Is There a Wearable Computer In Your Future?
(Extended Abstract)

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Abstract.

Wearable computers are beginning to appear in research environments and soon will be commercially available. We present several different philosophies behind wearable computers and then focus on a particular project at Carnegie Mellon University involving the development of a wearable designed for the maintenance of large vehicles. This computer is discussed in terms of its project use (both solo and collaborative), its development process (rapid)and its physical characteristics. The paper concludes by discussing some implications of wearable computers on the current user interface evaluation techniques, on user interface development environments and on models for cooperative work.

1 Introduction

With the decreasing size and increasing power of most of the components of a modern computer, it was only a matter of time until computers that can be worn on the body began appearing. Currently, there are several different approaches to body worn computer that have appeared in research laboratories.

Figure 1 - General Purpose Wearable Computer

Figure 1 shows a picture of a wearable computer that was developed at the University of Toronto [3]. This configuration consists of a display/CPU combination that is worn on one arm and a one handed input device that is worn on the other. This device is an example of attempting to bring general purpose computing to the body. Any program that can be driven with keyboard input (which is most programs) and whose output is legible on the display (currently a

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limited set but sure to grow) can be executed. This would be especially true if one of the new light-weight mouse input devices were incorporated into the keyboard.

Figures 2 and 3 show a picture of a wearable computer that was developed at Carnegie Mellon University [5]. The configuration shown in Figure 2 consists of a Virtual Vision goggles (currently VGA resolution) together with an input device and an embedded processor. Figure 3 shows an expanded picture of the input device and the processor. The interesting thing about the input device is that it consists of a dial and a pressure switch. This is not a general purpose input device but is specialized together with the software for the particular task of assisting maintenance of large vehicles by providing a hypertext version of maintenance manuals.

Figure 2 - Maintenance task oriented wearable computer

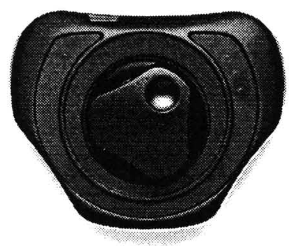

Figure 3- Processor, input dial and pressure switch from Figure 2 in close up

This dichotomy between general purpose computers and task oriented computers is not a new one (think of your VCR) but the trends of miniaturization and decreasing cycle times (time from concept to implementation) will make task oriented computers much more frequent. The focus on task orientated computers is also different from the focus on ubiquitious computing[6]. In ubiquitious computing, each person is assumed to be continually interacting with hundreds of nearby wireless interconnected computers. In task oriented computing, the user is assumed to be interacting with a single computer that supports a single task.

In the remainder of this paper, we will explain in more detail the task oriented computers being constructed by CMU, we will describe the future envisioned for this family of computers and we will explore some of the implications of the construction of this class of computers on Human Computer Interaction.

2 CMU Task Oriented Computers

The pictured iteration has a weight of 1.5 pounds including batteries, has a 386 processor and is an embedded system without an operating system.

The use of a dial enables the worker to manipulate the system wearing gloves or through the cloth of a pocket. It also facilitates the protection of the device from the grease and corrosive chemicals that are pervasive in a maintenance environment.

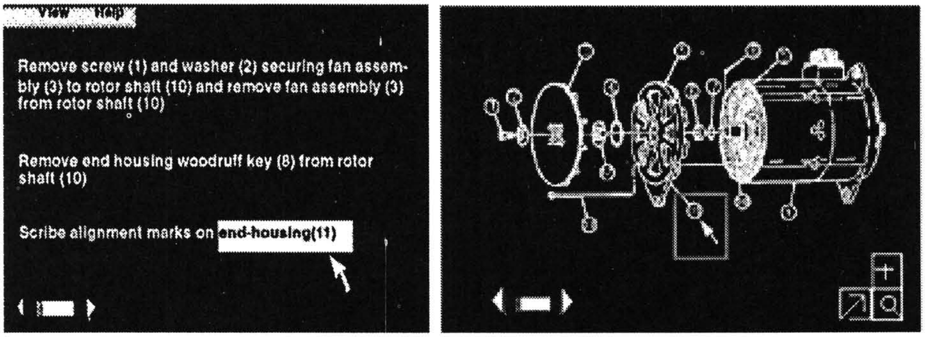

Figure 4 - Interface illustration of hypertext link to the corresponding schematic

The computer pictured is the sixth iteration in a process that heavily utilizes undergraduate students, takes nine months from conception through fabrication to final delivery and involves Industrial Designers, Human-Computer Interaction professionals, software, hardware and mechanical engineers. On some iterations, functionality is added to the system without extreme concern for size and performance. On the other iterations, the functionality achieved in the previous iteration is made smaller, lighter and more efficient.

3 Future for CMU Wearable Computers

The current version of the wearable computer is used only in solo situations. The goal is to extend the maintenance scenario to encompass collaborative problem solving where an expert is located in a remote location and views the maintenance scene through a video connection. The maintenance worker will have a lipstick video camera as a portion of the computer configuration and that camera will enable the two workers to collaborate to solve particular problems.

We also intend to add additional modalities to the wearable. In addition to the current dial, a speech recognition capability is currently under development and text to speech output is being investigated.

The goal, then, is to have a collection of hardware and software components so that a hands free application can be configured very quickly. The software for the different modalities will operate on a plug and play basis, the hardware components will plug into a common bus, the form factor will be chosen from a variety of available form factors and the system will operate in either solo or cooperative mode with a comfortable user interface.

4 Getting There From Here

The future we have sketched involves several different types of developments. Those of interest to the Human Computer Interaction community include the development of plug and play software modules for different modalities, understanding the user interface issues associated with mixed modalities, understanding the user interface issues associated with cooperative work where one participant is an expert consultant and the other is engaged in manual operations on some physical artifact, and understanding how the aesthetics of the form relate to the aesthetics of the user interface.

The next sections deal with some of these issues.

4.1 Plug and Play Software Modules for Different Modalities

Even given the single task of maintenance, there are differing input and output possibilities and differing scenarios of usage. For this reason, the software architecture should be designed to have a clear separation between the application dependent portions (independent of input/output considerations) and the input/output dependent portions (without specific application knowledge).

At the application level, then, we can focus on those aspects that are specific to each application area for the which a wearable might be used and at the user interface level, attention can be paid to making the various modalities work in a plug and play fashion.

This leads to a software architecture that has the form where each input or output modality has a library that manages the specifics of that modality and gives a common interface to the virtual device layer. The virtual device layer manages all of the decisions about what modalities are included in the current system. This yields a layered software architecture that has the following flavor..
The development of the complete set of libraries will be an evolutionary process. The libraries will be developed as needed by the various applications that we develop. Initial modalities will be the display device, dial and speech. Special attention will be focussed on those modalities that will be highly used., e.g., the display library.

4.2 Understand the User Interface

We are approaching understanding the user interface through a variety of field studies. Two have so far been completed. One involves the US Marines doing maintenance on amphibious vehicles. This application consists of performing a maintenance inspection to determine the necessity for parts replacement. A second field study involved a controlled experiment utilizing students at the Pittsburgh Institute of Aeronautics. In this experiment, a particular maintenance task was performed by students in four different conditions: alone using paper manuals, alone using computer based manuals, collaborating with a remote expert using audio communication and computer based manuals, and collaborating with a remote expert using both audio and video communication and computer based manuals.

The results of these field studies are informing both the design of the user interface for the next iteration and the longer term problem of deciding on the appropriate strategies for invoking expert assistance.

Two other field studies are in the planning stages. One involves actual lead mechanics from a variety of airlines who are being trained on the maintenance of a new Boeing aircraft and the other will result from a relationship with Daimler Benz that is just beginning.

4.3 Compatibility of Form and the User Interface

The size of the housing and the use of a dial for an input device are the results of requirements derived from the necessary electronics and the use of the device. The style chosen is the result of user investigations and application of industrial design techniques. The various portions of the physical components are in harmony with each other. The style of the user interface should also be in harmony with the physical style of the device.

5 Implications for Human Computer Interaction

In the past, most computers have been designed as general purpose devices. This is because, in large part, computers have been expensive to construct and the cycle time for a new computer has been long. Special purpose computers often have a small potential market and it did not pay to make the investment to produce them. With the decrease in cycle time and the increased availability of off the shelf miniaturized components, the construction of a specialized task oriented computer will much more frequently be cost effective.

5.1 Issues of Style

Currently, the only method we have to discuss style is through style manuals. That is, there are not tools that will test a description of a window boundary to determine whether it is Motif compatible. This, by itself, isn't particularly interesting but if the problem is framed "determine if two windows have the same style", it becomes more interesting. If the problem is framed "determine if the style of this user interface is the same as the style of this form, then we have a problem worthy of some effort. The solution to this problem assumes that we have some notational mechanism to describe style, that there is some concept of what it means to be of a certain style and the style concept extends between the look and feel of the user interface to the size shape and feel of the form.

5.2 Limited Resource Availability

Another problem, possibly another version of the style description problem, is how to build knowledge of the target system into the construction system. Wearable computers for many years, will have to deal with issues of limited display real estate, limited resolution, limited memory and limited power availability. Thus, prototyping and system construction tools should be able to understand the impact of particular choices on a target machine that has different capabilities. For example, when using a WYSIWYG builder on a computer with a high resolution display, I would like to be able to specify that the target system has VGA resolution and have font size, etc. be automatically constrained. An example is understanding the implications of selecting speech as an input modality on power, on the number of slots required during design and so on.

5.3 Multi-Modality

We sketched a layered software architecture that will support a plug and play collection of different modalities. Such an architecture will not support an intermixing of modalities. This is called the "put that there" problem [1]. For example, "Put that there" is spoken and the "that" and the "there" are gestures pointing to items on the display. In order for true multi-modality to be implementable, knowledge of the input to one modality has to be available to the others.

5.4 Rapid Development

The wearable computers are developed on a nine month cycle. This conforms to the school year and is, relatively, inelastic. Given that each cycle begins with a technology assessment and that the students all must be trained in the method used, the effective cycle time is about six months. This is from understanding the concepts to final delivery. Standard user interface design and evaluation methodologies are too time consuming to fit into this cycle. A normal evaluation takes at least several weeks for set up including detailed story boarding or prototype construction, selection of customers, and evaluation of results. Given construction times, the number of user evaluation iterations is strictly limited. Any design methodology that involves a through exploration of alternatives is also too expensive in terms of time.

What is needed are "lightweight" techniques such as those proposed by Jacob Nielsen[4]. These techniques are needed both during the user interface design process and during the evaluation process. In particular, one question to ask of a design process is at what point in the methodology does the selected technology for the computer become an element. If it is late in the method, then the method is likely too expensive to be useful in a situation where rapid deployment is important. A question to ask of an evaluation method is the cost (in terms of time) or using the method and the probability that the results are indicative of a particular class of users.

5.5 Computer Supported Cooperative Work

CSCW environments have traditionally been broken down by time and synchronicity[2]. This taxonomy is far too limited to be useful in the design of a cooperative wearable system with an expert helper. There is clearly a difference between cooperative authoring between peers using equivalent full featured work stations and a maintenance problem solving between an expert and a less skilled employee where one participant has a full featured work station and the other has a wearable computer. Although some systems have been constructed that are intended for one to one instruction, no general principles have as yet emerged to guide others in the construction of such systems.

6 Conclusion

Wearable computers constructed using a rapid development process are the logical extension of current trends both in development and in miniaturization. These trends will make task oriented computers realistic and, consequently, call into question some of our current assumptions about how one builds and evaluates a computer system. In particular, user interfaces must be constructed and evaluated in conjunction with the form and the electronics of the rest of the system. This paper gives some of the implications of these trends.

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