Wearable Computers: No Longer Science Fiction

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EDITOR'S INTRO

By using devices carried on the body, wearable computers allow the exploration of the principles of pervasive computing immediately instead of waiting for the deployment of the ubiquitous infrastructure often associated with the field. However, wearable computers are often misunderstood, both in their research and application. I've been wearing a computer as part of my daily life since 1993, and in this column, I'll explore the attributes that make wearable computers a unique approach to ubiquitous computing and discuss current topics in the wearable computing field. If you'd like to contribute a short essay or idea, please contact me at thad@cc.gatech.edu.

—*Thad E. Starner*

One problem with developing pervasive computing systems is making them, well, pervasive. To deploy computers and networking services everywhere that users might travel requires prohibitive expenses in infrastructure and maintenance. However, there is an alternative: wearable computers. By carrying their own infrastructure, users are guaranteed a certain level of service wherever they go. But what should a wearable computer contain? What is the market for such a device, and when will wearable computing products become profitable?

The answers to these questions vary widely depending on if you ask the public, commercial vendors, or academics. Often the public equates wearable computers with head-up displays, body-carried computers, and speech or one-handed keyboard interfaces. Academics often use the term to refer to a desirable set of features such as context awareness, proactivity, and hands-limited or hands-free use that are somewhat independent of the hardware implementation, whereas market forecasters might define a wearable computer as loosely as any computing device worn on the body. We will explore these differences in perspective in future installments of this column, but for this first issue, I will don the mantel of an entrepreneur and examine wearable computing from the commercial side.

RUMBLINGS OF A NEW INDUSTRY

Market forecasters predict that some form of wearable computing will become pervasive in the next several years, but there still is no consensus about the form of these devices or their level of functionality. A 1999 International Data Corporation study estimated a US $600 million market for a "fully functional PC that a person could wear as a peripheral to their clothing" by 2003.[1] A recent Gartner Group study predicted that by 2007, 60 percent of the European Union and US population aged 15 to 50 will carry or wear a computing and communications device at least six hours a day.[2] By 2010, Gartner predicts that this number will grow to over 75 percent. Bear Stearns and Jupiter Communications forecast that computing devices worn on the body and equipped with Internet access will exceed 100 million units sold by 2003.[3] Bear Stearns further reports that the market for point-to-point purchases made on such devices is expected to reach US $1 trillion by 2003.

Although these projections are often difficult to compare and could be affected by the 2001 market downturn, they hint of something afoot. The question is, what? Pen computing was in a similar state of flux in the early 1990s. Advocates, market analysts, and the press generated a lot of excitement, but almost five years elapsed before the introduction of the highly successful, horizontally positioned Palm Pilot. Many clues hinted where the markets would develop before Palm's introduction, though. Wearable computing is still waiting for a consumer-oriented horizontal platform, but several successful companies offer similar clues to potential markets and bear closer examination.

THE STATE OF THE INDUSTRY

One example of a successful early wearable computer is the portable digital music player, which sold over 3 million units in 2000.[4] Some might ques-

tion whether we should think of these players as wearable computers, but they *are* designed for mobility, and they contain many appropriate components: a processor, mass storage (such as flash or hard disk), earphones, and primitive displays and keyboards.

Although portable MP3 players are commonly viewed as a replacement for the portable compact disk player, companies began exploiting the computational aspects of these players to use them for museum tour guides or audio books. Computer enthusiasts have been known to rewrite an MP3 player's interface software to upload and download any type of data, effectively turning the device into the equivalent of a large floppy disk.

More recently, these devices are merging with PDAs and cell phones to create a wide variety of products. IDC expects sales of portable devices with digital audio playback capability to grow to 15 million units by 2005.[4] In a sense, these devices demonstrate a future market in wearable computers as flexible consumer electronics devices. Imagine a processor and hard disk encased in a pocket-sized base unit. The software downloaded to the device and the peripherals added to it would then determine the machine's functionality. In such a way, a wearable might morph between a portable music player, cell phone, or Web browser as the user desires.

Another ongoing success story is Symbol, which has sold approximately 100,000 units from its WSS 1000 line of wearable computers (see Figure 1). Depending on configuration, the WSS 1000 series costs between US $3,500 and $5,000 and consists of a wrist-mounted wearable computer that features a laser barcode scanner encapsulated in a ring worn on a finger. This device frees both hands so that the user can perform tasks while scanning barcodes. They are often used in warehouse receiving and picking, shelf inventory, point-of-sale checkout, package tracking, baggage handling, and parts assembly. Scanning a package or item with the ring scanner is part of the

motion made when reaching for a package. Because the user no longer has to fumble with a desk-tethered scanner, these devices increase the speed at which the user can manipulate packages and decrease the overall strain on the user's body. Symbol's success did not come overnight; it spent over US $5 million to develop this new class of device and was surprised repeatedly by human factors and usage problems during initial testing. However, the resulting product is a notable success, providing the company with a unique differentiator and profitable new markets.

Pittsburgh-based Vocollect also focuses on package manipulation—in particular, the warehouse-picking problem. In this scenario, a customer places an order consisting of several different items stored in a supplier's warehouse. The order transmits from the warehouse's computer to an employee's wearable computer. In turn, each item and its location are spoken to the employee through a pair of headphones. The employee can control how this list is announced through feedback via speech recognition and can also report inventory errors as they occur. The employee accumulates the customer's order from the warehouse's shelves and ships it. This audio-only interface also frees the employee to manipulate packages with both hands, whereas a pen-based system would be considerably more awkward (see Figure 2). As of December 2000, Vocollect had approximately 15,000 users and revenues between US $10 and $25 million.

Wearable computers are also successful as mobile medical aids. Modern heart pacemakers use a computer and sensor package that adjusts the heart rate based on the user's level of exertion. Some pacemakers even include screen output so that a patient can monitor his or her unit's effectiveness. Using a wireless short-range network, deep brain stimulators are programmed to provide the proper signals to help control tremor in Parkinson's patients. More commonly, companies such as

Figure 1. Symbol's WSS 1000 series wrist-mounted wearable computer with ring scanner.
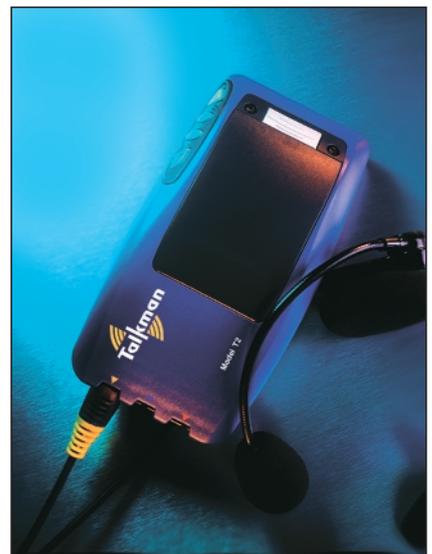
Figure 2. Vocollect's audio-based wearable computer.

Fitsense and BodyMedia now sell wearable computers that help monitor a user's health during exercise or everyday life.

Wearable computer markets are developing in inspection, repair, and maintenance. Carnegie Mellon University has shown that major time

and cost savings occur when using wearable computers instead of paper manuals to maintain equipment and infrastructure. Charmed Technology, with whom I am affiliated, provides open hardware and software wearable platforms that let corporate research and development agencies customize wearable computers to new tasks rapidly. Wearable manufacturers such as Via and Xybernaut support case studies with industrial partners to prove the value of wearable computers for such tasks. For example, Via recently completed a study with McDonald's restaurants, showing how its wearable computers can help reduce customer wait time and improve order accuracy.

Undoubtedly, between the consumer and industrial possibilities, wearable computers will become a larger market force in the near future. However, given that the first wearable computers were made in the 1960s, why has it taken so long to reach this stage? What is so hard about making a wearable computer? What are the next breakthroughs, and what does academia see in these devices? In each installment of this column, we will examine a different wearable computing issue in an attempt to answer these questions and demonstrate this new field's richness. **P**

COMING NEXT COMING NEXT COMING NEXT

A look into the research labs

Wearable computers have held an underground niche with researchers since the early 1960s when Ed Thorp and Claude Shannon created a wireless wearable computer that could predict the game of roulette. However, in the 1990s, independent university projects began to shape an academic field of wearable computing. The process continues today with active academic groups in Europe, Asia, and Australia. In the next issue, we will examine why wearable computing makes such a compelling research topic.

REFERENCES

1. C. Arrington, *Alternative Computing Devices Report Series: Wearable Computing*, tech. report #W19020, Int'l Data Corp., Framingham, Mass., 1999.

2. J. Fenn and A. Linden, *Wearing IT Out: The Growth of the Wireless, Wearable World*, tech. report SPA-13-2057, Gartner, Stamford, Conn., 2001.

3. J. Neff and W. Bean, *iAppliances*, Bear Stearns, New York, 2000.

4. S. Kevorkian and B. Ma, *MP3 Players and More: Forecast and Analysis of the Worldwide Compressed Audio Player Market, 2000-2005*, tech. report #W24064, Int'l Data Corp., Framingham, Mass., 2001.

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