

# Crossbreeding Wearable and Ubiquitous Computing: Design Experiences from the BubbleBadge

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**Abstract.** This paper describes the design of the *BubbleBadge*, a public wearable device that contains characteristics associated with ubiquitous computing and wearable computers. We show how designing devices that are a mixture of the two, in some ways diametrically different approaches, is productive and creative as it challenges conventional conceptions and categorizations. Questions of intended usage and perceived user of the BubbleBadge are articulated and addressed, identifying ways to design new devices in the intersection between wearable computers and ubiquitous computing.

## 1 INTRODUCTION

A number of technological approaches have been proposed during recent years, to transform the personal computer (PC) and make it usable in new places and situations. In ubiquitous computing [1], computers are envisioned as invisible and omnipresent, having moved away from the desktop to become seamlessly integrated with the physical environments in which we work and live. In this approach, the PC can be said to move away from the user into the environment, becoming less personal. In wearable computing [2], the personal computer is turned into a device that is worn like clothing, with the goal of becoming seamlessly integrated with the wearer. Aspiring to create the 'truly personal computer', the wearable computer approach moves the PC away from the desktop, closer to the user and thus becoming more personal. While these approaches differ from each other, not only in their view of how computers should be designed, but also in how they imply different use and relationship to computers, they in one sense promise the same thing: to free the user from the boundaries of the desktop and the limitations of the desktop computer interfaces.

When computers can support use in novel situations and locations, as well as support other activities than the conventional computers can, they will undeniably have an even greater impact on everyday life than they presently have. Continuous access to devices that provide enhanced communication and information processing functionality will change the environment in which we live in as the devices influence the way we communicate and interact socially. Given the goals of the approaches, ubiquitous computing and wearable computers can be placed on opposite ends of a scale describing how "close" we should be to computer technology.

Put in other words, they articulate the question: Should computers be “close” to their users, as wearable computing proposes, or should they be “distanced” from their users, as proposed by ubiquitous computing?

Our hypothesis is that, despite this polarity, crossbreeding “hybrids” between these two “extremes” is both productive and feasible as it challenges conventional conceptions and categorizations, leading to reaffirmations or redefinitions of what characterizes the approaches. By designing such prototype devices, both personal communication devices and information processing devices, we believe that one can learn more about how they effect how we present ourselves, how we communicate person-to-person, and ultimately how social boundaries in society are changed by the introduction of such technology.

To test this hypothesis, we designed a prototype device, the *BubbleBadge*, which highlights some of the possibilities and challenges of how we wish to communicate and present ourselves in an environment saturated with information technology. In this paper, we wish to bring forth and discuss the questions raised by the *BubbleBadge* design, as well as sharing the lessons learned. The following section serve two purposes; to provide a general design frame for both ubiquitous computing and wearable computers, and to draw some conclusions about what design implications these approaches suggest. We thereafter point to related work, and finally articulate and discuss questions raised by the *BubbleBadge* and its related examples.

## 2 BACKGROUND

The question, *Where is the computer?* is a central one, both when designing wearable computers and when designing ubiquitous computing environments. This question does not only address how to physically design the computer, but also how users should relate to them. As we describe the general design frames of these approaches, we will do so with the above question in mind. The investigation arrives at a number of connotations that serve as a starting point for the design of the *BubbleBadge* by requiring their transgression.

### 2.1 Ubiquitous Computing

Ubiquitous computing envisions a seamless interaction with manifold and omnipresent computational resources in the physical environment, strongly emphasizing that the computer should disappear into the background of attention. Rather than equipping users with personal desktop computers, or even laptops, their environment should contain numerous computers that can be used by anyone as needed. The power of ubiquitous computing, according to Weiser, ‘... comes not from any one of these devices; it emerges from the interaction of all of them. The hundreds of processors and displays are not a “user interface” like a mouse and windows, just a pleasant and effective “place” to get things done.’ [1]

The idea of ubiquitous computing originally emerged from the observation that people working in an office are not always stationed at their desktop, i.e. not all work is, nor should be, carried out on a desktop computer. Although ubiquitous computing has since evolved to encompass environments beyond the workplace, its essence remains – the user should not have to bring the task to the computer or the computer to the task. Instead, computational facilities that match their intended use should be as readily available and as easy to use as pen and paper. If each and every of these devices were to demand the same amount of attention from the user as the PC, the environment as a whole would become overwhelming and unmanageable. Therefore, challenges for ubiquitous computing are to make large parts of the interaction disappear and to reduce the complexity of using many different devices. In conclusion, ubiquitous computing offers several non-personal computers that effectively should be “invisible” to their users.

Some of the first ubiquitous computing systems, perhaps most noticeably the ParcTabs in the ParcTab system [3], are specifically designed to be personal. However, the common devices that are similar to this primordial device, PDAs and mobile phones, are not typically regarded as being examples of ubiquitous computing. This is probably at least partly due to the fact that although these popular devices are ubiquitous in the sense that one can find people carrying them everywhere, they are not accessible for use to all the people present. In order to avoid confusion in how we categorize devices in this paper, we refer to ubiquitous computing environments as environments where computational devices and resources are available to several people in an environment<sup>1</sup>.

**Ubiquitous Computing: communal devices and public information.** Because of their placement in public spaces, items such as cafeteria message boards, street signs, and train station information displays are well suited to convey information to several people. Speaking generally, such objects are shared resources, or communal, and the information they convey is public. Even if the information is intended for a specific person, e.g. a broadcast personal message or a personal note posted on a message board, the nature of the medium used to convey it will cause the information to be public or publicly available.

Similarly, if we embed computational power into the walls and objects of a location, effectively turning them into information resources, they should be very well suited to provide people with information. In ubiquitous computing environments, such information resources are regarded as communal as nobody can claim ownership to them. However, the fact that all computation and information is contained in the environment causes privacy concerns. It would therefore make sense if ubiquitous computing environments distribute public information, or information that is non-sensitive. In fact, many successful ubiquitous computing environments can be found in “smart room” applications that support collaboration between co-located people (c.f. [4, 5]), where the system has been designed to be communal. This suggests the conno-

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1. Without people perceiving that they are loaning devices to one another.

tation that computer systems based on communal devices are particularly suitable for public information or services.

## 2.2 Wearable Computers

The vision of wearable computers, as the name implies, is the idea of body-worn computing systems. The notion is that of a highly personal device, always powered on and always accessible, serving a sole user throughout all aspects of daily life. Wearable computers support accessing personal information at all times, while securing control of that information by minimizing the need for external infrastructure. At the core of wearable computing is, according to Mann, ‘... personal empowerment, through its ability to equip the individual with a personalized, customizable, information space owned, operated, and controlled by the wearer.’ [2]

Wearable computers are intended as constant companions, literally encapsulating their wearers with computational functionality. Hence, they allow a close, and personal association with the user, and can evolve over time to suit every need or preference of its wearer. One of the challenges of wearable computing is to design computers that function well without limiting the users in their everyday activities. In fact, one of the proposed design goals with these computers is to create prosthetic systems and devices that can be so closely integrated with their wearer that they become one with the person wearing them.

Similar to the case of ubiquitous computing, many increasingly common devices such as PDAs, mobile phones, and watches that are computers, are carried (or worn) by people and are constantly available for use. As these devices are not regarded as wearable computers in research communities, we will define wearable computers somewhat narrower than is usual by requiring that no preparation should be needed to use the devices<sup>1</sup>.

**Wearable Computers: personal devices and private information.** Diaries, wallets, and safe-deposit boxes are examples of objects owned by, or associated with, specific people, i.e. they are personal, and their content is handled solely by their owners. By being physically in control of the container, one is also in control of the content.

In terms of computing, the PC is one such container, and even more so if it can be worn. Because of how wearable computers are designed, it is difficult, if not impossible, for outsiders to access the information unless the user explicitly makes it available. Therefore, it makes sense that such computers are used to contain private information. Many wearable computing applications (c.f. [6]) are designed as such, e.g. E.-mail or personal notes, suggesting the connotation that highly personal computing devices are suitable for handling private information.

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1. For example, needing to be picked up from a table, pocket or belt clip.

### 3 THE BUBBLEBADGE

We designed the BubbleBadge with the goal of creating a device that was both communal and personal, and which handled both public and private information - but we were interested in how at the same time challenge the proposed connotations that personal devices should handle private information, and communal devices should handle public devices. We wanted to turn the wearable computer inside out to face the public, and let the ubiquitous computing environment be worn by people.

After evaluating several design concepts, we eventually decided to design a wearable device that borrowed characteristics from jewelry. The advantages of basing a design on jewelry was easy to motivate: they are conventional “wearables,” highly personal and in continuous contact with the wearer, but at the same time also public as they are viewed primarily by other people. We soon concluded that a brooch design would be especially suitable, because they afford viewing by other people than the wearer, a property that we capitalized on in our design. Hence, the final BubbleBadge design became that of a computer display residing in a brooch-like frame that is pinned to a wearer's clothing, making it a *public wearable display*.

Its design suggested that the BubbleBadge could function well in face-to-face conversations. Not only is it placed near the face, but a quick glance on the display does not necessarily interrupt a conversation and the BubbleBadge can thus be an unobtrusive part of the interaction between people. Figure 1 depicts the first generation of the BubbleBadge hardware.

The first generation of the BubbleBadge was based on the Nintendo™ GameBoy, an off-the-shelf handheld video game, from which we detached the display. The display was encased in the brooch frame and reconnected to the video game by a long cable, allowing the game computer to be worn separate from the display, e.g. on a belt. The second generation, as depicted in Figure 2, was designed with the Color GameBoy. For a brief technical description of this work, see Ljungstrand et al. [7].



Fig. 1. The first BubbleBadge prototype

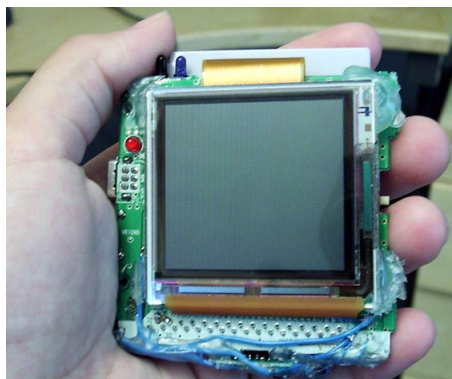


Fig. 2. The second generation BubbleBadge

### 3.1 Interacting with the BubbleBadge

By designing the BubbleBadge as a brooch, it is directed away from the wearer and towards the people with whom the wearer interacts. This is in contrast to a typical wearable computing system, which provides information solely for the wearer. Interestingly, this makes the viewer of the BubbleBadge the actual user, rather than the wearer. This has the implication that the information displayed should be of relevance to the viewer, either because the information is addressing that person or because the information is of contextual relevance to that person.

As the BubbleBadge is attached to a person who is not the actual user, we deliberately omitted input mechanisms such as buttons, making the display the only interface. Lacking input from the viewer, the BubbleBadge must request or retrieve information from other sources. In the current design, local servers and other BubbleBadges (e.g. the *viewer's* own device) provide this information. Below is a sample use scenario that highlights how the BubbleBadges may function in face-to-face conversations:

*Liza and John meet in the corridor and stop for a chat. Their BubbleBadges identify each other via infrared communication so that Liza's BubbleBadge is set to present information related to John, and vice versa. Liza's BubbleBadge runs an e-mail notification program that queries a local server for new e-mail, and when she has new e-mail, it requests that the message "Liza, You have new e-mail!" is shown on John's display. As John has allowed trusted sources to use his BubbleBadge to display such messages, Liza is notified about her new e-mail while she is talking to John without explicitly having to pick up any device or otherwise interrupt the conversation. A few minutes later, both BubbleBadges pick up a message, this time broadcast from a local server, reminding everyone about the weekly lunch meeting. John and Liza have both authorized this type of message, and this time, their BubbleBadges show the message on its own display, instead of forwarding it to the other device.*

As with wearable computers, the BubbleBadges are personal devices because they are worn by individual people. However, a BubbleBadge does not provide its wearer with information that is private to him or her. Because the display is directed away from the wearer, such information would make little sense to display. Hence, the BubbleBadge has been eliminated of one of the main properties of wearable computers - to display private information to the wearer.

When a public announcement is broadcast, such as in the case of the lunch meeting announcement, the BubbleBadges are used to display public information. This illustrates how the devices challenge the connotation between private information and personal devices by showing public information on a personal device. In addition, the BubbleBadge may function, to a viewer, as a display device of private information. In the scenario, Liza reads a private message (i.e. that she has new e-mail) on John's personal display. Thus, the BubbleBadge contradicts the connotation of using communal devices as a source for public information in two ways: by using a personal device as a

communal resource for information and by using that resource to show private information<sup>1</sup>.

## 4 RELATED WORK

Work conducted by c.f. Horovitz [8] to combine agents and direct manipulation, or the work of [9, 10] to couple digital information with physical objects, suggest that it is possible to combine paradigms and arrive at interesting and novel conclusions. One explicit example of interest to the BubbleBadge is the work of Rhodes *et al.* [10], in which a system combining wearable computers and ubiquitous computing is described. However, the system uses ubiquitous computational devices to support and enabling functionality for wearable computers rather than explore the possibilities of merging the concepts. Below, we discuss in greater detail two devices that are of specific relevance to the BubbleBadge as they have several characteristics in common.

The *Meme Tag* [12] is a display device worn around the neck, and hosts text messages, or memes, that can propagate via infrared communication over a “network” of devices. It is based on the idea of computer enhancing nametags used at social events such as conferences. Similar to the BubbleBadge, the Meme Tags have displays that are directed towards viewers rather than their wearers. The Meme Tag can be viewed as a device that challenges our proposed connotations for similar reasons as the BubbleBadge. The devices are worn and perform their own computation, but the information displayed is not intended for the wearers of the devices, but rather for the viewers. The main difference from the BubbleBadge is that the information displayed depends on information locally stored on the individual Meme Tags, which differs from user to user. In essence, it matters whom you talk to.

The Active Badge [13] is related to our discussion because it is a personal device used in a ubiquitous computing environment where information about the wearer is made public. Active Badges communicate their presence to infrared beacons mounted throughout a physical space in order to infer location information about people. This location information was made available on ordinary computer displays where the name and location of the Active Badge wearers was presented.

## 5 DISCUSSION

The BubbleBadge is interesting because its design raises interesting questions, rather than because of its technical specifications and functionality. How should we relate to a public wearable display? Is this wearable or ubiquitous computing? How should we understand such a device? It is not important that the BubbleBadge is a brooch, since a baseball cap with a electronic display or a T-shirt using the whole backside as a display

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1. Although one may object that presenting private information so that other people can see it makes it public, we still see the information as private (or perhaps personal) as it is addressed to one particular person.

area would bring forth the same type of questions. Although its physical appearance, i.e. a display that you wear like a brooch, is very simple, the answers to questions regarding how we should relate to such a display seem to be unexplored and potentially rewarding to how we view computers and their role in society. We believe that the valuable contribution of our work with the BubbleBadge is at least partly in the articulation of questions like *what is the benefit of a wearable public display?* and *what kind of information is interesting to display by individual people to others?* By outlining possible answers to these questions below, we illustrate some of the effects new personal communication and information presentation devices can have on social interaction and how one presents oneself to others.

The initial reaction from people that were presented with the BubbleBadge design primarily concerned the question of how public wearable displays could benefit them. Interestingly, the answer depends to a large extent on whether you are the viewer or the wearer of such a display. Nearly everyone expressed that it is more interesting to be the viewer of the BubbleBadge than the wearer. This is perhaps not so surprising, and while it is relatively easy to find reasons to why the BubbleBadge offers some functionality to a viewer of it, it is seemingly more difficult to find a rationale for wearing one. We believe that this partly is due to the standard preconception of what a computer is and what it should be used for. Claiming that the BubbleBadge is not interesting for its functionality, does not mean we dismiss the importance of providing it with meaningful applications. We believe that finding even only one good reason to wear it might suffice to increase our understanding of these types of devices. We therefore identified four possible uses of a computational device that is worn but presents output to other people.

If we make the parallel between the BubbleBadge and some of the artefacts we use to make statements ourselves, e.g. jewelry, clothes, hairdos, all of which we make very conscious choices about and often have very strong feelings about, we might find one kind of answer. Another idea is to view BubbleBadge as the wearer's puppet or herald that expresses or presents personal information or information that the wearer would like to express. Both these ideas are concerned with making the wearer feel a stronger personal attachment to the BubbleBadge. An alternative approach could be to do the opposite and make the wearer feel mentally unattached to it. The idea is to create a use for the BubbleBadge where it is easily accepted that it is not part of the wearer's usual image. One example of such an application area is within constructed events, such as role-playing or acting situations, where the BubbleBadge can be seen as a theatrical prop that has some importance, either in the narrative play or to the character. The final area of use we proposed for the BubbleBadge is as an icebreaker in arranged social situations, e.g. conference receptions, much like the proposed use of the Meme Tag. We believe that a prime requirement to the answer of why a person would want to wear a BubbleBadge lies in making the experience of wearing it a comfortable one, which will differ from person to person and from situation to situation.

Naturally, if a person would want to wear a BubbleBadge largely depends on the information it presents. The most salient objection to wearing one was the uncertainty about the nature of the presented information, simply because the wearers could not see the display themselves. Because the display was attached to them, the wearers felt

tempted to look down and see what the viewer saw. Nevertheless, they suggested situations where it would be beneficial to present information about the wearer. One suggestion, besides variations of the ones described above, was to let hospital patients wear BubbleBadges that displayed biophysiological information, e.g. heart rate or blood pressure. Another proposition was to let conference participants wear the BubbleBadges and present context-aware and tailored information when people meet.

We identified four sources of information for the BubbleBadge: *the wearer*, *the viewer*, *information relating to both*, and *information relating to the location*. The wearer has, as we have seen, been an obvious choice and easily for people to relate to. A more radical idea is to let the viewer be the source of information, as illustrated in the e-mail notification example in the scenario. In addition, it is interesting to let the information be a result of the specific people that interact (the Meme Tag is an example of a device that displays such information). The information displayed could e.g. relate to the persons previous encounters, or their mutual interests (c.f. [14]). Finally, the information could be provided by the location, also illustrated in the scenario above where a message was broadcast from a server.

In order to infer more general conclusions about public wearable displays, it is necessary to test the BubbleBadge in various use situations, as well as exploring what reasons compel people to be the wearers of public wearable displays. Further, additional types of public wearable displays and devices that are hybrids between the two approaches need to be constructed to gain a richer understanding of this design space.

## 6 CONCLUSION

In this paper, we have described the BubbleBadge, a public wearable display that provides information to viewers of the device. Further, we have given examples of use situations along with a discussion on how the interaction with a BubbleBadge differs from other personal computing devices.

During the process of designing the BubbleBadge, we identified two connotations regarding ubiquitous computing and wearable computers: *communal-public* and *personal-private*. Even though the BubbleBadge can be at least partially described in terms of both wearable and ubiquitous computing, it does not completely fit into either of them. It questions the connotations by being a device that is both communal-private (showing e-mail) and personal-public (showing public announcements). This disparity has let us articulate and explore questions concerning crossbreeding wearable computers and ubiquitous computing. By doing so, we can not only identify new areas information technology use, but also open up a route to gain a richer understanding of wearable computers and ubiquitous computing in general, and of hybrids between them in particular.

## 7 REFERENCES

1. Weiser, M. The Computer for the 21st Century. *Scientific American*, Vol. 265, No. 3, pp. 94-104, 1991.
2. Mann, S. Wearable Computing as Means for Personal Empowerment. *Keynote Address at ICWC'98, 1998*. Available at: <http://wearcam.org/icwckeynote.html>. Last visited: 09/12/99.
3. Want, R., Schilit, B.N., Adams, N.I., et al. *The Parctab Ubiquitous Computing Experiment*, Technical Report, CSL-95-1, Xerox Palo Alto Research Center, 1995.
4. Streitz, N., Geißler, J., Holmer, T. et al. i-LAND: An interactive Landscape for Creativity and Innovation. In *Proceedings of CHI'99*, pp. 120-127, ACM Press, 1999.
5. Abowd, G.D., Atkeson, C.G., Feinstein, A., et al. Teaching and Learning as Multimedia Authoring: The Classroom 2000 Project. In *Proceedings of MM '96*, pp. 187-198, ACM Press, 1996.
6. Rhodes, B. The wearable remembrance agent: a system for augmented memory. In *Proceedings of ISWC'97*, IEEE Computer Society, 1997.
7. Ljungstrand, P., Björk, S., and Falk, J. The WearBoy: A Platform for Low-Cost Public Wearable Devices. In *Proceedings of ISWC'99*, pp. 195-196, IEEE Computer Society, 1999.
8. Horowitz, E. Principles of Mixed-Initiative User Interfaces. In *Proceedings of CHI'99*, pp. 159-166, ACM Press, 1999.
9. Want, R., Fishkin, K.P., Gujar, A., and Harrison, B.L. Bridging Physical and Virtual Worlds with Electronic Tags. In *Proceedings of CHI'99*, pp. 370-377, ACM Press, 1999.
10. Ishii, H., and Ullmer, B. Tangible bits: towards seamless interfaces between people, bits and atoms. In *Proceedings of CHI'97*, pp. 234-241, ACM Press, 1997.
11. Rhodes, B., Minar, N., and Weaver, J. Wearable Computing Meets Ubiquitous Computing: Reaping the best of both worlds. In *Proceedings of ISWC'99*, pp. 141-149, IEEE Computer Society, 1999.
12. Borovoy, R., Martin, F., Vemuri, S. et al. Meme Tags and Community Mirrors: Moving from Conferences to Collaboration. In *Proceedings of CSCW'98*, pp. 159-168, ACM Press, 1998.
13. Want, R., Hopper, A., Falcão, V., and Gibbons, J. The Active Badge Location System. In *Transactions on Information Systems*, Vol. 10, No. 1, pp. 91-102, ACM Press, 1992.
14. Borovoy, R., McDonald, M., Martin, F., and Resnick, M. Things that blink: Computationally augmented name tags. *IBM Systems Journal*, vol. 35, no. 3-4, pp. 488-495, 1996

