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Mobile Browsable Information Access for the Visually Impaired

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ABSTRACT

Although a large amount of research has been done on building interfaces for the visually impaired that allows users to read web pages and to generate and access information on computers, little development addresses two problems faced by the blind users. First, sighted users can rapidly browse and select information they find useful, and second, sighted users can make much useful information portable through the recent proliferation of personal data assistants (PDA's). We describe an interface that has been built on a standard PDA that allows its user to browse the information stored on it through a combination of screen touches coupled with auditory feedback. The system also supports the storage and management of personal information so that addresses, music, directions and other supportive information can be readily created and then accessed anytime and anywhere by the PDA user. The system plus the design choices and design rationale are described.

Keywords

Information accessibility, mobile information browser, audio browser, non-visual interfaces for the blind and the visually impaired, audio-tactile interface.

INTRODUCTION

Blind and visually impaired users have a collection of devices for accessing computers, but choices are limited for three major reasons. First, there is no market for selling special software to aid the blind, thus limiting industry interest in developing products. Second, computer technology is constantly changing so that it is difficult to keep up with the technology. Third, the interface devices typically rely on a single secondary sense, either tactile (for Braille readers) or audio. These secondary senses do not supply the positional information or the gestalt overview that sighted users gain from a computer display, and some interfaces require the user to search through large amounts of unnecessary information to access or even understand what he or she is looking for.

The next wave of computer usage, that of mobile PDAs (personal digital assistants) provides a distinct advantage to sighted users, that of mobile access to information, but limits access for the blind or visually impaired because its usage relies on sight. However, the very mobility of these devices could be a superb aid for blind users who could then carry large amounts of useful navigation and access information on their person.

This paper presents the design of AudioBrowser, an information access tool for the blind and the visually impaired that is built into the software of a standard PDA. The design of AudioBrowser has several features built in to make the interface accessible and usable by a blind user. Using a standard PDA puts the purchase price of the device within economic reach of blind users. The interface uses the touch pad and buttons for input and non-speech and speech for output. This combination, plus a hierarchal storage of information allows the user to browse both information in the interface and interface commands.

In the next sections, we first present an overview of research that others have conducted in building interfaces for the blind. A usage scenario intended to give the reader an understanding of how AudioBrowser works follows this. The software architecture and physical device description of the system are presented followed by a description of the usability studies currently underway. A final closing section describes the future work we plan for the system.

PRACTICES IN THE FIELD

Two decades ago, developers started providing accessibility to information for visually impaired users. As a result of this effort, there are now products assisting blind users' navigation through information spaces, products making use of innovative interaction techniques, and products built on PDAs that support mobile access. Two exemplary instances of such products are screen readers and stand-alone non-visual Internet browsers.

Screen readers translate the information on a user's graphical user interface (GUI) into speech (Thatcher, 1994). For example, when a user opens a document using Windows Explorer™, the screen reader reads the document's titles and the operation options available to the user out loud. In turn, the user, upon hearing the information, decides on an appropriate or desired action. His or her action, in turn, leads to auditory feedback that indicates the current state of the system. Three of the most popular screen readers on the market are JAWS (Henter, 2003), Window Eyes (GW Micro, Inc, 2003), and Hal (Dolphin Group, 2004). The important features of screen readers include translating textual information on GUIs to speech output, echoing users' input with speech, and assisting in the location of needed information. Additionally, some of the products (such as JAWS) support Braille output, usually accomplished via a pin pad that generates Braille characters by raising specific pins. Screen readers provide significant access to information and technology for blind and visually impaired people. However, currently, they only work on desktop computers.

While screen readers were evolving, non-visual Internet browsers were also under development. These browsers are stand-alone applications that read Web pages aloud to the user based on each page's HTML structure. Advanced auditory Internet browsers produce non-speech audio to indicate non-verbal information, such as the information structure of the web page and its hyperlinks. The influential inventions in this product line include DAHNI created by University of Hertfordshire (Morley, Petrie, O'Neill, and McNally, 1998) and Home Page Reader by IBM (Asakawa and Itoh, 1998). The system features that benefit users' navigation include user control over the auditory display (such as changing reading speed), user control over the navigation (such as going back and forth in a web document), and the use of non-speech sounds as both information and feedback (such as using a distinct sound to indicate hyperlinks).

Internet browsers have successfully connected blind users to a variety of online information resources. They have significantly improved navigational control and the auditory representation of information for the visually impaired. However, as with the screen readers, these browsers currently do not work with portable devices. Furthermore, all control needs to be done through a specially designed keypad or a regular keyboard, which makes full portability difficult to achieve. In addition, there are many key patterns for visually impaired users to commit to memory in order to effectively use these tools.

In addition to keyboard controlled web content browsing, researchers have been creating an array of interaction mechanisms. Roth and his colleagues created an interface that receives user input from a touch screen and generates 3D auditory output for the user (Roth, Petrucci, and Assimacopoulos, 1998; Roth, Petrucci, and Assimacopoulos, 2000). When a user points to a block of content on the touch screen, the information is output via speech with added spatial characteristics that help characterize the location of the information. For example, if the information is on the top-left on the screen, the 3D auditory output sets the speech output to appear to be coming from the top-left portion of the user's hearing space. This location information can provide navigational assistance if the user remembers that what they were looking for was stored to the left of the current information.

Other relevant innovative interaction mechanisms include Brewster's gesture-audio interface (Brewster, Lumsden, Bell, Hall, and Tasker, 2003) and Friedlander's Bullseye menus (Friedlander, Schlueter, and Mantei, 1998). Brewster and his colleagues developed and evaluated an eyes-free interface for wearable devices. The interface receives input from the user's head movements and hand gestures and produces 3D auditory output around the user's head through a headphone worn by the user. The gestural input proved to be effective even when users were walking. However, the head gesture may be awkward when used in public, and these types of gross motor input mechanisms also do not allow for a large array of options to be input to the computer by the user. The Bullseye menus consist of a set of concentric circles divided into quadrants. A menu item is located in each quadrant. Non-speech audio cues are used to indicate the boundaries between menu items and the direction of the stroke (up down, left, right) further extends the number of menu items that can be accommodated with this method. In the evaluation of Bullseye menus as a potential input mechanism for visually impaired users, it was found that users could efficiently and effectively select a large number of menu items using non-speech audio feedback. A second study

looked at tactile feedback, which gave a slight “bump” as each concentric ring was passed. This, too, worked effectively, but was not as efficient as the sound feedback.

Along with researchers’ efforts in academia, industry has also launched mobile devices for blind users. These devices include PDAs for blind people, such as Braille ’n Speak and Type ’n Speak (Blazie Engineering, 2003), Voice Note and Braille Note (PulseData, 2003), and PAC Mate and Braille Lite (Freedom Scientific, 2003). These specifically designed PDAs use either stylus-written Braille or QWERTY keyboard input, and either speech or Braille output. There is no screen display or touch screen on the PDAs. They are portable tools for generating and editing text documents. No usability study has been reported on these products, but their innovation suggests new avenues for information input and access for the visually impaired.

In the next section, AudioBrowser, a portable personal information system is introduced. The motivation of the researchers was to design a tool that allows blind users to obtain, create, and maintain information with easy input and output mechanisms. Differentiating itself from existing products, AudioBrowser can be used (1) without learning a new language such as Braille - note that a significant portion of the blind have lost their sight in later years and may be slow in learning new languages (American Foundation for the Blind, 2001); (2) without using additional external input devices such as a keyboard, which reduce the portability of PDAs; (3) without using an interactive device designed specifically for the visually impaired, and thus, rendered expensive because of low market share.

AudioBrowser is the evolutionary next step for SoundNews, a non-visual news browser accommodating gestural input on a touchpad and auditory output. SoundNews was built for use on a standard PC (Williams and Tremaine, 2001), preferably a notebook with a touchpad. It allowed users to browse web-based newspapers without having to listen to a large amount of extraneous information. The browsing was accomplished through touchpad gestures, non-speech and text-to-speech audio feedback and a series of button presses. In the next section, we present the design of AudioBrowser through the ruse of a user scenario.

AUDIOBROWER

Exploring The Design Through a User Scenario

Elizabeth, a visually impaired twenty-year old college student, is on a train traveling to school. Becoming a little bored by the half-hour trip, she turns on her Compaq iPaq Pocket PC and starts AudioBrowser. The system first loads its function menu on the touchscreen. The menu items are displayed on the screen in the form of virtual segments (see Figure 1).

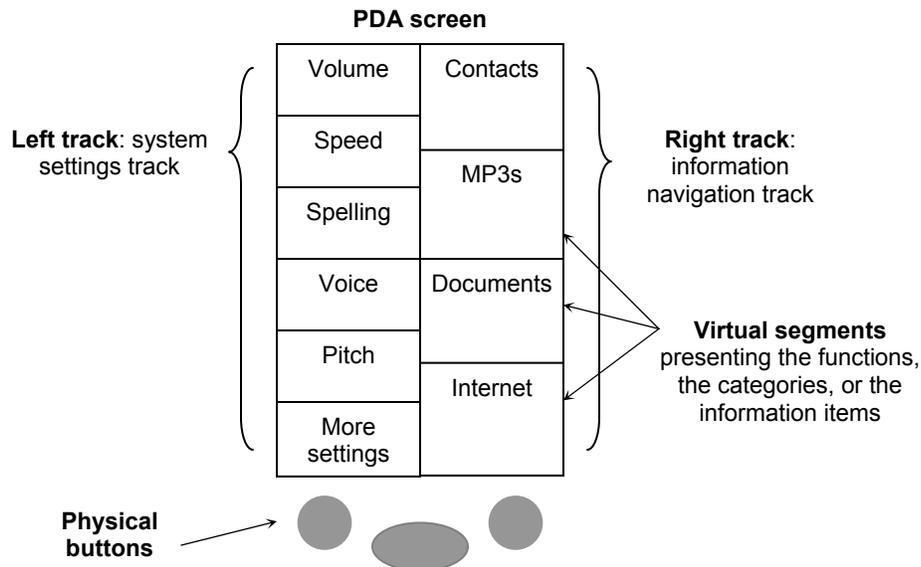


Figure 1. The non-visual interface of AudioBrowser

Elizabeth glides her fingers across the virtual segments on the touchscreen. Once touched, a virtual segment generates speech output and informs Elizabeth of the specific functions she can access. Elizabeth listens to the main information menu of AudioBrowser on the right track of the screen. “Contacts,” “MP3s,” “Internet,” “Documents” are spoken by the system as Elizabeth glides her finger over each segment. Elizabeth selects “Contacts” to update the cell phone number of one of her friends, Mathew. She does it by touching the contacts segment to shift the system focus to “Contacts,” and then clicking the zoom-in button on the bottom-right of the screen (see Figure 2). Once the zoom-in button is clicked, the system enters into “Contacts” mode and replaces the main menu’s available functions with the contact menu’s available functions. Elizabeth glides her finger across the new segments and listens to these menu items. With the action combination of gliding, stopping on a segment, and zooming in, she finds Mathew’s detailed contact information.

To edit Mathew’s cell phone number, Elizabeth moves her finger to the cell phone number segment and double clicks the zoom-in button (see Figure 2e). An interface similar to the dialpad of a telephone appears on the touchscreen (see Figure 2f). Elizabeth touches and hears a digit, and clicks the select/enter button to enter the digit. When she enters an incorrect digit, she clears it using the backspace button. When she finishes, she listens to the complete number by clicking the middle button. She can either save the number entered by touching the “save” segment and clicking the select/enter button, or abort the update by touching “abort” and clicking the select/enter button. Elizabeth decides to save the update and exit the editing mode. A key aspect of the input design is that the user can hear each of the selections before making a decision to make the menu selection. We call this ‘touch and tell.’

Changing system settings can be achieved by selecting segments on the left track on the screen. Elizabeth increases the audio volume by touching the “Volume” segment and pressing the right button until the volume is at the desired level (see Figure 3).

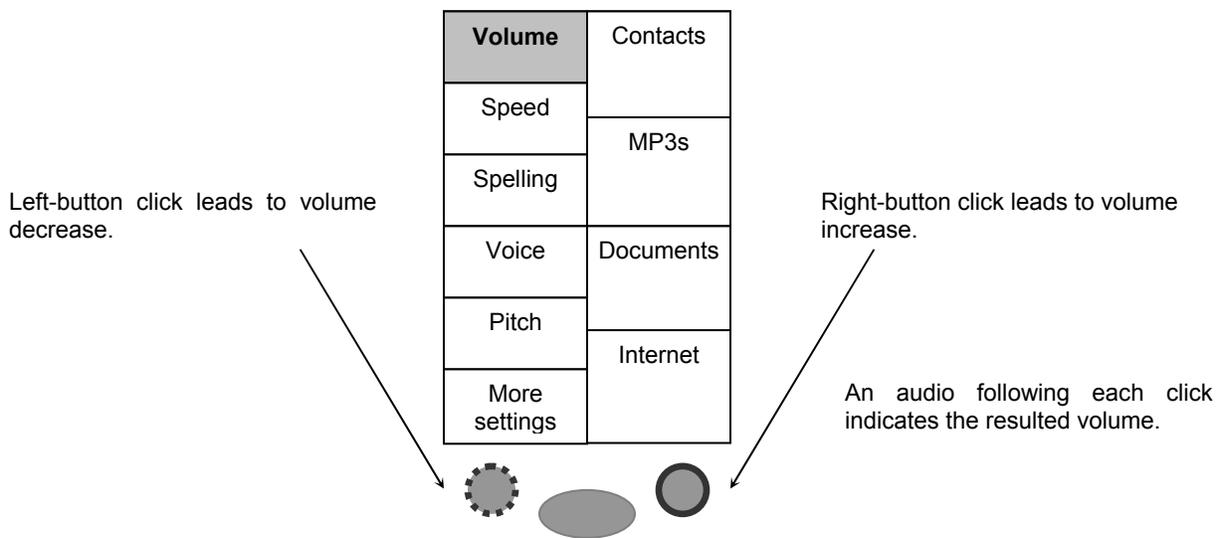


Figure 3. A use scenario of the left track of AudioBrowser: Editing the system settings

Hence, using AudioBrowser on an otherwise boring train ride, Elizabeth was able to update her address book. In addition, she can also entertain herself by listening to MP3s or browsing the Internet via the same overall ‘touch and tell’ structure built into AudioBrowser.

Design Rationale of AudioBrowser

The current version of AudioBrowser is a reflection of a number of design considerations.

(1) The coordinated gestural input and auditory output

The introduction of the gestural input via the touchscreen, as well as the auditory output triggered by the gestural input, has multiple advantages.

First, blind people have highly developed spatial and tactile senses. Operations on the two-dimensional screen space and the physical buttons allow blind people to take advantage of this acuity. The edges of the screen provide references for positioning.

Second, several of the disadvantages of sounds as an output form on a non-visual interface are compensated for. The greatest disadvantage of screen readers and other similar devices is that they display the sound sequentially. In addition, sound is not pervasive, and thus has to be searched for again if some key piece of information presented is forgotten. The auditory output triggered by the system's detection of the finger position on the touchscreen eliminates the sequentiality problem, since the finger can freely "jump" between different physical positions. In addition, the finger can go back to an information segment any time – thus, prior sounds can be more readily found. For example, a person can touch each segment only to hear the first phoneme of its contents and then jump to the next segment after recognizing that the current one touched is not the one being searched for.

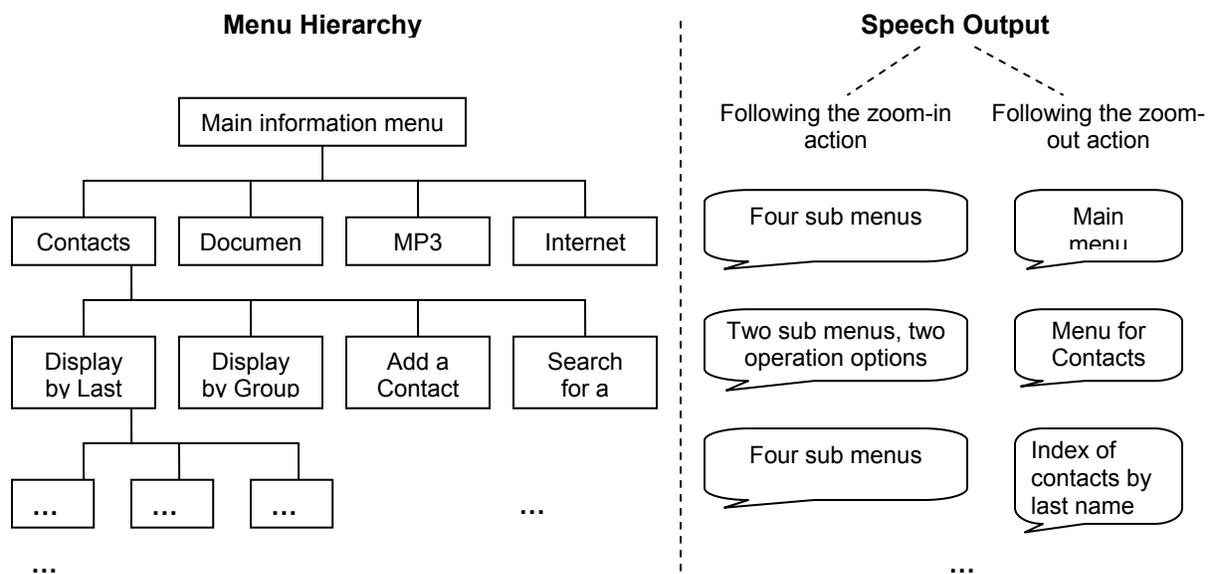


Figure 4: The hierarchical structure of AudioBrowser and the speech output providing navigational and overview information of the hierarchies

(2) The use of speech and non-speech audio as information conveyance

Speech is used not only to read the items displayed on the screen, but also to provide navigational and overview information. As shown in figure 4, the number of items in a menu is announced following a zoom-in action into this menu; the position of the user, is announced following a zoom-out action to this hierarchy. This feature helps users to gain location awareness.

Non-speech audio is used for indicating the position of the segment boundaries on the screen, successful and unsuccessful operations, and errors. These audio streams are used to draw the user's attention without consuming cognitive resources.

(3) Ability to control the auditory output

This control allows users to adjust the output in a preferred manner. Controls include those over the sound volume, pitch, the reading speed, voice, and the speech-output unit. The speech-output unit has five variations – output by word, by sentence, by paragraph, spelling a word, and output of the complete information item. When one of the first three output units is selected, the user hears one unit of information at a time, and goes back and forth using the button control to hear the next or previous unit. Thus the user has full control over his/her listening pace. Spelling a word is useful, especially when dealing with

potentially ambiguous information, such as names and addresses. A key feature of this system function control is that the procedures for making menu selections operates in the same way as the procedures for searching for information content. Overall, the same conceptual model of zooming in and out of a hierarchy of data is preserved.

(4) The ecological design considerations

Our ecological considerations deal with the naturalness of user operations and user's human motor performance requirements.

Our first consideration is the size of the user's fingers versus the size of the PDA's touchscreen. As a priority, we do not want to decrease the system's usability for those with larger fingers. We set the largest number of segments on a track to be six. In this case the size of each segment is large enough to allow pressure from a large finger to be detected without the finger's crossing over onto two or more segments.

Our second consideration is that functions used frequently should be put in places that are easiest to access. With this principle, the system settings manipulated frequently, such as volume, speed, spelling, etc., are put on the first page of the system settings track.

Our third consideration is the input mechanism. Our system is not designed to accept "enter/selection" operation through the touchscreen, because the exploration of the screen space requires the user to keep contact with the screen using his finger. Operations done by touching the screen would violate our "touch and tell" approach which allows the user to verify each menu selection that is being chosen before the final choice decision is made. "Touch and tell" also gives the user the advantage that graphical user interface users have, that is, of exploring the system commands and possibilities for possible future use.

A final fourth consideration was the use of only two tracks on the screen, except for the telephone keypad. Although, we can give feedback via non-speech audio for more tracks on a PDA, PDAs are designed to be held in one hand and looked at. Since we wanted to use a conventional device to keep our costs low, we were faced with the awkwardness of a user holding a PDA in one hand and trying to touch the middle of the screen. Since this would involve considerably more dexterity, we limited our design to make it possible for the user to touch the edge of the screen and still achieve viable results.

Technical Aspects

Having a large touch pad, a speaker and an internal microphone, and five auxiliary buttons, the PDA is an ideal platform as a mobile information browser.

Compaq iPaq Pocket PC h3970	
Processor	Intel 300Mhz Process with Xscale Technology
Memory, std.	64MB SDRAM, 40MB Flash ROM
Connectivity std.	Integrated Bluetooth wireless technology WLAN 802.11b
Display	3.8'' diagonal viewable and touchable size
Input type	Pen and touch interface
Weight	5.0 oz
System dimensions (w x d x h)	5.4 x 2.9 x .6

Table 1. Compaq iPaq h3870 Specification

In addition, the iPaq h3870TM has a mono internal speaker on the front top of the PDA and a headphone jack for stereo output to a possible headset. Both the speaker or the audio jack output can be used for AudioBrowser's auditory display.

For the implementation on the PDA, we chose Microsoft's Compact Framework .NETTM and the C#TM programming language plus Visual Basic. NETTM. Both languages provide the full features of an object oriented language and share a common library in .NETTM. Visual Basic.NETTM is mainly used for designing the navigation layout and C#TM is used for the audio displays and retrieving data from Outlook PocketPCTM (our source of names, telephone numbers and addresses). Unfortunately, the two functionalities of playing sound and accessing Outlook PocketPCTM are not yet supported by .NET Compact FrameworkTM. Therefore, we used a 3rd party API, PocketOutlookTM In the Hand, to access Outlook PocketPCTM data from .NETTM. To play wave format audio files, we used an open source library, Multimedia.Audio.dll (OPEN NETCFTM.org, 2003)

AudioBrowser	
Operating System	Microsoft Pocket PC 2002™
Platform	Microsoft .NET™ Compact Framework
Language	C#, Visual Basic.NET™
Address Application	Outlook PocketPC™
Synchronize Manager (PC/PocketPC™)	Microsoft ActiveSync™

Table 2. Operating System and Software Required for AudioBrowser

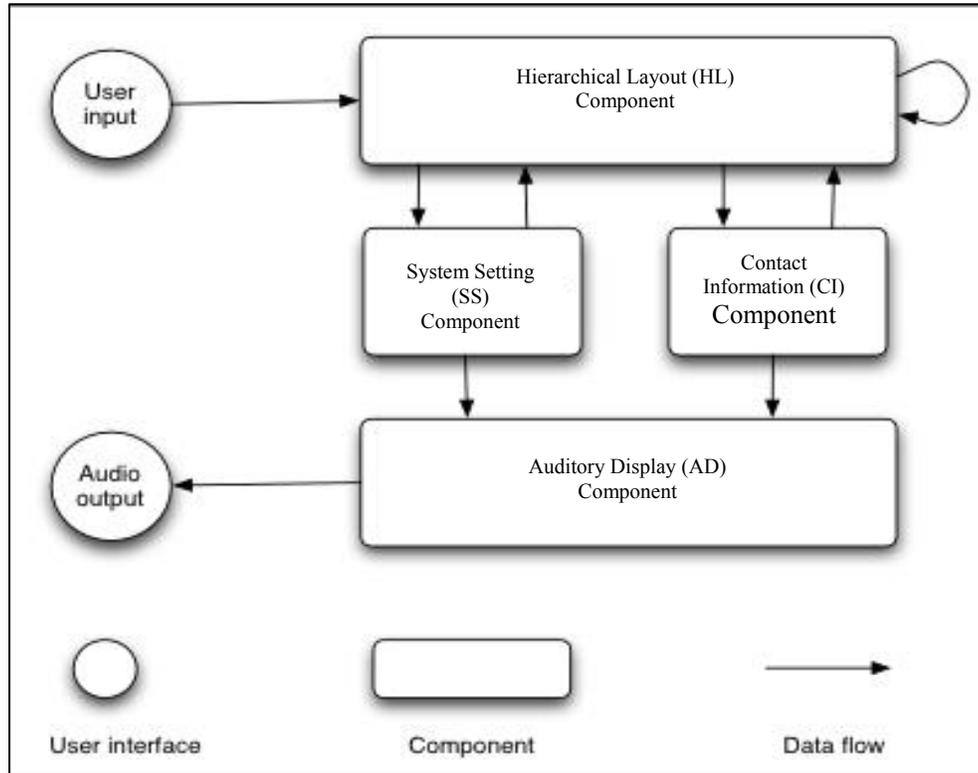


Figure 5. The Software Architecture of AduioBrowser

The AudioBrowser code is divided into four components: Hierarchical Layout (HL) Component, System Settings (SS) Component, Contact Information (CI) Component, and Auditory Display (AD) Component (see Figure 5).

The HL Component organizes the layout of navigational information on the touchscreen. When a segment on the screen is selected, associated information will be passed to other components and appropriate action will be performed. For example, when a segment assigned for volume control is selected, audio information will be passed to the AD Component while the SS Component is set to listen to the user’s action. If the user clicks a button to increase the volume, the SS component will increase volume accordingly and pass the resulting information to the AD Component. The AD Component receives text or the file path information as its parameter for finding the audio to play.

The CI Component retrieves contact information from PocketOutlook™ upon a user’s request generated by the user touching a segment on the navigational menu and pressing the selection button. Then, the component sends a message to the HL Component. The HL Component re-organizes the segments and reflects the current set of retrieved contacts on the touchscreen. In this way, a user searches for a piece of information by navigating a hierarchical data structure.

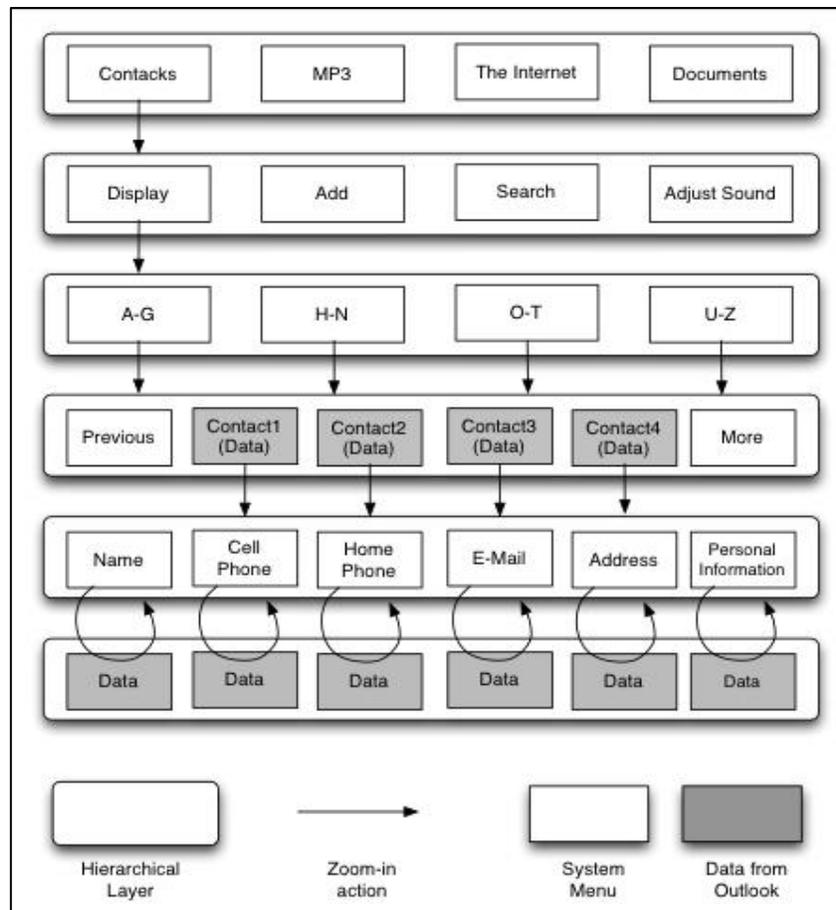


Figure 6. The Hierarchical Layout of the Navigation Track

In detail, the Hierarchical Layout Component can be divided into two phases, menu and data navigation (See Figure 6). Menu navigation is a phase that provides functionality for data, navigational categories, and sound settings. Instead of providing contacts from Outlook™, each menu provides the names of categories and functions. Because the text of the menu is fixed, it can be played by an audio file. Data navigation is a phase that provides detailed contact information from Outlook™. Because of its dynamic nature, the system requires Text To Speech (TTS) to read out the contact information.

PLANNED USABILTY STUDY

A series of usability studies examining the viability of this interface are in progress but not sufficiently completed to report on their results. The studies will test the following design assumptions: (1) that users can readily navigate complex hierarchies to find information desired; (2) that users will comprehend the conceptual model of hierarchy navigation and thus, use it effectively to find information; (3) that the method of browsing provided will allow users to skip unwanted information; (4) that the structure of information retrieved via the auditory display will be understood by the user and (5) that users will explore the interfaces to find command options they have forgotten. Each of these design assumptions has been mapped into a series of testable and measurable usability goals, e.g., for design assumption 1, one of the goals is: “the user will be able to find an item in a newspaper that is 4 levels deep in less than one minute of searching.”

To test out the interface design and the design assumptions, we are running the usability studies in two segments, one week apart. We are running each study on groups of four users, one sighted and one visually impaired. In the first segment of the study, each user is read aloud, a description of the study and the subject consent form. At this point the subject is asked to sign the consent form if they wish to continue with the study. They are then given a hands-on tutorial using the interface. Note that nothing visual is shown to the user. The sighted user only sees a blank screen on the PocketPC™. They are shown how to move their fingers through segments of the interface and to press the zoom in and zoom out keys to be able to move

down the information hierarchy to the information they are looking for. Once the user has completed a set of two practice tasks, they are asked to begin the actual study. At this point, a set of ten tasks is given to the user orally, one at a time. The user executes each task until he or she thinks that the task is completed and then announces task completion. At this point, the next task is read to the user. At any time, the user can ask the experimenter to repeat a task. The user is videotaped throughout the training and the usability session. At least two of the tasks will involve menu options that were not taught in the tutorial. This will help us test whether the user can explore the available menu options and find the appropriate one.

At the end of the session, the user is given a small exam. The exam consists of a series of true / false questions that test how well the user understood the underlying conceptual model of the system and its operations. This is followed by a set of questions that ask the user to describe how various tasks are performed, e.g., "How do you set the reading speed of the system to be faster?" Finally, the user is asked a series of satisfaction questions, some of them drawn from the standard usability questionnaire produced by the HCIL Lab at the University of Maryland. They also ascertain how difficult it was to hold the PDA and find specific sectors on it, how easy it was to hear the speech and how easy it was to figure out where one was in the hierarchy of information. One week later, each user is being asked to return and use the system again. In this session, the user is asked to perform another ten tasks with the system. This session is also videotaped and used to measure both the retention of usage information and the ability of the user to find out information that was forgotten during the interim week.

The videotapes for these studies are being examined for critical incidents. Critical incidents are problems that multiple users encountered with the system. The tapes are also searched for small errors that take considerable time to recover from. These problems plus wrong answers and dissatisfactions gleaned from the questionnaires are be used to guide the redesign of the interface until an instantiation of the interface meets the usability goals.

CONCLUSION AND FUTURE WORK

In this paper, the researchers have described a non-visual system that has been built on a standard PDA. The system allows its user to browse the information stored on it through a combination of screen touches coupled with auditory feedback. This is the first step in providing a complete personal information assistant that is accessible by blind and visually impaired users. In the next phase of development, its developers will iterate through usability studies carried out on the system in order to improve the basic design of AudioBrowser. Another key effort underway is the modification of the hierarchical format currently used for the information browsing so that it accepts a variety of the standard XML defined document structures. This change, could, for example, allow visually impaired (or driving) users to hear and browse newspapers wirelessly. It is also planned to develop a tutorial for the interface that allows visually impaired users to self-teach themselves how to operate the interface. Finally, we hope to add additional useful functionality, e.g., a mobile calendar and reminder system and the ability to mark and organize useful web pages for future access.

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