TAMPERE UNIVERSITY OF TECHNOLOGY

MIIKKA SALMINEN

MOBILE NAVIGATION WITH MIRROR WORLDS: USER EXPERIENCE AND NEEDS

Master's thesis

Examiner: professor Kaisa Väänänen-Vainio-Mattila
Supervisor: Dr. Tech. Thomas Olsson
Examiner and topic approved by the Faculty Council of the Faculty of Computing and Electrical Engineering on 5.12.2012

ABSTRACT

TAMPERE UNIVERSITY OF TECHNOLOGY
Master's Degree Program in Information Technology
SALMINEN, MIIKKA: Mobile navigation with mirror worlds: user experience and needs
Master of Science Thesis, 82 pages, 14 appendix pages
March 2013
Major: Usability
Examiner: professor Kaisa Väänänen-Vainio-Mattila
Keywords: mobile navigation, mirror worlds, street view, panoramas, user experience, user needs

Mixed reality applications have started to become more popular and widespread. One particular area where mixed reality is utilized is navigation applications. This thesis examines one such navigation application, Nokia City Scene. City Scene offers map and panoramic street view with points-of-interest. Main focus of this thesis is navigation; goal is to find out what people expect from navigation applications and Nokia City Scene, and how and on what purposes are different navigation modes used in City Scene. User experience of City Scene is also studied to a lesser extent.

At the beginning of the thesis, theoretical background is provided. Discussed areas are user experience, human navigation and computer aids, and mixed reality and mirror worlds. Nokia City Scene application is then introduced. Rest of the thesis deals with conducted research and its results. There were two studies: an Internet questionnaire for Nokia City Scene users and user study with tourist participants. Tourists traveled to cities supported by City Scene. They were interviewed before and after their trip. Nokia N9 phones with City Scene were loaned for them and they could use them on their trip as they saw fit. Tourists filled diaries while on their trips.

Research's most important finding was that not all users need detailed route information. Some users only needed to check their location and the location of their goal and then they found their own way. Map mode was most used but panoramas were used for confirmation and decision making, especially on last meters of navigation, and for learning details of locations. This means that navigation applications need to support both of these methods. GPS-locating must be fast and accurate and there should be a pointer that shows direction to destination. Since most current research on navigation applications focuses on routes, more research on navigation without routes is needed.

TIIVISTELMÄ

TAMPEREEN TEKNILLINEN YLIOPISTO
Tietotekniikan koulutusohjelma
SALMINEN, MIIKKA: Mobiilinavigaatio peilimaailmoilla: Käyttäjäkokemus ja tarpeet
Diplomityö, 82 sivua, 14 liitesivua
Maaliskuu 2013
Pääaine: Käytettävyys
Tarkastaja: professori Kaisa Väänänen-Vainio-Mattila
Avainsanat: mobiilinavigaatio, peilimaailmat, katunäkymä, panoraamat, käyttäjäkokemus, käyttäjän tarpeet

Sekoitetun todellisuuden (Mixed Reality) sovellukset ovat viime aikoina lisänneet suosiotaan ja levinneisyyttään. Yksi erityinen alue jolla lisättyä todellisuutta on alettu käyttää on navigaatiosovellukset. Tässä diplomityössä tutkittiin yhtä tällaista sovellusta, Nokia City Scenea. City Scenessa on kartta ja panoraama katunäkymä kiinnostavilla kohteilla. Työn painopiste on navigaatiossa; tarkoituksena on löytää mitä ihmiset odottavat navigaatiosovelluksilta ja Nokia City Scenelta ja miten ja mihin tarkoituksiin City Scenen eri navigaatiomoodeja käytetään. City Scenen käyttäjäkokemusta tutkittiin myös vähemmässä määrin.

Diplomityön alussa on työn teoreettinen tausta. Käsiteltyjä alueita ovat käyttäjäkokemus, navigaatio ja tietokoneavusteet sekä sekoitettu todellisuus ja pelimaailmat. Tämän jälkeen Nokia City Scene -sovellus esitellään. Työn loppu käsittelee tehtyä tutkimusta ja sen tuloksia. Työssä suoritettiin kaksi erillistä tutkimusta: kyselytutkimus Internetissä Nokia City Scenen käyttäjille sekä käyttäjätutkimus turisteilla. Turistit matkustivat kaupunkeihin joita City Scene tukee. Heidät haastateltiin ennen ja jälkeen matkan. Nokia N9 matkapuhelimet City Scene sovelluksilla lainattiin turisteille ja he saivat käyttää niitä matkallaan omiin tarkoituksiinsa. Matkan aikana turistit täyttivät päiväkirjaa.

Tärkein löydös oli etteivät kaikki käyttäjät tarvinneet yksityiskohtaisia reittejä. Osa tarkisti vain sijaintinsa ja kohteensa sijainnin ja sen jälkeen etsivät itse reitin kohteeseen. Karttamoodi oli yleisimmin käytetty mutta panoraamoja käytettiin varmistukseen ja päätöksentekoon etenkin navigoinnin viimemetreillä, sekä kohteiden yksityiskohtien opetteluun. Tämä tarkoittaa että navigaatiosovellusten täytyy tukea molempia näitä navigointitapoja. GPS-paikannuksen on oltava nopea ja tarkka ja sovelluksen tulee tarjota osoitin joka näyttää suunnan kohteeseen. Koska suurin osa nykyisestä navigaatiosovellustutkimuksesta keskittyy reitteihin, lisätutkimusta navigoinnista ilman reittejä tarvitaan.

PREFACE

When I was starting my studies at Tampere University of Technology master's thesis seemed an intimidating task far away. Looking back the road to it has been long but rewarding. In the end, the thesis was nothing to be afraid of but just a longer more thorough project than any other before it.

Thank you for my supervisor in both SeMiRe project and thesis writing, Thomas Olsson. You gave me great freedom to find my own focus but also guided me with good advice and suggestions. You made the whole thesis project a lot easier.

I would also like to thank my examiner professor Kaisa Väänänen-Vainio-Mattila for helpful comments at the end of the writing process. Also, special thanks to Tuomas Vaittinen for his participation in this research project and for going beyond the call of duty when circumstances were less than optimal.

Finally, a big thank you for my parents. My studies have taken a long time but you always supported me. I can't thank you enough.

In Tampere, 17.4.2013
Miikka Salminen

CONTENTS

LIST OF TERMS AND ABBREVIATIONS

Term or abbreviation	Explanation
Android	Google Android, operating system for mobile devices
Application, app	Applications program. A computer program specific for a particular role (Daintith and Wright 2008).
Augment	”to make greater, more numerous, larger, or more intense” (Merriam-Webster 2012)
Augmented reality, AR	Virtual information and objects displayed over real world image
Dictaphone	Device used to record dictation
GPS	Global Positioning System. A satellite based system to define positions on earth.
HUD	Heads-up display. A see-through display that shows information in front of outside view.
In-situ	Happening in site, for example in-situ experiment (opposite of laboratory experiment)
ISO	International Organization for Standardization
IT	Information technology
MAR	Mobile augmented reality, augmented reality on mobile devices
MR	Mixed Reality, various technologies mixing real and virtual information
MMR	Mobile mixed reality, mixed reality in mobile context
POI	Point-of-interest, for example a restaurant or shop in navigation program
SeMiRe	Collaborative research project between the Unit of Human Centered Technology in Tampere University of Technology and Nokia Research Center, part of TiViT’s service program
SIM card	Card that holds information such as phone numbers and contact information (Merriam-Webster 2012)
TiViT	Tieto- ja viestintäteollisuuden tutkimus TIVIT Oy, the Strategic Centre for Science, Technology and Innovation in the Field of ICT (TIVIT Oy 2013)

Term or abbreviation	Explanation
UX	User experience, an experience that is formed while using a device or service
VR	Virtual reality, computer provided artificial environment (Merriam-Webster 2012)
Waypoint	Point along a route usually used as a navigation help

1. INTRODUCTION

This thesis was done as part of SeMiRe research project that studied the user experience of a navigation application, Nokia City scene. SeMiRe was a collaboration between The Unit of Human Centered Technology (IHTE) in Tampere University of Technology and Nokia Research Center in 2012. SeMiRe was part of TiVit's services program. Nokia City Scene is a mobile application that features navigation on map and street view panoramas and point-of-interest data. City Scene's features and use is described in chapter 5. While whole project had a focus on overall user experience, author's contribution and this thesis is focused on navigation aspects of user experience and user needs in navigation.

This chapter provides background for thesis subject and presents objectives of the research. Research approach is briefly summarized but full description of used methods and research process is in chapter 6. Structure of the rest of the thesis is presented at the end of this chapter (see 1.3).

1.1 Background and motivation

Mobile phones have evolved fast in the last decade. While early phones were just for making calls and sending text messages, new smart phones are like miniature computers. At the same time, lots of new possible uses have been found for mobile phones. Mobile Internet connection and gps-sensors allow mobile phones to feature location-based services and navigation applications. This rapid technological development has opened possibilities for innovative applications and services.

One of the most novel innovations that are starting to appear on mobile phones are applications that merge virtual information on real world information. This mixing of real with virtual is called Mixed Reality (MR) (Milgram and Kishino 1994, p. 2). High quality cameras, GPS, fast Internet connections and better computing power on mobile phones have enabled developing MR apps for mobile use. Possible uses for this Mobile Mixed Reality (MMR) are for example searching additional information from objects in user's surroundings, retrieving additional content from printed media, aiding design for example by enabling architects to see planned buildings on their future location and giving navigation instructions. Because MMR is new concept, innovative applications for various purposes will probably appear in future. MR is defined more thorough with brief introductions of some current MMR

applications in chapter 4.

One possible application that may benefit from MMR is navigation. Navigation information can be overlaid either on top of real view of surroundings or image of location. Relevant landmarks can be emphasized with AR information and utilized on navigation instructions. Street view images and 3D maps can be used. It is interesting to find out if this kind of approach to navigation is beneficial and if users adopt it. MMR can enable new experiences for the users compared to more traditional navigation methods such as paper maps.

Previous studies and experiments (see chapter 3) suggest that traditional maps may still be superior to 3D maps and street view applications in navigation when users exclusively use one or the other. In combined use when user can freely select which mode to use on what purpose, 3D or street view may bring added value. However, in none of these studies users could freely choose the way they used navigation applications. No research was found concerning people's needs of navigation software, except for visually impaired (for example Quinones and Greene 2011; Pressl and Wieser 2006). It would be interesting to know in what kinds of situations people need to use navigation software. It is also possible that in some situations people choose to navigate without using navigation applications, even though the application is available. If navigation software offers various different modes like traditional map and street view, when do users use these modes? This was primary motivation behind this thesis.

1.2 Research objectives and methodology

SeMiRe project as a whole was motivated partly by Nokia's need to evaluate their new application and partly by participating researchers' research focus. We wanted to evaluate Nokia City Scene's user experience and at the same time research users' expectations and needs for navigation services. The project had a quite broad focus. Project consisted of two researchers and a research assistant (author of this thesis) and each brought in research questions that interested them. Author was given great freedom to choose his own narrower focus on which to write this thesis.

SeMiRe project as a whole had five research topics. These themes dealt with City Scene's quality, user experience and navigation.

1. Use of City Scene's navigation modes
2. Expectations of City Scene and navigation applications in general
3. Remote use versus use in context (in-situ)
4. Quality of City Scene's user interface, functionality and content

5. Feedback for City Scene's development

Main focus of this thesis is navigation. This means first and second themes are most important. How much are different navigation modes used and for what purposes? What expectations people have of Nokia City Scene and other navigation applications? Second important focus is user experience, that is an aspect of every research theme. Studies focused on human aspects of navigation; technological matters are outside of the scope of this thesis. Discussion of results in chapters 7, 8 and 9 focuses mainly on navigation and user experience; other findings outside of the scope of this thesis are mentioned briefly. Thesis had three main research goals:

1. Navigation: Find out how and on what purpose different navigation modes are used
2. Expectations: What people expect of Nokia City Scene and navigation applications in general?
3. User experience: What is the user experience of City Scene like?

Nokia City Scene was still under development when project started. A heuristic evaluation was conducted in the beginning to find obvious flaws in usability so they could possibly be eliminated before making City Scene public. In actual user studies we had two user groups. First group was users that downloaded City Scene from Nokia Beta Labs website or Nokia Store. With this group we used questionnaires, both to gather contact information for recruitment and to gather research data. Second group was tourists traveling from Finland to cities supported by City Scene. Tourists were free to use City Scene during their trip any way they liked. Diary and interviews were used with this user group to gather their experiences during the use of application.

1.3 Structure of the thesis

So far this introduction chapter has explained the background and motivation behind the research. Questions and goals of the research which this thesis is a part of have been introduced.

Chapter 2 defines user experience. First the concept of experience is defined before it is narrowed down to user experience by definitions from literature. Usability is discussed briefly and special aspects affecting mobile user experience are introduced. Lastly, some methods used to evaluate user experience are covered. Chapter 3 describes basic concepts of navigation. Cognitive maps, spatial knowledge and other aspect of human wayfinding are covered. Several studies on navigation aids are discussed. Chapter 4 introduces concepts of mixed reality and mirror worlds.

Virtuality continuum and various mixed reality types on continuum are introduced. Two Nokia City Scene's competitors, Google Maps and Google Earth are briefly discussed. Chapter 5 introduces Nokia City Scene mobile mixed reality application. Features and some technical aspects are discussed. Chapter 6 describes used research methods. Research schedule is presented at the start of the chapter. Chapter is divided in parts: first is heuristic evaluation, then Internet questionnaires and finally tourist study. Chapter 7 covers results obtained in research. Results are presented in same order than methods in previous chapter. Main results are summarized at the end of the chapter. Chapter 8 discusses what results mean. Validity and reliability of results are assessed. Results are compared to previous research on the subject and the usefulness of used methods are evaluated. Finally, success and importance of the research are reflected. Chapter 9 summarizes key findings of the research. Suggestions for future research and practical recommendations for design are presented.

2. USER EXPERIENCE

Usability, user-centered design and User Experience have been research trends in the 21st century. This chapter introduces and defines the concept of user experience. User experience of Nokia City Scene is a part of the focus of this thesis. As user experience is a type of experience, the concept of experience is presented before defining user experience. Usability, a perhaps more widely known term than user experience, is discussed to distinguish these two concepts. Nokia City Scene is a mobile application and mobile context has its own special factors affecting user experience.

2.1 Experience

Before user experience is introduced it is useful to define the underlying broader concept of experience. Merriam-Webster (2012) gives many definitions for word 'experience', for example "direct observation of or participation in events as a basis of knowledge", "the fact or state of having been affected by or gained knowledge through direct observation or participation" or "the conscious events that make up an individual life". Similarly Oxford Dictionary of English gives definition of experience as a noun as "practical contact with and observation of facts or events" and "an event or occurrence which leaves an impression on someone" (Stevenson 2010). In this thesis mostly the personal aspect of experience is relevant. These definitions imply that experience, as an event, always involves someone, the experiencer. This experiencer lives through an event observing it and is perhaps changed by the experience.

Experience is derived from nature. "It is not experience which is experienced, but nature — stones, plants, animals, diseases, health, temperature, electricity, and so on. Things interacting in certain ways are experience; they are what is experienced" (Dewey 1929, p. 4a). This definition presents two important aspects of experience: context and interaction. Experience always takes place somewhere; it is not removed from physical world even though experiencing is partly an internal process. Experience can be used as a verb, meaning the act of perceiving events and reality (Merriam-Webster 2012). While this definition makes experiencing seem passive, experience involves active participation. Experience and process of experiencing includes what men do, how they act and are acted upon, what they suffer,

endure, love, and desire (Dewey 1929, p. 8). This experiencing is also affected by previous experiences. Ways we believe and expect are set by social norms, education and traditions and this affects in what we believe and expect (Dewey 1929, p. 14). Experiencing can be seen as a cycle where past experiences affect on how new experiences are formed.

Wright et al. describe an experience framework that has two parts. First are the four threads of experience that describe experience from four points of view. Second part is about how we make sense in experience. The four threads are the compositional thread, the sensual thread, the emotional thread and the spatio-temporal thread. The compositional thread is the narrative structure, possibilities, plausibility, consequences and explanations of actions. The sensual thread is the what is sensed in an experience; the look and feel. Emotions felt during an experience is the emotional thread. Finally the spatio-temporal thread is the sense of time and space during an experience. Different sense making mechanisms are anticipating, connecting, interpreting, reflecting, appropriating and recounting. Anticipating refers to what expectations we bring to an experience. Connecting means our immediate response to a situation. Giving meaning to an experience is interpreting. Reflecting is about making judgments and putting value to an experience. Relating the experience to past and future experiences is called appropriating. Last mechanism is recounting which means discussing experience with others. (Wright et al. 2005, p. 46-50)

From these definitions experience can be summarized on personal scale as events of interaction with natural world. Experience happens to someone and has a context where it takes place and they are processed with different methods during the experience and after. Experiences may be connected to each other so that previous experiences have effect on later experiences; they shape our view of the world. Experiencing is a continuous process that is always present and happening.

Experience in general is a very broad concept. If we narrow it down to concern experience in certain situations, factors affecting it are easier to define and analyze. For example if we focus on experience while using a device or system, defining context, users tasks and other aspects is easier. This kind of experience is called user experience.

2.2 Defining user experience

User experience, UX differs from general experience in that it is derived from encountering systems (Roto et al. 2011, p. 6). User experience has many definitions. All About UX -website (2013b) lists 27 definitions from research, organizations and various websites. For example Nielsen Norman Group (2011) says that user experience ”encompasses all aspects of the end-user’s interaction with the company, its

services, and its products". Hassenzahl and Tractinsky (2006) say that user experience "is a consequence of a user's internal state (predispositions, expectations, needs, motivation, mood, etc.), the characteristics of the designed system (e.g. complexity, purpose, usability, functionality, etc.) and the context (or the environment) within which the interaction occurs (e.g. organisational/social setting, meaningfulness of the activity, voluntariness of use, etc.)". According to Alben (1996) experience while using products is "all the aspects of how people use an interactive product: the way it feels in their hands, how well they understand how it works, how they feel about it while they're using it, how well it serves their purposes, and how well it fits into the entire context in which they are using it". These definitions and the rest listed by All About UX have in common that they mention user and interaction with a product but otherwise they vary in their focus and scope. Roto et al. suggest that one clear UX definition would help to teach basics of UX, communicate it's meaning, clarify the perspectives of UX, advance UX as a research field and ground practical UX work in organizations (Roto et al. 2011, p. 4).

Usability Professionals Association (2010) defines user experience as "every aspect of the user's interaction with a product, service, or company that make up the user's perceptions of the whole". This definition is short and clear but does not mention emotions. According to Forlizzi and Batterbee (2004) "Emotion is at the heart of any human experience and an essential component of user-product interactions and user experience". Hassenzahl (2008, p. 12) emphasizes temporal phenomenon of UX and shift of attention from product and materials to human and feelings and says that UX is a "momentary, primarily evaluative feeling (good-bad) while interacting with a product or service". International Organization of Standardization (2010) gives their definition as "person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service". All these definitions have different focus. From these definitions it can be summarized, that user experience is formed by interacting with a product or service and it consists of user's perceptions and emotions.

2.2.1 Aspects of UX

According to Roto et al. (2011, p. 5) user experience has three aspects: UX as a phenomenon, field of study and practice. UX as a field of study means studying the phenomenon and investigating and developing UX design. As a practice UX is for example building prototypes to demonstrate desired UX, evaluating it and delivering designs that enable certain user experience. (Roto et al. 2011, p. 5)

User experience as a phenomenon is a subset of experience but it is more specific as it is related to experiences using a system. UX includes both active and passive encounters with system. Active encounters are personal use, passive for example

seeing someone else use a system. User experience is individual and it is influenced by prior experiences and expectations. Experiencing means perceptions, their interpretation and resulting emotions encountering a system. The noun user experience refers to how a period of encountering a system is experienced. (Roto et al. 2011, p. 5-9)

Socially constructed use experiences can be referred to as co-experience, shared experience or group experience. These terms emphasize experiencing a situation together. User experience has various time spans from before experiencing a system to after the experience. Before first use there is anticipated UX which means imagining the upcoming experience. Short changes of feelings during the use is momentary UX and specific usage episodes can be referred to as episodic UX. Views of a whole system after longer periods of use is cumulative UX. However there is no fixed sequence of user experience phases. When discussing UX the time span in focus should be clarified. (Roto et al. 2011, p. 5-9) Characteristics of user experience are similar to experience in general but it is a more specific concept. User experience is always related to some system that is used to some purpose, and there's always some kind of interaction with such system.

Three factors affect UX: context around user and system, the user's state and system properties. Context is composed of social context, physical context, task context, which means other surrounding tasks that require attention, and technical and information context. Changes in context can change UX even when other factors don't change. User is dynamic with changing motivation, mood, mental and physical resources and expectations. System properties may be properties designed into it, like functionality and aesthetics, the properties adds or changes in the system, like picture on a phone, and brand or manufacturer image. (Roto et al. 2011, p. 10) A major factor relating to system properties is usability, that is discussed in section 2.3.

Forlizzi and Battarbee (2004) present a framework for user experience. The framework has three types of user-product interactions and three types of experiences. Interaction types are fluent, cognitive and expressive. Fluent interactions are well-learned and automatic interactions that don't take much attention. Cognitive interactions focus on products and result in knowledge, confusion or error. These experiences change user because user learns a new skill or solution. Expressive interactions help user form a relationship with product by changing, modifying and personalizing it. Different types of experience are experience, an experience and co-experience. Experience is "... the constant stream of "self-talk" that happens while we are conscious". An experience has a beginning and end and it could be articulated or named. It often causes emotional or behavioral changes in the experiencer. Co-experience is experience in social context; an experience that is created together

or shared. (Forlizzi and Battarbee 2004, p. 262-264)

User experience has two perspectives: designer's and user's. Designer chooses and combines product features to relay an intended product character. Product features are content, presentation, functionality and interaction. When encountering a product user perceives products features and makes an apparent product character, that is a personal version of product character. Product character is composed of pragmatic and hedonic attributes. This apparent product character leads to consequences that are judgment's about products appeal, emotional consequences and behavioral consequences. Consequences vary between user experiences. User experience is subjective and actual user experiences may differ from intended user experiences. (Hassenzahl 2003, p. 32, 41)

2.2.2 Consolidation of UX definitions

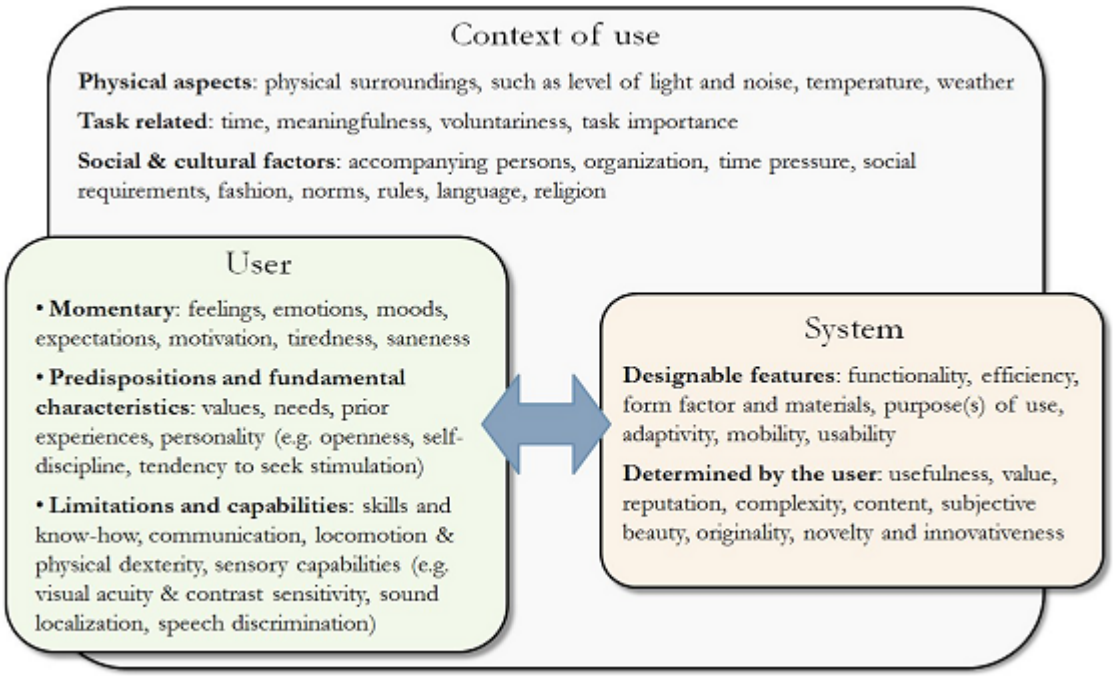

Figure 2.1: Factors affecting UX
(Olsson 2012, p. 19)

UX definitions by various researcher all present various points of UX. Olsson (2012, p. 19) has consolidated factors affecting user experience (figure 2.1). He divided factors into three categories: context of use, user and system. Context has physical aspects like light and noise, task related aspects like importance of task, and social and cultural factors like fashion and norms. User has momentary aspects like

emotions, predispositions and fundamental characteristics like prior experience, and limitation and capabilities like skills and know-how. System as designable features like functionality and efficiency, and aspects determined by the user such as value and complexity.

User experience is an umbrella term and more specific terms may be used to imply different perspectives (Roto et al. 2011, p. 6). When discussing user experience in mobile context the term mobile user experience may be used. This mobile UX is discussed in section 2.4.

2.3 Usability

Before researchers and designers started talking about user experience, usability was main issue when discussing how computers and humans interact. International Organization of Standardization (1998) defines usability as "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". Effectiveness is how completely and accurately users achieve their goals and efficiency is how much resources users spend. Satisfaction means positive feelings and lack of discomfort. Context of use is "Users, tasks, equipment (hardware, software and materials), and the physical and social environments in which a product is used". (International Organization for Standardization 1998) In this definition it is important to notice that users, goals and context are specified. This means that when evaluating usability it is important to define these attributes. For example it is not practical to measure products usability in tasks it is not designed to do or in context it is not designed to be used.

According usability consultant Jakob Nielsen (2003), "usability is a quality attribute that assesses how easy user interfaces are to use". Five usability qualities define usability: *learnability*, *efficiency*, *memorability*, *errors* and *satisfaction*. Learnability means how easily basic tasks are completed on first use. Efficiency means how quickly learned tasks can be completed. Memorability means how easy it is to return to using a design after a period of non-use. Errors means how many errors users make, how severe are they and how easy it is to recover from these errors. Satisfaction means the pleasantness of use. (Nielsen 2003) While aesthetics is not usability component in this definition, Tractinsky et al. (2000) found out that users perceptions of interface aesthetics is related to perception of system's usability. Compared to ISO's definition, Nielsen's definition above leaves out all external factors, like use context, but defines usability qualities more precisely.

Usability is much narrower in scope than user experience. All usability qualities except satisfaction are pragmatic and mostly objective, whereas user experience is mostly subjective. Despite these differences, usability can be considered as a part, or subset, of user experience. Especially satisfaction is a quality that can be applied

to user experience. Usability affects user experience; products with poor usability are unlikely to induce positive user experiences.

Whether design does what users need is called utility. Usability and utility are equally important to products usefulness. Usefulness means product does what users expect it to do and it's easy enough that users are able to do what they want. (Nielsen 2003) Usefulness of Nokia City Scenes's navigation features relates to navigation related research questions. While main interest is users' needs of navigation support, it is also interesting to see how well City Scene meets these needs. Research questions are discussed in section 1.2.

2.4 Mobile user experience

User experience while using mobile devices can be distinguished with the term mobile user experience. Mobile user experience differs from other types of user experience only by factors related to use context. Mobile phones can be used almost everywhere, which makes use context variable. Kim et al. (2005, p. 176) define mobile context as "any personal or environmental factors which may influence the person when he/she is using the mobile Internet". While this definition focuses on mobile Internet, replacing the word Internet with application or device, gives a more general definition. Contextual information consists of personal and environmental context (Kim et al. 2005, p. 176). Internal context is persons goals and emotions while external context is physical body; person's movement and availability of hands. Environmental context includes physical context which is visual and auditory distractions and social context which is co-location meaning other people present, and interaction with them. (Kim et al. 2005, p. 176-177)

Jumisko-Pyykkö and Vainio (2010) studied previous research on human-computer interaction and summarized components of mobile context. They divided context into five components: physical, temporal, task, social and technical and information context. Physical context means location and space, sensed environmental attributes like for example light, sound and weather, movements and mobility of users body, user and environment, and artifacts, the physical objects surrounding user. Temporal context is time related aspects and contains duration, which is the length of interaction, time of day, week and year of peak of user's interaction, actions before, during and after user's interaction, action's relation to time like hurrying and waiting and synchronism which describes whether action is simultaneous (synchronous) or not (asynchronous). Task context is about user's task and surrounding tasks and contains multitasking, which means performing multiple parallel tasks, interruptions, and task domain, which can be either goal-oriented (work) or action-oriented (entertainment). Social context is persons present, which can be present either physically or virtually, interpersonal interaction between persons, and cul-

ture, which is the ”values, norms and attitudes of certain culture”. Technical and information context contains other systems and services related to user's system or service, interoperability between and across devices, applications and networks, informational artifacts and access meaning artifacts containing information and how that information is reached, and mixed reality systems, which combine technical and information context with physical context. (Jumisko-Pyykkö and Vainio 2010, p. 8-13) Mixed reality systems are discussed more in chapter 4.

When using mobile phone outside, one obvious varying environmental factor is weather. Weather can have an effect in users mood; sunny weather promotes happiness and rainy day might depress. While moderate weather likely has minor effect on actual use of mobile technologies, extreme weather can even prevent use altogether. For example Apple recommends that iPhone, iPad and 4th generation iPod should be operated in temperatures between 0–35 degrees Celsius (Apple Inc. 2012). Besides temperature, heavy rain can also prevent usage of electronic devices. At low temperatures phones can experience symptoms such as SIM card errors, low battery readings, and eventually shutting down (Jääskeläinen 2012). Temperature can also affect the availability of hands. In cold temperatures user may wear gloves or mittens that make using mobile devices, especially those with touch screens, harder.

Social context can also have varied effects on user experience. When talking in mobile phone in crowded buss for example, user may not want to discuss private matters, because other people may hear. When playing mobile games, player may want to turn off sounds in public places or use headphones. In places where taking photographs is prohibited, pointing at things with mobile phone is not desirable, because it can easily be mistaken for taking pictures. Social context of user experience is very hard to predict.

Safety is one important aspect in mobile context. Mobile context might mean that user has several parallel tasks such as using a map with mobile phone, talking to a friend and walking on sidewalk. If one task demands too much attention, performance on other tasks can suffer. For example, users should not be too immersed in using mobile devices in traffic. Risks of using mobile phones while driving is so high that many countries have laws prohibiting it. Simulator test have indicated that even talking on a phone may increase risk while driving (Törnros and Bolling 2005). While risks may be somewhat lower while walking than when driving a car, using mobile devices may still decrease awareness. If user recognizes these risk, he may limit the use to safer situations.

2.5 UX evaluation methods

There are a lot of methods for evaluating user experience. In their study, Vermeeren et al. analyzed 96 methods (2010). Wep page All About UX lists 83 methods

(2013a). Bargas-Avila and Hornbæk reviewed methods of 66 empirical studies, and studied how research on User Experience was conducted. (2011) They found out that three most popular data collection methods were questionnaires (53% of studies), semi-structured interviews (20%) and live user observation (17%). Half (51%) of questionnaires were self-developed. Half of studies they reviewed were qualitative, a third quantitative and the rest (33%) used both methods.

On this study both questionnaires and semi-structured interviews were used. In addition to these highly popular methods, diaries were also used. According to Bargas-Avila and Hornbæk diaries are 7th most popular method with 11% of studies reviewed by them utilizing diaries (2011).

It should be noted that neither interviews nor questionnaires are UX-specific methods but both are used widely in other research areas also. There are also many UX-specific methods like AttrakDiff [1], but these are often focused on certain aspect of UX instead of wider scope. Interviews and questionnaires allowed studying the whole user experience at general level, although focusing on smaller details was not possible on same level as with more focused methods. Using multiple focused methods would have been too time consuming and too laborious for participants.

2.6 User experience summary

User experience lacks a single, all-inclusive, definition. User experience is, in short, an experience that is formed while using a device or service. UX is affected by product qualities, use context and user's personal qualities. Mobile user experience is user experience in mobile context. Mobile context can influence user experience in many ways, such as when poor weather makes use difficult or social context puts limits to what kinds of use are acceptable. There is a vast number of different methods used in research for studying UX, with questionnaires, semi-structured interviews and live user observation being three most popular data collection methods.

In this study, focus on user experience is on the whole experience instead of only certain aspects of it. This means that selected research methods had to suit broad focus instead of special methods focused on one or few aspects of user experience. Because of this, interviews, questionnaires and diaries were chosen as used methods. On the other hand, smaller details may have been left out because more specialized methods were not used. Used methods are discussed more in chapter 6.

[1] http://www.attrakdiff.de/en/Home/

3. COMPUTER AIDED NAVIGATION

Every time we move from one place to another we use information. First we must know where we are and then we must make decisions on how to get to where we are going. Travel between known locations like home and work is very common (Allen 1999, p. 48). In familiar surroundings this is usually easy to do just by remembering past routes. In unfamiliar or new environments this is not possible and traveler must resort to other methods, usually various navigation aids. Compass, maps, star charts and nautical charts are old but still used aids in navigation. While simple navigation with these instruments does not demand much skill or experience from the navigator, accurate navigation is hard and requires lot of training.

One focus of this thesis is needs for navigation aides. This chapter discusses what navigation means, how humans perform it and what kinds of computer aids have been developed and researched. First, principles and methods of human navigation are introduced. Theory and some research findings are covered in a scope that is relevant to this thesis. At the end of the chapter, various ways of providing navigation help by mobile devices are discussed with relating research.

3.1 Human wayfinding

While we travel we need to find our way to our destination, regardless of triviality of the travel task. During travel, traveler resorts to guiding processes to succeed in finding his way. According to Golledge (1999, p. 6) there are two types of guiding processes: *wayfinding* and *navigation*. Golledge defines wayfinding as "the process of determining and following a path or route between an origin and a destination". According to Allen (1999, p. 47) "successful wayfinding is reflected in the traveller's ability to achieve a specific destination within the confines of pertinent spatial or temporal constraints and despite the uncertainty that exists". Wayfinding involves interactions between attributes of the traveler and the environment (Allen 1999, p. 47).

Navigation has a more technical aspect. Merriam-Webster (2012) defines navigation formally as "the science of getting ships, aircraft, or spacecraft from place to place; especially : the method of determining position, course, and distance traveled". Loomis et al. (1999) say that "navigation involves the planning of travel through the environment, updating position and orientation during travel, and, in

the event of becoming lost, reorienting and reestablishing travel toward the destination". As terms, navigation and wayfinding don't differ much. These definitions imply that navigation is primarily based on determining current location relative to goal and wayfinding is more about planning a path and then following it. Navigation often refers to position locating and course plotting of ships and aircraft (Golledge 1999).

In this thesis, navigation and navigating as terms, are not used to mean navigating a vehicle but pedestrian navigation unless stated otherwise. Covered distances are very short compared to vehicle navigation; a few kilometers at most. Used means of navigation are also very different. While GPS is nowadays used in all kinds of navigation, ships still use various buoys and air planes use radio beacons.

According to these definitions wayfinding and navigation are very similar terms. Navigation emphasizes using technical aides in following route and locating destination. Wayfinding refers to whole process of finding one's way in more general sense. Wayfinding can be divided into smaller categories and various wayfinding methods can be identified.

Allen (1999) presents three different categories of wayfinding: travel to a familiar destination, exploratory travel with familiar return point, and travel to a novel destination. Travel between known locations, for example from home to work, is very common. Exploratory travel is also relatively common, such as when people visit a new environment, they usually explore their surroundings. In exploratory travel goal is to explore surroundings and return to the point of origin. When traveling to a novel destination, traveler may rely on guidance for example by map or verbal instructions. (Allen 1999, p. 48) These three categories demand different kinds of wayfinding methods.

3.1.1 Wayfinding methods

According to Allen (1999) there are various methods to accomplish wayfinding tasks. These methods are oriented search, following marked trails, piloting between landmarks, habitual locomotion, path integration and using internal representations. Oriented search means that traveler orients himself and then searches until finding the destination. Humans rely mostly on visual information while performing oriented search. Oriented search is mostly useful in exploratory travel and it is efficient only when distance is small, environment is stable, and systematic search heuristics are used. (Allen 1999, p. 48-50)

Second method is following marked trails. Examples of this are for example driving along a freeway, following a tether while diving, or following color-coded corridor floors in medical complexes. Trail following reduces cognitive demands and uncertainty. Cognitive demands may increase if multiple trails are indicated. (Allen

1999, p, 49) Car navigators often function by this method, providing a marked trail that a driver follows.

Third method is piloting between landmarks. In landmark-based piloting each landmark is associated with information that leads to another landmark. Success depends in recognizing landmarks and remembering their spatial relations. Landmark based piloting is efficient in traveling to familiar and novel destinations in known environment, and in unfamiliar environment it might be the standard wayfinding method. This is because verbal directions often are lists of conditions and actions. (Allen 1999, p. 49) Navigation applications sometimes offer instructions that are based on landmarks and their relations. Google maps (see 4.5.1) offers instructions based on road names and distances. Nokia City Scene (see 5) offers navigation instructions related to landmarks along the route. Landmarks are discussed further in section 3.1.2.

Habitual locomotion is a wayfinding method that is only used in familiar environments. If environment stays constant, repeating a same travel pattern can lead to its automatization. While environment is rarely so constant that travel would be fully automatic, familiar routes, like coming home from work, can be sufficiently stable that minimum attention is needed. (Allen 1999, p. 50) Since habitual locomotion is defined as automatic travel with minimal attention it cannot be aided by navigation devices; use of an aide would not be automatic travel anymore.

When returning to start after exploratory travel, or when wanting to reach a familiar destination by a more direct route, path integration may be used (Allen 1999, p. 50). Path integration means computing present location continuously from past trajectory and returning to starting point directly without retracing route (Müller and Wehner 1988, p. 5287). Path integration is similar to a navigation method known as dead reckoning. Dead reckoning means defining route by recording turns and distances (Hunt and Waller 1999). These two terms are sometimes used as synonyms (for example Müller and Wehner (1988)); path integration is used more in animal behavior research (for example Kimchi et al. (2004); Wehner (2003)). When using modern GPS-assisted navigation aides, these methods are not needed since current location is known. Path integration can be needed when accurate ”you are here” -information is not available.

Last and most sophisticated wayfinding method is relying on internal representation of places and their relationships. This internal representation can be either a vector based map derived from vectors between places or a topographic map derived from landmarks. This internal representation is commonly called *cognitive map*. (Allen 1999, p. 50) Cognitive maps are discussed in next section (section 3.1.2).

3.1.2 Cognitive maps and landmarks

According to Golledge (1999, p. 15) "Cognitive map ... is used to specify the internal representation of spatial information". Cognitive map can be used to know ones' current location, location of other objects, how to get somewhere and how to pass on spatial information. Cognitive maps are formed of points, lines and surfaces. Points are for example landmarks, lines represent routes and paths, and areas are for example neighborhoods. (Golledge 1999)

Landmark can be defined either as a focus point of travel or significant object that stands out from its environment. Besides being a commonly recognized object, landmarks can be places that have personal importance like someone's home. Usually landmarks are used as anchor points while organizing spatial information, for example describing locations of other environment features by their relation to prominent landmark. In wayfinding, landmarks can be used as aides while making decisions on turns, and as confirmation of being on right route. (Golledge 1999, p. 16-19)

Human travel has focused on paths or routes for a long time. These routes connect places and when they overlap, a *network* is formed. This network migh consist of, for example, roads, streets and alleys. Known and frequently used parts of routes can be used as anchor points for cognitive maps. Cognitive map is usually built while traveling, from knowledge gained with actual physical maps, or from processed knowledge gained while wayfinding. (Golledge 1999, p. 19)

3.1.3 Route choice

Urban navigation involves search and decision making and environmental cognition and route choice are its essential components (Stern and Portugali 1999, p. 99). According to Stern and Portugali (1999, p. 100-101) four components affect decision making:

1. The purpose of the trip affects the frequency of that navigation type; for example, going to work daily is more frequent navigation than tourist trips.

2. Navigators personal characteristics affect information retrieval, spatial abilities and data processing speed.

3. The means of navigation can have restrictions; for example cyclists have more available routes than truck drivers.

4. Navigation situation affects available choices. Situation may involve for example location and time.

Navigation decisions are made under various levels of time pressure and stress. When forced to deviate from a habitual route or when choosing a route for a first time, navigator is faced with uncertainty. (Stern and Portugali 1999, p. 101) In addition to factors affecting navigator, spatial attributes also have on effect on choices. Examples of these attributes are distance, ease of wayfinding, safety and scenic beauty (Gärling 1999, p. 82). If navigator has no time pressure he might select a longer more scenic route instead of shortest, fastest path. In a hurry shortest path might be preferred even disregarding safety. Availability of navigational aides such as maps or navigators can increase possible route options.

3.2 User studies on navigation aids

Human travel can take place either freely in unstructured environments, along paths formed by repeated use or on built or natural ways like streams or roads, and it is often guided by some sort of aides like maps or compasses (Golledge 1999, p. 6-7). In recent years navigation applications have found their way from distinct navigator devices to mobile phones. Global Positioning System (GPS) has made defining your location a trivial task and combined with electronic map it makes getting lost very hard. Portable GPS navigation devices have been available for many years and in recent years GPS navigation has become commonplace on mobile phones. These navigation applications offer route finding and thus user basically only has to choose destination and follow instructions.

Different methods and aids in providing navigation information have been studied broadly. Krüger et al. (2004) studied how pedestrians acquire route and survey knowledge. Their test participants walked a route where they were provided with a picture showing the right way at every intersection. After walking the route participants had to recall the locations of these decision points. Participants performed poorly in this recollection task, showing that systems with step-by-step information are poor at providing survey information of surrounding areas.

In related research Goodman et al. (2004) described a pedestrian navigation aid with audio and text instructions referencing to landmarks. This system also provided information on step-by-step basis. Test users took significantly less time in navigation tasks with navigation aid than map, with older participant group showing bigger difference. Both younger and older test user groups got lost less often with the navigation aid. Overall workloads were also significantly lower.

These studies imply that using step-by-step information has both advantages and disadvantages. While the actual navigation task benefits from these instructions, less information of surrounding areas may be acquired. A sudden malfunction of a navigation device, or running out of battery, might lead to getting lost if no knowledge of surrounding area was acquired.

3.2.1 Photographic aids

Using photographs as navigation aids have been studied in a number of papers. Beeharee and Steed (2006) demonstrated a navigation application that used geo-tagged photographs from existing collections in navigation. The app provides overhead map view with route line and instructions under the map, specific route tab with complete route instructions and viewer tab that shows photographs along the route. Application was tested in two modes: simple mode without photographs and augmented mode with photographs. Experiments demonstrated that photographs shortened average time to complete navigation route and helped users to get back on right route. Photographs were used for making and confirming decisions. (Beeharee and Steed 2006)

Hile et al. (2008) presented a system that generates navigational instructions from images taken from online geo-tagged photographs. System had a top-down map view and a landmark mode that shows images of landmarks with related navigation instructions. This system was tested with qualitative study where participants walked a route with the system. Usage of the two modes varied between users. While map mode was found to be easier to navigate with, landmarks were used in turns and the participants reported that it was useful and they would use it again. (Hile et al. 2008)

May et al. (2003) performed a study where participants were shown routes and then identified information that would be useful in navigating those routes. Two participants groups were used: one that used a schematic map in office and other that physically walked the routes. Both groups recorded navigation instructions on dictaphones. These instructions were collected in categories. Landmarks were by far the most used category in instructions. May et al. suggest that landmarks should be the primary method for providing navigation instructions and where possible they should be referred by name instead of category. Instructions should not rely on distances or road names. While information is needed at decision points it should also be provided between these points both to assure users that they are on correct route and to show that navigation aid is working. (May et al. 2003)

Chen et al. (2009) presented a system that used route videos to assist navigation. System constructs videos from 360 degree panoramas around chosen landmarks, which typically are near turns. System shows map of a route with thubnails of nearby landmarks. Video of the route is shown with red dot moving along the route indicating the location of the video. On the side of the screen there is a list of navigation instructions with written instructions and thumbnail images of landmarks. Video position can be set by clicking thumbnails either on map or on instruction list. a user study was performed where the videomap was compared with a photomap

that had photographs instead of videos. Test participants were given five minutes to familiarize a route either with videomap or photomap. Participants also had a printed set of driving instructions. After familiarization, participants performed a virtual drive of the route where video of the route played and participants had to choose correct turn option in intersections. On average, participants succeeded better in navigation with videomap. Participants also needed less looks on instructions per turn with videomap. Videomap was preferred over photomap 17 times out of 20. (Chen et al. 2009)

These findings of Beeharee and Steed (2006), Hile et al. (2008), May et al. (2003) and Chen et al. (2009) show that photographs, or even videos, of landmarks are useful aides in navigation. They provide easier decision making in turns and help verifying choices. Photographs should not be used to replace typical maps, but to offer additional information. Too much information has been shown to decrease navigation performances in research by Lavie et al. (2011). They studied aesthetics and usability of various types of in-vehicle navigation maps. Amount of data, level of abstraction and color schema were varied. In tests, participants had to track a moving target with steering wheel while participants imagined position was shown on a map. Occasionally, participants were asked navigation questions relating to their current position. Test system was halted at predefined times and participant was presented with questions about aesthetics and usability. Minimal detail maps resulted in best performance and received best evaluations. Gray maps produced more correct responses and shorter response times, but color did not affect perceived aesthetics or usability. Abstraction level alone did not affect performance. Perceived aesthetics were found to correlate with usability. (Lavie et al. 2011) Aesthetics have been found to affect usability also in other research (Kurosu and Kashimura 1995; Tractinsky 1997; Tractinsky et al. 2000).

3.2.2 3D and photorealistic street view

3D maps and photorealistic street view have been studied and compared with traditional 2D maps in a number of papers. Medenica et al. (2011) compared three methods to give navigation information to drivers. Tested methods were heads-up display (HUD) using augmented reality navigation device, street view navigation device and map-based navigation device. HUD device showed navigation instructions as line hovering over road. Street view device showed images from the route on drivers perspective with route instructions shown as a line on the road. Map-based device showed rotating a map of surroundings centered on drivers position with forward heading being always up. All three methods used identical spoken turn-by-turn directions. Navigation methods were tested in driving simulator. Test participants drove different routes with each navigation method. Each route were of

equal length and had two unexpected events where participants had to avoid collision. Driving performance was measured with eye-tracker, by calculating accidents and with questionnaires. HUD device allowed participants to keep looking at the road the most while street view needed most attention. Differences between real world and street view image were found difficult to resolve. HUD navigation device was most preferred method; traditional map view was preferred over street view. While there were no differences in the number of collisions, HUD device yielded the best driving performance, measured by lane position and steering wheel angle. (Medenica et al. 2011) While City Scene is not intended to be used while driving, these results imply that its street view mode could be impractical in navigation use compared to map mode.

Kray et al. (2003) evaluated 3D computer map with 2D paper map. Test participants performed six similar tasks, navigating from one place to another. First four tasks were done with 3D navigation application and last two with traditional map. 3D app had two view modes: one from pedestrian point-of-view and other a bird's-eye view from 25 meter altitude. In addition to 3D view it had a 2D map of same location. After tasks the participants were interviewed. With 3D app participants navigated by matching buildings with real world counterparts and by following direction arrow. Bird's-eye view was preferred over pedestrian view. 3D maps were slower than paper map in orientation and route finding. Participants would have improved the 3D application by adding more realistic and detailed buildings, street names and zoom feature on 2D map. Male users preferred paper map over 3D application, but most participants were males with map using experience. Because of small sample size and non-random participant selection, results cannot be generalized. (Kray et al. 2003) While results of this study cannot be generalized, it suggests that 3D navigation applications have disadvantages over traditional paper maps.

Oulasvirta et al. (2008) compared 2D maps with 3D mobile maps. Test participants used 3D virtual reality application on N93 mobile phone and paper street map. Participants had to perform three kinds of tasks: pointing on target in view, pointing on remote target not in view and navigation task where participant had to walk to the target. Targets were marked in 3D and 2D maps and participants used both visualizations in separate tasks. Three methods for searching reference points were observed: searching for a cue in one environment and then seeking the same cue in another, using previous knowledge of the environment to select a reference point and then searching it, and aligning virtual position and heading with real position and heading. In 3D environment many users raised the point-of-view to rooftop level. Test results showed that 2D maps outperform 3D maps. 2D map was better than 3D in task completion times, workload and time spent walking. Participants also needed shorter gazes at 2D map than 3D application, suggesting

that users extract needed information faster from 2D map. Test participants were young male computer gamers, which may decrease the generalizability of the results. (Oulasvirta et al. 2008) Results of this study are similar to study by Kray et al. (2003).

Partala and Salminen (2012) studied photorealistic navigation, comparing traditional map with photorealistic satellite map and street-view. Nine test subjects used all three navigation visualizations in urban navigation tasks and evaluated navigation support, user experience and task load with questionnaires. Results suggest that photorealistic maps provide more hedonistic simulation than traditional maps and that street-level view is effective in identification of local landmarks. On the other hand, photorealistic map was perceived as less pragmatic than traditional maps suggesting that pragmatic benefits overcome navigational benefits from richer scenery. (Partala and Salminen 2012)

Partala et al. (2010) studied the salience of different types of visual cues on buildings on 3D maps. Research was conducted as a laboratory study where participants virtual model of a city with N95 mobile phone. Participants performed tasks where they searched for specific buildings in the 3D model. In each task participants were shown a picture of building and then they searched for that building. Participants were instructed to think aloud and tell specifically which cues drew their attention in photographs, which cues helped to recognize correct buildings in 3D and which cues would help to recognize buildings. Signs with text were especially used cues in photographs. Buildings were recognized by location, environment, building shapes and landmarks. (Partala et al. 2010)

3.3 Summary

This chapter has covered the terms navigation and wayfinding, three types of human wayfinding and methods used in wayfinding tasks. In addition to wayfinding methods, factors affecting route choice were briefly discussed. A good number of studies relating to aiding human navigation have been introduced and discussed.

Overall studies discussed in this chapter suggest that photographs aid users in navigation, but traditional maps should not be replaced. Better way could be to add optional photographic information on top of electronic maps. Landmarks should be used when giving route instructions, with either photographs or video providing cues about decision points and confirming that person is on right route. Virtual reality or street view does not seem to be very beneficial or practical on navigation, but may provide useful as additional feature. While Nokia City Scene does not feature actual 3D (see 5), its street view is relatively close to 3D and results of virtual reality research may apply to street view as well. In two studies (Kray et al. 2003; Oulasvirta et al. 2008) users used virtual reality from elevated birds-eye view. While

this view probably gives better sense of surroundings, it is not supported in current street view applications, and would arguably be very hard to implement.

Later in this thesis, results obtained in studies are compared to results of these previous studies. It is interesting to see whether results differ or agree with previous studies. This comparison is in chapter 8, results are in chapter 7.

4. MIXED REALITY AND MIRROR WORLDS

In past few decades *Virtual Reality* (VR) has become widely known mainly from works of fiction, such as William Gibson's 1984 book Neuromancer and very successful 1999 movie The Matrix. Virtual reality has not yet become as popular and pervasive as might have been predicted in the eighties and nineties, but some applications exist. A mix of virtual information and real world, so called *Mixed Reality* (Milgram and Kishino 1994), or in short MR, has started to gain popularity.

Milgram and Kishino (1994) define Mixed Reality as "subclass of VR related technologies that involve the merging of real and virtual worlds". Mixed reality is a broad class of technologies that encompasses more terms that are narrower in scope and definition. These various technologies can be placed on a virtuality continuum presented in next section (4.1). Mixed Reality on mobile devices is called *Mobile Mixed Reality, MMR.*

This chapter introduces various Mixed Reality technologies. Presentation of relatedness of these technologies, a virtuality continuum, is discussed first. Next Augmented reality is defined. Mirror worlds, special case of mixed reality technologies is discussed in third section. At the end of the chapter, Google Maps and Goole Earth are covered as comparison to Nokia City Scene. Foursquare, a location based service that can be used in City Scene, is introduced. Nokia City Scene itself is covered in next chapter (chapter 5).

4.1 Virtuality continuum

Milgram and Kishino (1994) presented a virtuality continuum to classify mixed reality environments. Virtuality continuum is a scale where mixed reality environments are put according to their level of virtuality. On one end of the scale there are purely real environments and on the other end fully virtual environments. On this scale Milgram and Kishino placed *augmented reality* and *augmented virtuality.* In augmented reality, real environment is augmented by adding virtual objects in view. Augmented virtuality is opposite case, adding real world information, such as video, on virtual environment. (Milgram and Kishino 1994, p. 2-4)

Virtuality continuum has been expanded by others, adding definitions on scale. Kanade and Narayanan (1995) introduced Virtualized Reality where real scene is virtualized by capturing it from several viewpoints. Falk et al. (1999) present am-

plified reality that "...is to enhance the publicly available properties of a physical object, be means of using embedded computational resources". An example of amplified reality is BubbleBadge wearable public display that can be used to display information provided by user, viewer or environment (Falk and Björk 1999). Diminished Reality is the opposite of Augmented Reality; objects are removed from real view and replaced with background (Lepetit and Berger 2001). More generally controlling all visual information to viewer is called Mediated Reality (Mann 1994).

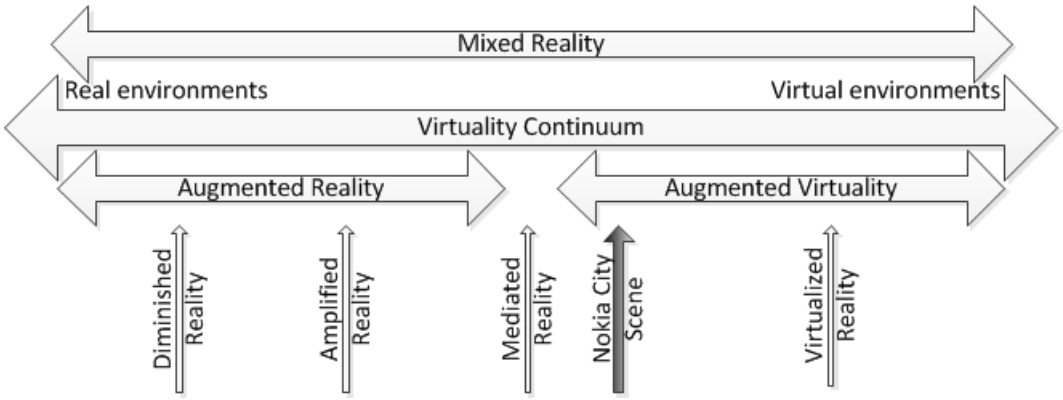

Figure 4.1: Virtuality continuum with Nokia City Scene placed on continuum. Adapted from Milgram and Kishino (1994), Mann (1994), Kanade et al. (1995), Falk and Björk (1999), Lepetit and Berger (2001), Schnabel et al. (2007), Olsson (2012)

Figure 4.1 shows virtuality continuum. On the left end of the continuum is real environments without any augmentations and on the right virtual environments without any real world information. Mixed Reality is the area between these extremes. First half of the continuum is Augmented Reality and second half Augmented Virtuality. Diminished Reality and Amplified Reality are categorized under Augmented Reality and Virtualized Reality under Augmented Virtuality. Mediated Reality falls between Augmented Reality and Augmented Virtuality. Mixed Reality applications can be placed on this continuum to describe the level of virtuality. Nokia City Scene's street view (see 5) is a virtual world with real world panoramas overlaying all virtual models. City Scene can be placed on augmented virtuality side of virtuality continuum but very near the continuum's midpoint, since it almost exclusively shows real world information. In fact, City Scene is a special case called mirror world. Mirror worlds are discussed in section 4.3.

4.2 Augmented reality

Augmented Reality is a variation of Virtual Reality; while Virtual Reality completely immerses user into virtual world, Augmented Reality let's user see the real world with virtual objects over it (Azuma 1997). AR "supplements the real world with virtual (computer-generated) objects that appear to coexist in the same space as

the real world" (Azuma et al. 2001).

Augmented reality is defined by three parameters (Azuma 1997; Azuma et al. 2001):

1. AR combines virtual information with real world
2. AR can be interacted with in real time
3. AR objects is three dimensionally aligned with real objects

There are three main display types used in AR-applications: head-worn displays, handheld displays and projection displays. Head-worn display is mounted on user's head and it provides information in front of user's eyes. Two types exist: optical see-through displays and video see-through displays. Optical see-through displays are transparent displays with projected AR-elements. Video see-through means capturing video from head-worn camera and displaying this with augmented content on opaque display. (Azuma et al. 2001)

Handheld AR-displays are displays with attached cameras. They provide handheld video see-through AR. Users use the display as window or magnifying glass through which real objects are shown augmented. (Azuma et al. 2001) Smart phones with cameras can function as handheld AR-displays. They can also be used as pointing devices to provide input (Carmigniani et al. 2010). Augmented reality on mobile devices is called *Mobile Augmented Reality, MAR.*

Projection displays project AR information directly on objects that are to be augmented. Projector can either be room-mounted or head-worn. Augmented objects can be covered with retroreflective surface enabling multiple users to see different augmentations on same objects. (Azuma et al. 2001) This type of AR is also called Spatial Augmented Reality (Carmigniani et al. 2010).

4.2.1 Challenges of Mobile Augmented Reality

Arth and Schmalstieg (2011) present multiple obstacles in mobile augmented reality on mobile phones. Camera quality and level of control over camera settings is low on mobile phones. Constantly running camera, network traffic and required algorithms can have a large power consumption leading to rapidly depleting batteries. AR applications can be heavily network dependent with high latencies leading to lagging. Network access is only possible with data plans that can be expensive and network coverage may be low. Display size and available interaction modalities, such as touch screen, have their own limiting qualities. Accurate localization of the AR device is another problem. Solutions to full six degree-of-freedom registration are dependent on very large databases and have high requirements for computing power, making them unsuitable for mobile AR. (Arth and Schmalstieg 2011)

Mobile augmented reality applications can have problems in aligning AR-content on top of real world image. This is because available sensors like GPS and compass are not accurate enough. While smart phones allow widespread AR applications, these limitations narrow the scope of applications and possibly decrease quality of user experience. (Wither et al. 2011) Currently AR data is visualized using map-based geographic information or location based services which both lack in positioning accuracy (Murphy et al. 2011).

Wither and al. (2011) present a solution to tracking problems in mobile AR. Their solution is Indirect AR which means using previously captured images of surroundings instead of live picture. Using panoramas, AR content can be placed on top of images with pixel accuracy. This moves registration errors from being between real world image and augmented content to being between device and real world. Registration errors became harder to detect because of borders around smartphone screen. (Wither et al. 2011) Taking this approach further, real world information could be replaced with accurate computer model of the world, so called *mirror world*.

4.3 Mirror worlds

Smart et al. (2012) define mirror worlds as "informationally-enhanced virtual models or 'reflections' of the physical world". First mirror worlds have been geographic information systems. These were first based on cartographic surveys and later augmented with satellite and aircraft images. Latest developments are ground-based images produced by car-mounted cameras. (Smart et al. 2012) Google Street View is an example of service produced with car-mounted cameras.

Murphy et al. (2011) propose mirror worlds as AR replacement for outdoor use. Their prototype allows users to view panoramic images nearest to their gps-location. By replacing real world view with mirror world panorama, augmented information is always exactly on right spot. Sensor inaccuracies only result in inaccurate view point which user can correct manually. Downside of panoramas is that they are not optimal for pedestrian use since they are gathered with cars and view is from streets. Advantage of mirror worlds is that locations can be browsed remotely, which is not possible with AR. Mirror worlds also have potential to be used as simple occlusion models for AR. (Murphy et al. 2011)

Nokia City Scene (see 5) and Google Street View (see 4.5.1) are examples of mirror worlds providing street-view imagery produced with car-mounted cameras. While Google Street View does not have much AR-content, City Scene uses mirror worlds as AR replacement by placing point-of-interest information on buildings. In City Scene sensor errors are limited to possible errors in gps-location, though POIs may be misaligned if underlying 3D models of buildings are not correctly aligned with panoramas.

4.4 Virtual worlds

According to de Freitas (2008, p. 7) "a virtual or immersive world is an interactive environment often although not exclusively in 3D or animated graphics". For example children's games may use 2D animations instead of 3D. (de Freitas 2008, p. 7) Virtual worlds have several defining characteristics:

- Avatar through which user interacts
- Collaboration and communality
- Persistence of the world
- 3D interactions, though some social worlds are 2D
- User generated sharable content
- Interactivity and immersion

(de Freitas 2008, p. 8-9)

Predecessors of modern virtual worlds were text-based multiple user dungeons in 1980s (de Freitas 2008, p. 10). According to de Freitas (2008, p. 14) current virtual worlds can be categorized in five categories:

- Role play worlds like World of Warcraft[1] and Everquest[2]
- Social worlds like Second Life[3] and Habbo Hotel[4]
- Working worlds like Project Wonderland[5]
- Training worlds like Americas Army[6]
- Mirror worlds like Google Earth[7]

Not all virtual world characteristics apply to all virtual worlds. For example Google Earth does not feature user avatars and World of Warcraft does not have user generated content (Lefebvre 2011).

[1] http://eu.battle.net/wow/en/
[2] http://www.everquest.com/
[3] http://secondlife.com/
[4] http://www.habbo.fi/
[5] http://openwonderland.org/
[6] http://www.americasarmy.com/
[7] http://www.google.com/earth/index.html

4.5 Mixed reality applications

While augmented reality has not made major breakthrough yet, there are some applications available. Some augmented reality browsers are already available, such as Layar[8] and Junaio[9]. Mixed reality has found its way into map applications. Perhaps the most popular map application today is Google Maps. Google Maps is perhaps the biggest competitor to Nokia City Scene.

4.5.1 Google Maps and Google Earth

Google maps (Google 2012b) is an online map service. It offers typical street map with optional traffic and weather information. User submitted images from Panoramio (Google 2012d) or available web camera feeds can be displayed on top of map. Google Maps also has satellite images that can be viewed with overlaid roads. Street View is also available with a very wide coverage.

Google Maps is available for mobile phones as Google Maps Navigation. In addition to same features that Google Maps has, Google Navigation provides English voice search, searching along routes, car dock mode, voice-guided navigation for walking and public transit navigation. (Google 2012c) There's also a version for Android phones, Google Maps for Android, that has indoor maps of some buildings (Google 2012e).

Google also offers more feature rich Google Earth (Google 2012a). It is a mirror world version of earth with satellite images around the globe. Additionally Google Earth provides 3D buildings and trees, sea view, space view showing galaxies and stars, models of the Moon and Mars, and access to Google Street View. (Google 2012a). Google Earth has location related links to several services such as Wikipedia and Panoramio.

[8] http://www.layar.com/
[9] http://www.junaio.com/

5. NOKIA CITY SCENE

This chapter introduces Nokia City Scene application as it was during the user study. City Scenes main features are discussed briefly. Technical details are covered only on aspects relevant to the scope of this thesis. All pictures of City Scene in this chapter are screen shots taken by the author.

Nokia City Scene is a MMR navigation application for the Nokia N9. It features maps from all over the world and panoramic street views from a number of cities. While making this thesis the number of cities with panoramas was still very low. There was a number of featured cities from US and London with usable amount of panorama images. In addition to featured cities, some other cities like Helsinki had more limited panorama coverage. Panoramas in Helsinki were limited to city center. In addition to panorama images City Scene offers point-of-interest (POI) data. City Scene can be used both horizontally and vertically, user interface is automatically rotated to match device orientation. Example of street view is on figure 5.2. Buildings are modeled in 3D and POIs are connected to these 3D models. However, user movement in street view is restricted to jumps between panoramas and thus is not free 3D movement. Likewise, the point-of-view is limited to car perspective, from the middle of a street, slightly higher than driver's point-of-view.

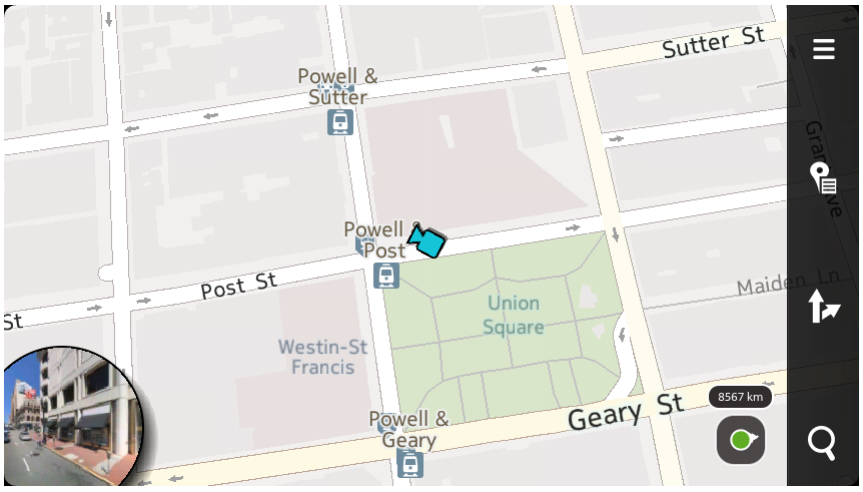

Figure 5.1: Map view

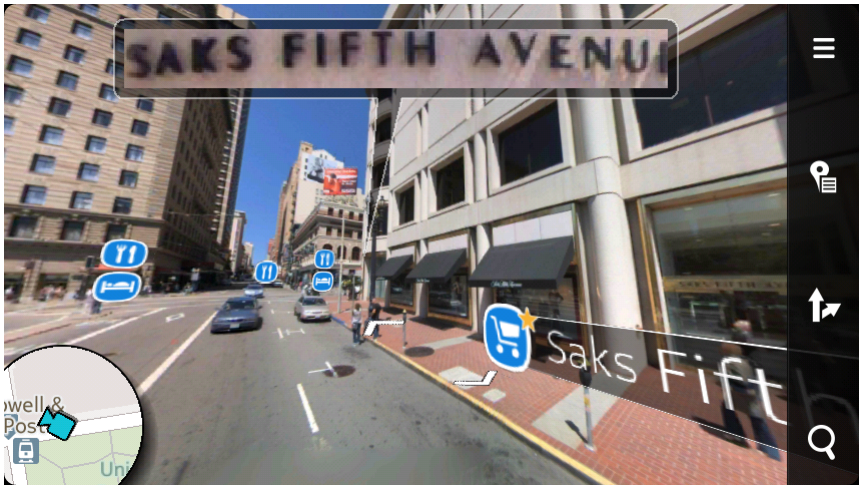

Figure 5.2: Street view

City scene has two main modes of operation: map mode and street view mode. Map mode is typical electronic map that shows streets, buildings, parks, water, bus stops and such. It is shown in figure 5.1. Users GPS location is tracked but City Scene also has a virtual position that can be moved. Virtual position is a spot where street view is located. User can switch to street view to see surroundings of virtual location as panoramic images as seen on figure 5.2. This view is a mirror world mixed reality application.

Points-of-interest are shown overlaid on buildings. Buildings are modeled in 3D, so overlaid POIs are positioned correctly on buildings and they adapt to buildings' shapes. User can tap buildings in street view and get a list of for example restaurants and stores in that building. Tapping an item on that list opens additional information such as reviews, pictures and open hours.

City Scene can also show text signs of buildings and these signs are also associated with additional information. This feature currently only works on some cities like San Francisco. POI list is shown on figure 5.3 and POI information is on figures 5.4 and 5.5. User can make a favorite list of POIs. This list is seen on figure 5.6.

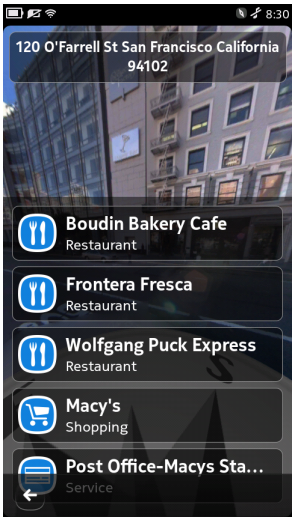

Figure 5.3: List of POIs

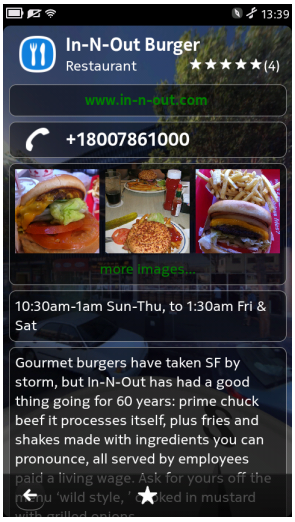

Figure 5.4: POI info 1/2

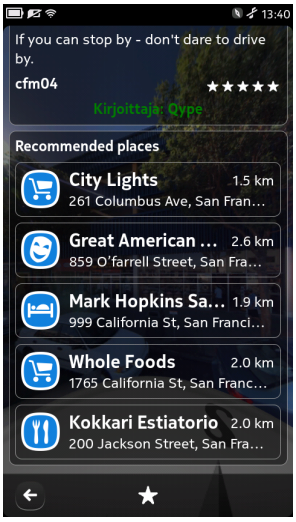

Figure 5.5: POI info 2/2

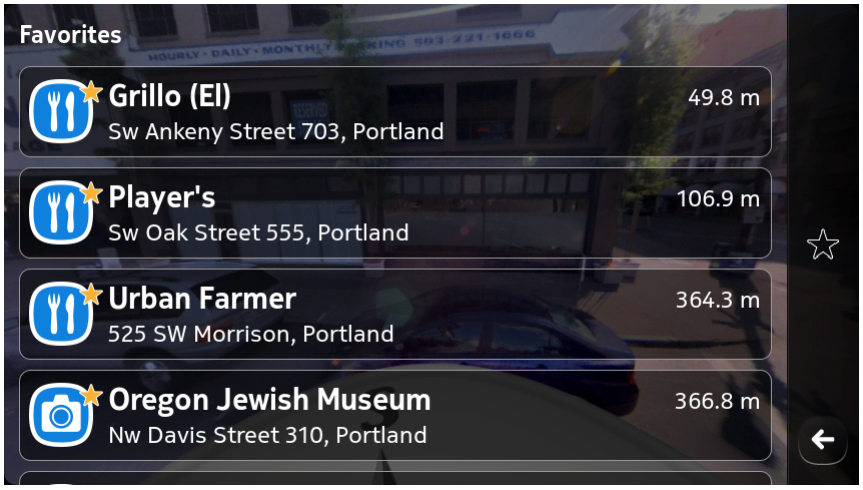

Figure 5.6: Favorites list

Nokia City scene is used completely through a touch screen. Map can be panned by dragging with finger and zoomed by dragging two fingers either away from each other or toward each other. User can tap on map to place his virtual position there. Street view works similarly by panning the view with one finger and zooming with two fingers. Moving in street view works by either tapping arrows on lower part of screen or double tapping on street view to move near that spot. Moving in navigation works by tapping arrows to move from waypoint to waypoint. Hurst and Bilyalov (2010) compared drag-based panning with dynamic peephole panning where device orientation determines view orientation and found in usability tests that while users preferred orientation-based dynamic peephole panning in looking around while they could stand up and rotate freely, drag-based panning was more convenient and efficient. Based on this, it might not be a problem that City Scene only offers drag-based panning. Orientation based panning might be a viable option

for street view.

City Scene allows navigation from one point to another. Application traces a route through walkable roads and paths and divides it into route points. City Scene offers written instructions on how landmarks and streets are located in relation to the route. User can move between these points and view the route on map (figure 5.7), on street view (figure 5.8) or special mode which shows only images of buildings along the path with short written instructions like "McDonald's to your left" (figure 5.9). User can freely switch between these modes but routes can have parts without available panoramas. In parts without panoramas City Scene automatically switches to map view. Navigation route is augmented by showing landmarks along the path. These landmarks are either photographs of buildings or text signs from building's facade. Building photographs and text signs are not yet available for all supported cities. Because of this, navigation mode that shows only photos of landmarks does not work in every city. Navigation is only possible inside cities with panoramas.

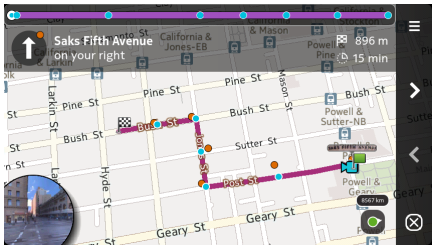

Figure 5.7: Navigation in map view

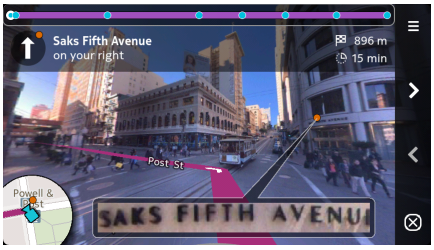

Figure 5.8: Navigation in street view

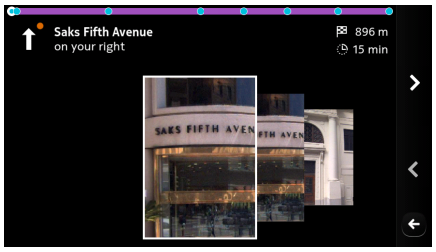

Figure 5.9: Navigation with landmark pictures

City Scene offers connection to Facebook and Foursquare. User can check their friends' check-ins through City Scene. Social interaction with City Scene was not a focus of this research so these features are not discussed further.

5.1 Drawbacks of City Scene

Battery drain of City Scene was not tested but while using City Scene it seemed to drain power relatively fast. Battery would probably last about same time as when talking on phone, around 6,5 hours. While users familiar with modern smart phones will probably reload battery often, less experienced users might have problems with

phone battery running out. This in fact led to first participants' phones running out of power, and rest of participants were specifically reminded to recharge often (see chapter 6).

Nokia City Scene is completely dependent on Internet connection; if there is no Internet connection when City Scene is started, it displays a dialog that only has options to quit or connect to Internet. This limits its use on tourism, since foreign SIM cards with data plan may be hard to get or expensive. In our own use, City Scene also seemed to need fast and stable connection to function properly. In urban environment 3G network coverage can limit usefulness of the application. In our study we provided test users with prepaid data SIM cards, but there was still some uncertainty on how well they would function since we could not test them. This is because all visited cities were abroad and foreign SIM cards could not be tested in Finland.

5.2 Comparing City Scene's user interface on previous research

There has been some research on usability of different types of map rotation. Seager and Fraser (2007) compared three types of map rotation with north-up aligned map. They found out that only physically rotating the navigation device was significantly more usable than using north-up aligned map. Automatic rotation was not stable enough and manual rotation by buttons caused a high workload. They suggested a combination of manual and automatic rotation, where user can align the map to his heading by pressing a button, as a possible solution. (Seager and Fraser 2007) In tests conducted by Hermann and Bieber (2003) users completed navigation tasks fastest with egocentric map (centered and aligned to users heading). These studies suggest that users might prefer a map that aligns to their heading or that they can easily align themselves. Nokia City Scene only features a north-up aligned map so there are no rotation options that might increase workload. However, since City Scene automatically orients user interface and map, so that north is always up when device is turned, users may experience some problems if they would like to align map to their heading. Also, map does not indicate the heading of user, so it does not provide much help in knowing which way to go. Street view might alleviate the possible need for heading aligned map since it can be aligned manually. It may also help users find the right direction.

6. RESEARCH METHODS

This chapter describes the application of used methods in detail. Goals of the research were discussed in 1.2. As a summary, goal was to find out answers to following questions:

1. How different navigation modes are used and on what purposes?
2. What expectations people have of Nokia City Scene and other navigation applications?
3. What is the user experience of City Scene like?

On SeMiRe project it was decided to both conduct an Internet questionnaire globally for City Scene users and to study the use of City Scene in more detail with small group of recruited participants. Both these methods emphasized free use of City Scene; no set tasks were used. This was done to find out what are the actual needs for navigation software and City Scene. Three possible options for user groups of second study were considered: students that have recently moved to Helsinki from elsewhere, tourists coming to Helsinki and tourists going from Finland to cities supported by City Scene. Options involving Helsinki were later dropped because panorama and point-of-interest content was found to be too low for meaningful study. Finnish tourists were selected for second part of research. Research was thus divided into two studies. During the preparation for these studies, City Scene's usability was evaluated with heuristic method to eliminate as many problems as possible before actual studies. Project began on July 2012 and ended officially at the end of the year, though analysis of the results proceeded until February 2013. Table 6.1 shows the schedule of the research.

In this chapter the heuristic evaluation method used in finding usability problems is discussed first. City Scene user questionnaire is covered next and tourist study last, at the end of this chapter. For both studies, overall process is described first, then participants and ultimately each part of the method is described in detail.

July	Background research, heuristic evaluation, planning, preparing questionnaires
August	Starting tourist recruitment, preparing questionnaires
September	Recruitment, preparing study material, starting questionnaire, meeting first participants
October	First meetings with rest of the participants, final meetings with some participants
November	Final meetings with rest of participants, questionnaire closed
December-February	Analyzing results

Table 6.1: Schedule of research 2012-2013

6.1 Heuristic evaluation

Nokia City Scene was still under development when SeMiRe research project started. A heuristic evaluation on City Scene's usability was performed to recognize usability issues in the application and if possible fix the issues before beginning user studies. Evaluation was conducted by doing a heuristic evaluation using Jakob Nielsen's usability heuristics (1995a). Heuristic evaluation means that evaluators inspect a user interface and compare it to a set of usability principles, the so-called heuristics (Nielsen 1995b). While heuristic evaluation is difficult for one evaluator and effectiveness would be better with several (Nielsen 1995b), evaluation was conducted by only one evaluator. This was because heuristic evaluation was not a major part of the research but it offered a quick way to familiarize with City Scene and report major usability problems to developers.

Heuristic evaluation was performed by going through all possible screens and functions of Nokia City Scene and making notes of all possible usability issues encountered. These issues were then rated by severity (using Nielsen's severity levels (1995c)) and categorized under heuristic categories. Results of the heuristic evaluation can be found in chapter 7. It was not possible to conduct this evaluation in actual use context, so it was conducted in an office. Because of this, possible context related problems could have been missed in the evaluation.

6.2 Internet questionnaires

First study in this research was three Internet questionnaires for Nokia City Scene users. These were users that downloaded City Scene spontaniously. Aim of the questionnaire study was to get quantitative information on users' first impressions on Nokia City Scene and feelings after using it for few weeks. Questionnaires were divided in three parts:

1. Contact information

2. Background and first impressions

3. Long term use of City Scene

First questionnaire part was only used to collect contact information from people that wanted to participate. This was necessary to eliminate false contacts so we could be sure that all questionnaires were sent to active e-mail addresses. This was done to make sure that addresses we used were not marked as junk email. Second part contained questions about participants' background and their initial feelings of Nokia City Scene. Questionnaire contained questions about first day experiences and expectations, previous navigation, social media and AR software experience and opinions of technology. Questions of the questionnaire can be found in appendix A.1. Last part of the questionnaire was longer and contained questions about where and how participants' have used City Scene, what navigation modes have they used and for what purposes and how they feel about City Scene. Questions were about context of use and activities performed, usefulness of City Scene in various activities, use and preference of navigation modes, and strengths and weaknesses of City Scene. There were also several statements about City Scene and participants had to select whether they agree or disagree with them. Questions of the questionnaire can be found in appendix A.2. In each questionnaire, we asked participant's name and e-mail address to make sure each participant answered in each part of the questionnaire.

Questionnaire questions had scales, open text fields or multiple choices for answers. Likert scales were used on statements to measure participants agreement. Likert scales commonly use 5-point scale (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree) to measure respondents agreement level, though sometimes 7 and 9-point scales are used or even numbered scale to prevent choosing indifferent option (Bertram 2007). This study's questionnaires used 7-point scales (strongly agree, agree, slightly agree, neither agree nor disagree, slightly disagree, disagree, strongly disagree). Participants were given an option to neither agree nor disagree in case they did not understand the statement or statement was in some way invalid. There is a caveat when analyzing these scales. Likert Scales are ordinal data, which means that differences between points may not mean same to all participants (Bertram 2007). While points on scale are given numbers from -3 to 3, difference between, for example, -3 and -2 cannot be considered same as difference between 0 and 1. This also applies to usefulness scale and means that it is not meaningful to calculate averages of scale answers. These problems are especially apparent on questions like "...using City Scene encourages my imagination". While positive side of scale is pretty straightforward in how much imagination is encouraged, negative side is somewhat indefinite. What is the difference between -1 and -3? Does -3 mean that City Scene disencourages imagination?

6.2.1 Recruitment procedure

Participants for Internet questionnaire were recruited from those who downloaded Nokia City Scene and those who saw our advertisement on Nokia City Scene's page on Nokia Beta Labs -website. Those who followed advertisement were presented with contact information questionnaire. Participants leaving their contact information and those who downloaded Nokia City Scene were sent background and first impression part of the questionnaire. Few weeks later, last part of questionnaire was sent to those who answered in first part. Questionnaires were send as e-mails containing Internet link to the questionnaire. Three gift cards to Amazon.com or its localized versions were raffled amongst those who answered all parts of questionnaire.

6.3 Tourist study

Second user study utilized tourists as participants. People traveling to cities supported by City Scene were recruited by messages on various travel related Internet message boards, intranet of Tampere University of Technology and Facebook. Participants were selected based on whose trip was during our study and who could come to Tampere for all interviews. No other elimination was neccessary. In this study, tourists used Nokia City Scene on their trips on tasks they needed it. They were not given any predetermined tasks on City Scene's use. During their trips participants filled a diary with their use cases, problems and ideas for future development. Tourists were interviewed before and after their trips.

Initially, using experience sampling method in tourist study was considered. In experience sampling method participants fill out brief questionnaires by responding to alerts (Consolvo and Walker 2003). Experience sampling method would have made possible to probe participants feelings right after using City Scene. However, no practical method of delivering these alerts to tourists and collecting data was found. Instead, tourists were encouraged to fill diary as soon as possible after using City Scene.

6.3.1 Procedure

After participants were selected, each participant was invited to one-to-one interviews. In these meetings first participants filled a short questionnaire about their experience with navigation applications. Then the purpose of the study was introduced, Nokia N9 and City Scene were presented and needed equipment was loaned to the participant. A short interview was held at the end of the meeting. In this interview participants were asked about previous navigation experience and their expectations of City Scene. All participants were given a diary to fill during their

trip and N9 phone with City Scene installed if they did not have N9 of their own. When necessary, a power adapter was also loaned. Each participant was given a prepaid data SIM card. All interview where semi-structured; there were prepared questions but participants answered could be followed with additional questions and discussion. All interviews were recorded and these recordings were transcribed. Transcribed interviews where then combined in one table where answers of all participants where organized under themes. Notable findings where then highlighted so they could be picked out easier when analyzing results.

First interviews

In the first meeting with study participant, they first filled a short background questionnaire. This questionnaire had questions about their previous experience with navigation software, car navigators, GPS-devices and paper maps. They were also asked how much they use or have used social media, augmented reality applications, virtual models and location-based-services. In the end of the questionnaire, participants were asked to rate their agreement or disagreement on various statements on technology use and map skills. Questions of this questionnaire can be found in appendix A.3.

After the questionnaire participants were shown a brief introduction presentation about Nokia City Scene and its features. Presentation showed most of City Scene's functions and it's limitations. It was seen necessary to inform participants of City Scene's limitations beforehand, especially rapidly draining batteries, when first participant reported that he was unable to use City Scene one day because he had not recharged his phone. Risk of losing days of use on short trips was seen greater than possible biases, that could result from informing participants of these downsides.

After the presentation, participants were given all needed equipment for their trip. This equipment was Nokia N9 phone with City Scene installed, recharger, power adapter (if needed), a prepaid SIM card and a diary. Finally a short interview was held. This interview participants were asked of previous navigation experiences, first impression of City Scene and expectations of City Scene's use on the trip.

Diary

Participants were free to use City Scene during their trip as they wanted. There were no required tasks to be performed, but participants were of course encouraged to use City Scene for navigation needs they might encounter. Participants were given a paper diary, where they could write down their experiences. First diary had tree pages with text boxes for short entries. Then there were three double pages for longer descriptions of more notable events or experiences. These double pages had

questions on what City Scene was used and where, what was the experience like, why City Scene was needed and what additional features would have been beneficial. After these pages there was one page for reporting technical problems and ideas for further development. In the end of the diary there were voluntary example tasks for getting familiar with City Scene. Diary is in appendix B.

Final interviews

When tourists returned from their trips a final one-to-one interviews were settled. In this final meeting all equipment and diary was first collected. Then a final interview was held. In this interview there where four themes: explorative use, navigation, quality and user experience, and further development. Explorative use was about exploring panoramas both in-situ and ex-situ. Use of points-of-interests was also covered. Navigation questions dealt with how participants used City Scene in navigation tasks, what kinds of navigation needs they had and how well they managed in these tasks. Quality and user experience theme was about participants experience in using City Scene, usability, how good was the information presented and did City Scene meet their expectations. Final part of the interview was about needs and ideas for further development of City Scene. Before it, the diary was gone through. If some entries needed clarification, they were discussed.

7. RESULTS

This chapter presents results of the study. First the results of a usability evaluation are presented. Then are the results of online questionnaire and after that the results of trial study with tourist participants. Since diaries were not filled very diligently they were mostly used to help discussion during interviews. Because of this their results are not presented separately but included in interview results. At the end of the chapter there's a short summary of main results related to thesis focus in section 7.4.

7.1 Heuristic evaluation

Usability of Nokia City Scene was evaluated using Jakob Nielsen's usability heuristics (1995a). These heuristics can be seen in table 7.1. Four severity levels were used for issue severity (Nielsen 1995c):

0: I don't agree that this is a usability problem at all

1: Cosmetic problem only: need not be fixed unless extra time is available on project

2: Minor usability problem: fixing this should be given low priority

3: Major usability problem: important to fix, so should be given high priority

4: Usability catastrophe: imperative to fix this before product can be released

H1: Visibility of system status	The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.
H2: Match between system and the real world	The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.
H3: User control and freedom	Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.
H4: Consistency and standards	Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.
H5: Error prevention	Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.
H6: Recognition rather than recall	Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.
H7: Flexibility and efficiency of use	Accelerators – unseen by the novice user – may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.
H8: Aesthetic and minimalistic design	Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
H9: Help users recognize, diagnose, and recover from errors	Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.
H10: Help and documentation	Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

Table 7.1: Usability Heuristics (Nielsen 1995a)

Severity level	Number of problems
0	1
1	11
2	16
3	6
4	0

Table 7.2: Problems found by severity

Heuristic	Number of problems
H1	7
H2	5
H3	3
H4	1
H5	17
H7	2
H8	2
H9	3
H10	1

Table 7.3: Problems found by heuristic. Note that some problems were classified under several heuristics.

There were a total of 34 usability issues found, though one of them was classified as 0 meaning it was not necessarily a problem. Number of problems of different severity levels can be seen on table 7.2. There were no usability catastrophes but there were six major problems. Most problems were minor or cosmetic. Number of problems on each heuristic can be seen on table 7.3. Some problems were classified under several heuristics, so total number here is bigger than total number of problems. Each heuristic had at least one problem matching it. By far most common problem heuristic was number five, error prevention.

Heuristic	Description
H6	Transition method between panorama and map is not self-evident.
H5	More images/less images link is extremely hard to hit.
H1/H5	Areas with panoramas are not indicated on map.
H5	Some routes have steps that take the view off the route.
H5	Turn arrow on navigation is occasionally incorrect.
H5/H9	Landmark image mode is not implemented but is still selectable

Table 7.4: Major usability problems (severity level 3)

All major usability issues found are on table 7.4. Some of these issues were fixed before user trials but some were not. Transition method between panorama and map (tapping on small map/panorama image) was not changed, but method was shown

to participants during first meeting. Areas with panoramas are still not indicated on City Scene map-view. Landmark image mode was implemented before user trials began.

7.2 Online questionnaire

This section presents the results of Internet questionnaire sent to City Scene users. Only those questions that yielded interesting and notable results are discussed. Questionnaires used can be found in appendix A. Results are presented in two parts: first results of the background questionnaire and then the questionnaire of Nokia City Scene use. Drop out rate was very big in the questionnaires; there were only nineteen participants who participated in all parts. Because of low amount of participants, quantitative analysis with statistical methods was not considered feasible.

7.2.1 Background questionnaire

After few participants were dropped because their answers seemed suspicious or they had not actually used City Scene, there was fourteen participants who had answered in all parts of the questionnaire. While number of participants in questionnaire was low, participants were from all over the world; there were ten participants from Europe, two from Asia, one from North America and one from South America. Notably all participants were male. Ages were between 22 and 53, average was 32,57. Nine participants never visited any city on City Scene's featured locations list. While this means that most likely could not use City Scene on actual location, it is still possible that they could have visited cities with limited support. All participants had used at least one of kind of digital map at least occasionally; some had had used several kinds often. Only one participant used augmented reality applications daily, most participants had never used them and four had only tried them. Four participants used virtual models occasionally; others had only tried them or had never used them. Three participants occasionally used location based services, one had only tried and one could not say. Others had not used location based services.

Results of question "Please select the option that best describes your opinion" can be seen in figure 7.1. In these questions it should be noted that on some questions, scale can be vague, especially on the negative side. For example on question "I browse content created by other people..." it is unknown whether those who answered zero mean that they don't browse or they do not know how to answer. However there does not seem to be any questions on which there would be a change of major misinterpretation.

All but one user considered himself to be skilled information technology user on

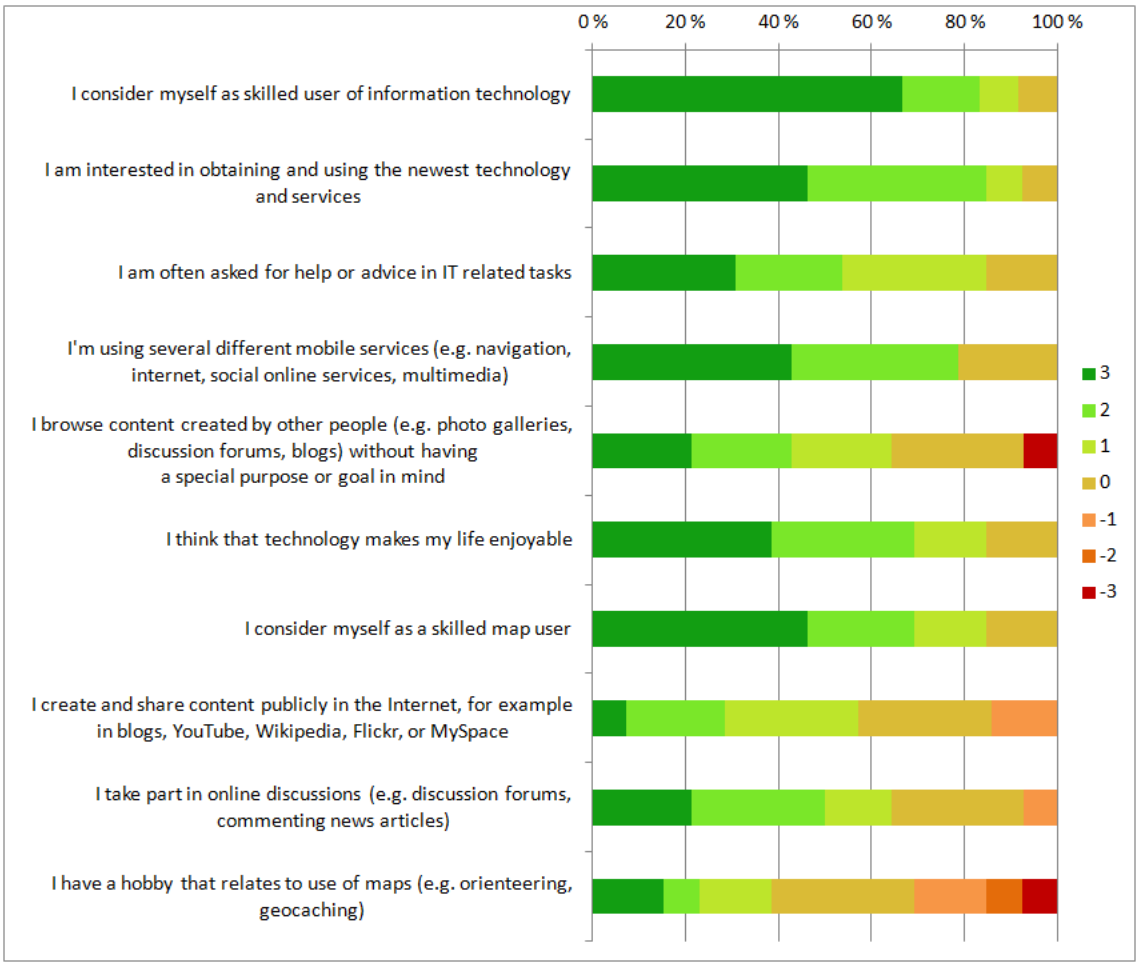

Figure 7.1: Please select the option that best describes your opinion. (-3 Strongly disagree, 0 neither agree nor disagree, 3 strongly agree)

some level and being interested in new technology. Also, all but two participants answered that they are asked for help in IT related tasks. When asked asked about mobile service use, all but three answers were positive. Nine participants browsed content created by others and think that technology makes life enjoyable. All but two considered themselves skilled map users on some level. Eight participants create and share content in the Internet, most of the participants also take part in online discussions. Statement "I have a hobby that relates to use of maps..." divided participants almost evenly. There were five positive answers, four zeros and four negative answers.

Results of background questionnaire summarized:

- 14 participants, all male
- Ages 22-53, average 32,57
- Ten participants from Europe, two from Asia, one from North America and one from South America

- Nine participants never visited any City Scene's featured cities
- All participants had experience in using digital maps
- Only five participants had any experience in using AR applications; one participant used AR daily, 4 had tried AR
- Participants considered themselves skilled IT users and had a positive opinion on technology
- All but one participant use Internet socially (browse or create content, participate in discussions)
- Most participants use mobile services
- No participant considered himself poor map user

All in all, participants had at least some experience in digital maps. They had a positive opinion of information technology and they use it socially. There were no surprises in the answers; all participants seem very typical technology users.

7.2.2 Questionnaire of Nokia City Scene use

Use contexts

The respondents were asked how often they used City Scene in various contexts. Results of this question can be seen in figure 7.2. City Scene was used relatively frequently in each context and there was only a little variation between them. Home was the most frequent use context and public transport the least frequent.

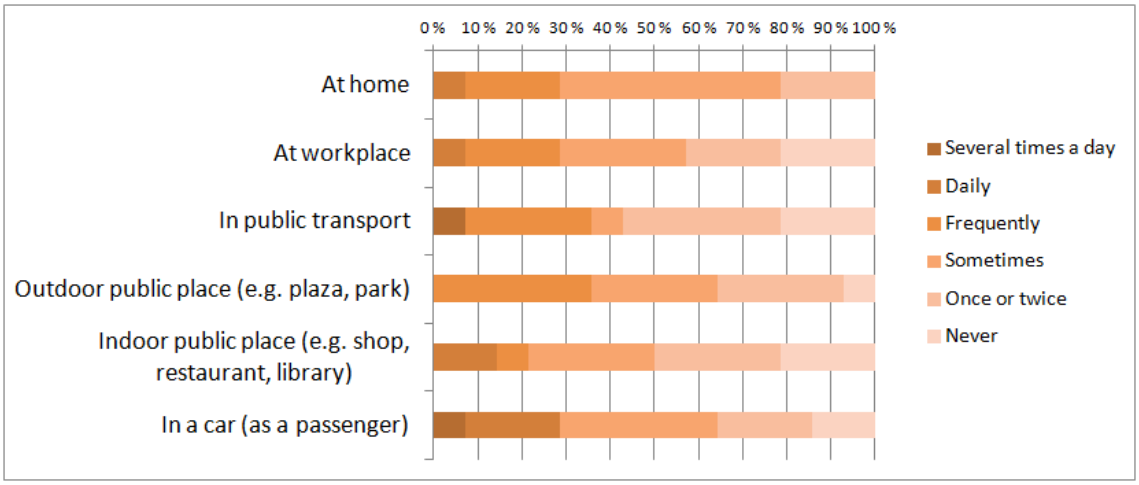

Figure 7.2: How often have you used City Scene in different places since installing the latest version?

Activity frequency

Frequency of City Scene's use in various activities can be seen in figure 7.3. There were no big surprises on activities City Scene was used in. Most performed activities were viewing and exploring panoramas both near user (in-situ) and elsewhere (ex-situ). Similarly City Scene was used to look for information about businesses and services near and far. Frequent in-situ use is slightly surprising since most participants never visited cities on City Scene's featured locations list. Navigation, planning routes and planning details of visit were also fairly frequent use cases. Due to low amount of supported cities, it is possible that some participants were limited to using navigation only on map mode. Showing places to others directly or remotely were surprisingly common as was reminiscing past trips and events.

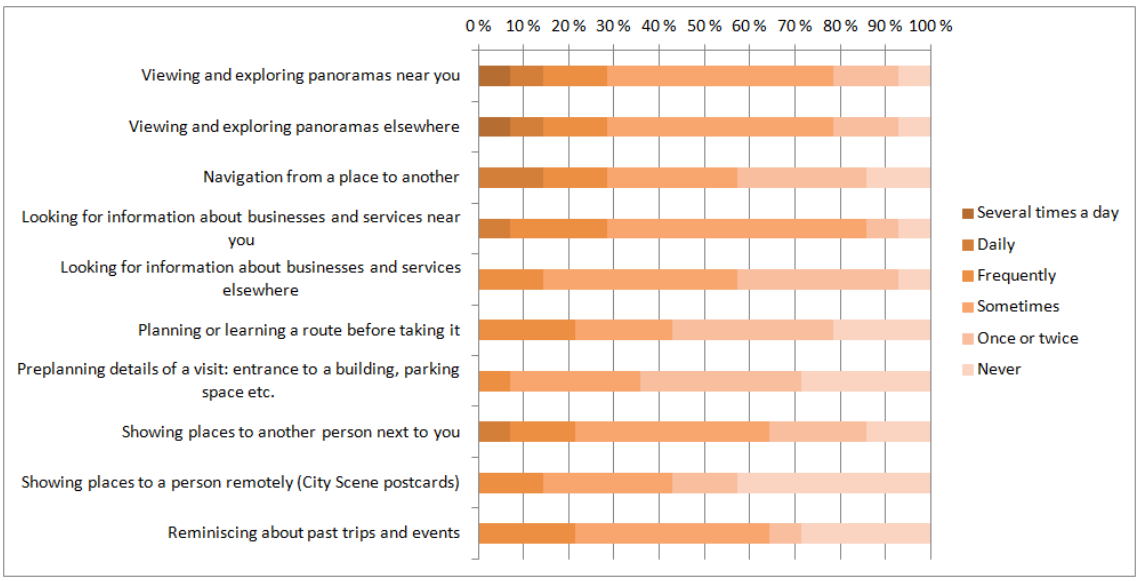

Figure 7.3: How often have you used City Scene in following activities since installing it?

Usefulness

Participants were asked to evaluate City Scene's usefulness in each of the same activities as before in activity frequency questions. Results of this question can be seen in figure 7.4. Exploring panoramas both near and far was rated very useful, although there were a few answers on useless side. Navigation was also seen very useful but slightly less so. Looking for information both near and far was rated very useful less but was also rated quite high consistently with 3 being lowest rating. Planning or learning a route and preplanning details of visit divided participants. City Scene was seen both useful and useless; in general answers were slightly more on useful side. Showing places to others directly or remotely and reminiscing past trips were seen somewhat useful in general.

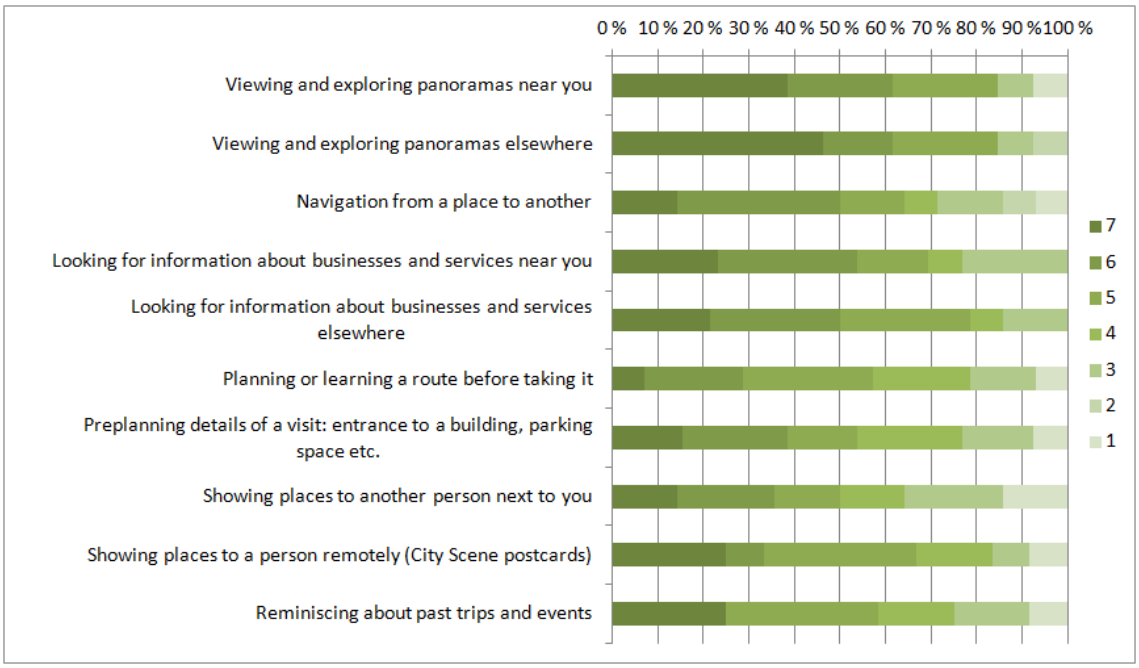

Figure 7.4: How useful do you think City Scene was in these activities? (1 useless, 7 very useful)

Navigation modes

Participants were asked how often they used the three navigation modes on City Scene and which mode they preferred in various tasks. All navigation modes were used by several participants but some participants had not used each mode. There were no notable differences between navigation modes on use frequency. Timeline mode was used surprisingly frequently, though it is possible that some participants might have misunderstood which mode it was. When asked which mode participants would prefer on short or long trips, map and panorama were selected most with map preferred six times and panorama five. Timeline was preferred only by one participant on both distances. Combination of several modes was selected twice on sort distances and once on long. Participants were then asked which mode they would prefer while walking, cycling, as a passenger in a car or while learning a route beforehand. As a whole, map mode was most preferred; it was preferred most on all except while walking where panorama was preferred most. While learning route beforehand, map and panorama were almost even with map preferred five times and panorama four.

Statements

Participants had to choose on what level they agree or disagree with several statements. Answers on these statements can be seen in figures 7.5 and 7.6. To distinquish Likert Scales from usefulness scale, Likert Scales are given numbers from -3

to 3 while usefulness scale uses numbers from 1 to 7.

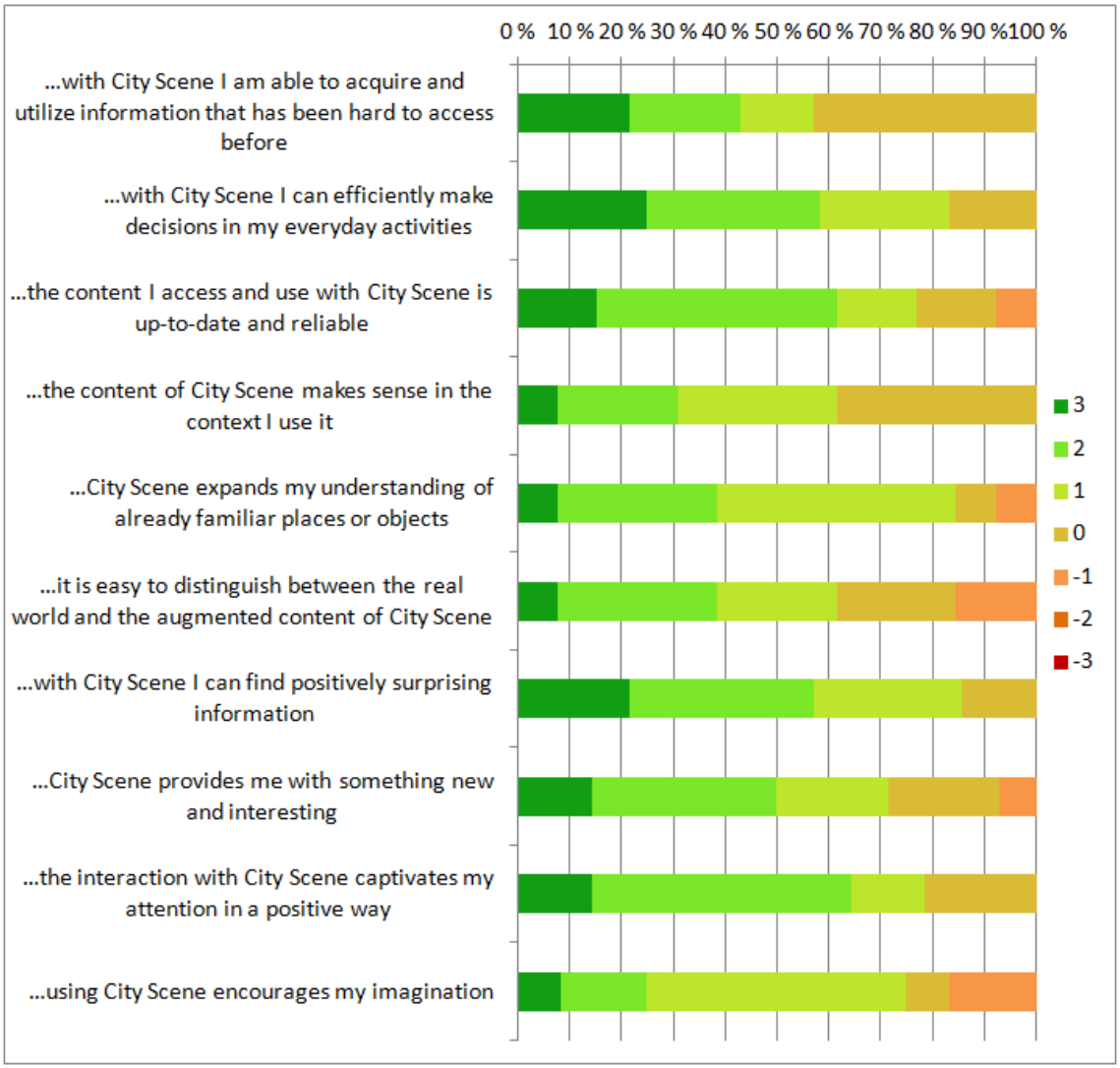

Figure 7.5: Please state your opinion with the following statements. (-3 Strongly disagree, 0 neither agree nor disagree, 3 strongly agree)

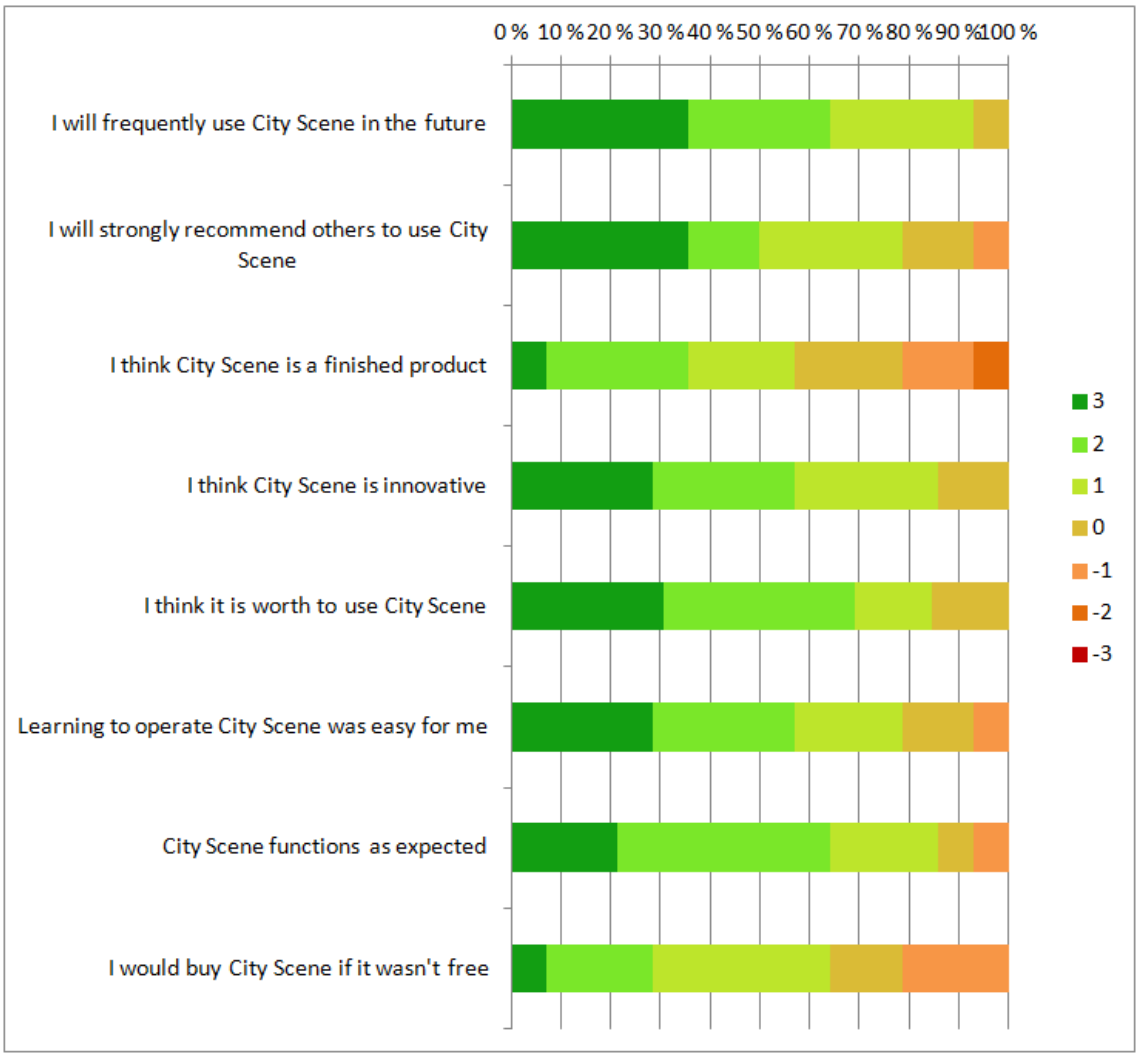

Figure 7.6: Please state your opinion with the following statements. (-3 Strongly disagree, 0 neither agree nor disagree, 3 strongly agree)

Most participants agreed at some level with all statements; also, there were no strongly disagree answers. Statements concerning the user experience of city scene (figure 7.5) got mostly agreeing answers. In total there where only seven negative answers and these were all only slight disagreement. They were also divided so that most negatives that a statements got was two slight disagreement answers. Most positively agreed statement was "...the interaction with City Scene captivates my attention in a positive way".

In the statements concerning the quality of City Scene (figure 7.6) most disagreed statement was "I think City Scene is a finished product". Still, most participants at least slightly agreed with the statement. Statement "I would buy City Scene if it wasn't free" was mostly agreed only slightly though no participant disagreed strongly. It could mean that if participants would pay for City Scene, they would not pay much. Other statements were agreed upon by most participants and there

were nothing that stands out.

Summary

Questionnaire results summarized:

- City scene was most used at home, least in public transport. Variation was low.
- Viewing and exploring panoramas was most common activity and most useful. Looking for information about businesses was also common and useful.
- Use on navigation was less common and useful than panoramas and information.
- Usefulness of planning or learning a route and preplanning details of visit divided participants; it was seen both useful and useless.
- Showing places to others was surprisingly common. It was seen somewhat useful.
- All navigation modes were used. Map and panorama were most used modes. Panorama was preferred most on walking; map while cycling, as a passenger in a car and while learning a route beforehand.
- All statements concerning user experience were agreed by majority. Most agreed statement was "...the interaction with City Scene captivates my attention in a positive way".
- Most slightly agreed with City Scene being a finished product but there were some that disagreed.
- Most slightly agreed that they would buy City Scene if it was not free.

Only real surprise in results was how common showing places to others was. In general results imply that most use was just trying City Scene out. Home was most common use context and viewing panoramas most common activity with navigation being less common. This could have affected estimations of usefulness. If use in actual context and with real purpose was rare, usefulness estimations may be unreliable. Similarly, user experience and quality estimations may not be reliable. However, since participants mostly probably just tried out City Scene and results show that user experience was positive, City Scene might give positive impression on first uses.

7.3 Trial study

This section presents the results of the study conducted with tourist participants. Results consist of three parts: background information questionnaire filled at the start of first meeting with participants, first interview carried out the end of the first meeting and final interview from last meeting. Participants diaries were discussed during interview, so their findings are included in interview results. All participants are referred to as 'he' regardless of gender to maintain anonymity.

There were 11 participants; 6 men and 5 women. Ages ranged from 18 to 45. Average age was 30,6 and median age 31. Cities that the tourists visited were Paris, London, Chicago, Dallas, Fort Lauderdale, Las Vegas, Los Angeles, New York, San Francisco and Orlando. Those who visited Paris or London did not visit other cities. Tourists in United States visited several cities on one trip, except one tourist who only visited New York. Those who visited several cities rented cars during their trip. Duration of stay in each city varied from one day to nine days; most tourists stayed in one city from two to four days. Total number of days visited in each city by all tourists ca be seen in table 7.5; those who visited Texas area did not mention how many days they spent in Dallas. Three participants used their own Nokia N9 mobile phones, others were given a N9 for the trip. Two participants had tried City Scene before, others had not used it before study.

City	Days visited
Paris	5
London	18
Chicago	3
Fort Lauderdale	2
Las Vegas	2
Los Angeles	4
New York	13
San Francisco	4
Orlando	2
Dallas	not specified but in Texas area a total of 14 days

Table 7.5: Cities visited by tourists and days spent in each city (total of all tourists)

7.3.1 Background questionnaire

Usage of navigation applications and devices

All participants had at least tried all Google's applications (Maps, Street View, Earth) in questionnaire. Maps was most used with majority of participants using it weekly. Street view was used less but all participants used it at least occasionally. Thus, all participants had some experience in using panoramic street view before using City Scene. All participants except one had used at least some digital map weekly or more; one used digital maps occasionally at most. One participant had never used car navigator, separate GPS-device or cellphone with GPS, others had at least tried some sort of GPS-location. All participants had at least tried paper maps.

Usage of AR and location based services

Augmented reality applications were rarely used with three participants having tried and others never tried. Virtual models of museums or other places were used slightly more with one participant having tried, three using occasionally and one monthly. Location based service question was apparently misunderstood by some participants since they reported digital maps, metro maps and car navigators. Only three reported that they had never used any location based services, though a few that reported using occasionally, did not elaborate what services they used.

Opinions on technology and map use

Participants opinions on technology and map use were measured on scale from -3 to 3, -3 being strongly disagree and 3 strongly agree. All participants were technology positive and at least somewhat skilled. Remarkably all agreed strongly on mobile use, however what services were used mobile was not elaborated on the questionnaire. It can be assumed that all participants are skilled users of mobile applications and services.

7.3.2 First interview

First interview was about participants expectations of navigation software and City Scene, and their first impressions of City Scene. During the interview of one participant, recorder ran out of battery power without interviewer noticing it. Because of this there is no recording of that interview and its results are unavailable.

Use in context (in-situ)

When asked how they would think they might use Nokia City Scene in context, most participants said they would likely seek places such as restaurants, shops and tourist spots. A couple mentioned navigation specifically. One participant said he would unlikely use City Scene in context unless he was especially seeking some place. One participant also mentioned that he would read reviews.

Use out of context (ex-situ)

Two participants said they would use City Scene out of context to familiarize themselves with it. Two said they would not use it beforehand; one of them because he had no time to do so before the trip and he had visited his destination before, so it would not be necessary. Three participants said they would plan their trip with City Scene; two of them by adding favorite locations. One said he would seek nearby restaurants while at his hotel.

Good or novel features, downsides and surprises

Several good or novel features were listed by participants based on their first impressions after City Scene was presented. City Scene was mentioned to potentially help finding places, especially places to eat. Street view panoramas were mentioned as good feature; one participant said that they could be used to assure himself of his location by comparing panoramas to real world. One mentioned using landmarks and other using text signs as aid in navigation. Points-of-interest were listed as was connection to Facebook and Foursquare. Possibility to add favorites and listing them based on distance from location was also mentioned once. One participant considered City Scene to appear clear and easy to use.

On downsides of City Scene it should be noted that no participant had used City Scene much. In City Scene's introduction during first interviews, drawbacks of City Scene were listed (see 6.3.1). This may have affected participants' answers. Four participants could not say any downsides at the first interview. Others mentioned limited content, especially in Finland and City Scene's slowness. One participant said that since content amount is low, users could perhaps create content. Short battery life was also mentioned twice but this may be a result of warnings in City Scene's introduction. After few participants had returned from their trip and reported quickly draining batteries, remaining participants had to be instructed to recharge their phones often, so that empty batteries would not prevent the use of City Scene, especially on short trips.

There were no great surprises on City Scene to participants. One said that street view had better quality than expected. One said that he had tried older version and

it had less supported cities. One participant said that City Scene maybe appeared to be easier to use than he expected. Rest of the participants said there were no surprises to them.

It should be noted that both good features and downsides mentioned may be heavily influenced by City Scene's introduction before interview. Some mentioned good features were features particularly presented in introduction. These are the use of landmarks and text signs in navigation instructions, points-of-interest and Facebook and Foursquare connection. It is possible that some of these were mentioned because they were still fresh in participants memory but that does not necessarily mean that they did not really consider them good or novel.

Previous navigation experience

When asked about previous experiences with navigation applications, most participants only listed applications they use and not particularly any any experiences. Two participants said they have bad opinions on navigation software. One said that he is likely to get lost using them and other considered them slow and cumbersome. Other participant was pessimistic of navigation applications functioning abroad, since they don't work without data connection and GPS usually works poorly. He also felt that navigation applications usually don't give the shortest route. One participant mentioned a special case: he occasionally uses the trace of is path on Nokia Sporttracker if he gets lost, to find his way back. He also occasionally uses landmarks and traffic noise to find his way out of forest. One participant said that with cellphone navigation applications, it is often difficult to determine what direction is right since applications usually don't know which direction phone is pointing.

Tourist maps were mentioned three times when asked if participants had used paper maps. Two participants said they use paper maps while hiking. One participant said he usually has a paper map along electronic maps as a backup and stress reliever. One said he keeps a road map in his car.

Situations where participants used maps or navigation applications were mainly finding places and routes. More specifically one participant said he makes estimations of distance, travel time and when he should leave. Other participant mentioned that he usually checks the size of roads from paper road maps.

All participants except two rated themselves at least decent navigators; one said that he does not consider himself a good navigator and one was not asked, probably a mistake by interviewer. One participant that considered himself to be a good navigator assumed that his navigation skills decline because he uses navigation applications. Other participant said that he has occasionally been misled by roadsigns and other said that he stays on map if he has one, but might get lost without a map.

7.3.3 Final Interviews

The use of City Scene on participants' trips was limited in some cases by SIM cards that did not work and limited data content on destination cities. One participant faced both issues and could not use City Scene in meaningful way. On his case, interview focused on other navigation applications used and ideas for features. Of those participants whose SIM card did not work, one could use it quite well on free wlan-networks and other used City Scene a few times with other SIM card. One user had network connection problems even though SIM card worked. Because of this, points-of-interest were often unavailable. He reported that places were often found faster from paper map that was used as a back-up.

Diaries

Diaries were integrated into interviews by going through them with participant and discussing entries. Mostly diary entries were short and these are not reported separately but there were some more notable entries.

A participant was eating at a restaurant and seeked a route back to hotel. City Scene could not find his exact location. He took a metro but got off it one station too soon. He searched a route from hi GPS-location to hotel in favorites. Navigation was hard because GPS-location did not update and first he started to walk in wrong direction. He reloaded the route which took a long time and finally took a taxi to hotel. This case is a prime example how technical difficulties may lead to abandoning the use of the application.

Other participant was lost a few times and had saved useful locations in favorites. He reported that while he would have needed the map mode, City Scene automatically switched to panoramas on navigation and getting back to map demanded multiple taps on map button for some reason (was unresponsive). He also would have needed direction indicator to know which way to go. His opinion was that panoramas were "unneccessary hifi" when being lost. This case shows the need for simple and robust navigation, especially when lost. Because of this, more demanding features such as panoramas should not be primary methods for navigation.

Exploratory use

Use in context varied greatly between participants. Most only tried a couple of times to view their own surroundings for fun or to test the feature, while three used or tried to use City Scene for in-situ browsing constantly. Use in this purpose was usually not possible if SIM card did not function, since WLAN coverage is often limited to cafes, restaurants and hotels. Use for in-situ browsing was also limited by low amount of points-of-interest. Often this was a limitation of City Scene but

two participants visiting Dallas, reported that Dallas downtown is mostly business district that has no interesting places.

Using out of context (ex-situ) was more common than in context use. Only two said that they did not use City Scene to view places where they weren't at the moment, though both mentioned such cases later in the interview. One participant said that viewing remote places was the main benefit of City Scene and that he used it to find shops were he visited later. One participant viewed places from New York before he arrived there on his road trip. Places he viewed was the neighborhood around his hotel and the location of car rental.

Uses in exploration:

- Adding favorites, planning trip
- Learning features of places
- Browsing places in area

Most participants used City Scene to view locations beforehand or searched locations and added them as favorites. Those who viewed locations beforehand did so to learn features of places. Examples of this are viewing musical theaters and what they look like to recognize them later, checking out hotel and nearby restaurant also to recognize them when arriving and browsing stores near tomorrow's destination.

Categories used or needed:

- Restaurants, cafes
- Hotels
- Stores
- Museums, theaters, tourist sights
- Car rentals, gas stations
- Medical services

Used and needed categories were collected from interviews and since there was no logging available, it cannot be confirmed how much participants actually used them. Restaurants were most common point-of-interest category used. Cafes, hotels and stores were also very common. Rest of categories were used or needed by only one or two participants. Better and more specific categories were wanted by a couple participants; one participant wished that he could arrange restaurants based on reviews. One participant wished that points-of-interest would also show on map and other reported that browsing for interesting places is hard when you don't

know specifically what you want. He also said that Nokia City Lens was better for browsing without a goal, since it showed points-of-interest from further away.

Information used or needed:

- Location
- Reviews
- Opening hours, prices, type of food and other general information

Reviews were most common information used apart from location and when they were not available a few participants' said they would have needed them. Opening hours were also often missed when they were not available. A couple of participants read reviews to get info on restaurants style and prices; general information on food style and price level was wanted.

Navigation

Two main types of navigation use were recognized: first was seeking a route from point to point and second was checking current location and destination without seeking a route with City Scene. On some cases participants chose not to seek a route because City Scene functioned slowly or because GPS-location was inaccurate. One participant said that it was helpful to see the whole route on map and to see what the route looked like in street view; he used City Scene a lot on navigation. Other participant said that he did not need routes but checked locations only, other said that while he searched a route, he occasionally only looked the general direction. How much participants viewed panoramas and map during navigation varied, some viewed turns and difficult parts, and looked up street names, some checked occasionally that they are on right course. When arriving at destination, participants often recognized destination building either from building's appearance or some text sign on the building. If destination was not visible, participants used panorama view and GPS to make sure they are on right spot.

Types of navigation used:

- Searching and using a route
- Checking current location and destination

Desired navigation features

Three participants wished that City Scene would automatically update panoramas when user moves on route. One participant also wished that there were spoken instructions and that City Scene would give a warning, for example vibrate, if user

strays from route; other wished that time and distance left would be updated when moving along a route. Currently when using routes, user has to move manually between way-points by pressing arrows and viewing panoramas between way-points is not possible when route is displayed. One participant noted that determining direction is hard since you either have to look at panoramas or start walking and look where GPS-location moves. City Scene would thus benefit from some sort of direction pointing compass. One other participant also said that direction pointing compass would be good, although he did not report problems determining direction.

Desired navigation features:

- Automatic GPS-follow and route update
- Warning if straying from route
- Heading indicating compass

Landmarks

The participant visiting Paris said he used Eiffel Tower and Notre Dame as landmarks to know hotel's location. Other participant mentioned using a statue as a landmark. Rest of the participants did not report using landmarks. One participant said that he felt that searching for route was more useful than just viewing locations, but he did not really benefit from the route. He felt that street view was more complex than map and did not bring additional value. He used mostly only map mode, and he used Nokia Maps more than City Scene. One participant said he did not see any benefit over Nokia Maps. Other participant also mentioned using maps more than street view but occasionally checking right direction from buildings in street view. He also tried the timeline mode showing only pictures of buildings, but said that buildings looked too similar for it to be beneficial.

Quality and user experience

All participants had something to complain about overall user experience of Nokia City Scene; at the least poor GPS-location or slow operation was mentioned. Most positive was a participant who said that even though City Scene is slightly clumsy, he's used to clumsier mobile software and was pleasantly surprised. Most negative comment was that City Scene is way too complicated and views were too crammed. He felt that there was too much information visible at the same time. When asked to be more specific, he estimated that he was frustrated when City Scene showed panoramas when they were not needed. He also felt that virtual location symbol (point where street view is) was not needed on map view.

Reported problems:

- Poor and slow GPS-location
- Slow data-connection leading to slow operation
- Too complex or cumbersome for some participants
- Poor search function
- No points-of-interest on map view
- Errors in software and usability issues

Participants were frustrated about slow operation, poor GPS-location, software errors and usability. Particular software errors and usability issues were problems moving from map to street view and back, which occasionally required repeated taps without anything happening, searches that are easy to accidentally close and too easily changing user interface orientation. One participant reported being frustrated about cumbersome search and navigation. Other participant said that while City Scene was workable while it had no issues with connection, but he did not bother to try when it was breaking up.

Participants had some needs that City Scene did not fulfill. One participant would have needed a hospital or medical center but could not locate any with City Scene. One participant wished that search results would be presented somehow better than just a list, which was hard to make sense. It was laborious to click each result to see where it is. Two participants wished that points-of-interest would be shown also on map and could be accessed there.

Positive findings:

- Street view panoramas are helpful
- Major buildings named on map
- Easy to use (though there are differing opinions)

Participants were asked to name strong points of City Scene. Panoramas were considered helpful in determining right direction, finding destination in last few meters and making correct turns if street signs are not useful. One participant mentioned that viewing places on street view helps making estimates about for example restaurants. One participant liked the possibility to view places before visiting them. One participant considered City Scene to be versatile. Despite criticism by a few other participants towards City Scene's usability, one participant considered clarity, ease and usability to be strong points of City Scene. He also said that it is nicer to see places on street view than just map. One participant also said that possibility

to see street view was good, although he did not need it on his trip. One participant liked named buildings on map view. Participants felt satisfaction when they could ascertain their location or direction from street view. Two participants felt satisfaction when City Scene functioned well and was useful viewing places remotely.

Negative findings:

- Lack of content
- Slow operation
- Poor GPS
- Need for constant Internet access
- Panoramas don't follow and update automatically
- Heavy and confusing (though there are differing opinions)
- Unfinished
- Bugs
- Does not help in random browsing
- Not enough feedback on technical problems

Most commonly mentioned down sides were lack of content, slow operation and poorly working GPS. Points-of-interest were generally positioned correctly, though there were occasional misplaced points. Perhaps the most notable incident was incorrect placement of Eiffel Tower. This might be because City Scene has several locations for Eiffel Tower: most at the actual location of the tower but at least one location that has the whole tower on view. One participant also encountered a restaurant that was misplaced about 100 meters.

There were no major usability problems that would have prevented the use of City Scene. When asked about usability, some participants reported problems with GPS and network, and slowness of the application. One participant said that City Scene does not give any feedback if it has problems with data connection. One participant skipped visiting a museum since City Scene loaded the route there so long that he changed his plans. Other participant also reported that connection problems occasionally prevented use. One participant suggested that since panoramas are not always needed, City Scene should limit downloading them as downloading disturbs other use. One participant said that navigation feature is useless and too stiff because of slowness. Apart from network problems, application was considered fast enough.

Meeting expectations

City Scene met most expectations that participants had beforehand. One participant expected landmarks to be useful on navigation, but did not find them that useful. He also considered street view to be essential feature but navigation is too slow and clumsy to be useful. Other participant did not really get any help in finding places to eat because search function found so many places. A participant expected street view to be easier to use than map but found it to be other way around because crossroads were easier with map.

Further development

Participants were asked whether they considered City Scene to be finished product. Responses were mixed with three considering it to be finished and eight not. However, only one of those who considered City Scene to be finished product did not mention anything to improve right away. Other two mentioned rapidly draining batteries and needed feature offline feature and seeing points-of-interest on map. Those who did not consider City Scene to be finished, listed problems with data connection and GPS, missing features and content, bugs and general lack of polish as reasons why City Scene is not ready and finished product.

Features suggested by users:

- Offline mode: possibility to use limited features without Internet connection
- Possibility to add content
- Audio guidance and narrated information on locations
- Ability to rotate map
- Filtering search results and categories
- Ability to view points-of-interest on an area
- City Lens integration (or combining City Scene with City Lens)
- Automatic following and updating panoramas
- Calculated distance left on routes
- Optional routes
- Integration with public transportation information
- More social media integration (more integrated services in addition to Facebook and Foursquare)

Participants came up with several additional features which are listed above. On the other hand one participant said that additional features would make the application more confusing. Narrated information means for example narration on tourist spots like for example birth place of a famous writer.

Participants were also asked if they considered some features to be useless. One participant said that landmark based navigation instructions and the whole navigation feature to be useless, though it was mostly because he did not personally need it. He also said that navigation routes occasionally had too many way points. Other participant mentioned text sign based navigation instructions since in real life they could be obscured for example by parked vans. One participant said that he never used points-of-interest but he would not consider them useless. Other participant presented an idea that user could select his "main thing" like navigation or street view browsing and unrelated application features would then be hidden. One participant listed several poor features. He said that mini map/mini street view is too small to be of use but at the same time too ugly and occluding. He also noted that compass in street view covers too much if view is on steep hill viewing downwards, moving in street view retains zoom level, which is annoying if zoomed in, movement from navigation point to another is too fast and confusing in street view, and that moving next to selected point-of-interest is annoying.

7.4 Summary

Here are the summarized results relating to thesis focus of navigation and user experience:

- Participants expected to use City Scene to seek places such as restaurants and shops nearby, and to plan visit beforehand
- Panoramas help in confirmation and decision making, last meters of navigation and learning details of locations
- Point-of-interest categories need to be inclusive
- Navigation needs to provide both good routes and support navigation without routes
- Features from car navigators are desired
- Technical problems hamper user experience of City Scene
- While easy to use for most, City Scene would benefit from simpler basic functions

- Better support for random browsing is needed
- Search function needs improving
- There should be an option to display points-of-interest on map

While panoramas were not always used on navigation, they helped participants finding their destination if it was not clearly visible at the location shown by City Scene. Participants also used panoramas to view details of locations before visiting them. A number of point-of-interest categories currently missing were needed or seen as beneficial. City Scene was used in navigation in two ways: either by searching a route and using it, or by checking current location and the location of destination. Participants wished for several features typically found in car navigators such as automatic GPS-following, route update and warning when straying off course.

Several technical problems hindered using City Scene. Slow network connection and slow GPS-location made the use of application slow. When encountering technical problems, City Scene did not provide enough feedback which led to confusion of exact reasons of poor operation. While most considered City Scene easy to use, one participant criticized it heavily on poor usability. City Scene did not offer enough support for random browsing. Only option was to either use search function, in which case you need to know what you are looking for, or start browsing panoramas which is slow. A number of participants wished a feature that would show all points-of-interest in an area, or all of certain category. Search function was also seen as poor. It does not show results on map, so each location has to be selected one by one to see where they are. Feature that would show points-of-interest on map was requested.

8. DISCUSSION

In this chapter the main results found in the research are discussed. First the expectations of City Scene and navigation needs recognized are covered after which the specific needs for Nokia City Scene application are discussed. At the end of the chapter the validity and reliability of the results are assessed.

8.1 Navigation needs

Participants of the tourist study had several navigation needs during their trips:

- Checking own location
- Checking location of destination
- Finding a route to a location
- Help on difficult route parts like turns
- Confirmation on staying on route
- Confirming that destination has been reached
- Finding exact target on final meters of navigation
- Learning a route beforehand
- Checking features of the route (feasibility)
- Browsing for interesting locations nearby

As mentioned in the results (chapter 7), tourists used navigation in two distinct ways. Some used the navigation function to seek a route to the destination and others only checked their location and the location of the destination. While navigating, help on difficult parts was occasionally needed as was confirmation on staying on route. When destination was reached the exact goal was not always on sight, so some confirmation was also needed to make sure location was correct. These needs are typical for navigation situations. Some of the needs correspond to human wayfinding methods discussed in chapter 3 section 3.1.1. Knowing one's location is important in oriented search and using navigation features routes is following

marked trails. Navigating by checking own location and location of destination can be seen as piloting between landmarks. It is also possible that some of those who did not use navigation routes relied at least partly on cognitive maps, but it cannot be verified with the results.

Learning a route and viewing its features beforehand was perhaps the most special use case in the research. A participant of the study needed to walk a fairly long way (several kilometers) from a sports stadium to his hotel. He needed to seek a route that would be walkable. This means that it would not go through highways or streets without sidewalks and neighborhoods it went through would be safe since he would be walking back late. Some participants also needed to browse nearby area for interesting locations. These needs led to the need to use several features of City Scene. These City Scene specific needs are discussed further in next section.

8.1.1 Needs for City Scene

Several features of Nokia City Scene were needed by study participants:

- GPS Location
- Routes
- Panoramas
- Business and service information

GPS location was unsurprisingly useful. While it is not unique to City Scene but widely available in cell phones and other navigation devices, it is mentioned here since there were lot of problems with it. While City Scene offers other options of selecting navigation start point, there were cases when participant did not use navigation because poor GPS. Because correct location is very important for using application at all in navigation, GPS should function flawlessly.

While not all tourist participants used them, navigation routes were needed by some participants. Along with routes, panoramas were utilized in navigation. Tourists also explored panoramas. Both navigation routes and panoramas are valuable features even though some users might not need them. However, panoramas should not be fetched and displayed unless user specifically chooses so, since application was often reported as slow. City Scene could possible be used without Internet connection if panoramas are not needed always.

In online questionnaire panoramas themselves were more used and seen as more useful than navigation. Information on businesses and services was also commonly used and seen as useful. Online questionnaire results would suggest that City Scene is more useful in explorative use than navigation, however questionnaire is lacking in reliability (see 8.4).

Wanted features of City Scene

Several features were requested by tourist participants. Notably features from car navigators were wanted. These were automatic updating panoramas, updated distance left and optional spoken route instructions. All participants had at least tried car navigators and some used them often. This may be reason why these features were requested. It should be noted that while these features were wanted, it does not mean that they would work in practice. For example updating panoramas while user moves might need more panoramas to be fluent. These features will require testing before including them in City Scene.

A feature that could be added without too much testing is heading indicator. Indicator that would show users facing on map would help deciding correct direction in navigation. Currently it can be problematic since user might need to start walking randomly to see where GPS-pointer is moving.

While point-of-interest categories used and needed by tourist participants were mostly found in City Scene, better categories and more points-of-interest are needed. User should be able to filter out categories they do not want. This would make search function better. Also, user should be able to view search results location on map. Currently user must choose each result separately to see where it is. In addition to search function, City Scene should have some support for browsing nearby points-of-interest other than just browsing panoramas or doing random searches. Ability to list nearby points-of-interest by category could be useful feature.

8.2 User experience

User experience statements on Internet questionnaire got positive answers. It should be noted that other results from Internet questionnaire hinted that participants mostly just tried out City Scene at home. Positive UX answers and test-like use suggest that first impression of City Scene was positive for questionnaire participants. While all UX-related statements got positive answers two statements that got least positive answers were "..City Scene is finished product" and "I would buy City Scene if it wasn't free". This suggest that participants probably were not fully satisfied with the finishing of City Scene.

Participants of tourist study were more vocal about defects affecting user experience. Frustration stemming from technical problems were often reported. Usability issues and software errors were also mentioned. Currently it seems that poor finishing on technical and usability issues are main downsides on City Scene's user experience.

On positive side, City Scene's panoramas were considered helpful in navigation. While panoramas were not needed in all navigation use, they were helpful when user

needed more confirmation on direction or destination. Street view panoramas are a welcome addition in navigation applications. Still, navigation instructions should primarily be given on map and panoramas should be an option user has to select before they are used. This is because map mode was usually used if extra help was not needed, and because panoramas can be slow on mobile applications.

8.3 Mirror worlds in navigation

Based on the results of this study mirror worlds bring utility in navigation. While navigation was primarily done on map, panoramas were utilized on special occasions. Extra confirmation other than GPS-location was occasionally needed and then panoramas were useful. Panoramas were also used to plan details of trips. Viewing destination location can help recognize the location later in actual context. Panoramas can also be used to make sure certain routes can be used while for example walking or cycling.

While mirror worlds are beneficial they also have downsides that must be taken into account, especially in mobile context. Mirror world applications can be slow and prone to poor operation if Internet connection is not fast and reliable. This is often the case in mobile phones. Because of this mirror world features in mobile navigation software should be secondary after a quick and reliable map. User should not be forced to use panoramas, and application should never load and display panoramas unless user clearly has selected to do so.

8.4 Validity and reliability

Reliability means that repeated measurements yield similar results (Carmines and Zeller 1979, p. 11). While the term reliability as a term is used for quantitative research, its' idea is used in all kinds of research (Golafshani 2003). Validity means that used methods actually measure what they are used to measure (Carmines and Zeller 1979, p. 12). Although reliability and validity are more important in quantitative research and studies in this thesis are of qualitative nature (even Internet questionnaire study is more qualitative than quantitative since the amount of participants was very low), both aspects are discussed here to assess how well used research methods succeeded.

On Internet questionnaire low amount of participants lowers reliability greatly. Also, participants mostly used City Scene in private settings and did not visit any supported city. This means that most participants never used City Scene for actual need. This lowers the reliability of results, especially usefulness evaluations.

Validity of results of the tourist study can be seen as good. Participants used City Scene in real context and moreover they had no set tasks nor observer present

distracting them. On the other hand lack of observer lowers reliability since results rely on what participants reported and these reports cannot be validated. Lack of set tasks makes use cases more authentic, but also makes some results less general, since not all participants do some things and meet same circumstances. It should be noted that while diaries were used to help participants remember events in the interview, they still had to recall past events. Reliance on participants memory lowers the reliability of results.

Technical issues with SIM cards did limit the use of City Scene on few occasions. Since this lowered the number of participants who could use City Scene without technical problems, reliability of the results is lower. Naturally, foreign SIM cards could not be tested in Finland so best that could be done was to try to solve each problem when a tourist reported it. Unfortunately, some problems could not be solved remotely.

The results of the tourist study cannot be generalized to a broader public since all participants were tourists. Also, number of participants was not particularly high and how well each participant could use City Scene varied greatly. Results would be more reliable if all participants would have visited same city and that city would have all City Scene's features available. However, conducting such study was not possible.

Questionnaire study's reliability and value was greatly reduced by very small number of participants. It was also evident that some participants had limited English skills, which raises the likelihood that they did not understand all the questions fully.

As mentioned earlier in results (chapter 7), tourists were given a presentation where several limitations of City Scene were mentioned. This had an effect on their first impressions but it is taken into account when analyzing results.

8.5 Comparing results with previous research

As mentioned earlier in chapter 3, section 3.2, Goodman et al. (2004) found that step-by-step instructions were better than map. In our study, some participants preferred map, and step-by-step instructions were mostly used for confirmation when having some difficulties. However, in our study the use of route function was often limited by technical difficulties. It is possible that route instructions would have been more popular if they would have functioned better. Use of panoramas for confirmation was also noticed in studies by Beeharee and Steed (2006), and Hile et al. (2008). Krüger et al. (Krüger et al. 2004) found out that using photographic step-by-step navigation provides survey information about surroundings poorly. This can also be a reason why map was preferred over panoramas in navigation, though connection of information on surroundings and navigation mode preference would

need more research to say for sure.

May et al. (May et al. 2003) studied what information people found to be useful in navigation instructions and found out that landmarks were used most. While landmark support in City Scene's navigation is still quite low, two participants mentioned using landmarks in other ways. Participant visiting Paris used Eiffel Tower and Notre Dame to know his hotel's location. Other participant mentioned using a statue similarly. Of those who did not use landmarks per se, some used buildings in panoramas to know direction and one mentioned named buildings in map mode to be helpful. This indicates that landmarks could have had more value if they were better supported in City Scene.

Overall the studies covered in chapter 3 showed that photographic information is useful addition but should not replace map. Results of this thesis support this. Panoramas were often useful but a map is irreplaceable. Especially since panoramas need more downloading than map, they should not be primary method of navigation in mobile applications that may suffer from poor Internet connection speeds.

8.6 Evaluation of methods

Vast majority of results was acquired from interviews. Interviews were very useful and yielded much usable results. Questionnaires on the other hand did not produce as much data as hoped. This was because high dropout rate left final number of participants very low. Exact reason of high dropout is unknown. It may be that there was too much time between each part of the questionnaire. Questionnaire on the whole or parts of it might also have been too laborious. One possibility is also that long English questionnaire is not very attractive for non-English participants.

Diaries varied greatly in usefulness. Some participants barely filled them at all, while some were more diligent. Results of diaries would have been limited on their own but they did generate discussion during interviews. It is unknown whether participants would have filled diaries more if it had been the only reporting method. Tomitsch et al. (2010) conducted a very similar diary study and found paper diaries to work well on mobile context. One reason for their better success with diaries might be difference in participants. Tomitsch et al. had participants use the evaluated device during normal daily activities. Our study had tourists on their trips. It might be that a tourist is less likely to interrupt his activities to fill out a diary, since tourist trips are for rest and relaxation, not work. Reminding participants more to fill the diary or offering a computer diary might have increased the number of entries.

8.7 Success and importance of the research

The most important research themes were the use of City Scene's navigation modes, and expectations of City Scene and navigation applications in general. Research succeeded in finding out which modes tourists preferred. Map mode was found to be the most used by tourists; panoramas were used mainly to help making decision and getting confirmation on location. Expectations of City Scene were found to be activity related. Tourists expected to seek places and plan details of visit. They did not mention any expectations concerning what features or functionalities they expect from navigation software in general. In hindsight, there should have been more focus on expectations on interviews.

There were several important findings on navigation that should be taken into account when developing new navigation applications. This research shows that navigation applications need support for quick and easy location finding in addition to more detailed routes. Some users prefer not to use navigation route features. However, panoramas are useful in confirmation and decision making needs. This means there is potential in utilizing panoramas in navigation, though this potential may not be fully tapped in yet. Practical recommendations for navigation applications are in conclusion chapter 9).

9. CONCLUSIONS

Most important finding in this research was that not all navigation application users need detailed routes. Some prefer to only check their location in relation to their goal and then find their own way. While in this kind of use, map mode is more useful than panoramic street view, panoramas have their use in confirmation and decision making. They help in unclear turns and final meters of navigation. Panoramas are also helpful in planning details of visit, for example is certain route walkable.

Nokia City Scene was found to have some technical problems and lacking some needed features. City Scene was occasionally slow and did not give adequate feedback on problems. GPS signal was often slow and inaccurate. Browsing for nearby locations was found to be troublesome, mainly due to inadequate search function. These findings can be formulated into practical recommendations for navigation applications.

9.1 Practical recommendations

First and foremost navigation application has to offer various levels of navigation support. For those who do not need route information, application has to provide fast and accurate GPS-location. Application should also have a simple pointer showing direction to target. Otherwise user might need to find the right direction through trial and error. In addition to quick location finding, route feature should be also available. It needs to be fast so it should default to map view and show panoramas only after user chooses to view them.

Since mirror world features such as panoramas can be slow on mobile applications, these features should always be optional. Application should never start to load panoramas unless user chooses to load them or loading can be done in background without interrupting applications other functions. Panoramas can be distracting to users if they are offered when user does not need them.

Navigation applications need to support browsing without a goal. This means that point-of-interest categories must be inclusive and clear. This means that categories should cover all possible points-of-interests but still be explicit. Categories with subcategories, for example category food with subcategories fast food, fine dining, etc. might be useful. Search function needs to have an option to search only certain categories and show results on map. There should also be an option to list

all points-of-interest nearby or in a city, and filter this list by selecting and excluding categories.

9.2 Future research suggestions

In this research some participants chose not to use route information in navigating. A lot of research is done concerning various ways of giving route information but there is considerably less research on navigating without a given route (some examples (Pielot et al. 2011), (Robinson et al. 2011)). Research on navigating with direction and distance information or with "you are here"-information and target location would be beneficial for developing better navigation applications.

Research on categorizing points-of-interest would also be useful. While more and better categories would be useful, it is unknown how specific categories should be and are subcategories needed. More specific categories leads to a larger number of categories which at some point might turn into too many categories. These are all things that need researching.

REFERENCES

Alben, L. 1996. Quality of experience: defining the criteria for effective interaction design. *interactions 3,* May/June 1996, 11–15.

All About UX. 2013a. All UX evaluation methods « All About UX. [WWW]. [accessed 1.3.2013]: `http://www.allaboutux.org/all-methods`.

All About UX. 2013b. User experience definitions « All About UX. [WWW]. [accessed 1.3.2013]: `http://www.allaboutux.org/ux-definitions`.

Allen, G. L. 1999. Spatial abilities, cognitive maps, and wayfinding: Bases for individual differences in spatial cognition and behavior. In *Wayfinding Behavior. Cognitive mapping and other spatial processes*, R. G. Golledge, Ed. The Johns Hopkins University Press, Baltimore, Maryland, 46–80.

Apple Inc. 2012. iPhone, iPad, and iPod touch (4th generation): Keeping device within acceptable operating temperatures. [WWW]. [accessed 28.8.2012]: `http://support.apple.com/kb/HT2101`.

Arth, C. and Schmalstieg, D. 2011. Challenges of Large-Scale Augmented Reality on Smartphones. In *ISMAR 2011 Workshop*. Basel, Switzerland, 1–4.

Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., and MacIntyre, B. 2001. Recent advances in augmented reality. *Computer Graphics and Applications 21,* 6, 34–47.

Azuma, R. T. 1997. A survey of augmented reality. *Presence-Teleoperators and Virtual Environments 6,* 4, 355–385.

Bargas-Avila, J. A. and Hornbæ k, K. 2011. Old Wine in New Bottles or Novel Challenges ? A Critical Analysis of Empirical Studies of User Experience. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, Vancouver, BC, Canada, 2689–2698.

Beeharee, A. K. and Steed, A. 2006. A natural wayfinding exploiting photos in pedestrian navigation systems. In *Proceedings of the 8th conference on Human-computer interaction with mobile devices and services*. ACM, Helsinki, Finland, 81–88.

Bertram, D. 2007. Likert Scales are the meaning of life. Tech. rep.

Carmigniani, J., Furht, B., Anisetti, M., Ceravolo, P., Damiani, E., and Ivkovic, M. 2010. Augmented reality technologies, systems and applications. *Multimedia Tools and Applications 51,* 1, 341–377.

Carmines, E. G. and Zeller, R. A. 1979. *Reliability and validity assessment.* Quantitative Applications in the Social Sciences. Sage Publications, Inc., Beverly Hills / London.

Chen, B., Neubert, B., Ofek, E., Deussen, O., and Cohen, M. F. 2009. Integrated videos and maps for driving directions. In *Proceedings of the 22nd annual ACM symposium on User interface software and technology - UIST '09.* ACM Press, Victoria, BC, Canada.

Consolvo, S. and Walker, M. 2003. Using the experience sampling method to evaluate ubicomp applications. *Pervasive Computing, IEEE 2,* 2, 24–31.

Daintith, J. and Wright, E. 2008. *A Dictionary of Computing.* Oxford University Press. [WWW]. [restricted, accessed 2.8.2012]: `http://www.oxfordreference.com/views/BOOK_SEARCH.html?subview=BookHomePage&book=t11`.

de Freitas, S. 2008. Serious virtual worlds: a scoping study. Tech. rep., SGI Serious Games Institute.

Dewey, J. 1929. *Experience And Nature.* George Allen And Unwin, Limited. [WWW]. [accessed 21.8.2012]: `http://archive.org/download/experienceandnat029343mbp/experienceandnat029343mbp.pdf`.

Falk, J. and Björk, S. 1999. The BubbleBadge: a wearable public display. In *CHI '99 extended abstracts on Human factors in computing systems.* ACM, Pittsburgh, Pennsylvania, 318–319.

Falk, J., Redström, J., and Björk, S. 1999. Amplifying reality. In *Handheld and ubiquitous computing*, H.-W. Gellersen, Ed. Lecture Notes in Computer Science. Springer Berlin / Heidelberg, 274–279.

Forlizzi, J. and Battarbee, K. 2004. Understanding experience in interactive systems. In *Proceedings of the 2004 conference on Designing interactive systems processes, practices, methods, and techniques - DIS '04.* ACM, Cambridge, Massachusetts, USA, 261–268.

Golafshani, N. 2003. Understanding Reliability and Validity in Qualitative Research. Tech. Rep. 4, University of Toronto.

Golledge, R. D. 1999. Human wayfingding and cognitive maps. In *Wayfinding Behavior. Cognitive mapping and other spatial processes*, R. G. Golledge, Ed. The Johns Hopkins University Press, Baltimore, Maryland, 5–45.

Goodman, J., Gray, P., Khammampad, K., and Brewster, S. 2004. Using Landmarks to Support Older People in Navigation. In *Mobile Human-Computer Interaction - MobileHCI 2004*, S. Brewster and M. Dunlop, Eds. Lecture Notes in Computer Science. Springer Berlin / Heidelberg, 37–57.

Google. 2012a. Google Earth. [WWW]. [accessed 25.10.2012]: `http://www.google.com/earth/index.html`.

Google. 2012b. Google Maps. [WWW]. [accessed 16.8.2012]: `https://maps.google.com/`.

Google. 2012c. Google Maps Navigation for mobile. [WWW]. [accessed 16.8.2012]: `http://www.google.com/mobile/navigation/`.

Google. 2012d. Panoramio - Photos of the World. [WWW]. [accessed 16.8.2012]: `http://www.panoramio.com/`.

Google. 2012e. Start here. - Google Maps. [WWW]. [accessed 16.8.2012]: `http://maps.google.com/help/maps/starthere/index.html`.

Gärling, T. 1999. Human information processing in sequential spatial choice. In *Wayfinding Behavior. Cognitive mapping and other spatial processes*, R. G. Golledge, Ed. The Johns Hopkins University Press, Baltimore, Maryland, 81–98.

Hassenzahl, M. 2003. The Thing and I: Understanding the Relationsip Between User and Product. In *Funology*, M. Blythe, K. Overbeeke, A. Monk, and P. Wright, Eds. Human-Computer Interaction Series. Springer Netherlands, Chapter 3, 31–42.

Hassenzahl, M. 2008. User experience (UX): towards an experiential perspective on product quality. In *Proceedings of the 20th International Conference of the Association Francophone d'Interaction Homme-Machine*. ACM, Metz, France, 11–15.

Hassenzahl, M. and Tractinsky, N. 2006. User experienceÂ -Â a research agenda. *Behaviour & Information Technology 25,* 2, 91–97.

Hermann, F., Bieber, G., and Duesterhoeft, A. 2003. Egocentric maps on mobile devices. In *Proceedings of the 4th International Workshop on Mobile Computing*, G. Bieber and T. Kirste, Eds. IRB Verlag, Stuttgart, 32–37.

Hile, H., Vedantham, R., Cuellar, G., Liu, A., Gelfand, N., Grzeszczuk, R., and Borriello, G. 2008. Landmark-based pedestrian navigation from collections of geotagged photos. In *Proceedings of the 7th International Conference on Mobile and Ubiquitous Multimedia*. ACM, Umeå, Sweden, 145–152.

Hunt, E. and Waller, D. 1999. Orientation and wayfinding: A review. Tech. rep., University of Washington.

Hurst, W. and Bilyalov, T. 2010. Dynamic versus static peephole navigation of VR panoramas on handheld devices. In *Proceedings of the 9th International Conference on Mobile and Ubiquitous Multimedia*. ACM, Limassol, Cyprus.

International Organization for Standardization. 1998. ISO 9241-11:1998(E) Ergonomic requirements for office work with visual display terminals (VDTs) Part 11: Guidance on usability.

International Organization for Standardization. 2010. ISO 9241-210:2010(E) Ergonomics of human-system interaction Part 210: Human-centred design for interactive systems.

Jääskeläinen, O. 2012. Sub-Zero Weather: Can Your Smartphone Stand The Cold? | PCWorld. [WWW]. [accessed 28.8.2012]: `http://www.pcworld.com/article/249134/subzero_weather_can_your_smartphone_stand_the_cold.html`.

Jumisko-Pyykkö, S. and Vainio, T. 2010. Framing the Context of Use for Mobile HCI. *International Journal of Mobile Human Computer Interaction 2,* 4, 1–28.

Kanade, T., Narayanan, P., and Rander, P. W. 1995. Virtualized reality: Concepts and early results. In *Representation of Visual Scenes*. IEEE Comput. Soc. Press, 69–76.

Kim, H., Kim, J., and Lee, Y. 2005. An Empirical Study of Use Contexts in the Mobile Internet, Focusing on the Usability of Information Architecture. *Information Systems Frontiers 7,* 2, 175–186.

Kimchi, T., Etienne, A. S., and Terkel, J. 2004. A subterranean mammal uses the magnetic compass for path integration. *Proceedings of the National Academy of Sciences of the United States of America 101,* 4, 1105–9.

Kray, C., Elting, C., Laakso, K., and Coors, V. 2003. Presenting route instructions on mobile devices. In *Proceedings of the 8th international conference on Intelligent user interfaces - IUI '03*. ACM Press, Miami, Florida, USA, 117–124.

Krüger, A., Aslan, I., and Zimmer, H. 2004. The Effects of Mobile Pedestrian Navigation Systems on the Concurrent Acquisition of Route and Survey Knowledge. In *Mobile Human-Computer Interaction - MobileHCI 2004*, S. Brewster and M. Dunlop, Eds. Lecture Notes in Computer Science. Springer Berlin / Heidelberg, 446–450.

Kurosu, M. and Kashimura, K. 1995. Apparent usability vs. inherent usability: experimental analysis on the determinants of the apparent usability. In *Conference companion on Human factors in computing systems*. ACM, Denver, Colorado, USA, 1–2.

Lavie, T., Oron-Gilad, T., and Meyer, J. 2011. Aesthetics and usability of in-vehicle navigation displays. *International Journal of Human-Computer Studies 69,* 1-2, 80–99.

Lefebvre, E. 2011. 'Quality concerns' keep user-created content out of World of Warcraft | Massively. [WWW]. [accessed 29.10.2012]: `http://massively.joystiq.com/2011/10/11/quality-concerns-keep-user-created-content-out-of-world-of-war/`.

Lepetit, V. and Berger, M.-O. 2001. An Intuitive Tool For Outlining Objects in Video Sequences : Applications To Augmented And Diminished Reality. In *Second International Symposium on Mixed Reality*. Yokohama, Japan, 1–2.

Loomis, J. M., Klatzky, R. L., Golledge, R. G., and Philbeck, J. W. 1999. Human navigation by path integration. In *Wayfinding Behavior. Cognitive mapping and other spatial processes*, R. G. Golledge, Ed. The Johns Hopkins University Press, Baltimore, Maryland, 125–151.

Mann, S. 1994. Mediated reality.

May, A. J., Ross, T., Bayer, S. H., and Tarkiainen, M. J. 2003. Pedestrian navigation aids: information requirements and design implications. *Personal and Ubiquitous Computing 7,* 6, 331–338.

Medenica, Z., Kun, A., Paek, T., and Palinko, O. 2011. Augmented reality vs. street views: a driving simulator study comparing two emerging navigation aids. In *Proceedings of the 13th International Conference on Human Computer Interaction with Mobile Devices and Services*. ACM, Stockholm, Sweden, 265–274.

Merriam-Webster. 2012. Dictionary and thesaurus - merriam-webster online. [WWW]. [accessed 30.10.2012]: `http://www.merriam-webster.com/`.

Milgram, P. and Kishino, F. 1994. A taxonomy of mixed reality virtual displays. *IECE Transactions on Information Systems E77-D,* 12, 1–15.

Müller, M. and Wehner, R. 1988. Path integration in desert ants, Cataglyphis fortis. *Proceedings of the National Academy of Sciences 85,* 14, 5287–5290.

Murphy, D. J., Vaittinen, T., and Mattila, V.-V. 2011. Mirror Worlds as Large-Scale Outdoor Mixed Reality Enablers. In *ISMAR 2011 Workshop*. Basel, Switzerland, 1–4.

Nielsen, J. 1995a. 10 Usability Heuristics. [WWW]. [accessed 22.2.2013]: `http://www.nngroup.com/articles/ten-usability-heuristics/`.

Nielsen, J. 1995b. How to Conduct a Heuristic Evaluation. [WWW]. [accessed 22.2.2013]: `http://www.nngroup.com/articles/how-to-conduct-a-heuristic-evaluation/`.

Nielsen, J. 1995c. Severity Ratings for Usability Problems. [WWW]. [accessed 6.2.2013]: `http://www.nngroup.com/articles/how-to-rate-the-severity-of-usability-problems/`.

Nielsen, J. 2003. Usability 101: Definition and Fundamentals - What, Why, How (Jakob Nielsen's Alertbox). [WWW]. [accessed 27.8.2012]: `http://www.useit.com/alertbox/20030825.html`.

Nielsen Norman Group. 2011. User Experience: Our Definition. [WWW]. [accessed 30.10.2012]: `http://www.nngroup.com/about/userexperience.html`.

Olsson, T. 2012. *User Expectations and Experiences of Mobile Augmented Reality Services*. Tampere University of Technology.

Oulasvirta, A., Estlander, S., and Nurminen, A. 2008. Embodied interaction with a 3D versus 2D mobile map. *Personal and Ubiquitous Computing 13,* 4, 303–320.

Partala, T., Nurminen, A., Vainio, T., Laaksonen, J., Laine, M., and Väänänen, J. 2010. Salience of visual cues in 3D city maps. In *Proceedings of the 24th BSC Interaction Specialist Group Conference*. British Computer Society, Swinton, UK, 428–432.

Partala, T. and Salminen, M. 2012. User Experience of Photorealistic Urban Pedestrian Navigation. In *International Working Conference on Advanced Visual Interfaces*. ACM, Capri Island, Italy, 204–207.

Pielot, M., Poppinga, B., Heuten, W., and Boll, S. 2011. A Tactile Compass for Eyes-Free Pedestrian Navigation. In *Human-Computer Interaction - INTERACT 2011*, P. Campos, N. Graham, J. Jorge, N. Nunes, P. Palanque, and M. Winckler, Eds. Springer Berlin Heidelberg, 640–656.

Pressl, B. and Wieser, M. 2006. A computer-based navigation system tailored to the needs of blind people. In *Computers Helping People with Special Needs*, K. Miessenberger, J. Klaus, W. Zagler, and A. Karshmer, Eds. Lecture Notes in Computer Science. Springer Berlin / Heidelberg, 1280–1286.

Quinones, P. and Greene, T. 2011. Supporting visually impaired navigation: a needs-finding study. In *Proceedings of the 2011 annual conference extended abstracts on Human factors in computing systems*. ACM, Vancouver, BC, Canada, 1645–1650.

Robinson, S., Jones, M., Williamson, J., Murray-Smith, R., Eslambolchilar, P., and Lindborg, M. 2011. Navigation your way: from spontaneous independent exploration to dynamic social journeys. *Personal and Ubiquitous Computing 16,* 8, 973–985.

Roto, V., Law, E., Vermeeren, A., and Hoonhout, J. (eds). 2011. User experience white paper. [WWW]. [accessed 20.8.2012]: `http://www.allaboutux.org/files/UX-WhitePaper.pdf`.

Schnabel, M. A., Wang, X., Seichter, H., and Kvan, T. 2007. From virtuality to reality and back. In *Proceedings of the International Association of Societies of Design Research*. 1–15.

Seager, W. and Fraser, D. S. 2007. Comparing physical, automatic and manual map rotation for pedestrian navigation. In *Proceedings of the SIGCHI conference on Human factors in computing systems - CHI '07*. ACM Press, San Jose, Califonia, USA, 767–776.

Smart, J., Cascio, J., and Paffendorf, J. 2012. Metaverse Roadmap - Pathways to the 3D Web - A Cross-Industry Public foresight Project. [PDF]. [accessed 16.10.2012]: `http://metaverseroadmap.org/MetaverseRoadmapOverview.pdf`.

Stern, E. and Portugali, J. 1999. Environmental cognition and decision making in urban navigation. In *Wayfinding Behavior. Cognitive mapping and other spatial processes*, R. G. Golledge, Ed. The Johns Hopkins University Press, Baltimore, Maryland, 46–80.

Stevenson, A. 2010. *Oxford Dictionary of English.* Oxford University Press. [WWW]. [restricted, accessed 30.10.2012]: `http://www.oxfordreference.com/view/10.1093/acref/9780199571123.001.0001/acref-9780199571123`.

TIVIT Oy. 2013. Tieto- ja viestintäteollisuuden tutkimus TIVIT Oy | TIVIT. [WWW]. [accessed 22.3.2013]: `http://www.tivit.fi/`.

Tomitsch, M., Singh, N., and Javadian, G. 2010. Using diaries for evaluating interactive products: the relevance of form and context. In *Proceedings of the 22nd Conference of the Computer-Human Interaction Special Interest series.* ACM, Brisbane, Australia, 204–207.

Törnros, J. E. B. and Bolling, A. K. 2005. Mobile phone use-effects of handheld and handsfree phones on driving performance. *Accident; analysis and prevention 37,* 5, 902–9.

Tractinsky, N. 1997. Aesthetics and apparent usability: empirically assessing cultural and methodological issues. In *Proceedings of the SIGCHI conference on Human factors in computing systems.* ACM, Atlanta, Georgia, United States, 115–122.

Tractinsky, N., Katz, A., and Ikar, D. 2000. What is beautiful is usable. *Interacting with computers 13,* 2, 127–145.

Usability Professionals Association. 2010. Usability glossary | usability body of knowledge. [WWW]. [accessed 22.8.2012]: `http://www.usabilitybok.org/glossary/`.

Vermeeren, A. P. O. S., Law, E. L.-C., Roto, V., Obrist, M., Hoonhout, J., and Väänänen-Vainio-Mattila, K. 2010. User experience evaluation methods: current state and development needs. In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries.* ACM, Reykjavik, Iceland, 521–530.

Wehner, R. 2003. Desert ant navigation: how miniature brains solve complex tasks. *Journal of comparative physiology. A, Neuroethology, sensory, neural, and behavioral physiology 189,* 8, 579–88.

Wither, J., Tsai, Y.-T., and Azuma, R. 2011. Indirect augmented reality. *Computers & Graphics 35,* 4, 810–822.

Wright, P., McCarthy, J., and Meekison, L. 2005. Making sense of experience. In *Funology*, M. Blythe, K. Overbeeke, A. Monk, and P. Wright, Eds. Human-Computer Interaction Series, vol. 3. Springer Netherlands, 43–53.

APPENDIX A: QUESTIONNAIRES

Questions of the questionnaires are in this appendix. If questionnaire was in Finnish as background questionnaire for tourists was, questions are translated into English. Introductions are omitted. Type of question (e.g. scale or text field) is indicated in parentheses after the question.

A.1 Nokia City Scene First Impressions

1. Thinking of the first few days of using City Scene, how positive did you feel about the experience? (scale: 1 not positive at all – 10 very positive)
2. Please elaborate the reasons behind your rating. Why was it positive or why not? (text field)
3. How did your experience correspond with the expectations that you had before actually using City Scene? (text field)
4. Why were you initially interested in installing City Scene? (text field)
5. I am... (radio button: Still using the application — Not using it anymore)
6. I have used the latest City Scene (released July 31) on N9 (radio button: Several times — One or two times — I haven't yet used latest City Scene)
7. I have used a previous version of City Scene on N9 (radio button: Regularly — Several times — One or two times — I haven't used a previous version of City Scene)
8. Please indicate how often you approximately use the following applications, services or technologies. (scales: Haven't used — I've just tried it — Occasionally — Monthly — Weekly — Daily — Several times a day — Hard to say)
    - Google Maps
    - Google Street View
    - Google Earth
    - Nokia Maps
    - Other digital maps
    - In-car navigators
    - Handheld GPS

- Paper maps
- Other navigation tools

9. If you have used other navigation tools, what were they? (text field)
10. Please indicate how often you approximately use the following applications, services or technologies. (scales: Haven't used — I've just tried it — Occasionally — Monthly — Weekly — Daily — Several times a day — Hard to say)
    - Facebook
    - Foursquare
    - Augmented Reality applications such as Layar, Wikitude, Junaio or Google Goggles
    - Virtual models of museums or other real-world places
    - Other location-based services
11. If you have used other location-based services, what were they? (text field)
12. Country you live in (list)
13. During these first days of using City Scene I have lived or visited (check boxes)
    - Paris, France
    - London, UK
    - Atlanta, US
    - Chicago, US
    - Dallas, US
    - Denver, US
    - Detroit, US
    - Fort Lauderdale, US
    - Las Vegas, US
    - Los Angeles, US
    - Louisville, US
    - Miami, US
    - Minneapolis, US
    - New York, US

- Newark-Jersey City, US
- Orlando, US
- Philadelphia, US
- Portland, US
- San Antonio, US
- San Francisco, US
- San Jose, US
- Seattle, US
- I have not visited any of the cities above

14. During these first days of use I have browsed City Scene content (panorama images, businesses etc.) from (check boxes)

    - Paris, France
    - London, UK
    - Atlanta, US
    - Chicago, US
    - Dallas, US
    - Denver, US
    - Detroit, US
    - Fort Lauderdale, US
    - Las Vegas, US
    - Los Angeles, US
    - Louisville, US
    - Miami, US
    - Minneapolis, US
    - New York, US
    - Newark-Jersey City, US
    - Orlando, US
    - Philadelphia, US
    - Portland, US
    - San Antonio, US
    - San Francisco, US

- San Jose, US
- Seattle, US
- I have not visited any of the cities above

15. Gender (radio button: Male — Female)
16. Your age (text field)
17. Please select the option that best describes your opinion (scale: -3 Strongly DISAGREE – 0: Neither agree nor disagree – +3: Strongly AGREE — Hard to say)

    - I consider myself as skilled user of information technology
    - I am interested in obtaining and using the newest technology and services
    - I am often asked for help or advice in IT related tasks
    - I'm using several different mobile services (e.g. navigation, Internet, social online services, multimedia)
    - I browse content created by other people (e.g. photo galleries, discussion forums, blogs) without having a special purpose or goal in mind
    - I think that technology makes my life enjoyble
    - I consider myself as skilled map user
    - I create and share content publicly in the Internet, for example in blogs, YouTube, Wikipedia, Flickr, or MySpace
    - I take part in online discussions (e.g. discussion forums, commenting news articles)
    - I have a hobby that relates to use of maps (e.g. orienteering, geocaching)

A.2 Nokia City Scene Final Questionnaire

1. How often have you used City Scene in different places since installing the latest version? (scale: Never — Once or twice — Sometimes — Frequently — Daily — Several times a day)

   - At home
   - At workplace
   - In public transport
   - Outdoor public place (e.g. plaza, park)
   - Indoor public place (e.g. shop, restaurant, library)
   - In a car (as passenger)

2. How often have you used City Scene for the following activities since installing it? (scale: Never — Once or twice — Sometimes — Frequently — Daily — Several times a day)

   - Viewing and exploring panoramas near you
   - Viewing and exploring panoramas elsewhere
   - Navigation from a place to another
   - Looking for information about businesses and services near you
   - Looking for information about businesses and services elsewhere
   - Planning or learning a route before taking it
   - Preplanning details of a visit: entrance to a building, parking space etc. (but not routes)
   - Showing places to another person next to you
   - Showing places to a person remotely (City Scene postcards via e.g. email)
   - Reminiscing about past trips and events

3. How useful do you think City Scene was in these activities? (scale: 1: Useless — 7: Very useful — Hard to say)

   - Viewing and exploring panoramas near you
   - Viewing and exploring panoramas elsewhere
   - Navigation from a place to another
   - Looking for information about businesses and services near you
   - Looking for information about businesses and services elsewhere

- Planning or learning a route before taking it
- Preplanning details of a visit: entrance to a building, parking space etc. (but not routes)
- Showing places to another person next to you
- Showing places to a person remotely (City Scene postcards via e.g. email)
- Reminiscing about past trips and events

4. Are there any other activities you have used City Scene for? What are they? (text field)

5. Of those cases when you used City Scene for navigating from a place to another, how much did you use each of the three navigation modes? (scale: I never used it — I only tried it — I used it a few times — I used it frequently — I used it daily — Hard to say)

   - Map
   - Timeline
   - Panorama

6. Please select the navigation mode you prefer on the following activities. (radio buttons: Map — Panorama — Timeline — A combination of several — Hard to say)

   - Short (e.g. less than 500m) navigation from one point to another
   - Long (e.g. over 1km) navigation from one point to another
   - While walking
   - While cycling
   - As a passenger in a car
   - Learning a route beforehand

7. Were there situations where City Scene could not help you in navigation? Please shortly describe the situation(s) and why City Scene failed to help you. (text field)

8. What do you regard as the main strength(s) of City Scene? (text field)

9. What do you regard as the main weakness(es) of City Scene? (text field)

10. Please state your opinion with the following statements. (scale: -3 Strongly DISAGREE – 0: Neither agree nor disagree – +3: Strongly AGREE — Hard to say)

- ... with City Scene I am able to acquire and utilize information that has been hard to access before
- ... with City Scene I can efficiently make decisions in my everyday activities
- ... the content I access and use with City Scene is up-to-date and reliable
- ... the content of City Scene makes sense in the context I use it
- ... City Scene expands my understanding of already familiar places or objects
- ... it is easy to distinguish between the real world and the augmented content of City Scene
- ... with City Scene I can find positively surprising information
- ... City Scene provides me with something new and interesting
- ... the interaction with City Scene captivates my attention in a positive way
- ... using City Scene encourages my imagination

11. Please state your level of agreement/disagreement with the following statements (scale: -3 Strongly DISAGREE – 0: Neither agree nor disagree – +3: Strongly AGREE — Hard to say)

    - I will frequently use City Scene in the future
    - I will strongly recommend others to use City Scene
    - I think City Scene is a finished product
    - I think City Scene is innovative
    - I think it is worth to use City Scene
    - Learning to operate City Scene was easy for me
    - City Scene functions as expected
    - I would buy City Scene if it wasn't free

12. If you have come up with ideas for additional features or functionalities that City Scene could have, feel free to write them here. (text field)

13. During these first weeks of using City Scene I have lived or visited (check boxes)

    - Paris, France
    - London, UK

- Atlanta, US
- Chicago, US
- Dallas, US
- Denver, US
- Detroit, US
- Fort Lauderdale, US
- Las Vegas, US
- Los Angeles, US
- Louisville, US
- Miami, US
- Minneapolis, US
- New York, US
- Newark-Jersey City, US
- Orlando, US
- Philadelphia, US
- Portland, US
- San Antonio, US
- San Francisco, US
- San Jose, US
- Seattle, US
- I have not visited any of the cities above

14. During these first weeks of use I have browsed City Scene content (panorama images, businesses etc.) from (check boxes)

    - Paris, France
    - London, UK
    - Atlanta, US
    - Chicago, US
    - Dallas, US
    - Denver, US
    - Detroit, US
    - Fort Lauderdale, US

- Las Vegas, US
- Los Angeles, US
- Louisville, US
- Miami, US
- Minneapolis, US
- New York, US
- Newark-Jersey City, US
- Orlando, US
- Philadelphia, US
- Portland, US
- San Antonio, US
- San Francisco, US
- San Jose, US
- Seattle, US
- I have not visited any of the cities above

15. Name (text field)
16. E-mail (text field)

A.3 Background questionnaire for tourists

- Date (text field)
- Name (text field)
- Please indicate how often you approximately use the following applications, services or technologies. (scales: Haven't used — I've just tried it — Occasionally — Monthly — Weekly — Daily — Several times a day — Hard to say)
  - Google Maps
  - Google Street View
  - Google Earth
  - Nokia Maps
  - Other digital maps
  - In-car navigators
  - Handheld GPS
  - Paper maps
  - Other navigation tools
- If you have used other navigation tools, what were they? (text field)
- Please indicate how often you approximately use the following applications, services or technologies. (scales: Haven't used — I've just tried it — Occasionally — Monthly — Weekly — Daily — Several times a day — Hard to say)
  - Facebook
  - Foursquare
  - Augmented Reality applications such as Layar, Wikitude, Junaio or Google Goggles
  - Virtual models of museums or other real-world places
  - Other location-based services
- If you have used other location-based services, what were they? (text field)
- Please select the option that best describes your opinion (scale: -3 Strongly DISAGREE – 0: Neither agree nor disagree – +3: Strongly AGREE — Hard to say)

- I consider myself as skilled user of information technology
- I am interested in obtaining and using the newest technology and services
- I am often asked for help or advice in IT related tasks
- I'm using several different mobile services (e.g. navigation, Internet, social online services, multimedia)
- I browse content created by other people (e.g. photo galleries, discussion forums, blogs) without having a special purpose or goal in mind
- I think that technology makes my life enjoyble
- I consider myself as skilled map user
- I create and share content publicly in the Internet, for example in blogs, YouTube, Wikipedia, Flickr, or MySpace
- I take part in online discussions (e.g. discussion forums, commenting news articles)
- I have a hobby that relates to use of maps (e.g. orienteering, geocaching)

APPENDIX B: DIARY

Introduction is omitted. Diary was originally in Finnish.

Daily summary of the application's use

- Date (text field)
- Time (text field)
- Duration (text field)
- Description of use (text field)

Three pages with three description slots on each page.

Longer use cases and particularly memorable experiences

- Date and time (text field)
- Duration (text field)
- Situation was (selection box: longer use case — other particularly memorable experience while using the application)
- Briefly describe for example following (text field)
    - On what purpose you used the application? In what kind of situation?
    - What features of the application did you use?
    - What was the experience like? Were you satisfied, did something disappoint you, or did you experience something very interesting?
    - What aspects of the application or surroundings affected your experience?
- Describe your experience with three adjectives (text field)
- How did the situation start or how did you decide to use the application?
- Location (if you moved from place to another, tell both origin and destination)(text field)
- In described situation
    - Other people affected my experience (scale: 1 not at all — 7 very much)
    - I was in a hurry (scale: 1 not at all — 7 very much)
    - Task, which I was doing was (scale: 1 insignificant — 7 very important)

    - Technical problems affected my experience (scale: 1 not at all — 7 very much)

- Do you have in mind a feature that you would have needed in the situation? Should some feature function differently? Please describe also all technical difficulties you encountered. (text field)

Three double pages for longer descriptions.

Ideas and needs for further development

- You can freely describe problems you encountered, ideas for further development and needs you would want the application to support. (16 text fields)

Suggestions for getting familiar with the application

Next tasks are meant to familiarize you with the use of Nokia City Scene. Performing these tasks is absolutely *voluntary*. You can try these e.g. if you want to recall how some feature worked or if you notice that you haven't used the application for several days. Please also remember to enjoy your trip; you don't have to use City Scene all the time, even though you're participating in research.

Before trip or e.g. in the hotel:

- Find a bank and go into street view near it. Navigate to some hotel that is at least 200m away using map view.
- Navigate from the hotel you searched in last task to closest theater using street view.
- Try navigating with landmark pictures. Seek a navigation route that is at leas one kilometer long and go into landmark pictures by pressing route line on the upper edge of the screen. (if your destination does not support this feature, try it in e.g. San Francisco)
- Find your hotel and add it into favorites. Alternatively, seek an easily recognizable landmark (e.g. sight) and add it into favorites.

During your trip, outside:

- View buildings around you in City Scene and check what interesting services they have.
- Seek a café or restaurant under 1km away. Navigate to it using one of application's navigation modes.

- Read reviews of the café or restaurant you searched. If reviews are not available seek another café or restaurant with reviews.
- If you find an interesting location, seek it in City Scene and add it to favorites.
- Browse the street view on your current location. Try to find differences in picture and actual location.