A Graphical Interface for Wearable Computing

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A few years ago, wearable computers were dedicated systems constructed by and for a single person. The machine was customized to suit the individual's preferences, perhaps using unconventional input/output devices to achieve different interaction techniques. Most of the user interfaces used on these machines have been an amalgamation of conventional desktop user interface systems and novel input/output devices.

Compared to the desktop graphical user interface (GUI), there has been little research into the interaction between a person and a wearable computing device [1]. It is clear from our own observations and from others' research ([5]) that a desktop user interface is poorly suited to use in a mobile environment. As yet, there has been no formal definition of how the interface between the user and the wearable computer should be implemented, what rules it should abide by, what a good mobile user interface should provide and - probably most important of all - what *should not* be included in the interface. The lack of well-defined guidelines provides problems when designing a user interface for a wearable computer.

The developers of the current generation of wearable computers have adopted the use of head-mounted displays and chording keyboards as replacements for the monitor and keyboard of a desktop machine. The interaction methods used are also based on current desktop user interfaces. This has assisted in the rapid prototyping of wearable systems but restricts the use of such a machine. In order to design a wearable user interface system we must first define the environments in which a wearable will be put to use in, the interaction methods available and the kind of tasks the machine will be expected to perform.

We believe that the ideal human-computer interface for use on a wearable computer is one that pays attention to its user; understands what the user has asked it to do using speech recognition, gestures, and other channels of information; carries out the user's request autonomously; and presents the results back to the user when it is most appropriate and in a suitable format-a *multi-modal* user interface. We have developed *Sulawesi*, an agent-based user interface *framework* [3] which is flexible enough to encompass a wide range of interaction techniques, can be adapted through well-defined programming interfaces, and can be tailored for a specific purpose. There are three distinct parts to the framework:

- an input stage which gathers raw data from the various sensors;
- a core stage which contains a natural language processing module and service agents to process information gathered from the input stage and produce (where possible) a mode-neutral output;
- an output stage which decides how to render the results from the service agents. (This could be, for example, spoken output to the user, or a message to control a hardware device.)

The agents in the system can monitor the input and output streams of data and autonomously retrieve information depending on the system's perception of the user's environment. The input controller has a limited natural-language parsing capability which allows meaning to be determined from reasonably natural sentences and appropriate services started and configured. Sulawesi is written entirely in Java to achieve platform-independence and has been demonstrated on Linux and Windows.

In fact, the type of man-machine interaction that is desired will be determined by the type of tasks a user will want to accomplish with the wearable computer. If the user is using the machine directly to assist in a task, then it makes sense for the user interface to assist in the user's primary task-a so-called *primary user interface*. If, on the other hand, the user is not directly using the machine to perform a task and the machine is working in the background, offering potentially relevant information to the user but not directly involved in the users task, then this type of interface has been called a *secondary user interface*. These two types of interaction methods contribute to different design issues for a wearable user interface.

Although Sulawesi is usually able to ``render'' output in any of several forms (speech, text, ) on the fly, we have found that it is useful to have a fixed visual interface, a ``wearable GUI''. This is obviously vastly less detailed than a desktop GUI, and must be significantly easier to operate as it must be capable of being driven by speech and gesture as well as pointing device. The purpose of this paper is to describe such an interface and the design decisions that led to it.

At the moment there are three types of display which can be realistically used in a mobile environment. The first utilizes normal graphical displays which can be worn on the body. This encompasses PDA screens and custom arm-mounted displays. This type of display is good for a *secondary user interface* in that it can work in the background, providing information to the user, and the user will consult the device when information is needed. The second type of display utilizes small LCD graphic screens which are placed in the user's field of view; the M1 [2] is a good example. These displays provide limited graphics capability, usually 320D7240 pixels. They are conventionally used in monocular mode; that is there is only one screen which is placed over, or just to one side of, a user's eye. This type of display is often referred to as *fully immersive* because it is viewed directly-in other words, the user's field of view is obscured. Again, this type of display has been classified as being good for a secondary user interface because it obscures the field of view: a user would have to change their focus of attention from a task to the display to be able to use it.

The third type of display is similar to the second type described: small LCD screens are used but, instead of the devices being placed in the user's field of view, they are placed *out of the main field of view* and half-silvered mirrors or prisms are used to bounce the light from the display device into the eye so that the image from the LCD screen is overlayed onto the real world. This type of *augmented* display is used by Micro-Optical [4] and Virtual-i/O [6] in their display glasses. These types of display can be used to implement a *primary user interface* and overlay information from a machine to assist the user in their task. We are concerned primarily with this type of display device.

A wearable computer provides a mobile computing platform. This inherently means that it could be used within buildings and outdoors in different environments. The main consideration for a wearable GUI is thus visibility: can the user see the GUI clearly enough to understand it? There are physical limitations on the display devices available, such as limited contrast. These physical limitations cannot be changed (easily) but a wearable GUI must be able to accommodate them. These constraints apply dynamically, so that the visibility must be maintained in transitional lighting environments such as movement from indoors to outdoors, or from working during the afternoon into the night.

A desktop user has the ability to move away from the interface when desired. A user interface which is present in the user's field of view all the time must not becomes overpowering, so that the user feels ``trapped'' inside the machine. Hence, the ability to turn off the user interface is desirable, especially in a primary interface. Resolution is also a consideration: most wearable users prefer to use a text mode console for working, providing 40D725 characters with a very limited graphics capability. This is at least partially due to the periods of time spent using these machines (some up to 12 hours a day!): the use of a low resolution, low data rate, and large text makes it easier for the brain to process and integrate the computer output without it dominating the real world.

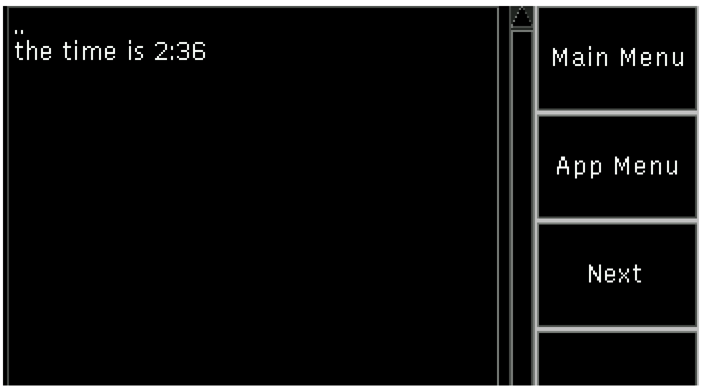

Figure 1: The Gili user interface for wearable computing

A prototype monocular primary user interface, known as Gili, has been constructed in the context of the above considerations. A Virtual-i/O [6] augmented head-mounted display (HMD) was used to project the user interface over the user's physical environment. One of the display panels was removed to make the system monocular: this has been found by many to ease the information overload placed on the user. As can be seen in figure 1, the user interface is black and white rather than grey-scale. This enables the user to see through the user interface, with as little of their vision obscured as possible; and the interface remains visible and usable in a wide range of lighting conditions. (This is also true of the console system used by many wearable users, where the background is black and the foreground text is white.) The user interface has been designed for (relative to current desktop systems) low graphical resolution and color depth (only 320D7240 grey-scale pixels), so the use of expensive miniature high-resolution graphical displays is not needed.

The main graphical widgets have been placed out of the user's foveal field of view. A text entry box is at the bottom left of the user interface, and a row of menu-selection buttons are on its right-hand side (for a right-eye view; the buttons can be switched to the other side for a left-eyed user). The buttons provide some form of visual feedback by flashing black-on-white for a brief period of time when pressed. The main panel is used by applications for their displays. A mechanism is provided within the Sulawesi framework to allow multiple applications to be ``stacked," only one being visible at any one time. The buttons provide the mechanism to flip between applications, a scheme that was developed to keep the field of view as uncluttered as possible. When the desired application is in focus, the actions of the buttons may be overridden by it to allow some simple forms of user interaction. The last button (`Show/Hide`) gives the user the ability to turn off the main panel, thus freeing up most of the field of view. A similar mechanism for controlling interactive menus using buttons has recently been developed independently of our work [7], which perhaps illustrates its practicality in the wearable context.

Sulawesi is also able to monitor the user's environment and manipulate the user interface accordingly. For example if Sulawesi detects from its positional input stream (normally GPS) that the user is moving at speeds greater than about 10 miles/hour, the display can automatically be hidden until the user stops moving.

References

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