Experiences from Mobile e-Meetings with the Borderland Wearable Computer

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Abstract. *People are presented with an increasing number of opportunities to communicate regardless of location as wireless network connectivity becomes more prevalent. Questions that arise are in what form this communication is and what challenges it poses? Can the experience of group communication be enhanced so that a feeling of actual presence can be conveyed? Can we enable participants to experience the world from another person's perspective? We believe so, in this paper we discuss our experiences of group communication when using a wearable computer that is always connected to the network.*

Key words: Wearable, Wireless, Group Communication Architectures

1 Introduction

The division of Media Technology at Luleå University of Technology are working on two prototypes called Always Best Connected (ABC) and Borderland[1].

With ABC we strive to always use the best network connection available depending on where we are, what we are doing and what our needs are. ABC should allow us to seamlessly switch between different networks or use a certain network for a certain application depending on its needs, e.g. demands of Quality-of-Service (QoS), IP-multicast or low latency. For example, this can mean that we use wired Ethernet or IEEE 802.11b in our home, switch to GPRS or UMTS when going outside and then fixed LAN when arriving at the office, all without any interaction needed from the user's part. Essentially, this masks the underlying networks and enables the user to remain connected throughout the day. In the inevitable situations when no network is available, ABC will suspend open connections and still allow the user to continue working locally without failures related to loss of connection.

In Borderland, we are doing research in combining wearable and pervasive computing in order to achieve the best from both worlds. This means having your personal wearable computer and extend it by utilizing devices in your surrounding. For example, the user should be able to walk up to a stationary computer and have its keyboard and mouse redirected to his wearable computer. Another option is to automatically redirect graphical output from the wearable computer in a similar manner. We also investigate how the wearable computer can delegate computational work to other devices.

These two prototypes together can be used to support a variety of mobile applications, including e-meetings[1]. The user should be able to participate from any place and in any situation, as long as there is some form of network connection available. There should be no setup time to prepare hardware and software for participating; it should just work when the need arises, and wearable computing may be the key to that.

The research questions this brings forward include by what means communication can take place, how user interfaces should be designed for such platforms and how important media stream adaption becomes when we are able to switch between heterogeneous networks. How do we prioritize which media, e.g. audio, video and text, is most important when bandwidth is sparse? What can be done to accommodate all participants in an e-meeting when anything from a mobile phone or PDA to a desktop or wearable computer can be used? How can a wearable computer be empowered by devices in its surrounding environment? Do user interfaces need to be differently designed for wearable computers than for desktop applications? How can the same application be used in both environments and how can it take advantage of a wide range of different wearable interaction methods?

There is also the question of how this way of communicating will affect the participants involved in the e-meeting, what advantages and disadvantages there are with this form of communication.

The organization of the paper is as follows. In section 2 related work in this area is discussed. In section 3 we will discuss the platform in more detail, what hardware it currently consists of and what software it is running. Based on our experiences from fairs and exhibitions where the platform has been used, in section 4 we will point out the most important technical challenges that we have found to be problematic in mobile e-meetings. Following, is section 5 with an evaluation of the platform. Section 6 concludes the paper together with a discussion of future work.

2 Related Work

Although collaborative work using wearable computers has been discussed in several publications [2–4], there is still little information about what effect the use of wearable computers can have in more informal meeting situations. As pointed out in [5], wearable computers tend to be most often used in isolation. We believe it is important to study how communication with other people can be enabled and enhanced by using such a platform.

In [6], Rhodes et al. present a combination of wearable and ubiquitous computing that is very similar to Borderland. While they mention ways of redirecting graphical output to another display, they do not discuss how user input from external devices can be redirected into the wearable computer which is something we attempt to solve. Much focus is also on so called smart rooms, while instead we are working to make Borderland take advantage of any environment - including those with no predefined infrastructure.

[1] With e-meetings we mean participants who meet online and are able to collaborate over a network. This is a term we will use for the remainder of this paper.

A wearable computer is inherently mobile; the current Internet Engineering Task Force (IETF) standard for host mobility is Mobile IP [7]. A major drawback of Mobile IP is that it uses triangular routing with foreign agents that must be deployed all around the Internet. Although, these problems are solved in Mobile IPv6 [8, 9], support for mobility will be restricted only to native IPv6 networks that are not widely deployed yet. To support mobility without problems of deployment, ABC uses a novel data stream in-band protocol for mobility and connection management meaning ABC will work on any IP network.

3 The Mobile e-Meeting Participant

We see the mobile e-meeting participant as one using a wearable computer that is seamlessly connected to the network throughout the day, regardless of where the user is currently situated. Here we discuss our current hardware and software solution used for enabling this.

3.1 Hardware Equipment

The wearable computer prototype consists of a Dell Latitude C400 laptop with a 1.2 GHz processor, 1 GB of main memory and built-in IEEE 802.11b. Connected to the laptop is a semi-transparent head-mounted display by TekGear called the M2 Personal Viewer, which provides the user with a monocular full colour view of the regular laptop display in 800x600 resolution. Fit onto the head-mounted display is a Nogatech NV3000N web camera that is used to capture video of what the user is currently looking or aiming his head at. A small wired headset with an earplug and microphone provides audio capabilities. User input is received through a PS/2-based Twiddler2 providing a mouse and chording keyboard via a USB adapter. The laptop together with a USB-hub and a battery for the head-mounted display are placed in a backpack for convenience of carrying everything. What the equipment looks like when being worn by a user is shown in figure 1.

Fig. 1. The Borderland wearable computer prototype.

Note that the hardware consists only of standard consumer components. While it would be possible to make the wearable computer less physically obtrusive by using more specialized hardware, that is not a goal in itself at this time. We do, however, try to reduce its size as new consumer components become available. Ideally it should no longer be noticeable for anyone else but the one who wears it.

3.2 Software Solution

The commercial e-meeting application Marratech Pro[2] running under WindowsXP provides the user with the ability to send and receive video, audio and text to and from other participants using either IP-multicast or unicast. In addition to this there is also a shared whiteboard and shared web browser. An example of what the user may see in his head-mounted display is shown in figure 2.

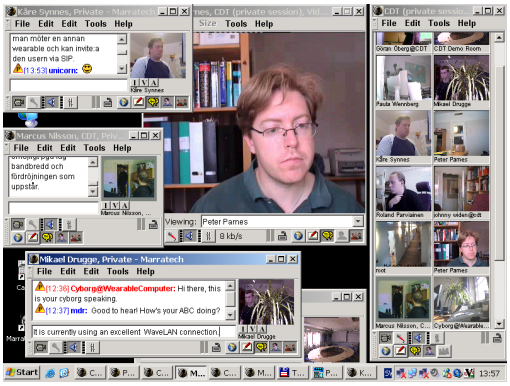

Fig. 2. The e-meeting application as seen in the head-mounted display.

As we have access to the source code for Marratech Pro, we have been able to incorporate the research done in ABC to create a proof-of-concept solution demonstrating how this works in practice by enabling the application to always choose the best available network. When combining this ABC-enabled application with a wearable computer, the result is a highly mobile solution allowing e-meetings to take place from basically anywhere. The mobility this provides is applicable in a physical sense as the user can roam the environment freely, and this freedom is further extended in a broader sense thanks to ABC. Not only is roaming made possible in a limited environment, e.g. in a company setting with WaveLAN base stations, but it can now be extended to networks normally not part of a company's infrastructure. This allows for a truly mobile network connected user.

4 Challenges

Several technical challenges need to be addressed when taking part in mobile e-meetings. In addition there are some social challenges as seen from a user perspective, and these must also be taken in consideration. Most of these were experienced when we attended the "SITI Mobility 2003" fair and used the platform during the day as part of our own exhibition. The one among us who was wearing the ABC-enabled Borderland prototype was in an e-meeting with the rest of our research group at the university and also with the people at our main exhibition booth. In this section we will discuss the most important issues we have identified.

4.1 The Importance of Text

Even though audio may be well suited for communicating with people, there are occasions where textual chat is more preferable. The main advantage of text as we see it is that unlike audio, the processing of the information can be postponed for later. This has three consequences, all of which are very beneficial for the user.

[2] http://www.marratech.com

1. The user can choose when to process the information, unlike a voice that requires immediate attention. This also means processing can be done in a more arbitrary, non-sequential, order compared to audio.
2. The user may be in a crowded place and/or talk to other people while the information is received. In such environments, it may be easier to have the information presented as text rather than in an audible form, as the former would interfere less with the user's normal task.
3. The text remains accessible for a longer period of time meaning the user does not need to memorize the information in the pace it is given. For things such as URL:s, telephone numbers, mathematical formulas and the like, a textual representation is likely to be of more use than the same spoken information.

While there was no problem in using voice when talking with the other participants, on several occasions the need to get information as text rather than voice became apparent. Most of the time, the reason was that while in a live conversation with someone, the interruption and increased cognitive workload placed upon the user became too difficult to deal with. In our case, the user often turned off the audio while in a conversation so as not to be disturbed. The downside of this was that the rest of the participants in the e-meeting no longer had any way of interacting or providing useful information during the conversation. [3]

There may also be privacy concerns that apply; a user standing in a crowd or attending a formal meeting may need to communicate in private with someone. In such situations, sending textual messages may be the only choice. This means that the user of a wearable computer need not only be able to receive text, he must also be able to send it. We can even imagine an e-meeting with only wearable computer participants to make it clear that sending text will definitely remain an important need.

Although hand-held chord keyboards such as the Twiddler exist, these still take time to learn and for those who seldom need to use them the motivation to learn typing efficiently may never come. Other alternatives that provide a regular keyboard setup, such as the Canesta Keyboard^{TM}Perception Chipset^{TM}that uses IR to track the user's fingers on a projected keyboard, also exist and may well be a viable option to use. Virtual keyboards shown on the display may be another alternative and can be used with a touch-sensitive screen or eye-tracking software in the case of a head-mounted display. Voice recognition systems translating voice to text may be of some use, although these will not work in situations where privacy or quietness is of concern. It would, of course, also be possible for the user to carry a regular keyboard with him, but that can hardly be classified as convenient enough to be truly wearable.

In our Borderland research, we believe there is yet another option for providing keyboard input, and that is by being able to use devices in your surrounding. We are currently working on making it possible to walk up to a computer and automatically get keyboard and mouse events redirected to the wearable computer. While this may not be a solution for all situations, it will solve some of them and so this is part of an area we are actively researching today.

[3] This was our first public test of the platform in an uncontrolled environment, so neither of the participants was sure of what was the best thing to do in the hectic and more or less chaotic world that emerged. Still, much was learnt thanks to exactly that.

There is one final advantage of text compared to audio, and that is the lower bandwidth requirements of the former compared to the latter. On some occasions there may simply not be enough bandwidth, or the bandwidth may be too expensive, for communicating by other means than through text. With an ABC-enabled platform, we should still be able to communicate even when network conditions are sparse.

4.2 The User Interface

The common desktop user interface which is based on the WIMP[4] metaphor appears not to be the best choice when it comes to using it in a wearable computer, as pointed out in [10]. While moving windows around may not be very difficult on a desktop computer, our experience shows that on a wearable computer this tends to cause too much inconvenience in the long run.

Based on our experiences from the "SITI Mobility 2003" fair, we found that even some of the simplest tasks became too difficult when they needed to be done with a wearable computer in this kind of setting. For example, in the e-meeting application used there is a small button for muting incoming audio which is easily accessible through a single click with the mouse in the graphical user interface. When walking around at the fair, the audio was always on so that the user would hear comments from the other participants, but upon being approached by someone the user wanted to quickly mute the audio and focus entirely on that person. It was at this point that several unforeseen difficulties arose.

The social conventions when meeting someone involves making eye-contact, shaking hands, presenting yourselves and making sure to memorize the other person's name and affiliation. The deceptively simple task required to mute audio involves looking in the head-mounted display (preventing eye-contact), using the hand-held mouse to move the pointer to the correct button (preventing you to shake hands), and trying to ignore the voices in the headset while listening to hear who the person presents himself as. These conflicts either made it necessary to ignore the person approaching you until you were done, or to try and do it all at once which was bound to fail. The third alternative, physically removing the headset from the ear, was often the most practical method we chose to use in these situations. It should be noted that during tests in more relaxed environments, the user has not had any problems in finding and invoking the correct button. What separates that environment from a fair is likely to be the increased stress and movement of people around the user. The latter may make it more difficult to use a semi-transparent head-mounted display since the background of moving people now interferes with what is shown in the display [11].

Although this episode may sound somewhat humorous, which it in fact also was at that time, there are some serious conclusions that must be drawn from this experience. If such a simple task such as muting audio can be so difficult, there must surely be a number of other tasks that can pose similar problems in this kind of setting.

Apparently it is not enough just to transfer a well functional desktop application to a wearable computer and expect it to be as easily used there. Something as trivial as carrying the Twiddler in your right hand can effectively prevent you, or at least make it

[4] Window, Icon, Menu, Pointer

more inconvenient, to shake hands with someone. We must ask ourselves whether there are other social conventions that we risk breaking when the use of wearable computers becomes more common. All in all, this makes designing useful user interfaces for use in this kind of environment very challenging, and by that also much more interesting. These are long-term research questions we have started to work on in Borderland.

4.3 Involving Ordinary Persons in e-Meetings

When in an e-meeting, it is sometimes desirable for an ordinary user to be able to jump into the discussion and say a few words. Maybe a friend of yours comes by your office while you are in an e-meeting with some other people, and you invite him to participate for some reason - maybe he knows a few of them and just wants to have a quick chat. While this is trivial to achieve when at a desktop - you just turn over your camera and hand a microphone to your friend - this is not so easily done with a wearable computer for practical reasons.

Even though this situation may not be that common to deserve any real attention, we have noticed an interesting trait of mobile users participating in e-meetings. The more people you meet when you are mobile, the bigger chance there is that some other participant in the e-meeting will know someone among those people, and thus the desire for him to communicate with the other becomes more common. For this reason, it has suddenly become much more important to be able to involve ordinary users - those you just meet happenstance - in the e-meeting without any time to prepare the other person for it.

We base this on the “SITI Mobility 2003” fair experience as well as some local exhibitions done at our university. On all occasions the wearable computer user met or saw a few persons who some participant turned out to know and wanted to speak with. Lacking any loudspeaker, the only way to convey information was for our user to act as a voice buffer, repeating the spoken words in the headset to the other person. Obviously, it would have been much easier to hand over the headset, but strangely enough several people seemed intimidated by it. They would all try on the head-mounted display, but were very reluctant to speak in the headset. [5]

To alleviate this problem, we found it would likely be very useful to have a small loudspeaker as part of the wearable computer through which the persons you meet could hear the participant. That way, the happenstance meeting can take place immediately and the wearable computer user need not even take part in any way, he just acts as a walking beacon through which people can communicate. Of course, a side effect of this novel way of communicating may well be that the user gets to know the other person as well and thus, in the end, builds a larger contact network of his own.

We believe that with an ABC-enabled mobile e-meeting participant, this kind of unplanned meetings will happen even more frequently. Imagine, for example, all the people you meet when walking down a street or entering a local store. Being able to involve such users in an e-meeting the way it has been described here may be very socially beneficial in the long run.

[5] Another exhibitor of a voice-based application mentioned they had the same problem when requesting people to try it out; in general people seemed very uncomfortable speaking into unknown devices.

4.4 Becoming a Knowledgeable User

One of our key findings at the "SITI Mobility 2003" fair was how easily a single person could represent our entire division, provided he was part of an e-meeting and mobile. When meeting someone, our user could ask questions and provide answers that may in fact have originated from someone else at the division. As long as the remote information, e.g. questions, answers, comments and advices, was presented for our user in a non-intrusive manner (see the discussion in section 4.1), it provided an excellent way to make the flow of information as smooth as possible. [6]

For example, if a person asked what a certain course or program was like at our university, the participants at my division would hear the question as it was asked and could respond with what they knew. Our user then just had to summarize those bits of information in order to provide a very informative and professional answer.

4.5 The Need for Media Adaption

An important problem arises when switching from a network with high bandwidth to one with significantly lower bandwidth, e.g. from IEEE 802.11b to GPRS. Because connections remain open thanks to ABC, media streams previously suitable for high bandwidth may exhaust the resources in the new network. For example, regular video streams from participants may no longer be possible to show because of the lower bandwidth, or they may simply be deemed as too expensive to transport in the new network.

We have so far done very little in testing the ABC functionality of Borderland as the exhibitions and fairs we have attended have all had good WaveLAN coverage, thus eliminating the need to switch to another network. Pilot tests show however that when switching networks, live video may become useless due to latency and the lack of available bandwidth. This means the e-meeting must continue with text or audio only. We are investigating how this adaption can be done preemptively when switching networks.

5 Evaluation

When a user is equipped with a wearable computer he is able to convey a feeling of presence that is highly realistic. This is based on experiences from the fairs and exhibitions we have attended so far, as well as from pilot studies done at our university. Testimonies from participants in such e-meetings indicate that they got a feeling of more or less *being* that user.

While a similar feeling might be achieved through the use of an ordinary video camera that a person is carrying around together with a microphone, there are a number of points that dramatically sets the wearable computer user apart from such.

- The user will eventually become more and more used to the wearable computer, thus making the task of capturing information and conveying this to other participants more of a subconscious task. This would mean the user can still be an active contributing participant in the e-meeting, and not just someone who is recording.

[6] Note that in this kind of more formal, representative, situation it may in fact not be desirable to involve the other participants directly as discussed in section 4.3.

- As the head-mounted display aims in the same direction as the user's head, a more realistic feeling of presence is conveyed as subtle glances, deliberate stares, seeking looks and other kinds of unconscious behaviour is conveyed. The camera movement and what is captured on video thus becomes more natural in this sense.
- Some participants reported a feeling of motion sickness with a high framerate (about 5 Hz), and for that reason preferred a lower framerate (about 1 Hz) providing almost a slideshow of still images. However, those who had no tendency for motion sickness preferred as high framerate as possible because otherwise it became difficult to keep track of direction when the user moved or looked around suddenly. In [12] it is stated that a high framerate (15 Hz) is desirable in immersive environments to avoid motion sickness. This suggests our notion of high framerate was too low, by increasing it further it might have helped eliminate these problems.
- Audio was deemed as very important. Through the headset microphone the participants would hear much of the random noise from the fair as well as discussions with persons the user met, thereby enhancing the feeling of "being there" tremendously. Of course, there are also situations in which participants are only interested in hearing the user when he speaks, thereby pointing out the need for good silence suppression to reduce background noise.
- The participants could interact with the user and tell him to do something or go somewhere. While this is possible even without a wearable computer, this interaction in combination with the feeling of presence that already existed gave a boost to it all. Not only did they experience the world as seen through the user's eyes, but they were now able to remotely "control" that user.

6 Conclusions

We have presented our prototype of a mobile e-meeting platform in form of a wearable computer with ABC-functionality. This platform serves as a proof-of-concept that these kinds of meetings are possible today.

Based on experiences from fairs and exhibitions, we have found and identified a number of areas that need further refinement in order to make mobile e-meetings more convenient for everyone involved. The importance of text and better user interfaces has been exemplified, as well as the importance of media adaption in heterogeneous networks. We have discussed some examples on how presence is conveyed and what it can be like to be part of an e-meeting when one of the participants is mobile.

6.1 Future Work

As discussed in section 4.5, further research in media adaption is needed. We are working on modifying Marratech Pro so that it can adapt media streams based on the receiver's capability.

We currently lack quantitative measures for our evaluation, but are in the midst of preparing a user study which intends to find out how information can be presented for the user in a non-intrusive manner without increasing his cognitive workload. Based

on the results, we will be able to construct wearable user interfaces that better help eliminate the problems discussed in section 4.1.

Today, our Borderland prototype is based on a laptop and thus too large to be truly wearable. Our intention is to replace the laptop with a PDA to significantly reduce its size. When the head-mounted display is replaced with a more lightweight version, the entire platform will be less intrusive and can be used more commonly.

When migrating to a PDA, the Marratech Pro application will likely be replaced with mPocketPro - a version for PocketPC developed especially for use on a PDA [13].

We will also work to move the implementation of ABC to the operating system layer and develop it further to provide generic TCP and UDP support for any application.

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