Embodied Systems:

Introducing General-purpose Wearable Computers

Daniel Fällman
`daniel.fallman@informatik.umu.se`
Department of Informatics
Umeå University

Abstract

The thesis presented in this paper outlines a notion of computing named Embodied Systems. It is suggested that this concept will move the computer devices from the desks to the users' bodies. The users would then, apart from merely controlling the actual computing itself, also control and decide the context in which the computing takes place. As a step further, the context may in fact trigger computing by interacting with the embodied system.

An embodied system is a wearable computer with no single dedicated field of application. Rather, it provides a basic set of properties thought to be common and useful for the design of a general-purpose wearable computer for everyday use.

Keywords: Wearable Computers, Embodied Systems

BRT Keywords: C, HC01, GA03, HA08

Introduction

The development of computer devices has to this day persistently kept a remarkable pace and there is no clear evidence that this line of progress is ceasing. Computer devices that only a few years ago were considered high-end workstations are sold for pocket money at jumble sales. The trend—smaller computer devices equipped with more processing power sold for less money—seems to continue.

The earliest computers were extensive mainframes run only by professionals for narrow and dedicated purposes. The minicomputers that followed had the same or improved processing power but were smaller and less obtrusive to use, not to mention inexpensive by comparison. Consequently, they were adopted by semi-professional groups and used for purposes that were more general. Following the minicomputers came the prevailing notion of the personal computer. Within the white-collar world especially, the vicinity of desktop computers seems almost indispensable. As a consequence of the expansion of networking it seems significant to notice that there has been a shift away from using the computer solely as a means of carrying out explicit work and well-defined tasks. Rather, many of today's computers are used fundamentally as means of communication, where they allow their users to share resources, information and tasks, leaving calculation as a secondary objective.

From a historical perspective, use of computers and information technology arose from work-related tasks, and the understanding of how we use and relate to information technology is formed through encompassing working life conditions (Dahlbom et. al., 1993, Ehn, 1989, Kyng et. al., 1997). In other words, the traditional view of the use-context of information technology promotes and accounts for specific tasks carried out by professionals during working hours.

However, it does not seem unreasonable to assume that people will want access to the services and the flow of information that today's computers provide not only at their desks during working hours but also on a more continuous basis. Already, great many people have already access to computers in their homes, and some have also started to carry numerous other devices both at work and in their leisure time; Personal Digital Assistants, cellular telephones, pagers, radios, walkmans, CD-players, clocks, laptop computers, etc. These devices facilitate certain desired services independent of time and their users' locations, some of which to diminish the division between work and leisure time. This may suggest—in conjunction with the widespread computer knowledge that persists among the general public, the pace of development in computer hardware and software, and the current trend towards mobility and networking—that the traditional work and task related view of computer use is changing and that we are emerging a new pattern of computer and information technology conception, subsequent to the current desktop paradigm.

This article intends to investigate one potential way in which the development of information technology and computer use may come to steer. What clearly separates this view from other, previous, notions of computing is that the computer-based system argued is designed to dwell at one definite location: your body, rather than you desk, hallway or pocket. This notion of computing is addressed by the term *Embodied Systems* throughout the paper, drawing on the concept of embodiment as seen and understood by phenomenologist philosopher Don Ihde (1990).

The most basic idea on which this notion builds is that the embodied systems should provide features to augment human capabilities in human contexts, rather than the current situation where users in general only enhance computer capabilities in a given—and certainly dehumanized—environment. Few of today's computer systems truly enhance human capabilities, e.g. a word processor does not generally enhance the actual process of writing, it is merely used to keep, layout and spell check documents. In addition, the writing has to take place at a given location, where the system is placed. Authors would probably argue that the process of writing is not solely isolated to the exact time and place when the text is written, ideas and impulses are just as likely to occur when driving or watching TV. Computers as we know them, which basically are either used or not used at a given time and place, do not have the ability to assist authors when these ideas appear and consequentially do not sufficiently enhance their writing. It would be a significant improvement if the users' abilities could be enhanced in contexts decided by the users—not the computer. People wish to solve their tasks and problems, whatever these may be, and computers are conceptually merely tools with which they manipulate the world to alter its state. Embodied systems should strive to allow computing to be as transparent as possible to the users, and the goal to dismantle the barrier between the world of bits and the world of atoms. This would make the world the interface of computing itself, having invisibility as the most important objective (Gershenfeld, 1999), i.e. to try to bridge the gap between cyberspace and the physical environment (Ishii et. al., 1997).

Related Work

A wearable computer may be defined as a computer system that is worn by you in a fashion similar to how you carry clothing. It should be easy to use and maintain, at the same time as being comfortable to wear. However, this broad definition of a wearable is not sufficient enough to distinguish it from mobile devices, e.g. PDAs and cellular telephones. To more accurately define a wearable computer, Rhodes (1996) suggests the following as characteristics: wearables can be used while walking or otherwise moving contrary to both desktop and laptop computers; they often aim to minimize the tying up of users' hands by providing ubiquitous input devices such as speech recognition; they usually have sensors for the physical environment as a complement to user inputs. Wearables should also be able to pass information to its user even when not being actively used, de-emphasizing the importance of whether or not you are "using" the computer in a given situation. Hence, a wearable needs to be able to operate in the background, and is not, e.g. as a PDA, only switched on when a specific task needs to be carried out. It should allow both operational and interactional constancy (Mann, 1998).

Wearables are closely related to the notion of embodied system given in this paper. In general, wearables have the potential to aid two basic issues with today's computers. First, they make it possible for a computer to aid and enhance human abilities, instead of the other way around. One example of such an activity would be wearables that uses a speech-recognition systems to provide people with hearing disorder instantly readable sub-titling text translations of what other, hearing, people are saying. People that do not suffer from hearing disorder could use video cameras on their wearables to capture the sign language and continually translate the signs into synthesized speech. Second, wearables try to be where they are most needed. Looking at the difference between standard wired telephones and cellular telephones illustrates this problem. The cellular telephones have the advantage of usually being closely tied to the person to which they belong. Wired telephones, on the other hand, are more closely tied to a physical location, e.g. an office or a specified room, than to an actual person. Consequently, when calling someone over a traditional wired telephone you do most likely intend to talk with someone specific, but instead you primarily reach a specified location in space and time. The location of the telephone does not by any means guarantee that the person in mind for conversation is actually there. In other words, you want to talk with people, not their office desks. Similarly, wearable computers are clinched to their users and able to assist when needed in the users' context. A matured wearable computer system, such as the embodied system, with unobtrusive input and output devices, intrabody and interbody communication channels and context awareness abilities should be able to provide the user with a truly mobile, worn, augmented reality, where numerous complex, repetitive or simply boring tasks may be electronically assisted in the problem space.

However, apart from experimental and scientific usage, wearable computers have been designed almost exclusively to fulfill specific work-related purposes and tasks for well-defined groups of users (see e.g. Najjar et. al., 1997, Ockerman et. al., 1999, Siewiorek et. al., 1998, Smith et. al., 1995, Stein et. al., 1998). The field of application of the embodied systems outlined here is broader to its nature, as does neither solely focus on a specific target group of users nor on a specific set of tasks to be solved, but rather intends to acquaint a wearable computer for everyday use. Steve Mann (1997, 1998a) introduced the concept of personal imaging, where the computer shares its user's first person perspective, and WearComp as the wearable computer system that makes that possible. While Mann's inventions are designed for everyday use and remain close to that of the embodied systems, he focuses almost exclusively on personal imaging and sensory inputs, and more recently what he refers to as humanistic intelligence (Mann, 1998b). The WearComps are first and foremost single systems with restricted communication abilities, while the embodied systems are intended to form networks and be able to communicate with each other and with other devices in the surrounding environment.

Characteristics of Embodied Systems

The embodied notion suggests that the computer itself is located on the body of the actual user. Thus, the first fundamental principle of embodied systems is that the system should be where you are, rather than you being constrained to the location of the computer. Because the embodied system is always present and always on, there is a shift away from the traditional notion where you use the computer for a defined set of tasks. Rather, with operational and interactional constancy, computing may become situated to its nature, and in time more and more unconscious. Drawing on the work of Markham (1998a, 1998b), it seems reasonable to reframe the notion of "using" to "being-with" the embodied system. Users do not necessarily have to decide where and when they want to use the computer, because when the computer is where the user is, the situation—and not the users' whereabouts—can cause computing to take place. This certainly allows for a more intimate relationship between the user and the computer system, and which makes it difficult to even talk about a "user". Instead, "be-er" would be a more appropriate title.

In addition, situated computing would allow devices to detect, interpret and respond to the user's local environment (Hull, 1997). The embodied system would be able to be triggered by and respond to information in its neighbor environment, as well as vice versa—where the embodied system trigger devices in its context.

Also, by the use of embodied systems, socializing human activities such as direct communication and group activities should not be restricted by the computer system itself due to the fact that what you experience is real-life, not only data or models of real-life rendered on a screen.

The second principle on which the embodied systems build is the networking of carried, worn and portable devices. Today, even though several devices carried by an individual perform similar or related tasks, they have generally no means of communicating. For instance, you might carry a PDA where you keep names and telephone numbers of your friends, associates and clients. When you intend to call someone on the list, you have to look for the number on your PDA and then type it by hand on the cellular telephone. Alternatively, you will have to keep a similar register on your cellular. When change takes place, you will have to update all devices that carry the same piece of information separately. Hence, these devices are capable of providing instant communication gratification, but are not able to manage our communication needs (Gershenfeld, 1999). They use the user as the intermediary in communicating technology-to-technology. While this is the easiest implementation from engineering point-of-view, it does not use the potential digital devices possess and does not care for the users' needs. Rather, instead of forcing the user to act as an intermediary it seems conceivable that the embodied systems should facilitate intrabody communication among mobile devices, which would allow the user to do other things while the cellular telephone communicates directly with the PDA. If the devices were able to communicate with each other, they would also be able to share output and input devices.

The third principle is that the embodied systems should provide a convenient means of secure interbody communication with networks and systems. These may be other people's embodied systems, networks such as the Internet, your desktop computer system, stand-alone services such as ATM machines and credit card readers. We might consider using traditional technologies such as copper wires for the intra- and interbody communication. Given the number of nodes that has to be connected this would soon become obtrusive and unaesthetic to the user. Instead, the Personal Area Network (PAN) may provide a simple but quite effective method by which embodied systems could communicate both internally and externally. PAN uses the natural conductivity of the human body to create an external electric field over which data is carried (Zimmerman, 1996, Rhemi et al.,1997). The idea is that you touch something or someone with whom you want to exchange information. The mere touch closes the circuit that allows information to be sent in either direction. When this method is used to network and communicate among devices on the user's body, such as between the PDA and the user's cellular telephone, the wet-wiring may be called intrabody communication. Alternatively, when the body is used to communicate with devices off the user's body, such as ATM machines and public telephones, it does so by the use of interbody communication.

These three principles form the fundamental concept which constitute this notion, and are too what most clearly distinguishes embodied systems from previous notions of computing. Currently, numerous portable devices developed to this day try to reproduce the traditional office setting and are not designed to care for the users' environments or provide mature networking capabilities. These devices, e.g. PDAs and laptop computers, may also be cumbersome to use on the move since they rely on previous notions of computer interaction. In a real-life context, interactional devices that sufficiently fulfill their intentions in a desktop computer environment are generally awkward to operate, partly because the users' hands and eyes may need to be elsewhere (Thompson, 1997). embodied systems need to be operated non-obtrusively to be able to enhance everyday situations in a context fully determined by their users.

Fields of Application

Starner et al. (1995) sees three loose categories into which typical wearable computer applications fall: data storage, real-time data access and head-up display clients. While these three categories may be adequate for early wearable applications, they do not seem sufficient when it comes to more mature and general wearables that by use of inter- and intrabody communication build complicated systems. It seems impossible to address the ways in which the embodied system will be used without conducting proper experiments and evaluation. However, not every conceivable area of use is feasible and even feasible areas of use may involve intricate considerations to be properly implemented. The position that it is impossible to tell all future areas of use before people themselves figure them out implies that the embodied systems, with both hardware and software solutions in mind, should be designed in a component-based fashion, where devices and software are easily added and moved to suit the users' needs.

Nevertheless, we can identify three main categories into which most applied use of the embodied systems fall. The first is the augmentation of everyday activities, such as keeping your toaster preferences, network your mobile devices and provide you with a truly personal key to your car. The second category contains assistance with information handling, money transactions and matters of verifying identity. Into this category fall, among other things, the ability to have constant access to large databases and networks, the software agents that take care of your monthly bills and the ability to pay your dinner by touching the bill. The third category, which indeed is related to both the first and the second, contains the inter-human communication abilities the embodied system would provide. Here go, for instance, the ability to instantaneously send and retrieve personal messages, the possibility to access colleagues' schedules despite the fact that you are currently in Japan.

Notice that despite the trend within computerized society in general, and even though the prerequisites are present, e.g. augmented reality, mobility and computer enhanced perception (Billinghurst, 1998), very little effort towards collaborability has been made within the area of wearable computers. Most of today's wearable computer systems are designed as standalone systems that provide little or no support for inter-personal communication and collaboration. Wearables equipped with both audio and video conferencing capabilities and direct access to shared knowledge bases should prove ideal for building effective collaboration tools, especially for mobile field workers (Kortuem, 1998).

Computing in a Context

To further enhance the embodied system, hosts of sensors that keep track of their users' contexts should be considered. The idea being that the system itself should be able to keep track of and monitor certain information, and in that avoid unnecessary user input. These sensors may include everything from being aware of basic entities such as the time and date to more complex systems, in order to provide an interface that is able to take on the responsibility of serving the user, moving away from the current desktop computer interfaces where it up to the user to serve the interface (Abowd, 1999). Satellite data could be used to locate users' exact locations; light sensors to automatically tune and focus the head-up display; heat sensors to keep the users body at a constant temperature and heart and breath rate sensors to monitor their medical conditions. While these sensors may be comfortable features for a modern human that may ease everyday annoyances they are not sufficient from a psychological point of view. Computers that merely react to simple inputs from sensors are not always correct. In other words, what people want is usually far more complicated than, for instance, what the temperature of their underwear implies. As for collaborative efforts, imagine an indoor auditorium where hundreds of embodied systems try to change the temperature. It would be impossible for the radiators to correspond correctly to everybody's sensory systems of which some wish to reduce the heat while others, perhaps those that belong to users located near the auditorium windows, would on the contrary want to increase the temperature.

These examples make it obvious that the embodied systems would need more sophisticated sensory systems as well as carefully designed software systems to accomplish the right tasks at the right time, also counting on what other systems nearby are doing at the same time. For instance, when an allergic person is present, a system would recommend its user not to smoke. Later, the system may wish to de-emphasize the fact that smoking really is bad for your health. Picard et al. (1997) have equipped a wearable computer system with sensors and tools which enables recognition and logging of affective patterns. Sensing physiological patterns is not a new thing; it has been used for years to monitor heart rate and blood pressure for people with various medical complications. By including emotional inputs from the user such as anger, relief, stress and anxiety, it should be possible for the system to better "know" where and when to do certain things. Most current computer systems pay no attention to the affective cues the user shows, although they could be quite useful, especially for embodied systems. If the user sends out cues of anger or stress, the "aware" system may choose not to inform of the need for defragmentation of its hard drive system—it may be done later—and its user is not further stressed or interrupted.

A paradox with the measurement and evaluation of physiological affective clues is that we try to measure complex patterns of behavior, but uses simple inputs such as breath rate or heart beat to determine them. Not surprisingly, one of the major problems in emotion theory is determining what physiological patterns accompany each emotion (Picard et. al., 1997). Different people tend to respond differently to their emotions. When stress occurs, some people respond by increasing their heart rate, while others start to sweat or breath faster. To overcome this problem, the emotion sensitive systems within the embodied system will have to be adaptable, i.e. "learn" from their user, and undergo constant evaluation of the outcome of its decisions. By doing so, the system should eventually learn how to more correctly respond to its user's emotional state. However, the making of "intelligent computers" that learn and are context-aware is difficult and there are many obstacles yet to overcome (see Weiser, 1993), even within a rather close environment. To apply the same principles to the much more complex environment of the embodied system seems of course proportionally difficult to achieve.

Issues of Security and Integrity

A mature general-purpose embodied system will, as mentioned, be used to network numerous devices close to or carried by the user and ease communication with other devices and networks. Payments will then no longer be made by bank notes or credit cards, but by sending and retrieval of information stored on your embodied system. Evidently, the information and data stored on your embodied system will need protection. There are several reasons behind this need. First, you would not want to reveal sensitive personal information. Second, even when you want to communicate certain information you would not want everyone to have access to all the information on you embodied system. You would not want unauthorized people or devices to be able to log in to your system and retrieve information they are not allowed to see.

Several methods have been developed to allow information to be encrypted a sender and decrypted by an authorized receiver. The trade-off is usually that the less obtrusive or complicated a method of encryption is, the less secure it becomes. The handling overhead, in terms of obtrusive passwords and keys that have to be submitted and kept by the user, may be discouraging. If the discouragement and obtrusiveness of the cryptography method is high, the users may decide not to use the encryption at all, disregarding the fact that it does provide good security. If the passwords or keys are too short or simple, they are easy to break by an intruder and security is not provided. On the other hand, if they—in order to make things more complicated for the intruder—are long and complex, the users may write them down on notes that are kept nearby, and security still fails. We might consider some classes of information important enough to consider encryption, while some remains unencrypted. Common and public information that may be found at other locations must not be encrypted since it is available elsewhere. A user may wish to keep it encrypted anyway, because the mere presence of certain information may indicate the user's position in sensitive areas, e.g. multiple annual back-volumes of "The Daily Worker" may indicate a user's political belonging. However, this need is more a matter of integrity than an issue of security.

The embodied system could be designed to operate as a server to which other people would be able to log in and fetch information. It would probably not be appropriate if they had access to all available information. For instance, a medical record should only be available to hospitals and medical personnel, not to your boss or your friends. Furthermore, the information that you would want available for your friends is certainly not the same kind of information you necessarily would like to share with your family or with your co-workers. The need to allow different people access to different information implies the use of groups of authorization. Generally, two groups are easily identified: a public group and a private group. The public group is used to keep information that you wish to make easily accessible to everyone. The private group, on the other hand, is not accessible to anyone other than yourself. Here is the place to keep sensitive information that you do not want other people to know about.

Obviously, certain information—such as your medical record—does not fit into any of these two categories or groups. This kind of information should be accessible by certain people, but not everyone. Hence, we need several categories that persist in between the public and the private sphere, i.e. groups that are accessible-on-authorization. The different groups that specific users are authorized to use form a domain of information, which they might query or browse. By use of such grouping method, embodied systems should be able to keep sensitive information secret and able to share selected information with the general public or with defined groups. However, possession and communicating of encrypted information is a controversial subject in many ways. Intelligence services and the police will want to continue to track criminals, perhaps even tap wires, and electronic messages. This wish would be severely obstructed by common use of a well-developed ciphering system. The matter of security and integrity of both the individual user and the community at large are urgent issues in the development of embodied systems that need to be addressed with concerns both for individual freedom and for the well-being of society as a whole.

Biometrics as the Key to Authorization

It seems conceivable that an important function of the embodied systems will be to verify the identity of their users. Today, you might need an ID-card at work, another ID-card to withdraw money from your own bank account or to prove your identity when using your credit-card, a driver's license and a passport to travel. These written certificates have all the same basic function; they are intended to prove that you are who you say you are.

Methods of cryptography provide reasonable security to information and transactions, but they do not prove identity. The fact that people possess the correct passwords does not mean that they necessarily are who they say they are. Currently, as communication is often carried out remotely—e.g. over the Internet—it may be fairly easy to have several appearances; multiple personae. This may not be too bothersome in certain situations but under certain circumstances, for instance when there are issues of money, citizenship or law involved, the need to identify an individual is more obvious. Since the embodied systems are intended to support and facilitate easy transaction both directly and remotely, there is an apparent need to provide identification of the users.

What appears to be a feasible way to perform this identification is to use biometrics, where we verify a person by physical characteristics or personal traits. Biometrics tries to distinguish a person from everyone else, by use of statistical analysis of biological characteristics. Hence, authorization is given to something that is a part of you, rather than something you know or own (Hopkins, 1997). With this in mind, the embodied systems could be designed not to function without a constantly present, and living, user attached to it. If the correct user is not present, that embodied system should not function. In this way, the user is protected from someone stealing or misusing his or her embodied system and, in a similar fashion, people who communicate with the user will be certain that the user is who he claims to be. Obviously, someone—such as the government—will still have to grant the person's identity in the first place, as people are not born with known biometrical outlines.

In this context, it is important to understand that verification and identification using biometrical methods are two very different tasks with different levels of complexity attached to them. Hence, most existing implementations are used for purposes of verification, not identification. Biometrical methods of verification aim to answer the question "Is this person who he claims to be?" They do so by comparing previously stored profiles against an actual physical profile taken at the time of comparison. Biometrical methods developed to provide identification, on the other hand, compare a fresh profile against a library of stored data from several people's profiles. This method may be used to ensure that the profile, the biometrical identity, has no duplicate within the library and may therefore be added to the library. The building of such a record, where each person's biometrical profile must be added sequentially and compared one by one to the rest of the database, would be extremely time consuming and perhaps not even possible to conduct even within a minor community (Hopkins, 1997).

The use of sufficient biometrical methods to provide known and indisputable identity would be feasible in most transactions. However, in certain situations you might not want to reveal your identity. When you pay a bill at a restaurant with the embodied system, money is automatically drawn from your account. This is indeed both easy and practical. Nonetheless, as you pay using your credit card stored in the embodied system, the payment will be logged to the exact time and restaurant, which later may be used to follow your actions. By the use of embodied systems, you will undoubtedly leave loads of digital traces of your whereabouts and actions. With the use of biometrics, these digital traces will be indisputably connected to you.

One of the advantages of having your body work as the password is that you cannot lose your body—as you might lose your car-keys or your driver's license—and that it is more difficult to steal than passwords or id-cards. However, when such things as crime and misuse occur, written certificates or passwords kept in the users' minds have—on the contrary—the advantage of being separable from its owner. For instance, electronic ID cards used by employers to gain entrance to their office building may be stolen and misused to allow unauthorized people entrance. If the same kind of security was instead provided by biometrical profiles kept by the employers embodied systems, criminals would have to attend to kidnapping in order to achieve the same result. When security is tightly connected to the human body—as with biometrics—the body itself is more likely to have to appear at the scene of crime. Proponents of biometrics justify the use of these methods by implying that what they intend to perform is verification of identities, not prevention of crime. It is not the biometrical methods that carry out the crime, they say, and thus biometrics should not be accused of something for which it is not responsible.

Finding the Level of Computerization

To this day, we have no such things as fully developed embodied systems; partly because the technology needed is not yet sufficient and partly because the scope of personal desktop computers seems to be strongly rooted in people's minds. Nevertheless, the technology needed to build embodied systems is rapidly emerging, and some would even say present. When the technology itself proves not to be obtrusive or uncomfortable, it seems conceivable that the traditional scope of the computing state-of-affairs would also be subject to change. As with most new developments in technology, a group of people will pioneer as users of embodied systems, while most of the individuals in the community are not concerned with the technology. Specialized groups of people which may gain obvious benefits in their work from the use of embodied systems, e.g. military personnel, field medics, maintenance personnel and personnel conducting routine inspections (Thompson, 1997), will probable be the initial test pilots. The devices these groups of professionals will use, and actually already use to some extent, may be quite different from the general-purpose systems sketched here. While the areas of use might differ, the technology itself will be subject to useful field testing. When teething troubles and other technological obstacles have been seen to as a result of the field testing and evaluation embodied systems may be introduced to a more general public.

Perhaps the most immensely important question a user society of embodied systems will have to deal with is the question of finding the right level of computerization. What do we want computers to do for us? Under some circumstances, the embodied system will be able to carry out work on its own, such as having software agents monitoring and paying incoming bills. In most cases though, an embodied system will try to augment the user's current task, e.g. assist in note taking. The notion given in this paper suggests a design of these systems that strives to augment human activities, not creates or increases situations where the user will have to come second. In this sense, the embodied system should be passive rather than active, and—as Ljungberg et. al. (1998) point out—it may in fact be one of the uniqueness of information technology that it depends on human beings to act and interact. Mann (1998b) goes at least one step further, and addresses a similar idea by the term humanistic intelligence, in which technology is highly intertwined with the human users and their capabilities. The human may step in and out of the feedback of the computer's signaling processing loop at any time, which is thought to form a symbiotic relationship between the human and the computer, where *"…the high-level intelligence arises on account of the existence of the host (human), and the lower-level computational workload comes from the signal processing hardware itself."* (Mann, 1998b)

What Am I Talking To?

Embodied systems, using feasible software and head-up displays, might be able to display associative information to aid conversations and discussions. For instance, while talking to your mother-in-law the embodied system could provide information about what has been discussed at previous conversations, the date of her birthday, the date of her dog's birthday, and possibly even suggest suitable topics for further conversation when that terrible moment of silence appears. However convenient, this does suggest several implications. What is honest concern about you and what is small talk decided and managed by the opposite person's embodied system? Hence, it would be possible that the embodied systems designed to facilitate and enhance communication between people may in fact come to impede that same communication. The traditional scope of one-to-one communication will be altered, since it is not possible to know what goes on in the other person's head-up display. This uncertainty may cause caution, distrust and suspicion to the communicating parties and the embodied systems would then act as obstacles rather than facilitators of communication.

Somewhat related to the implication about communication described above, it seems reasonable to examine what consequences the embodied systems' capability of storing, finding and displaying information will have on the role of the human brain, which currently is carrying out these tasks. As we might have everything we need available from within the embodied system, why should we ever bother to learn anything? Why learn Whitman by heart when you could have it displayed on your head-up display, preferably with visible clues to the correct intonation given the context of the performance? Similarly, the introduction of calculators in schools is likely to have caused today's youth to perform worse than previous generations at mental arithmetic. On the other hand, the calculators allow pupils to perform more complicated calculations in a fashion impossible to that of the pre-calculator era. As pupils are able to complete complicated calculations, they rely firmly upon technology as a component of their mathematical proficiency, as opposed to previous generations where the mind alone provided the means of arithmetic. This "learned helplessness", where the users become dependent of technology such as the embodied systems, makes people vulnerable if the technology they depend upon fails to operate properly. The same kind of criticism has throughout history been made against several different technologies and novelties, including calculators, higher-level programming languages, comic strips and television. It is important to realize that apart from the traditional notion of fundamental education—which is likely to remain in some form—different times need different sets of knowledge. Today, as the amount of available information is too great to grasp, even within a restricted area of interest, it becomes just as important to possess knowledge of how to collect and evaluate information as it is to actually have the information in mind. In this scenario, embodied systems should provide a useful context in which this knowledge may be put into practice. A far worse scenario is the risk of further separation between those in a community that possess knowledge of computer use and those who do not. Embodied systems will demand knowledge of computer usage to a level which many people, but not all, possess even today.

Implications on a Human Level

If people were equipped with embodied systems, so what? Ihde (1990) provides a phenomenological foundation of how to conceptualize and account for human use of technology. Phenomenology assumes there exists a correlation between what can be experienced in the world and how it is experienced by the user, a correspondence between what can be seen, heard, felt, tasted or smelled and what is actually so (Rathswohl, 1991). Ihde bases several of his ideas on the philosophy of technology developed by Heidegger; for whom technology is a set of conditions, or a framework, within which human activity takes place. For Heidegger, tools are very different from other objects in our environment. A tool is an object whose function is defined by its context, design and human use. Tools, consequently, belong to an environment where they are being purposively utilized by humans. Ihde extend the idea by implying that technology mediates human—world relations. For instance, what is perceived through eyeglasses is different from what is perceived by the naked eye. Thus, the correlation between the world and how it is experienced may be altered by the use of technology.

Eyeglasses are an example of what Ihde calls embodiment relation, which is the most basic relation between humans, technology and the world. In such, the world is directly experienced by humans through technology. The tool persists in between the user and the world, but is not the primary focus of the user's attention, and may be seen as an extension of the user. The tool becomes gradually transparent and will eventually require very little particular attention. But when the bodily capacities are extended using technology, the technology also transforms them. An experience through technology amplifies certain desired aspects while suppressing other. Because of this, technology can be said to magnify the non-neutralness of our own senses, because the design and the use of the technology will decide what is amplified and what is suppressed—and what then is perceived is not the actual state of the world. Nevertheless, the human sensory systems are not neutral themselves, since they—much like technology—focus on certain aspects of the environment while other cues are filtered out. Perceiving the actual state of the world, either through technology or human sensory systems, is an extremely difficult task. To some extent the embodied systems could be used as extensions to the human sensory systems, helping us find and filter sensory input that might be too complex or insignificant for the human sensory system alone to recognize. It would also be much easier to decide what should be emphasized, since what is amplified in this sensory system is a part of the technology, while human sensory systems are much more difficult to reprogram. Using the embodied systems in a similar fashion, e.g. as extensions of our sensory systems, surely creates an interesting situation where the virtual created by technology blends with real-life. What the effects are remains to be carefully examined.

A second type of human—technology relation proposed by Ihde is the hermeneutic relation. Here, the user is not able to perceive the world, and the technology serves as the only representation through which the user may experience the world. Thus, the experience is indirect in that the user's primary focus is on the tool and not the world itself. Consequently, what are perceived are visualizations of the state of the tool, and not the state of the world itself. The hermeneutic relation is common in everyday life. People in many different areas have to depend upon displays to perceive the state of the world. Perhaps the most obvious example available is the cockpit of an airplane where hundreds or thousands of displays inform the pilot about the state of the aircraft and its environment. Ihde points out that the enigma in the hermeneutic relation lies in the correlation between the technology and the referent. The user usually has no means of knowing whether the tool displays the true state of the world or not. On some occasions, where the tool malfunctions in a physical manner (such as power failure or fire), the user might understand that the view of the world the tool gives should be considered incorrect or at least questionable. On many occasions, however, when there is no clear physical evidence that the tool is erroneous, the user has no easy and independent way of verifying the state of the world that is displayed. The user has to believe the world as being provided by the tool, and act according to that. Also, it might be extremely difficult to realize when a complex system is malfunctioning, because it is able to do so on many levels. The user may notice if an embodied system malfunctions on a physical level, e.g. when there is no power available. This is somewhat equal to when a user finds the hammer physically out of order, e.g. divided or otherwise ragged. However, the embodied system, as opposed to a hammer, can also malfunction on a theoretical level, which might be extremely difficult for its user to recognize. For instance, the software used can be incorrectly designed and does not fulfill its intentions because of that, or the software could simply carry out minor miscalculations.

An embodied system is not, in Ihde's sense, embodied until the user is focused on the tasks being carried out and the features provided by the embodied system are utilized in a natural and non-obtrusive manner, transparent to the user. When the users proficiently make use of features of the embodied system without consciously considering the fact that they are actually using technology, the embodied system could be said to function in a truly embodied fashion. In other words, the embodied systems are embodied when their functionality blends with that of its user.

However, some of the functionality provided by the embodied systems as introduced earlier is likely never to be embodied in this sense, and will relate in a more hermeneutic sense to the user. Because the embodied systems would constitute complex sets of technologies that would offer several very different services and features, thus not being a single distinguishable tool, it becomes a difficult task to strictly apply Ihde's framework. It is perhaps even viable to suggest that the embodied systems break down Ihde's distinction between embodiment and hermeneutic relations to technology. A well-developed embodied system could by the use of technology turn hermeneutic instruments, that require cognitive interpretation, into improvements of perception which appear embodied to the user, much like what Virtual Reality is trying to achieve. If so, much of our perception of the world would be the outcome of advanced and complex processing done by the embodied system, now acting as a technological intermediary. In the context of the embodied systems, given that they would be used at the same time as events take place in the real world, this would be feasible since a cognitive interpretation of the processing carried out by the technological "in-between" would not be required from the user. In this sense, it becomes difficult to identify whether the embodied system relies on embodied or hermeneutic relationships between the user and the technology. Again, the blend between the virtual and the real that may be created by a piece of technology such as the embodied systems is a key factor that is unequaled and its weaknesses and strengths should need to be carefully examined. Up to now, humans perceive the world and translate parts of it into representations that can be manipulated by computers. Embodied systems would allow the opposite to be possible. Computer devices would perceive parts of the world that we do not fully understand or grasp and provide us with a comprehensible representation. The perceptions of our sensory systems would then blend with sensory information provided by computers. If done unobtrusively, we might tend to forget that parts of what we perceive is provided by computers and the ambitions of invisibility the embodied systems pledge have been fulfilled. This ubiquitous relation between humans and technology are not met by Ihde's framework, and unique in the sense that the digital world merges with the physical world. The bits of the digital world and the atoms of the physical world will merge into world of "bitoms". What impact this bitomian world will have on life and humans is unknown, and surely provides a new frontier to science.

Conclusions

Embodied systems rely on three basic properties that make them proficient for general-purpose everyday use. First, where computing itself takes place is decided by the user, not the computer. This supports situated computing and problem solving in the context of the problem. Second, embodied systems would make mobile devices communicate with each other, without the need of the user as an intermediary. Third, embodied systems would be able to securely communicate with other systems and devices. The embodied system could enhance human capabilities in a human context, where the world becomes the interface of computing itself. The goal is to create a transparent interface where computing blends with experiences of the real world.

The embodied systems would become continuously available and play a much more important role in our lives than computers do today, where they are merely appliances for work or entertainment. They would loosen the boundaries between work and spare time, being just as important and useful in both areas. Nevertheless, to build them successfully we must bridge several gulfs; social, psychological as well as technical. At the end of the day, what seem to be invincible technological issues may prove to be the easiest to overcome. Rather, what seems to be needed is a new approach to interaction between computers and humans. The perhaps most difficult issue in developing embodied systems is how to allow more and more computation to trespass peoples lives while the computing itself becomes increasingly transparent to them. It seems likely that if computers are going to immerse our lives and if information is going to be incorporated in our context, people neither will nor should accept the cumbersome and unobtrusive interfaces of today. This issue constitutes the initial obstacle in the development of general-purpose, everyday wearable computers: embodied systems.

References

Billinghurst, M., Weghorst, S., Furness, T. (1997), Wearable Computers for Three Dimensional CSCW, Human Interface Technology Laboratory, University of Washington. In Digest of Papers, The First International Symposium on Wearable Computers

Abowd, G. D., Dey, A. K., Brotherton, J., Orr, R. J., (1999) Context-awareness in Wearable and Ubiquitous Computing. Virtual Reality, Vol. 3

Dahlbom, B., Mathiasen, L. (1993) Computers in Context, the Philosophy and Practice of Systems Design, Cambridge, Blackwell

Ehn, P. (1998) Work-Oriented Design of Computer Artifacts, Stockholm, Arbetslivscentrum

Gershenfeld, N. (1999) When Things Start To Think, Hodder and Stoughton, London

Hopkins, R. (1997) A Challenge to the Biometrics Industry, IBM Corporation, Advanced Identification Solutions, Feltham

Hull, R., Neaves, P., Bedford-Roberts, J. (1997) Towards Situated Computing, Proceeding of the 1st International Symposium on Wearable Computers, ISWC '97, October 13-14, Cambridge, Massachusetts, USA

Ihde, D. (1990) Technology and the Lifeworld, from Garden to Earth, Indiana University Press, Bloomington and Indianapolis

Ishii, H., Ullmer, B., (1997) Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms, Proceedings of Conference on Human Factors in Computing Systems (CHI ‘97), ACM, Atlanta, March 1997, pp. 234-241

Kortuem, G. (1998) Some Issues in the Design of User-Interfaces for Collaborative Wearable Computers, Wearable Computing Research Group, University of Oregon, Position Paper for the VRAIS ’98 Workshop on Interfaces for Wearable Computers

Kyng, M., Mathiasen, L. (1997) Computers and Design in Context, Cambridge, MIT Press

Ljungberg, F., B. Dahlbom, H. Fagrell, M. Bergquist and P. Ljungstrand (1998). Innovation of New IT Use: Combining Approaches and Perspectives in R&D Projects. The Fifth Biennial Participatory Design Conference, Seattle, US, CPSR and ACM

Mann, S. (1997) Wearable Computing: A First Step Toward Personal Imaging, Computer, 30 (2), 25-32

Mann, S. (1998a) Wearable Computing as Means for Personal Empowerment, Keynote Address for The First International Conference on Wearable Computing, ICWC ’98

Mann, S. (1998b) Humanistic Intelligence: ‘WearComp’ as a New Framework and Application for Intelligent Signal Processing, University of Toronto, Department of

Electrical and Computer Engineering, Toronto, Ontario, electronic document: http://genesis.eecg.toronto.edu/hi/index.html
Markham, A. (1998a) Life Online, Researching Real Experiences in Virtual Space, London, Sage
Markham, A. (1998b) Research on Computer-mediated Communication (CMC). CMC as a tool…as a place…or as a way of being, NCA/ICA International Communication Conference, Rome Italy
Najjar, L. J., Thompson, J. C., Ockerman, J. J. (1997) A Wearable Computer for Quality Assurance Inspectors in a Food Processing Plant, In Proceedings of the 1st International Symposium on Wearable Computers, October 13-14, Cambridge, Massachusetts, USA
Ockerman, J. J., Najjar, L. J., Thompson, J. C. (1999) FAST: Future Technology for Today's Industry, Computers in Industry, 38, 53-64.
Picard, R. W., Healey, J. (1997) Affective Wearables, MIT Media Lab, Cambridge
Rathswohl, E. J. (1991) Applying Don Ihde's Phenomenology of Instrumentation As a Framework For Designing Research in Information Science, in Nissen, H.-E., Klein, H. K., Hirschheim, R. (eds.) Information Systems Research: Contemporary Approaches and Emergent Traditions, Elsevier Science Publishers
Rhodes, B. J. (1996) The Wearable Remembrance Agent: a System for Augumented Memory, MIT Media Lab, Cambridge
Rhemi Post, E., Reynolds, M., Gray, M., Paradiso, J., Gershenfeld, N. (1997) Intrabody Buses for Data and Power, Physics and Media, MIT Media Laboratory, Cambridge
Siewiorek, D., Smailagic, A., Bass, L., Siegel, J., Martin, R. and Bennington, B., (1998) Adtranz: A Mobile Computing System for Maintenance and Collaboration, In Proceedings of the 2nd International Symposium on Wearable Computers, 19-20 October, Pittsburgh, Pennsylvania
Smith, B., Bass, L., Siegel, J. (1995) On site maintenance using a wearable computer system, In Proceedings of the CHI '95: Human Factors in Computing Systems, New York, NY, USA, ACM Press
Starner, T., Mann, S., Rhodes, B., Healey, J., Russel, K. B., Levine, J., Pentland, A. (1995) Wearable Computing and Augmented Reality, MIT Media Lab Vision and Modeling Group Technical Report no. 355, November
Stein, R., Ferrero, S., Hetfield, M., Quinn, A., Krichever, M. (1998) Development of a Commercially Successful Wearable Data Collection System, In Proceedings of the 2nd International Symposium on Wearable Computers, 19-20 October, Pittsburgh, Pennsylvania
Thompson, C., Najjar, L. J., Ockerman, J. J. (1997) Wearable Computer Based Training and Performance Support Systems. In Aronberg, S. (ed.) 19th Interservice/Industry Training, Simulation and Education Conference Proceedings, Arlington, VA: National Training Systems Association
Weiser, M. (1993) Some Computer Science Issues In Ubiquitous Computing, Communications of the ACM, 36 (7), 74-83
Zimmerman, T. G. (1996), Personal Area Networks: Near-field Intrabody Communication, IBM Systems Journal, Volume 35