Abstract

The Pebbles research project (http://www.cs.cmu.edu/~pebbles) has been studying the use of hand-held personal digital assistants (PDAs) along with other kinds of hand-held computers, at the same time as other computing devices. A key focus of our research is that the hand-held computers are used both as output devices and as input devices to control the activities on the other computers. Our previous articles have described parts of the project in detail. This article presents four scenarios that illustrate some of the capabilities we are already investigating.

Using Multiple Devices Simultaneously for Display and Control

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The Pebbles research project (http://www.cs.cmu.edu/~pebbles) has been studying the use of hand-held computers simultaneously with other computing devices. A key focus of our research is that the hand-held computers are used both as output devices and as input devices to control the activities on the other computers. Our previous articles [1-3] have described parts of the project in detail. This article presents four scenarios that illustrate some of the capabilities we are already investigating.

Scenario 1: Presentations

The presenter of a briefing or talk has a laptop, and the display is projected onto a large screen. The laptop's powerful processor is needed to control the animations and external applications that are part of the presentation. In the presenter's hand is a PDA on which the current slide's notes are displayed. The PDA can be used to cause the presentation to go forward, backward, or skip to a specific slide under discussion. Also on the PDA are custom controls to switch among various other applications on the laptop that the presenter will be demonstrating and discussing. Each member of the audience sees on their personal hand-held the current slide, which is kept synchronized with the talk. Audience members can also make private notes and annotations on their PDAs. When enabled by the presenter, an audience member's marks on their PDA can be displayed on the main screen for general viewing and discussion.

This scenario is partially implemented in our "Slide Show Commander" application [3]. Figure 1 shows some screenshots. This application has been released commercially by Synergy Solutions (http://www.synsolutions.com/software/slideshowcommander). In the future, we will be investigating more on supporting the audience members and note-taking.

Scenario 2: Public and Private Spaces

In a military command center, several large displays show maps, schedules, and other visualizations of the current situation that will be useful to the group. Individuals carry a personal PDA. While in the command center, someone might want more details on an item displayed on a large display. Rather than disrupting the main activities and the main display, the PDA can be pulled out, and a special unobtrusive cursor will appear on the main display, so the user can point to the item of interest. Then the user can privately "drill down" to get the additional specialized information displayed on the PDA. The display of the information is appropriately adjusted to the limited size of the PDA screen.

We are currently exploring various aspects of this scenario as part of the "Command Post of the Future" project (see http://www.cs.cmu.edu/~cpof). In cooperation with MayaViz (www.mayaviz.com), we have created a PDA-based visualization and control program that runs on Windows CE and Palm. On the PDA, you can see a view of a map on which you can scribble and select objects, and a table view of the detailed information. The user can operate either connected (so operations on the PDA are immediately reflected on the main screen) or disconnected. Figure 2 shows some example screens.

We have a number of other applications that support meetings where the participants are co-located. All participants' PDAs are in continuous two-way communication with the main computer, which is often projected on a screen to serve as the focal point of the discussion. Some of our initial applications use the PDAs as remote mice and keyboards so that everyone in the meeting can control the main computer. This might be used as a shared whiteboard that supports multiple inputs simultaneously, for private side messages via a "chat" program, and to display multiple cursors for pointing and scribbling on arbitrary applications. More details on our groupware applications are presented in another paper [1].

Scenario 3: Augmenting the Desktop

When the user is sitting and working, various devices are placed on the desk: a laptop, a PDA, a cell-phone, etc. They immediately communicate with each other to establish each device's capabilities and specifications. As the user works, various controls appear on the screens of the other devices rather than on the laptop's screen. For example, scroll bars might be drawn on the PDA so the user can operate them with the left hand while using the mouse with the right hand, which has been shown to be fast and effective. The user's custom shortcuts for the laptop applications also appear on the PDA, and the user has memorized their location and can operate them

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Figure 1. *The Pebbles Slideshow Commander program. (a) and (b) show a HP Jornada Windows CE machine. (a) shows the full device, on which you can see a thumbnail of the slide on the top, and the notes for that slide on the bottom. Drawing on the thumbnail causes the same drawing to appear on the main screen. (b) shows a close-up of the screen viewing the list of titles for the presentation. Tapping on a title causes PowerPoint to change to that slide. (c)–(f) show the user Slideshow Commander on the Palm. (c) shows the Palm, viewing the thumbnail of the slide. (d)–(f) are close-ups of the Palm screen. (d) is the Notes pane, (e) is the list of titles, and (f) is a timer. Meanwhile, a PC is running PowerPoint and a PDA is in continuous two-way communication with the PC.*

quickly without looking. Information can be easily moved among the devices, and other information is automatically distributed based on predefined user preferences.

We have started to investigate some aspects of this scenario. The PDA can be used as a scrolling device, as a general-purpose button panel (to create screens of "shortcuts"), as an index page or table of contents for web surfing, and to cut and paste information back and forth from the PDA to the PC. Initial studies show that scrolling with the PDA in the left hand while using the right hand to select items in the window with the mouse can be faster than using the mouse with conventional scroll bars [2]. A related study shows that moving both hands off the keyboard to the PDA on the left and the mouse on the right (or back to the keyboard from the devices) is only about 15 percent slower than moving one hand to the mouse. Thus, there is little penalty to using both devices. Figure 3 shows some example screens we have created with our "Shortcutter" application. Other related applications are described in another paper [3]. Currently, we are only using PDAs, and the communication uses the PDA's cradle and serial cable, but in the future we will expand to other devices and wireless communication such as Bluetooth [4].

Scenario 4: Universal Personal Controller

When the user points a PDA at a light switch, at a photocopier in an office, at a machine tool in a factory, at a VCR at home, at a piece of test equipment in the field, or at almost any other kind of device, the device sends to the PDA a description of its input and output requirements. The PDA converts this description into a custom control panel, taking into account the properties of the controls that are needed, the properties of the PDA (the display type and input techniques available), and the properties of the user (which language is preferred, whether left or right handed, how big the buttons should be based on whether the user prefers using a finger or a stylus). The user can then control the device using the PDA. The device will not need to dedicate much processing power, hardware, or cost to the user interface, since it will only need to contain a description of its capabilities and storage for the current settings, along with hardware for wireless communication. The PDA programs will use intelligent "model-based" techniques to create useful and appropriate interfaces that are customized for each user.

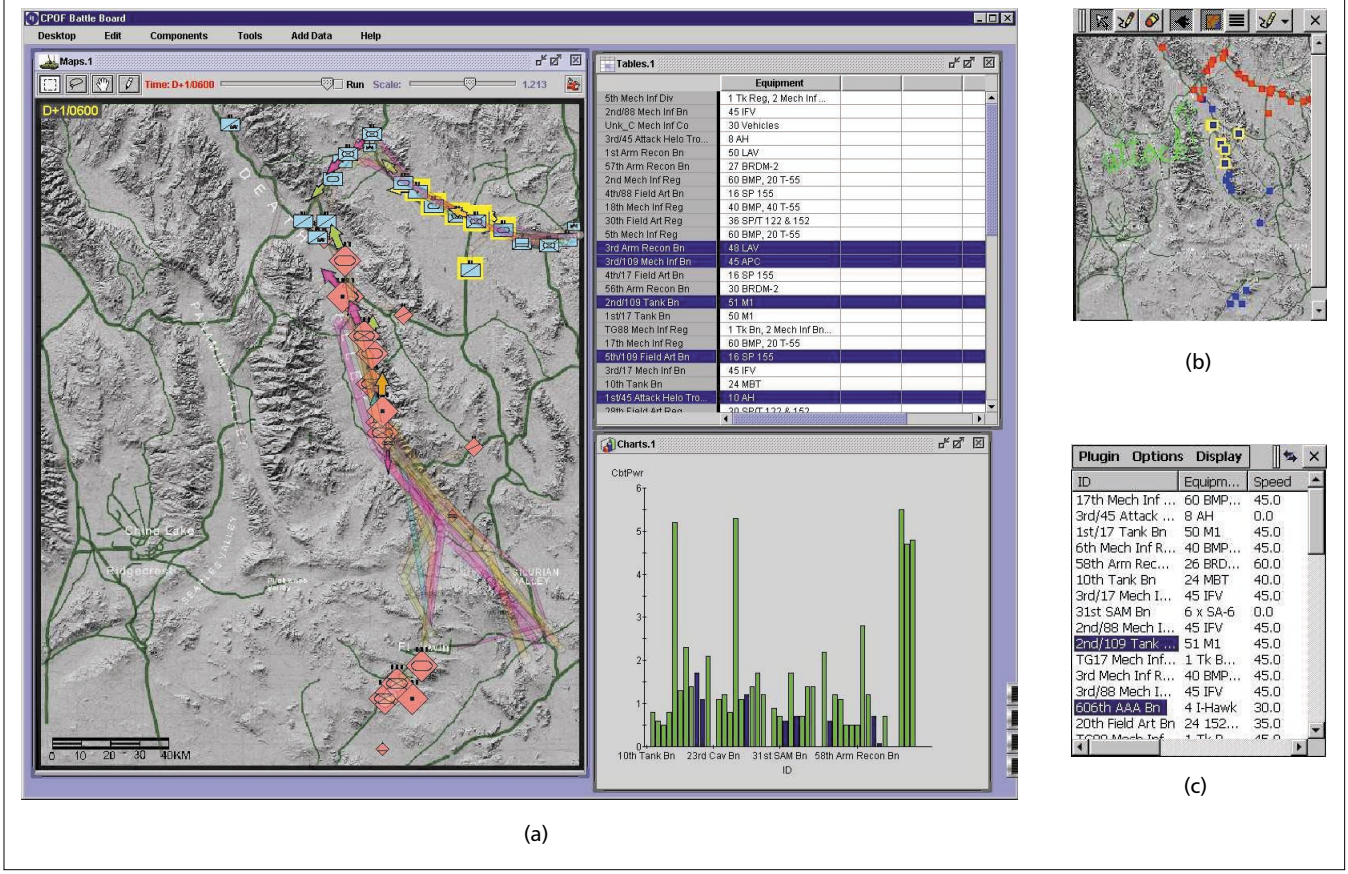

Figure 2. *(a) A public view displayed on the wall from a PC, and the views (b)–(c) on a palm-size Windows CE machine for private viewing and editing. (b) is the map view, and (c) is the table for drill-down information.*

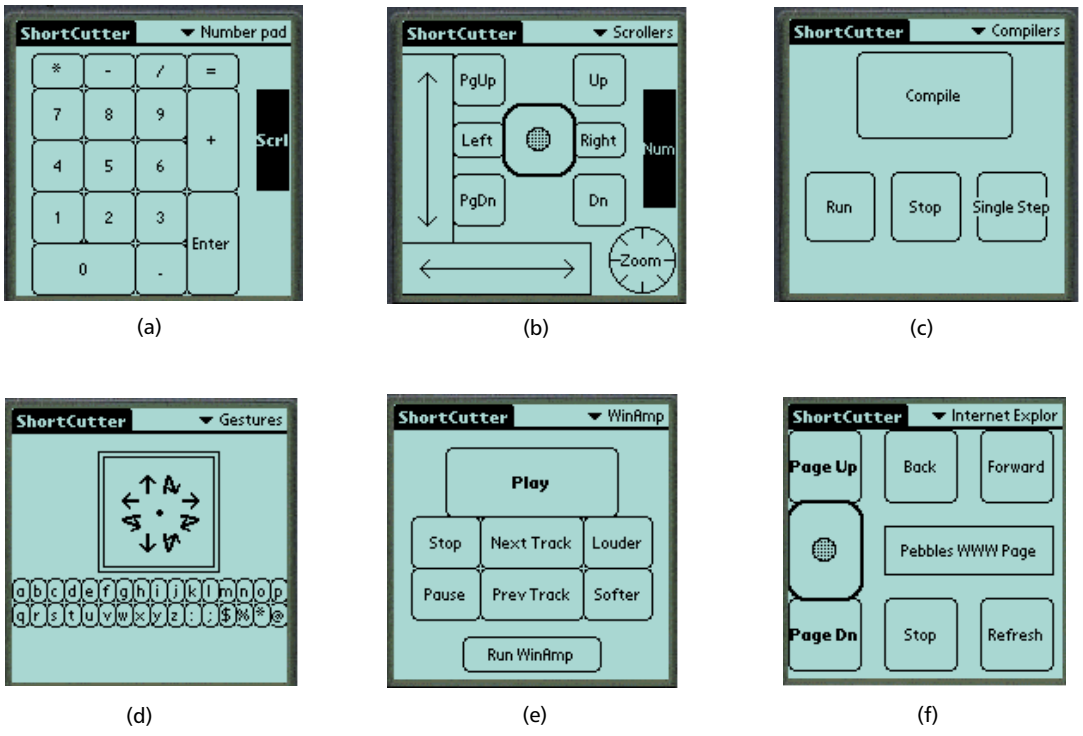

Figure 3. *Panels created with Shortcutter: (a) a numeric keypad; (b) a collection of scrollers and a knob; (c) buttons for controlling any of a set of compilers; (d) a gesture pad and two rows of small buttons; (e) a controller for the WinAmp MP3 player for PCs; and (f) a panel for browsing in Internet Explorer.*

We are just beginning to explore this scenario, and are investigating related technologies such as XML, the WML language for WAP (Wireless Access Protocol (www.wapforum.org)), Salutation (www.salutation.org), Universal Plug-And-Play (www.upnp.org), etc.

Research Issues

Many significant research issues are involved in bringing these visions to fruition, which we are committed to investigating as part of the Pebbles project. None of the other research projects investigating novel ways to use PDAs (e.g., [5–8]) have addressed these issues. We are particularly interested in the appropriate ways to distribute the user interfaces across multiple devices, how to support multiple people interacting with the same screen using their various devices as auxiliary input and output devices (which is sometimes called "single-display groupware" [9]), the automatic creation of appropriate and usable control panels from high-level specifications, and usability issues with multi-computer interaction techniques. The Pebbles research project has made substantial progress by building example applications, releasing them for general use, and formally testing them in usability experiments. Many of these applications are available from our web site (http://www.cs.cmu.edu/~pebbles) and have been downloaded more than 25,000 times in the last 2 1/2 years. We invite you to try these out and let us know about other ideas for using multiple devices at the same time.

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Biography

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