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DESIGN IMPLICATIONS FOR MOBILE USER INTERFACES OF INTERNET SERVICES

Doctoral Dissertation

Elina Vartiainen

Helsinki University of Technology
Faculty of Information and Natural Sciences
Department of Media Technology

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Doctoral Dissertation

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Dissertation for the degree of Doctor of Science in Technology to be presented with due permission of the Faculty of Information and Natural Sciences for public examination and debate in Auditorium T2 at Helsinki University of Technology (Espoo, Finland) on the 20th of November, 2009, at 12 noon.

Helsinki University of Technology
Faculty of Information and Natural Sciences
Department of Media Technology

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Opponent(s)	Professor Albrecht Schmidt and Professor Kaisa Väänänen-Vainio-Mattila
Supervisor	Professor Petri Vuorimaa

Abstract

Internet services are becoming essential in people's daily lives. In addition to accessing them on a PC, Internet services offer functionality and content that are also relevant for mobile use. At the same time, mobile devices of today are technologically sophisticated enabling online access anytime, anywhere. The remaining challenge is to utilize the capabilities of a mobile device in a way that offers people a positive user experience when they are using Internet services on the go.

This Thesis belongs to the area of Human-Computer Interaction focusing on the use of Internet services on a mobile device. It considers the limitations of a mobile device in terms of user interface design and its goal is to define design implications that assist in designing mobile user interfaces for Internet services. The design implications mainly aim to give guidance on how to design a mobile Web browser, but they are completed with research findings on designing a mobile client application for an Internet service.

The research was implemented through user needs studies, user interface design, and user evaluations. The research studies focused on two approaches that support the use of Internet services on mobile devices: the Minimap Web browser and the Image Exchange mobile client application presented these two approaches.

The resulting design implications suggest that the following aspects should be considered when designing mobile user interfaces for Internet services: content optimization, utilization of desktop and mobile usage patterns, full exploitation of device capabilities, compensation for device resources, and content updating. The possible differences in characteristics of a mobile Web browser and a mobile client application are also examined. Finally, this Thesis discusses the latest developments that enable alternative ways to support Internet services on mobile devices in the future.

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Vastaväittäjä(t)	Professori Albrecht Schmidt ja Professori Kaisa Väänänen-Vainio-Mattila
Työn valvoja	Professori Petri Vuorimaa

Tiivistelmä

Internet-palveluista on muodostunut olennainen osa ihmisten päivittäistä elämää. Siksi on tärkeää, että palveluiden tarjoamaa sisältöä sekä toiminnallisuutta pääsee tietokoneen lisäksi käyttämään myös kännykällä. Kännykkälaitteet mahdollistavatkin tänä päivänä yhteyden verkkoon milloin ja missä tahansa. Internet-palvelujen kännykkäkäytön haasteena on kuitenkin se, miten hyödyntää kännyköiden teknisiä ominaisuuksia ja samalla tarjota käyttäjälle positiivinen käyttökokemus.

Tämä väitöskirja kuuluu ihmisen ja tietokoneen välistä vuorovaikutusta tutkivaan tieteenalaan, ja se tarkastelee Internet-palvelujen käyttöä kännykällä. Väitöskirjassa käydään läpi kännykän asettamia rajoituksia käyttöliittymille ja pyritään määrittelemään suunnittelusuositukset, jotka auttavat suunnittelemaan kännykkäkäyttöliittymiä Internet-palveluille. Suunnittelusuositukset koskevat pääasiassa kännykän verkkoselaimen suunnittelua, mutta niitä on täydennetty tutkimustuloksilla siitä, mitä tulisi ottaa huomioon suunniteltaessa erillissovelluksia Internet-palveluja varten.

Tutkimus toteutettiin käyttäjien tarvetutkimusten, käyttöliittymäsuunnittelun sekä käyttäjäevaluointien avulla. Minimap-verkkoselain ja Image Exchange -erillissovellus edustivat kahta mahdollista lähestymistapaa, joilla tuetaan Internet-palveluja kännykällä.

Tuloksena saatujen suunnittelusuosituksien mukaan seuraavat näkökannat tulisi ottaa huomioon Internet-palvelujen käyttöliittymäsuunnittelussa: sisällön optimointi, tietokoneen ja kännykän käyttötavat, kännykän kykyjen laaja hyödyntäminen, kännykän resurssien kompensointi sekä sisällön päivitys. Tämän lisäksi väitöskirja käy läpi verkkoselaimen ja erillissovelluksen piirteiden mahdollisia eroja. Lopuksi väitöskirjassa käsitellään uusia kehityssuuntia, jotka tarjoavat vaihtoehtoisia tapoja tukea Internet-palveluja kännykällä tulevaisuudessa.

Asiasanat	Kännykkäkäyttöliittymät, käyttökokemus, Internet-palvelut, Web-selailu
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Preface

This Thesis is the result of the research work that I have conducted while working at the Nokia Research Center between 2004 and 2009. My background is in computer science with a special interest in user interface design and user research. When I joined Nokia in 2004, I was fortunate to participate in the project developing the Minimap Web browser. I stayed with the project for over 2 years and learned a lot about the Web, user research, and user experience. In 2007, I moved to the Internet Consumer Services team and participated in developing the Image Exchange service. I gained invaluable knowledge about Internet services and was able to continue user research in that context. During the years, I was able to take study leave and concentrate on the Thesis with the help of two Nokia Foundation scholarships.

First, I would like to thank my professor, Petri Vuorimaa, who supported my studies already during my Master's degree. Preparing a doctoral thesis in an industry environment can be a lonely journey, but Petri encouraged and assured me that it is possible. Furthermore, I was honored to have Professor Kaisa Väänänen-Vainio-Mattila and Doctor Eija Kaasinen as the pre-examiners of my Thesis. Their insightful and constructive comments helped in finding the scope of my research and gave me a valuable lesson on argumentation.

I have been lucky to work with many talented people at Nokia. Guido Grassel hired me to Nokia to the Minimap browser team and was also the team leader. He encouraged me to develop my skills and fully supported my doctoral studies, and I owe him an acknowledgment for it. Virpi Roto, who was the user experience expert in the project, has been my teacher in conducting research and preparing a doctoral thesis. She has definitely been the biggest help along the way and I truly appreciate it. In the Minimap project, I was also honored to work with Andrei Popescu, Antti Koivisto, Mika Rautava, Salla Myllylä, and Janne Kaasalainen. Great memories,

cheers for that! I am really happy that we have continued to keep in touch even though the work has taken us on different directions.

Tuomas Tammi has been my second team leader at Nokia during the Image Exchange project. He has always trusted in my judgment and also in the completion of this Thesis even though I had my doubts sometimes. Thanks Tuomas, it has been a pleasure to work in your team! Janne Kaasalainen continued working with me in the Image Exchange project and has been together with my more recent colleague Toni Strandell a valuable colleague and friend. I truly appreciate your (tele-) presence! I am also thankful to the project manager Timo Pakkala and members Carlos Quiroz, Oleksandr Kononenko, Davin Wong, and Hannu Mettälä for letting me share the experience of developing a great Internet service with you and follow its journey in the real world. I also want to thank James Reilly, Mikko Honkala, and Kari Pihkala for the guidance on my post-graduate studies.

I am grateful to my lovely friends, I cannot stress your importance enough. Especially, I want to thank all of my friends preparing their doctoral theses for the peer-support. As said, conducting research can be quite lonesome and feel even hopeless sometimes, but talking about it with your dear friends is the best support you can have.

Lastly, I want thank my family (especially my little sis, Paula) for their love and support throughout the years of studying. I am not sure if my parents meant 23 years of studying when they stressed the importance of a degree but still they have always been there for me. I would also like thank Olle for his love and care, and for making me laugh.

Helsinki, 10th of September, 2009

Elina Vartiainen

Contents

List of publications

This Thesis summarizes the following publications, referred to as [P1]-[P6]:

[**P1**] Virpi Roto, Andrei Popescu, Antti Koivisto, and Elina Vartiainen. 2006. Minimap: a web page visualization method for mobile phones. In Proceedings of Human Factors in Computing Systems conference (CHI), pages 35-44, Montreal, Canada.

[**P2**] Elina Vartiainen, Virpi Roto, and Andrei Popescu. 2007. Auto-update: A concept for automatic downloading of Web content to a mobile device. In Proceedings of the 4th international conference on mobile technology, applications, and systems and the 1st international symposium on Computer human interaction in mobile technology, pages 683-689, Singapore.

[**P3**] Elina Vartiainen, Virpi Roto, and Janne Kaasalainen. 2008. Graphical History List with Multi-Window Support on a Mobile Web Browser. In Proceedings of the Third International Conference on Internet and Web Applications and Services (ICIW'08), pages 121-129, Athens, Greece.

[**P4**] Elina Vartiainen, Janne Kaasalainen, and Toni Strandell. 2008. Designing user experience for a mobile imaging application. In Proceedings of IADIS International Conference Interfaces and Human Computer Interaction, pages 197-204, Amsterdam, Netherlands.

[**P5**] Elina Vartiainen, Toni Strandell, and Janne Kaasalainen. 2008. Fully service-integrated mobile application for photo-sharing. In Proceedings of The 12th IASTED International Conference on Internet and Multimedia Systems and Applications (IMSA 2008), pages 38-43, Kailua-Kona, Hawaii, USA.

[**P6**] Elina Vartiainen. 2009. Improving the user experience of a mobile photo gallery via supporting social interaction. International Journal of Mobile Human Computer Interaction, 1(4), 38-52, October-December.

Author's contribution

This Chapter describes the contributions of the author in each paper. The Publication [P1] has previously formed part of Virpi Roto's Doctoral Thesis. Other publications have not previously formed a part of another Thesis.

Publication [P1]

This publication describes a Web page visualization method called Minimap that was developed to solve the usability problems of Web browsing on a mobile device. The publication also explains the user evaluations of Minimap. The author designed and implemented the Minimap prototype together with Andrei Popescu and Antti Koivisto and also participated in planning and executing the user study. The author also took part in writing the article. Virpi Roto was the lead author for the user study and the article.

Publication [P2]

This paper explains the concept of Auto-update, which was developed for downloading Internet content to a mobile device in an intelligent way. Auto-update lets users control the data costs and device resources by means of high level profiles that hid underlying complexity from users. The publication also presents the user evaluations of Auto-update. The author designed and implemented the Auto-update prototype together with Andrei Popescu, Mika Rautava, and Virpi Roto. She planned, executed, and analyzed the user study with Mika Rautava and Virpi Roto. The author held the main responsibility for writing the article.

Publication [P3]

This publication introduces a solution called Rolling History that was designed to address the usability problems in back stepping and window management on a mobile Web browser. The proposed user interface was targeted for mobile devices

that provide 4-way navigation control and graphics acceleration hardware. The publication also includes the results of the user evaluations of Rolling History. The author designed the Rolling History prototype together with Janne Kaasalainen, Virpi Roto, and Mika Rautava. She implemented the prototype by herself. The author also planned, executed, and analyzed the user study with Mika Rautava and Virpi Roto. The author took the lead in the writing of the article.

Publication [P4]

This publication describes the design process of a mobile client application for the Image Exchange photo sharing Internet service. The goal was to guarantee a positive user experience by utilizing the most essential use cases for mobile photo sharing identified in user interviews. The author designed the mobile application of Image Exchange together with Janne Kaasalainen and Toni Strandell. She was mainly responsible for implementing the user interface of the mobile application. The author also planned, executed, and analyzed the user study with Janne Kaasalainen. The author was mainly responsible for writing of the article.

Publication [P5]

This publication introduces the overall design of a fully service-integrated mobile client application for the Image Exchange Internet service. The target was to offer a pleasant user experience via deep integration without requiring any configuration from the user. The publication also includes initial user study results. The author designed the client application of Image Exchange together with Janne Kaasalainen and Toni Strandell. She was responsible for implementing the user interface of the mobile application. The author was also mainly responsible for planning, executing, and analyzing the user needs study and evaluation, and writing the article.

Publication [P6]

This publication explains the results of a user study, in which the mobile client application of the Image Exchange photo sharing service was compared to a traditional

mobile photo sharing upload tool. The findings show that users were more socially active when using Image Exchange, which indicates that better user experience encourages users to use social Internet services more actively. The author designed the client application of Image Exchange together with Janne Kaasalainen and Toni Strandell. She took the lead in implementing the user interface of the mobile application. The author also planned, executed, and analyzed the user study. The author wrote the whole text to the article.

1 Introduction

Thinking about the importance of the Internet in people's daily life, it is easy to see the Internet going mobile. The Internet will not be bound to Personal Computers (PCs), but mobile devices will provide users with access to the Internet anywhere, anytime. Mobile devices can be used for performing many tasks that were earlier possible only on a PC. Especially, people are increasingly using Internet services on the go, as their mobile devices are always with them and capable of offering access to Internet services.

However, as the technological sophistication of a mobile device has grown, user interfaces of mobile applications are becoming more complex to use. The mobile device has a limited set of resources compared to a PC in terms of input and output capabilities, processing power, connectivity, and memory. This means that the user interface design cannot be directly transferred to a mobile device from a PC. In addition, the mobile context can be totally different from the one where a PC is used. When the user is using a mobile device, he might be on the move and have only a limited and possibly fragmented time to spend on a task [109]. The fragmented nature of mobile environment needs to be considered in interaction design for mobile applications.

Today, mobile devices are starting to reach maturity in terms of new technologies. The level of battery performance and Internet connectivity are satisfactory, and mobile devices are small and light-weight. The latest models have various new input mechanisms, such as touch and voice input. Hence, as the mobile devices have become mass-market commodities, more emphasis is needed on the user experience of mobile devices and applications: aesthetics, usability, utility, and emotional aspects need careful consideration [101, 54, 65].

This Thesis is about defining design implications for mobile user interfaces of Inter-

net services. It covers the challenges and limitations of a mobile device and aims to specify the design implications that give guidance on how to design mobile user interfaces for Internet services to enable a positive user experience. The user interfaces should be designed for mobile usage, simple and enjoyable to use, and hide unnecessary technical details from the user.

1.1 Focus and scope

The goal of my research work is to study how to design mobile user interfaces that enable the use of Internet services. My research belongs to the field of Human-Computer Interaction (HCI), which focuses on researching the interaction between a human and a computer. My focus area is the interaction between a human and a mobile device, in other words, whenever a human uses a mobile device to access the Internet. By means of the research, I aim to define how the user interfaces can be designed in a way that hides the technical details but offers a pleasant user experience. The Thesis explores mobile user interfaces for Internet services via two approaches: a mobile Web browser and a mobile client application.

1.2 Terminology and definitions

The term *mobile device* refers to a handheld device that includes a wireless data communication channel, a display possibly with touch input, and/or a miniature keyboard. A mobile device has traditionally been used for audio and textual communication but nowadays they are increasingly equipped with cameras, larger memories, and fast data connections enabling capturing of photos, Web browsing, music, and game playing. The research work described by the publications [P1-P6] has been based on the Nokia S60 platform. The user interface style on S60 offers a 5-way interaction with a joystick (4 directions and a selection) and two softkeys (cf.,

Figure 1.1). The S60 devices used in the research did not include a touch or pen interface but all the interaction was done with the joystick and softkeys.

Figure 1.1: The user interface style of the Nokia S60 platform.

The term *mobile application* stands for applications that run on mobile devices. When mobile applications are designed, the characteristics of a mobile device need to be considered. For example, the input methods have a strong influence on user interface design of a mobile application. The Nokia S60 platform supports the installation of additional 3rd party mobile applications.

Web browser is an application that enables a user to display and interact with content that is located on a Web page at a Web site on the World Wide Web (WWW). The content can be text, images, music, and videos. Web pages can contain hyperlinks to other Web pages and a user can navigate between Web pages via the links. *Mobile Web browser* is an application running on a mobile device designed and optimized for displaying Web content most effectively on a small screen device. The publications [P1-P3] discuss the design and implementation of a mobile Web browser.

Today, most mobile Web browsers are able to display Web pages written in HyperText Markup Language (HTML), Extensible HTML (XHTML) Mobile Profile (also known as Wireless Application Protocol (WAP) 2.0), or Wireless Markup Lan-

guage (WML). WML was the first standard markup language for creating mobile-optimized WAP sites that aim at enabling access to the Internet from a mobile device. XHTML Mobile Profile was the successor to WML and the most recent mobile services specification created by the WAP Forum [42]. The goal of XHTML Mobile Profile was to unite technologies for mobile Internet browsing as before WAP developers made use of WML to create WAP sites, while Web developers used HTML and XHTML to build Web sites. In this Thesis, I use the term *Internet services* to refer to services located in the WWW (including HTML/XHTML sites) and *mobile services* to point to services in the mobile-optimized Web (including WAP sites).

The key concept in this Thesis is *Internet service*. An Internet service is a service operating on the Internet targeted for an organization or an interest group. It can be a content aggregate or a Web site including many Web pages that are covering a specific topic or produced by a particular organization. In this Thesis, an Internet service is considered as a Web site that enables its members to create, view, and share content. The Internet service also offers an Application Programming Interface (API) for client applications that can connect to the service and use its content. For example, a mobile application can act as a client to an Internet service.

Mobile client application of an Internet service is an application running on a mobile device that directly enables the use of an Internet service. A mobile client application is designed specifically for one (or more) Internet service(s) and implemented to run in the mobile device environment enabling an access to the device resources. The publications [P4-P6] discuss the design and implementation of a mobile client application.

Mobile widgets are interactive tools that are typically designed to offer an access to a single-purpose Internet service including the latest news, weather information, stock market data, or a calendar. Mobile widgets run inside a widget engine that is installed on a mobile device providing the basic functionality common to all widgets. The widget engine might also set the look and feel, and the interaction style of

widgets, while each widget provides a specific and dedicated functionality [96, 12, 22]. In other words, mobile widgets are restricted to use the functionality offered by a widget engine, while, for example, mobile client applications can access directly the device resources and define their own interaction style.

The formal definition of *User experience* is still work-in-progress in academia. This Thesis considers that user experience describes the overall experience a person has as a result of interacting with a particular product or service. As defined by Hassenzahl, *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., organizational/social setting, meaningfulness of the activity, voluntariness of use, etc.)" [50]. Furthermore, as this Thesis is about mobile user interfaces of Internet services, it especially focuses on *Mobile Internet user experience*, which refers to how a person feels about using the Internet on a mobile device [119].

Roto has defined the aspects of user experience related to mobile Web browsing (Figure 1.2). As the list of aspects is quite extensive and some prioritizing is needed, Roto states that the actual Web site delivers most of the user experience to the user in the mobile browsing system. The other parts of the system are just enablers for this experience. This Thesis focuses on researching an enabler, the mobile Web browser, and particularly its user interface, to prepare the way for a positive browsing experience. It is not in the scope of this Thesis to define how the Web site should be designed to provide the most value to the user.

1.3 Research questions

The use of Internet services can be supported in two ways on a mobile device [72]: First, on a mobile Web browser that is optimized for mobile use and considers the

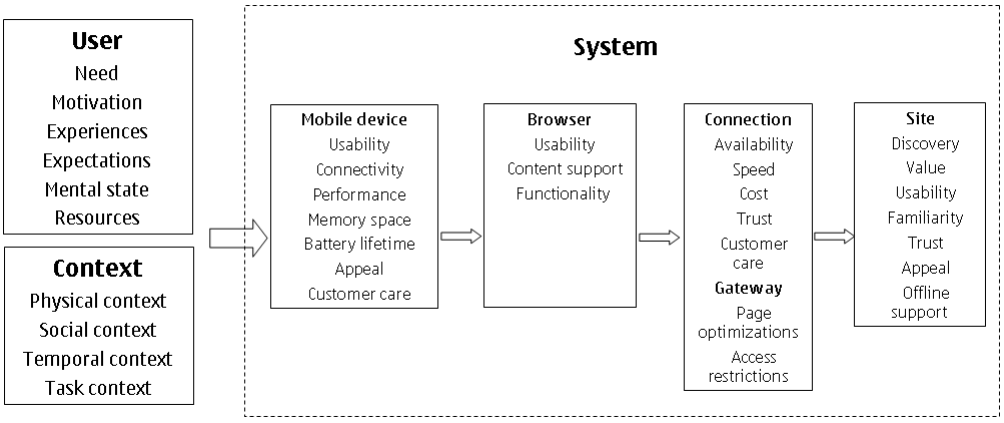


Figure 1.2: The components affecting mobile Web browsing user experience [117].

limitations of a mobile device while enabling access to various available Internet services; and second, on a mobile client application that is fully integrated with one Internet service and optimized for the requirements and functionalities of the service and mobile use.

The main research question of the Thesis is:

What are the design implications that need to be considered when designing mobile user interfaces for Internet services?

As an answer to the main research question, this Thesis aims to define design implications that would entail the main aspects to be considered when designing how to support Internet services on a mobile device in terms of user interface design. There is also the following additional research question that this Thesis strives to answer:

What differences can be found in characteristics of user interfaces for a mobile client application and a mobile Web browser?

This Thesis examines the research questions by describing two solutions that present the approaches for supporting Internet services on a mobile device. The first solution

is a mobile Web browser, Minimap, and the second one is a mobile client application for a photo sharing Internet service, Image Exchange.

My assumption is that the mobile Web browser is today the main approach to support the use of Internet services on a mobile device. It is not optimized for a specific service but a common platform for all Web content. Furthermore, it has to copy many elements of interaction paradigm from the PC as most of the Web sites are currently designed for desktop Web browsers. However, next generation mobile devices overcome some of the earlier limitations and enable development of mobile client applications that are fully integrated to Internet services offering a positive user experience. These mobile client applications represent an alternative way to support Internet services on a mobile device in the future.

1.4 Research approach

The research approach employed in this Thesis is design-science research as described by Aken [3] and Järvinen [68]. The goal of design-science research is to implement an innovation and evaluate its utility. The motivation for building a new innovation is either the lack of that innovation or the low quality of old innovations. As an outcome, design knowledge prescriptions developed, which can be used by a professional to design solutions to problems. The prescriptions are of a heuristic nature; they should be used as a solution concept and described as "if you want to achieve Y in situation Z, then something like X will help". These heuristic prescriptions need to be translated to a specific problem at hand. This Thesis aims at giving design implications in regards to designing mobile user interfaces for Internet services.

The design-science process includes two stages: build and evaluation. In the build process, the specification of the innovation is first constructed by the researcher and users, and then implemented including design alternatives. Finally, the build process may evaluate the innovation compared to existing solutions if there are any.

The evaluation process, in turn, measures aspects such as completeness, simplicity, elegance, understandability, and ease of use of the innovation [94]. Both of the applications described by this Thesis have followed the process of design-science. The evaluation of the applications has been conducted as user tests with a special focus on user experience and usability.

1.5 Overall results

The overall results of this Thesis define the design implications for mobile user interfaces of Internet services. The design implications are mainly based on the Minimap study but completed with the findings of the Image Exchange study. The design implications suggest that the following aspects should be considered in the user interface design:

- Content optimization
- Utilization of desktop and mobile usage patterns
- Full exploitation of device capabilities
- Compensation for device resources
- Content update

Image Exchange presents only one type of mobile client application and cannot provide any general guidelines. However, it can give a glimpse at future solutions and its characteristics outline the possible differences between a Web browser-based and client-based mobile solution for Internet services in terms of user interface design: the Web browser presents a more general solution, while the mobile client application is an optimized solution for one Internet service; the client application may be able to prepare and recover from offline use cases more extensively than the browser; the

browser is less demanding on device resources than the client application; the client application may be able to support better the account creation needs for the service; when the service is built on user-generated content, the client application is able to synchronize automatically the content; and if the use of the service introduces a lot of interaction, the client application can provide a fast and highly responsive user interface.

1.6 Organization of Thesis

This Thesis is organized as follows: In Chapter 2, the related work is reviewed, focusing on mobile user interface design and especially for mobile Web browsers and client applications. Chapter 3 presents the methodology that was used to conduct the research including human-centered, interaction, and user experience design. It also describes the research techniques used when designing the Minimap and Image Exchange solutions. Chapter 4 introduces the solutions and the findings of the research. Finally, Chapter 5 concludes the research and Chapter 6 introduces discussion and the future work for the topic.

2 Related work

Next Chapters will first cover the general findings and guidelines defined by the earlier research on how to design user interfaces for mobile applications and what should be considered. After that, the more specified research on different implementations and user studies of mobile Web browsers and client applications is introduced in addition to an overview of mobile widgets. Lastly, I will explain the current state of the research on mobile Internet user and show the gap that exists in the related work and explain how this Thesis aims to fill it.

2.1 User interface design for mobile applications

Internet services are mainly used via a Web browser on a PC. It is a convenient way of accessing the services as they all can be accessed via the same application, the Web browser. On a mobile device, the situation becomes more complicated. The mobile device has a limited set of resources compared to a PC. Thus, it is vital to consider the special characteristics of the device when designing mobile user interfaces for Internet services instead of copying user interface style from a PC [54, 65, 135, 117, 114, 37]. When a user uses Internet services on a mobile device, the following limitations need to be considered in the user interface design:

- **Input and output capabilities.** A mobile device may not have a pointing tool or a full keyboard. Also, the screen-size is relatively small.

- **Device resources.** A mobile device has limited resources such as disk space, processing power, and connection speed compared to a PC.

- **Cost.** Downloading content via a cellular connection may be very expensive for a user, if he does not have a flat fee agreement for mobile data traffic.

- **Mobile context.** In the mobile context, the user might be on the move and have only a limited and possibly fragmented time to spend on a task. Therefore, the user interface of a mobile application should be intuitive and easy to use. The mobile context also introduces its own set of use cases: on-the-go lookup and entry of information and quick communication.
- **Usage patterns on PC.** It is important to consider how to design a unique user interface for a mobile device without displacing the deep-seated usage patterns that people have found useful on a PC.

In the next Chapters, I will go through these limitations and introduce insights and solutions that have been presented in earlier research.

2.1.1 Input and output capabilities

Mobile devices have limitations on the amount of information that they can present at one time, as the screen is significantly smaller than on a PC. Thus, the user interface design must create new ways to fit content and possible control objects to the screen in a way that provides a good user experience. One solution is to think about the content format and how that could be modified to better fit the requirements of a mobile device and use [65]. On the graphical representation level, there are many tricks that optimize the screen space, such as using semi-transparency to show the content and control objects at the same time [74]. Also, icons can save space and may provide users additional assistance, if they are well-designed and coherent [135, 65]. Mobile user interfaces should be intuitive and descriptive, which should be borne in mind when designing icons and other user interface components [54].

Reading large amounts of information from mobile devices can require large amounts of scrolling and focused concentration from the user [46]. Optimizing menus and navigation can result in a significant reduction in the number of clicks, when the

user is interacting with a mobile application [129]. The optimization for menus and navigation can be executed through multilevel or hierarchical mechanisms. However, when using hierarchical menus a special attention must be paid on the classification of the items to prevent user's memory load from increasing [65]. It should be clear how to navigate through the menus within the application, for example, by offering feedback and guidance to the user [135]. The minimization of clicks should not be the main goal but to make task flow and interaction as simple as possible to the user [54, 65]. Today, the scrolling mechanisms in mobile devices are sophisticated and vertical scrolling is acceptable to show a document that requires more than one screenful [65].

A mobile application can offer a pleasing user experience, when special attention is paid to how the user navigates within the application. Two parameters can be identified that affect the user experience: engagement and transparency [77]. Engagement can be considered as an enhanced variation of feedback. A system gives feedback to the user when it has received the input and is processing it. If the feedback is given immediately and in a continuous and reversible way by using transformation between application states, the user interface becomes more pliable and the user more engaged. Transparency, in turn, involves the pleasure when a user has a clear and unambiguous understanding on how the application works and the interaction flows in the interface.

Text entry can be a laborious task on a mobile device. For example, user studies on text input indicate that the need to enter text makes people slow down while walking [100]. Text entry can be avoided by offering a list of pre-defined options for the user in a selection list. However, this is not always possible, as the number of options might be extensive. A more enhanced solution to eliminate the use of a keypad for text entry is to attach a temporary keyboard to the mobile device [130, 135]. In addition, there are studies exploring different text input methods that aim to overcome the challenge of typing with the 12-key keypad [128, 136]. A stylus can also be used to write input directly on the screen of the device by introducing

gesture recognition. Alternatively, virtual keyboards can be drawn to the screen and each key is selected by clicking it with a stylus.

Alternative input/output modalities (such as audio, haptics, and gestures) can help in overcoming the limitations of a mobile device. When modalities for a user interface are designed, the presentation needs to be adapted to the cognitive requirements of a mobile device: when the system wants to present data to the user that is important to be remembered, the most effective presentation mode should be used; when the system simply has to inform the user, the most appealing presentation mode should be used [38].

User studies have shown that audio can help in minimizing undesired and intrusive interruptions. Sound output may continue to be a viable interface alternative for mobile devices in the future, although there may be difficulties in presenting certain visual information, such as maps or other graphics [130]. Especially, commonly identified sounds can improve intuitiveness, learnability, and memorability of notifications [45], and be beneficial to overall usability [13], especially when combined with gestures [15]. Also, audio feedback can enable users to interact with a user interface without looking at the screen [91]. Audio feedback can be improved via the use of an additional modality: combining audio and haptics seems to enhance the perception of audio quality [25], while another user study showed significant usability improvements for the gesture/audio-based interface over a standard visual/pen-based display [110].

Haptics has become a more popular output method, as many mobile devices today include a touch screen. Tactile feedback has a key role to play in improving interactions with touch screens [14, 56]. Initial work on tactile feedback already exists covering the possibilities and needed enablers [93] and it suggests that tactile feedback is able to provide more effective, comfortable, and enjoyable interaction and can result in an improvement on user performance [111]. Gestures such as tilting operations [116] and wrist rotation [31] are gaining more momentum as an input

method for mobile interaction, and they used in many mobile devices already today, for example, to detect the screen orientation. Using seamless feedback with gestures leads to a more consistent user experience [85].

In the future, more advanced input and output methods will be available for mobile devices further improving the interaction. Interaction might be more implicit based on situational context, where devices can ”see, hear, and feel” without any explicit input required from users [125]. Sensing techniques for mobile interaction can help deliver devices that are simple and pleasant to use while still allowing direct control when necessary [55]. Using human speech as an input method for mobile devices will also become increasingly practical as voice recognition technology continues to improve. Grasp-recognition has the potential to provide significant enhancement to current mobile user interfaces by offering a unique and intuitive interaction method [132].

2.1.2 Device resources and cost

Optimizing user navigation and inventing novel means of data input will result in a reduction in the consumed device resources, such as battery power [129]. The context (including time and place, situation, and interest level) and user input can also be used to determine how to save on device resources and also take into account cost considerations [36]. The format of the content shown in a user interface may also help when optimizing disk space and processing power [65].

The mobile application and its user interface should also consider that the cellular and wireless data connections are prone to failure [135]. Today and in the future, there will be situations, where there is no coverage or the speed of the data transfer is very slow. Examples of such situations are subways and rural areas. The mobile application should prepare for these situations by being stable and recover after the network goes back online.

Mobile data transfer often costs money. Cost and billing models of mobile data traffic have an effect on how people consume online data, how satisfied they are with the connection and services [5], and user experience especially in mobile Web browsing [118]. Currently, it is hard for the users to know how costs cumulate, and to follow and control them. Thus, problems in mobile data traffic costs are hindering the use of Internet services on mobile devices. In addition, a mobile device may only support limited types of content means, which may cause a situation that a user retrieves information that is unusable on their device but he still needs to pay for it [114].

2.1.3 Mobile context

People are likely to use mobile devices in distracting environments. Thus, the user interface design for mobile applications should take into account the context of use, which is the actual environment where the application is used. The best way to prevent users from making errors, is to design the user interface in a way that makes it almost impossible to make errors [54]. However, sometimes errors do happen and user interfaces should allow users to make mistakes and be forgiving by offering, for example, an ”undo” command [135].

The user interfaces should be consistent and intuitive so that users are not required to learn new user interface paradigms every time and they are able to use the application quickly, even immediately on a first attempt [54]. For mobile applications, it is essential to consider time constraints in initial application availability and recovery speed, as waiting a few minutes for an application to start in a mobile context may not be in the user's best interest [46].

When designing user interfaces for mobile contexts and split attention, using other modalities than the visual modality may be very beneficial. For example, voice output, and tactile feedback may work well in an environment, where a user has to

concentrate on many tasks and be aware of what is happening in the surrounding environment as well [129, 46, 13, 111]. The context might also give hints about modalities that would offer more natural way of communicating with the mobile device [65].

The mobile user interfaces should also utilize the context as much as possible. The context can be used to foresee what type of information the user needs next, provide it at the right time [54, 65], and also modify the user interface accordingly. The information can be retrieved in two ways: by pushing and pulling. When the information is pushed to the user, the user's mobile device will receive it automatically (assuming that the user allows it). By pulling the information, the user actively requests the information and it is pulled to the user's device.

2.1.4 Usage patterns on PC

The terminology and processes can be retained from a PC to the mobile user interface when they are appropriate for a small screen device [135]. Similar metaphors can also be used as users have learned them while using a PC earlier. However, this should not hinder creating new and innovative user interface designs specifically for mobile devices [65]. Some interaction redesign is always needed, when a PC application is transferred to a mobile platform. It might be that the use cases in a PC and a mobile environment totally differ from each other.

On a PC, users have got used to manipulating objects by clicking them directly in the user interface [135]. When using a mobile device with a joystick, the interaction usually happens through menus and lists. This might lead to consequence, where the user feels that he is not anymore in control. By enabling a cross-linking between application areas or separate applications, it is possible to create an illusion, where the user feels that he has similar freedom as when using a PC.

2.2 Mobile user interfaces for Internet services

There are two approaches to support the use of Internet services on a mobile device: a mobile Web browser and a mobile client application. Recently, mobile widgets have been gained a lot of interest in the mobile industry as they present a new intermediate solution between the two approaches. Next Chapters describe the earlier research on mobile Web browsers and mobile client applications for Internet services and also introduce the current situation of mobile widgets.

2.2.1 Mobile Web browsers

People are increasingly using Internet services on their mobile devices, as their mobile devices are always with them and capable of offering them with access to Internet services on the go. In addition, earlier research work has found out that more than half of the occurrences of mobile device Internet access took place in locations where users had also access to a computer [107]. This indicates that a mobile device is not only a backup solution to access the Internet for when there is no computer available, but a tool that often provides quicker and more convenient service than a PC.

Internet services might have mobile optimized content but they mainly offer the same data as in desktop versions. This is important as history has shown with the WAP that having a separate mobile Internet is not a viable solution. People want to access all the content in the WWW on their mobile devices also, even though the usability of WAP services might be better [69, 17]. Most of the Web browser activities that users do with their PCs occur when they access the Web on their mobile devices [33].

A lot of research has been conducted on how to support Web page viewing on mobile devices as many of the Web pages are originally designed for PC screens.

There has not been a clear answer, whether the user interface style on a mobile Web browser should be consistent or inconsistent with a PC Web browser and in which circumstances [78].

Several methods apply the overview+detail method, in which an overview is used to display the whole Web page and a detailed view shows a close-up of a part of the Web page. The overview and the close-up can be presented next to each other [137], separately [99], or by overlapping [43]. If the views are shown simultaneously, the overview on top of the detailed view, transparency can be used to avoid distracting the detailed view [92]. Figure 2.1 shows an example of the overview+detail method, in which the views are presented separately.

(a) An overview. (b) A detailed view.

Figure 2.1: SmartView is an example of the overview+detail method including an overview and a detailed view of a Web page [99].

Implementations of the overview+detail method can be divided into two groups: methods that only visualize a Web page in a different way but do not modify its content [9, 88, 43, 137]; and methods that make modifications to the Web page content to optimize it for mobile devices [21, 99, 20, 89, 11, 19]. Generally, the overview+detail method requires a pointing device, a touch screen, or a Personal Digital Assistant (PDA) screen. Commercial Web browsers on touch devices, such as

Apple's iPhone [1] and Google's Android phone [2], utilize the overview+detail method and let users zoom between the views.

Besides the overview+detail method, one approach is to simply eliminate some of the content without offering any possibility to view the page in its original form [48, 57, 138, 34, 133]. By using this method, the layout and the content of a Web page are modified for good and a user is not able to view the Web page as he would on a PC.

Many commercial mobile Web browsers use Narrow Layout as a visualization method. Narrow Layout reformats a Web page into one column that fits the width of a mobile device display. This way, the need for horizontal scrolling is eliminated and the user will see all the content just by scrolling down. However, Narrow Layout has several drawbacks [120]:

- It often destroys the intended logical grouping of content, leading to situations where users cannot recognize even familiar pages.
- It hinders users from realizing that they have proceeded to a new page after selecting a link, because the first screen of the new page may look exactly the same as that of the previous page.
- It forces Web pages into a one-dimensional layout, which may break pages that rely on a two-dimensional layout, such as timetables and maps.
- It is not compatible with dynamic Web content, where client-side scripting is used to modify the document.

To fix the issues of Narrow Layout, the mobile Web browsers using the method also include functionality to show the Web page in its original layout, as on a PC.

[1] Apple iPhone, available at *http://www.apple.com/iphone/*. Accessed September 2009.

[2] Google's Android phone, available at *http://developer.android.com/*. Accessed September 2009.

This, however, introduces modes in the user interface, causing interaction to work differently in different views, which in turn is difficult for the user to comprehend.

Rolling back to previously visited Web pages is one main activity for a Web browser as more than half of Web page visits are to pages previously visited by the user [95, 131]. However, this area has not been investigated much in the mobile context. Instead, many studies have been focusing on desktop Web browsers and their functionality for Web history [7, 53, 98]. The results have shown that a Back menu of visited pages is more efficient than individual Back button presses for distant navigation tasks [28]. Especially, thumbnails of Web pages can help users to identify the correct page in the history [27]. Commercial Web browsers for touch-enabled mobile devices have introduced graphical solutions for the Web history, where thumbnails are utilized in the visualization (for example, The Iris Browser [3]).

Another important use case for a Web browser is multiple windows management. People encounter this functionality through opening a new window on purpose or as pop-ups [51]. There has not been much research on this area, not even related to a desktop Web browser. What has been found out is that people frequently move between windows on PCs when they browse the Web, but they do not necessarily remember which window the wanted page is in. Solutions designed for PCs are not applicable to mobile Web browsers as they rely on having a big screen [75, 16]. Both Google's Android phone and Apple's iPhone visualize multiple windows in a separate view, where each window is presented as a thumbnail indicating the currently open Web page inside a certain window. As iPhone and Google's Android phone are touch-enabled device, the tab view is designed to work with touch input.

In addition to the traditional Web pages, Internet service content can also be accessed by other means through a Web Browser: by Really Simple Syndication (RSS) feeds, podcasts, and widgets. These tools show the trend of interesting information automatically coming to the user, instead of the user fetching the content from the

[3]The Iris Browser, available at *http://www.irisbrowser.com/*. Accessed September 2009.

Internet. This pattern suits mobile use very well, as people often have some idle time on the go to check the received content, but they do not like to wait for the material to load or they might not have network coverage at all. The following important aspects should be considered in prefetching:

- Prefetching content should happen often enough to have the latest content ready on the device.
- Downloading content frequently via a cellular connection may be very expensive for a user.
- Extensive content prefetching consumes the battery and disk space, which may affect other, more important functions.
- New enablers are installed to mobile devices preparing the way for new connectivity methods, such as WiFi.

Only few studies have been conducted to investigate prefetching of Internet content to a mobile device. One solution is presented in [6], where the authors consider user input besides the parameters of the network conditions and the device resources to determine how the prefetching is done. This solution requires a server-side implementation, which may not be feasible when deploying a large-scale solution.

2.2.2 Mobile client applications for Internet services

As earlier defined in Chapter 1.2, a mobile client application is a separate application installed to a mobile device and is directly connected to an Internet service. A mobile client application is implemented to run in the mobile device environment enabling the access to the device resources. It also requires an advanced device and development and deployment of the software [122]. A mobile client application is capable of optimizing, for example, network use and offering a more immediate

experience as it is directly connected to a corresponding Internet service and does not fully rely on the request/response paradigm inherent in Web browsers and sites. It can offer graphically rich and highly interactive experiences, in which focus indication, screen transitions, and navigation techniques are specifically designed for mobile [139]. Furthermore, a mobile client application can be used offline and the information can be synchronized with the Internet service once the connection is re-established. Examples of mobile client applications include Google Maps for mobile [4] and Facebook for Windows Mobile [5].

User studies have indicated that the role of a Web browser role may diminish in the future because of the diverse user activities that the mobile Web supports [33]. The future mobile interaction design should hide the unnecessary boundaries between mobile and the Web, and streamlining user interaction with online content. A seamless integration with Web-based information services increases the perceived value of mobile applications, including an optimized user interface [97]. This may lead to a situation, where it might be difficult for the user to distinguish what exists on the mobile device and on the Internet service [79]. Thus, it is vital for the success of an Internet service that its mobile user interface is well-designed [84].

Mobile image sharing has been an important topic in the research literature covering the use of Internet services on mobile devices. The focus has been on how people share images [82, 81, 61, 60, 108, 26] and how to improve the image sharing process [2, 1, 30, 124, 127]. The mGroup project [64] studied the collective creation of mobile media in terms of instantaneous messaging, while the Zurfer project [102] concentrated on consuming and viewing shared mobile images. A pleasant user experience has also been an important aspect of the design in these studies. In the Flipper project, one of the design goals was to provide a minimal set of features, but maintain focus on photo content [30], while the Zurfer project aimed at enabling

[4]Google Maps for mobile, available at *http://www.google.com/mobile/products/maps.html#p=default*. Accessed September 2009.

[5]Facebook for Windows Mobile, available at *http://www.microsoft.com/windowsmobile/en-us/downloads/facebook.mspx*. Accessed September 2009.

simple and easy access to the user's own and their contacts' photos. The design also endeavored to be intuitive and have playful interaction with the content.

2.2.3 Mobile widgets

Mobile widgets offer a way to access a specific Internet service on a mobile device. Mobile widgets are not independent applications nor traditional mobile or Web sites, but they run inside a widget engine that may determine the rules for capabilities, appearance, and interaction of mobile widgets. People, however, might perceive mobile widgets as separate applications.

A widget engine can be implemented in different ways [96, 12]. The most common solution is to use the Web browser as a widget engine and implement mobile widgets with Web technologies such as HTML, JavaScript, and Asynchronous JavaScript And XML (AJAX). Such solutions are currently provided by Apple iPhone [6], Nokia [7], and Opera [8] widgets. The providers usually offer extensions to existing JavaScript libraries to enable access to platform resources and device data. Furthermore, the libraries might include user interface components that are impossible or difficult to implement with the basic Web technologies.

Another approach is to implement the widget engine as a proprietary system, where mobile widgets are developed with specific tools and languages. In that case, the widget engine is often written in Java as shown by examples of Plusmo [9] and Yahoo! Go [10]. The widget development can be automated to a level, where the developer only needs to provide a Uniform Resource Locator (URL) for an RSS feed and a mobile widget is created accordingly to show the feed data. However, if more

[6] Apple iPhone widgets, available at *http://developer.apple.com/iphone/*. Accessed September 2009.

[7] Nokia widgets, available at *http://www.forum.nokia.com/Resources_and_Information/Explore/Web_Technologies/Web_Runtime/*. Accessed September 2009.

[8] Opera widgets, available at *http://widgets.opera.com*. Accessed September 2009.

[9] Plusmo , available at *http://plusmo.com/*. Accessed September 2009.

[10] Yahoo! Go , available at *http://mobile.yahoo.com/developers*. Accessed September 2009.

complex interaction methods are needed, an API to access platform data and create user interface components is required.

As mobile client applications, mobile widgets allow an easy and quick access to Internet services. However, there are substantial issues with mobile widgets. The standardization of mobile widgets is still work-in-progress [22] and each widget engine offers different capabilities and features, which makes it difficult for developers to design and implement widgets [96]. This may also introduce problems to users as they cannot use the same mobile widgets with different widget engines. Widget engines also entail different user interface and interaction styles, which forces users to adapt their behavior each time they use another platform.

Mobile widgets have also many limitations compared to mobile client applications. The development of mobile widgets should be as simple as possible to ensure a wide developer base and selection of widgets. Widget engine APIs, however, tend to be quite constricted compared to platform APIs and do not offer an extensive set of tools for designing user interfaces within a mobile widget. As an exception, the API for Apple's iPhone widgets provides a wide range of methods to access platform components and create rich interaction methods. iPhone widgets are based on the Web technologies and the iPhone platform provides touch as an input method, which fits better to the Web interaction style than a 5-way navigation control.

2.3 Contribution of Thesis reflected to related work

The research field of mobile Internet user experience is relatively young. The common research goal in the field is to make the use of the mobile Internet a pleasing experience for billions of potential users [119]. A part of activities focus on designing and developing an Internet service that would work nicely on a mobile device. The research introduced by this Thesis also fits to this area. Other activities include investigating who, why, how, where, and when people use Internet services on mobile

devices to form relevant frameworks and theories. Researchers have identified four improvement areas in the area of mobile Internet user experience [70]: understanding the users and use of the mobile Internet better, improving services and service discovery, improving device hardware and software, and improving infrastructures such as connectivity, network proxies, pricing policies, guidelines, and standards. This Thesis aims to give insights about the mobile use of Internet services.

As stated in Chapter 1.3, there are two approaches to support the use of Internet services on a mobile device: a mobile Web browser and a mobile client application. Currently, the mobile Web browser seems to be the most common approach to access Internet services on a mobile device, but in the future the mobile client application might become a more preferred solution due to a better user experience. The earlier research has not addressed the task of giving guidance on a general level on how to design mobile user interfaces for Internet services. Therefore, it is worthwhile to define the design implications that could help in the user interface design and be applied to both mobile Web browsers and client applications.

This Thesis also suggests what kind of differences the two approaches, a mobile Web browser and a mobile client application, have in characteristics of user interfaces. Related work has not addressed this comparison but it indicates that a mobile client application has a superior performance over its Web-based counterpart: Ryan [122] discovered that a mobile client application can optimize network use and utilize client-side processing more extensively instead of requesting data from the server, while Weiss [135] noted that mobile client applications can take advantage of the rich user interface features of the mobile device without the limitations of mobile device Web browsers. However, implementing a mobile client application for every Internet service is a laborious, time-consuming, and non-scalable option. Mobile widgets could offer a more economical solution but the development environment is not mature enough to offer a feasible alternative [96].

The related research on mobile Web browsers has been mainly targeted to mobile

devices with a pointing device, a touch screen or a PDA screen. Thereby, solutions introduced by those studies are not directly applicable for Nokia S60 devices, which use the joystick and keypad as the input method. The commercial mobile Web browsers have implemented versions for S60 devices as well, but as summarized before, Narrow Layout incorporated in them has issues that make it difficult to use. The earlier studies have neither introduced solutions for back-stepping, handling multiple windows, nor accessing other Internet content in mobile Web browsers, even though these are important use cases. They also require special consideration in the mobile context, as the user interface design cannot be directly transferred from a desktop Web browser. Altogether, the earlier research lacks in considering how a user interface for a mobile Web browser should be designed to enable a positive user experience.

As far as mobile client applications for Internet services are concerned, the related research has been largely focusing on mobile services, only targeted to the mobile use. There are also studies about using Internet services on a mobile device, but I am not aware of any research on seamlessly integrating a mobile client application with a corresponding Internet service and how that would affect the user experience. The studies usually introduce tools, which share and download specific pieces of content in Internet services, but they do not offer a seamless experience between the mobile client application and the corresponding Internet service, which should be one essential aspect in service design for mobile devices [69]. A good example of this is photo sharing on mobile devices. People are today able to share their mobile photos to photo sharing Internet services via upload tool applications. The upload tool applications are add-ons to existing mobile gallery applications and usually require account creation and configuration of settings before they can be used. With a setup of this nature it is troublesome to offer a seamless and positive user experience. Hence, research studies have shown that many people are not able to share their mobile photos at all [115].

This Thesis does not make a stand on how Web pages should be designed for a

mobile Web browser as there have already been many studies and recommendations on how to improve the user experience and usability of mobile Web sites [44, 23, 86, 87, 90, 4, 66, 114, 113]. Especially, mobile commerce has been the pioneer in developing mobile services and earlier research has defined guidelines on how to design mobile user interfaces for the services and applications. An example is seen in Table 2.1. Mobile commerce applications are an intermediate form of how to support Internet services on a mobile device similarly as mobile Web widgets: They use the Web page user interface paradigm but are separate applications of a mobile device.

Guidelines
Avoid scrolling, especially horizontal scrolling.
Use a flat hierarchy.
Design a navigation system consistent with a regular Web browser.
Design a ”Back” button functionality as it is in a regular browser.
Provide a history list.
Provide indication of signal strength and downloading progress on every screen.
Do not require users to remember items.
Limit the search scope to improve search efficiency.

Table 2.1: Design guidelines for wireless applications [24].

3 Research and design methods

Next Chapters introduce the research and design methods used in the research. First, Chapter 3.1 introduces the Human-Centered Design (HCD) process that describes design activities throughout the life cycle of interactive systems. Chapter 3.2 gives an overview of the discipline of interaction design that defines the behavior of products and systems that a user can interact with. After that, Chapter 3.3 presents user experience design that aims to impact positively the overall experience a person has with a particular interactive system. The actual research techniques incorporated when designing and implementing the Minimap and Image Exchange solutions are explained in Chapter 3.4. Finally, Chapter 3.5 argues why Minimap and Image Exchange were good study targets with regards to the research questions defined in Chapter 1.3.

3.1 Human-centered design

ISO 13407 describes the HCD process (Figure 3.1), in which the end-user needs, wants, and limitations are considered at each stage of the design process of a system [39]. HCD can be characterized as a multi-stage problem solving process that not only requires designers to analyze and foresee how users are likely to use the system, but also to test the validity of their assumptions in regards to user behavior. We have based our design process on these principles.

Contextual Design is a process that follows the HCD standard and defines explicit steps and deliverables for each stage of the design process [10]. It is based on observing how people work, and the data gathered steers all design decisions to discover the optimal design for products. It also includes techniques for managing the design process in a multi-disciplinary teams and keeping the focus on the data gathered through the user observations. Contextual Design has the following parts:

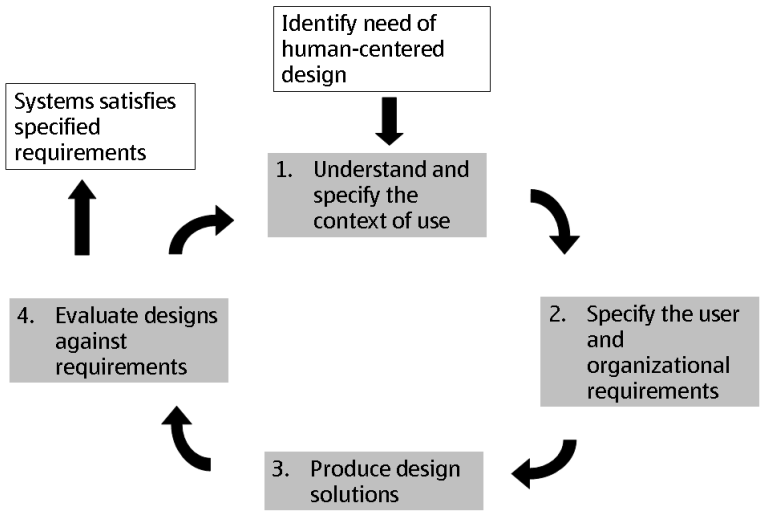


Figure 3.1: ISO 13407: Human-centered design process [39].

Contextual Inquiry, work modeling, consolidation, work redesign, user environment design and mockup, and test with customers. The Contextual Inquiry phase includes contextual interviews with users, which are conducted in a real environment where users use the particular system. In a contextual interview, the interviewer's role is to be an apprentice and learn from users how they use the system currently. Also, the interviewer and the user form a partnership, in which the interviewer aims at understanding the work practice. We have followed the process of Contextual Design for user needs studies introduced in this Thesis, as it is a successful method in the development of mobile devices [134]. However, we have used the more simplified and efficient version of the process as described in [59] and Chapter 3.4.

Personas are a tool for enhancing engagement and reality in a design process [29, 47], which is why we included them in our HCD process. They are a good method to engage and communicate with real users in design, development, and testing to proceed more effectively. Personas also help the design team and real users to imagine the actions people would or would not take in the scenarios they are put in

[8] and facilitate innovation [126].

3.2 Interaction design

The goal of interaction design is to design interactive products to support people in their everyday and working lives [112]. Thus, it follows the principles of HCD. Interaction design is about understanding the goals that people want to achieve with a certain technology [65]. It will lead to user interface designs that focus on more detailed look and feel aspects of a product. This Thesis has utilized the process of interaction design to create user interfaces for Minimap and Image Exchange. Interaction design defines four basic activities to create interactive products:

1. Identify needs and establish requirements.
2. Develop alternative designs that meet those requirements.
3. Build interactive versions of the designs so that they can be communicated and accessed.
4. Evaluate what is being built throughout the process.

Many researchers have defined design principles for user interfaces to guide what should be provided and what avoided to making them usable. For example, both Norman [106] and Nielsen [104] have defined a set of design principles to simplify tasks in user interfaces. Nielsen's ten principles for user interface design are listed in Table 3.1 and they are consistent with Norman's principles. These principles make sure that the user can figure out what to do with the system and the user can tell what is going on.

These principles for user interface design guide the design process to fulfill usability goals that can be defined for interactive products. Preece defines the goals as follows

Principle	Description
Visibility of system status	Keep users informed about what is going on, through appropriate feedback within reasonable time.
Match between system and the real world	Speak the users' language. Follow real-world conventions, making information appear in a natural and logical order.
User control and freedom	Support recovering from mistakes by offering functions for undo and redo.
Consistency and standards	Be consistent with and follow platform conventions.
Error prevention	Aim at eliminating error-prone conditions or present users with a confirmation option before they commit to the action.
Recognition rather than recall	Minimize the user's memory load by making objects, actions, and options visible.
Flexibility and efficiency of use	Support both inexperienced and experienced users.
Aesthetic and minimalist design	Contain only relevant information on dialogues.
Help users recognize, diagnose, and recover from errors	Error messages should be informative for users.
Help and documentation	Aim at designing the system to be used without documentation, but also provide help if needed.

Table 3.1: Design principles for user interface design [104].

[112]: The products should be easy to learn, effective to use, and enjoyable from the user's perspective. Similar objectives have also been defined for mobile user interfaces that emphasize that the aspects of the mobile context need to be incorporated into the requirements [54, 135, 65]. These objectives include consistency, stability, and designed to be used on the go.

When the interaction design process takes into account the principles and the usability goals, the conceptual model of the applications should evolve into one, where the user can predict the effects of his actions. Norman defines three aspects of a conceptual model: the design model, the user's model, and the system image as seen in Figure 3.2. The design model is the model of the product that the designer has in mind, while the user's model is what the user develops to explain the operation of the system. In an ideal case, these models are the same, but in reality, the designer and the user communicate through the system image. To make the system understandable and usable for the user, the conceptual model and its three aspects must be consistent.

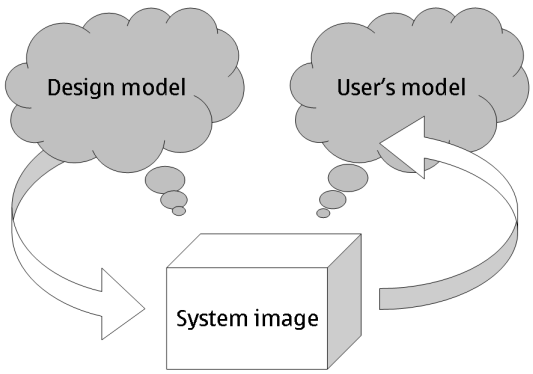


Figure 3.2: Three aspects of conceptual model [106].

3.3 User experience design

Researchers in the HCI community have developed meanings and models for user experience that have aspired to understand people's goals and actions when they interact with a product [50, 54, 41, 76]. There have also been studies that focus on interactions between individuals and products and the user experiences that result from those [40]. In addition, some research studies describe the issues that must be considered in the design and evaluation of a product to create a pleasant user experience [67, 105, 63, 35]. Next, I will present the research methods that were used when designing the Minimap and Image Exchange applications. They aim at defining user experience and then describe the design guidelines and processes that have been defined to create products with a compelling user experience.

Hassenzahl [49] has presented a model for user experience that takes into account both pragmatic (individuals' behavioral goals) and hedonic (individuals' psychological well-being) attributes of a product. Hassenzahl considers the model in a similar way to Norman who identified the three aspects of a conceptual model of a product (Figure 3.2): the key elements of the model can be seen from a designer's perspective and a user's perspective as seen in Figure 3.3. A designer defines a feature set for a product that forms the intended product character. The feature set includes content, presentation style, functionality, and interaction style. When a user starts to use a product, he constructs a personal version of the product character, the apparent product character, based on his perception of the product features. This character consists of pragmatic and hedonic attributes. Moreover, using a product with a particular product character in a particular usage situation has certain emotional and behavioral consequences. These consequences may vary as the specific usage situation is not always the same.

Roto and Rautava [121] have built on the earlier studies on user experience definitions and have defined user experience elements that consider the brand promise of Nokia. These elements are utility, usability, social value, and enjoyment, and they

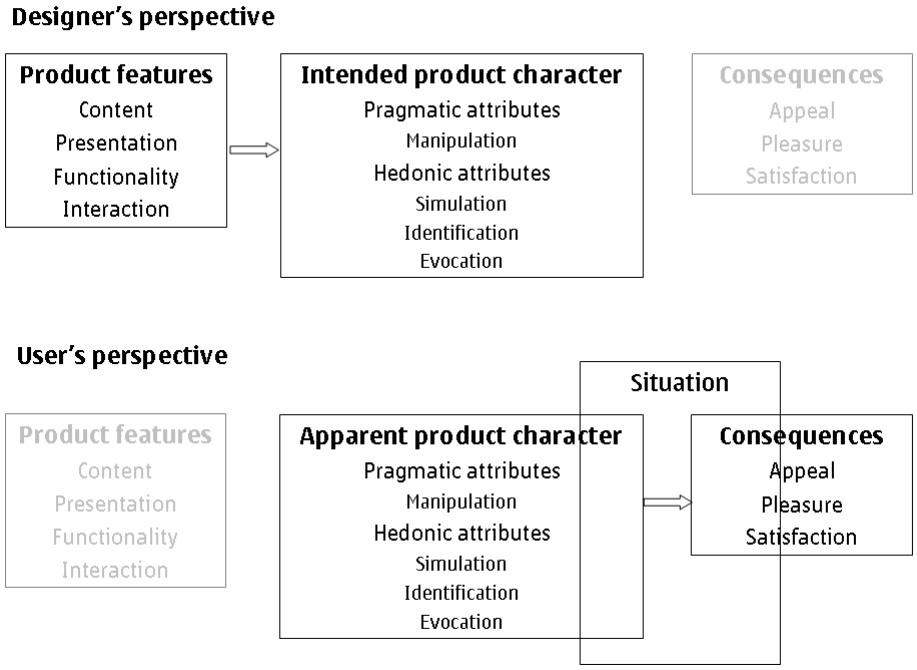


Figure 3.3: Key elements of the model of user experience from a designer perspective and a user perspective [49].

have been used in the user experience evaluations of Image Exchange.

Besides explaining the model of user experience, researchers have been developing design processes that take into account user experience. At its best, a product would offer the user an optimal user experience, "flow", in which the user feels that his skills match the needed challenges when using the product. The user's goals are clear, he can fully concentrate on the task at hand, and he gets constant feedback on how he succeeds in the task [32]. The user experience goals of an interactive product have been defined as satisfying, enjoyable, fun, entertaining, helpful, motivating, aesthetically pleasing, supportive for creativity, rewarding, and emotionally fulfilling [112].

Jordan [67] has proposed a hierarchy for user needs that can be used in product design. The first level is the functionality; the product is useless and will cause

dissatisfaction if it does not contain the necessary functionality or cannot perform the expected tasks. Thus, we need to have an understanding what the product will be used for and the context of use. The second level is usability; once the product has the required functionality, it should be easy to use. Finally, the third level is pleasure; the products should bring emotional benefits for the user. Hiltunen suggests a similar approach: when a technology is mature enough, more emphasis should be placed on the user experience of a product [54]. Jordan proposes four main stages to describe how pleasurable products can be designed and a set of methods to achieve that goal:

- Understanding the people for whom the product is designed
- Understanding the practical, emotional, and hedonic benefits required from a product
- Linking these benefits to the product design
- Evaluating design solutions

Norman defines three levels for product design that are based on the emotional and cognitive system of the human brain [105]. The levels of brain processing are visceral, behavioral, and reflective: The visceral level is the automatic, primitive layer, which makes fast judgments; the behavioral level controls the everyday behavior; and the reflective layer contains consciousness, feelings, and emotions. These three levels of brain processing translate into three different kinds of design aspects. Visceral design refers primarily to the initial impact of a product and its appearance. It is mostly about the physical characteristics of a product. Behavioral design is about look and feel and how the product is used - traditionally researched by usability studies. Finally, reflective design is how one experiences the product afterwards, how it makes one feel, and about the message it sends to others. Self-image and culture are also important aspects of reflective design. These three levels can be used to define and evaluate user experience of a product.

The following conclusions can be derived from the research related to user experience design. First, it is essential to understand the people who the product is designed for. Second, the products should be easy to use and useful to establish a firm ground for a positive user experience. Third, we need to understand the emotional benefits that are related to using a product to enable a pleasurable user experience. Fourth, the designs need to be evaluated by real users.

3.4 Research techniques

Next Chapters explain the research techniques that we used for designing Minimap and Image Exchange. The research has followed the design-science process. In the building process, we first used contextual interviews to identify the user needs. After that we created personas, scenarios, and user interface diagrams to design the first versions of the user interface of the application and to communicate the motivations of the design within the project team. In the evaluation process, the prototypes were evaluated in user studies including methods such as field, expert, and laboratory studies. The applications were further improved in an iterative fashion. The timelines for the empirical studies of Minimap and Image Exchange are presented in Figure 3.4.

3.4.1 User needs studies

The Minimap and Image Exchange projects have followed the design process of Contextual Design [10, 59]. As described in Chapter 3.1, human-centered design is based on human needs, and interviewing users gives us a realistic view of the current needs and problems. With Contextual Design, we were able to find out usage patterns, how and why users are using a product/service, and reasons behind the worries and wishes of users.

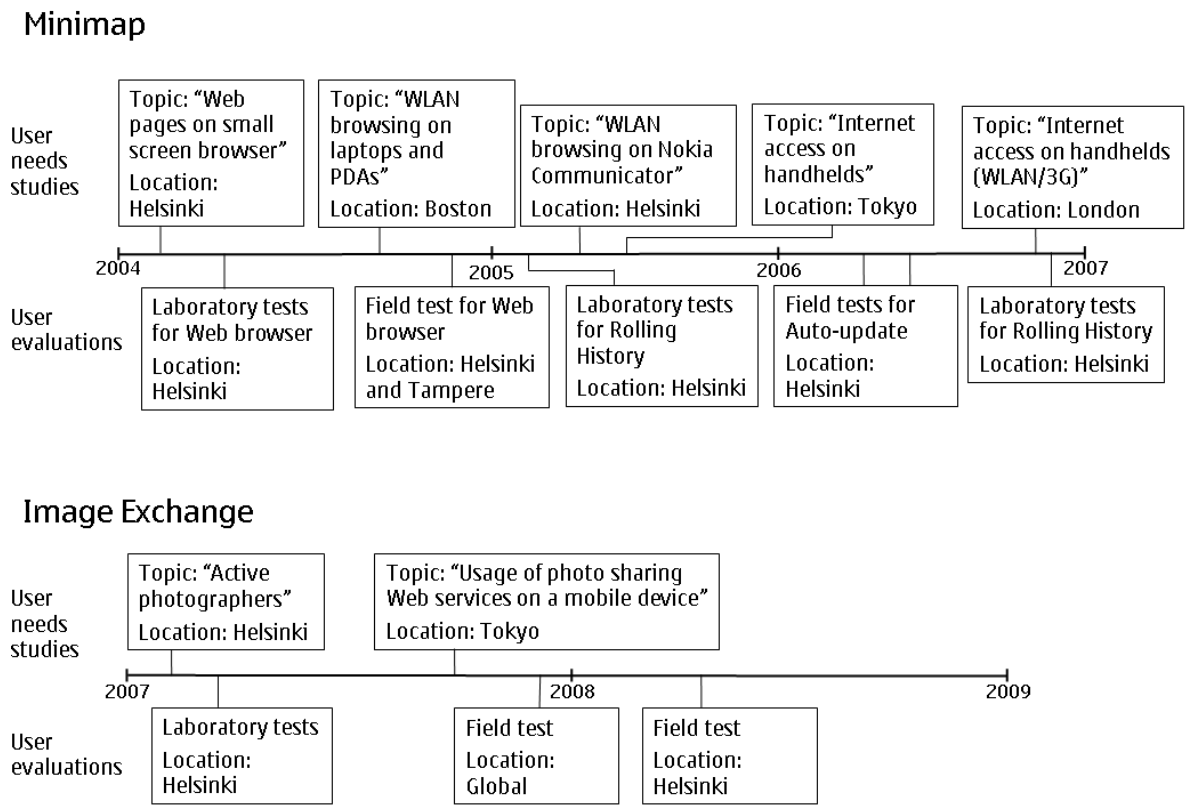


Figure 3.4: The overall timelines of the empirical studies of Minimap and Image Exchange.

In both of the projects, the design process included contextual interviews conducted in real environments, where the applications were used. The target was to observe and identify real user needs related to user's tasks. It was important to keep a focus during the interview and concentrate on research questions that are related to the project. We aimed at recruiting a heterogeneous set of users for the interviews to represent different types of users.

In the Minimap project, the contextual interviews were organized in different parts of the world: Helsinki, Boston, Tokyo, and London. 35 interviews were conducted in total, 6-9 interviews per location. The focus of the interviews was on online access on mobile devices, including mobile Web browsing and other types of online content, such as RSS feeds and podcasts. The interviews were conducted in cafes, the home

environment or the work place.

While conducting research for the Image Exchange project, we ran contextual interviews in Helsinki and Tokyo. Tokyo was selected to present the pioneer location of mobile services, while Helsinki represented more of a mainstream audience. All in all, 16 interviews were conducted, 8 per location. The aim was to gain an understanding of how people take photos and use photo sharing mobile/Internet services with their mobile devices (mobile phone or PDA). The interviews were conducted in the participants' home environment or work place.

The reason for conducting the contextual interviews in different locations of the world was to gather common knowledge how the applications were used in different countries. Furthermore, some countries like Japan represent the pioneer in mobile industry and are able to give new ideas for new features and applications. We did not use the data to create variations of the applications for different cultures but to design applications that could work well in many cultures.

The interviews started by going through a typical day related to the use of the specific system. Also, users described the tools that they were using to complete tasks. Next, we asked the users to explain their recent use cases with the system. In some of the studies, we asked the participants to keep a diary during the week before the interview to help them to remember the use cases. In the Minimap project, we especially paid attention to how the mobile Web browser was used, the use cases for mobile browsing, and how online information was accessed. When conducting the interviews for the Image Exchange project, we focused on the mobile camera and photo-sharing use cases. In both of the projects, we were interested in how the connection speed and the cost of use affects the use and who pays the phone bills. Finally, we asked the participants to list three wishes for their future online access or photo sharing needs.

Once the observations were conducted, we interpreted the data collected in the

interviews within the design team. Key points of the data were captured into affinity notes, which included interpretations of events, use of the system and artifacts, problems and opportunities, questions, insightful quotes, and even design ideas. We also built user profiles of the participants entailing demographic information. Typically, we had 400-700 affinity notes per study.

As a next step, the affinity notes were grouped together and built into an affinity diagram to see common themes in data. An affinity diagram is a hierarchical representation of the user data that is built from the bottom up. It lets the data suggest labels for groups of notes. We used three levels of category labels usually having 8-10 bigger themes arising from the study.

Finally, we organized a workshop within the project team to design a response to the user data presented by the affinity wall. The study data was shared with all the members of the team through the affinity wall, where everyone could see the original user data and how it was analyzed into a hierarchical representation. Design ideas and inventions were gathered during the workshop and used later when developing Minimap and Image Exchange.

In the Image Exchange project, we also used the contextual interviews to modify personas that we had created to communicate the user needs within the project team. Earlier research has identified a potential for integrating contextual design and personas in the design process [123, 10, 58]. Instead of creating the personas after the contextual interviews, we gathered feedback on the validity of the personas already in the user interviews and modified the personas later if we found them contradicting the results of the interviews.

3.4.2 User interface design

The user interfaces for Minimap and Image Exchange were designed within a multidisciplinary team including interaction designers, HCI specialists, and developers.

The design process was not isolated from the engineering process to ”get the right design” and ”get the design right” [18]. Having a design process running in parallel with the implementation process enables a better user experience.

The design processes for both Minimap and Image Exchange used sketching as a method for designing user experiences. Sketching is a very cheap and easy way to design and explore many alternatives in user interfaces and get feedback at the same time [18]. Its benefits include being quick, timely, and inexpensive. The sketches are disposable and plentiful, meaning that many alternatives for the user interface designs can be explored and tried out. They are also a good way to communicate and provoke discussions within the team. Sketching incorporates various techniques, of which we used drawings, animations, and paper interfaces in the design process.

In Image Exchange, we also used personas and scenarios to communicate and bear in mind the most important use cases of the application. We wanted to keep the focus and optimize the user interface to include only a minimal number of steps for the most important functions.

The user interfaces for Minimap and Image Exchange were designed in an iterative fashion: the sketches and more complete prototypes were evaluated with users and improved according to the feedback. When a user interface is designed in an iterative way, it evolves along with the user needs providing a satisfactory user experience [62, 54]. Throughout the process for user interface design, we kept in mind the heuristics and guidelines for user interfaces as described in Chapter 3.2.

3.4.3 User evaluations

To evaluate Minimap and Image Exchange, we conducted laboratory studies and expert evaluations to find the critical usability problems and long-term field studies to identify issues related to user experience. Usability testing in a laboratory environment is sufficient when studying user interface and navigation aspects of a mobile

application [73], but also for contextual issues [83]. The expert evaluations also reveal potential usability problems of a product and are a quick and cheap usability inspection method to test the system before engaging real users. Field studies are more time-consuming but worthwhile when user behavior and experience are investigated in a natural context. Conducting field studies is especially important when evaluating mobile applications as they are used in various environments and situations [54]. Field studies also help to identify the specific contexts, where a mobile Internet service is used in real life, and focuses on usability problems occurring in those contexts [80]. Also, problems related to cognitive load and interaction style are identified more effectively in field studies [103].

The laboratory tests were conducted in a laboratory setting, where users were asked to complete a set of tasks in a 2-hour session. With the laboratory tests, we aimed to identify usability problems in the user interface of Minimap and its view for Web history, called "Rolling History" (one study is explained in [P3]). The users were advised to think aloud during the session so that we could know the reasoning behind their actions. After completing the tasks, we asked the users to fill out questionnaires to give ratings to different aspects of use.

We used expert evaluations to find usability problems in Image Exchange in the early phases of the user interface design process. The experts we used had 5-10 years of experience on the HCI field. The expert evaluations were conducted as face-to-face interviews, where the expert could explore the user interface freely. The interviews lasted 1-2 hours.

For both Minimap and Image Exchange, we arranged one comparative field study (reported in [P1] and [P6], respectively), where users used two applications designed for the same purpose one after the other. In the Minimap field study, we had 20 participants using the applications for 8 days each, while the field study for Image Exchange, included two groups of five participants using the applications for 7 days each. The participants executed daily tasks in addition to their own usage. We

gathered data about the usage with task feedback, diaries, questionnaires at the end of the testing period, and focus group discussions. In the Image Exchange field study, we also used logs to collect usage data.

Two other field studies aimed at exploring the user behavior when using Minimap and Image Exchange for a longer period of time (described in [P2] for Minimap and in [P4] and [P5] for Image Exchange). For Minimap, we had a 2-week period for evaluating the Auto-update concept. Auto-update aimed to prefetch Internet content such as RSS feeds or podcasts to a mobile device in an easy and care-free way that saves data traffic costs, battery, and disk space. Participants performed tasks every second day and they were also encouraged to use it for downloading their own favorite Web content. After the test period, we arranged a group feedback session, where the participants first filled in a questionnaire and later gave verbal feedback in a focus group discussion. In Image Exchange, we launched a trial of the mobile client application and Internet service to a closed group of people. A couple of months after the launch, we organized a Web survey and requested the users to answer the survey and give their feedback. 21 users replied to the survey. The survey included rating questions, in which we tried to find out both the usability but also user experience related issues of the application.

3.5 Summary

The goal of design-science research is to build innovations that can be improvements to existing entities [68]. The objective is to develop technology-based solutions to important and relevant business problems. As an outcome, design knowledge prescriptions are developed, which can be used by a professional to design solutions to problems.

Solution concepts are typically studied in the intended context of application to explore its effectiveness and the influence of less well-known factors. Therefore, the

preferred research design is the multiple case-study [3]. The knowledge is built via reflective cycles: first through alpha-testing, where the design knowledge prescriptions are analyzed in the original context. The next step is beta-testing, where the design knowledge prescriptions are evaluated and analyzed in other contexts. This phase can give invaluable insights about the design knowledge prescriptions and their application domain, and ideas for final improvements.

The Minimap Web browser and Image Exchange client application were selected as the study concepts with regards to the research questions. They present the two approaches, or ”cases”, for using Internet services on a mobile device. Both Minimap and Image Exchange are solutions for relevant business problems as they have been developed in a real business environment. Minimap is the solution of today, while Image Exchange exemplifies a future solution, where the use of an Internet service is supported via a connected client application. The resulted design knowledge prescriptions are the design implications for mobile user interfaces of Internet services. The prescriptions were tested with Minimap and Image Exchange in the alpha- and beta-testing phase, respectively. Minimap formed the basis for the design implications, while Image Exchange gave hints how the design implication can be applied to and affected by future solutions.

4 Results

This Chapter introduces Minimap and Image Exchange that present two approaches to support the use of Internet services on a mobile device. The design decisions of the user interfaces are justified for both applications through the results of the user experience evaluations.

4.1 Solution of today: Minimap

The Minimap mobile Web browser presents the most common approach to support the use of Internet services on mobile devices (presented in [P1-P3]). We considered the limitations of mobile devices (see Chapter 2.1) in the user interface design and developed a solution that would enable a compelling user experience. Minimap and its user experience were evaluated in 6 user studies during the development process.

4.1.1 User interface design

The first task in the user interface design was to tackle the limitation of a small screen [P1]. This was particularly important when defining how to visualize Web pages, as they are mainly designed for desktop screens. In addition, we needed to outline a good design for the visualization of a Web history and multiple windows, as they are important use cases on a PC [95, 131, 51] but have many challenges when transferred to a mobile device.

For Web page visualization, we designed a method that scaled down the layout of a Web page to fit more content to the screen (Figure 4.1). The method modified the size of the text relative to the rest of the Web page contents and limited the maximum width of the text paragraphs to the width of the screen of the mobile device. Hence, the text paragraphs were at most as wide as the screen and the need

for horizontal movement was eliminated while reading text. The Web page was still navigated by scrolling, as today's mobile devices are capable of performing scrolling efficiently [65]. As for a navigational aid, we created an overview of the Web page laying it transparently on top of the Web page view. In the overview, the user could see his location within the Web page when scrolling.

Figure 4.1: The Web page view in Minimap.

For a user's browsing history and windows, we designed a separate view, where the user could move within the Web history and between browser windows with a navigation key (Figure 4.2) [P3]. We named this view as "Rolling History". The view consisted of a graphical representation of the Web history of the current window and the other open windows, where the Web pages were visualized as thumbnails. The Web history was aligned on the horizontal line and the currently open browser windows were displayed on a vertical line. Each thumbnail in the Web history presented a Web page the user had visited during the browsing session in the same browser window, while in the window list a thumbnail image illustrated a Web page that was currently opened in the window.

Both views were optimized for a 5-way navigation key, a joystick. In the view for Web page visualization, the vertical and horizontal movements of the joystick were reserved for scrolling the page, while the select action activated a link. Rolling History used the horizontal movement for navigating in the Web history of the

Figure 4.2: Rolling History: The view for the Web history and multiple windows.

current window, while the vertical movement switched between browser windows. A user selected a page in Rolling History with a joystick select action. The views did not necessitate a pointing device or a touch screen for input. Moreover, the views did not require a zoom key to work, as most mobile devices do not provide a dedicated key for zooming.

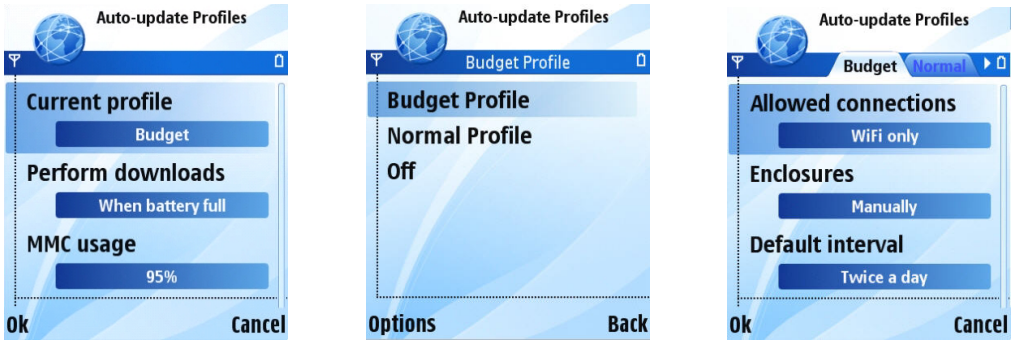
The Web page view and Rolling History did not include modes in their user interfaces enabling interaction mechanisms to be always analogous in one view. This is essential in the mobile context as the user might be interrupted and have difficulties in remembering which mode was currently active. Using modes in the user interface design introduces a frequent source of errors and frustration to the users and should be avoided if possible [104]. Rolling History also employed animations in the user interface to give a visual aid for the users. Rolling History was a relatively new concept for users, so we needed to make it more intuitive and usable on the go.

The Web page visualization method of Minimap used an algorithm for the hyperlink selection: When a user scrolled within the Web page, the link selection moved accordingly. The user could select any link, which was visible in the browser view. The link selection aimed to be as natural as possible to the user, who is accustomed to using a mouse cursor for hyperlink selections on a PC screen. Here, it was

beneficial to copy a usage pattern from a PC, even though other user interface paradigms might be more effective. Rolling History also demonstrated how to design a unique user interface for a mobile device without displacing the deep-seated use patterns that people have found useful on a PC. It used the same paradigm for multiple windows as on a PC, even though windows did not really exist on a S60 user interface style. People, however, need multiple windows on a PC in several situations and having the functionality on the mobile device, improves the user experience. Nonetheless, the user interface can be optimized for a mobile device, although the paradigm would remain.

Rolling History also contributed to overcoming the limitation of restricted mobile device resources. Getting a previous Web page back on the screen on a mobile device may take a while due to the bandwidth and processing power and may also consume battery and memory. Furthermore, some Web pages require non-cacheable content from the Web so downloading content via a cellular connection while back stepping may even add browsing expenses. Rolling History enabled a user to select only the page he desired, as the page thumbnails were easily recognizable. Furthermore, the user did not need to load all Web pages along the way if he needed to step multiple pages back in the Web history.

The limitations of disk space, battery, and connection costs become fundamental when people are accessing other types of content than Web pages in Internet services with their mobile devices. Examples include RSS feeds and podcasts. An essential aspect of Internet content is its timeliness: people should have the latest content ready on the device, when they want to access it. We designed a concept called Auto-update to be included in the Minimap Web browser to solve this problem [P2]. Auto-update aimed to prefetch Internet content in a delicate way to a mobile device. If a user had subscribed to RSS feeds or podcasts, the system tried to save data traffic costs, battery, and disk space elaborately. The details were hidden behind profiles: the user only selected, which profile he wanted to use and the system took care of the rest. The user interface of Auto-update is presented in Figure 4.3.



(a) The main view for profiles. It shows the selected profile and profile-independent policies that the user can modify.

(b) The view for selecting profile. Auto-update contained three profiles with default values, but a user could modify them to suit his preferences.

(c) The settings view for each profile. Each profile contained policies for device resources that the user could modify.

Figure 4.3: The user interface of the Auto-update concept.

4.1.2 User experience evaluations

We organized 6 rounds of user studies to evaluate the user experience of different functionalities of Minimap, as our ambition was to develop user interfaces in an iterative fashion. After each study, we went through the issues discovered by the study and further developed the solutions and their user interfaces. I will go through the most essential user study results of Minimap in this Chapter.

Minimap's method for Web page visualization was evaluated in two user studies: First, in a laboratory test with 8 subjects; and second, in a field study with 20 participants [P1]. In the field study, Minimap was compared to a commercial Web browser that used Narrow Layout as a method for Web page visualization. The participants used Minimap and the other browser for 8 days each. Evaluation data was collected through questionnaires, task feedback, diaries, and logs. We also gathered qualitative data in focus groups, where the participants discussed Minimap

and the study. Comparing two applications enabled the participants to have a reference point to their evaluation: it is easier to compare two options than to evaluate a single solution.

The overall user experience was measured by asking the participants' preference between the two browsers. We asked the participants to evaluate, which browser they would prefer, if they had the need for browsing Web pages on a mobile phone. We decided to use a simple preference question because at that time we were not aware of any other standardized way to evaluate the overall user experience [117]. The results shown in Figure 4.4 clearly demonstrate a preference for Minimap, as 12 users out of 20 strongly preferred it.

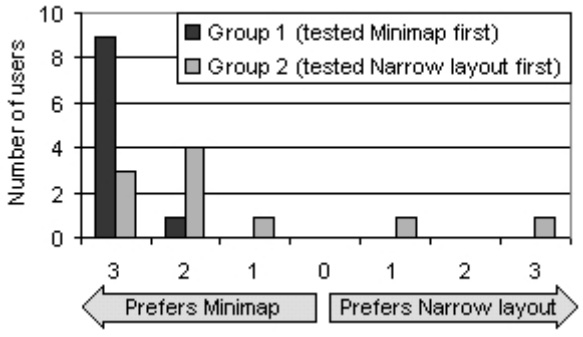


Figure 4.4: 18 out of 20 users preferred Minimap Web browser.

Rolling History was evaluated in two laboratory studies [P3]. The results of the first study indicated that the initial version of the solution was not intuitive enough, as participants without technical background or experience on mobile Web browsing were confused with pages and windows shown in the same view. We analyzed the problem as being the graphic design. After improving the solution, we conducted another user study, where the solution was compared to a state-of-the-art tab approach. Participants conducted a set of tasks including all the basic interaction that users experience when handling pages in the Web history and multiple windows. After completing the tasks, the participants gave feedback by filling out a question-

naire. The overall user experience was again evaluated according to preference and the results showed that most participants preferred our solution across all functions as seen in Figure 4.5.

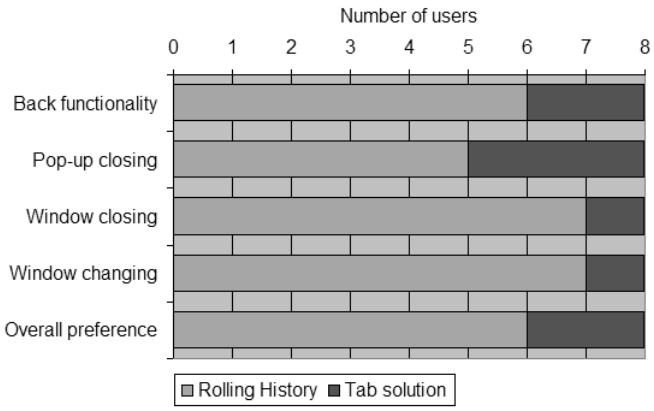


Figure 4.5: Rolling History was preferred by most users across all functions.

To evaluate the user experience of the Auto-update concept, we arranged two field studies, in which participants used the system in their daily lives for two weeks [P2]. Both studies lasted for two weeks and we gathered evaluation data by task feedback, questionnaires, and focus group discussions. Figure 4.6 summarizes the results of the latter field study by presenting the average values of how each feature was evaluated by the users. We used a 5-point Likert scale, 0 meaning that a user totally disagrees with the statement and 5 that he or she totally agrees. The usefulness of updating both RSS feeds and podcasts scored well in the study. The participants understood based on the feedback that they would have saved a considerable amount of money by, for example, fetching the feeds over WiFi connection. In addition, the participants wanted to have control over the device resources according to their own preferences.

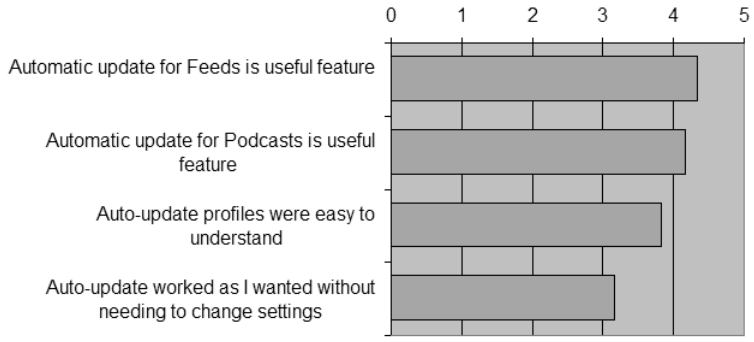


Figure 4.6: Overall ratings of the Auto-update concept.

4.1.3 Summary

The Minimap Web browser presents a solution, where a user interface paradigm is transferred from a PC to a mobile device in a way that preserves the familiar desktop usage patterns but offers unique solutions in the mobile user interface design. The user experience evaluations showed that the designed solutions to surmount the limitations of a mobile device were successful and support the use of Internet services on a mobile device.

The benefits of Minimap can be summarized as follows:

- It is optimized for a small-screen mobile device.
- It does not require a pointing device or a touch screen but makes good use of 5-way navigation key.
- It does not present modes in the user interface.
- It utilizes the familiar desktop usage patters.
- It presents unique solutions for new usage behavior that the mobile context introduces.

- It introduces unique user interface solutions to compensate the limited resources of a mobile device.

If we look at the use of a specific Internet service on a mobile device, even Minimap is not fully optimized for the mobile context. It copies the interaction style from a PC, where it tries to stimulate the navigation with a hyperlink selection algorithm. Thus, it is not optimized for mobile nor fully capable of utilizing device resources [135, 122]. Moreover, a mobile Web browser is technology-wise tied to the request/response paradigm of the Web, which prevents it from providing an immediate experience for the user when he is interacting with an Internet service. For example, when a registration or a login to an Internet service is done on a mobile Web browser, it demands a considerable amount of user input. As text input is laborious and mobile context is full of interruptions, completing such a task might be too difficult for a user and prevent him from using Internet services on a mobile device. Thus, the user experience of a specific Internet service on a mobile device may be improved by developing a more optimized solution.

4.2 Solution of tomorrow: Image Exchange

Image Exchange exemplifies a future solution for supporting the use of Internet services on a mobile device, a mobile client application (presented in [P4-P6]). The Image Exchange mobile client application is fully integrated to the corresponding Internet service: the application is always connected to and user's image collection up-to-date with the service. The mobile client application provides a way for users to share and interact with photos in real-time on the go. The intended target users for Image Exchange were Internet-aware early adopters interested in image sharing and expressing themselves.

As before, we took into account the limitations of a mobile device in the user interface design of Image Exchange. However, this time we were able to fully exploit device

resources and user interface possibilities unlike with Minimap. The user experience of Image Exchange was evaluated in two user studies.

4.2.1 User interface design

The Image Exchange mobile client application was developed for advanced mobile devices equipped with an always-on, flat-fee data connection, longer battery lifetime, and enough CPU power to run fast rich user interfaces. In addition, the application was designed exclusively for mobile use, as on a PC Internet services are commonly used on a Web browser. Therefore, the user interface design could exploit the opportunity for unique mobile-specific solutions. We still needed to consider the limited input and output methods and the mobile context in the design process as those limitations remained.

The user interface of the Image Exchange mobile client application was designed by identifying the essential use cases for mobile photo sharing [P4]. The use case definitions were formed and prioritized through user interviews and evaluations of other mobile photo sharing applications. The results indicated that the most important use cases were publishing images, having one's entire image collection with him all the time, and to be notified about new events on his and his friends' images. Finally, the use cases were used to define the requirements for the mobile client application. The aim was to find a simplistic and pleasant user interface design that would offer a positive user experience.

The main views of the Image Exchange mobile user interface are presented in Figure 4.7. When the application was launched, the main menu was displayed on the screen and the latest captured image was shown full-screen in the background. A user could access images through different categorizations in the main menu by using the 5-way navigation key. Thus, the need for text input was eliminated. All selections in the main menu item led to the image browsing view, which optimized the screen area

and displayed a specific image full-screen. The left and right arrow keys were used to flip through the images in the image browsing view.

(a) The main menu. (b) The image menu. (c) The image browsing view.

Figure 4.7: The user interface of Image Exchange.

The image menu was used to show functions that were available for the selected image. We decided to create our own menu style instead of using the option menu that is offered by the platform in many mobile devices. The reasoning for this was that usually the options menu does no separate the functionality and the settings of the application but has all of them presented in the same list. We wanted to make a clear separation between the functionality that is available for a certain image versus the application-wide settings. As we were developing an application that would directly run on top of the platform, we could take a full advantage of the rich user interface features, such as animations.

As the mobile context requires that people's tasks on their mobile devices are quick and simple to complete, we needed to make the interaction between the mobile client application and the Internet service easy and fluent [P5]:

- To facilitate the registration process to the service, we decided to use the identification number of the device as an initial user name for the Internet service to minimize the effort. A user account was created without any user input except for asking permission to use the network connection. By removing the need for any input, we lowered the entry barrier for the user to start

using the application.

- To enable people to share their images right on the spot, Image Exchange transferred captured images transparently without requiring any user input. As a result, a user could trust that his image collection was always present on the device and in the service.

- To provide the user with a way to add additional data to the images, he could modify the title and description and add comments through the image menu with a couple of clicks. Whenever the user decided to change a title or description or add a comment either on the mobile device or in the service, the changes also appeared immediately in the other end.

4.2.2 Benefits in contrast to mobile Web browsers and other state-of-the-art solutions

When a mobile Web browser is used for accessing Internet services, it requires at least some amount of text input for registration and possibly for logging in. Typing text on a mobile device can be a laborious task, especially when a task such as a registration or login requires text entry without any typographical errors. For Image Exchange, we were able to simplify and facilitate the registration process, as the client application could access the device resources and make use of the platform data. Similarly, when a Web browser is used for uploading content to an Internet service, it usually requires filling out a form by inputting text. In Image Exchange, we transferred the captured mobile images transparently without requiring any user interaction. As a result, the user's image content was automatically up-to-date without any effort from the user.

When using the Web browser to access content on an Internet service, the user might need to navigate through many Web pages and links until he can access the latest content. In addition, the Web browser may need to send many requests to

the service and wait for the responses until it can show the content to the user. Therefore, content browsing on a Web browser might not be fluent and immediate from the user's perspective. When the user started the Image Exchange application, he could access the latest online photos by two clicks. This led the user to an image browsing view, where he could browse online images with the left and right arrow keys. The browsing between images occurred immediately without any waiting periods, as the application fetched the latest online images published and cached them to the device memory. The service would only send screen-size thumbnails of the images to make the transfer fast and save network bandwidth. Still, the whole screen area was used for showing the image.

Modifying content on an Internet service with a Web browser might also require many link selections, filling out a form, submitting the form, and waiting for a response. The Image Exchange application used a dialog activated directly with a mouse click to enable modifying of image data, such as titles, descriptions, or comments. The image data was up-to-date with the corresponding Internet service without any need to specifically submit or update the information.

Nowadays, the state-of-the-art mobile client applications that people can use to share their mobile photos (e.g., Facebook [11], Kodak EasyShare Gallery [12], Pictavision [13], Radar [14], Share Online [15], ShoZu [16], and Yahoo! Go [17]) are upload tools for specific Internet services. The applications are usually add-ons to existing gallery applications offering functionalities for separately uploading and downloading images and the data linked to them. However, the image gallery application and the user's image collection are not fully integrated and synchronized with the service.

[11] Facebook, available at *http://www.facebook.com/*. Accessed September 2009.
[12] Kodak EasyShare Gallery, available at *http://www.kodakgallery.com/*. Accessed September 2009.
[13] Pictavision, available at *http://www.pictavision.com/*. Accessed September 2009.
[14] Radar, available at *http://radar.net/*. Accessed September 2009.
[15] Share Online, available at *http://www.nokia.com/betalabs/shareonline/*. Accessed September 2009.
[16] ShoZu, available at *http://www.shozu.com/*. Accessed September 2009.
[17] Yahoo! Go, available at *http://mobile.yahoo.com/go/*. Accessed September 2009.

Also, the upload tool applications require account creation and configuration of settings before they can be used. In the mobile context, users who might be on the move and have only a limited and possibly fragmented time to spend on a task are unable to use a mobile application that is hard and slow to use and configure. Furthermore, the upload tools might be developed by a different party than the developers of the gallery application or the corresponding Internet service. This might result in a mismatch between the available functions and features on the mobile gallery application and the Internet service. Thus, the upload tool applications cannot guarantee a deep integration of the gallery application and the service.

4.2.3 User experience evaluations

Image Exchange was evaluated in two field studies. First, we launched the mobile client application and the corresponding Internet service to a closed group of participants and conducted a small-scale user study to find out if the concept was useful and fun in practice [P5]. The results showed that the integration of the mobile application and the service was appreciated because of the automatic synchronization of data and how the whole concept worked seamlessly. In addition, the user interface and the user experience of the mobile application were positively rated by the participants.

To evaluate Image Exchange more thoroughly, we conducted a field study of 2 weeks to compare Image Exchange with a state-of-the-art gallery application combined with an add-on tool for photo sharing [P6]. The earlier studies have shown that a mobile client application offers a superior way to interact with an Internet service compared to its Web-base counterpart [122]. That is why we decided to compare Image Exchange to a state-of-the-art mobile client application, ”Gallery”, instead of a mobile Web browser. In addition, Image Exchange could be used as an image browser application to view user's own image collection on his mobile device, so the Gallery application presented a good point of comparison in that extent as well.

The Gallery application was not fully integrated to an Internet service but used an upload tool for transferring and updating the content. We wanted to show that the full integration of a mobile client application and an Internet service is crucial to enable a compelling user experience.

The field study included two groups each containing five participants. Both groups used the Image Exchange and Gallery applications for seven days each. One group started with Image Exchange and the other one with the Gallery application. The focus of the study was on the overall user experience of implemented features and how that would affect the social activity within the group during the test period. We collected data through task feedback, questionnaires, logs, and focus group discussions.

Figure 4.8 shows the preference of the participants after using both applications for 7 days each. We used a 7-point scale, 3 meaning strong preference for either application and 0 meaning no preference. 7 out of 10 participants preferred Image Exchange very strongly and 8 participants in total (Figure 6).

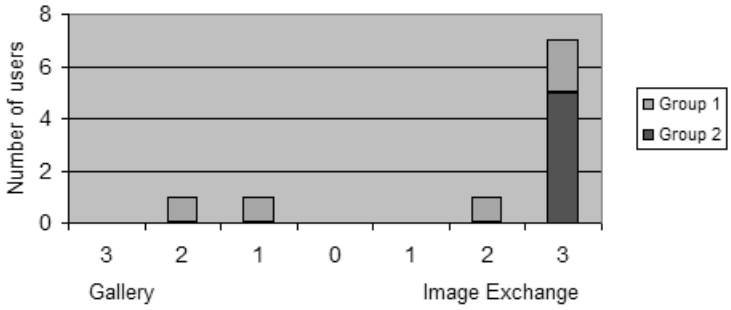


Figure 4.8: 7 out of 10 participants preferred Image Exchange very strongly and 8 participants in total.

The Image Exchange application was especially appreciated because of the user experience (Figure 4.9). The rating questions aimed to include different aspects of user experience as defined by Hassenzahl [50]. The results showed that Image Exchange

scored better in 5 out of 6 questions. Particularly, the ease of use and the design solutions attracted the participants and they listed the ease of use and simplicity as the key design solutions of Image Exchange. The participants enjoyed the use so much that they would even recommend it to an interested friend. Furthermore, the participants considered Image Exchange to be excellent and support the self-image that they want to show to the others. The participants explained that they highly appreciated the look of the application and they described it as ”stylish”, ”modern” and ”beautiful”. Image Exchange also managed to surprise the participants positively from time to time and they commented that the application was fun to use.

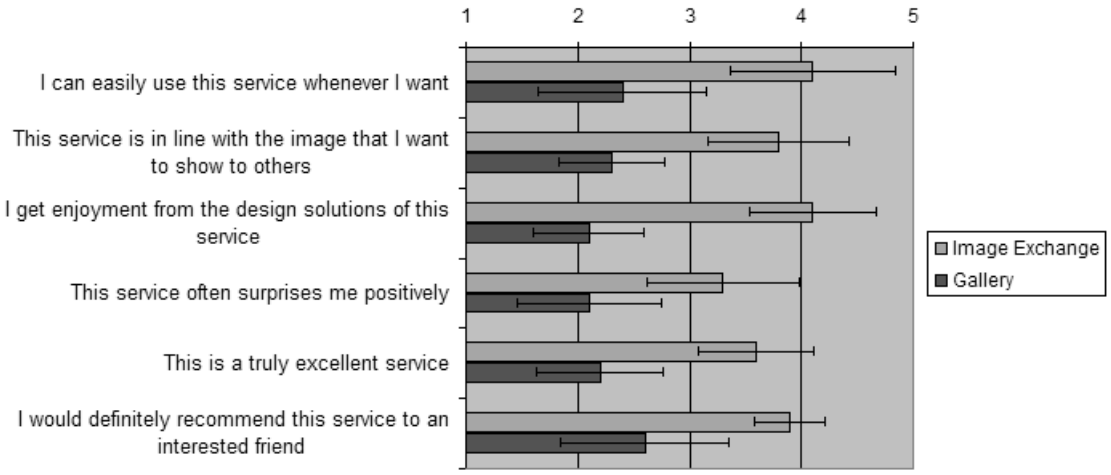
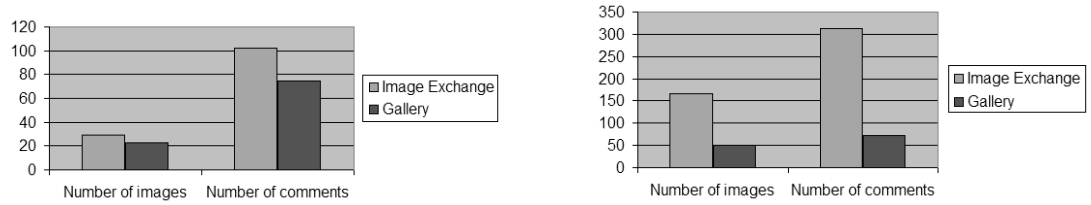


Figure 4.9: The Image Exchange mobile application scored significantly better in 5 out of 6 user experience evaluation questions. The results include standard deviation.

The user experience evaluation also explained why Image Exchange was strongly preferred by the participants compared to the Gallery application. The participants took pleasure in using the solution even though they also got things done with the Gallery application. Image Exchange enabled the participants to interact enjoyably with one another in real-time on the go, while the Gallery application still required the participants to take care of many tasks (e.g., uploading an image, synchronizing

the image data) before they could concentrate on the actual communication.

The results of the social activity within the participant groups are shown in Figure 4.10. The social activity was measured through the number of published images and comments during the test periods. The results revealed that the participants were more socially active when using Image Exchange, which could indicate that a better user experience encourages users to use Internet services more actively. Moreover, the social activity was not dependent on the order in which participants used the applications and services, as both groups used Image Exchange more frequently.



(a) The results of social activity of Group 1.

(b) The results of social activity of Group 2.

Figure 4.10: The participants of the study were more socially active when using the Image Exchange mobile client application.

4.2.4 Summary

Image Exchange demonstrates a solution, in which the mobile use of an Internet service is supported via a fully service-integrated mobile client application. The application is optimized for the requirements of the service and it strives to take full advantage of mobile device resources and capabilities. The user interface design of the application is unique as it is developed purely for the mobile use and the corresponding Internet service.

A fully service-integrated mobile client application has an opportunity to provide a pleasant user experience for the use of Internet service. There are several reasons for this:

- The mobile user interface can be optimized for the needs of the Internet service: Navigation in the user interface can be simplified and the service can send an update to the client without a separate request from the user.

- The mobile user interface can directly utilize device capabilities: Technical details are hidden from the user and smart defaults can be offered to remove the need for modifying complex settings. Many functions can also be automated and the need for user input decreases. Furthermore, the user interface is able to offer an immediate experience and becomes more aesthetically pleasing and fast as it can benefit from the rich user interface features. Finally, the mobile client application can also be used when offline.

- The full integration with the corresponding Internet service improves the user experience: The content is always up-to-date between the mobile client application and the Internet service. There is no need for manual updating thus fitting better to the mobile context of use.

In practice, developing a mobile client application for each Internet service is not feasible. It requires a lot of design and implementation work, especially if it is aimed to function on many platforms. Hence, in cases such as the deployment of a new Internet service it may be more practical to concentrate on making the user experience of the Web site of the Internet service as pleasing as possible and let users access it with their mobile Web browser.

5 Conclusions

The Internet is going mobile. Mobile devices have become more technologically sophisticated and they can be used to access the Internet anytime, anywhere. In particular, many Internet services are relevant for people on the go, and people find it meaningful to access them via their mobile devices. However, the user experience of Internet services on a mobile device still requires improvement. Mobile devices have many enablers to offer, but these have not yet been fully utilized in supporting Internet services.

Today, there are two approaches to support the use of Internet services on a mobile device. The assumption of this Thesis was that the main approach is currently the mobile Web browser, which can generally support the use of several types of Internet services in a similar way as on a PC. However, the mobile Web browser is not optimized for any Internet service and thus cannot offer an optimal experience for a specific Internet service. Thus, a future solution to support the use of Internet services may be a mobile client application that is fully integrated to the corresponding Internet service. The mobile application is capable of utilizing the platform capabilities and optimizing the user interface for the needs of the Internet service. Hence, it has a possibility to provide a better user experience than the mobile Web browser. Nonetheless, the development of a mobile client application might be laborious and not feasible for every platform.

The related work has extensively identified the limitations of a mobile device. Furthermore, general guidelines for mobile user interface design are available in the literature proposing solutions to the limitations. Many research studies have also introduced design guidelines in a specific scope, including the use of particular services on a mobile device. However, what has remained to be addressed, is the definition of design implications that would assist other practitioners and the mobile industry in designing mobile user interfaces for Internet services. The design implications could

be applied to mobile Web browsers and client applications. Furthermore, there has not been any research on exploring what differences can be found in characteristics of a mobile Web browser and a mobile client application in terms of user interface design.

5.1 Answers to research questions

The main research question of this Thesis was (as defined in Chapter 1.3):

What are the design implications that need to be considered when designing mobile user interfaces for Internet services?

The focus was not to define how to design Internet services but to investigate how to support them on a mobile device in regards to the user interface. As an answer to the main research question, I have defined the following design implications drawn from the conclusions of the Minimap study (Chapter 4.1.3) and completed with the findings of the Image Exchange study (Chapter 4.2.4):

Content optimization. In the mobile Web browser, the Web content should be optimized to match the output capabilities of a mobile device. It should at least have a visualization method that modifies the content for the small screen (as presented in [P1]). The mobile client application can optimize the user interface for the needs of a specific Internet service including its content [P4].

Utilization of desktop and mobile usage patterns. The mobile Web browser should utilize the familiar desktop usage patterns, but also introduce novel solutions for mobile use [P1-P3]. The mobile client application can be uniquely designed for a mobile device and mobile use [P4].

Full exploitation of device capabilities. The user interface of the mobile Web browser should offer a pleasant user experience via a good use of the 5-way navi-

gation key, a small-screen, and a consistent interaction [P1, P3]. The mobile client application can utilize the rich user interface features that a mobile device has to offer including enhanced graphics and immediate feedback [P4, P5].

Compensation for device resources. The mobile Web browser should introduce unique user interface solutions to compensate for the limited mobile device resources [P2]. The mobile client application has an opportunity to fully utilize device capabilities to hide technical details from user, offer smart defaults, automate functions, and enable offline use [P4, P5].

Content update. The mobile Web browser is able to offer manual updating as well as automatic downloading of Internet content. It should optimize the updating in such a way that it is useful to the user [P2]. The mobile client application can be fully integrated with the corresponding Internet service: It can provide an access to up-to-date content without requiring manual updating [P5].

The design implications aim to give guidance to other practitioners and the mobile device industry on how to support Internet services on a mobile device in terms of user interface design. It needs to be noticed that Image Exchange presents only one type of mobile client application and cannot provide general answers for other Internet services and their client applications. Every Internet service is unique in terms of content and user interaction, so each case should be considered separately. However, Image Exchange is able to provide hints about future solutions for supporting Internet services on mobile devices.

As an answer to the additional research question **"What differences can be found in characteristics of user interfaces for a mobile client application and a mobile Web browser?"**, the following initial findings can be outlined as a result of the Minimap and Image Exchange studies:

Generalization vs. optimization. The mobile Web browser offers a general support for Internet services on a mobile device. It is able to offer a good user

experience even though the interaction paradigm is not optimized for a 5-way navigation key or the needs of a certain Internet service [P1]. Developing a mobile Web browser requires design and implementation work but it needs to be done only once. A mobile client application can be optimized for a certain Internet service and has an opportunity to provide a good user experience for the service [P6]. However, supporting many Internet services through client applications entails a considerable amount of development work, especially if the target is to support many platforms.

Offline use cases. If the Internet service is useful in offline situations as well, a mobile Web browser can prepare for those use cases by, for example, saving relevant Web pages to the local storage of a mobile device [P2]. A mobile client application may have even better possibilities to support offline use cases. It can record user's commands and update the Internet service, when it is reconnected to the service. The mobile client application can also recover from connection errors.

Device resources. The mobile Web browser can run on many mobile devices today as it mainly counts on a data connection that can be created as needed and does not require other advanced device resources [P1-P3]. Thus, it seems to be the most common way to access Internet services on a mobile device. The mobile client application is able to take full advantage of always-on connectivity and it may also rely on extensive use of other device resources [P5].

Cost of usage. Both the mobile Web browser and client application can reduce the data connection costs with intelligent design solutions. For example, they can download content from the Internet only when a free WiFi network is available [P2]. The mobile client application is able to cut down the data costs even further by optimizing the amount of data sent to the service [P5]. When data is sent via the mobile Web browser, the user is generally in charge of the submitted data.

Account creation. If the Internet service requires account creation, the user experience becomes better if the user does not need to carry out a complex registration

or login process on the mobile device [P6]. The fully service-integrated mobile client application can optimize the registration process by utilizing the device data and thus eliminating a need for text input [P5].

User-generated content. If the Internet service is built around user-generated content, it is very convenient from the user's perspective if the content is automatically or with a little effort synchronized between the mobile device and the service [P6]. Thus, the fully service-integrated mobile client application can help in this aspect.

Amount of interaction. If the use of the Internet service requires a great deal of user interaction, for example, for browsing the content, the fully service-integrated mobile client application can provide a good user experience by having a fast and highly responsive user interface [P6].

The Minimap study showed that interaction paradigms can be successfully transferred from a PC to a mobile device with clever user interface solutions, even though the mobile device offers a more limited development environment. The Image Exchange study, on the other hand, indicated that the mobile client application is able to offer a pleasant user experience when it is carefully designed for a mobile device and mobile use. The mobile Web browser is less exacting on device resources and can deal with the limitations of a mobile device with inventive user interface designs, whereas the mobile client application aims to take full advantage of mobile device capabilities and offer a compelling user experience via a delightful user interface. The full integration to the Internet service is the key aspect in the design of the mobile client application, as shown by the user evaluations of Image Exchange.

5.2 Influence of the research

Today, both Minimap and Image Exchange are publicly available for users of Nokia devices. Both solutions have got a great deal of positive feedback in the public and been described as pioneers in supporting Web browsing and the use of Internet services and in creating unique user interface solutions for mobile devices.

A modified version of our original Minimap Web browser is installed to the latest Nokia S60 devices. The first S60 devices including the browser came on to the market in 2006. The productized Minimap Web browser includes all the main features related to the Web page visualization and Web history. The support for multiple windows and the Auto-update concept has only been implemented on top of the Minimap Web browser in our research projects. According to a research study, 70% of Minimap browser users chose their Nokia phone partly due to the browser [71] so it has clearly been a success. Also, in the academia, the research work has had an effect on the work on defining user experience [117].

The Image Exchange photo sharing service was launched in Nokia Beta Labs in December 2008 and it has many users worldwide. The mobile client and the Web site are accessible in Nokia Beta Labs [18] [19]. As Image Exchange presents a new type of mobile application for Internet services, it has also been an important novel example in the research area of mobile Internet user experience [119].

Nowadays, Nokia is investing strongly in Internet services in addition to mobile devices. It has launched a set of Internet services under the Ovi environment [20] including services for music, images, maps, and other personal content. Thus, it is extremely important for Nokia to ensure that these services work seamlessly with the Nokia mobile devices as it is Nokia's biggest strength in the competitive area

[18] Nokia Beta Labs, available at *http://betalabs.nokia.com/*. Accessed September 2009.

[19] Nokia Image Exchange, available at *http://imageexchange.nokia.com/*. Accessed September 2009.

[20] Nokia Ovi, available at *http://www.ovi.com/services/*. Accessed September 2009.

of Internet services. The research work employed in this Thesis has aimed to build the basis for creating a positive user experience for Internet services on a mobile device. The work should continue as new services and new mobile technologies are introduced continuously. As both projects, Minimap and Image Exchange, are available for people, they will be able to gather input and help Nokia in designing future solutions.

6 Discussion and future work

The research approach employed by this Thesis was design-science research and the output was the design implications as presented in Chapter 5.1. The design implications were defined through two studies, Minimap and Image Exchange, presenting the alpha- and beta-testing phases in the research process, respectively. However, Image Exchange exemplifies only one type of mobile client application and is not able to provide general guidelines. Every Internet service is a unique combination of features, interaction, and content, and needs to be considered separately. More work needs to be conducted and the design implications should be tested with alternative mobile client applications in their contexts to continue the design-science research process and form general design implications for user interfaces of mobile client applications.

Additionally, it might be beneficial in the future to explore more deeply how two approaches, a mobile Web browser and a mobile client application, compare with each other. By designing and evaluating mobile client applications of different Internet services, the design guidelines could be expanded to answer questions such as when it is beneficial to develop a mobile client application for an Internet service and when the support via a mobile Web browser is enough. For example, a fully service-integrated mobile client application might be more demanding than a mobile Web browser in regards to device resources as it may require a full integration with the corresponding Internet service. Thus, the needed enablers should be evaluated when charting whether it is sensible to develop and implement a mobile client application for an Internet service. Such questions are relevant as developing a mobile client application is not be feasible for all Internet services because it requires development work and the software also need to be maintained.

Another topic for future research is to explore new enablers for mobile client applications. Today, Web technologies such as JavaScript and HTML enable the creation

of Web applications that may appear as separate applications in the user interface of an operating system, but actually run on top of the Web browser and its engine. The benefit of these applications is that they are platform-independent and can be updated and maintained easily without software distribution or installation. The client-side processing enables immediate experience that does not require the Web page to reload after submitting information.

One use case for Web applications has been Web widgets. Many mobile device platforms, such as Nokia's S60 and Apple's iPhone, support mobile Web widgets as mentioned in Chapter 2.2.3. The mobile platforms commonly offer a JavaScript API, through which widgets can selectively access device resources and utilize content available on a mobile device. However, the widgets cannot freely utilize the device capabilities but are restricted by the scope of the API. The tools for designing user interfaces optimized for a 5-key navigation control are also still very limited. For example, the only methods that Nokia Widgets provide related to user interface design are for accessing the Options menu of the S60 platform. This results from the fact that Web interaction is designed for a pointer as an input method. In addition, mobile widgets are still platform-dependent, although the standardization process has been initiated [22].

Mobile devices are also starting to support Flash as a method for creating rich Web applications (e.g., Flash Lite [21]). Flash applications require a plug-in support from Web browsers but are also platform-independent as the more traditional Web applications. Flash enables richer interaction methods in the user interface than Web widgets as it is not limited by the functionality that the Web browser offers. However, device platforms still restrain Flash applications from using all the capabilities that they offer to mobile client applications.

Many Internet services nowadays offer a mobile Web site to support mobile use.

[21] Flash Lite, available at *http://www.forum.nokia.com/Technology_Topics/Web_Technologies/Flash_Lite/*. Accessed September 2009.

People can access the Web site through their mobile Web browser. The mobile Web sites are optimized for small screens and they aim to contain only information that is relevant for mobile use. Thus, they are able to save on the amount of transferred data and make navigating within pages faster. Google's Android phone takes a full advantage of the mobile Web sites and offers direct access to the Internet services so that people do not even need to start their mobile Web browser. In that case, people might not even realize that they are using a mobile Web site instead of an application. This is an especially sensible solution when the device offers a touch user interface as the Web interaction is designed for a pointer. However, offline situations need to be carefully considered in the case of mobile Web sites and Web widgets if they appear as traditional mobile applications from the user's perspective. Many parties have seen the opportunity in mobile Web widgets and sites and there is already on-going work on how to enable offline Web applications, such as Google Gears [22] and the HTML 5 specification and its APIs for offline Web applications [52].

In the future, all these methods have a chance to serve as powerful methods for supporting the use of Internet services on a mobile device. In particular, as mobile devices are increasingly equipped with new input mechanisms, such as touch, it gives an opportunity to create a positive user experience through more light-weight mechanisms (e.g., Web applications) than through implementing a mobile client application that runs directly on top of the platform. Moreover, the methods that are capable of solving the interoperability issue of different platforms have a chance to succeed in large-scale. Image Exchange is well suited for such experiments and the future plan is to compare in more depth different technologies and modalities for the user interface and their effect on the user experience. Internet services will continue to be an important part of people's online life and mobile devices have a good chance to become the prime method to access them.

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