Fulltime-wear Interface Technology

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Abstract

"Wearable interface devices" are the key to realizing a wearable computer. However, it is difficult to achieve both usability (ease of use) and wearability by simply miniaturizing conventional interface devices such as the keyboard and mouse. We reconsider interface mechanisms on the premise of "worn on the body for constant availability (= fulltime-wear)" and introduce a few examples of implementations that we have been working on.

1. The computer as a 'brain enhancement device'

Computers were originally designed as machines for performing calculations, but now they have also come to serve as an indispensable link between persons and between people and the world of information as well. The computer allows people around the world to interact via the Web and e-mail, and to access the virtually unlimited knowledge that exists on the network. It can thus be regarded as a machine that enhances man's knowledge and ability to communicate ('brain enhancement' function).

If we regard the computer as a brain enhancement device, we would naturally want to be able to use it at any time and any place as we go about our daily lives, rather than having its use restricted to certain times and places. Originally considered to be a very difficult problem, this scenario, too, is gradually being realized through the penetration of the personal computer into ordinary homes and the proliferation of the cell phone (itself a kind of small computer) that can connect to the Internet. We could also say that 'any time, anywhere', a phrase which has long been used to express a goal of the future information society, has been achieved for the most part.

However, the ability to obtain information as soon as the need for it occurs to us (immediacy) is important to the goal of handling information on the same level as our own memory or thinking. Unless a result can be obtained immediately after the need for it arises, many opportunities will be lost, so such delayed information is not useful for supporting daily life activities. No matter how small and powerful portable devices are made, they cannot be available for use as soon as the thought to use them occurs if they must be carried in a pocket or purse, because such devices must first be taken out from where they are being carried. One solution to that problem is to wear the device on the body full-time as one goes about one's daily life. Although the term 'wearable' is often used to refer to an advancement of the 'portable' concept, an important element in its meaning is the ensuring immediacy of availability, in addition to improvement in portability through miniaturization.

Past research on wearable devices has emphasized making a computer (processing device) that can be worn on the body. In a world where continuous connection to a network is commonplace, however, the need for a computer (information processing mechanism) to be worn on each person's body fades. In such a world, the computation and memory functions can be positioned on the network side, where great processing power is available and there are no strict limits on size or power consumption. In that case, what must ultimately be 'worn' is only the 'interface' for conveying the user's intentions to the network and displaying the results from the network to the user.

However, we believe that the approach of simply miniaturizing interface mechanisms that have been designed for use on the desk top, such as the keyboard

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or mouse, creates problems for both usability and wearability. Interface mechanisms must be designed anew and specifically for devices that must be worn full-time, such as 'brain enhancement' devices.

We are doing research and development on interface mechanisms that satisfy the conditions listed below; we refer to such mechanisms as fulltime-wear interfaces.

① Wearability: Does not interfere with daily activities even if worn full-time.

② Usability: Rapid input and output without disturbing the flow of the user's thought is possible.

③ Immediacy: Can be used immediately after the desire to use it arises.

In the following sections, we describe various interface mechanisms that are suitable for fulltime-wear devices and present some implementation examples.

2. Fulltime-wear interfaces

Some examples of fulltime-wear interfaces are listed in Table 1. In the following subsections, we consider methods for implementing fulltime-wear interfaces for various input/output media, such as text, voice and images.

2.1 Input mechanisms

(1) Keyboard input mechanisms for text and commands

For conventional keyboards that are operated by pressing buttons with the fingers, it is difficult to achieve miniaturization without decreasing usability. If we think of a keyboard as a mechanism for input by moving the fingers, however, the need to have buttons arranged in an array disappears. The glove-type input mechanism is a well-known means of input based on finger movement [1], but gloves hinder our everyday activities by covering the fingertips and other sensitive parts of the hand that are important to the sense of touch. One way to detect typing movements without covering the fingertips is to attach acceleration sensors at the fingertips and wrists to detect the impact created by striking keys [2], [3]. An example of input using this method is presented in the next section.

(2) Pointing mechanisms

The mouse, a typical pointing device used with personal computers, requires space for operation and so is not suitable for wearable systems. The track ball, another computer pointing device, does not require much space but it is difficult to use small track balls for fine pointing. Rod-type pointing mechanisms [4],

Table 1. Examples of fulltime-wear interfaces.

INPUT	Keyboard	An array of key switches is difficult to use in a Fulltime-Wear environment. → Direct detection of finger movements • Detection of tapping impact by accelerometer (FingeRing/UbiButton) • Detection of finger bending angles from myoelectric signals (CyberFinger) • Detection of finger bending angles by optical fiber (DataGlove) • Use of ultrasonic or light reflection
	Pen input	Requires a pad (difficult to achieve both wearability and usability) → Padless operation • Combination of pen-shaped 3D locator and translucent HMD
	Speech-to-text interface	Difficult to use in the presence of others (nuisance) → Less need to speak loudly by improved feedback of own voice (FingerWhisper) → Inferring utterances from changes in mouth shape (lip reading) • Lip reading by recognition of images from a small camera • Use of myoelectric signals from mouth muscles
	Visual input	Post-processing is heavy, but the device itself has good wearability.
OUTPUT	Audio output	High simultaneity (can be used while performing other tasks). → Fulltime-Wear because of ultra-small earphone • Feedback by text-to-speech conversion
	Visual output	Low simultaneity (hazardous because visual field is obstructed or reduced). → Use only when necessary • HMD is optimal for miniaturization of high-resolution, wide view-angle screens.
	Other sensory channels	Touch, pain, temperature, and itchiness → For special purposes (evoking caution, etc.)

* The red letters indicate examples that are introduced in this article.

on the other hand, retain usability even in limited-space installations, so they are easily wearable. In particular, single-hand operation can be realized by attaching a flat, multi-axis pressure sensor to a fingernail or the side of a finger.

(3) Voice input

The input of text and commands by voice recognition is fast and requires no training. This method is also suitable for fulltime-wear systems because only a small microphone is required. At this time, however, the appearance of talking to oneself in public is not socially accepted. Voice input earphones and microphones may be useful sometime in the future when such behavior becomes acceptable, but until such a time, a method that is more socially acceptable is needed. One example is the wristwatch-type handset that implements a telephone-like operation style as described in the next section.

(4) Visual input

An interface for visual input of commands by recognition of mouth movements and facial expressions can be used without disturbing those around us. However, capturing images of the body requires a certain distance for positioning the image capture device, which decreases wearability. Recognition of one's surroundings from images acquired by a camera worn on the body, on the other hand, does not suffer from positional and optical restrictions and so is very implementable. For example, character recognition of text that appears in signs or address displays in images of the user's surroundings [5] can be used to surmise the user's location. Also, face recognition technology could be used to identify other persons in a conversation so that the user's memory could be supplemented by retrieving information about those persons from a database.

2.2 Output mechanisms

(1) Image display

With conventional display panels, the same as with keyboards, it is difficult to achieve both wearability and usability (ease of character reading and browsing) at the same time. This problem can be solved by using a head-mounted display (HMD), which can present a wide field of view with a small display panel or a device that projects images directly onto the retina [6]. However, systems that provide constant visual feedback are disadvantageous in terms of safety. Visual output should be turned on explicitly with a switch for use only when needed.

(2) Audio output

A small wireless earphone has excellent wearability. Furthermore, sound can be used to convey information without interfering with other actions (i.e., it has the quality of simultaneity), so it is suitable as an output mechanism in a fulltime-wear environment.

On the downside, it is difficult to convey information rapidly with text-to-speech conversion, so methods of data compression such as text summarization and conversion to symbol form using musical icons may be used together with methods of increasing the data presented by three-dimensional sound fields.

(3) Touch, pain, temperature and other senses

Output methods of these kinds have a higher degree of simultaneity than does sound, and they do not have disturbing effects on the user's surroundings. On the downside, however, they are not suitable for conveying a large amount of information.

In any case, it is difficult to cope with all circumstances with a single means of output. We expect that multiple media will be used in combination, as described below for example.

① The arrival of information is announced by tactile means such as vibration

② A short audio summary of the information is given via an earphone

③ Details are displayed when a visual feedback device is manually turned on

3. Implementation examples of fulltime-wear interfaces

In this section, we describe an input mechanism that employs the impact of finger tapping, as in typing, and an audio mechanism that employs the conduction of sound by bones as examples of implemented fulltime-wear interfaces.

3.1 Fulltime-wear command input interface

UbiButton [3] is a fulltime-wear command input interface. It uses a single one-axis acceleration sensor attached to the wrist to detect the impact of fingertips tapping in a typing-like motion. The timing of the tapping can be used to distinguish among a set of from 10 to 30 commands in a manner similar to Morse code. The small sensor can be installed inside a wristwatch, allowing the user to go about daily activities while wearing it. The input operation can be done on any surface, such as a desk, a purse or one's lap, so it is not necessary to select a keyboard and the immediacy required of a fulltime-wear interface is achieved. Even when no tapping surface is at hand, input can be accomplished by lightly touching fingers together ("OK tapping"). In particular, when UbiButton is installed in a wristwatch, one-handed operation in which the wristwatch can be controlled by the hand on which it is worn is possible. Furthermore, by incorporating UbiButton into eyeglasses or earphones, devices can be operated without the need to press small buttons by simply tapping lightly near the device with a fingertip. Future development will aim at further miniaturization of sensors by using microfabrication technology and increased expressive power by discriminating the tapping force and tapping finger.

The UbiButton sensor and the "OK tapping" operation are shown in Fig. 1.

3.2 Fulltime-wear keyboard

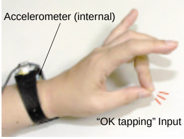
The number of commands can be increased by putting a sensor like UbiButton on each finger to make it possible to know which finger is being used for typing. One example of this approach is FingeRing [2], a mechanism in which a ring-like one-axis acceleration sensor is worn on each finger. Because the fingertips are not covered, as they are with glove-type keyboard input devices, this mechanism has little adverse effect on daily activities.

As with UbiButton, it is not necessary to find a typing surface, so this interface can be used anywhere. Commands are expressed as combinations of strokes of the fingers used in typing. From 30 to 50 commands or characters can be input relatively quickly (200 characters per minute for a skilled person) by using a combination of 'simultaneous tapping,' in which multiple fingers are tapped at the same time, and 'sequential tapping,' in which fingers are tapped at short intervals.

The FingeRing sensor is shown in Fig. 2. Further technological advances for this fulltime-wear command and text input device may lead to a "virtual keyboard" that enables the same kind of input operation as does an ordinary full keyboard, but with nothing more than a device worn on the wrist like a wristwatch.

3.3 Handset mechanism worn on the wrist

"FingerWhisper" (referred to as simply Whisper below) is a communication handset designed to be worn on the wrist as a fulltime-wear interface [7]. It is used by inserting the index finger or middle finger of the hand on which it is worn into the ear canal. The received voice signal is converted to vibrations by an actuator (electro-vibration converter) in the wrist unit, and the vibrations are conducted through the bones of the hand to the fingertip and then to the ear. The user's speech is captured by a microphone in the wrist unit. (When the user's finger is in the ear for listening, the wrist is close to the mouth). Using bone conduction of sound allows miniaturization while still maintaining a suitable distance between microphone and 'speaker' (i.e., the distance between wrist and fingertip). Thus miniaturization is achieved without loss of usability. The bone conduction method also allows listening in a noisy environment without turning up the volume (an improvement of 13 dB compared to a conventional handset in the case of surrounding noise of 90 dB). It also allows the user to speak in a softer voice (improvement of 6 dB under the same circumstances). Whisper can be worn on the wrist and is difficult to distinguish from an ordinary wristwatch, so it does not give others the impression that the user is 'wearing a strange device' as conventional wearable devices have done. To others, the user of this device appears to be using a telephone that has a small handset rather than talking to himself, as it seems when using an earphone-microphone device. This feature may also be effective for use in voice operation of a computer. Combined use with UbiButton described above makes hook and dialing operations possible without pressing small buttons, thus improving usability. Whisper is expected to serve as



(Input by "OK tapping" is possible, even while walking)

Fig. 1. Fulltime-wear command input mechanism (UbiButton).

Fig. 2. Fulltime-wear text input mechanism (FingeRing).

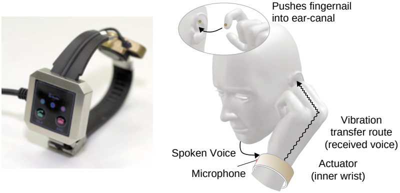


Fig. 3. Wrist-worn handset (FingerWhisper).

a bridge to the future era of wearable devices by lowering the resistance to "life with wearable machines." The appearance and structural diagram of the prototype are shown in Fig. 3.

4. Toward a bioinformation interface

The goal of regarding portable information devices as thinking support systems is to make use of the obtained information on the same level as one's own memory and thinking. However, although fulltime-wear interfaces provide a high degree of immediacy, the act of 'operating a machine to obtain information' remains as a gap that separates the use of such devices from one's own thinking. If it were possible to tap directly into the signals that are transmitted by the nerves of our bodies, however, it would be possible to access information on the same level as our own thinking, without using our hands (effectors) or our eyes and ears (sensors). DoCoMo has therefore targeted the establishment of techniques for measuring and analyzing neural magnetic fields, which have high temporal and spatial resolution, for application to the interface. The results of that work will be useful for nerve signal analysis as well as being applicable to interfaces that employ neural magnetic fields directly. Nerve signal analysis will be essential to the implementation of 'implants', which will be the next step after wearable devices. In that future, humans and information will be directly linked.

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