ALTERNATIVE COMMUNICATION SYSTEM FOR PEOPLE WITH SEVERE MOTOR DISABILITIES USING MYOELECTRIC SIGNAL CONTROL

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***Abstract* — We have now sufficient evidence that the use of bioelectric signals in the field of Augmented and Alternative Communication (AAC) is feasible. Moreover they are particularly suitable for people with severe motor disabilities, for example, people with high levels of spinal cord injury or with locked-in syndrome. The development of solutions for this kind of people implies in the finding of ways to use sensors that fit the user needs as well as the constrains involved, translating the intentions of the user in commands. This paper presents a human-computer interface (HCI), based on the acquisition of electromyographic (EMG) signals to interact with an Assistive Communication System (ACS). The developed tool was tested successfully by patients severely disabled by amyotrophic lateral sclerosis (ALS) and other diseases.**

***Keywords*— Edith, EMG, AAC, Motor Disabilities, Assistive Technology.**

I. INTRODUCTION

A considerable research work has been dedicated in the last 20 years on the development of assistive technology (AT), notably in the field of augmentative and assistive communication (AAC) [1]. Devices in order to offer to people suffering from severe motor disabilities of various origins, e.g., amyotrophic lateral sclerosis (ALS), tetraplegy, muscular dystrophy, cerebral palsy, etc., associated with disorders of verbal communication, have been developed to become possible their communication with people who are near and have some control over their environment. These devices are operated by the AT with HCI sensors that receive informations given by the user with disabilities to operate a graphic interface [2].

When working in the field of AAC, considering that each user is unique in its limitations, one of the recurring problems is to discover which bioelectric signal can be provided by each one. Normally, three sources of control have been used: electromyography or simply EMG [3, 4], electrooculography or EOG [3] and electroencephalography or EEG [5]. The other thing is the selection of the sensor that is best suited to the motor capabilities of the user, regardless of the AT type used. As consequency, one of the first tasks to be performed is to identify which feature can be used and what is the best sensor, or the most suitable among the set of available devices on the market or developed in research labs.

One of the main difficulties in finding a good device is the selection process that is strongly influenced by the specific needs of the user, which in turn has a strong impact on the type of sensor to be used [6]. Thus, this process cannot be done without taking into account the complete analysis of the man-machine system that will be applied [7]. Therefore, it is necessary to study the performance of the human machine interface integrated to the alternative communication system in a way to obtaining the better performance of the set.

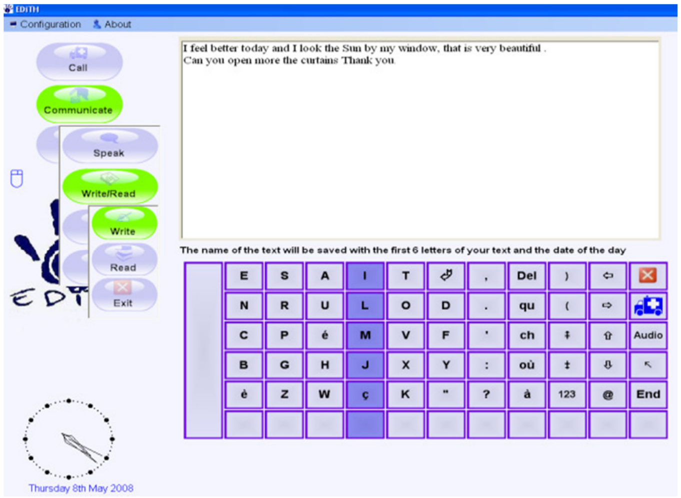
In this paper we show the development of an EMG-HCI to interact with an assistive communication software designed for people with severe motor disabilities. The first part covers the EDITH software [8], and the second shows the sensor designed to interact with it.

II. MATERIALS AND METHODS

EDITH: THE SYSTEM TO BE CONTROLED

The EDITH system (Digital Teleaction Environment for People with Disabilities) is a software package that integrates many features to assist the communication and control of a multimedia environment [8]. Its first version was developed in 1996 for a user with amyotrophic lateral sclerosis. The system is based on the sequential scan of rows and column, as referred in Fig. 1, and can be controlled by an on-off sensor which will be covered later in this paper. The software aims on giving users a control and communication device for interaction with the environment in which the user lives, integrating the latest advances in the field provided by AAC. The software is available for download at the research center site, and users can join and participate in the discussion forum [9].

The EDITH system was design for a multimedia PC for reasons of convenience to be used in hospitals. The system has two main components: a functional interface and a configuration interface. The functional interface that offers various facilities (eg, calling a nurse, reading of texts of communication by audio or written, etc..), the configuration interface allows the user to configure the system, for example, adjust the scanning time, add books, movies, music, subscribe e-mail, etc.. To test the functionality of our project based on EMG-HCI, we have used only the EDITH's virtual keyboard, shown in Fig. 1. To select a character on this virtual keyboard, the user should proceed as follows. First, he/she selects the column containing the wanted character as soon as the dark automatic scanning stays over it. After that, the scanning color changes to green and only the characters of the chosen column are scanned. In this way, the user will be able to select the wanted character as soon as the corresponding key becomes green. After summarizing the basic structure to be controlled, we present in next section the development of our EMG-HCI for interacting with the software.



I feel better today and I look the Sun by my window, that is very beautiful .
Can you open more the curtains Thank you.

The name of the text will be saved with the first 6 letters of your text and the date of the day

Figure 1. EDiTH's virtual keyboard (column-row scanning).

THE EMG BASED HCI

The HCI developed can be understood in two steps: the first one is the EMG signal acquisition as well as its processing procedure, and the second is the generation of the mouse click to interact with the EDITH software (see Fig. 2).

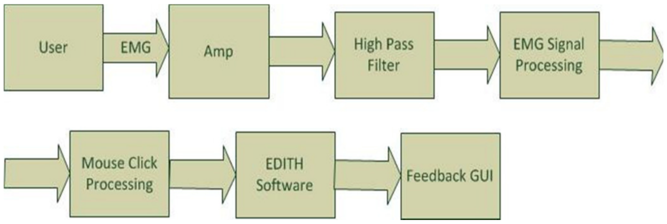


Figure 2. Block diagram of the EMG-HCI.

We decided to use the EMG, the first for its versatility and the second is the best strategy for the limitations of the first volunteers.

EMG SIGNAL ACQUISITION

Bioelectric signals such as the EMG are considered as an alternative mechanism to interact with AT [1]. In fact, an EMG device is relatively easy to interact with an HCI [10]. However, for a user with severe motor limitations, control of any AT device is not an easy task. For such task, a sensor was developed based on the bioelectric signal EMG to interact with the system (in a next project will be used other bioelectric signals, see conclusion).

Generally, the EMG signal amplitude varies from 0 to 10 mV (peak to peak) and the usable energy of the signal is limited to the frequency range of 0-500Hz [11]. Therefore it was used two self-adhesive Ag/ AgCl surface electrodes that were placed on the midline longitudinal of the capable muscle of the user [12]. The collected signal was amplified 2100 times with a differential instrumentation amplifier with a CMRR of 110dB and then filtered with a 10Hz high pass filter.

EMG SIGNAL PROCESSING

At this stage, the strategy was chosen to use the signal envelope for ease of hardware implementation.

Due to sensitivity of the equipment, in the EMG signal processing, the signal passes through a notch filter of 60Hz. It is necessary to minimize noise interference from the power supply system. With this, we can increase the sensitivity of the equipment, lowering considerably the intensity of fatigue for the user. Following, the signal is rectified by a full wave rectifier and them undergoes a second order Butterworth filter to extract the signal envelope.

Having the possession of the envelope signal, a comparator was used to trigger the click of the integrated circuit (IC) which was an TC9350BFN (see Fig. 3), which was chosen due to its USB interface and simple use for implementation, in addition, its USB interface can be used in any multimedia PC without the need for any specific program, making it much easier to use the equipment for people who have no training in using an AT.

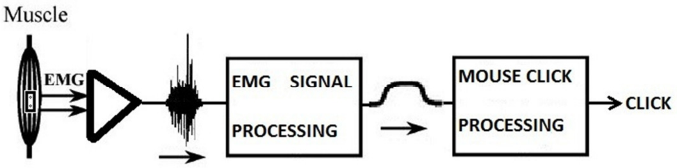


Figure 3. Signal Processing for the click.

To further facilitate the use of the sensor, the entire system was mounted on a headband so as to facilitate the adaptation of the sensor according to the limitation of the user (see Fig.4).

III. TESTING AND RESULTS

The system (EDITH + EMG-HCI) was tested with several different types of people with severe motor limitations. One example was a user with ALS with severe motor limitations including lack of speech, having only limited voluntary control for the eyes and some facial muscles, with EMG signal amplitude of 0-1.5 mV. In this situation, two EMG surface electrodes were placed on the masseter muscle and the reference electrode on the user forehead according to SENIAM's recommendations (see Fig.4).

Figure 4. User utilizing the EMG-HCI.

In his first use of the system, the user was instructed to select one of the three buttons on the main menu interface of EDITH, succeeding in nine out of ten times that the user was prompted to select an specific button.

In a second moment, without further training, the user has obtained an acceptable use of the system in which it could write a sentence of 15 characters correctly in less than 3 minutes.

Later, after two hours of assisted training, the user wrote a sentence with 42 characters in 5 minutes. Besides writing, the user could gain domain over other system resources such as watching videos, listening to music, use of specific care functions, activate functions of pre-established phrases (eg, calling the nurse's attention), etc.

IV. DISCUSSION

Results obtained in this work are indeed very encouraging. The combined method of automatic scanning with the click based on the EMG signal proved to be a very interesting way to efficiently conduct an assistive communication system.

Although with only one EMG channel and with all the acquisition and signal processing embedded, the performance of our system showed be robust, stable and reliable.

Even employing various techniques to minimize the noise to increase the sensivity of the device, the user reported fatigue after using the system for two hours. This may be linked to the pathology of the user who does not have enough strength to contract the masseter muscle for long time, besides the muscle being atrophied, and because the user is in this situation of severe motor limitation for six years.

This work is part of a series of efforts to provide EDITH with a more powerful HCI system, in the expectation to extend its use to a greater number of users with different disabilities and skill levels. Although useful for many users, the current version of EDITH was still controlled exclusively by electromechanical transducers. For this reason, our team works towards a hybrid system where the control strategy can be customized, considering the abilities of each user allied to comfort of use.

Another important advantage of a versatile assistive system is the possibility of periodic changes of control strategies even for the same user. This could contribute significantly to reducing the high level of rejection of AT systems by patients. According to the 1990 U.S Census Bureau's National Health Interview Survey, about a third of assistive devices used are abandoned in just three months after they were initially acquired [13]. As a future work, trying to contribute to this field, our research group will investigate other sources for control based on bioelectric signals like EOG and EEG, as well as their combinations with the EMG, with the aim of developing a multi-functional sensor platform.

V. CONCLUSION

Considering only the task of writing on a virtual keyboard, the technique of automatic sweeping combined with the EMG-click used here, presented a performance similar to that obtained with systems based on newly developed AT. Moreover, the method proposed here has a great potential to be exploited, not only in performance but also in relation to the complexity and cost of the final system.

Even with all the ease of using EMG sensor, it is necessary that the user trains the muscles, and this is not an easy task, becauseusually the muscles atrophied in this very case, and get with the ability to control the system a relatively short scan time (t <700ms, average value of estrous users without mobility limitations), requires patience and practice.

The complexity and costs involved in adopting additional channels of EMG or other bioelectric signals to support the cursor movement was functionally replaced here by automatic scanning technique. That greater level of complexity could become the system more difficult to operate by patients severely disabled and for this it was not within the scope of this particular study.

In the near future, with the goal of turn this EDITH tool available to more users, our staff will be working on the development of a multifunctional sensor (which uses signals with EMG, EOG and accelerometry) to meet the diverse needs of users.

VI. ACKNOWLEDGMENT

The authors would like to thank the University of Metz, France, the Federal University of Uberlandia, Brazil, and CAPES for funding this study (project CAPES/COFECUB Ma 627/09)

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