

## Wearable Computing for the Masses

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The term “*wearable computer*” often conjures up images of a person encumbered with electronics, including a characteristic heads-up display (Figure 1) – eliciting a smile or two from members of the mainstream computer science community (and the majority of those who report on the subject). Some may even describe the imagery as reminiscent of the infamous “Borg,” an advanced alien race on latter-day Star Trek spin-offs linked together through cybernetic implants to form the so-called “Borg collective.” To be fair to the wearable community, many of whom are our good friends and colleagues (and I hope will remain so after this article), this stereotype is a little outdated. The modern computer systems used to assemble a wearable computer are becoming very compact and are easily concealed in everyday clothing. Even the displays can be integrated into a more natural looking set of glasses, although admittedly with rims that are somewhat thicker than the more fashionable variety. However, the future of these systems is not only determined by technical feasibility, but also the fragile social criteria of user acceptance. Anybody who has talked to a colleague using a wearable device is faced with the disconcerting issue of trying to figure out if the “Borg” person is paying attention to them, or surfing the web between verbal exchanges. Few of us wish to be the early adopters of wearable computing if we are subjected to the inevitable judgmental view that would classify us as social outcasts, particularly if it jeopardized personal or professional relationships.



Figure 1 A Classic Wearable Computer



Figure 2 The Intel Research Personal Server

Why is there still an interest in wearable computing even with the negative stereotypes and encumbering equipment? In many respects, wearable computers serve to augment our social and work practices without requiring us to carry a separate computing device

in our hands. A wearable permits a large amount of data to be carried and accessed without the interruption of an explicit action, such a “pulling out” one’s PDA, and without requiring the user to physically go anywhere to get at their data. If done well, information can be found with minimal effort from a user, and if done very well, it can even be overlaid onto the real world using *Augmented Reality* techniques. In some ways, wearable computers allow us to become augmented people, not in a strength or an aesthetic sense, but rather an intellectual one. Ironically, the same component that enables these kinds of applications is the core piece of technology that gives them a bad reputation: the heads-up display. Whether it is because the display is ugly, or a person is distracted when using it, the result is that bystanders have relatively poor impressions of the technology. If you are prepared to use special eyeglasses, then modern wearable displays are very effective. However, if eyeglasses are not desired, traditional wearable computing is a non-starter.

How can the advantages of wearable computing be brought to the masses without affecting our fashion conscious egos –preserving the basic etiquette of social interaction as a first-class experience? The personal server (Figure 2) is the fusion of three technologies: high-density storage, low-power high-performance processing, and short-range wireless communication. The key to our approach is that the design has no display, a radical departure from the mainstream view of wearable computing and traditional mobile electronics such as PDAs and laptops. How can a device without a display be good for anything? The answer is all around us: since 1983, beginning with the debut of the first IBM PC, there has been a relentless deployment of electronic infrastructure. Today, there is hardly a modern venue that does not use multiple computers as cash tellers, storefront displays, ATMs, information kiosks, or publicly accessible web surfing tables. Enhanced with standardized wirelessly connectivity, all these devices afford the potential to provide the interaction medium for our personal storage and computation needs (Figure 3). At this point in time, most local resources are not easily accessible because they lack wireless capability, but this is a situation that will soon change because of the standardization of wireless technologies such as IEEE 802.11 and Bluetooth. There are many architectural research questions concerning how a personal server device would interact with local resources, but these are beyond the scope of this article – instead we focus on the wearable aspects of the Personal Server as well as the range of applications that it enables.



Figure 3 ATM machine used to check email messages.

### ***Where to wear a wearable?***

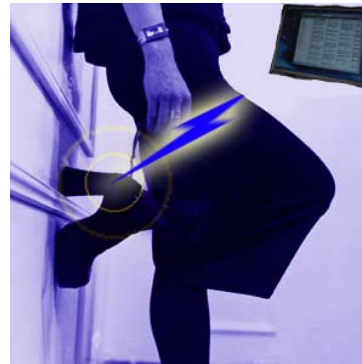
One of the intriguing consequences of separating the interaction from the processor is that a person does not need to physically touch the device at all. The device no longer needs to be easily accessible, allowing Personal Server physical designs to be considerably more adventurous than its hip-hugging clip-on PDA cousins: you can leave it in a bag (Figure 4), sew it into clothing, or even integrate it into the heel of a shoe (Figure 5). As long as the device is close by it can wirelessly serve its purpose of enabling digital interaction through the nearby infrastructure.



**Figure 4 Access is not important so the personal server could be stored at the bottom of a purse**



OR



**Figure 5 A Personal Server could be designed into the heel of a shoe**

Although a potentially smaller package design is one advantage of the Personal Server concept, it still needs a source of power and so charging a small, unobtrusive device becomes an interesting problem. In the case of a shoe server, you can imagine a small connector socket at the back of the shoe that would allow recharging of an internal battery. Discreetly placed sockets of this kind could be associated with all the clothing options you can imagine, but the larger issue quickly becomes: “could I remember to actually plug in my *jacket*” – not the sort of thing one usually thinks about. Another option is to use inductively coupled charging technology, allowing for the device to be charged merely by placing it *near* an electrical contact – enabling a range of secondary appliances, such as the “power shoe rack”: an organizer that lives in a closet and will both hold and charge a personal shoe server overnight – the possibility for novel Christmas gifts becomes endless.

### ***Wearable applications for the masses***

A compelling consequence of the Personal Server is that any computer can now easily become *your* computer by simply sitting in front of it you will be able to bring up your familiar desktop data and applications (Figure 6). Of course, nothing has really changed

on the desktop device – you are simply using a window on that device to wirelessly reach into it and interact with you personal data.



**Figure 6 A hotel lobby display is a convenient point to check a personal address book**



**Figure 7 An airport display is used to view a travel schedule stored on the personal server**

Large public displays (Figure 7) open up the possibility that you could see things that were specific to you as you walked by. For instance, you could arrange to see your travel schedule for the remainder of that day, served off your Personal Server. Using public infrastructure in this way might require a small payment to be made by the user – if implemented well, this would encourage the availability of ad-hoc infrastructure without burdening the user with unreasonable costs.

Public spaces, such as cafés, are prime candidates for interface sharing – why bother bringing your own laptop when you could borrow your neighbors (Figure 8)? It's easy, convenient, and who knows... you might meet somebody interesting!



Figure 8 Need to borrow a display?  
That man at the table next to you doesn't seem to be using his!



Figure 9 Serendipitous capture of information from a nearby restaurant

As we progress through our daily lives, there are many applications that don't even require a display. For example, the Personal Server could serendipitously capture menus from restaurants as you walk past (Figure 9), allowing you to browse menus of interesting looking restaurants later on, when a large screen display happens to be available (Figure 10). Or, since it is quite possible to have large quantities of CDs stored in MP3 or other compressed formats, access to your favorite music will be a matter of donning a wirelessly enabled headset or just being in the same room as a computer controlled entertainment center that plays music stored on your personal server.



**Figure 10** The bus shelter display is now a great place to check out the menu from that cozy restaurant you remember from a few blocks back.

The automobile is an important environment that is becoming progressively integrated with computing. Access to maps, personal music collections, seat height and ambient temperature settings should not be stored solely in the memory of a car, but rather in a user's Personal Server as they are more closely associated with a particular person. If you rent or borrow a car, your customization could then follow you from vehicle to vehicle...

Customization of any electronic device is conceivably within scope. For example any telephone could adopt your speed-dial preferences, giving you access to your most commonly dialed numbers at the touch of a button – on any phone!

## ***Conclusions***

Despite the advantages we have presented here there are still some people who believe it is essential to have a mobile display at hand. Early adopters of today's PDAs, such as the Palm Pilot, Handspring Visor, and Compaq iPAQ, often express this viewpoint. Our view of computing does not prevent the use of always-available displays like those provided by these PDAs – rather, a PDA becomes a window into personal data kept on a personal server (Figure 11), allowing users to borrow, rent, or break a display without losing data. This approach is a considerable improvement over the standard self-contained PDA since your data is not bound to any particular device. In the near future it is possible that PDAs and other tablet computers may become so inexpensive they can be used like scrap paper, scattered around our work environments with no explicit owner, waiting for a server enabled person to pick up and use. If you consider, the cost reduction that has occurred for the once expensive electronic calculator, and how prevalent these devices are today in the workplace, this may not be such an unlikely vision.



**Figure 11 Here ‘any’ PDA is used to access my data on my personal server in my purse. The PDA could have been borrowed or was available to customers of this coffee shop.**

If the personal server becomes the popular model for personal computing, doesn't this mean the death of the PC (Personal Computer)? For those of you who have noticed the affiliation of the authors this may seem like a curious research path for us to take. However, we feel quite the opposite is true: the personal server will actually encourage the proliferation of even more PCs than ever before. Once a significant number of people are using personal servers of this kind, there will be an expectation that all work and entertainment locales should provide interaction portals to facilitate access to our wearable devices. A consequence will be the installation of embedded PC systems on an unprecedented scale. Our prediction is that wearable computers for the masses will actually result in an explosion of PC infrastructure that will also encompass a diversity of industrial designs for novel appliances. In this future, furniture, architecture, appliances, and automobiles may all become part of the infrastructure to support wearable computing for the masses.

The Personal Server device brings a new vision to wearable computers – capturing the always-available and customized nature of personal wearable systems without the encumbering display and interactions mechanisms. The core technologies needed are wirelessly connected systems that allow ubiquitous access to personal data through any interface medium available. These advances will transform mobile computing, as we know it, moving us away from compartmentalizing data in individual devices and towards a flexible infrastructure designed to conveniently serve our needs.