Report on e-Skin Interface Prototype Development

(Private Version, A. Schiffler, 13 March 2005)

Aim

During the time preceding the KTI feasibility study, a portable e-Skin interface prototype was developed by the project partners. This early prototype allowed us to study how the skin based modalities of touch, vibration, temperature and proprioception could be sensed by an interface and how these modalities could be used to control multimedia environments. In order to explore how this interface could be augmented into a navigation and information aid for visually impaired and normal people, a further prototype development phase was undertaken during the last months of this feasibility study. This prototype development phase aimed at building both functional and design models of a wearable and ergonomic interface which helps in navigating complex environments and obtaining information on objects present therein. The two most important requirements which had to be met by this interface prototype were:

- provide feedback through modalities which are particularly useful for visually impaired people

- integrate and rely on technical infrastructure which will eventually become predominant in public and private spaces

Rationale

The aim of this feasibility study was to contact and eventually gain support from commercial partners in order to initiate the main project phase: to develop a wearable interface that helps visually impaired and normal people to navigate in complex environments and to gain access to information. While many commercial partners expressed their principle interest in the interface concept, their willingness the commit themselves was significantly hampered by the fact that our interface ideas weren't sufficiently backed by demonstrator prototypes. For this reason, we concluded that a further interface prototype development phase was an essential prerequisite to gain industry funding.

Implementation

In collaboration with the Wearable Computing Lab of the ETH Zürich, the Artificial Intelligence Lab of the University of Zürich and the Institute for Cultural Studies of the Hochschule für Gestaltung und Kunst Zürich, the Global Information Systems Group of the ETH Zürich developed a wearable interface prototype, which was subsequently tested at the Usability Test Lab at the Institute of Psychology of the University of Basel.

The functional prototype consists of readily available electronic components and custom circuits which have been integrated into fabric. The main component of the functional prototype is a belt which integrates a low frequency micro RFID reader, a corresponding reader disc antenna, a linux PDA as computational unit, a battery back, a power converter board, and an audio amplifier board (see Figure 1 and 2). The audio amplifier board of the belt in connected to a miniature speaker which is embedded into a shoulder pad (see Figure 3).

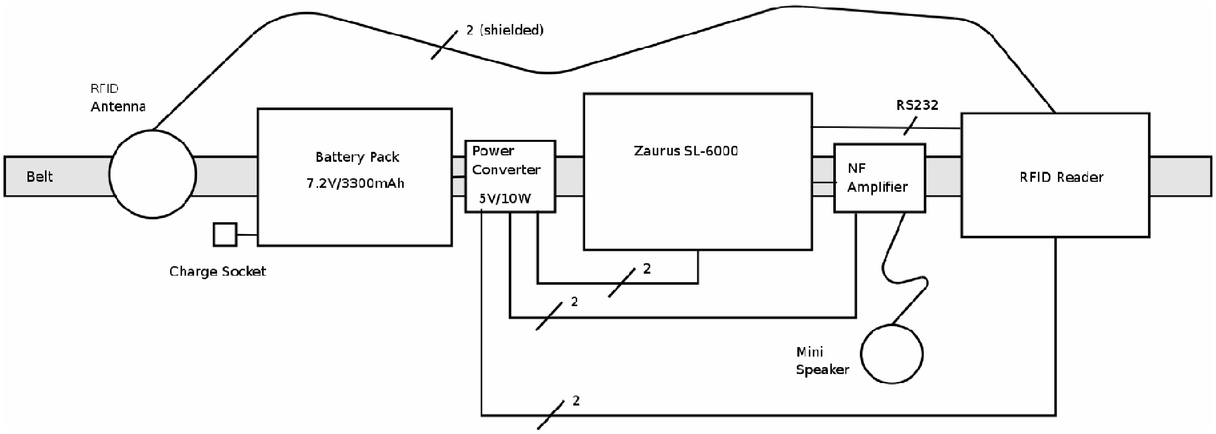


Figure 1: RFID Belt Prototype Schematics

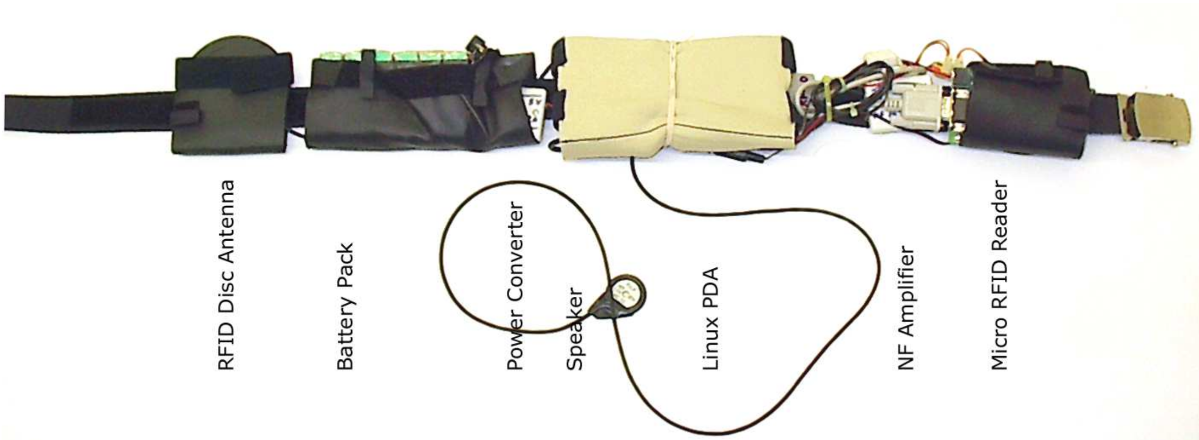


Figure 2: RFID Belt Prototype

Figure 3: Audio Feedback Shoulder Pad

A mobile Wavelan network and a Linux based PC Laptop form a wireless TCP/IP network into which the belt based PDA integrates.

Programmable transponder cards are tagged to objects and obstacles within an an interior space and build the basis for tracking the position of the interface and identification of objects. As soon as a transponder card is within the reader's antenna range is transmits its identification code. Via a database, this code is mapped into both positional information and textual descriptions about the tagged object. This information is played back to the user via text to speech conversion software and as prerecorded mp3 audio files.

The design prototypes serve to illustrate ergonomic and aesthetic aspects of the wearable interface. In addition, these prototypes integrate some of the high-tech textile and electronic components which will eventually become part of the interface. The design prototypes encompass the following three interface parts:

- a belt which integrates a QBIC computer and it's power source (see Figure 4). This belt will eventually be extended with a horizontal array of vibration motors which indicate direction and orientation.

- two arm bands, one contains embroided circuitry and a second one possesses an outer layer of pressure sensitive fabric. Both armbands contain pockets which can house sensory components such as acceleration and/or magnetic field sensors. Furthermore, one of the arm bands extends to the thumb and will integrate a bone speaker system.

- a shoulder pad which will house an ultrasonic ranger for obstacle detection on head level, an electronic compass to determine the wearers orientation.

Figure 4: Left: QBIC Belt Computer, Right: Shoulder Pad

Figure 5: Left: Arm Band with Embroided Circuitry Right: Arm Band with Pressure Sensitive Fabric and Extension for Bone Phone.

Usability Tests

For both the functional and design prototypes usability tests were conducted. The functional prototype was tested in the Usability Test Lab at the Institute of Psychology of the University of Basel. A pseudo shopping environment was setup in the test lab. This environment consisted of tagged shelves containing tagged products and a shopping trolley. Test persons were asked to navigate in this space while keeping their eyes closed. Concrete tasks consisted of finding particular products and putting them into the trolley.

The design prototypes were tested both in the Usability Lab and at a real COOP supermarket in Basel. The Usability Lab was transformed into a small dance stage. In this setup, dancers tested the interface with regard to wearing comfort, interference with movement, and robustness against slipping. The tests at the COOP supermarket dealt with wearing comfort as well as noticeability and acceptance.

Further Developments

The functional prototype has been devised in such a way that it can easily integrate further functionality. We have devised schematics and acquired further material which will allow us to augment the current prototype (see Figure 6). Plans for augmentation include:

- Attachement of vibration motors to the inside of the belt in order to provide orientation and navigation information through tactile vibration feedback
- Replacement of the miniature speaker with a bone speaker
- Integration of an electronic compass into the shoulder part in order the determine the users orientation
- Integration of an ultrasonic range sensor into the shoulder part which allows visually impaired people to detect obstacles on the head level
- Integration of acceleration sensors into the arm band in order to recognize gestural movements
- Integration of pressure sensors in the the arm band which transform the arm band into a tactile input device

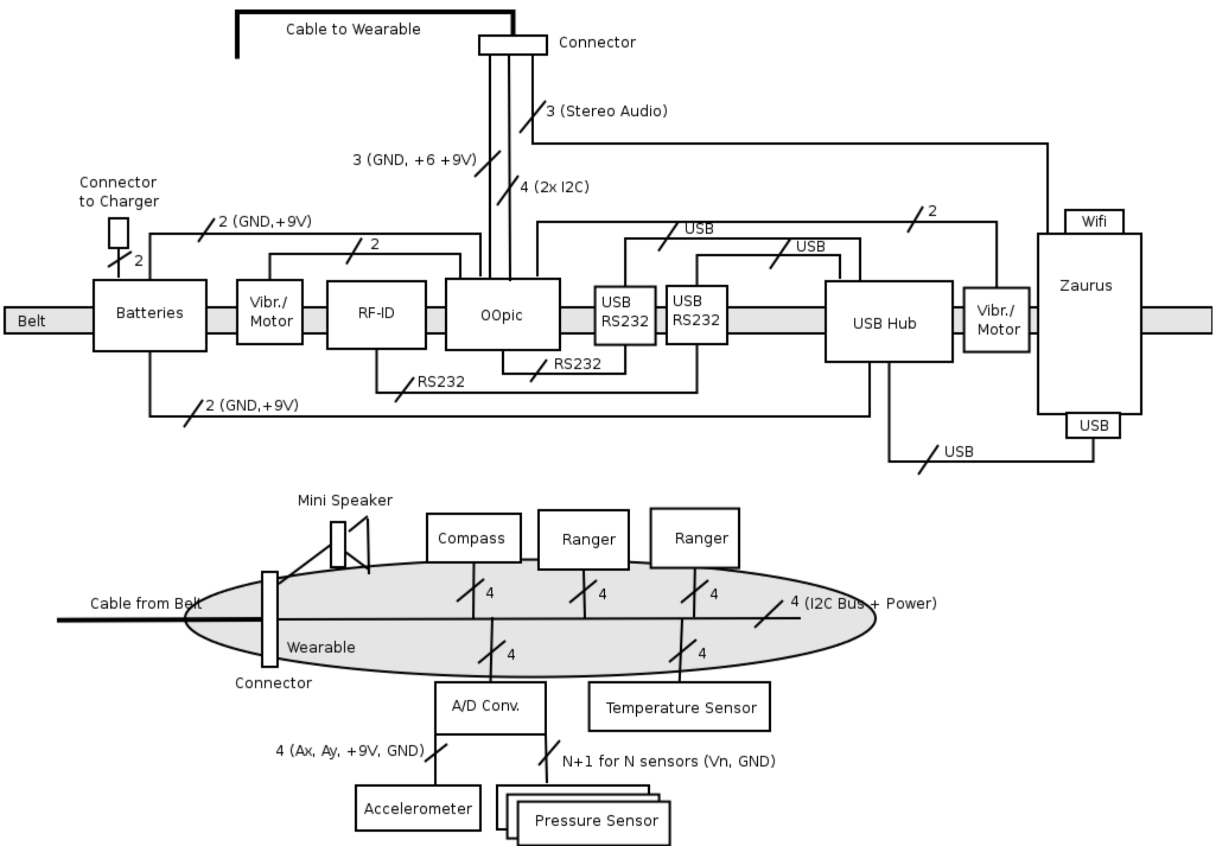


Figure 6: Schematics of an augmented wearable interface prototype

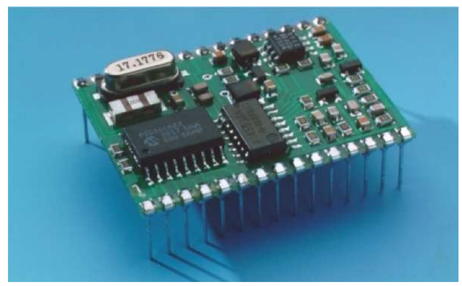
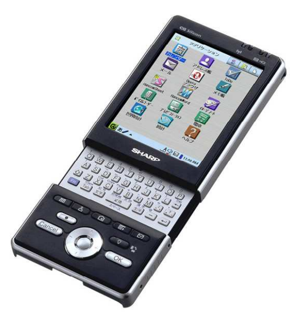
Appendix

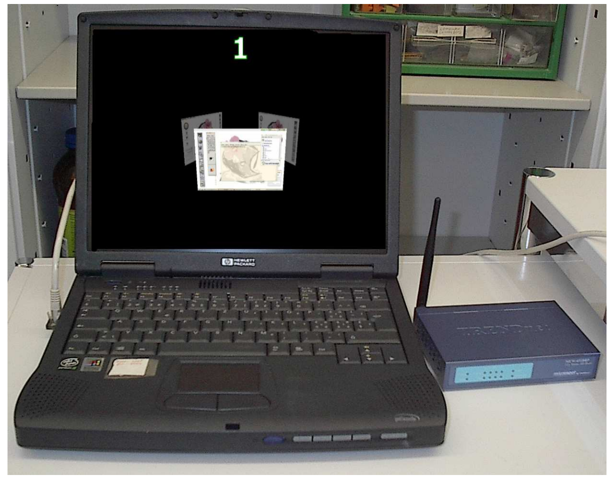
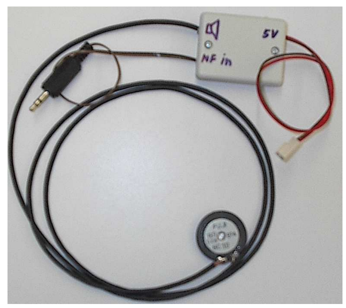
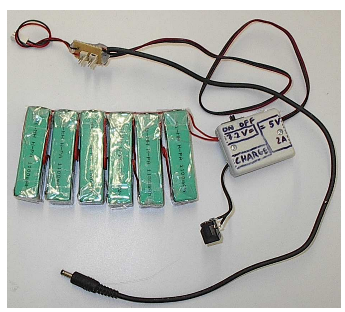
This Appendix provides a detailed overview of all the hard- and software components which have been developed or adapted for the e-Skin interface prototype.

Hardware Components

The functional prototype integrates an RFID based tracking and object identification system into a wearable interface. The interface produces acoustic feedback which helps the user to navigate or provides identification and background information on objects.

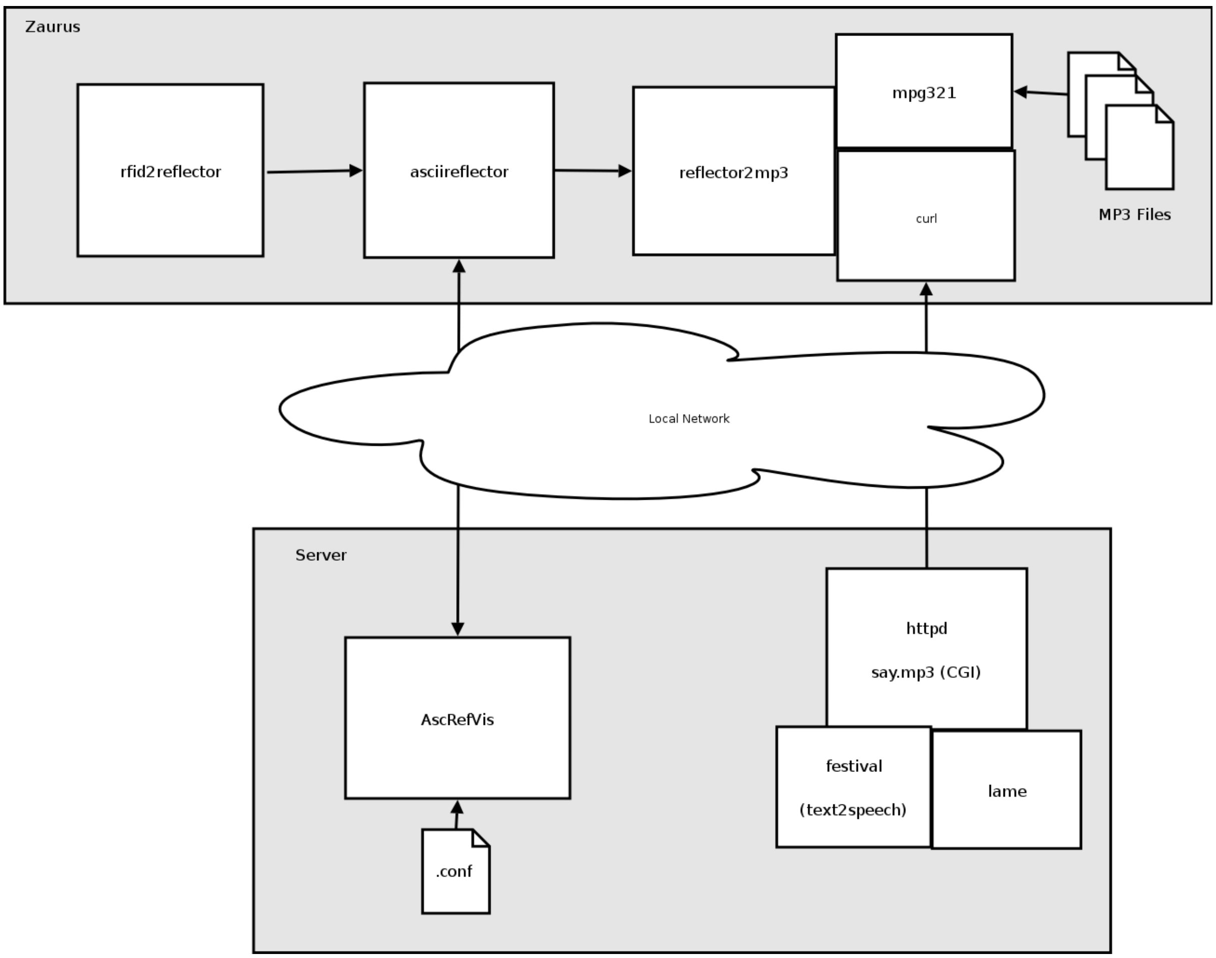
The following lists all the hardware components which have been adapted or custom designed and are part of the wearable interface.

Name and Description	Image
Texas Instruments Micro RFID Reader	
RW RFID card transponders and several other tags	
Sharp Zaurus SL6000 running OpenZaurus	

Name and Description	Image
Hewlett Packard Omnibook XE2 running Mandrake Linux and Microspot Wifi Broadband Router	
NF Amplifier board and speaker	
Battery Pack consisting of 18 AKKU NIMH H-PA 1100 batteries and a power converter	

Software Components

A TCP/IP based ring buffer (AsciiReflector) serves as central information storage and retrieval system which coordinates the various software components. The RFID tag ids are acquired by driver software and fed into the ring buffer (RFID2Reflector). A further software components (AscRefVis) retrieves the tag ids from the ring buffer and maps these to textual information and sound files. The textual information is transformed into an mp3 audio file by text to speach conversion software (Festival, Lame). The audio filenames are fed back into the ring buffer. Finally, a software component (Reflector2MP3) retrieves the audio file names from the ring buffer and passes them to an mp3 player (mpg321).



The following table describes the software components which have been developed or adapted during the prototype development phase in more detail.

Software	Description
AsciiReflector	Language: C Author: Andreas Schiffler Platform: Sharp ZaurusSL6000 running OpenZaurus A TCP/IP based ring buffer for strings. Clients can "PUSH" new strings into the ring buffer or "PULL" strings from the ring buffer. The AsciiReflector acts as a central hub for exchanging information (sensor values, commands, etc) between different computers in a TCP/IP network
RFID2Reflector	Language: C Author: Andreas Schiffler Platform: Sharp ZaurusSL6000 running OpenZaurus A program which acquires transponder identifiers from a RFID reader and feeds them into the AsciiReflector
AscRefVis	Language: Java Author: Daniel Bisig Platform: HP PC Laptop running Mandrake Linux A program which retrieves information from the AsciiReflector and transforms this information into commands for playing or generating audio files which are fed back into the AsciiReflector. It stores a list of mappings from transponder ids to sound files or text together with timing information. It can handle an arbitray number of commands and filenames per tag id. In addition, it graphs a history of all acquired tag id's.

Software	Description
Reflector2MP3	Language: C Author: Andreas Schiffler and Daniel Bisig Platform: Sharp ZaurusSL6000 running OpenZaurus A program which retrieves information from the AsciiReflector and transforms it into commands for playing mp3 sound files. It can play files with are stored locally on the PDA or obtains files remotely from a Linux Laptop which acts as a web-server. In the latter case, a set of parameters (words in a sentence) is sent to a CGI-program running on the webserver, which ultimately transforms these parameters into sound via a text to sound conversion routine. Only one audio file is played at a time.