A Wearable Malossi Alphabet Interface for Deafblind People

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ABSTRACT

Deafblind people have a severe degree of combined visual and auditory impairment resulting in problems with communication, (access to) information and mobility. Moreover, in order to interact with other people, most of them need the constant presence of a caregiver who plays the role of an interpreter with an external world organized for hearing and sighted people. As a result, they usually live behind an invisible wall of silence, in a unique and inexplicable condition of isolation.

In this paper, we describe DB-HAND, an assistive hardware/software system that supports users to autonomously interact with the environment, to establish social relationships and to gain access to information sources without an assistant. DB-HAND consists of an input/output wearable peripheral (a glove equipped with sensors and actuators) that acts as a natural interface since it enables communication using a language that is easily learned by a deafblind: Malossi method. Interaction with DB-HAND is managed by a software environment, whose purpose is to translate text into sequences of tactile stimuli (and vice-versa), to execute commands and to deliver messages to other users. It also provides multi-modal feedback on several standard output devices to support interaction with the hearing and the sighted people.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces And Presentation**]: User interfaces - *Input devices and strategies*, H.5.2 [**Information Interfaces And Presentation**]: User interfaces - *Haptic I/O*, K.4.2 [**Computers And Society**]: Social Issues – *Assistive technologies for persons with disabilities*.

General Terms

Design, Human Factors.

Keywords

Ubiquitous Computing, multimodal feedback, deafblindness, tactile alphabet.

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1. INTRODUCTION

According to the Australian Deafblind Council (ADBC), "deafblindness is described as a unique and isolating sensory disability resulting from the combination of both a hearing and vision loss or impairment which significantly affects communication, socialization, mobility and daily living". The deafblind population is small (just over 20,000 in the UK and about 150,000 in the European Community [2]), widely dispersed and also very heterogeneous because it consists of individuals of different ages, whose sensory conditions vary as well as the causes of their disability and the period of life when the phenomenon occurred. Thus, no statistical data about the actual population is available. Although the majority of deafblind people has some residual vision or hearing, their sensory impairment often comes in association with other handicaps such as physical problems, mental retardation or developmental and behavioral disorders.

Managing to acquire a complete independence in communication is the most difficult task for the deafblind community, but it is also the most important: especially congenitally deafblind people have to rely on the presence of a caregiver who advocates for them. They can use various non-verbal methods to relate to others and to overcome the problems of isolation such as behavioral, pictographic and object communication. However, the most effective way for a deafblind person to relate to the others is by using the hands to recognize gestures (e.g. sign language and dactylology, block letters) or facial expressions resulting by the speech act (e.g. Tadoma); tactile alphabets, such as Braille and Malossi, are also very effective [3]. Not surprisingly, each of the above individualized communication systems need an appropriate knowledge of the language. Nonetheless, the shortage of interpreters is a serious barrier to gain access to all levels of communication and interaction.

In conclusion, to break through the isolation of deafblindness, children and adults need communication systems to allow them to have autonomous access to information, to express themselves without the need of an assistant and to gain independence in social participation.

2. STATE OF THE ART

During the past few years deafblind people have benefited from advances in information technology: several new communication solutions have come on the market. Nonetheless, recent research projects also focused on ubiquitous assistive technologies. Most of these devices consist of a sign language sensor and a display.

Unfortunately, sign language and finger-spelling are visual by definition and vision loss can greatly affect the ability of the deafblind to access these forms of communication. The same can be said about speech-recognition systems and text-to-speech engines with respect to the auditory channel. Since little or no attention has been focused on this problem, it is typically not addressed in evaluations: deafblindness is still considered and treated as a single-sense handicap. As a result, many deafblind subjects are incapable of learning the above language systems. Other types of systems, such as the patent CA2179559, [4] rely on gloves equipped with tactile transducers that acquire characters written in sign language. Moreover, a robotic arm [5] aimed to convert text messages into a manual alphabet. Such devices seem to be more expensive than efficient; in fact, their projects are actually discontinued.

As a result, the most effective assistive technology actually available for deafblind people is still based on Braille alphabet: users learn very fast how to type it on dedicated PC keyboards and they read on ad-hoc displays. However, once they leave the site in which the Braille device is installed, they are lost and alone again, since is difficult to realize portable versions of these expensive peripherals.

3. MALOSSI ALPHABET

Deafblind people can communicate using Malossi method, in which the hand (usually the left one) becomes a typewriter for the receiver of the message: words are composed letter by letter by the sender by touching and pinching in sequence different parts of the interlocutor's palm which correspond to the characters. It is very impressive to see the speed with which two deafblind people can communicate using Malossi alphabet. This method is often used by those who had learned to read and write before becoming deafblind, it is also taught to children and it is, in general, an excellent way to relate with people who see and hear normally [1]. Figure 1 shows the distribution of the symbols in Malossi alphabet: the first 15 symbols (from "A" to "O") have to be pressed. The letters are disposed on the phalanxes and on the upper metacarpus (right under the knuckles) from the first to the fifth finger, as a 5x3 matrix. The other letters (15, from "P" to "Z", excluding "W") have to be pinched. The characters are located on two phalanxes (the middle one is left empty), from the first to the fifth finger, as a 5x2 matrix; the remaining character (the letter "W", which is also pinched) is located between the second and the third finger, in the middle of the letters "L" and "M". Thus, 26 symbols can be written. Numbers are expressed as in the Braille alphabet (using the first 10 characters, preceded by the letter "N").

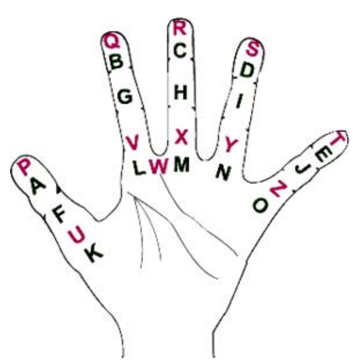

Figure 1. Location of the characters in Malossi alphabet

4. DB-HAND

The main idea at the basis of the interaction design of the system is that it is easier to write a dot on a tiny block-notes held in a hand and to show it to all of our friends than to draw a shape on a big album on a desk and to ask to the members of our family to come and see it. The metaphor fits the problem if we consider that sign languages consist of shapes while Braille displays and keyboards have approximately the size of a big photo book. We have had the opportunity to observe Malossi communication between deafblind people: once they had known the palm of their interlocutor, they could type as fast as standard users do on a keyboard; surprisingly, they could also write on their caregiver's hand and read his answers while walking.

DB-HAND combines both the advantages of Malossi technique as an alphabet-based language and as a ubiquitous tactile communication system and implements them into a natural interface. It is a wearable-hardware/portable-software system that includes a glove equipped with transducers that convert signals from tactile impulses to text messages and vice-versa. Messages are sent and received by the user in Malossi alphabet exactly as it is taught to deafblind people, without any other variation. However, although the output modality remains the same (words are delivered as sequences of tactile impulses to the palm of the left hand of the user) we introduced a modification to the original communication method in order to realize the input interface as a wearable device: when he wants to interact, instead of taking the receiver's hand, the user simply types messages on the same glove he wears on his left hand (he writes on his own hand as it was that of his interlocutor).

Communication in Malossi is turn based: it is bidirectional but it occurs in half-duplex mode; thus, input signals and output stimuli never interfere, because they are never concurrent. Once they are sent by the user, tactile impulses are converted to digital format and they are then interpreted by DB-HAND software application, which distinguishes them as commands or simple text, depending on the content of the message. In the first case, the user's input is recognized as a control signal for an application (e.g. "close the window" or "open a file"); otherwise, it is entered as text in the program having the focus. Feedback is provided by converting the response of an application in Malossi alphabet: messages are delivered to the user's hand as sequences of vibrations in the areas where the letters are located. So, deafblind people are enabled to autonomously operate a personal computer, read and write text documents, surf on Internet pages, chat, send e-mails, participate to forums and, extensively gain access to information and establish social relationships.
We approached to the interaction design of DB-HAND with the intention to realize an interpreter between the deafblind and the hearing and sighted people. So, we implemented multimodal input and output capabilities: hence, deafblind users read and write using tactile impulses while interlocutors view messages using a visual display (or hear them through audio speakers) and reply by typing on a standard keyboard. As a result, deafblind people are enabled to interact with the external world as well as their friends and their family are not required to learn any dedicated language if they want to talk to their beloved (and they do not need the presence of an interpreter). In addition, we hypothesized that DB-HAND might also be a support to learn other communication systems: we applied a Braille label on each to assist the transition between these communication methods.

4.1 Hardware design

DB-HAND interactive glove incorporates couples of transducers (pressure sensors and tactile actuators), which are located on the 16 points defined by Malossi alphabet. Phalanxes that can be pinched as well as pressed contain two symbols and, consequently, two couples of transducers. Once worn, the DB-HAND glove does not prevent the grasping of light objects and tools (e.g. a stick), also without impairing the tactile feeling of their use; furthermore, the user has a free hand (usually the right one) that can perform specific tasks that require a better grip (e.g. holding a Hearing Dog) or a more accurate sense of feedback (i.e. distinguishing different coins).

The peripheral was designed to be modular: it consists of three independent functional units (Physical, Control and Connection layers); in addition, input and output can be joined or split into two separate devices. It is also extensible: additional electronic boards can be plugged directly on the control layer to provide new functionalities to the device (e.g. an LCD display). Also, it is detachable: it can be converted to a stand-alone device (so, it is enabled to work without a PC) by adding a board equipped with an additional control unit, a text-to-speech module and a battery. By doing so, the DB-HAND glove is enabled to convert written messages to speech; this may be useful to interact in contexts where communication is one-directional only (e.g. a centre for deafblind people where an assistant can be invoked in case of need).

The device operates at low-voltage (5 V) and can be powered by its host PC or with a (rechargeable) battery. The actuators ensure low power consumption and high battery duration thanks to their limited current absorption (75-90mA).

Figure 2. An early prototype of DB-HAND

4.1.1 Physical Layer

This layer contains the circuitry and the electronic components (respectively sensors and actuators) that are required to acquire the input (press and pinch actions on the surface of the palm of the hand) and provide the output (vibrations in different areas of the inner part where the fabric is in contact with the skin). We employed low-profile (0,5 x 0,5 x 0,3 cm) tactile switches to acquire impulses. Miniaturized (1 x 1 x 0,3 cm) button-style (shaftless) pager motors were used as transducers for the conversion of electrical signals into tactile stimuli to provide vibrations. The Physical Layer also consists of all the cables that connect the input sensors and output actuators circuitries, which are assembled as two different subsystems, to the Control Layer.

Figure 3. A switch (on the left) and a motor (on the right)

4.1.2 Control Layer

This layer mainly consists of the control unit that manages the device operation. Its main purpose is to decode (respectively encode) input (respectively output) messages in Malossi alphabet: when the user types on the glove, the microcontroller receives sequences of electrical inputs from the sensors located in the physical layer, converts them and sends them as characters to the Connection Layer; when it receives data from the CL, it realizes a letter-to-letter conversion of messages from text to tactile stimuli and fires the actuators in sequence.

4.1.3 Connection Layer

This module consists of the electronic components that allow the device to transfer data and to interact with the computer. DB-HAND is designed to support several types of cable or wireless connection protocols, depending on the connection module: Serial (DB9) and USB options allow the device to be powered by the computer. Wireless solutions, such as Bluetooth and X-Bee (under development) require an additional battery. However, the other layers work regardless of what connection is established, so they are not affected by any change within this module. There is no CL in a detached setup of the DB-HAND hardware.

4.2 Software design

Interaction with the physical interface is managed by the software component, which purpose is to setup the device and to allow the user to control the Operating System and to gain access to applications such as Internet browsers, word processors, instant messaging tools and many other programs. In addition, it parsers the content of the messages which are sent with the device: they may contain a command for of the operating system (i.e. "open a file") or an input for an application (i.e. for a registration form or a chat) or a sentence that the user wants to communicate (i.e. "I need some water"). Nonetheless, since standard output is not tactile, WIMP interfaces of the Operating Systems and its programs have to be converted into simple text before they can be "visualized" with DB-HAND glove. So, the software architecture was designed to be also an extensible framework which contains the main elements to realize multimodal input and output. In fact, one of the most important elements we had to take into account is that even if DB-HAND allows deafblind people to be autonomous in the interaction, there is usually an assistant with them, especially if they have other disabilities. Therefore, we developed a set of tools dedicated to the interaction with co-located people, who may sit in front of the same computer where the DB-HAND device is connected. The software was coded using Java and C#.

4.2.1 Device Layer

The low-level subsystem of the software component allows the Control Application and other computer programs to directly interact with the glove using a higher-level instruction set. The driver exposes several commands. There are four main directives: writeString, readString, getParameter and setParameter, which are used respectively to fire an actuator, to wait for a sensor to be pressed (or pinched), to get the current status of a parameter or to configure the device by modifying a parameter value. The DB-HAND Device Driver was developed as a portable library and as a stand-alone application for many of the Operating Systems or desktop and mobile computers.

4.2.2 Control Application

The Control Application manages the DB-HAND hardware and software configuration and contains programs developed ad-hoc, such as utilities to support deafblind people in their most common tasks (e.g. an application that converts the messages they type to speech). Not surprisingly, this category of impaired users need a highly customizable interface (more than normal users do): tactile sensitivity varies from one subject to another and it may differ from the upper phalanx of the first finger to the middle phalanx of the fifth; so, the strength and the duration of vibrations have to be calibrated, as well as the speed of each message (or the interval between letters); All these setup operations are realized in the control application and various configurations can be saved for different users.

4.2.3 Communication Framework

The Communication Framework allows several applications to exchange input and output with DB-HAND glove. Once acquired from the device, the input is redirect to the program that has the focus using a Virtual Keyboard: whenever a tactile impulse is detected, the VK emulates the corresponding keystroke event and the character is written. To overcome the lack of support for tactile output in WIMP applications, the Communication Framework also contains a module that interprets Windows menus and controls into a tactile interface. The set of application that can interact with the Communication Framework can be extended with dedicated plug-ins.

5. CONCLUSIONS AND FUTURE WORK

The use of a set of discrete symbols instead of continuous gestures allows a less complex design because sensors and actuators do not require to be read or fired in clusters to acquire an impulse or to produce a stimulus (there is a one-to-one correspondence between characters and sensor-actuator couples). Thus, the device is cheaper. Compared to an average portable Braille display (output only), which price is about 1400$, DB-HAND has a manufacturing cost of 150$ and implements both input and output functionalities.

Tactile switches and coin-style vibrating actuators are really low profile and compact size transducers, which can be embedded within a thin (less than 1 cm) layer of wired fabric. As a result, the device does not have the bouffant aspect of a pugilism glove: it is flexible, easy to wear and also comfortable, it. An advantage with respect to text-to-speech systems is that DB-HAND is silent: stimuli are provided as small vibrations so, even if actuators emit a soft drowning noise when they utter, their sound form has a fast decay, thus it is perceivable only within a very short range (about 0,5 mt). Furthermore, the peripheral grants a high-level of privacy to the user: unlike visual or auditory systems, whenever a message is delivered to the device, it is received only by the one who is wearing the glove.

Although various mock-ups of the device were successfully tested with normal and deafblind people, an experimental study, which aim is to verify the effectiveness of the system in real-life situations, is actually in progress. Details and results of the experiment will be provided.

Regarding the software, we found that it can be improved by adding routines that enable the system configuration to be adaptive: parameters should auto-adjust according to the evolution of the user. In fact, a lot of effort during the evaluation of DB-HAND was spent in a constant calibration work because subjects adapted to the device so fast that most of the time was absorbed by tuning the device configuration.

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