Chapter 1

Introduction

1.1 The Limitations of Mobile Computing

The past two decades have seen continuous improvements in computer power and miniaturisation. In the early 1990's this technology reached the point where it was possible to fit all the components of a desktop personal computer into a small and lightweight box, while still retaining most of the speed and power of the desktop model. When this style of computer is designed to be portable and easily used outside of an office, it is called a *mobile computer*. The extent of the mobility of these machines are determined mostly by their size and weight, and to a certain degree by their shape.

The portability of the older mobile computers was limited by the size of the internal components, such as disk drives and the CPU. As the technology progressed, the size of the components was no longer the limiting factor. The computer itself could be the size of a small keyboard, but it could not become any smaller. It could become thinner and lighter, but any further reduction in size would make the keyboard interface more difficult to use. The requirement of a keyboard interface imposed limitations on the situations in which these computers could be used. The mobile computers were small and light enough to be carried anywhere, but operating them required the user to sit down and place the device on their lap, a table, or a similar surface. Mobile computers had reached the point where their input devices were preventing them from becoming any more portable.

In recent years handwriting recognition has come of age. Systems have been built with more than 97% accuracy (MacKenzie & Zhang, 1997). This has enabled a new spurt in computer miniaturisation. Computers are again partly limited by the size of the components, but they are also limited by the stylus input. The stylus needs a flat surface to write, which forces the computer into a notepad-like shape.

The usefulness of a mobile computer is dependent on how well it functions in a *mobile environment*, a place where there are no standard surroundings and the facilities at hand (i.e. power supply, resting surfaces, etc) cannot be guaranteed. A notebook computer is portable, but not especially usable in a mobile environment, because of the afore mentioned limitations imposed by the keyboard. A handheld computer is portable and usable in mobile environments, but is limited in size and shape by the stylus-and-notepad interface. The next step in computer miniaturisation is the wearable computer. A *wearable computer* is a computer made up of parts small enough to be worn on or as clothing. The monitor is often worn like glasses (although often much bulkier). The CPU is usually attached to a belt, and the input devices are located on the CPU or mounted somewhere on the body. This frees the user from needing to carry the computer, making it even more portable than a handheld computer. The problem with wearable computers is that no common input devices are mobile enough to easily interact with them.

1.2 Designing Mobile Input Devices

Since no existing input device is up to the task, in order to make wearable computers a feasible option, we need to find a new style of input device which does not put any constraints on the overall shape or size of the computer. With this primary requirement, we can derive a set of basic design goals by considering four factors. These factors are: the environment the devices will be used in, the kind of person we expect to use the devices, the tasks the devices will be used for, and the hardware the devices will interact with.

These devices should be designed to be used in a mobile environment. In this setting we cannot know what surroundings there will be, so the devices must be able to operate without requiring the user to be in a specific position, such as sitting down, nor require any surfaces on which to brace the device. This can range from hostile environments, such as underwater to more everyday uses such as working outside or while commuting.

These devices must accommodate the type of person who currently uses mobile computers, and also those who would benefit from the additional mobility of a wearable computer. The former type of user is the *nomadic user*, who takes their computer from place to place, but only uses it while not moving. This sort of user is easy to accommodate, even with existing systems. The latter type of user is the *continuous user*, one who uses their computer while moving, and, in all likelihood, performing non-computer tasks simultaneously. These people are more difficult to accommodate, since they need to access information on a computer quickly, easily, and in a way that does not interfere with their performance of real-world tasks. These users need a mobile interface which is invisible enough that they can switch between computer and real-world tasks at will and with detriment to neither.

The expected tasks for these devices are also similar to the normal mobile PC usage. Handheld computers are commonly used for personal information management. Notebook computers in a mobile environment are often used for some of the simpler tasks performed on a desktop computer. Consequently, the new devices should be designed to be capable of operating a windows-style interface as well as being able to handle general text input, including basic composition.

Finally, the new input devices should be designed to run using existing wearable computer systems. This means that they can be attached to the computer in a standard way, i.e. via keyboard, mouse, serial or parallel ports or by using PCMCIA cards. They should also be compatible with existing operating systems, preferably windows-based. The input devices should not require excessive computing power to run. These devices should be able to be used with existing computer speeds and memory, i.e. requiring no more than 133MHz or 16Mb RAM.

These basic design goals are the minimum requirements we have for a mobile input device. In order to determine how to design and build a mobile input device we need to examine existing devices and extrapolate from their design principles to arrive at a set of guidelines for creating mobile interfaces. This is the subject of the next chapter. The remaining sections of this chapter outline the objectives, scope, main contributions and structure of this thesis.

1.3 Objectives

This thesis examines the important factors in the design of text and graphic input devices and reconciles them with the limitations imposed by a mobile environment. Using these as guidelines we have developed new input devices, designed specifically to be unobtrusive, easy to use, and portable. These devices are the Chording Glove and the Biofeedback Pointer.

The Chording Glove is a chord keyboard, with the keys mounted directly on the fingers of a glove. Instead of the fingers pressing buttons on a board, the buttons are on the fingers and can be pressed against any hard surface. The Biofeedback Pointer uses the bioelectric impulses generated by moving the wrist to control a two dimensional graphic pointer. Moving the wrist horizontally or vertically causes the computer pointer to move in that direction.

The performance of each device was examined empirically. The goal of this is to show that the concept behind the devices is feasible and that devices based on one or both of these could work as input devices for mobile computers.

1.4 Scope

Our primary concern with mobile computing is graphic and text input and how these devices affect the portability of a computer. We will not be considering the details of mobile computers themselves, only the design of the input devices. Mobile computers are only considered for their size and shape. The internal workings of the computer are irrelevant to our discussion. We will merely assume that they work.

The input devices will be considered primarily for their hardware design. Software design will be limited only to where it directly involves use of the device, such as pattern recognition or motion scaling. The graphic user interfaces will all be assumed to be based on the standard windows interface. As a consequence, the input devices analysed will either be two dimensional pointing devices or devices for entering written English text. Three dimensional interfaces and speech-based operating systems are discussed briefly, but only for comparison. Any further analysis of such devices is beyond the scope of this text.

A fair amount of understanding of physiology is necessary to fully appreciate the biological systems discussed in this thesis. In order to simplify matters we will limit discussion to bioelectric signals which can be detected by surface measurements. In addition, only those bioelectric signals which are involved with movement will be considered. This should limit the amount of necessary background to allow a fair discussion of the processes without getting bogged down by details.

The devices introduced in this thesis are for proof of concept. The intention is not to make a marketable device, but to investigate the uses of such a device and how it could be made more efficient.

1.5 Contributions

The following are the three main contribution of this thesis.

1. Several text and graphic input devices are reviewed in order to evaluate their design, determine their portability, and compare their performance. The current types of mobile computers are discussed, concentrating on how their shape and input devices limit their mobility. These factors are used to determine the most portable styles of input devices.

2. The results of the input device analysis are used to design two new input devices with the intent to maximise mobility. The Chording Glove is introduced as a wearable text input device. Pressure sensitive triggers mounted on the fingertips of the glove replace the keys on a chord keyboard. Chords are generated by pressing the fingers against any solid surface. In creating the chord keymap for the Chording Glove, a method for generating a chord keymap was developed. This can be adapted to create a keymap for any chording system, or develop new, specialised keymaps for

the Chording Glove. In addition, a theoretical method for comparing different chord keymaps is introduced.

3. The Biofeedback Pointer is introduced as a new portable graphic input device which translates wrist movements into motion of a two-dimensional pointer. This is done by sensing and analysing the bioelectric signals generated from the muscles which control the wrist. The methods used to control the Biofeedback Pointer can easily be adapted to other muscles or other graphic input styles (such as navigation).

1.6 Organisation

This thesis is organised into seven chapters, the contents of which are as follows:

Chapter two provides an overview of existing text and graphic input devices in order to determine their portability, performance, and to generate a set of design criteria to assist in creating new input devices. Special attention is paid to the use of Fitts' Law as a tool for determining the performance of graphic input devices and to the physiology necessary to understand bioelectric computer interfaces. The various styles of mobile computers are discussed and four factors are introduced by which their input devices can be rated for portability.

Chapter three introduces the Chording Glove and the Biofeedback Pointer. Details of the development phases of the devices are given, along with the final hardware and software designs. Potential uses each of the devices are discussed, both separately and as a unified system.

Chapter four describes the experiment used to determine the input speed, learning rate, error rate and other performance features of the Chording Glove.

Chapter five describes the experiment to determine the relative performance of the Biofeedback Pointer and the mouse. In addition, the neural networks used to analyse the subjects' bioelectric signals are examined and compared.

Chapter six considers the potential sources of error in the experiments in an attempt to ascertain any effects on the validity of the experiments. The second part of the chapter discusses areas for future research and experimentation.

Chapter seven provides a summary of the thesis with a discussion of the contributions and their implications.