Challenges in Human-Computer Interaction Design for Mobile Devices

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***Abstract*—Designs in human-computer interaction (HCI) aim to create interactive products that are easy and enjoyable to use. However, owing to the multidisciplinary nature of HCI and the different value systems of interface users from various backgrounds and experiences, it is highly challenging for designers to create applications which are usable and affordable to such a heterogeneous set of users. Nowadays, more and more people are heard complaining about the bad interaction design of mobile devices. Is this problem caused by the bad design of products or by the users' ignorance of the logics of human-machine interaction design? This paper aims to explore the human-computer interaction challenges in designing applications in both hardware and software for mobile devices. It also makes an attempt to investigate the principles for designing mobile interfaces that result in greater user acceptance and figure out possible solutions to the problems with interaction designs for mobile devices.**

Keywords: Human-computer interaction, mobile interface, mobile device, interaction design.

I. Introduction

Human-computer interaction (HCI) is the study of the interaction between people and computers [1]. Such interaction is mainly done at the user interface. One of the major concerns of professional practitioners in the field of HCI is the design of interactive computing systems for human use. As a result, it is a basic goal of HCI designers to make computers more usable and more receptive to the user's needs. To provide the best possible interface within given constraints, the HCI designers are supposed to develop systems that minimize the barrier between the human's cognitive model of what users want to accomplish and the computer's understanding of the users' task [2].

Interaction between users and computers occurs at the user interface, including both hardware and software. Interaction design means designing interactive products to support people in their everyday and working lives. Because HCI concerns a human and a machine in conjunction with each other, designing a user interface requires knowledge on both the human and the machine side. On the one side, information about communication theory, graphic disciplines, social sciences, cognitive psychology, etc. are needed; on the other side, techniques in computer graphics, operating systems, programming languages, etc. are required.

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Mobile devices play an important role in the modern society. They are being used by people of all walks of life for various purposes. They can be found in the fields of education, entertainment, medicine, communication service, military systems, and so on. Due to the multidisciplinary nature of HCI, designing user interfaces for mobile devices poses several interaction challenges [3]. Some of these challenges are hardware-related, while the others software-related.

II. Statement of Problem

Owing to the fast development in the digital technology, the operation of human-computer interface is becoming more and more complicated. Consequently, to catch up with the speedy and fleeting transformation, the user of digital interactive products can only keep on learning various operating interfaces, programming languages, and development environments. Nowadays, in our daily lives, we can hear more and more people complaining about the bad design in interaction interface. Is this problem caused by the bad design of the interactive products or by the shortage of users' knowledge about the logics of the human-machine interaction design?

Most researchers in HCI take interest in developing new design methodologies, experiencing with new hardware devices, prototyping new software systems, and exploring new paradigms for interaction. Designs in HCI aim to create user interfaces which can be operated with ease and efficiency. Many digital products that require users to interact with them to accomplish their tasks have not necessarily designed with the users in mind. The designer always claims how usable the products are; however, an even more basic requirement is that the interface should allow the user to carry out relevant tasks completely. In other words, the design must be both usable and useful for the user and it must be a user-centered design.

Current mobile computing devices such as palmtop computers, Personal Digital Assistants (PAD), and mobile phones have a problem in common—attempting to provide users with powerful computing services and resources through small interfaces [4]. As is usually the case with mobile devices, limited screen size makes it difficult to efficiently present information and help users navigate to and from the information they want. And since mobile devices are often required to possess multiple functionalities, the convergence of electronics, computing, and communication is becoming a

must in the mobile industry. In addition, because mobile devices need to operate with limited battery charge, how to deal with the power consumption has also become one of the most important issues for system designers.

Therefore, it is very crucial for interface designers to make efforts to develop interactive mobile products that are easy to learn, effective to use, and provide an enjoyable user experience. Nowadays, mobile devices are widely used by different types of people who have different goals of operating such interactive products. Designing applications for usable and useful mobile devices to meet the requirement of different types of interface users encounter a couple of challenges. Users, designers, and technical practitioners should cooperate and collaborate to contribute to its success.

Based on the problems in HCI design for mobile devices mentioned above, this paper addresses the following research questions:

1. What are the major challenges of designing interactive products for mobile devices?
2. What are the possible solutions to such problems in developing a good user-centered design for mobile computing devices?
3. What are the principles of user interface design for mobile devices?
4. What are the new trends in mobile industry in the near future?

III. MOBILE DEVICES

Mobile devices can be defined in different ways when they are looked at from different perspectives. They can be defined in terms of the services they offer or based on the level of functionality connected with the devices. According to Sharp et al. [2], they refer to the devices that are handheld and intended to be used while on the move. Nowadays, mobile devices are being used by different people for various purposes.

A. Types of Mobile Devices

A mobile device refers to a pocket-sized computing device, typically having a small display screen, a small keypad with miniature buttons or a touch screen with stylus of input. Examples of mobile devices include mobile computers like handheld or palmtop PC and personal digital assistant (PDA), handheld game consoles such as Nintendo DS and Game Boy Advance, media recorders like digital still camera (DSC) and digital audio recorders, and communication devices such as mobile phones, cordless phones and pagers. As is often the case, mobile devices have wireless capability to connect to the Internet and home computer systems. However, wireless capability poses a number of security risks. It takes considerable knowledge of the threats posed to mobile devices to deal with the risks.

B. Use of Mobile Devices

Mobile devices are increasingly being used by different types of people. In medicine, for instance, PDAs are used to record symptoms for patients and to support the cardiologist in the medical decision-making process and have been proven to help both diagnosis and pharmacy selection [5]. Besides, they are also used to improve the effectiveness of communication between the patient and the hospital during follow-up treatments.

In education, mobile devices are being used in different schools and universities for specific applications under the name of mobile learning or m-learning. M-learning is the use of mobile or wireless devices for learning while the learner is on the move. It has been found that m-learning has more advantages compared to electronic learning or e-learning [6, 7]. And they are also used in cooperative educational activities where teachers and students can collaborate by using common mobile devices to transfer information between each other [8]. Other common educational applications for mobile devices include electronic dictionaries, translators, scientific calculators, remote presentation controls, etc.

Another important use of mobile devices is that in entertainment. People are widely using mobile devices for playing music, watching movies, playing games, and so on. For example, mobile games have been increasingly used by people of various backgrounds to the extent that nowadays we can hardly find a mobile phone that does not have some video games installed in it by the manufacturer.

Global Positioning System (GPS) is another well-known use of mobile devices. It is a satellite navigation system owned and operated by the U.S. Department of Defense and available for general use around the world [9]. A GSP receiver is used to get the signal from the orbital satellite to pinpoint the geographic location. It can be a personal computer, a laptop or palmtop, a watch, a mobile phone, or a PDA. Some PDA-based GPS systems, for example, have been found to be very useful for geological mapping projects in remote regions and in situations where there is limited power supply [10].

C. Operating Systems for Mobile Devices

Several operating systems developed by different companies and programmers are being used to run mobile devices. One of them is Microsoft Windows Mobile, which is a compact operating system developed and owned by Microsoft Corporation. Windows Mobile has been updated several times, with the current version being Windows Mobile 6.1, which was announced on April 1, 2008 [11]. Windows Mobile 6.1 is a minor upgrade to the existing Windows Mobile 6 platform. It makes it easier to stay connected and manage your life from just about anywhere. Devices running Windows Mobile include Pocket PCs, Smartphones, Portable Media Centers, and on-board computers for certain automobiles.

Palm OS, also known as Garnet OS, is another widely-used operating system for mobile devices. It is an embedded operating system originally developed for personal digital assistants by U.S. Robotics owned Palm Computing, Inc. in 1996. Then Palm OS changed its owners for several times. On January 25, 2007 one new owner, ACCESS Systems Americas, Inc., announced a name change to their current Palm OS Garnet computing system, now titled 'Garnet OS'. The latest stable version of Garnet OS is Garnet 5.4; it presents standard communication libraries for telecommunication, Wi-Fi, and Bluetooth connectivity (http://www.access-company.com).

IV. Interaction Design

Interaction design is a term used by different people from various backgrounds. The term is used to describe different activities in designing and creating different artifacts including artistic objects, websites, PC applications, GPS systems, etc. It makes it difficult to define such a term. Sharp et al. [2] defined this term as "designing interactive products to support the way people communicate and interact in their everyday and working lives" (p. 8). From this definition, we can observe two key points of interaction design. For one thing, the authors attempted to emphasize that interaction designers have to deal with their designs from the consumer's perspective; in other words, they must involve users in the designing process. In addition, interaction designers ought to view their designs as products that are going to be sold in the market. The other key point here is that these interactive products should be useful for their potential users in their daily lives; it follows that interactive products should help people in their homes, offices, stores, vehicles, and anywhere they are.

Another definition of interaction design was proposed by Terry Winograd [12], who defined this term as "the design of spaces for human communication and interaction", and "the construction of the 'interspace' in which people live, rather than an 'interface' with which they interact" (p. 149). Once again, this definition put an emphasis on the importance of understanding the user's need in the process of designing products. In some way, this definition draws a clear line between interface design and interaction design. Interface design is part of the development process of interaction design, while interaction design includes more processes than just the interface design.

Academically speaking, according to Jones and Marsden [13], interaction design is the discipline of defining the behavior of products and systems in response to their users. Some basic principles of cognitive psychology provide an underlying foundation for interaction design. Interaction designers lay a great emphasis on user goals and experience and evaluate designs in terms of usability and affective influence [2]. Good interaction design is user-centric; its goal is to reduce frustration and increase user productivity and satisfaction. It is the user that makes actual use of a product or system. Therefore, only by involving real users can an interaction designer appropriately tailor and maximize usability.

Varieties of processes are involved to end up with an effective interaction design. These include understanding people's needs and establishing their requirements, developing prototypes, usability testing, and system evaluation. They are a set of activities that are iterative [2]. It means that the design process does not occur in a one-way or clear-cut fashion; instead, designs are formed and reformed over and over again in the process.

V. Challenges in HCI Design for Mobile Devices

Designing user interfaces for mobile devices implicates many human-computer interaction challenges. In this section, the researcher will explore these challenges in HCI design for mobile devices in terms of hardware-related challenges and software-related challenges.

A. Hardware Challenges

Due to the limitations of size and weight for portability purpose, the interface design for mobile devices comes with more hardware challenges when compared to other regular-sized devices such as desktop phones or printers; these challenges include limited input facilities, limited output facilities, and designing for mobility.

Limited Input Facilities

According to Muhanna [14], there are three main input facilities for mobile devices that are on the market: the keyboard, the stylus with the touch screen, and the scroll wheel. The keyboard allows a user to hit a key to perform a task or navigate through the mobile menu functionalities; the stylus with the touch screen allows a user to hit the screen to do the task; the scroll wheel can be scrolled and pushed by a user to do a task and also navigate through the menus and submenus.

The design of keyboards for mobile devices has been a challenge because the space for key installation on a mobile device is limited. In an earlier research, the authors claimed that the size of a keyboard in a mobile device does not affect data entry rates; they also found that making a smaller keyboard does not increase error rates [15]. However, the later researches showed that mobile interfaces can be quite tricky and cumbersome to use when compared to the fully-blown GUI, especially for those with poor manual dexterity or fat fingers and those who have difficulty in selecting tiny buttons on mobile devices [16].

Research directions on this limitation have come up with different alternatives and solutions. Green, Kruger, Faldu, and Amant [17] described a specialized keyboard 'Stick' that maps four rows of a standard QWERTY keyboard onto the home

row to decrease the physical space. However, a drastic key reduction in order to achieve sufficient portability decreases text entry performance, and requires additional effort to learn a new typing method. Kim, Sohn, Pak, and Lee [18] adopted a new keyboard minimization method of reducing key pitch to address this problem, and have developed the One-key Keyboard that gives consideration to social acceptance, input speed, and learnability.

The stylus and touch screen which are widely used in personal digital assistants and smartphones can be a good alternative for the keyboard in some cases. However, touch input would be problematic if the screen of a mobile device is small and that would lead a user's fingers to occlude the graphical elements he wishes to work with. There have been different solutions trying to address this limitation; one of them, for example, is allowing the user to control the application by touching the back of the device [19].

The scroll wheel can be a different solution as well to overcome the challenge of the limited input facilities in mobile devices. According to Sears et al. [15], a scroll wheel can be used to navigate a mobile device menu in one direction, either horizontally or vertically. It can also be used as a push button to do a specific task to support the use of one hand to interact with the mobile device [20].

Limited Output Facilities

There are various output facilities that are used on mobile devices. The small-sized screen is one of the mainly and most commonly used output facilities for mobile devices. Designing the screen for outputting is a trade-off challenge that needs to be experimentally studied to find out which is the efficient and most effective size of the screen that can be used for the different types of mobile devices [14]. For example, having a larger screen can solve a limited output facilities challenge; however, it will bring up another challenge of designing for mobility that will be discussed in next subsection.

The audio output is another output facility that is commonly used on mobile devices. It can be a good output facility for feedback messages to the user, and can be used in conjunction with the graphics and text messages to have an effective interaction between the human and the device [14]. The importance of audio is increasing as we are moving towards multimodal user interfaces where audio is one of the major components. By utilizing real-time signal processing, ways of using audio feedback become more efficiently and intelligently in mobile user interfaces. Sound effects are capable of passing information to the user to some extent, but they are more useful in impressing the user and making existing audio feedback sound better [21].

Designing for Mobility

A mobile device should be portable and easy to be held by the user, and this brings up the big challenge of designing for mobility [22]. The power facility in a mobile device is the main challenge of designing for mobility that is characterized by limited and dynamically varying available resources and stringent application requirements.

Ashwini, Thawani, and Srikant [23] indicated that the power consumed by an application depends on the performance level requested by the user or application, and that the mobile device can be viewed as the collection of devices. They proposed a power management middleware for mobile devices, which not only considers energy savings for the processor but also optimizes energy savings for other devices such as display unit, RF unit, keyboard, and memory.

The power management of mobile devices is getting more important as ubiquitous computing is coming true in daily life. The power aware system management relies on techniques of collecting and analyzing information on the status of I/O devices or processors while the system is running applications; however, the overhead of collecting information using software while the system is running is so huge that performance of the system may be severely deteriorated. Therefore, it is very crucial to design a power management unit which collects information in hardware so that the performance of the system is not degraded [24].

B. Software Challenges

Software-related challenges in HCI design for mobile devices have also interested many researchers and industrial developers. In the rest of this section, the current researcher will explore the mainly recognized challenges in designing software applications for mobile devices.

Hierarchical Menus

According to Paap and Roske-Hofstrand [25], having a menu in a desktop application can help the experienced users find the items they want in a fast manner. However, taking a successful design from a desktop and apply it to a mobile device without a clear understanding of the translation inputs and outputs can lead to an ineffective interaction design [2]. The mainly and widely used alternative is the use of hierarchical menus. With a hierarchal menu, a user can select a menu item that can then open another submenu; and so on until the user reaches the desired function he or she is aiming to reach.

In the last few years, there have been plenty of research studies regarding the layout of the hierarchal menu in a mobile device, aiming to find an optimal way to structure information hierarchically. For example, in a research, it was found that an effective interaction with a hierarchal menu can be achieved by having as many menu items as needed in the root menu and the final level of menu structure, and as less menu items as possible in the intermediate levels [26]; while in a later research, the most effective hierarchy for use with mobile devices was found to be one with only four to eight items on each level and it was better to order in a hierarchy with more levels than in a hierarchy with more items per level [27].

Navigating and Browsing

Navigating and browsing also pose challenges in HCI design for mobile devices that generally have small screens. According to Wang and Sajeev [4], to display information that is well suited for larger screens, the information has to be segmented into many small presentation units that can fit into the small screen of mobile devices. And this makes it difficult to effectively organize information and help users navigate to and from the information they want. Therefore, the researchers presented a new interface technique 'Roller' that helps alleviate the screen real estate limitations in user-interface design and provides rich contextual information to ease users' navigation tasks.

In another research study, Anderson, Hirsh, and Mohr [28] presented a unique interface design for mobile devices that addresses major user pain points with deep menu systems and page scrolling. Using a series of one to five wheels of content, arranged in a combination-lock style on a single mobile screen, this design enables a user to consume a multitude of personalized internet and web content without ever scrolling up/down or selecting from a menu. The researchers claimed that the results from iterative testing across US, Japan, and China show the model to be an effective and desirable mode of consuming personal and internet content on the mobile device, despite very different navigation paradigms and cultural expectations in each of the countries.

Images and Icons

Images and icons are commonly admitted as important types of data and information visualization in desktop computers. However for mobile devices, it is still quite restricted compared to desktop computers with regard to the display of graphical representations, such as images, drawings, diagrams, maps, and logos. Therefore, how to downscale the images from a regular size in a personal computer to the appropriate size in a mobile device is an important research direction that should not be neglected [29].

Rosenbaum, Schumann, and Tominski [30] indicated that mobile devices suffer from limited resources due to size and application, especially if large graphical content must be displayed; the needed system resources often exceed the capabilities of a mobile device. Their research concluded some guidelines for the display of graphical content described by raster and vector graphics on mobile devices to allow appropriate and resource-saving implementations.

VI. Conclusion

This paper aims to explore the human-computer interaction challenges in designing applications in both hardware and software for mobile devices. Since mobile devices are being increasingly used by more and more people of all walks of life and from different backgrounds and experiences, user interface designers are sure to meet with more and more challenges in designing applications for such devices. A key design challenge is how to make such devices usable and affordable to a heterogeneous set of users. Portability is the main core of the design to meet the requirement of mobility. As a result, miniaturization of hardware seems to be the trend in the future development in HCI for mobile devices. For instance, most mobile devices are pocket-sized computing devices, so they must have a display screen with touch input or a miniature keyboard. More and more palmtop or simply handheld computers will take the place of desktop or laptop ones to meet the needs of varieties of people on the move.

Owing to the need for portability, mobile devices generally have small-sized screens. However, designing for mobility or portability poses a trade-off challenge for HCI designers. Current mobile computing devices share a common problem—attempting to offer users access to powerful computing services and resources through small interfaces, which usually have tiny visual screens, limited input and out put facilities, and poor audio interaction techniques.

Due to the limitations of size and weight, compared to the regular-sized devices like desktops, the design for mobile devices comes with more hardware challenges. Small-sized screens make it difficult to present information, especially when information of large volumes must be displayed, because they have to be split into lots of small blocks to fit into the small device. To address this problem, a 3D-oriented interface which can present both linear and hierarchical data can be a nice alternative. Specialized keypads, styluses with touch screens are also indispensable techniques for mobile computing devices.

For the part of software technologies, designers will encounter even tougher challenges in designing mobile interfaces. A key question for interaction design here is: how do designers optimize the users' interactions with the interactive system and operating environment so as to identify the users' needs and match their activities that are being supported [13]. In order to design usable, useful, and enjoyable systems, interface designers and technical practitioners should always take into account the people who are going to use the interactive products, where the products are going to be used, what may help users with the way they are doing things, and what may provide quality user experiences. Just as Sharp et al. [2] put it, there are three key characteristics of interaction design process: a user focus, specific usability criteria, and iteration. These are very similar to what Gould and Lewis [31] proposed as three principles which would lead to a computer system useful and easy to use. No design practitioners of interactive products can ignore practical users. However, on account of the different value systems possessed by diverse users, it is highly challenging to design products to eliminate the barriers between the human cognitive model of what the user wants to accomplish and the designer's comprehension of the user's task.

REFERENCES

[1] A. Dix, J. Finlay, G. Abowd, and R. Beale, *Human-computer interaction*, 3rd ed. New York: Prentice Hall, 2003.
[2] H. Sharp, Y. Rogers, and J. Preece, *Interaction design: Beyond human-computer interaction*, 2nd ed. New York: John Wiley & Sons, 2007.
[3] A. Sears and J. A. Jacko, Eds., *The human-computer interaction handbook: Fundamentals, evolving technologies and emerging applications*, 2nd ed. Boca Raton, FL: CRC Press, 2007.
[4] L. Wang and A. S. M. Sajeev, "Roller interface for mobile device applications," in *Proceedings of the Eight Australasian Conference on User Interface*, 2007, pp. 7–13.
[5] E. T. Velde, D. E. Atsma, R. Hoekema, J. E. Luijten, C. I. Buddelmeijer, H. J. Spruijt, and N. H. J. J. Putten, "A multicenter PDA project to support the clinical decision process," in *Proceedings of the IEEE Conference on Computers in Cardiology*, 2004, pp. 177–179.
[6] D. McPhee, N. Thomas, P. Thomas, and J. M. Ware, "Evaluating the effectiveness of m-learning in the teaching of multi-media to first year university students," *International Journal of Emerging Technologies in Learning,* vol. 1, no. 1, pp. 31−37, 2006.
[7] R. Ting, "Mobile learning: Current trend and future challenges," in *Proceedings of the Fifth IEEE International Conference on Advanced Learning Technologies*, 2005, pp. 603−607.
[8] M. Sa and L. Carrico, "Handheld devices for cooperative educational activities," in *Proceedings of the 2006 ACM Symposium on Applied Computing*, 2006, pp. 1145−1149.
[9] A. El-Rabbany, *Introduction to GPS: The global positioning system*, 2nd ed. Boston, MA: Artech, 2006.
[10] P. Clegg, L. Bruciatelli, F. Domingos, R. R. Jones, M. De Donatis, and R. W. Wilson, "Digital geological mapping with tablet PC and PDA: A comparison," *Computers and Geosciences*, vol. 32, no. 10, 1682−1698, 2006.
[11] Microsoft Corporation. (2008). Microsoft Windows Mobile. [Online]. Available: http://www.microsoft.com/windowsmobile [Accessed: Dec. 12, 2008].
[12] T. Winograd, "The design of Interaction," in *Beyond calculation: The next fifty years of computing*, P. Denning and R. Metcalfe, Eds. Santa Clara, CA: Springer-Verlag Telos, 1997, pp. 149−162.
[13] M. Jones and G. Marsden, *Mobile interaction design*. New York: John Wiley & Sons, 2006.
[14] A. Muhanna, "Exploration of human-computer interaction challenges in designing software for mobile devices," master's thesis, University of Nevada, Reno, USA, 2007.
[15] A. Sears and Y. Zha, "Data entry for mobile devices using soft keyboards: Understanding the effects of keyboard size and user tasks," *International Journal of Human-Computer Interaction*, vol. 16, no. 2, 163−184, 2003.
[16] K. A. Siek, Y. Rogers, and K. H. Connelly, "Fat finger worries: How older and younger users physically interact with PDAs," in *Proceedings of INTERACT'05*, 2005, pp. 267–280.
[17] N. Green, J. Kruger, C. Faldu, and R. Amant, "A reduced QWERTY keyboard for mobile text entry," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2004, pp. 1429−1432.
[18] S. Kim, M. Sohn, J. Pak, and W. Lee, "One-key keyboard: a very small QWERTY keyboard supporting text entry for wearable computing," in *Proceedings of the 18th Australia conference on Computer-Human Interaction,* 2006, pp. 305−308.
[19] D. Wigdor, C. Forlines, P. Baudisch, J. Barnwell, and C. Shen, "LucidTouch: A see-through mobile device," in *Proceedings of the 20th Annual ACM Symposium on User Interface Software and Technology*, 2007, pp. 269–278.
[20] A. K. Karlson, B. B. Bederson, and J. L. Contreras-Vidal, *Studies in one-handed mobile design: Habit, desire and agility* [Tech Report HCIL'06]. Computer Science Department, University of Maryland, College Park, Maryland, USA, 2006.
[21] H. Korhonen, J. Holm, and M. Heikkinen, "Utilizing sound effects in mobile user interface design," in *Proceedings of INTERACT'07*, 2007, pp. 283–296.
[22] B. A. Myers, J. Nichols, J. O. Wobbrock, and R. C. Miller, "Taking handheld devices to the next level," *IEEE Computer Journal*, vol. 37, no. 12, 36−43, 2004.
[23] H. S. Ashwini, A. Thawani, and Y. N. Srikant, "Middleware for efficient power management in mobile devices," in *Proceedings of the 3rd International Conference on Mobile Technology, Applications and Systems*, 2006.
[24] Y. S. Hwang, S. K. Ku, C. M. Jung, and K. S. Chung, "Predictive power aware management for embedded mobile devices," in *Proceedings of the 2008 Conference on Asia and South Pacific Design Automation*, 2008, pp. 36−41.
[25] K. R. Paap and R. J. Roske-Hofstrand, "The optimal number of menu options per panel," *The Human Factors*, vol. 28, no. 4, 377−385, 1986.
[26] R. Amant, T. Horton, and F. Ritter, "Model-based evaluation of cell phone menu interaction," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2004, pp. 343−350.
[27] A. Geven, R. Sefelin, and M. Tscheligi, "Depth and breadth away from the desktop: The optimal information hierarchy for mobile use," in *Proceedings of the 8th Conference on Human-Computer Interaction with Mobile Devices and Services*, 2006, pp. 157−164.
[28] C. Anderson, S. G. Hirsh, and A. Mohr, "Wheels around the world: Windows live mobile interface design," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems,* 2008, pp. 2113−2128.
[29] T. Rist and P. Brandmeier, "Customizing graphics for tiny displays of mobile devices," *Personal and Ubiquitous Computing*, vol. 6, no. 4, 260−268, 2002.
[30] R. Rosenbaum, H. Schumann, and C. Tominski, "Presenting large graphical contents on mobile devices - performance issues," in *Proceedings of IRMA'04,* 2004.
[31] J. D. Gould and C. H. Lewis, "Designing for usability: Key principles and what designers think," *Communications of the ACM*, vol. 28, no. 3, 300−311, 1985.