Wearable Multimodal Interfaces *

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ABSTRACT

Wearable Computing is a relative new research field and it is a rather unusual intersection of different research areas such as science, design, fashion and engineering. In the last decades this field made a huge improvement and it seems that it will become even more important in the near future. Due to the immense improvements in miniaturization and better battery technologies we can now build devices which we expected as science fiction only years ago. The aim of this paper is to give a short overview over the topic of Wearable Multimodal Interfaces.

Categories and Subject Descriptors

C.0 [**Computer Systems Organization**]: General—*Hardware / Software interfaces*; H.5.2 [**Information Interfaces and Presentation**]: User Interfaces—*Input devices and strategies* ; H.1.2 [**Information Systems**]: User/Machine Systems—*Human Factors, Human information processing*

General Terms

Human Factors, Measurement, Design

1. INTRODUCTION

Wearable Computing is a young research discipline which has been rapidly developed since the early sixties. In the early ages of Computer Sciences a user was bound to a static place where he could do his work. The rapid development in electronic miniaturization and the development of better batteries, the industry was able to develop even smaller computers. Because of this progress a user is not any more bound to a specific place where he can interact with his computer. Now he is able to carry his computer everywhere he like to go. Today Smart Devices have a big influence on our daily life and it seems that it will persuade us even more in the next years. The direction is clear, we are going towards a continuous, persistent interaction with our devices. This paper gives an overview over the domain of wearable computing in terms of multimodal interfaces. Multimodal interfaces are strongly related to Wearable Computing and play a major role. Today the focus is on more complex devices which can handle multiple and distinct tasks. This leads to the fact that we need systems which are able to handle different modalities for input and output. Nevertheless there are many devices which only use a single modality such as basic Hearing Aids or wristwatches. The first part of the paper covers the background of Wearable Computing, its definition, history and main domains. The second part covers the topic of Wearable Devices in general. We discuss important attributes, modalities used for communication and how to model interaction. Then we take a look at a real Wearable Multimodal Device and argue about advantages and disadvantages. Further we discuss the challenges we have to face in the area of Wearable Computing. The focus of this paper is on Wearable Devices and its different modalities, we do not get into details about issues of multimodal interfaces in general.

*The Paper is a deliverable of the Msc Research Seminar *Seminar Multimodal Interaction on Mobiles Devices* in 2012, DIVA Group University of Fribourg, supervised by Dr. D. Lalanne

1.1 Definition

So what exactly is Wearable Computing? The term has been defined in the mid nineties by the U.S. Defence Advanced Research Projects Agency (DARPA) as follows [1]:

„Data gathering and dissemination devices which enable the user to operate more efficiently. These devices are carried or worn by the user during normal execution of his/her tasks.“

A year later Steve Mann defined the term more precisely, his definition leads to three fundamental properties which a wearable device must fulfill. A Wearable Computer must be worn and therefore must be a part with the wearer. This means a mobile device is not a Wearable Device because it is only carried and not worn by the user. The second property defines that a user must be able to control the system, which must not be necessarily intentional. The third property states that the system must be always active and act in real time to provide a consistent and continuous interaction between the user and the computer[1].

1.2 History

The first approach of a Wearable Devices was the Thorp / Shannon Wearable Roulette Prediction System of the year 1961. This system was composed of a device placed in the

shoes of the user. With his toes he could then operate switches which were used to analyse the roulette wheel and the type of balls they used. With the same system worn by another user which controlled the ball position during the play it was possible to predict the outcome of the game up to a chance of 44%. Since then a multiplicity of devices have been developed [1, 3].

1.3 Main Domains of Wearable Computing

Today there are many different devices and applications available. Most of them are located in the following domains: military, health and personal assistance.

The military quickly recognized the potential of Wearable Computers to improve their infantry. They can be used for command and control, providing tactical or navigational information and to provide vital informations of the wearer. It is also often used for immersive training of armed forces and emergency workers. In the field of medicine, Wearable Computers are also widely used with great success. The main task of the system is to monitor the user. The pallet of devices is large and goes from simple neck mounted sensors for measuring the blood flow to very complex systems designed for people with special needs. The last domain is personal assistance, where wearables try to help and improve effectiveness of everyday tasks. We rather speak about intelligent agents which are working more or less autonomously or with just a minimal interaction of a user. Devices must be carefully designed to be accepted by the user and a variety of systems have been developed such as camera based applications or functional textiles [1, 6, 8, 9].

2. WEARABLE DEVICES

Wearable Computing is a big step towards the dream of a human computer symbiosis. It is more than just wearing a device which does some computation for us, it can be seen as a real extensions of our senses. The Wearable should act as personal assistant which always senses the world, delivering useful information and learn from the behaviour of the user.

2.1 Attributes

Based on the definition of Wearable Computing Thad Starner et al. [1, 2] defined some ideal key attributes which a system should have. Those attributes are somewhat ambitious and not all of them can be implemented easily, but with the ongoing improvements in this area they will become manageable in the near future [2].

2.1.1 Constant and persistent data service

The device must be able to interact with the user continuously and stable at any time, interrupt the user when necessary and act appropriately on everyday situations. Therefore it has to be designed resistant for everyday and mobile usage. On the other hand the user must have a quick and intuitively access to the device and to the information he needs. To guarantee consistency the Wearable should also provide information about its own internal state to the user for example over a display output [2, 9].

2.1.2 Sense and model context

The Wearable should provide mechanisms to observe, sense and model different context such as the user environment and the state of the user itself (context awareness). Sensors across the body manage the interaction between the device and its environment. For this task the device needs to be designed open for the user so that he can provide additional contextual cues to help the system [2, 9].

2.1.3 Multimodal Adaptation

The adaptation of multimodal input and output for a specific situation must be handled automatically by the system. This is a difficult task because not every modality is appropriated for an intrinsic situation. The device has to be able to decide which modality serves best for a specific situation and then switch automatically to this mode. For example during a meeting the system could communicate through a head-up-display but while driving a car it should switch to an audio interface. Mostly the system is not primarily involved in a user task and therefore it seems necessary that it gathers the minimal amount of attention from the user. The user interface should provide privacy of interaction, which means that the user ought to adapt the interface to his needs. Also the systems should be able to learn and adapt to situations autonomously [2, 9].

2.1.4 Augment and mediate interactions

A continuous information support is a must. This includes the collection of information based on the current physical location. This data has to be processed in a way which serves best for the user in his current situation. The interface must be adapted autonomously to the current tasks or needs of the user. Also the system has to treat interrupts such as phone calls or incoming messages appropriate to the current situation [2, 9].

2.1.5 Seamless integration

The device should not influence the freedom of movement of a user. It must be seamlessly integrated into his clothes or be attached to a body part without interfering normal physical activities [9].

2.2 Modalities

A Wearable System is meant to be an extension of our senses. Today there are numerous sensors on the market which can measure almost anything. In this report we do not cover sensors in details, we focus on how to perceive information and how multimodal interaction is modeled.

To perceive stimulation from the outside a human body has its five main senses. Out of theses five senses three are used successfully in Human Computer Interaction. Those senses are sight, hearing and touch. The most common way to present information to the user is via Audio or Video input. Touch can also be used but it is mostly reduced to the task of notification such as vibration of a mobile phone on an incoming call. Besides those senses also thermo-reception and the sense of balance have been investigated but it is hard to use them for natural interactions [4, 7]. Our body contains over 600 muscles which can be used in different combinations for interaction. But only a few of them are really meaningful when it comes to the task of interacting with a computer. The main body parts used for interaction are fingers, hands and arms. But also other parts are successfully used for input such as the head or legs. Another important input source

while interacting with the environment is speech [4, 7]. Figure 1 shows a nice visualization of the human body and the corresponding modality type (perceiving, interacting).

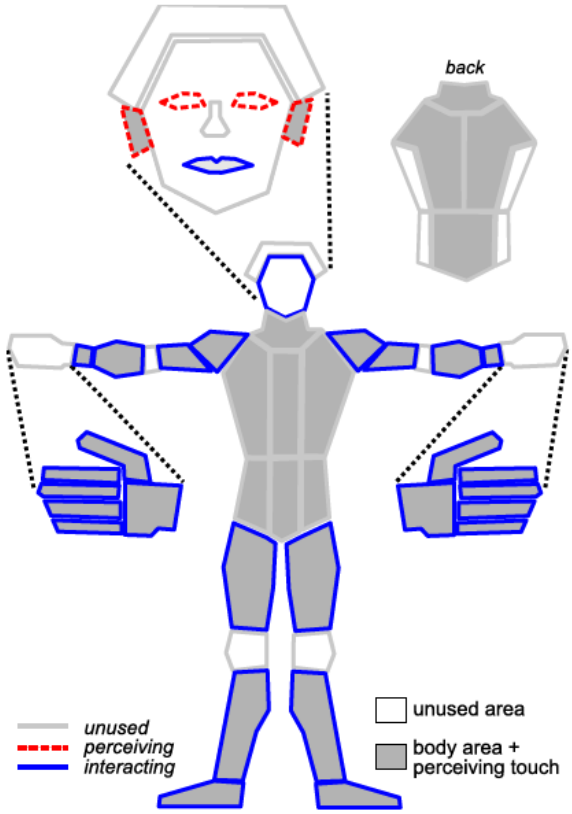

Figure 1: Body areas considered for interaction [4].

3. MULTIMODAL INTERFACES

A Multimodal System responds to information input of more than one communication channel. This includes handling of different combinations of these channels simultaneously. Those kinds of interfaces have several advantages such as: greater bandwidth for communication, interface robustness, better error correction possibilities and many more. On the other hand it is hard to build a natural and efficient interface which feels natural for a user [7]. Another problem concerns the data handling it is still difficult for a artificial system to handle user and context awareness properly. The system has to properly handle multimodal input, which means it contains several modules handling and combining distinct data. This complex task can be handled with multi-agent system architectures. To support a intuitive and natural user interface a system has to adapt the interface to a specific user or task, handle errors and interruptions gracefully. On the other hand the system needs a fusion mechanism to integrate input from different modalities [7].

As an example we will take a brief look at a Wearable Multimodal Augmented Reality System which was designed to support workers in the field of building maintenance, emergency rescue and reconnaissance missions. The main goal of the system is to improve situational awareness and to boost the efficiency of specific tasks.

The system combines four input modalities: hand gestures, unidirectional trackball motions, voice commands and head orientation. All features of the input data are extracted and interpreted independently before they are combined with late integration. The user inputs his commands via speech, hand-tracking and also with a wireless hand-held trackball. For the output channel a head mounted display is used, to display virtual data on top of the physical world (augmented reality) [6].

For interaction with the real and virtual world they used a three staged rendering environment. In this staged environment they combined the finger environment which is used for selective probing, the tunnel environment which can be seen as a frustum shape into the virtual representation of the world. With this tool a user can control three different vertical planes to select different rendering behaviours for each region. This approach enables a user to interactively explore complex 3D environments [6]. The user can interactively manipulate or add virtual objects into the virtual scene. This is useful for creating geometric shapes or annotating physical scenes. To add such an object the user needs to perform several steps using voice commands, hand gestures, head pose and trackball input.

This system shows us some advantages and disadvantages of multimodal interfaces. A big advantage or improvement is the seamlessly working combination of different modalities to fulfil a given task. Such a system can be really helpful in a complex work environment. Nevertheless it shows us clearly where the limitations of such systems are. Performing just a simple task such as placing an object is still quite complicated. A user has to remember a lot of different operational procedures to successfully complete a task. Furthermore the device seems to be not very comfortable to wear. The user interface looks complex and the handling seems to be unnatural. Clearly this must not be the case for other systems, but it shows us some critical points in the field of Wearable Mutlimodal Interfaces.

4. CHALLENGES

In this section we focus on technical and user specific challenges. The design process of a Wearable Computer is difficult because it needs to fit two very different domains. First we have to deal with technical limitations and then we have to adapt the device to the user which means we have to consider physical impacts, fashion and usability. This task to combine those domains is maybe one of the hardest part in designing a wearable.

4.1 Technical

A wearable devices should be ideally always available and therefore it will continuously consumes power. This leads to the problem that we need an energy source which can provide the requested need of power which is one of the most limiting factor. Although batteries are getting smaller they still are the main mass of a mobile device. It gets even complicated if the device contains multiple components which are distributed over the body. A simple approach would be to use solar power. The problem is that wearable and therefore

flexible solar panels have less conversion efficiency and they would not have an continuous sun exposure. The usage of rechargeable batteries could slightly overcome this problem, but the user would always be forced to maintain them. Another approach would be to use the movement of the body to gain energy, which is possible but we are still waiting for the commercial breakthrough. A further possibility would be to power the device via an electric field like in RFID technique [3].

With the persistent consumption of energy we have to face another problem. Heat dissipation is a serious problem. There are many solutions to this problem such as, using heat pipes which we know from laptops. We could also use the environment, when the user moves we could use the airflow to cool down the device. The usage of non conducting fluids is also a possibility to transfer heat away from the processor. The possibility to use the human body for cooling has already been research also the usage of phase-change materials which can absorb a huge amount of heat [2].

Wearable Computing affects different communication styles like, off body, on body and near body networking. Off body communication involves communication between a mobile device and a static infrastructure usually managed by a network cell. Here we have to overcome the situation that a user is not always in the range of such a cell. A solution approach could be aggressive caching or a big local data storage. Dealing with on body communication is less complicated, since it requires less energy. But every device needs to have its own power source which could also be critical. Research results have shown that with energy-conservation and low bandwidth an on-body sensor can operate with only one charge in a year [3].

When dealing with private data and networks we also have to consider privacy and security issues. Where privacy involves the control over personal information whereas security includes the protection of data from unauthorized users [3].

4.2 User based

When designing a Wearable Device we also need to respect the user. Wearable Computers still do not have the same widespread acceptance as desktop systems. We have to consider several important aspects such as the weight of the device, freedom of movement, fashion, usability, expense, portability and many more [1, 3, 5].

Besides the rather hardware dependent problems we also need to consider software issues. User interfaces are rather complex and do not support a natural or intuitive feeling of control. Context awareness or user awareness is really hard to implement. It is difficult to automatically decide which data is important for a user or which information is necessary for context awareness. And at last an application should adapt its interface to the skill level of a user which is also hard to manage.

5. CONCLUSIONS

This seminar paper describes just a small amount about the topic of Wearable Multimodal Interfaces and it mainly covers aspects of Wearable Computing. This field can be seen as a subpart of Ubiquitous Computing, a model of human-computer interaction which deals with information processing totally integrated into everyday objects and activities. Therefor both domains share similar problems. From the perspective of Wearable Computing we still have to deal with major technical and user based problems such as: provide a stable network connections, heat dispensation, seamless integration of devices and power consumption, user acceptance and many more. From the side of Multimodal Interfaces we have other complex problems needed to be solved. For example provide real user and context awareness without limitations, simple, effective and intuitive user interfaces, a general working multimodal adaptation mechanism etc. .

The research field is in its early ages and it will grow continuously and with great effort. Today there are already many interesting and useful Wearable Devices. Nevertheless we can not speak about a massive breakthrough on the market. I am sure that Ubiquitous Computing will be the future and Wearable Devices will definitively play a major role.

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