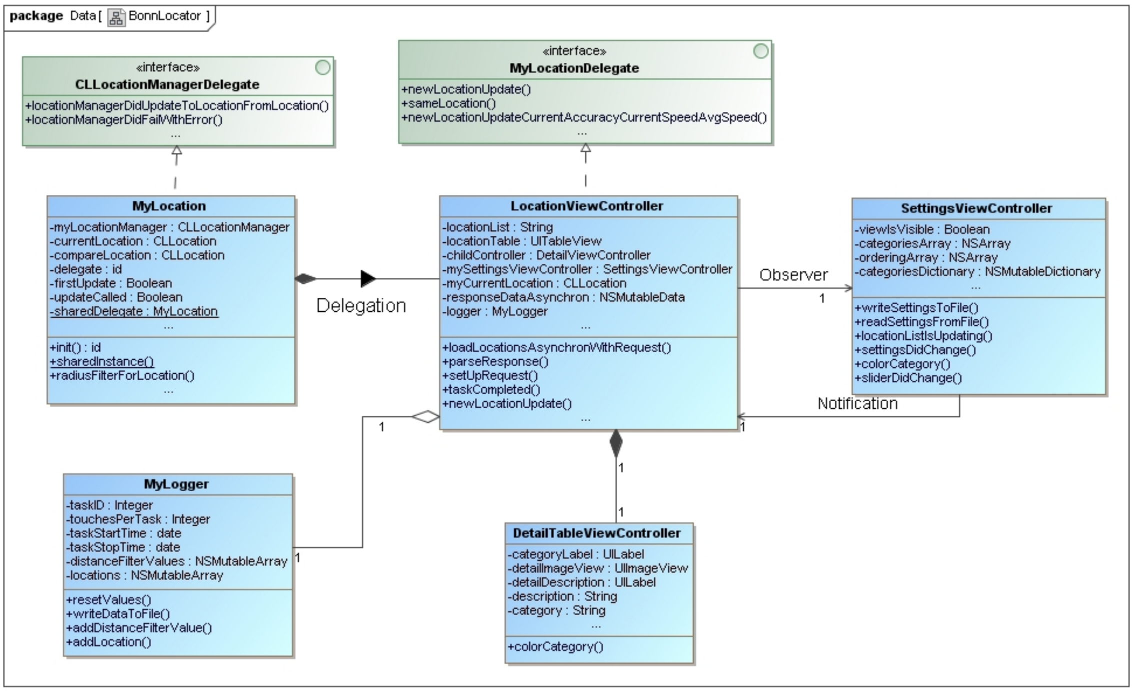


Figure 4.9: Class diagram: important classes of the client

changed. Depending on the changes specific methods are called.

The task of the *MyLogger* class is to log pre-defined events. The log files are used to evaluate the participants' performance during the experiment. They are saved in XML file format, so that post-processing of the data is easier.

Location Update Sequence

The sequence diagram in figure 4.10 describes the flow of the initial update. The *LocationViewController* class initializes an instance of *SettingsViewController* (1), its parameters are used in later sequences.

The creation of the *MyLocation* object (3) starts the positioning process. The process is conducted until certain criteria of the positioning algorithm are fulfilled. The location information is delegated to the *LocationViewController* class (4), where the data is further processed and sent to the logic tier (5). The logic tier queries the data tier for the entries around the current location and sends the data back to the client in a XML file format (6). In the last step of the sequence the location list is reloaded with new data.

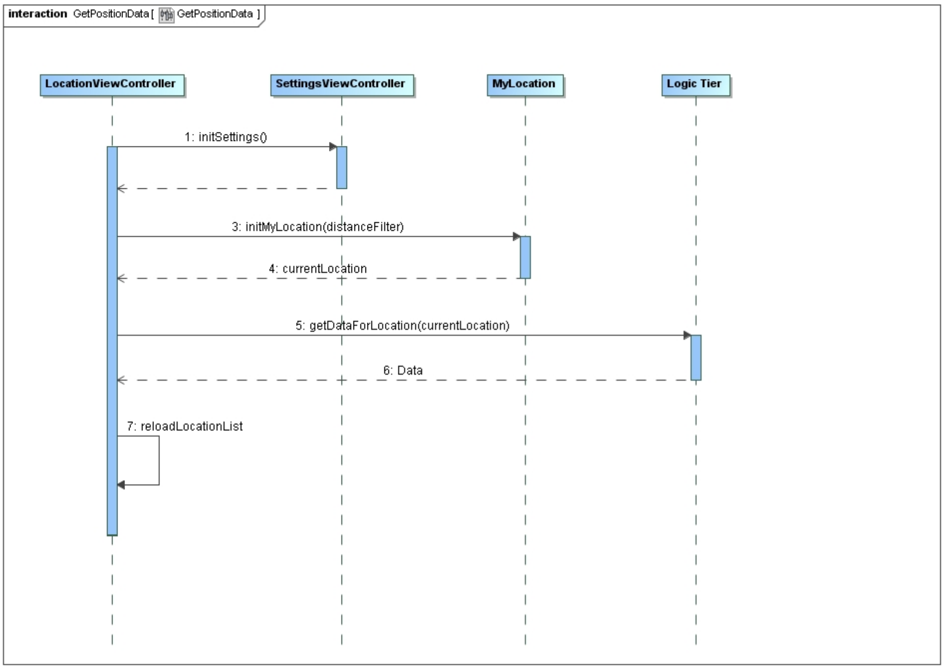


Figure 4.10: The sequence describes the process for the initial location update (UML 2)

4.4.3 Validation of the System

Important for the in-field experiment

To retrieve the right level of software quality an appropriate test strategy has to be applied. The ISO/IEC Norm 9126-1 classifies software quality into a structured set of characteristics[9]. The norm says that the measure of quality conforms to the fulfillment of the requirements. For this work this means that the test strategy is predetermined by the functional and non-functional requirements defined by the Volere Snow Cards (Appendix B). The discussed test techniques depict an excerpt of the test results. They are classified into two classes, in static tests and dynamic tests [Lig02]:

Static techniques The main characteristic of static tests is that no code is executed when a test is conducted. Although all static tests can be executed without the support of test tools, it is not advisable to do so. The exception are code-inspection and review techniques.

Dynamic techniques Dynamic test techniques execute code, which differentiate them from static techniques. Dynamic test techniques require

[9]The six characteristics are: Functionality, Reliability, Usability, Efficiency, Maintainability and Portability

the execution of software with precise input – the test data. Their goals are the creation of test cases, which are:

- representative
- error sensitive
- of low redundancy
- economic

In the different test phases both classes of test techniques were executed. The VTG underwent the following test phases:

Unit test The task of the unit test is to measure the quality of the specific components of a software. In most cases these components are individual classes. In the case of the VTG the important classes were tested.

Integration test An integration test tests specific components of a system that are connected bit by bit, and tested against the specification. Not yet integrated components are simulated through test stubs. In contrast to a system test, it is not assumed that an integration test is conducted under real conditions.

System test A system test is a test of the finished software against the predefined functional and non-functional requirements. It is performed in the actual system environment under real conditions.

Unit Test

The example in table 4.3 shows a test case where the method *radiusFilterForLocationlocationToUpdate* in the class *MyLocation* is tested. The method calculates the distance between the last updated location and the new location to be used, if the new location exceeds a certain threshold an update with the new location is granted, otherwise not.

Integration Test

Two different methods of integration tests were conducted. The first was a dynamic method which seeked for possible memory leaks within the application. The second one was a static method. It was conducted with the Clang Static Analyzer[10] .

[10] http://clang.llvm.org/

TestID	Input date (Lat, Long)	Expected result	Actual result	Pass
	(50.73421, 7.09922)	YES	YES	YES
9	(50.73407, 7.09972)	YES	YES	YES
	(50.73403, 7.09920)	YES	YES	YES
	(50.73394, 7.09986)	NO	NO	YES
	(50.73063, 7.10175)	NO	NO	YES

Table 4.3: Test case of location update distance

No garbage collection

Memory Control Objective-C for the iPhone does not provide garbage collection. Hence memory management lies in the hand of the programmer, he is responsible for freeing the memory of unused objects.
The memory management system in Objective-C relies on reference counting. Every object in Objective-C has a number, the *retain count*. The number expresses the amount of references which point to an object. To free an object from the memory the retain count has to be reduced to zero. Otherwise the object will stay in the memory and create a memory leak.

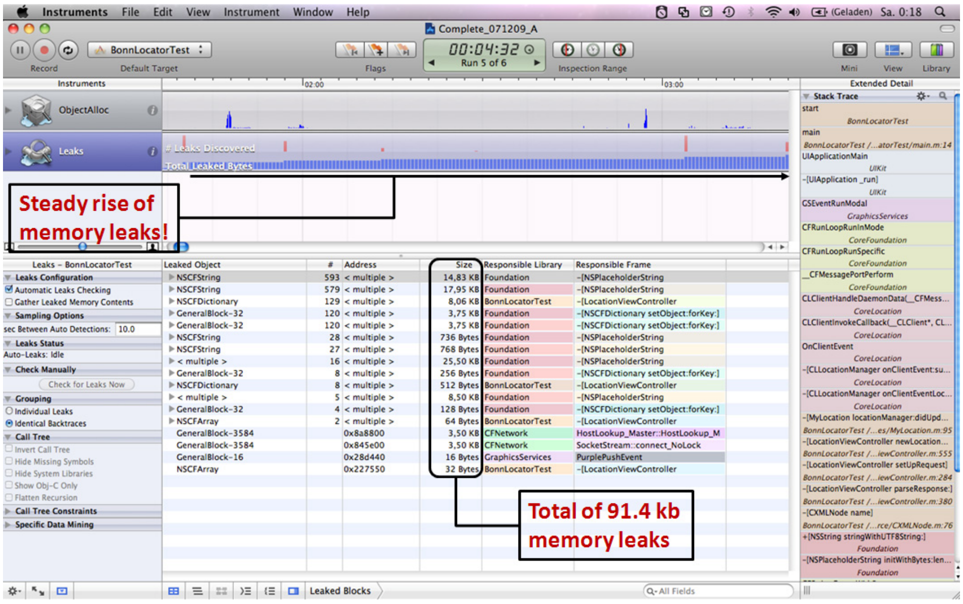


Figure 4.11: Memory leaks at the beginning of the test phase (Test run: Complete_071209_A)

XCode provides a performance test application with Instruments (Section

3.2.2) which helps to identify memory leaks among others.

The memory leak test was executed systematically. In every test run three location updates were conducted, the presentation style was changed eight times, and the radius filter was changed three times. The attribute changes were executed with the same values over all iterations. At the beginning of the integration tests the application leaked a total of 91.8 kilobytes (Figure 4.11). The memory leaks continuously increased during the test.

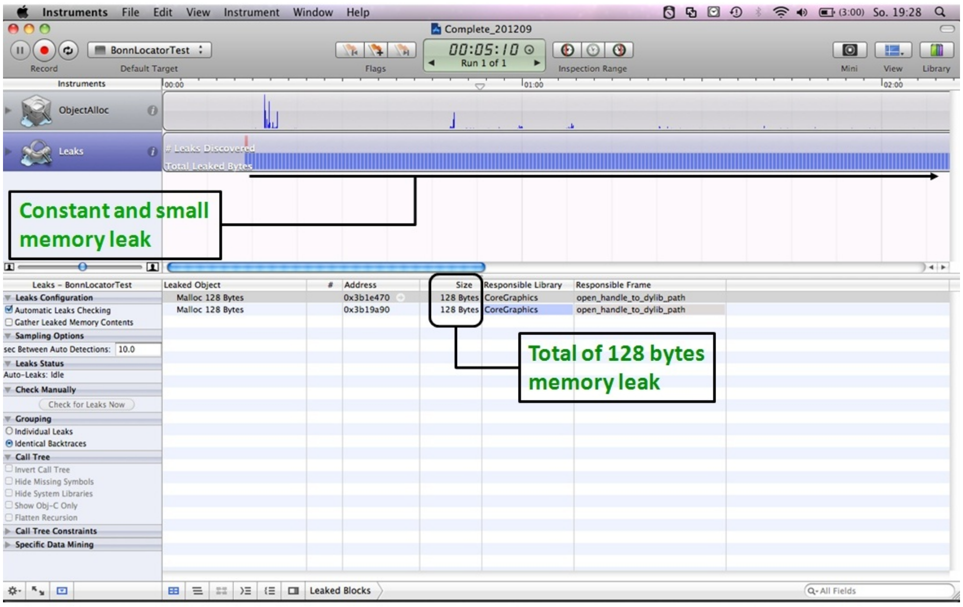


Figure 4.12: Memory leaks at the end of test phase (Test run: Complete_201209)

At the end of the test phase the total amount of leaked memory was reduced to 256 bytes. The memory leak occurred only at the start of the application and no other leaks arose. The memory leaked inside the system library "CoreGraphics" and therefore was difficult to locate. Identifying the leak would consume too many resources and the application would not really benefit from it. The leak was insignificant and classified as low priority. No further optimization was necessary.
Table 4.4 summarizes the results of the two example test runs:

Static Analysis with Xcode Static tests were executed with XCode's 3.2 built-in static analyzer. The static analyzer is built on top of the compiler

Test run		
071209	Total amount leaked bytes:	91.8 Kbytes
	Total amount memory allocated:	2.06 Mbytes
201209	Total amount leaked bytes:	256 Bytes
	Total amount memory allocated:	873.74 Kbytes
	Reduction of leaked memory:	99.7%
	Reduction of total objects allocated:	58.6%

Table 4.4: Comparison between test run Complete_071209_A and Complete_201209

front end Clang and *Low Level Virtual Machine* (LLVM)[11].
The static analyzer provides the following features:

- Advanced warnings for unsafe code
- Identifying bugs
- Code path traveling
- Identifying logical errors such as unreleased memory

Figure 4.13: Unreferenced variable identified through Clang static analyzer

During the implementation phase the static analyzer was used continuously for debugging the code. Fig 4.13 shows an example of a code path traversal for an undefined variable.

[11]http://llvm.org/

System Test

The system test of VTG was conducted in the experiment zone. It was divided into two parts, the first test was executed three times. In every iteration eight tasks had to be accomplished each with another presentation style. During the system test the location updates, network calls and other important events were logged.

The first iteration revealed serious failures with the location update process and four system crashes. The system crashes occurred because of an inconsistency of the location list entries. They arose when the data was loaded asynchronously from the logic tier and at the same time settings were changed or the detail view was initialized for an "old" value.

In-field test reveals system failures

The second iteration did not show any of the aforementioned serious failures. Instead three incorrectly categorized entries in the database were identified. Also two minor problems with the radius filter and the update-rate were resolved.
In the third iteration no failures were found.

The second part of the system test was the conduction of a pilot study. The pilot study imitated a run of the experiment with a participant under real conditions. The setup for the complete experiment had been finished and the experiment flow could be tested. The details of the experiment design are explained in the following chapter 5.
The pilot study did not reveal any technical system failures. But it showed that the test participant had problems to understand the questions of task 1 and 5. Therefore the questions had to be rewritten. No other system failures or experiment problems have been revealed. That made a start of the actual experiment feasible.

4.5 Summary

This chapter has presented the global design of the experiment which was specified by the refinements made in Section 3.3.
An in-field experiment to test different presentation styles for a mobile pushed LBS will be conducted. For this purpose a tourist guide application was developed. The experiment will be conducted in the city center of Bonn. It is disguised into an adventure trip through three continents, basically in the form of a scavenger hunt.

For the information space three alternatives of spatial data distribution have been examined. The *virtual data* approach was elected. It allows the flexibility to distribute the spatial data uniformly in the experiment zone.

The iPhone 3G has been tested against the localization and network quality in the experiment zone. The results let to the conclusion that the iPhone 3G would not influence the experiment negatively.

The third part of the chapter focused on the development of the client application VTG. The implementation section explained the features of VTG and its structure. Different design patterns were used to encapsulate conceptual units programmatically. VTG's features were presented on different abstraction levels and they were precisely tested, which resulted in a robust client application.

Chapter 5

Conducting the User-Study

This chapter outlines the general setting of the experiment and presents its results. The first section lays out the general design of the experiment and its goal. It describes which variables are manipulated and which are measured in the task-driven experiment. It explains how a certain level of quality has been achieved by following specific methods in the design of an in-field experiment.

The results of this experiment are discussed the latter part of this chapter. The findings are evaluated with descriptive and inferential statistics to assure the validation of the perceived results. Appendix C lists all the statistical terms used in this thesis.

5.1 Evaluation Method

This section describes the evaluation methods used in the experiment. It is divided into five parts: The general design of the experiment, the characteristics of the participants, the distribution of the spatial data, the material used in the experiment and its actual procedure.

5.1.1 Experiment Flow

This section explains the flow of the experiment with its features. The goal of the experiment is to identify the participants' favored presentation styles of presenting spatial data on a mobile LBS. An experiment zone was developed within the city center of Bonn, where 13 zones (countries) with 65 POIs were distributed. The data was exploited to test eight different presentation styles in a task-driven experiment. The eight presentation styles were assigned to eight main tasks, each divided into three sub task, which the participants have to complete. The main tasks are counterbalanced

Virtual touristic environment created

with Balanced Latin-Square design [FH03] to control carry-over effects.

A total of 16 people participated in the repeated-measures in-field experiment, the group represented a homogeneous set of characteristics. They were accompanied by a researcher who monitored the participants and measured their task performance. Figure 5.1 summarizes the general flow of the experiment.

5.1.2 Design of the Experiment

Design of the experiment

The study used a repeated-measures design , every participant participated in all conditions of the experiment. The independent variable was *presentationstyle* (with eight levels). Each level represented a different presentation style on the iPhone. The eight presentation styles (Table 5.1 and 5.2) displayed the spatial information in the location list in a certain manner.
In the experiment every participant had to complete eight main tasks, each main task was divided into three subtasks.

Task-oriented repeated-measures design.

The general goal of a main task is to identify specific entries in the location list. Participants had to fulfill these tasks in a specific order on a predefined route, with changing presentation styles. Figure 5.2 depicts the controlled environment with the route the participants had to walk.
The presentation styles and the eighth main tasks were counterbalanced to control carry-over effects[1]. Participants experienced the conditions in one of eight sequences using Balanced Latin-Square design .

The experiment itself was disguised into an adventure trip through three continents, basically in the form of a scavenger hunt. This camouflaged the task-oriented approach from the participants and increased the motivation while conducting the experiment.

The goal of the experiment was to identify the participants' favored presentation styles with which they would find geo-referenced information in an unfamiliar virtual environment. The main contributors to measure the favorability of the presentation styles were:

1. The mean task completion time for each *presentationstyle*.

2. The mean amount of touches per *presentationstyle*, whereby a higher value indicates a greater mental effort by the participants.

[1]Systematic effects that carry over from one condition to the next.

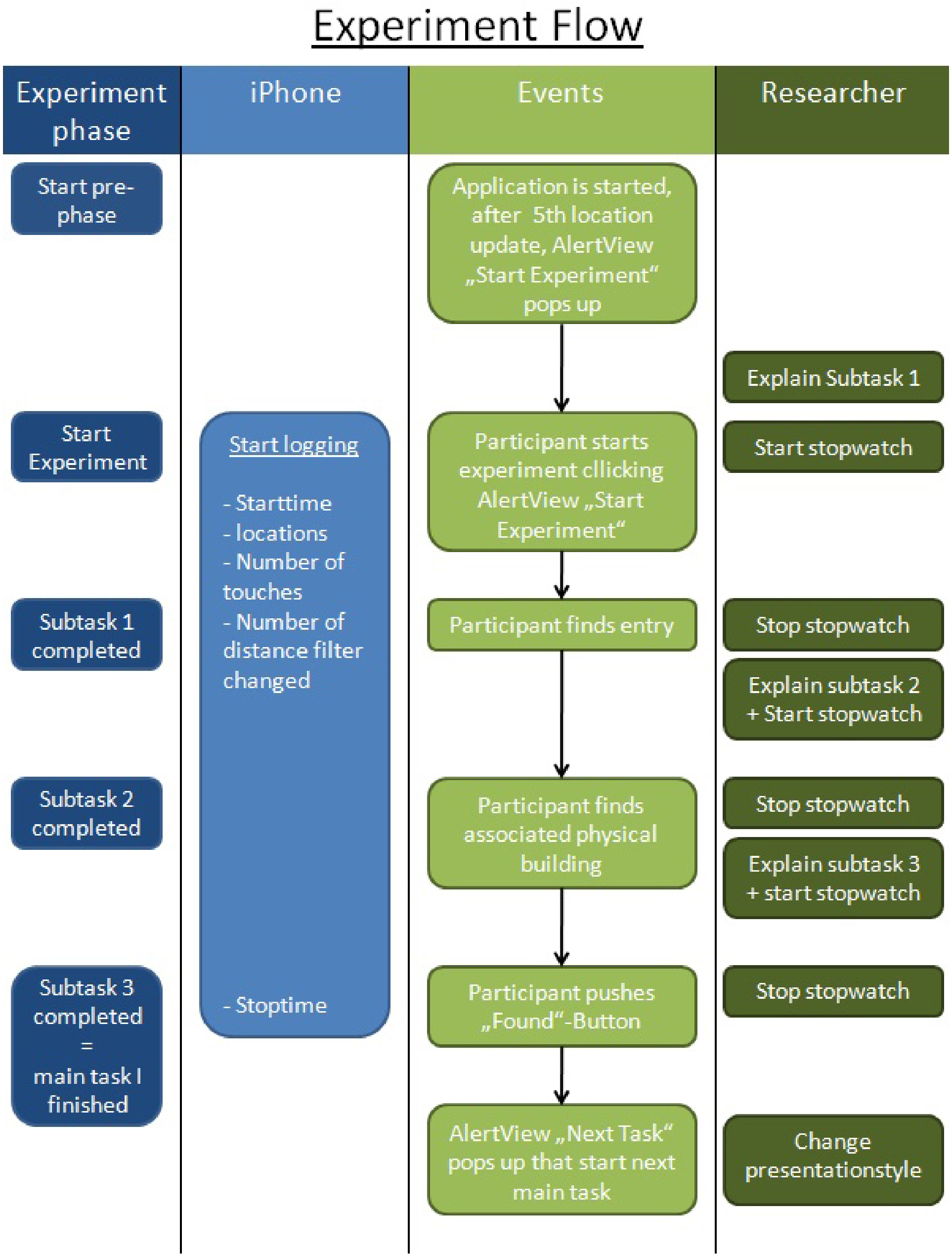


Figure 5.1: Overview of components in the experiment flow

3. Evaluate the participants' opinion on the presentation styles through questionnaires.

Presentation Style

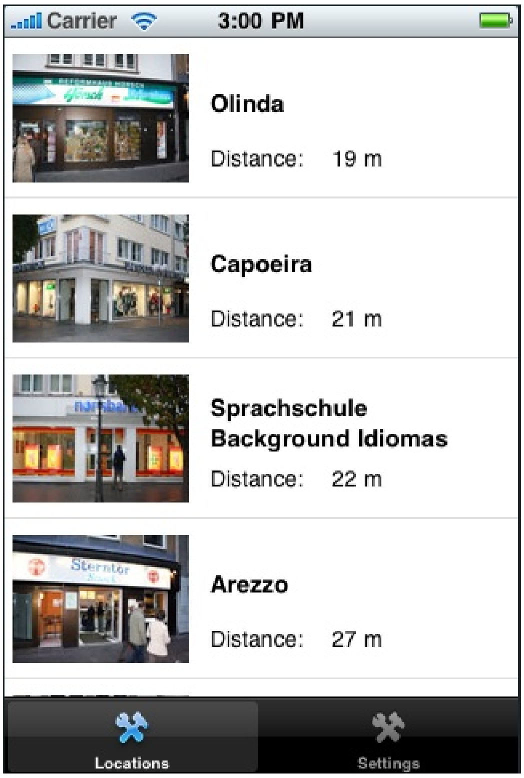
Evaluation of 8 alternative presentation styles

Table 5.1 and 5.2 present the eight levels of the independent variable *presentation style*. Each level provides a certain way of how the data is presented. The selection of a set of presentation styles was part of the functional requirements See Section 3.3 or Appendix B. Their definition and implementation is an achievement of this thesis.

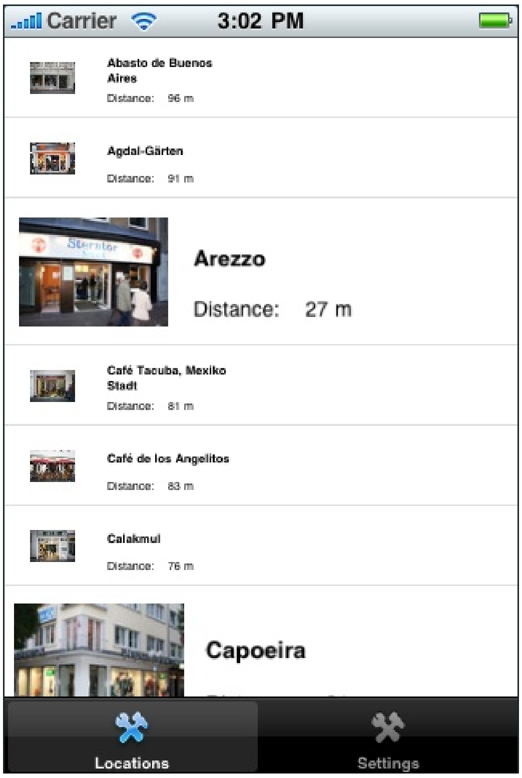
1. *Order by distance*
   The entries in the list are ordered by distance to the current position.
2. *Scale by distance*
   Entries nearer to the current position are bigger than objects further away + entries are ordered alphabetically.
3. *Scale by distance + Color by category*
   Scale by distance + entries are labeled by their category + entries are ordered alphabetically.
4. *Order by category + Color by category*
   Entries are ordered in categories, within the category they are sorted alphabetically + Color by category
5. *Order by distance + Scale by distance + Color by category*
   Combination presentation styles 1 and 3.
6. *Order by category + Order by distance + Color by category*
   Entries are ordered by their category, within the categories they are ordered by distance, in contrast to presentation style 4 + Color by category.
7. *Order by category + Order by distance + ColorByCategory + Scale by distance*
   Like presentation style 6 with the addition that entries within the category are scaled.
8. *Order by alphabet*
   Entries are ordered alphabetically.

Radius Filter

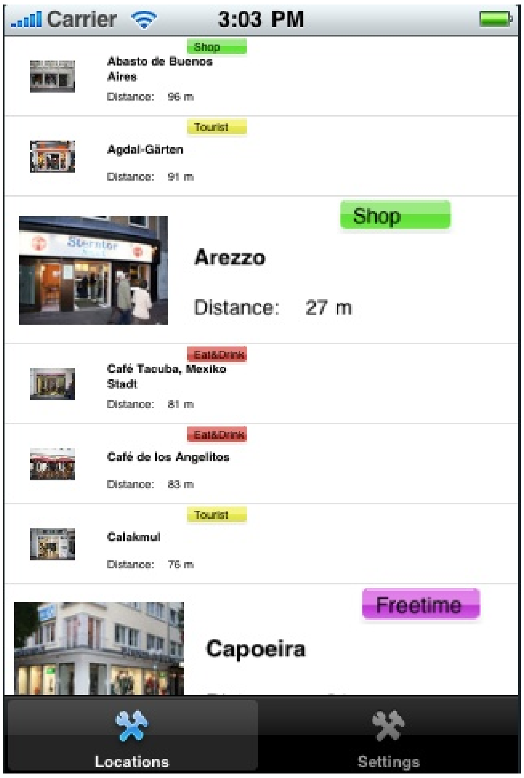
During the experiment the participants could change the radius filter at will. The radius filter allowed the participants to filter information within a certain distance range according to the participants' current position. With this additional factor it was possible to examine how participants exploit



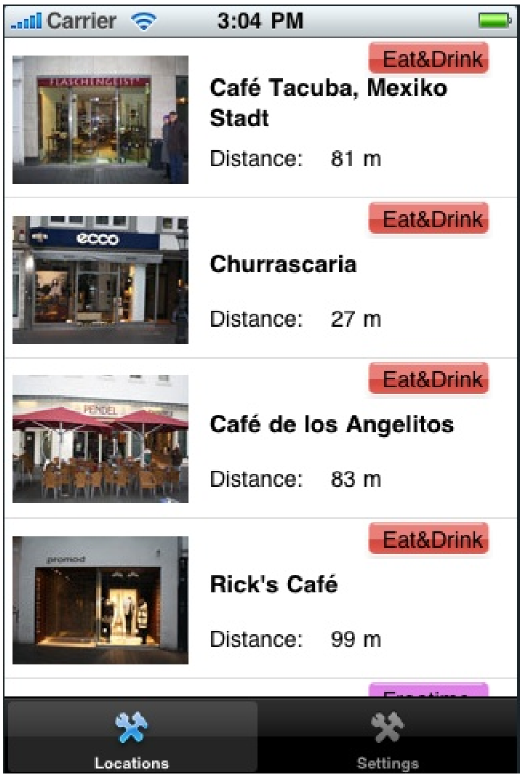
Order by distance



Scale by distance

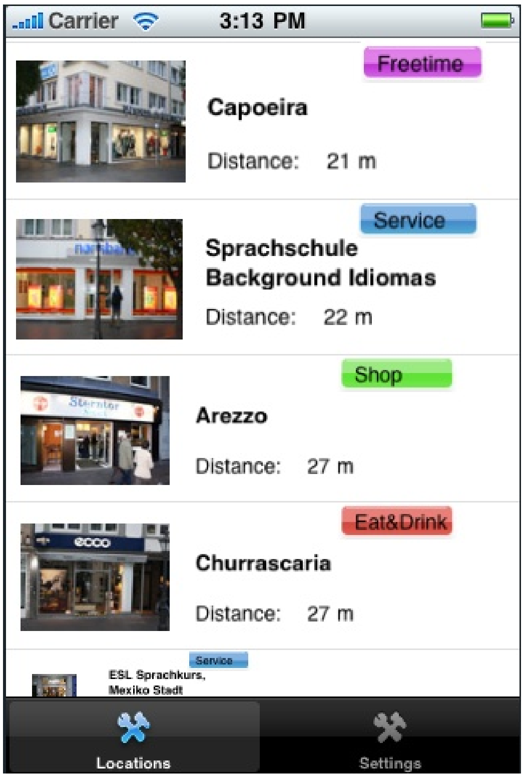


Scale by distance + Color by category

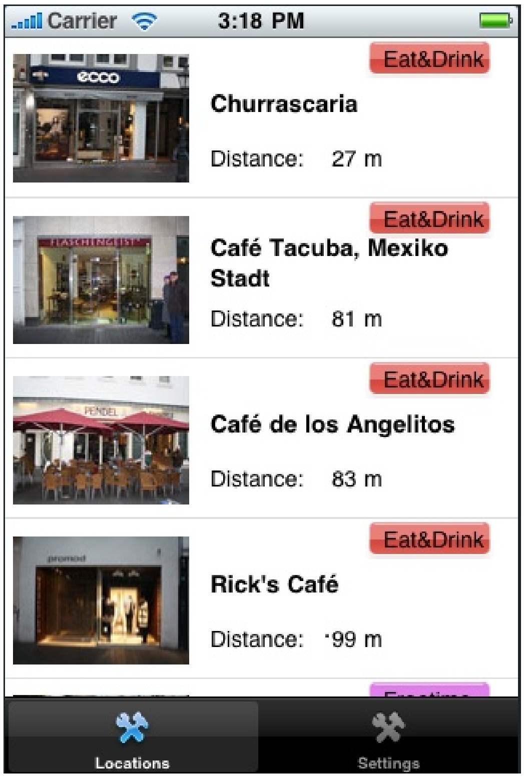


Order by category + Color by category

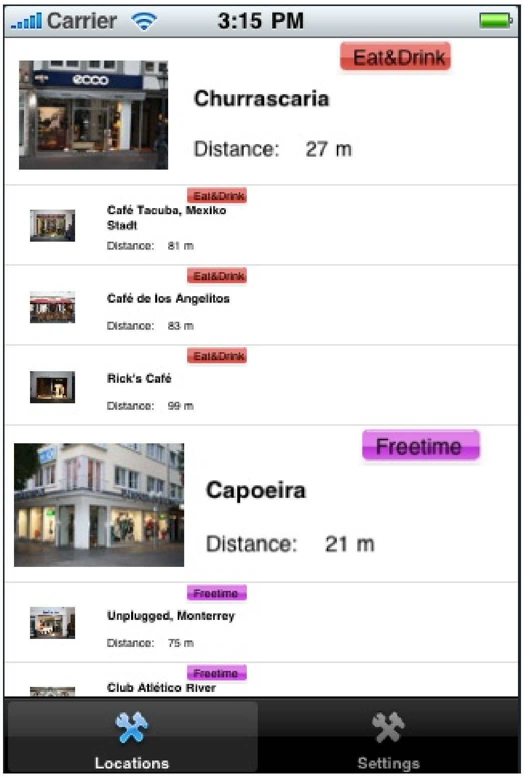
Table 5.1: Presentation styles 1 - 4



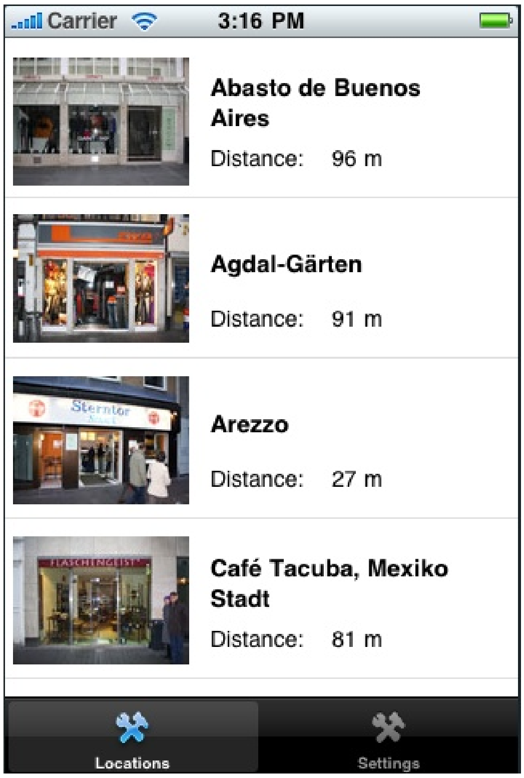
Order by distance + Scale by distance + Color by category



Order by category + Order by distance + Color by category



Order by category + Order by distance + ColorByCategory + Scale by distance



Order by alphabet

Table 5.2: Presentation styles 5 - 8

Figure 5.2: The controlled environment with eight task areas

the radius filter to find the information within the location list. The maximum range of the radius filter was set to 100 meter, otherwise participants could exploit the radius filter to identify all available entries without being near the specific objects.

Dependent Variables

During the experiment the following six dependent variables were measured:

***Completion time main task* (in seconds)** The time needed by the participant to complete a main task.

***Completion time experiment* (in seconds)** The time needed by the participant to complete the whole experiment.

Number of device touches per task The number of device touches while completing a main task.

Number of device touches per experiment The number of device touches after the experiment has been finished.

Number of times radius filter changed Number of times the radius filter was changed for a presentation style.

Position The position to every location update was logged to monitor the participants' movement during the experiment.

5.1.3 The Participants

Important for the study was to have a homogeneous group of 16 persons, eight female and eight male, who had approximately the same characteristics.

Homogeneous group of participants.

The participants were between 18 and 32 years old (M 26.9, SD 4.31). The main attributes of this group were that they are technology-affine and have a good knowledge about the usage of mobile devices. Figure 5.3 depicts the group's basic characteristics. It shows that all participants have at least medium computer experience and all of them have operated on a smartphone with a touch display. Although 4 of the 16 participants have not used a mobile LBS before, an unpaired t-test revealed no significance for the total task completion time ($t(14)= .405$, $p =.692$) between the two groups.

Participants did not get paid. Instead the experiment was boxed into a scavenger hunt competition, where the three fastest participants would win prizes and receive certificates (see Appendix F). This was done to raise the motivation of the participants.
The fastest participant wins a voucher value of 25 Euros for a restaurant, the second place receives a 15 Euros voucher for the cinema and the third a voucher of 10 Euros for a restaurant.

5.1.4 The Material

The material gathers user data of the experiment. Three independent sources, the iPhone, the researcher and two questionnaires were used to collect user input.

The iPhone

The iPhone monitored the participants' behavior during the experiment. It logged the gross time for the main task a participant performed. The application saved the number of touches and the number of changes of the radius filter. The fourth dependent variable the iPhone measured, were the locations of the participants over time. The dependent variables of each main task were saved in an XML file.

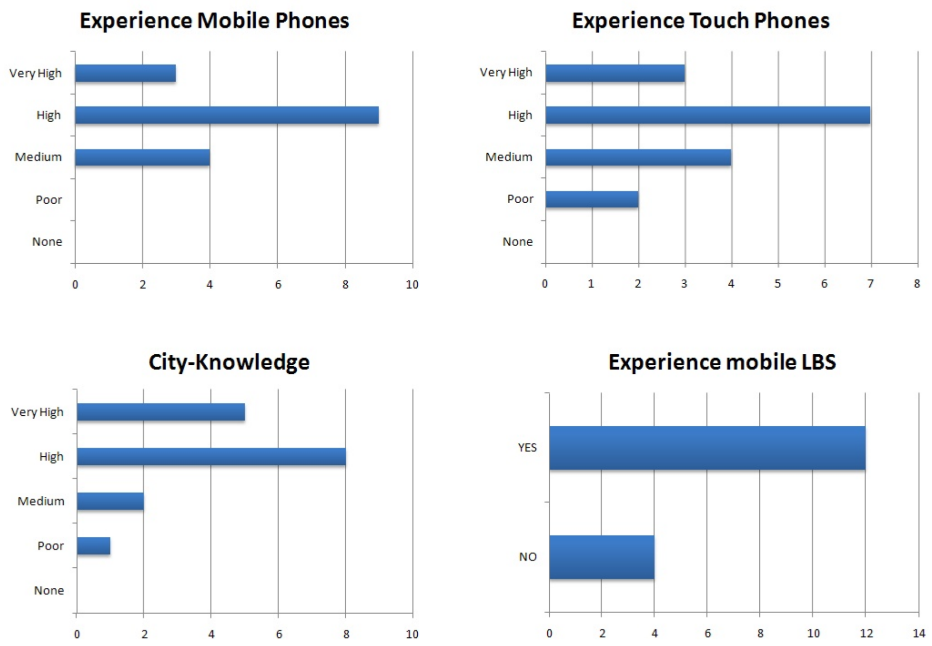


Figure 5.3: Main characteristics of the participants

Role of the Researcher

The researcher's main task was to document the participants' behavior during the experiment and to stop the time for every completed subtask. He carried a clipboard where he wrote down the participants performance on the one side.
On the other side was a map of the experiment environment. The map helped the participants to orientate themselves within the experiment environment. After a task has been completed the participant had the chance to give their feedback about the execution of the task. After that the researcher explained the next task.

The Questionnaires

After the experiment the participants filled out two questionnaires. The first questionnaire, the *general questionnaire* (see Appendix D) had two purposes, on the one side to generate a user profile of the participants, and on the other side to receive feedback about the flow of the experiment. It contained 16 questions.

The second questionnaire, the *usability questionnaire* (see Appendix E), focused on the participant's user experience with the application. It was important to distinguish how much of the participant's task performance could be assigned to the presentation style and how much to a general problem of the application. This questionnaire was also used to check if the non-functional Volere requirements *#7, #8, #9* (Appendix B) were fulfilled. The questionnaire took 17 questions from IBM Post task questionnaires [Lew95] and NASA Task Load Index (TLX) [HS88] using a 5-Point-Likert scale. This has the advantage that results are comparable with other studies that used the same questions.

2 questionnaire to receive participants' feedback

5.1.5 The Procedure

The participants were welcomed at the University Library of Bonn (ULB). There the researcher explained the flow of the experiment. The participants were informed that they had to play the scavenger hunt with the iPhone in the city center of Bonn which would take about one hour including answering the two questionnaires. The mean time for executing the experiment was 19:05 minutes (SD: 2:14) (excluding the questionnaires).
The experiment was conducted on weekdays during the day-time where shops were open and many people in the streets, putting the participants into a real use case scenario.

The Task

The following enumeration lists one main task with its subtasks, and the goal of each subtask. An actual example provides a better understanding of how a main task was conducted.

1. Subtask: Identify an object in the location list with a certain characteristic.

2. Subtask: Identify specific information about the physical object, which is associated with the object from Subtask 1.

3. Subtask: Identify an object in the list that belongs to the same group/land and identify specific information about the entry in the description text, as shown in the detail view.

Goal of the Task

1. Goal of 1. Subtask: How fast do participants identify an object with a specific presentation style?

2. Goal of 2. Subtask: Check if participants have really identified the object from the 1. Subtask.

3. Goal of 3. Subtask: Which presentation style lets user find an object the fastest way?

Example of a Main Task

The following illustrates an example of the three subtasks for the main task 6 to give a better understanding of how a participant would proceed to complete a main task.

1. Task: Find a jeweler in South Africa. *Answer: Juwelier Prins and Prins, which is associated with the store "Galeria Kaufhof."*
   The participant starts at the location of Kenia with a specific presentation style and has to fulfill sub task 6.1. Figure 5.4 depicts how the participant identifies the entry "Juwelier Prins and Prins" near the South Africa zone.

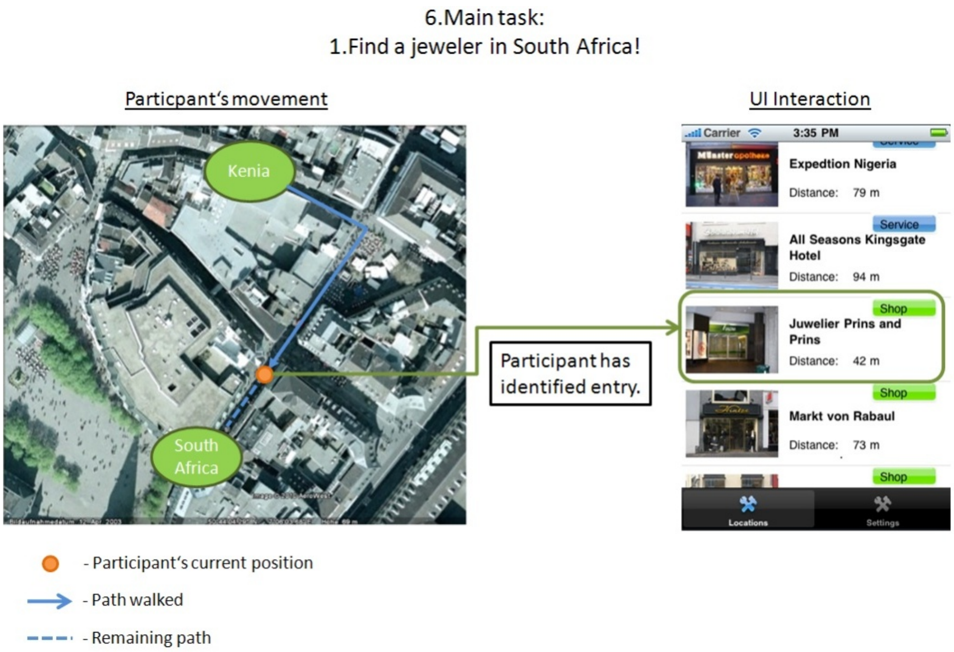


Figure 5.4: Subtask 6.1

2. Task: To which house does an information sign refer at the entrance of the Galeria Kaufhof? *Answer: Breuning'sche Haus.*
   The subtask 6.2 wants the participants to associate the virtual object with the real building in the experiment zone. The participant has to find a certain piece of information at the entrance of the "Galeria Kaufhof" store (Figure 5.5).

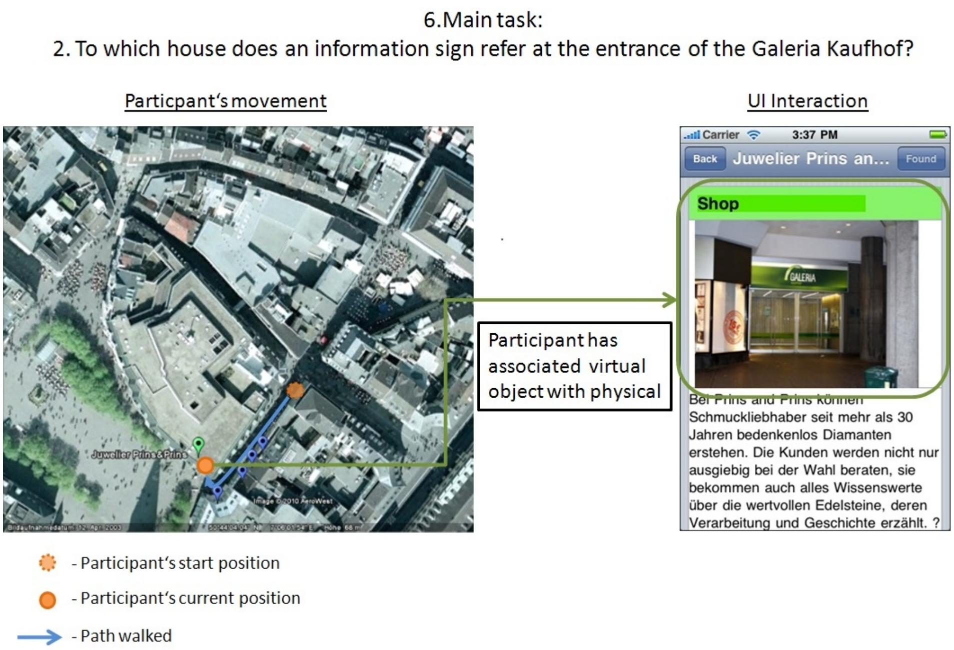


Figure 5.5: Subtask 6.2

3. Task: How much does a bungie jump in South Africa cost? *Answer: 160 Rand*
   In the subtask 6.3 the participants first has to find the correct entry in the location list and then the information in the description text (Figure 5.6).

Embedding Virtual Data into the Experiment Flow

The virtual data contained tourist information from three continents. The experiment itself should imitate a realistic scenario where "tourists" try to find Point-Of-Interests (POI) in an unfamiliar environment.
The idea for the scavenger hunt was packed into a "journey" through three continents. Every of the thirteen zones was associated with one country, every country consists of five POIs, each belonging to one of the five categories.

Layout of the Experiment

The researcher illustrated the flow of the experiment on a map, where the scavenger hunt game was played. Each of the main tasks was completed with a specific presentation style. All eight presentation styles were shown and explained to each participant at the beginning.

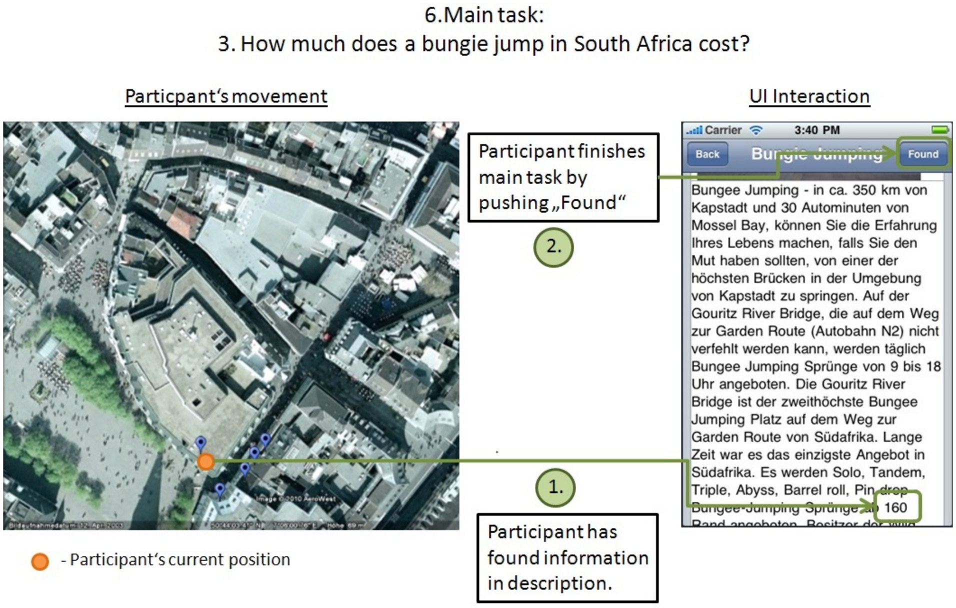


Figure 5.6: Subtask 6.3

Figure 5.7: Map the of complete environment of the experiment

Training session

After the participant signaled that he had understood the procedure of the experiment, he and the researcher moved to the training zone. In the training zone the participant had to complete a training session. In this session he had to execute a main task with a specific presentation style. This way the participant made himself familiar with the application and the procedure of the experiment.

Experiment Progress

After the training session the participant and the researcher walked towards the experiment zone. 100 meters before the start point the application was initiated. The iPhone's internal distance filter for the location updates was set to 5 meters.

LBSs tend to have a long waiting time for the first position fix, and the first location updates are often inaccurate. Because of the high inaccuracy of the first updates the variation of the location updates was high, five location updates were awaited before the experiment started. After the fifth location update an alert view appeared on the iPhone to inform the participant that the experiment will start when he pushes the "OK"-Button.

Participant is active factor during experiment.

When he reached the start point the researcher explained the first subtask and pointed on the map to the first location. After the participant indicated that he had understood the task, he started the experiment by pushing the "OK"-Button on the alert view. At this point the iPhone started its internal logging procedure, and the researcher started his stopwatch. The participant walked towards the designated location, the researcher walked behind him, observing his behavior. The participant was allowed to walk fast, but was not allowed to run. This way more sportive participants would not have advantages regarding the task completion time.

Researcher observes user-behavior

When the participant notified the researcher that he had found the entry for the first subtask, the researcher stopped the stopwatch and explained the next subtask. When the participant had understood the next subtask, the researcher started the stopwatch again and stopped it when the subtask was completed. This procedure was repeated over the course of the whole experiment. The participant was always the one who initiated the start of a subtask.
A main task was completed when the participant found the right entry, gave the right answer and pushed the "Found"-Button in the detail-view. This notified the iPhone that a main task had been completed, and all the

logged data was saved in an XML-File.

The participant was informed by an alert view that he had successfully completed a main task. The researcher then changed the presentation style for the next main task and the next subtask was assigned to the participant. When the participant pushed the "OK"-Button of the alert view the logging procedure started once again. This experiment terminated when all eight task had been completed. Figure 5.1 outlines the flow of the experiments with its main steps.

5.2 Evaluation Results

This section summarizes the experiment's statistical results. The task completion time performance and the touches per presentation style were evaluated.

5.2.1 Task Performance

Before the data was evaluated, it had to be pre-processed. The distances between the main tasks were not of equal length, which made the task completion time performances not comparable. Therefore the task completion time performances had to be normalized to make comparison between the task completion times for the eight presentation styles feasible. Table 5.3 shows the normalization for the total task completion time of the experiment (Mean: 24:03 min, SD: 01:06 min). All measured data from the experiment were normalized according to their normed length ratio. The normalized data was the basis for the calculation of the parametric tests which will be presented in the following section.

Data had to be normalized

Before running any parametric tests, it was checked if the data originate from a population that is normally distributed. A Kolmogorov-Smirnov[2] test showed no significance for the task completion time and touches for the eight presentation styles. This means that it is appropriate to conduct parametric tests on the data.

Results Task Performance

The results from the one-way repeated measures analysis of variance (ANOVA) indicate that task performance was not significantly affected by the presentation style $F(7, 105) = 1.68$, $p = .12$, $r = .2$. This was expected as the user's walking time was the main contributor to the overall task completion time rather than the presentation style themselves. Mauchly's test

[2]Objective test which measures if a sample is normally distributed.

Normalized task performance per main task							
1	2	3	4	5	6	7	8
Sum brutto time of main tasks (minutes)							
38:53	46:13	43:12	26:12	31:06	43:29	27:30	48:14
Length ratio POIs							
1,52	1,87	1,84	1,00	1,29	1,89	1,12	2,06
Sum net time of main tasks (minutes)							
25:33	24:45	23:25	26:12	24:10	23:04	24:09	23:26

Table 5.3: Normalization of task completion time performance

of sphericity showed that the assumption of sphericity had not been violated.

4 - 6 perform well

Figure 5.8 depicts the mean times for the eight presentation styles with their associated error bars . presentation styles *4 - 8* all range below a mean task completion time of 90 seconds, with presentation style *6* achieving the best performance of $M = 86.8$ (SE = 2.5) seconds. The presentation styles *1 - 3* have a mean task completion time higher than 90 seconds, with presentation style *2* performing worst with $M = 99.8$ (SE = 6.4) seconds.

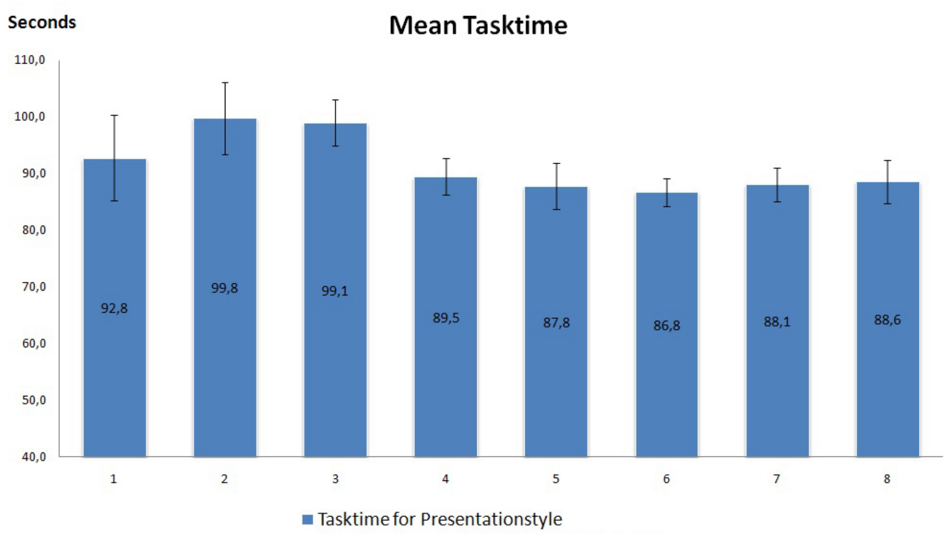


Figure 5.8: Comparison of the mean times of the presentation styles

Results Touches

The One-way repeated measures ANOVA revealed that the number of touches during a main task was significantly affected by the presentation style $F(7,105) = 2.11$, $p < .05$, $r = .26$. Mauchly's test of sphericity showed that the assumption of sphericity had not been violated. Bonferroni post hoc comparison revealed a significant difference between presentation style 5 and 8, CI_{95} = -14.25 (lower) - .17 (upper), $p < .05$. No other comparisons were significant (all $ps > .05$).
Figure 5.9 illustrates the mean times for the eight presentation styles with their associated error bars. The participants touched the iPhone the fewest with presentation styles *5* (M = 14.5, SE = 1.3) and *7* (M = 14.7, SE = 2.5). The presentation styles *6* (M = 14.7, SE = 2.7), *4* (M = 20.8, SE = 2.6) and *8* (M = 21.8, SE = 2.0) caused the most touches during the experiment.

5 and *7* have fewest touches

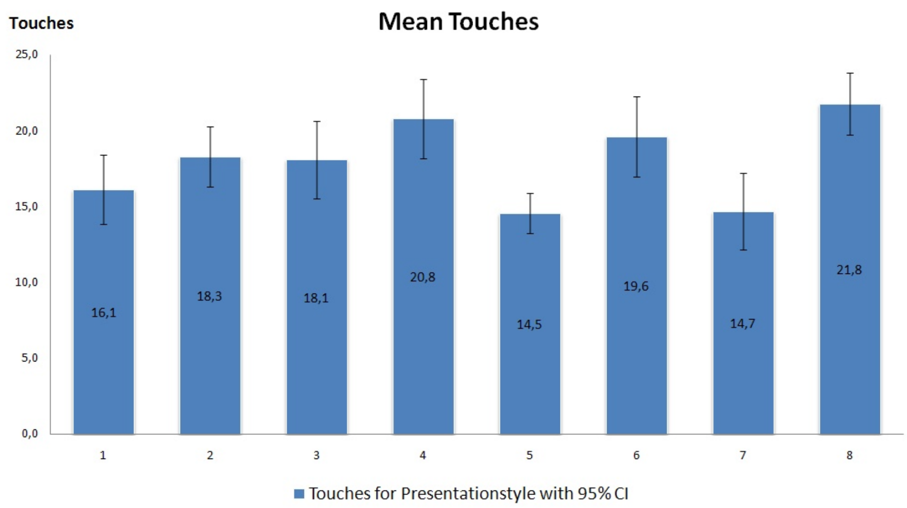


Figure 5.9: Comparison of the mean touches of the presentation styles

Results Radius Filter Changes

There is no data available for radiusfilter changes because none of the participants used the radius filter to decrease entries in the location list.

5.2.2 Comparison Female versus Male

To examine if there is a difference regarding the presentation style performance between the female and male participants, parametric tests were conducted.

Results Task Performance between Genders

The results from the one-way repeated measures ANOVA with the between-subject factor *gender* showed that the presentation style did not affected the task completion time $F(5.5, 77.1) = 1.71$, $p = .14$, (r) = .21. Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(27) = 44.89$, $p < .05$, therefore degrees of freedom were corrected using Huynh-Feldt ($\varepsilon = .79$). This result was expected since the participant's walking time was the main contributor to the overall task completion time rather than the presentation style themselves.

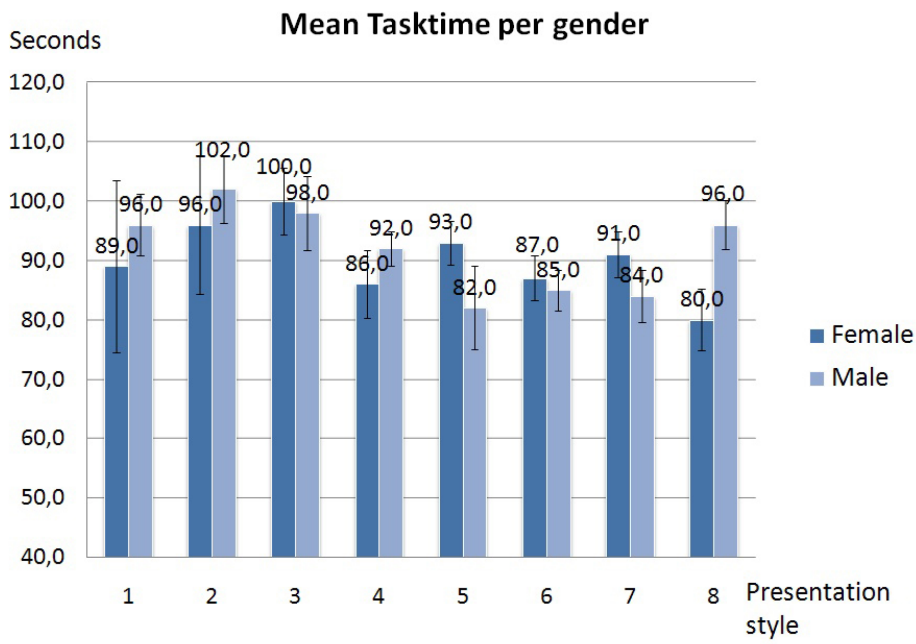


Figure 5.10: Comparison of the mean task completion time of the presentation styles between the genders

The interaction between the independent variable *presentationstyle* and the between-subject factor *gender* revealed no significance for the task performance regarding the presentation style $F(5.5, 77.1) = 1.21$, $p = .314$, $r = .11$. Figure 5.10 depicts the mean task completion time for the eight presentation styles. The biggest difference in the task performance can be seen for presentation style *5* (11 seconds) and presentation style *8* (16 seconds).

Results Touches between Genders

The results from the one-way repeated measures ANOVA with the between-subject factor *gender* showed that the presentation style did not affect the amount of touches $F(7, 98) = 2.04$, $p = .06$, (r) = .25. Mauchly's test indicated that the assumption of sphericity has not been violated.

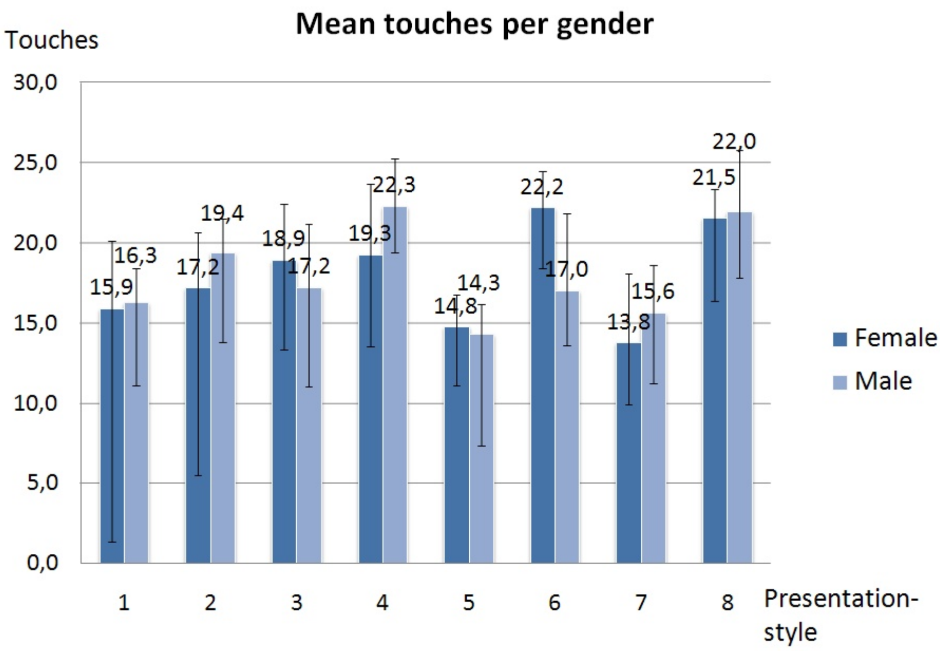


Figure 5.11: Comparison of the mean touches of the presentation styles between the genders

The interaction between the independent variable *presentationstyle* and the between-subject factor *gender* revealed no significance for the task performance regarding the amount of touches $F(7, 98) = .48$, $p = .85$, $r = 0$.
Figure 5.11 depicts the mean amount of touches for the eight presentation styles. The biggest difference between the amount of touches can be seen for presentation style *6*, a difference of 5.2 touches.

5.2.3 Questionnaire Results

After the participants had conducted the experiment, they filled out two questionnaires. The first one, the *general questionnaire* asked for the participants' opinion about the flow of the experiment and the participants' characteristics. The second one, the *usability questionnaire*, measured the user experience the participants had with the application during the experiment.

General Questionnaire

The first part of the general questionnaire evaluated the participants' characteristics (Figure 5.3). They indicated that a homogeneous group of people was chosen for the experiment. This should result in a low variance among the participants' results and make the results more reliable.

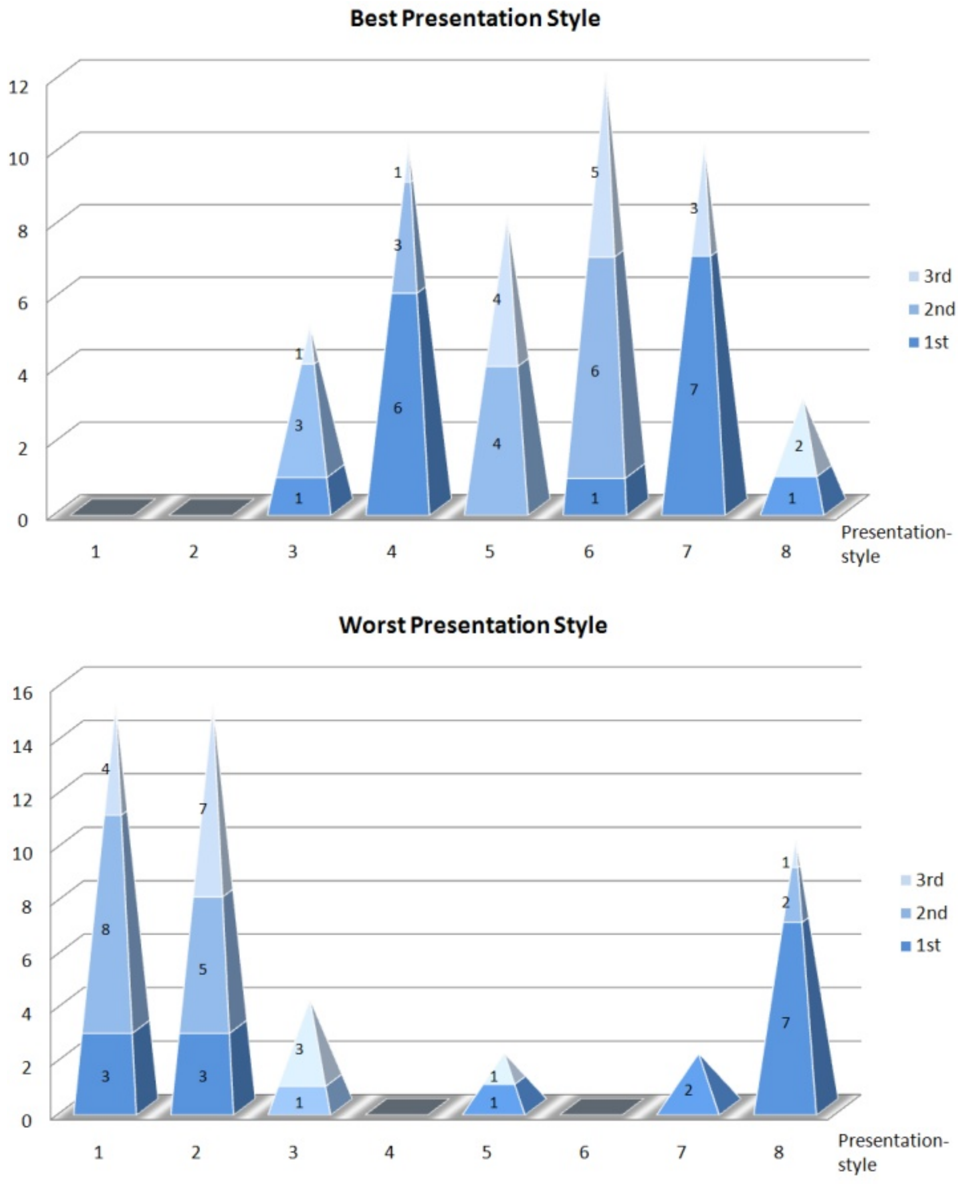


Figure 5.12: Comparison of the participants' favorite presentation styles

Two questions from the questionnaire inquired the participants' three most and least favored presentation styles (Table 5.1). The results in Figure 5.12 illustrate that presentation style *6*, *7*, *4* were the three favorites. All three presentation styles have in common that the category label is assigned to every entry in the location list and they are ordered by category. Presentation style *4* sorts the entries alphabetically within their category whereas presentation styles *6*, *7* sort them by distance. The difference between *6* and *7* is that presentation style *7* scales the entries by their distance within their category.

Participants favor *4*, *6* and *7*

Although presentation style *6* got the most votes (12), its mean value is the highest (M=2.33, SD=0.65) compared to presentation style *7* (M=1.6, SD=0.97) and *4* (M=1.5, SD=0.71). The participants preferred the entries to be ordered by their category and within the category alphabetically when searching for objects in their environment. presentation style *6* was the second or third choice.

The participants evaluated presentation styles *1*, *2* and *8* as the worst. Presentation style *8* and *2* ordered the entries alphabetically, whereas presentation style *2* scales them by distance. In contras presentation style *1* sorts the entries by distance. None of the three presentation styles uses category labels.
The participants' least favorite presentation style is *8* with M = 1.4 (SD = 0.70) , the other two presentation styles are ranked lower, presentation style *1* (M = 2.1, SD = 0.80) and *2* (M = 2.3, SD = 0.70).

The rest of the questions of the *General questionnaire* were open questions. They will be discussed in Chapter 6.

Usability Questionnaire

The goal of the questionnaire was to examine how the participants evaluated the usability of the application. A good overall result would indicate that the results were achieved by the experimental conditions and not by any misbehavior of the application.
Figure 5.13 shows the result. The first diagram *Mental Workload* asked the participants to measure the effort they had to put in to using the system. The results indicate that the own satisfaction level was high (M = 4.12, SD = 0.62) when using the system, and the frustration level was low (M = 2.13, SD = 1.31).

The participants were satisfied with the interaction speed of the system. The chart *Interaction Speed* depicts that the interaction was easy (M = 1.81, SD = 0.75) and the perceived interaction speed was fast (M = 2.31, SD = 0.75). The results for the *System Usability* were high, all scores ranged

Participants satisfied with the system

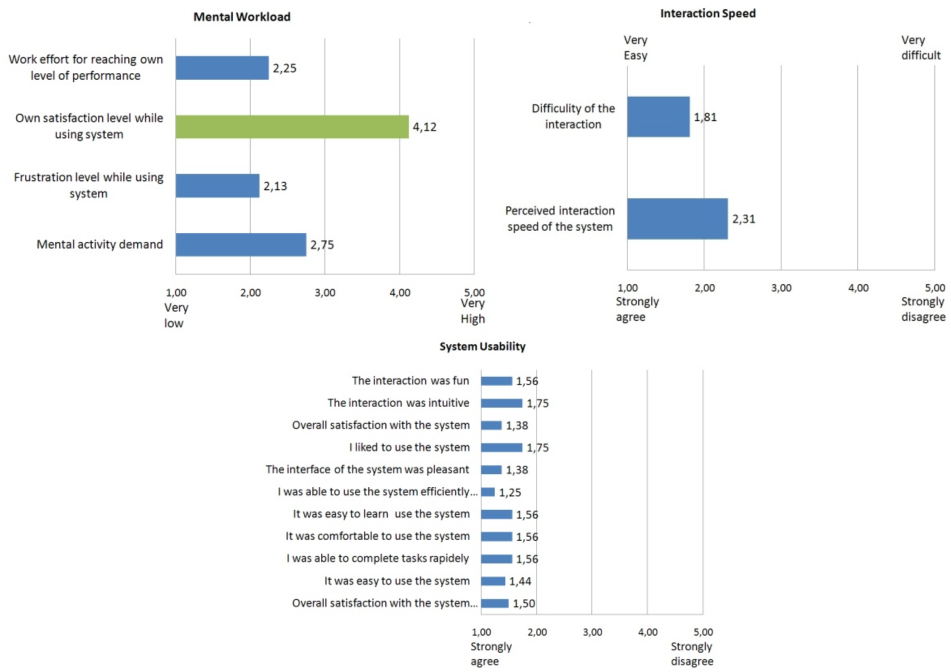


Figure 5.13: Comparison of the results from the usability questionnaire

between "strongly agree" and "agree" with a overall satisfaction of M = 1.5 (SD = 0.63).

Retrospectively the results from the usability questionnaire approve that the participants were satisfied with system usability and fulfill the non-functional requirements #7 - #9. Therefore it is concluded that the results were generated by the different conditions of the experiment and not by any malfunction of the system.

5.3 Summary

The focus of this chapter was to present the setup of the experiment and its results. It documented the goal of the experiment and the methods used to achieve the goal.

The 16 participants from a homogeneous group participated using a repeated-measures design. They conducted a task-driven experiment with push-based mobile LBS in a controlled experiment zone. A set of 65 POIs with virtual data was uniformly distributed in the city center of Bonn. In this experiment zone the task performance of the participants regarding the independent variable *presentationstyle* was evaluated with eight levels.

It was measured with six dependent variables (Completion time main task, Completion time experiment, Number of device touches main task, Number of device touches experiment, Number of times radius filter changed, position). The participants additionally contributed to the results by answering two post-experiment questionnaires.

The second half of the chapter presented the results of the experiment. Before any statistical test was conducted, the raw data had to be normalized to make a the data comparable.
Two main test-statistics were performed. One for comparing the mean task completion time between the eight presentation styles and one for measuring the number the touches for each presentation styles. The results showed that the mean task completion time varies between the presentation styles. The group of presentation styles *4 - 8* had the lowest mean task times. For the mean touches test the presentation styles *5* and *7* had the fewest touches.

The second row of tests compared the difference of the task performance between the genders. The mean task completion time test showed that females needed 11 seconds more to complete a main task with presentation style *5* than men. But they were 16 seconds faster with presentation style *8* than men. For the amount of mean touches the two genders performed equally, the biggest difference occurred with presentation style *6*, where women needed 5.2 touches more than men.
The results from the questionnaire illustrate that participants have identified three favorite presentation styles (*4*, *6*, *7*) and three least favorite (*1*, *2*, *8*).
The answers from the *usability questionnaire* revealed that the participants were satisfied with the usage of the application and with their own performance.

Chapter 6

Result Discussion

This chapter summarizes important findings of the experiment. The findings are divided into three sections. The first section presents the objective results measured by the dependent variables. The second section interprets the participants' answers from the two questionnaires. The third discusses interesting user-behavior that has been observed in the experiment.

Interpretation of the Results

6.1 Interpretation of the Task Performance

This section summarizes the results of the participants' task performance during the experiment and explains how the can be interpreted.

6.1.1 Category Labels are Important

Presentation styles *4 - 8* ranged all on the same mean time level. The results from the task performance indicate that assigning a category label decreases the time for identifying entries.
Only presentation style *8* is an exception, which had no category label assigned. It seems that it was easier for the participants to find an entry in the location list if it was alphabetically ordered than when the entries were ordered by distance (presentation style *1*). This result was not expected.

6.1.2 Scaling Entries Reduces Touches

The evaluation of the touches per task revealed that the presentation styles *5* and *7* had the fewest touches, indicating that people needed less interaction to find the entries with these styles. Both scaled the entries by distance and had the category label assigned which made identifying closer objects easier. The main difference between both presentation styles is that *5* ordered the complete location list by distance and *7* by category and within the category by distance. This result shows that combination of scaling and having a certain ordering by distance reduces the amount of touches a user would do.

Presentation styles which ordered the the complete location list alphabetically (*8*) or within a category (*4*) were touched the most times during a main task. Surprisingly presentation style *6* (entries ordered by category and within the category ordered by distance) was touched the third most time. This leads to the conclusion that scaling the entries by distance decreases the interaction participants need with a LBS.

6.1.3 Presentation Styles *5* and *7* Performed Best

Scaling entries improves usability

Looking at the results from both one-way repeated measures ANOVA we draw the conclusion the presentation styles which performed best were *5* and *7* (Figure 6.1). Both presentation styles scale their entries by distance which made the distinction between farer and closer objects easier, decreased the the amount of touches and the time for searching an object in the environment.
This is a contrasting finding to the adaptive interfaces discussed in the state of the art section 2.5.3), where the adaptive interfaces did not show an improvement to static interfaces.

It is concluded that entries in a location list of an (tourist-based) LBS are required to be ordered by their distance on the first level (presentation style *5*) or on the second (presentation style *7*) and scaled by distance. If the entries are categorized, the user must be made aware of this. In this work entries were assigned a category label.

6.1.4 Comparison Between Genders

The comparison between female and male participants indicated a difference for the task performance regarding time and touches but the findings from the test statistics were weak. Therefore it is advisable to observe the results as a trend, but not to draw a general conclusion.

6.1.5 Radius Filter Was not Used

An interesting finding of the experiment was that none of the participants used the radius filter to decrease the amount of entries in the location list, although it was introduced in the training session. The questioning of the participants revealed three reasons that have caused this behavior:

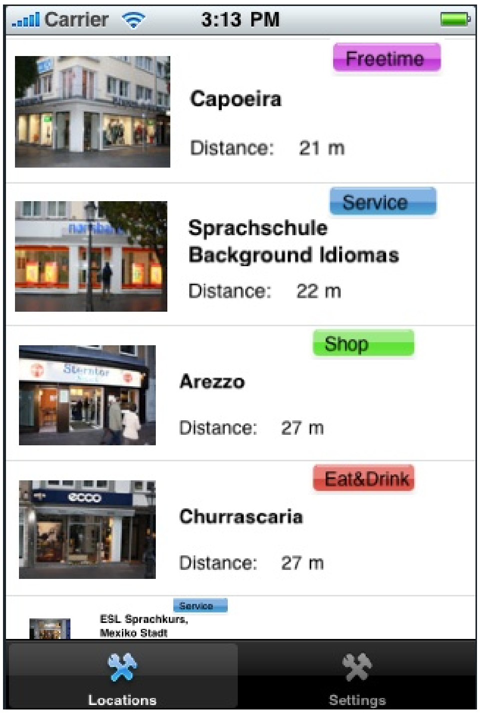
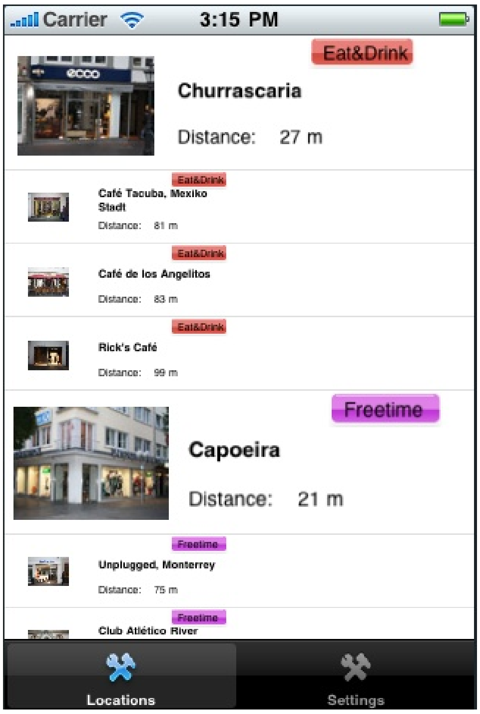
<table>
<tr><th>Presentation style 5</th><th>Presentation style 7</th></tr>
<tr><td>
</td>
<td>
</td></tr>
<tr><td>Order by distance + Scale by distance + Color by category</td><td>Order by category + Order by distance + Scale by distance + Color by category</td></tr>
</table>

Table 6.1: Presentation styles 5 and 7 with best performance

1. During the task-driven experiment the participants were too focused on solving a task and forgot about the radius filter.

2. The participants did not feel the need to use it because they never felt overstrained by the amount of entries in the list. A higher density of POIs in the experiment may have caused a different behavior.

3. The usage of the radius filter was too laborious in this task-driven experiment. Switching between the settings view and content view to decrease the amount of content was too time consuming for the participants. An approach where the iPhone's multi-touch feature had been exploited to interpret an input gesture may have caused a different result.

6.2 Interpretation of Participants' Feedback

The participants expressed their perception of the experiment in the two questionnaires. The interesting findings are presented in this section.

6.2.1 Participants want The Entries to be Ordered by Category

The two most preferred presentation styles were *4* and *7*. Both presentation styles categorize the entries on the first level. On the second level presentation style *4* orders the content alphabetically whereas *7* orders it by distance. Presentation style *7* also scales the entries by distance.
This result show that user of LBSs want the entries to be classified into categories. It makes it easier for them to identify the specific entries in the location list. This conclusion is supported by the fact that the third elected presentation style *5* also orders its entries by their category.
These findings answer the research questions raised by A. Hinze and G. Buchanan [HB05] in subsection 2.5.2.

6.2.2 The Best Presentation Style

Participants elect presentation style *7*

The participants' election and the statistical evaluation of their performance highlights presentation style *7* as the best in this experiment. The ordering by category makes it easy for participants to look for entries of a certain category. Scaling the entries and ordering them by distance decreases the interaction with the device. These performance results create a high acceptance among the users and make presentation style *7* the best presentation style.

6.2.3 Participants Like Push-Based LBS

In the *general questionnaire* 13 of the 16 participants said that the push-based system was comfortable to use. The results from the *usability questionnaire* (5.2.3) underline this statement. The push-based approach is a convenient method to provide users with geo-referenced data. This finding supports the observation from the GUIDE project [CMD02] where the push-based approach was only imitated through the Wizard-of-Oz method (see 2.3.2).

6.2.4 Investigation of Passive Push-Based LBS

A 6 out of 16 participants would have liked to use the push-based LBS passively by having the mobile system e.g. in a trouser pocket or handbag. The answers to how they would like to be informed were diverse. A range of notifications like vibration, vibration and ring tone or ring tones assigned to a specific category were requested. An experiment based on the work of Garzonis [GJJO09] could be conducted in the experiment zone to investigate the preferences.

6.2.5 Participants Enjoyed the Experiment Design

All of the 16 participants liked the procedure of the experiment which is documented by the questionnaires. The participants liked the mix of a traditional game from the their youth (scavenger hunt) with state-of-the-art technology. They enjoyed the mental challenge to associate virtual data with the physical objects.

6.2.6 Reference Design for Other Studies

The innovative idea of detaching spatial information from the physical landmarks can be exploited to other studies. It has the advantage that any kind of spatial data can be placed in a certain environment and gives the researcher the flexibility to adapt the design to the researcher's objective. The positive feedback from the participants about the experiment design give reason to conduct this technique.

Experiment design can be exploited in other studies

The reference environment created in this thesis could be easily exploited for other in-field studies (see Chapter 7.2). The data tier could be extended with other information, since the experiment zone has been tested against location and network quality (see Section 4.2).

6.3 Observation of User Behavior

This section interprets interesting participants behavior that was monitored during the experiment and corresponds to important HCI issues.

6.3.1 High Participant Motivation

The weather conditions during the evaluation phase were not optimal, the experiment was conducted in the winter time. But the competition approach was a good way to keep the motivation high. The idea came out of necessity because there were not enough resources available to pay all participants.

For a task-driven experiment the competitive approach has the two advantages that the motivation of the participants is kept high and that it saves costs. The participants' motivation to complete the tasks rapidly was very high and not expected by the researcher.

6.3.2 Participants Forget about the Environment

More research needed

The high motivation of the participants had also a downside: they were so engaged in solving the tasks on the mobile phone that they did not pay attention to their surroundings. Situations occurred where the participants cut a pedestrian's way, one of them almost ran a red light to perform better in the experiment.
This is a usability issue which has to be further investigated. The association between the information on the mobile client and its physical pendant must handled in a way that the user is still aware of his environment.

6.3.3 Update Problem

When the application updated the content of a new location, the application notified the participant with a loading screen and blocked any interaction with the UI. This approach was tested in a pilot study and gave no reason for being changed. Updates of new content were performed within two seconds.

Location-Update

Serious usability issue

An important usability issue occurred during the experiment. It was difficult to control the number of location updates, although the update rate was set to five meters and the implemented location update algorithm filtered out locations with low accuracy. The technical limitations of the iPhone's localization technologies do not allow to control the amount location updates with high granularity, which would have been required for the experiment.

The issue arose in the latter part of the experiment, and was an unsystematic problem of the application which occurred from time to time. Although a pilot-study was conducted to find these kind of problems, this specific problem was not discovered. The problem occurred only to few participants. It was noticed by the participants and also documented in the *usability questionnaire* where these participants rated the interaction speed with "average".

Apart from this problem, the participants were irritated by the unexpected update-behavior. The irregularity disturbed them. They could not accustom themselves to the update behavior.

Content-Update

Another problem within the update process was that a few participants had to wait longer than five seconds before the content was downloaded to the iPhone (in this case the researcher stopped the stopwatch to give the participant a fair chance). This is a general problem when using LBSs in a mobile context, they have to deal with a great range of variable download rates. With the implemented approach participants came into the situation where they had to wait longer than two seconds to continue using the application. Though it happened seldom, it is an unacceptable behavior.

The Solution

Both of the described problems are technical issues that occur in the mobile context. They must be hidden from the user to achieve a good user experience. Since the architectural Model-View-Controller pattern (MVC) [Bur92] was obeyed during the implementation, this could be easily fixed.

When an update is called, the new data is loaded into a buffer. When the download of the data is completed, the content view is updated with the new content from the buffer. The implementation of this pattern allows to interact with the application while new content is downloaded in the background and does not constrain the participants with downtimes. These findings underline the result from Kjeldskov et al. [KGP+05] that critical and serious problems are more likely to be identified in-field. The identification of usability problems was one of the sub-goals of this work.

6.3.4 Participants' behavior to Content Overwriting

Content overwriting accepted by participants

It can be concluded that the participants did recognize the overwriting of the content after a location update as a usability issue because the participants were mostly standing when they were looking at the VTG's location list. In cases when they were walking the updates were processed rapidly so that they did not felt disturbed.

However, it occurred a couple of times that the location update or the download process took longer than expected (see previous paragraph). In these cases the iPhone's location sensors needed more time than usual to determine the new position or the download rate was very low. Though this problem appeared seldom it is an occurring issue when using devices in the mobile context. The result was that the participants felt disturbed by this behavior because they could not use the application. The issue was not addressed by VTG, since the system test (see Section 4.4.3) did not reveal this problem.

When the participants read the text of an location list entry in the detail view, this problem was not noticed by the participants because the update was executed in the background.

6.4 Summary

This section discussed the main findings of the experiment. Two presentation styles (*5* and *7*) performed best in the experiment. In conjunction with the participants' answers, presentation style *7* was elected as the best way to present geo-referenced data on a mobile LBS. This answers the general research question of this thesis: *"How do users of a mobile push-based LBS behave in a task-oriented in-field experiment with different presentation styles?"*. Despite the interpretation of the performance results, important usability in-field issues were uncovered and participants' behavior was discussed. Both parts need more investigation in future work.

Table 6.2 summarizes the presentation style results in the different disciplines and ranks them.

Rank[1]	Presentation-style	Mean task completion time	Mean time touches	Participants' opinion
I	7	3	2	2
II	5	2	1	5
III	6	1	6	3
IV	4	5	7	1
V	3	7	4	4
VI	1	6	3	7
VII	2	8	5	6
VII	8	4	8	8

Table 6.2: Final ranking of presentation styles

[1] Ranking is calculated by weighted average of the individual results.

The following summarizes the answers this work has delivered to the open research questions which have been determined in Section 2.5. They were divided into I. Usability and II. Methodical problems.

I.a No evaluation of the presentation style Eight different presentation styles, defined by this thesis, have been evaluated in an in-field experiment. For the evaluation three different sources (task completion time, touches and user feedback) have been exploited to determine the favored presentation style. This results answers the questions raised in TIP on how to present the data in a list view. It also indicated that participants get along with an adaptive interface if the elements in UI are user-friendly, which confirms the assumption made in WUI (see Section 2.5.3).

I.b Low configurability The feedback from the initial questionnaire (see Section 3.1.1) show that users want to have control over context-aware systems. These findings answer one of the question "How much control should be assigned to the user of a context-aware system? [BE01]. Therefore both developed applications, the Wikipedia-Browser and the Virtual Tour Guide (VTG), were highly configurable.

In the in-field experiment the user's possibilities to change the settings were limited to the change of the radius filter. The reason for this decision was the task-oriented approach of the experiment. To examine users' preferences of a context-aware system a non-task oriented study like the GUIDE project (see Section 2.5.1) would be more applicable.

I.c Content Adaption The findings of the experiment indicate that the participants had no problems when the content was overwritten for new location updates. But technical issues which occur in the mobile context like sensor or download problems have to be hidden from the users to not decrease the user-experience (UX).

II.a Location Granularity The iPhone's positioning features allow to exploit three different positioning techniques. They have been tested in the test environment. The results of the iPhone's position quality were satisfying. The participants were always informed about their position, with an inaccuracy mainly below 20 meters.

II.b No evaluation with smartphones The observation of the participants' behavior showed that they enjoyed using the smartphone during the experiment. They handled the disadvantages of the small screen well and liked the operation of the touch display. Additionally, the participants liked the experiment design. They enjoyed the scavenger hunt in a virtual tourist environment.

II.c Implementation of different LOIs Although three different Levels of Interactivity (LOI) were implemented (passive and active information push and information pull), only the active information push was implemented.

The participants' feedback revealed that they liked the push-based LBS, which approves Cheverst findings when they examined the push-based approach with the Wizard of Oz method (see Section 2.3.2) and a bigger device [CMD01]. One problem of the push-based approach is that users may become unaware of their environment as this study revealed. They become too focused on the reception of new data and only stare at the device.

Further investigation is needed to find solutions to this problem.

Chapter 7

Conclusion & Future Work

7.1 Conclusion

The thesis' goal was to examine user-behavior in a in-field experiment with a push-based LBS.

It was examined how participants identify entries in a list view efficiently, and which kind of presentation style they prefer.
Another major goal was to evaluate serious usability problems which occur when using a push-based LBS in-situ. Based on prior research open questions were examined in an in-field experiment. To assure a certain quality of this work, the following well-established methods have been used:

Goal of thesis achieved

- Interviews
- Scenarios
- Use cases
- Prototyping
- Expert review/workshop
- In-field experiment

7.1.1 Major Findings

A design for a user study has been developed. The novel approach of implementing a virtual scavenger hunt to evaluate presentation styles of an push-based LBS was appreciated by the participants. This reference design could easily be transferred to other in-field experiments with mobile LBSs.

The experiment environment with its spatial virtual data could be used for other types of studies. Or the spatial data could be easily exchanged with other information types in the experiment environment.

The in-field experiment was conducted with a push-based LBS. No previous studies have investigated a fully implemented push-based LBS in-field as designed in this thesis. The experiment revealed serious usability problems which have been discussed in Chapter 6 and therefore achieved its goals.

The participants' feedback concludes that push-based approach is a convenient method to provide users with spatial data. However, the identified usability problems, especially with location update process needs more investigation. The push-based technique, implemented in this thesis, is put into context with prior research (see Section 2.5) in Figure 7.1.

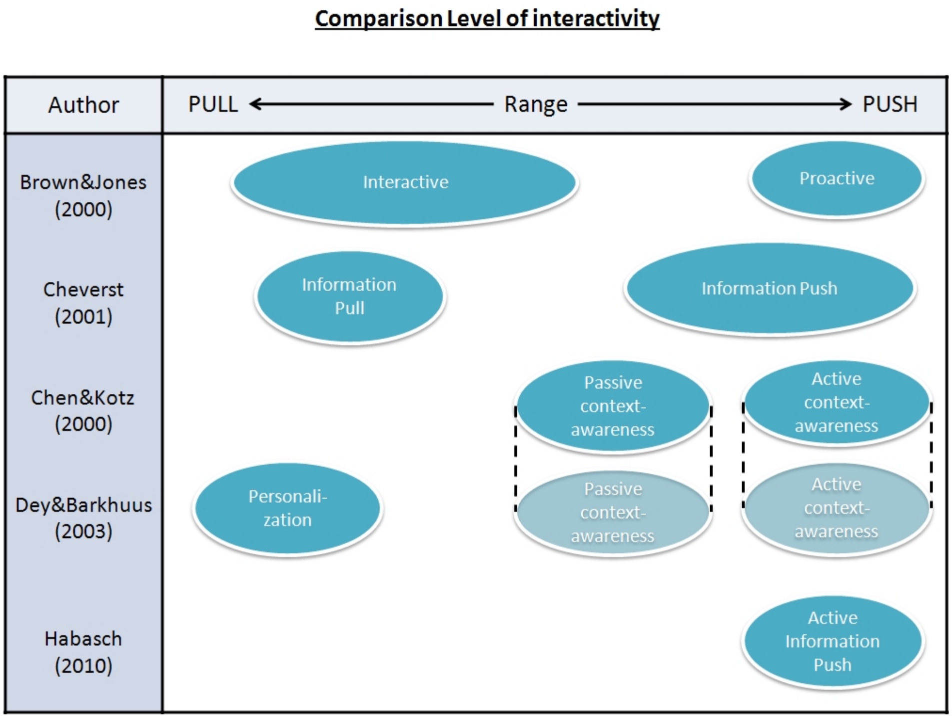


Figure 7.1: Thesis' Level of Interactivity in context with prior research

Results sustained with 3 sources

The thesis examined eight alternatives of a list-based presentation style on a mobile LBS. The findings of the experiment identified two favorite presentation styles, presentation style *5* and *7*. They performed best regarding the task completion time and the number of touches. The participants' feed-

back revealed presentation style *7* as the best presentation style.
The experiments' findings concerning the presentation style are supported by three different sources: the task completion time, number of touches and the participants' feedback. This sustains the objectivity of the experiment's findings.

7.2 Future Work

This section presents possible future area of work based on the contribution of this thesis.

7.2.1 Increase the Density

An equal in-field experiment could be conducted with a higher density of POIs. In this thesis' study the countries' centroids had a medium distance of 157 meters. In a future study the density could be increased with a medium distance of 80 meters. It would be interesting to observe if users would behave differently if the data amount is increased. Maybe then another presentation style would be favored?

7.2.2 Adaptive Interfaces - Part II

The experiment's findings indicate that users get along with adaptive interfaces. The best two presentation styles *5* and *7* (see Section 6.1.3) scaled their entries by distance. This result gives reason for more investigation. A user-study could be conducted which focuses completely on adaptive interfaces. The spatial content is already provided by the work done in this thesis. The experiment design could be similar structured as in the two papers of Kane et al. [KWS08] and Yamabe et al. [YT07], where the adaptive interface is tested against static interfaces. However, the usability issues that both afore mentioned works had, have to be avoided. The adaptive interface could present the data in a list-based view, as it was implemented in this thesis, or a map-based view could be tested, where the maps zooms in and out depending on the user's speed.

7.2.3 Decrease the Mental Effort

One big problem the experiment revealed was that the participants did not pay attention to their surroundings while conducting the study (see Section 6.3.2). Transferring this observation into real life, this could mean that the user could cause serious accidents with other participants or even vehicles. Hence, techniques have to be evaluated which decrease users' mental effort to operate with mobile devices, so that they are more aware of their surroundings. A user-study could be conducted where participants use the mobile device only with one hand. The participants would interact with the mobile device with gestures. Nowadays smartphones like the iPhone have a set of different sensors which could be exploited to interpret the participants' gestures. For new information the participants could be informed via a combination of ringtones and vibration. This kind of study may reveal interesting findings on how to decrease a user's mental effort.

7.2.4 Notification Experiment

In their feedback 6 participants indicated that they would like to use the push-based LBS passively. An notification experiment based on Garzonis et al. [GJJO09] could be conducted. A combination of different ringtone types and vibration could be evaluated to identify which combination users would prefer.

Appendix A

First Questionnaire

Questionnaire 1

Version: 0.4

Comment: The questions will be asked in german.

Begin questionnaire:

0.1 Befragte Person in nicht- oder technik-affin Gruppe einteilen(+, -)

0.2 Wie alt bist du?

0.3 Männlich oder weiblich?

1. **Von welcher Marke/ welchem Hersteller ist dein Mobilfunkgerät/ Handy?**

Bei mehreren Mobilfunkgeräten / Handys bitte auf dein Hauptmobilfunkgerät / -handy beziehen, sprich auf das Mobilfunkgerät / Handy, das du hauptsächlich nutzt, egal ob privat oder geschäftlich.

❍	BenQ	[1]
❍	LG Electronics	[2]
❍	Motorola	[3]
❍	Nokia	[4]
❍	Sagem	[5]
❍	Samsung	[6]
❍	Siemens	[7]
❍	Sony Ericsson	[8]
❍	Panasonic	[9]
❍	Apple Iphone	[10]
❍	Sonstige, und zwar:	[11]
❍	Weiss nicht	[99]
❍	Keine Angabe	[98]

2. **Um was für ein Gerät handelt es sich bei deinem Mobilfunkgerät / Handy**

Bei mehreren Mobilfunkgeräten / Handys bitte auf dein Hauptmobilfunkgerät / -handy beziehen, sprich auf das Mobilfunkgerät / Handy, das du hauptsächlich nutzt, egal ob privat oder geschäftlich.

- ❍ Handy [1]
- ❍ PDA [2]
- ❍ smartphone [3]
- ❍ Blackberry [4]
- ❍ Sonstiges, und zwar: [5]
- ❍ Weiss nicht [99]
- ❍ Keine Angabe [98]

3. Welche der folgenden Funktionen Ihres Mobilfunkgeräts / Handys nutzt du noch, außer dem Telefonieren

Mehrfachantwort möglich

- ❑ SMS/ Kurznachricht [1]
- ❑ MMS [2]
- ❑ Internet [3]
- ❑ Musik hören bzw. MP3-Player [4]
- ❑ Spiele [5]
- ❑ Fotografieren [6]
- ❑ GPS/ Navigation (GPS = Global Positioning System; per GPS kann zu jeder Zeit eine Positionsbestimmung sehr schnell durchgeführt werden) [7]
- ❑ E-Mails versenden [8]
- ❍ Keine der genannten [9]

3.[9] Wieso nutzt du sie nicht? (offen zu allen nicht genannten außer Internet nachfragen)

b) Was fehlen dir für Multimediafunktionen? (offen)

Wenn Frage 3 = 3 (Internet genutzt);

Welchen Tarif nutzt du, wenn du das Internet über dein Handy nutzt?

Bei mehreren Mobilfunkgeräten / Handys bitte wieder auf das hauptsächlich genutzte beziehen.

- Datenflatrate [1]
- Minuten- oder Datenpakete [2]
- Grundpreis + Minutenpreis
- Weiss nicht [99]
- Keine Angabe [98]

Wenn Frage 3 ≭ 3 (Internet genutzt);

a)Wieso nutzt das Internet nicht über dein Handy?

b) Gibt es Anwendungen die dich interessieren bzw. zur Nutzung motivieren würden?

4. Was verstehst du unter einer orts-sensitiven Anwendung?(ungestützt)

(das Konzept von orts-sensitven Anwendungen erläutern, wie Daten übertragen werden und was für Anforderungen erfüllt werden müssen, damit man so eine Anwendung nutzen kann)

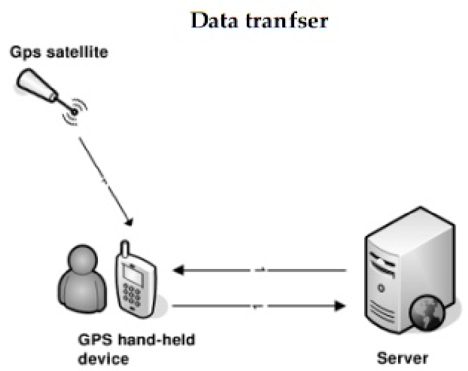


Abbildung 1

Beispielszenario für eine orts-sensitive Anwendung

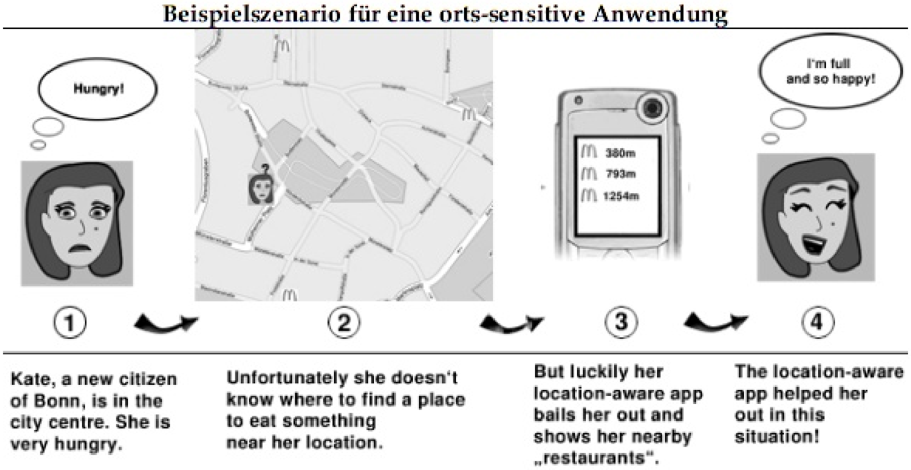


Abbildung 2

5 **Wie interessant ist allgemein die Nutzung von orts-sensitiven Anwendungen für dich?**

Nicht interessiert	1	2	3	4	5	6	Sehr interessiert

6. **Welche Vorteile siehst du bei der Nutzung einer solchen Anwendung?**

7. **Welche Nachteile siehst du bei der Nutzung einer solchen Anwendung (z.B. Versand persönlicher Daten)? Bzw. Verbindest du irgendwelche Ängste mit der Nutzung einer solchen Anwendung?**

8. **Könntest du dir orts-sensitve Anwendung vorstellen, die für dich besonders interessant wären?**

9. **Wäre es für dich in Ordnung, um eine ortsensitive Anwendung zu nutzen, ein extra Gerät für die Lokalisierung zu tragen, um die Genauigkeit der Positionierung zu verbessern?**

a) Ja
b) Nein

c) weiß nicht

(eigene Anwendung kurz vorher beschreiben)
10. Du hast von GeoLocator gehört und möchtest es installieren. Wie sollte deiner Meinung nach die Installation verlaufen?

11.1a) Vollig automatisch
11.2b) Nutzerinteraktion währen der Installation
11.3c) Weiß nicht
11.4d) k.A.

11. Wieviel Kontrolle möchtest du über die Anwendung haben?

a) Anwendung übernimmt die komplette Konfiguration
b) User hat die Kontrolle über die Einstellungsmöglichkeit

Anwendung übernimmt Kontrolle	1	2	3	4	5	6	User übernimmt Kontrolle

12. Stell dir folgendes Szenario vor: Du liest dir gerade orts-sensitve Informationen, die dir von GeoLocator zur Verfügung gestellt werden, auf deinem Handy durch, während du durch die Stadt läufst. Nun tritt der Fall auf, dass die von dir gerade gelesene Information verschwindet und durch eine neue aktualisiert wird, obwohl du die alte Information noch nicht zu Ende gelesen hast.
Würde dich diese Art des Updatens stören?

Ja) Welche Möglichkeiten fallen dir ein, um das Problem zu lösen?

13. Wie sollte deiner Meinung nach das Updaten der Daten geregelt werden?

a) zeitabhängig
b) streckenabhängig
c) geschwindigkeitsabhängig
d)…………………….(eigener Vorschlag)
e) weiß nicht
f) keine Angabe

14. Sollte die Anwendung im Hauptfenster laufen oder lieben im Hintergrund, und nur bei neuen Informationen aufpoppen?

a) Hauptfenster
b) Aufpoppen
c) Weiß nicht

End questionnaire

Appendix B

Volere Requirement Specification Template

B.1 Glossary for the Volere Requirement Shell

Functional Requirements : Functional requirements are the fundamental or essential subject matter of the product. They describe what the product has to do or what processing actions it is to take

Nonfunctional Requirements : Nonfunctional requirements are the properties that the functions must have, such as performance and usability. Do not be deterred by the unfortunate type name - these requirements are as important as the functional requirements for the product's success.

Requirement # : A sequential number, starting in 1 for each service. Requirement numbers should not be reused. If a previously written requirement has been deleted, that row must be emptied but the requirement number must be kept.

Requirement Type : Type of requirement as defined in the Volere requirement classification.

Description : A one sentence statement of the intention of the requirement.

Rationale : A justification of the requirement.

Fit Criterion : A measurement of the requirement such that it is possible to test if the solution matches the original requirement.

Customer Satisfaction : Degree of the stakeholder happiness if this requirement is successfully implemented.

Customer Dissatisfaction : Degree of the stakeholder unhappiness if this requirement is not implemented.

B.2 Requirement Shells

Volere requirement types used in this thesis:

9. Functional Requirements
11. Usability and Humanity Requirements
    (a) Ease of Use Requirements
    (c) Learning Requirements
12. Performance Requirements
    (a) Speed and Latency Requirements
    (d) Reliability and Availability Requirements
17. Legal Requirements
    (c) Standards Requirements

B.3 Functional Requirements - Part I

Requirement #	**1**
Requirement Type	9
Description	Application requires exploiting different positioning methods.
Rationale	Conjunction of different positioning techniques increases the positioning quality.
Fit Criterion	Implement at least two different positioning techniques.
Customer Satisfaction	5
Customer Dissatisfaction	5

Table B.1: Requirement Shell 1

Requirement #	**2**
Requirement Type	9
Description	Application adapts position update to user's velocity.
Rationale	Adaption of position update to user's velocity increases the user experience because user disturbed with too few updates or under-informed by too few updates.
Fit Criterion	Change the distance for the position updates if a certain threshold is exceeded.
Customer Satisfaction	4
Customer Dissatisfaction	3

Table B.2: Requirement Shell 2

Requirement #	**3**
Requirement Type	9
Description	Data size adapts to network speed.
Rationale	The adaption decreases latency and therefore increases the user-experience.
Fit Criterion	Change type content if a certain download threshold is exceeded. Define at least three ranges :1. Below 64kBit/s, 2. Between 64 - 128 kBit/s, 3.Higher than 128 kBit/s.
Customer Satisfaction	5
Customer Dissatisfaction	2

Table B.3: Requirement Shell 3

Requirement #	**4**
Requirement Type	9
Description	Presentation style adapts to the user's movement speed.
Rationale	The user's speed is interpreted as different use cases in which an adaption of the presentation style will increase the usability.
Fit Criterion	Define certain speed range in which only specific content types are provided.
Customer Satisfaction	5
Customer Dissatisfaction	2

Table B.4: Requirement Shell 4

Requirement #	**5**
Requirement Type	9
Description	Geo-referenced content requires being available in a wide area.
Rationale	Application is usable in different placed and not only bound to certain test environment.
Fit Criterion	Geo-referenced content must be available at least in the city of Bonn (Germany).
Customer Satisfaction	5
Customer Dissatisfaction	4

Table B.5: Requirement Shell 5

Requirement #	**6**
Requirement Type	9
Description	Application requires giving the user control over the settings.
Rationale	The user can match the settings to his preference.
Fit Criterion	The user must be able to select at least: • The update-type • Content-type • Update-rate • Update notification via vibration
Customer Satisfaction	5
Customer Dissatisfaction	4

Table B.6: Requirement Shell 6

B.4 Non-functional Requirements

Requirement #	**7**
Requirement Type	11a
Description	The application requires to be easy to use for the participants of the evaluation.
Rationale	A certain level of usability assures that the participants can focus on the user study and not on the usability of the device.
Fit Criterion	Reach at least a value of 2,5 (or lower) [1] on the ease of use level in the post-study questionnaire.
Customer Satisfaction	4
Customer Dissatisfaction	4

[1] On a 5-point Likert Scale, where 1 is the best and 5 is the worst value.

Table B.7: Requirement Shell 7

Requirement #	**8**
Requirement Type	11c
Description	The application requires to be easy to learn for the participants of the evaluation.
Rationale	A certain level of easiness of learnability assures that the participants can focus on the user study and not on the usability of the device.
Fit Criterion	Reach at least a value of 2,5 (or lower) on the easiness of learnability level in the post-study questionnaire.
Customer Satisfaction	4
Customer Dissatisfaction	4

Table B.8: Requirement Shell 8

Requirement #	**9**
Requirement Type	12a
Description	The response time of the application must be fast so that the participants are not disturbed with a frozen application during the user-study.
Rationale	A fast response assures that the participants can focus on the user study and do not have to wait for the application's response which would decrease the user experience.
Fit Criterion	Reach at least a value of 2,5 (or lower) on the interaction speed level in the post-study questionnaire.
Customer Satisfaction	5
Customer Dissatisfaction	5

Table B.9: Requirement Shell 9

Requirement #	**10**
Requirement Type	12d
Description	The application must have a high reliability so that the participants are not disturbed with a frozen application during the user-study.
Rationale	Asserts a certain level of software quality.
Fit Criterion	The application requires to comply with the iPhone Human Interface Guidelines.
Customer Satisfaction	5
Customer Dissatisfaction	5

Table B.10: Requirement Shell 10

Requirement #	**11**
Requirement Type	17b
Description	The application requires complying Apple iPhone standards.
Rationale	Asserts a certain level of software quality
Fit Criterion	Reach at least level of uptime of 99% during the user study.
Customer Satisfaction	5
Customer Dissatisfaction	5

Table B.11: Requirement Shell 11

B.5 Functional Requirements - Part II

Requirement #	**12**
Requirement Type	9
Description	Create own geo-referenced data set.
Rationale	Gives full control over the data quality and allows to distribute data uniformly.
Fit Criterion	Create at least 50 geo-referenced data set.
Customer Satisfaction	1
Customer Dissatisfaction	1

Table B.12: Requirement Shell 12

Requirement #	**13**
Requirement Type	9
Description	Data requires to be divided into categories.
Rationale	Allows to filter data by category
Fit Criterion	Create at least five distinctive categories.
Customer Satisfaction	1
Customer Dissatisfaction	1

Table B.13: Requirement Shell 13

Requirement #	**14**
Requirement Type	9
Description	Implement a push-based LBS.
Rationale	Only few studies have focused on pure push-based LBSs.
Fit Criterion	The prototype must implement a push-based location update system.
Customer Satisfaction	1
Customer Dissatisfaction	1

Table B.14: Requirement Shell 14

Requirement #	**15**
Requirement Type	9
Description	Use different presentation styles for the geo-referenced information.
Rationale	Examine which kind of presentation styles are the participants' favorites.
Fit Criterion	Provide at least eight different presentation styles which shall be examined.
Customer Satisfaction	1
Customer Dissatisfaction	1

Table B.15: Requirement Shell 15

Requirement #	**16**
Requirement Type	9
Description	It is required to gather qualitative and quantitative data.
Rationale	The gathering of both types of data assure a better data quality.
Fit Criterion	Gather quantitative with data logging and questionnaires. Qualitative data will be recorded through a researcher and the participants' comments.
Customer Satisfaction	1
Customer Dissatisfaction	1

Table B.16: Requirement Shell 16

Appendix C

Statistical Terms

Appendix C explains important statistical terms which have been used in this thesis [FH03].

Standard Deviation (SD) The standard deviation is measure of how well the mean represents the data.

Standard Error (SE) The standard error expresses how well a particular sample represents the population. It is the standard deviation of sample means.

Effect Size (r) The effect size is an objective and standardize measure of the magnitude of the observed effect. It lies between 0 (the experiment explains none of the variance) and 1 (the experiment explains all of the variance).

Kolmogorov-Smirnov The Kolmogorov-Smirnov test is an objective test of the distribution. It test compares the set of scores in the sample to normally distributed set of scores with the same mean and the standard deviation.

Analysis of Variance (ANOVA) The ANOVA test is used when an experiment has more than two independent variables. It is expresses the overall experimental effect.

One-Way Repeated Measures ANOVA If the experiment has three or more experimental groups (comparison of three or more means), and the same participants are used in each group, then the one-way repeated measures ANOVA has to be used to analyze the data.

Sphericity Sphericity is an assumption, which assumes that the variance between the treatment levels are equal in a one-way repeated measures ANOVA. So that the means of the experimental groups are comparable. The Mauchly's test checks the hypothesis that the differences between each pair of treatment levels have equal variances.

Appendix D

General Questionnaire

Allgemeiner Fragebogen

1. Alter

2. Geschlecht

3. Wie gut kennst du dich in der Bonner Innenstadt aus?

   a) Gar nicht
   b) Wenig
   c) Durschnittlich
   d) Gut
   e) Sehr gut

4. Wie würdest du deine Erfahrung mit Computer einordnen?

   a) Keine
   b) Wenig
   c) Durchschnittlich
   d) Hoch
   e) Experte

5. Wie würdest du deine Erfahrung mit Handys einordnen?
   a) Keine
   b) Wenig
   c) Durchschnittlich
   d) Hoch
   e) Experte

6. Hast du bereits Erfahrungen mit Touchdisplay-Handys machen können?
   a) Keine
   b) Wenig
   c) Durchschnittlich
   d) Hoch
   e) Experte

Figure D.1: Page 1 of the General Questionnaire

7. Hast du bereits Erfahrungen mit einer ortssensitiven Anwendung auf einem Smartphone machen können?

   Ja / Nein

8. Bitte ordne die Art die ersten 3 Präsentationstile ein, die dir am besten gefallen haben.

Präsentationstyp	**Präferenz (1. 2. 3.)**	**Grund (freiwillig)**

9. Bitte ordne die Art die ersten 3 Präsentationstile ein, die dir am wenigsten gefallen haben.

Präsentationstyp	**Präferenz (1. 2. 3.)**	**Grund (freiwillig)**

Figure D.2: Page 2 of the General Questionnaire

10. Etwas, was du an dem Experiment als gut empfunden hast?

11. Etwas, was du an dem Experiment als schlecht empfunden hast?

12. In welchen Situationen würde die Nutzung von orts-sensitiven Anwendungen für dich am hilfreichsten sein?

13. War die Art, der push-basierten Updates angenehmen für dich?

JA/NEIN
Falls, NEIN: Welche Art von Update wäre für dich angenehmer? (z.B Manuell, Hinweis das neue Infos da sind, wie bei einer SMS)

Figure D.3: Page 3 of the General Questionnaire

14. Würdest du das Gerät bei pushbasierten Updates lieber passiv benutzen (z.B. in die Hosentasch stecken) und nur bei neuen Informationen aufmerksam gemacht werden?

JA/NEIN
Falls JA: Was wäre für dich eine angenehme Art über neue Informationen aufmerksam gemacht zu werden?

a) Vibration
b) Allg. Klingelton
c) Kategoriebezogener Klingelton
d) Vibration + Klingelton
e) Andere Art:

15. Weitere Kommentare und Vorschläge?

Figure D.4: Page 4 of the General Questionnaire

Appendix E

Usability Questionnaire

Interaction Technique:

	Trifft stark zu	Trifft zu	Weder noch	Trifft nicht zu	Trifft überhaupt nicht zu
1. Insgesamt, bin ich mit der Bedienbarkeit des Systems zu frieden.	1	2	3	4	5
2. Es war einfach das System zu benutzen.	1	2	3	4	5
3. Ich war in der Lage Aufgaben schnell mit dem System durchzuführen.	1	2	3	4	5
4. Ich fand es komfortabel das System zu benutzen.	1	2	3	4	5
5. Es war einfach zu erlernen, wie man das System benutzt.	1	2	3	4	5
6. Ich denke, ich könnte in kurzer Zeit effizient mit dem System arbeiten.	1	2	3	4	5
7. Das Interface/Benutzeroberfläche des Systems war angenehm.	1	2	3	4	5
8. Ich mochte es das Interface/Benutzeroberfläche zu benutzen.	1	2	3	4	5
9. Insgesamt bin ich mit dem System zufrieden.	1	2	3	4	5
10. Die Bedienung/Interaktion war intuitiv	1	2	3	4	5
11. Die Bedienung/Interaktion hat Spaß gemacht	1	2	3	4	5

Figure E.1: Page 1 of the Usability Questionnaire

12. Empfundene Interaktionsgeschwindigkeit des Systems war:

1.Sehr schnell	2. Schnell	3.Durchschnittlich	4.Langsam	5.Sehr langsam

12. Schwierigkeit der Interaktion

1.Sehr einfach	2.Einfach	3.Durchschnittlich	4.Schwierig	5.Sehr schwierig

	Sehr gering	Gering	Unentschlossen	Hoch	Sehr hoch
A. Mentale Anforderung. Wieviel mentale und empfundene Aktivität wurde verlangt (z.B. Denken, Entscheiden, Erinnern, Schauen, Suchen, etc.)?	1	2	3	4	5
B. Frustration Ebene. Wie unsicher, entmutigt, irritiert, gestresst, belästigt Vs. sicher, befriedigt, entspannt warst du während der Benutzung der Anwendung?	1	2	3	4	5
C. Performance. Wie sehr warst du mit deiner eigenen Leistung bei der Benutzung des Systems zufrieden?	1	2	3	4	5
D. Bemühung: Wie sehr musstest du arbeiten (mental und physisch) um deinen Grad der Leistung zu erreichen?	1	2	3	4	5

Positive Aspekte: ______________________________

____

Negative Aspekte: ______________________________

____

Kommentar: ______________________________

____

____

Figure E.2: Page 2 of the Usability Questionnaire

Appendix F

Scavenger Hunt Certificate

Figure F.1: The certificate for the best three participants of the study

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