A Mobile Device as User Interface for Wearable Applications

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ABSTRACT

In this paper, we describe the Tampere University of Technology's involvement in the research of machine washable and wirelessly rechargeable wearable technology and using mobile devices as input and output interface and as means of data transfer and processing for wearable applications.

Keywords

Wearable technology, smart clothing, wireless wearable system, machine washable electronics

1. INTRODUCTION

In the late 1990's many leading figures of wearable technology predicted that very soon wearables would overthrow the mobile handset and electronics would move in even closer to the user's body. The prediction is yet to come true and when the high-tech boom slowed down most became more cautious with their estimates. Wearable electronics haven't still made mass market, but teaming up with mobile devices could eventually solve some of the key problems in wearable applications.

The Tampere University of Technology (TUT) has conducted research in wearable technology since 1997 [1]. The TUT Kankaanpää Unit (KP1) was established in 2003 and its research concentrates on wearable technology and garment integrated electronics.

2. THE CHALLENGE

Current wearable applications still have several problems to be worked out before mass market. Many of them are related to the maintenance of the device, e.g. machine washing, recharging of batteries and customer service. Bringing a function close to the body can often be of more service than merely delivering hands free operating, but interfacing the wearable devices can be complicated. If the wearable device requires both input and output and needs to be operated on-the-go, an integrated wearable user interface may cause more problems than it solves.

First of all the usability may suffer if for example text input, or any multi-key input must be used; constructing a soft washable keypad is possible [2] but efficient typing may be difficult for lack of suitable rigid surfaces on the body against which to press the keys. If the keypad itself is made rigid the textile garment may no longer carry the added bulk, not to mention the obtrusive appearance. Secondly, for the same reasons high resolution display output is not yet an option as the flexible displays still really aren't flexible and tough enough to withstand regular garment wear [3]. Woven optical fiber displays [4] are softer in feel and lighter, but so far don't offer needed resolution or brightness. Thirdly, hard objects larger than a button or a zipper in soft textile are likely to damage the fabric in machine wash. Constructing them waterproof and rigid enough to be able to take a washing cycle is expensive and time-consuming. Finding a perfect location for the display and a keypad is hard from a usability and ergonomic point of view [5]. A shirt with a display can't show output if the user is wearing a jacket over the shirt. Even further, displays as well as most other output devices consume much energy in relation to sensor electronics and combined with wireless data transfer the overall energy consumption may require larger batteries that add weight and bulk.

A good alternative to integrated user interfaces in wearable technology would be to use a wirelessly connected mobile tool, preferably one with good input/output capability, one that is widely available and customizable for different target groups and tasks and one that nearly everyone is already familiar using and carrying along with them. Why make another wireless handset when most people already carry one wherever they go? By making the mobile phone a part of the system the toughest problems of added manufacturing (and purchasing) costs and the maintenance of the garment-integrated electronics could be solved.

3. THE SOLUTION

Figure 1. illustrates a wearable system linked with external devices with a mobile phone as the user interface and communication hub between the personal space and the environment.

Many of today's mobile handsets have inbuilt Bluetooth (BT) or even Wireless Local Area Network (WLAN), and support General Packet Radio System (GPRS) and can run third party applications. A garment with BT fits nicely into the wireless loop and can be accessed through a custom application fitted in a menu structure, which offers the actual service. BT may not be an optimal solution for implementing a Body Area Network (BAN), but, along with IrDa, currently the only standard system widely used in mobile phones. On the other hand BT is a more suitable protocol for a Personal Area Network (PAN), which requires a higher bandwidth.

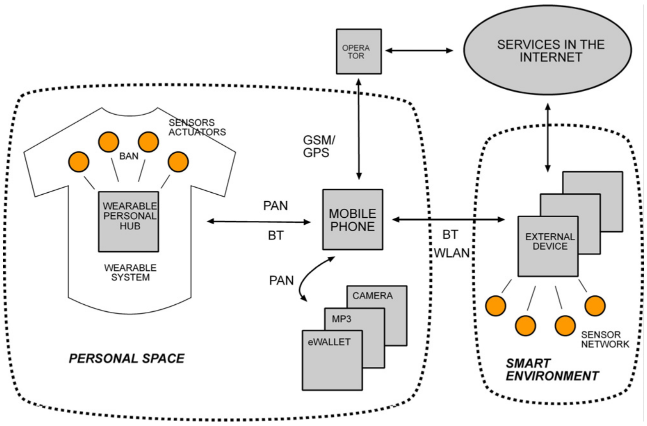

Figure 1. A mobile phone as the user interface and communications hub for wearable electronics.

3.1 Body Area Network

There are several options for creating a Body Area Network. They can be divided into three categories based on the data transferring method.

The first category is the most obvious and old-school, where the data between for example the CPU and the sensors is carried by wiring placed inside the garment. The wiring can be done by commercially available plastic-encased conductive textile yarns. The benefit of this method is that the wiring can include power supply for the sensors. A downside is the added sewing work when assembling the wiring to the garment; also the placement of the wiring needs to be done carefully to avoid dragging and restricting movement. A more sophisticated version of this is to include the conductive traces in the textile in the knitting phase, but for now this is a much too costly method. The traces could also be printed in the textile, but it too can be costly with the print having to withstand stretching, abrasion, moisture and sweat.

The second category builds on using the body's skin surface for sending signals. This requires a direct skin contact so it is most practical in garments that touch the skin surface. In this alternative all pieces of electronics need to have their own power supply.

The third category is wireless data transfer. Its benefits include less need for adapting the garment to the added technology and possibility to use short-range data transfer with moderate power consumption. Bluetooth is a good media for data loads around 1 Mbps, but a sensor-BAN however only moves a few bytes of data at a time and most of the BT channel capacity would be left unused. BT also consumes unnecessarily much power for a BAN. A better option for wireless data transfer in a BAN would be Zigbee [6], which has a capacity of up to 250 Kbps. Other alternatives include Wireless USB (WUSB) or Bluetooth v.2.

3.2 Personal Area Network

The BAN concept includes all parts of the wearable system located in the garment (e.g. sensor electronics) but to further include user's additional mobile devices and applications (e.g. mobile phone, camera, eWallet) we need to expand the concept of communication space from BAN to PAN which includes everything in the user's close proximity (Personal Space in fig. 1.).

The mobile phone serves a role as the mediating user interface between the BAN and PAN for reading the output from the garment sensors and acting as the input device for configuring the wearable device's settings. The mobile phone can be used to process the garment data; alternatively the phone can send the data further to an external service for processing over either a BT or GPRS or WLAN. Equally, an external device can monitor the environment where the user is located (Smart Environment in fig. 1.) and send input to the wearable system.

4. THE RESEARCH

The TUT Kankaanpää Unit is strongly focused on the wearables-infrastructure and has experience in manufacturing machine washable electronics by casting flexible circuit boards (FCB) in soft polymer. Several rounds of casting experiments have been made with help from the polyurethane specialists at Pucast Oy of Vammala, Finland and the results have been very promising; the cast electronics have proven to be unobtrusive and non-restricting.

4.1 Polymer Casting Electronics

Two kinds of molds were built for casting: closed molds with a pouring channel and an air groove, and open molds with layered construction. The open casting process is smoother from a manufacturing point of view, and depending on the accuracy of the mold there's little if any need for finishing a hardened, ready cast (Fig. 2.). Also 3D-shapes can be made. Closed casting also requires an amount of pressure to fill the cavity evenly and any flexible items inside the mold such as the FCB or fabric may twist or bend and place unevenly in the cast.

Fig. 2. Open-cast machine-washable, flexible, polymer-cast circuit board. Note the microphone in the cavity.

4.2 Testing the Prototypes

We built and cast three FCBs meant for testing ability to withstand machine washing. The wash test-boards were tested one at a time in a regular household washing machine at 40˚C/104˚F with color detergent. The program was set to spin-dry at a normal 900rpm. When the two first washes produced the same result, the third FCB was spared for later.

The wire contact of both FCBs had apparently taken some knocks in the wash and a connection was achieved only when bending the board at the contact (Fig. 3.).

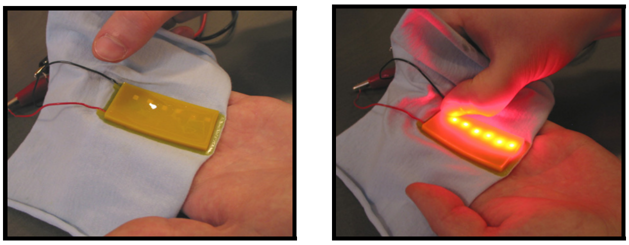

Fig. 3. The wash-test FBC was damaged at the contact.

The etched copper-tracing on the FCB was broken; the traces of the hand-made FCB were probably too thin to handle the strain put on by the mass of the soldered wire contact. The wires of the test boards were ordinary electric copper wire and the result would probably have been better with a lighter and thinner conductive textile wire. The tests proved the problem is mechanical, as the boards functioned right when bent at the corner. This can, on the other hand, be interpreted as a successful, water-proof cast.

The TUT is building a device for testing and monitoring flexibly encased electronics. As seen in the previous tests the ability to withstand mechanical strain is the main concern with FCBs. With the new system the connections within and between rigid and flexible materials can be tested. Also the layout design of FCBs will be evaluated as the placement of flexing points between more rigid areas can crucially affect the long-term reliability of flexibly encased electronics.

4.3 The Noise Shirt Concept

The TUT KP1 Wearable Electronics Maintenance Project set out to produce a functional prototype of a garment integrated electronic device implementing the research on flexible encasing and wireless recharging. We decided not to make the prototype an outerwear garment, as most current intelligent garment concepts tend to be outerwear due to their forgiving ability to carry bulky devices. Instead, we built a concept of a shirt, which would be easier to demo and which would clearly show how well we succeeded in making a wearable electronics shirt with permanently integrated devices.

We first and foremost wanted to test polymer-cast electronics, and LEDs were decided to be the best way of seeing if the device still works after different phases of testing. We also decided to make the actual function as simple as possible to be able to concentrate on the essential.

A concept of a Noise Shirt was accepted for a makeshift function. A microphone measures the surrounding environments noise level and shows it as a vertical 5 step ‘equalizer’ bar with the LEDs. Each LED marks a rise above a certain decibel level. The three lower LEDs are green and go from 65dB to 84dB. The top two LEDs are red and mark a noise level exceeding 85dB and 100dB (Fig. 4).

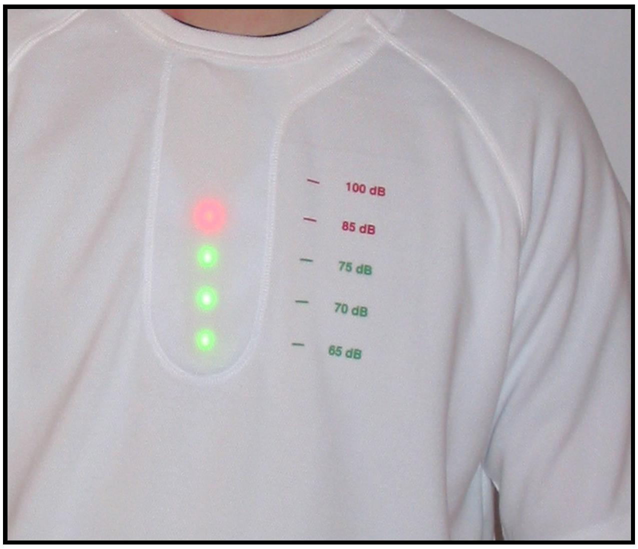

Figure 4. The Noise Shirt LED-panel.

Continuous exposure exceeding 85dB is the limit set by the EU authorities for recommended use of hearing protection. The device has a small battery with a wireless recharging induction loop in the neck tab. The garment is functional whenever charged and won't require any user input.

4.4 Wireless Recharging

Even after a wearable concept has been stripped of an integrated user interface it will still need power to operate the sensor logic and wireless data traffic. Our Noise Shirt concept of course needs a power source too. Water-proof connectors seemingly suitable for a smart garment concept are large and expensive. For usability reasons we also wanted to avoid a need to plug in the shirt after use or care. We knew that our concept wouldn't consume much power so wireless power transfer would be an alternative. After a little research inductive power transfer [7] seemed the best option for our purpose.

The most sensible and simple interface for wirelessly recharging a shirt with wearable electronics is a clothes hanger. As the two inductive coils need to be aligned as centrally as possible, a clothes hanger would automatically position them over one another. The hanger would ideally incorporate all the electronics and it would be connected to a mains socket. The hanger hook seems the most logical place to interface. No functional conductive hook has been made yet; so far the wiring runs to the shoulder tip of the hanger.

The system was first constructed in a regular hanger, which could house the electronics and was sturdy enough to carry a flap with a flat, spiral coil (Fig. 5.). After testing and some modifications a custom hanger mock-up was built from fashionable, transparent acrylic. The new hanger was shaped to make the shirt's neck tab drape over the hanger neck, to make the two coils meet. More custom hangers will be built in the future.

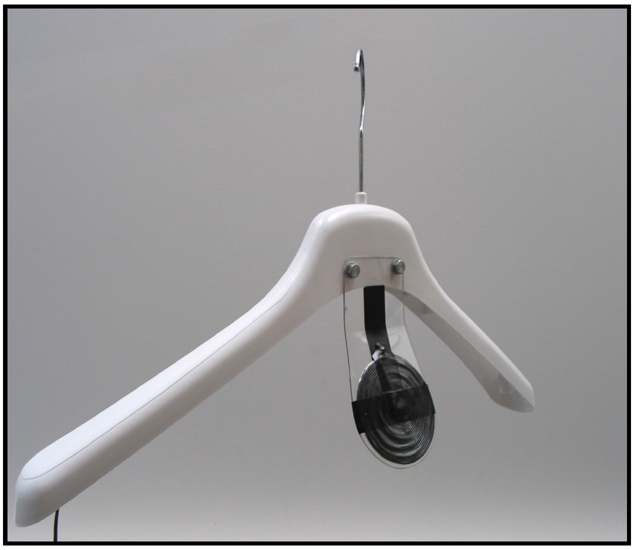

Figure 5. The first version of the recharging hanger.

Initial tests proved the hanger concept to be quite suitable for recharging the shirt. The spiral coils need to be researched further, though. The first prototypes were coiled by hand from copper wire, but the best alternative proved to be to etch an FCB with a spiral coil; thus the recharging electronics as well as the battery could all be fitted to one board (Fig. 6).

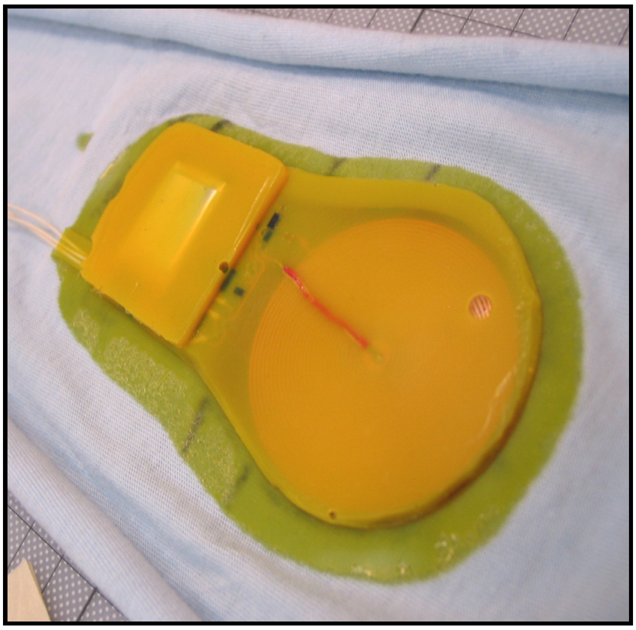

Figure 6. The neck-tab with recharging coil and electronics. A slightly messy cast.

The current system takes about 3 hours to recharge the empty Lithium-polymer battery and depending on the amount of ambient noise the Noise Shirt will run from 2 to 4 hours.

4.5 User Interface

The results in the field of infrastructure and maintenance solutions for wearable technology have shown that problems described in chapter 2 can be overcome with flexibly encased electronics and wirelessly rechargeable batteries. The next step in the research of the wearables-infrastructure is using wireless communications and a mobile user interface in order to access services and applications produced outside the garment.

The use of a mobile phone as an input and output device can solve interfacing problems associated with wearable technology and flexibly encased electronics. The input data to the garment is usually low bit rate information used just to control major functions (e.g. power control, operation mode). Text-form input is rarely used with sensory garments but as applications get more complex and new services are provided, the amount of input data needed to control the garment increases.

Most of the garment's output data is usually measurement data and in some applications text-form information on the garment's status. This output data can be either processed in the mobile phone to get the required results or passed on to a third party service provider for further analysis.

5. CONTINUING RESEARCH

The polymer-casting research goes on with the TUT Smart Polymer Project, and in the near future we'll get to cast in rubbers and different plastics. Another promising outlook is to get rid of the circuit board and print the traces on a fabric with conductive ink before casting. This would also require researching textiles as component base. The project could also venture into finding more ways of using cast polymers in wearable electronics, such as interference shielding or conductive polymer sensor patches for body monitoring. The recharging research goes on with customizing the spiral coils for each concept to make them as small as possible and building better custom hangers. Downsizing the recharging electronics continues alongside.

The TUT is also starting a new project on implementing wearable elements for well-being and fitness. For this project the use of a mobile phone as user interface is an important feature.

6. THE CONCLUSION

Everybody's still waiting for a wearables market to form and the killer-application to hit the shops, but with more effort and attention paid to the infrastructure around wearable applications both the consumers' and the manufacturers' confusion could be eased. So far the few commercial wearable products have been little more than marketing efforts, but when reliable and cost-efficient production technologies are developed, a commercial mass-producible application of wearable technology suddenly does not seem so far away. At least the problems in interfacing and maintenance may soon be solved, quite possibly by means of a mobile device interface and machine washable, fully garment-integrated electronics.

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