Time and Time Again: Parallels in the Development of the Watch and the Wearable Computer

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Abstract

The watch long ago encountered many of the major issues confronting wearable computing today. This paper examines the parallels in the development of the watch and the wearable computer. It discusses how the locations where the watch was worn on the body have changed over time, examines a variety of user interfaces for watches, and looks at how the watch affected cultural concepts of time and time discipline. The lessons for wearable computing are that the physical wearability will be determined as much by fashion as by human anatomy, that the user interface will gradually become simplified as people become more acquainted with computers, and finally that the cultural impact will be a broadening of the definition of information, a rationalization of representing information, and an increasing synchronization of personal events.

1. Introduction

Three of the major issues for the future of wearable computing are placement on the body, user interface, and potential impact on society. There is broad speculation on all three fronts, with no end in sight. The design and use of wearable computers is uncharted territory, with many options to be explored. But perhaps wearable computers are not as ground-breaking a technology as is commonly supposed. History has already given us an example of a technology that evolved physically from immobile to portable to wearable, that employed a variety of user interfaces, and that revolutionized cultural conceptions: Time-keeping.

Before examining the wearable aspects of both computing and time-keeping, it is worthwhile to note the similarities in their overall developments. Where the computer is the key machine of the information revolution, enabling a vast collection, sorting, and analysis of data, the clock was the key machine of the industrial revolution, allowing the accurate determination of power and energy, which in turn allowed the engineering of steam engines and other machinery which we commonly associate with the industrial revolution [9]. Without accurate time-keeping, the concepts of efficiency, performance, and productivity, the driving intellectual forces of the industrial revolution, are meaningless [5]. We speak of "embedded computers," computers within larger systems that users do not think of as computers, but embedded clocks are even more common, in the form of timers in household appliances, in manufacturing equipment, even in computers themselves.

While the general similarities between time-keeping and computing are striking, it is important to examine the similarities in the wearable forms of each technology for two reasons. First, the two fields already have close ties, as the first mass-produced wearable computers were probably wristwatches in the mid-1980's that had address book and calendar functions [1]. More recently, IBM has introduced a Linux-based computer in a wristwatch form factor [10]. Second, the watch is so commonplace that it is easy to overlook the lessons that can be learned from the course of its development. These lessons learned may permit an easier deployment and more effective use of wearable computers in the future.

This paper will give a history of several areas of the development of the watch and examine the parallels between its development and the development of the wearable computer, concentrating on wearability, interface, and societal impact. From these parallels the paper concludes that the physical wearability will be a function of fashion as well as a function of human anatomy, that the user interface will gradually become less of a problem as people become more acquainted with computers, and finally that the societal impact will be a broadening of the concept of information because of the ever-presence of the wearable computer.

The remainder of the paper is organized as follows. Section 2 will examine the wearability of the watch, discussing the parts of the body on which watches have been worn and how these have changed through the ages. Then Section 3 will cover the user interface of the watch, presenting examples of visual, audio, and haptic representations of time. Section 4 will discuss the societal impact of watches and their role in

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changing our culture's notions of and attitudes toward time. Section 5 gives the conclusions to be drawn from the parallels between the development of the watch and the wearable computer.

2. Wearability of the watch

The first aspect of watches this paper will study is their wearability, where on the body they have been worn. Wristwatches are the most common form of wearable technology today. But the wristwatch is the latest of many generations of wearable time-keeping. It became the most popular form in the years following World War I, when it found favor with soldiers in the trenches who valued being able to keep their hands free when checking the time. Wearing a watch on the wrist seems the most natural location to us now, but it was not always so. The first watches were carried in the hand, hung from a belt around the waist, or worn about the neck [2]. Then for several centuries the pocket watch was the predominate form. It was only in the twentieth century that the wristwatch became popular, although it had been in existence for at least a century [3] and the necessary level of miniaturization had been available for even longer.

Throughout the history of the watch, one sees that its size and form as well as the location in which it was worn was driven by fashion. The earliest watches date from about 1500-1520 and were worn around the neck [2]. These were called "musk-ball watches," after the spherical metal perfume containers that early watchmakers fit the clockworks into. As watches became more popular, watchmakers began designing their own cases instead of using the widely-worn musk balls. The "pocket" watch became common in the 1600's, although due to its size it was rarely carried in a pocket but was still worn about the neck like the musk-ball watches or hung from a belt. At first pocket watch cases were ornate, but with the increasing popularity of the waistcoat in the 1800's, the pocket watch disappeared from view and the cases became less decorated. When watches disappeared into the waistcoat, they also became larger, reversing a trend toward further miniaturization in men's watches. The pockets of the waistcoat allowed a larger watch to be carried than could be carried in other pieces of clothing, and a larger watch tended to be more accurate, less delicate, less expensive, and consequently more desirable.

What was desirable for men's watches was not necessarily desirable for women's. While the men carried watches in their waistcoats, women wore watches pinned to their clothing like brooches. One of the forces in the miniaturization of time pieces was the desire of women to reduce the weight of watches, because heavier watches tore delicate fabrics [8]. Women were the first to commonly wear wristwatches, beginning probably in the late 1800's when a London saddler introduced a watch on a leather strap [4]. Until World War I, the wristwatch was considered to be a feminine accouterment. But when the blood- and mud-spattered soldiers of the European trenches returned sporting wristwatches, they became popular among men as well.

Outside of Europe, the placement of the watch was quite different. In Japan, for example, watches were worn in a pouch hanging from a belt around the waist, with the pouch slotted so that the face of the watch could be seen without removing it from the pouch, as shown in Figure 1. Because Japanese clothing had no pockets, the pocket watch never developed. And for cultural reasons to be discussed later, the Japanese watches were not small enough to be worn elsewhere.

Another interesting aspect of size and miniaturization is that watches became bigger when they became more accurate, but not because the improved mechanisms were more difficult to fabricate. The first watches were meant to be wound daily, which was not an undue burden since they kept time so poorly that they also had to be set daily. But with improvements in the watch mechanism, watches became better and better at keeping time. Watch makers began using larger springs as the watches became more accurate, so that the watches would run for longer periods of time between windings. So the trend toward smaller watches was not monotonic. Like the wearable computer, people were willing to pay for increased performance with increased size and weight.

So far we have discussed where on the body watches were typically worn, but there are examples of watches meant to be located elsewhere. These were usually baubles, gadgets collected by the well-to-do, including watches fitted to finger rings, key chains, and swords. The first known example of a watch fitted to a finger ring dates from 1542 [4], and later examples are quite sophisticated: King George III was given a finger ring a half inch in diameter in 1764 [13], and a French watchmaker built a ring watch with a calendar in 1779. One of the more interesting ring watches belonged to Queen Elizabeth: Its alarm consisted of a small needle that scratched her finger [5]. Other examples of miniature watches include chatelaine watches, where the watches were mounted on the jeweled key rings of ladies [12], and watches fitted to the hilts of daggers and swords [2][5]. If a sword seems a useless place for a watch, one must remember that warfare at the time depended on the coordinated movements of hundreds of soldiers spread

Figure 1. Nineteenth century Japanese belt-mounted watch. The watch is on the left; the pouch for carrying it is on the right. After [14].

over large areas; if a commander moved the men in his charge too early, the battle might be lost. In this light a watch on a sword is no more useless than a computer on an automatic rifle.

This history of where on the body watches have been worn shows the first major lesson for wearable computing. Wearability will be a function of fashion as well as a function of anatomy. The watch was small enough and inexpensive enough to have been worn on the wrist for well over a hundred years before this location was widely acceptable, but the wristwatch only came into vogue with men due to romantic notions of warfare and masculinity. That many of the first wearable computers were belt- and back-mounted is not solely due to their weight and size: Most were designed on college campuses, home of the fanny- and backpack. Like the early watchmakers, who fit their clock works into the common musk balls, the early wearable computer builders fit their designs into common fashion accessories. Shoulder and neck-mounted wearables are comparatively rare perhaps because they resemble purses, shoulder bags, and necklaces too closely. Most wearable computer users are men, who from years of societal training would be apprehensive about appearing to be effeminate. The watch is worn for adornment and status as well as for utility; there is no reason to suspect that the wearable computer will be any different.

3. User interface

The second major aspect of the watch this paper will examine for parallels with wearable computing is the user interface. While the watch makers experimented with where on the body the watch was worn, they also experimented with how the time was conveyed to the wearer. Most of these interfaces were visual, but the watch makers also created haptic and audio interfaces. Queen Elizabeth's finger ring, with its scratching alarm, is obviously a haptic interface. A more common haptic interface became popular in the mid-1600's: Raised buttons on each hour so that the time could be read in the dark. Baillie relates a quote from a fellow in 1644 who would undoubtedly have seen the advantages of a vibrating pager over a beeping one:

> ...it smacks too much of the business man to look at your watch in company; it is impolite to your hosts because it looks as if you had another engagement and were in a hurry to keep it. As for striking watches, they are very tiresome, because they interrupt conversation. That is why one should adopt the new kind of watch in which the hour and half hour marks are raised enough to enable one to feel them with the finger and so tell the time without having to take out the watch and look at it. [2]

The "striking watch" mentioned above is a repeater watch, which indicates the time with a series of tones. They were probably first made for use by the blind, but became popular with the general population in an age with no electric lights and no matches. The first repeater watches indicated only the nearest hour, but at the height of their popularity, examples could be found which indicated the nearest minute [7]. Furthermore, because of the interruption caused by their chimes in company, later repeater watches were made so that the case would vibrate instead of having the chimes rung [5]. One could then check the time surreptitiously, as with a watch having raised hour marks.

While haptic and audio interfaces were common, the most usual interface was visual. A variety of visual representations were tried, especially after minute hands became widely available. Figures 2-4 show several forms that were in vogue at various times. Figure 2 shows a sun-and-moon watch face, where the hour is indicated by a sun or a moon to distinguish between day and night, and the minutes are indicated by a hand. Figure 3 shows a differential watch face. The lone hand indicates the minute on the fixed outer dial and the hour on the rotating inner dial. Finally, Figure 4 shows a wandering hour watch face. The hour visible in the small circle points to the minutes.

Although each of these examples is from about 1700, watches in these styles were common for over 50 years after the minute hand became the norm. Some of the alternate forms of representing the time were partly embellishments, attempts to differentiate products in a vast market, but they also indicate that the watchmakers feared that the wearers would not understand how to read the watches. Even when the watch face settled down to the two hands sweeping concentric circles that we are familiar with, there is evidence that the watchmakers were cautious about the wearer's ability to tell time. When minute hands first became available, most watches had the minutes numbered in large Arabic numerals and the hours in smaller Roman numerals. Every five minutes and every hour were numbered. As time passed, only every fifteen minutes were numbered, and then no minutes were numbered, while each hour was still marked. It was not until the twentieth century that watches were sold with no numbers on their faces whatsoever, as people became more familiar with time and the concepts of hours and minutes [5].

This history of the watch interface shows the second major lesson for wearable computing. The interface will gradually become less of a problem as people become more acquainted with computers. While the information to be conveyed by the wearable computer is more diverse than that conveyed by a watch, both sets of devices share a common difficulty in conveying it: The ability of the user to understand the format of the information. When the user understands the format, more of the interface can be devoted to the information itself. Finally, another lesson to be drawn from this history of the watch interface is that watch makers experimented with haptic and audio interfaces long before wearable computer designers, often for similar reasons, and that these interfaces became less popular because of changes in other technologies and in societal norms.

4. Cultural impact

The third aspect to study for parallels between the watch and the wearable computer is the cultural impact. That people would be unfamiliar with time measurement seems odd to us as we near the end of the twentieth century. But until only a few centuries ago, time was kept by the sun and the stars rather than by time pieces. The time of the day was measured with "temporal hours", wherein each period of daylight was considered to be 12 hours and each period of night was considered to be 12 hours [2]. At the latitude of northern Europe, these hours varied between 40 and 80 minutes over the course of the year [7]. When clocks and watches were first introduced, not every

Figure 2. A sun-and-moon dial. The minutes are indicated by the hand, while the hour is indicated by the location of the sun (day time) or moon (night time). The time shown on this clock is 7:04 p.m. This particular watch also indicates the day of the month along the outermost ring, and the seconds on the small dial near the bottom. After [14].

Figure 3. A differential dial. The hand indicates the minutes on the outer dial and the hour on the rotating inner dial. The time shown is 3:20. After [14].

one understood the "constant hours" that the clocks kept. The situation today is reversed: Most people have never even heard of temporal hours, and would probably have difficulty setting their schedules with them. Our day begins when the hands of the clock are in a particular arrangement, whether the sun has risen or not.

The watchmakers were clearly affected by the cultural transition from temporal to constant hours. Early watches were sold with "watch papers" bearing equations of time, instructions on how to set the watch by a sun dial so that the watch would show noon at mid-day. Some watches were even sold with small sun dials to aid in this setting. The monk Gerbert worked out a schedule of the length of day and night for each day of the year and gave instructions to monasteries on how to set their water clocks to show proper temporal hours for each day of the year. The belt-mounted Japanese watch mentioned previously had movable numbers on its face so that it could show temporal hours. Periodically the numbers would be shifted by the user so that the watch read the appropriate time in temporal hours. (That the Japanese did not develop watches as small as their European counterparts until after the late 1800's, when constant hours were introduced by Westerners, is perhaps due to the limitation of having to move the numbers on the watch face.)

Figure 4. A wandering hour dial. The minutes are indicated by the position of the hour visible in the small circle. The time shown is 8:20. This example also indicates the quarter-hours on the inner most ring. After [14].

While the time pieces were affected by the cultural attitudes toward time, those attitudes were in turn affected by the time pieces. The advent of the clock tower gave rise to fights between factory owners and their workers over control of the clocks [6]. The workers believed that unscrupulous owners set their clocks ahead in the morning and back in the evening. When watches became affordable for the workers, the owners could no longer easily cheat their workers. But the watches also made the workers conscious of time outside the shop, causing workers to organize and schedule their personal time more strictly, and creating a dichotomy between what Landes calls "my" time and "company" time [5]. The 16th and 17th centuries saw the first maxims about wasting time. The concepts of efficiency and productivity introduced in the workplace spread into the personal life. The watch, not the house clock or the clock tower, was the agent of the spread of these notions. One was often out of sight of a clock or out of earshot of a clock tower, but the watch was an ever-present reminder of the passing of time.

This is the third lesson for wearable computing. Where watches created a dichotomy of "my" time versus "company" time, wearable computers will set up a dichotomy of "my" information versus "company" information. As people become more familiar with computers, they will broaden their concept of "information." Information will no longer be just the data a person enters at work, data from measurements; information will become aspects of their lives that they currently consider un-quantifiable, un-computerizable. A few years ago a person's schedule was carried in a small binder, but now it's a document on her laptop or PDA. Similarly with an address book. Photographs, those pictures of memories people once collected in shoe boxes and photo albums, will be taken digitally, and stored digitally. Though some might be printed onto paper, most will be kept on CD-ROM's and hard drives. While we currently think of the photograph as the medium, the photographic paper, soon we will think of it as its form alone, independent of the medium upon which it is presented. The desktop computer has already started this change of thinking, but the wearable computer, due to its being ever-present, will carry the change into areas unavailable to the desktop.

By having the time with them, on their person, people were able to monitor and synchronize their actions in a way that was not previously possible. Likewise, wearable computers will create a new level of synchronization, a synchronization of information

in addition to synchronization of time. The wearable computer, like the watch before it, will change the pace of society due to this increasing synchronization.

5. Conclusions

While the watch is a commonplace to us, it is only so after centuries of development. Wearable computers are currently in the position of the watch in the 1600's: A bauble for the wealthy, educated few. At the same time it appears to be poised on the brink of widespread utility and acceptance, awaiting only the first wearable computer fashion fad.

As with the watch, wearability will not be determined by size and weight alone. This paper has shown that the popular fashions of the day will be a determining factor in acceptable weight, size, and form factor. When the design criteria for a wearable computer is to "fit in a pocket," it should be specified whether the pocket is on an office worker's business suit or a mechanic's coveralls. Should our society again develop a taste for the waist coat, then wearable computers can be larger than those of today, which must fit into a hip or shirt pocket. On the other hand, if the masses develop a taste for Lycra bicycle shorts and shirts, the wearable computer will have to become considerably smaller.

This paper has also shown that watchmakers experimented with a variety of modes for the user interface long before wearable computer designers. Haptic and audio interfaces for watches were probably initially intended for use by the handicapped, but became popular with the general public as well because of lack of light at night and because of social propriety. After changes in other technology (i.e., electric lights) and societal norms, these interfaces became less popular.

The change in the watch face as society's notion of time changed leads one to suspect that the difficulties with the wearable computer user interface may be a conceptual problem of how to represent information rather than a technological problem of conveying it to the user. Just as the change from temporal hours to constant hours enabled the new watches to have a simpler interface, a change in our concept of information may be necessary before interfaces can become intuitive and easy to use, or before a single interface can be used for a what we now consider to be disparate types of information. The representation of information is deeply involved with the manipulations that can be performed on it. For example, division is easier with Arabic numerals than it is with Roman numerals [11]. Even if our concepts and representations of information change, the user interface will not become simpler until computing and its underlying concepts permeate society. The changing cultural understanding of time allowed a simplification of the watch's user interface. Wearable computers will benefit from the same process.

Another lesson from time-keeping is that the contemporary decisions about the interface and the representation will likely have lasting impacts long after the reasons underlying those decisions become unimportant. For example, many clocks and watches today have Roman numerals for the hours, a holdover from the 1600's, and there are 24 hours in a day and 60 minutes in an hour because the ancients desired units that were easily divisible by small integers ($24 = 2 \times 3 \times 4$; $60 = 3 \times 4 \times 5$) [11]. Consequently, interfaces and representations must be judged not only by how well they meet our current needs, but also by how they may limit future changes.

In summary, the field of wearable computing can learn from the development of the watch about wearability, user interface, and cultural impact. Wearability will likely be determined as much by fashion as by functionality and human anatomy. As for the user interface, it will become less of a problem as people become more acquainted with computers. User interfaces now should strive not just for usability, but for ease of future simplification. The cultural impact will be a broadening of the definition of information, a rationalization of representing information, and an increasing synchronization of personal events. If we do not learn the lessons about wearability, user interface, and cultural impact apparent in the development of the watch, we will repeat them, time and time again.

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References

[1] Asano, K.; Sakami, Y.; Watanabe, H.; Fujioka, Y. "Development of wrist computer system." Journal of the Horological Institute of Japan, no. 110, 1984. pp. 48-72.

[2] Baillie, G. H. *Watches: Their History, Decoration and Mechanism*. Methuen and Co. Ltd. London, 1929.

[3] Breguet, E. *Breguet: Watchmakers Since 1775: The Life and Legacy of Abraham-Louis Breguet (1747-1823)*. Alain de Gourcuff. Paris, 1997.

[4] Bruton, E. *Clocks and Watches*. Frederick A. Praeger. New York, 1967.
[5] Landes, D. *Revolution in Time*. The Belknap Press of Harvard University Press. Cambridge, MA, 1983.
[6] Macey, S. *Clocks and the Cosmos: Time in Western Life and Thought*. Anchor Books, Hamden, CT, 1980.
[7] Macey, S. *The Dynamics of Progress: Time, Method and Measure*. University of Georgia Press. Athens, GA, 1989.
[8] McCarthy, J. *A Matter of Time: The Story of the Watch*. Harper and Brown. New York, 1947.
[9] Mumford, L. *Technics and Civilization*. Harcourt, Brace and Co. New York, 1934.
[10] Narayanaswami, C., and Raghunath, M. "Application Design for a Smart Watch with a High Resolution Display," Proceedings of the Fourth International Symposium on Wearable Computers, October 2000, pp. 7-14.
[11] Pannekock, A. *A History of Astronomy*. Dover Publications, New York, 1989.
[12] Rashkovan, N.V. *Starinnye chasy XVI-XIXvv ("Antique Timepieces of the 16th to the 19th Century")*. Moskva Izobrazitelnoe iskusstvo, (Moscow?) 1990.
[13] Sobel, D. *Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time*. Walker and Co. New York, 1995.
[14] T. P. Camerer Cuss. *The Camerer Cuss Book of Antique Watches*, Antique Collectors' Club, Woodbridge, England, 1976.