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INTEFACE DESIGN FOR HANDHELD MOBILE DEVICES

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Abstract

Mobile computing has attracted a lot of attention from both the industry and academia in recent years. While a number of mobile applications have been developed, there are no established guidelines on the design of mobile device interfaces. This paper presents our initial efforts to provide a set of practical design guidelines for mobile device interfaces.

Keywords: Handheld, Mobile, Guidelines, Interface, Device, Design

Introduction

Handheld mobile devices, including personal digital assistants (PDAs) and cell phones, have become increasingly prevalent. A well-designed and usable interface is critical, given the unique constraints of mobile devices (Johnson 1998, Tarasewich 2002). The most challenging problems facing mobile interface designers include (Holland and Morse 2001):

- Constantly changing context of usage
- Limited user attention given to the device and application
- Mobile device user’s hands are typically occupied with other physical tasks
- High mobility during tasks as well as the need to adopt a variety of positions and postures
- Interacting with devices while in motion (at high speed), driven by external environment

To address these problems and challenges, we review existing input/output interaction methods with mobile devices, and propose a set of mobile device interface design guidelines. Since mobile device interface design is more restrictive than desktop interface design because of constraints such as limited computing power, always-changing context, smaller platform sizes, and limited user attention (Gorienko and Merrick 2003, Satyanarayanan 1996), special design considerations are often needed.

While Shneiderman’s (1998) “Golden Rules of Interface Design” have existed for almost a decade, no similar rules have been developed for mobile devices. This paper presents our work-in-progress toward addressing this gap. Using Shneiderman’s “Golden Rules of Interface Design” as a starting point, we proposed a set of guidelines for mobile device interface design that is grounded in previous research on mobile device interface design and use.

Mobile Interface Design for Input Interaction

Input interaction refers to the different ways in which users can enter data or commands. Commonly used technologies for input interaction with mobile devices include keyboards, keypads, styluses, buttons, cameras, microphones, scanners, and sensors.

The standard QWERTY keyboard (named for the sequence of keys at the upper left of the keyboard) is being used on some
portable devices such as laptops. The problem with using a full keyboard is that users must adjust to smaller keys, which may even require users to learn to type messages with both thumbs on small handheld devices. Smaller keys pose data entry problems and increase error rates. On the other hand, devices such as phones and handheds usually rely on a limited keypad for input because of limited device space. As such, data entry can be very cumbersome.

Most phones use a standard 12-button numeric keypad. Each of the keys from 2 through 9 also corresponds to three or four letters. There are several common approaches for entering text using a keypad. One of them is known as the Multi-Tap input method in which the user must hit a key that corresponds to the desired letter multiple times to get to it. For example, the letter “i” would require that the “7” key (labeled with “pgrs”) be pressed four times. A user must also pause or press an additional key to move onto the next letter. A different method that uses two-key input requires selecting a letter’s group with the first key press and the location of the desired key with the second key press. For example, the letter ‘e’ (the second character on the “3” key which is labeled “def”) requires the key press sequence 3-2. Another approach uses dictionaries of words and linguistic models to “guess” the word intended by a series of keystrokes. For example, the sequence 8-4-3 (corresponding to “tuv”-“ghi”-“def”) might produce the word “the” out of all possible letter combinations.

Mackenzie and Soukoreff (2002) provided a review of existing text entry methods, including small keypad based methods (e.g., cell phone keypads, chording keypads) and stylus based methods, such as handwriting recognition, soft keyboards, and gesture input methods (e.g., Graffiti, Jot). Twiddler (Lyons et. al. 2004), one of the most well-known chording keyboard techniques, requires users to press more than one key at the same time in order to get a desired letter. While efficient for practiced users, it suffers the drawback of a slow learning curve. Similarly, gesture recognition methods may require users to memorize a set of specially designed gestures, and have greater hardware processing requirements. As another alternative, keyboards (or other key configurations) can be created virtually on a screen. These “soft-keyboards” use a Stylus to press the virtual keys. Soft keyboards currently suffer from a lack of tactile feedback often found on full keyboards, although feedback can be provided through sounds generated as keys are “pressed.”

One way to eliminate the use of a keypad for text entry is to attach a temporary keyboard to the device being used. Many vendors have developed miniature and/or full-size folding keyboards for this purpose. Examples of such keyboards include the Half Keyboard, fabric keyboards, gloves (Goldstein et al. 1999) and “finger rings” (Fukumoto and Tonomura 1997). A potential problem with these types of devices is the additional training time that may be needed to use the device effectively.

Mobile device input can also be achieved through mouse buttons, thumbwheels, and other special-purpose buttons. Pagers normally only have three or four buttons which can be used for text entry purposes (Mackenzie 2002). Mobile phones often have dedicated buttons with labels such as “call,” “ok,” and “clear” in addition to a numeric keypad. Mouse buttons are toggle switches that allow one-dimensional cursor movement. Small joysticks, which allow two-dimensional cursor movement, are sometimes found integrated into the keypads of laptop computers, and more recently on mobile phones. Handheld devices usually have a mouse button and a few other special-purpose buttons, but no keyboard or keypad. Some handheld devices also feature a built-in thumbwheel. However, the location of the thumbwheel limits which hand can hold the device for one-handed operation.

Using human speech as input to mobile devices is also becoming increasingly practical as voice recognition technology continues to improve. Voice input allows those users who cannot type or use a stylus to interact with a device. It may also be a viable interface alternative for devices too small for buttons or for those without a screen. However, voice input suffers from possible privacy and social issues. For example, users may feel uncomfortable speaking input aloud instead of typing or writing it, and certain places (e.g., libraries) might restrict the use of voice input to maintain a quiet environment.

With the shrinking size of camera lenses and the increasing sophistication of digital photography, video is becoming more common as a form of input with mobile devices. Video might also be used as input through the recognition of hand gestures or facial expressions. For example, MouthType (Lyons et al. 2004) is a system that uses a camera to recognize the mouth shape for text entry purposes.

Similarly, scanners may also become part of the wireless environment. They can be used for reading text, bar codes, or other symbols. Wireless devices that scan UPC symbols as input could be part of in-store mobile commerce applications used for comparison-shopping or for purchasing merchandise without the need of a cash register and sales attendant.

Finally, input can also come from sensing technologies that automatically sense environmental parameters. For example, the Global Positioning System (GPS) allows any device equipped with a GPS receiver to determine its geographic location within about 10 meters. All mobile phones sold in the U.S. will be required to have the ability to determine their location. There are also various other types of sensors that are capable of measuring parameters such as temperature, speed, direction, and heart rate.
Mobile Interface Design for Output Interaction

Output interaction concerns the ways in which users receive data, prompts, or the results of a command. Technologies used for output interaction with mobile devices include LCD screens, speakers, and tactile feedback.

The liquid crystal display (LCD) screen is the primary technology used to produce output in the form of images and text on current mobile devices. Screen size varies greatly from one type of device to another. Most mobile phones have small (1” to 2” square) screens that can display up to a dozen lines of approximately 20 alphanumeric characters each. Handheld devices have relatively larger screens (about 3” by 4”) that are more suitable for graphics as well as text, but are still limited by low screen resolutions (usually 240 by 320 pixels). Most phones and handhelds have color screens, which helps increase device usability.

The current limitations of screens on wireless devices are their size and resolution. These limitations make it difficult to display large amounts of text and graphic-based output (e.g., maps, charts, or Web pages). There are, however, recent technological developments that may address some of the disadvantages of current wireless device screens. Flexible screens are on the horizon, which may eventually allow screens that can be rolled or folded up. E Ink (www.eink.com) and Gyricon Media (www.gyriconmedia.com) are developing displays with electronic ink technology (e-paper). The screens hold an image until voltage is applied to produce a new image, using less overall power than LCD screens.

Monocular units or goggles can be used with magnifying glasses to enlarge small displays (less than an inch diagonal) so that they look like an 800 x 600 resolution monitor. Goggle-type products include InViso’s eShade (www.inviso.com/products), Sony’s Glasstron (www.ita.sel.sony.com/products/av/glasstron), and Olympus’ Eye-Trek (www.eye-trek-olympus.com). Microvision (www.mvis.com) is developing devices that project an image, pixel by pixel, directly onto the viewer’s retina. These types of devices allow viewing of color images with similar sizes and resolutions as those found on desktop computers. Potential concerns with these technologies include interference with users’ other visual inputs, and the social acceptance of wearing and using such technologies.

Sound is the other primary form of output from a mobile device. The different forms of this output range from words to music to various beeps, buzzes, and other noises. These can be created through speakers or through headphones. Laptops usually have a set of speakers built in for stereo sound production, while smaller mobile devices have a single speaker at best. Sound output may be a viable interface alternative for devices without a screen, although there may be difficulties in presenting certain visual information (e.g., graphics). Voice output is also generally produced and comprehended slower than visual output. On the positive side, sound allows those users who cannot see a screen to receive output. Ultimately, it may be that multi-modal browsing, where voice and visual output are combined, may be best suited for mobile devices (Nah and Davis 2001).

Interface Design for Mobile Device Usability

Mobile interface designers may not be familiar with the unique requirements of handheld computers, and therefore attempt to use desktop metaphors on their designs (Shoemaker 1999). Although mobile devices and their desktop counterparts share common usability concerns, there are many usability requirements that are unique to mobile devices.

In the following sections, usability requirements for mobile devices will be presented, starting with the well known Shneiderman’s eight interface design guidelines for desktop applications and their adaptation to the unique usability requirements for mobile devices.

Interface Guidelines That Carry Over to Mobile Devices

Among Shneiderman’s eight rules, four of them can be directly applied to mobile devices. These are:

Enable Frequent Users to Use Shortcuts

As the frequency of use increases, so does a user’s desires to reduce the number of interactions and to increase the pace of interaction. Because time is often more critical to a mobile device user (Poupyrev et al. 2002), reducing the number of operations needed to perform regular (i.e., repetitive) tasks is a key factor in the ease of use of mobile devices.
Offer Informative Feedback

For every operator action, there should be some system feedback, such as a beep when pressing a key or an error message for an invalid input value. Such feedback should be substantial and understandable by the user. For example, the messages “HTTP404 ERROR” and “THE PAGE CAN NOT BE FOUND” may be equivalent, but users are more likely to understand the latter than the former.

Design Dialogs to Yield Closure

Sequences of actions should be organized into groups with a beginning, middle, and end. Users should be given the satisfaction of accomplishment and completion, no matter whether they are using desktop computers or mobile devices.

Support Internal Locus of Control

Users want to be in charge of the system and have the system respond to their actions, rather than feeling that the system is controlling them. Systems should be designed such that users initiate actions rather respond to them. This guideline is applicable both to traditional desktop applications and mobile device applications.

Existing Usability Rules That Need To Be Extended

The remaining four of Shneiderman’s guidelines require modifications or extensions for application to mobile devices.

Consistency

Consistency takes on an additional dimension with mobile applications: the consistency across multiple platforms and devices for the same application (Chan et al. 2002). Users of mobile devices may need to switch between their desktop machines and different mobile devices frequently. For example, a user may want to transfer some documents from a home desktop computer to a PDA, read them while riding the subway, and call colleagues to discuss the documents with them. Hence, consistency should be maintained between desktop computers and PDAs (and possibly cell phones). Consistency can also be achieved by creating input/output interactions that are device independent. Isokoski and Raisamo (2000) proposed a Minimal Device Independent Text Input Method that can be used consistently across devices.

Reversal of Actions

Allowing easy reversal of actions may be more difficult for mobile devices because of the lack of available resources and computing power (Satyanarayanan 1996). However, because of the nature of mobile computing discussed earlier (limited attention, changing context, etc), users are more likely to make errors with mobile devices. Therefore, providing a flexible error reversal mechanism is critical for mobile interface design.

Error Prevention and Simple Error Handling

Preventing and handling errors on mobile interfaces are similar to that on desktop interfaces, although the need becomes more critical due to the more rapid pace of events in the mobile environment. Error prevention also needs to take the physical design of mobile devices into account.

Reduce Short-Term Memory Load

Given the limitations of a user’s short-term memory, interfaces should be designed such that very little memorization is required during the performance of tasks (Chan 2002). When in the mobile environment, a user has to potentially deal with more distractions than with a desktop computer (Tarasewich 2003). A mobile application may not be the focal point of the user’s current activities (Holland 2001), and a user may not be able to suspend his or her primary task to interact with the mobile device (Gorienko 2003, Kristoffersen 1999). Using alternative interaction modes such as sound can be beneficial (Poupyrev 2002).
Additional Design Focus and Guidelines for Mobile Devices

As we have seen in previous sections, input/output technologies for mobile devices are radically different than for traditional desktops. Therefore, design of user interface for mobile devices is also greatly different than for desktop computers (Shoemaker 1999). In the following sections, additional guidelines specifically for mobile device interface design are proposed, and they could be critical for design due to the unique characteristics of mobile devices and mobile users (Satyanarayan 1996, Gorienko 2003). In short, mobile device interface design is more restrictive than desktop interface design because of the challenges discussed earlier.

Design for Multiple and Dynamic Contexts

The contexts of computer applications used in the office, home, or similar settings are relatively stable. On the other hand, with mobile applications, there can be a significant number of additional people, objects, and activities vying for a user’s attention aside from the application or computer itself (Tarasewich 2003). Environmental conditions (e.g., brightness, noise levels, weather) can change depending on location, time of day, and season. The usability or appropriateness of an application can change based on these different context factors (Kim et al. 2002). For example, in the presence of strangers, users may feel uncomfortable speaking input aloud, and certain places (e.g., libraries) might restrict the use of voice input. Small text sizes may work well in office conditions but become unreadable in bright sunshine or in dimly lit surroundings. In addition, one or both of the user’s hands could be occupied while using a mobile device (Kristoffersen and Ljungberg 1999). Therefore, to account for the different contexts, allowing operations to be carried out with 0, 1, or 2 hands becomes extremely important to the viability of the interface (Kim et al. 2002). One way to solve the problem of changing contexts is to implement context-awareness capabilities and self-adapting functionalities (Hinckley et al. 2000). This can potentially reduce users’ effort and frustration, and increase the usability of applications. Usability in a dynamic environment could also be improved by devices that derive input indirectly from the user. Schmidt discussed a vision of mobile computing where devices can “see, hear, and feel” (Schmidt 2000).

Design for Multi-Modal Interfaces

As technology continues to advance, mobile platforms will continue to shrink in size and include items such as bracelets, rings, earrings, buttons, and key chains. New or modified interaction techniques may be necessary to overcome physical limitations of these devices. Speech input is a viable alternative for devices too small for buttons. Sound can also be used for output, taking the place of text or graphics. Holland and Morse (2001) investigated an audio interface for a navigation system that frees a user’s eyes and hands for other purposes.

Design for Limited and Split Attention

Users of mobile devices often need to focus on more than one task (Kristoffersen and Ljungberg 1999). A mobile application may not be the focal point of the user’s current activities (Holland and Morse 2001). Mobile devices that demand too much attention may distract users from more important tasks. Interfaces for mobile devices should be designed to require as little of the user’s attention as possible (Poupyrev et al. 2002). For example, this can be accomplished by designing for hands-free interaction or even eyes-free interaction. According to Gorlenko (2003), eyes-free interaction provides the greatest freedom of movement during interaction, as visual attention constrains body movement. Whenever possible, it might work better to use sound or tactile output to present information instead of visual displays (Poupyrev et al. 2002). A nice example of a limited attention interface can be found in Pascoe, Ryan, and Morse (1999), who developed a PDA application that allowed observers (using telescopes) to count the number of bites giraffes take from tree leaves without looking away from the animals.

Design for Speed and Recovery

For mobile devices and applications, time constraints need to be taken into account in application availability and recovery speed. When time is critical, waiting a few minutes for an application to start may not be in the user’s best interest. Given the different contexts under which mobile devices are used, users may need to quickly change or access functions or applications (Poupyrev et al. 2002). When such situations arise, a user would need to quickly and securely save any work already performed and resume it later without any loss.
Design for “Top-Down” Interaction

Mobile devices with small screens have limitations on the amount of information that can be presented at any one time. Reading large amounts of information from such devices can require large amounts of scrolling and focused concentration. To reduce distraction, interactions, and potential information overload, a better way of presenting information might be through multilevel or hierarchical mechanisms (Brewster 2002). For example, a mobile worker may not need or want the entire contents of a message. However, they may wish to receive a notification that a message is available, along with an indication of how important it is. That way, the worker can make their own decision whether or not to stop their primary task to access the contents of the message.

Allow for Personalization

Mobile devices, by their nature, are more personal. While traditional telephones and desktop computers can many times be shared among different users, a mobile device is usually carried and used by only one person. Therefore, it is more likely that a user of mobile applications will personalize the device and its applications to his or her preferences. Different users have different usage patterns, preferences, and skill levels. So it is important to allow for variations among users. For example, when visibility is good, it is reasonable to show more text on a screen; while in a dark environment, bigger fonts might allow better readability. However, the interface design should not exclude the possibility that some users may always prefer larger fonts regardless of the lighting conditions.

Design for Enjoyment

While functionality and usability are keys to mobile application success, other factors such as aesthetics and enjoyment are also important. Aesthetics refers to designing an overall enjoyable user experience with mobile devices. Karlsson and Djabri (2001) have begun to investigate “aesthetics in use”, which they define as dynamic interaction that invokes a positive affective response from the user. In addition, color and its manipulation are important considerations for visual interfaces. Shneiderman (1998) provided some interface color use guidelines that can generally be carried over to mobile devices, although some of the effects of color could be different on smaller screens. Holding functionality and usability constant, an application or device that is attractive will appeal more to users. Donald Norman, after years of stressing product design that focuses squarely on usability, realizes that emotion plays a large part in our interaction with objects (Norman 2004).

Guidelines for Mobile Interface Design

Based on the usability concerns for mobile device interface design discussed above, a list of practical guidelines is proposed below, which should be carefully considered when designing mobile interfaces:

- The “look and feel” should be the same across multiple platforms and devices
- Elements of mobile interfaces such as names, color schemes, and dialog appearances should be the same as their desktop counterparts
- Create input/output methodologies that are device independent - avoid using methods specific to mobile platforms where possible
- Mobile applications should rely on network connectivity as little as possible
- Nothing potentially harmful should be triggered by too simple an operation (e.g., power on/off)
- Rely on recognition of function choices instead of memorization of commands
- Use modalities such as sound to convey information where appropriate
- Allow users to configure output to their needs and preferences (e.g., text size, brightness)
- Allow for single- or no-handed operation
- Have the application adapt itself automatically to the user's current environment
- Provide word selection instead of requiring text input
- Provide sound and tactile output options
- Allow applications to be stopped, started, and resumed with little or no effort
- Application should be up and running quickly
- Present high levels of information and let users decide whether or not to retrieve details
- Provide users the ability to change settings to their needs or liking
- Applications should be visually pleasing and fun as well as usable
Conclusion

This paper presents a review of existing input/output interaction technologies and a set of proposed guidelines for the design of handheld mobile device interfaces. These guidelines are developed based on a review of the literature on the unique requirements for designing mobile user interfaces and eight traditional guidelines for desktop user interfaces. The reviews and proposed guidelines should be useful to practitioners who develop mobile applications, and to HCI researchers working on mobile interface design and usability.

References


