Universal Mono-Command Support System For Users With Severe Tetraplegia And Anarthria

Rita Pizzi*, Danilo Rossetti*
*Department of Computer Science, Università degli Studi di Milano, Italy

ABSTRACT

The paper describes two input devices and a software interface that allow severely impaired people to easily interact with a personal computer. The first input device does not require residual movement but makes use of skin electrical signals and applies Artificial Neural Networks to decode the mind-driven commands. The second input device is an evolution of a proximity sensor that can be activated using minimal residual movements, therefore it is suitable for the main part of motor disabilities. The software interface can be adapted to any kind of input device and makes it possible to access any standard software installed on a PC.

Keywords - disability support, mono-command interface, proximity sensor

I. INTRODUCTION

The applications of electronic and computer technology to disability constitutes an evident achievement. Any kind and grade of disability can nowadays take advantage of the use of both software and electronic tools [1,2,3,4,5,6]. An extremely high number of electronic and software supports for visual, auditory, motor and cognitive disabilities are available. People with severe disabilities have been able for the first time to exercise a form of autonomy on the environment and/or communication and social relationships.

Moreover the technology-supported computer access, and the development of telecommunications and of highly interactive graphics software, made it possible playing, remote working, internet browsing, social interacting and so on, literally opening the world to disabled people previously forced to total isolation.

Nonetheless , the use of personal computer , tablets, smart phones or dedicated mobile devices, although coupled with advanced input devices, is for the most part inhibited to children and adults affected by severe tetraplegia and anarthria.

Advanced BCI (Brain-Computer Interface) systems devoted to such severely impaired patients are going to be introduced during the last few years [7,8,9,10,11] but are nonetheless cumbersome, expensive, often poorly usable [12,13]. Thus we concentrated to the objective to develop a hardware/software device that could make accessible the IT world to these patients in an unexpensive and immediate way.

As the severe disease of these patients does not allow to coordinate the residual, often minimal movement they can produce, we were constrained to design an input device that could exploit the first minimal movement expressed by the patients without any directionality bond, and a software that could manage the computer interface by means of this only signal.

Thus the problem was twofold: on one hand the development of an effective and sensitive input device, on the other a general software and environment that could manage this mono-command driven, non-directional input.

The paper addresses an effective solution based on an affordable input device coupled with a novel mono-command interface.

II. THE INPUT DEVICES

Some years ago we developed for the Unity of Developmental Neurology of the National Neurology Institute C. Besta, Milan, a special input device with the purpose to allow children affected by severe tetraplegia and anarthria to interact with the environment by means of a computer. The child wears a special sensor applied to a finger and concentrates on a movement thought. The sensor picks up an EMG signal, the electrical signal received by the sensor is processed by the above described ANN, that identifies the moment when the child generated the movement thought, producing a code that activates another special software, that manages the computer mouse pointer (Focus magazine 73, 11.15.1998, RAI 3 MediaMente, national broadcasting channel, first broadcast: 4.20.1999, last broadcast: 9.10.2004).

The importance of the software that decodes the neural signals must be stressed. Such software is constituted by a novel self-organized Artificial Neural Network (ANN) that adapts itself to the signal variability and classifies the signals by means of a binary code [14,15]. Starting from the assumption that the spikes train analysis could not be sufficient to fully extract the semantics of the neural signals, the ANN allows a multi-channel non-linear analysis not only of the signal frequencies but also of the signals amplitudes and their succession inside the time series, capturing the whole information content. This Artificial Intelligence method allowed a fine differentiation of the neural responses depending on the pattern stimulations.

The same ANN algorithm was applied to decode the neural signal of the first human-electronic creature, developed by our group [16].

The system was experimented on a small group of children affected by severe tetraplegia and anarthria, who learnt quickly and with enthusiasm to use the computer for playing and for other purposes. Nonetheless the use of the device was psychologically fatiguing and could not be sustained by children for a long time.

Although we believe that BCI devices will be the future of the assistive technology, even in the form of directly implanted chips, at the moment this technology is still expensive, dangerous and poorly effective. For this reason we developed another input device: an IR proximity sensor based on the reflection of a light ray transmitted in the infrared range.

A thin infrared beam, emitted by a LED diode, is modulated at a 10Khz frequency with a square wave signal with 20/80 duty cycle. Interposing an obstacle before the light beam, this is reflected and hits a phototransistor used as a receiver. The signal received by the phototransistor passes through a 50 Hz Notch filter. This filter eliminates the interferences generated by other lights existing in the room and working at 50 Hz frequency (in Europe).

Afterwards the signal is improved and cleaned by means of another fifth order bandpass filter whose middle is tuned on the working frequency of the modulator, i.e. 10 kHz.

After the filter, a rectifier converts the signal into a continuous voltage proportional to the signal received by the phototransistor. The continuous voltage is applied to a comparer with adjustable threshold and afterwards to a stage trigger that, after a control circuit, activates a small Reed relay.

The possibility to adjust the comparer threshold is useful to set the working distance of the sensor. This distance can range from few centimetres to a maximum of around 50 cm, and is normally calibrated for an optimal working distance of around 30 cm. Delay and supply circuits complete the device.

The working distance is determined also by the kind of surface of the obstacle that reflects the light beam. A light surface reflects more than a dark surface, therefore a larger commutation distance will be obtained. The Reed relay has been used to fully separate the sensor electronic circuit from the pc circuits.

In order to simplify the sensor circuit and the management software, we used a USB-parallel converter. In this way one single bit is enough to control the software program. For a safe usage all the sensor circuits are 12 V supplied.

An interesting feature of this device is its low cost in comparison with the current commercial special devices and its extreme comfort, as the user has nothing to wear.

III. THE SOFTWARE INTERFACE

The signal acquisition string coming from the USB-parallel converter is written in machine language.. The signal bit is analysed on a continuous cycle, and the acquired information is passed to a timer that is set in such a way as to distinguish when the sensor is used to cause a mouse click, a double click or a movement.

Once the kind of event is determined, the control passes to the subroutines that manage the single events. For this purpose the software uses the Windows API **mouse_event** to control the mouse.

The main program's output is a form with a blinking arrow shape, whose properties are shape, size and blinking speed. The Windows API determines, on the base of the mouse pointer position, which position should have the blinking arrow. This software statement allows the mouse to be always active on the screen and can be used to help the child/user in the most complex situations, or in general to use the PC together with a friend or an assistant.

The program, currently compiled with Delphi, is completely portable on other programming environments.

The software is conceived with the precise purpose to release the user from the need of dedicated software programs for impaired people, and to give a complete freedom to use any kind of software.

On the screen a colored arrow appears (Fig. 1) that rotates around the mouse pointer blinking at each of the four cardinal points. When the user decides a direction to move the mouse pointer to, she/he just waits for the arrow to place itself along the decided direction, then activates the sensor just approaching it in the easiest way (with a small movement of hand, knee, head etc.).

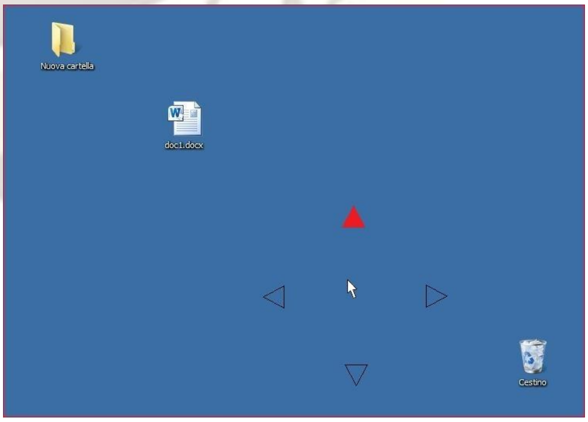

Fig. 1 - The rotating arrow around the mouse pointer

The sensor is mounted on a flexible arm anchored to a fixed support and can be approached to the user in the most suitable way.

Now the mouse pointer is dragged by the colored arrow to the chosen direction and stops when the user stops the sensor activation. Activation remains steady even though the user movement is minimal, uncoordinated or moves the sensor in any way. From the new position of the mouse pointer, the user can decide a further approach to the screen place that she/he aims to reach or, if the position has already been reached, she/he can activate the icon or the command with another sensor activation.

In this way the user can work on the PC in a completely standard mode, released by the need of a restricted number of dedicated software. To write on a word processor a screen keyboard can be used, and the user can write in this way on any word processor, Internet browser, e-mail client, Social Network and so on.

The children involved in the experimentation also used several games and learnt in time a better dexterity in the use of the system. It is well-known that children, who are extremely receptive and develop the ability to interact with electronics and computers much more quickly than adults, take the maximum advantages to the progresses of technology.

Reaching an interaction with the external world is an exciting experience for severely impaired children, and opens all the possibilities of interpersonal communication, learning, game and - in the future - work that IT technologies makes available.

IV. Conclusion and future Developments

The described input devices can be used also separated from the PC interface, as an easy switch to activate wheelchair, remote house-hold appliances, smart building controls, and in general devices devoted to several purposes, games and work. A mobile display with the same graphical interface of a smart phone or tablet can be placed on the wheelchair, in order to drive many different functionalities.

The current software interface can be further refined both by improving the interface visibility and endowing it with control windows to adjust the system parameters (sensor sensitivity, sliding speed, dial size, single/double click time, etc.).

It must be stressed that this software can also be used with any kind of input device, in such a way as to be adapted to different kinds of impairment. Touch sensors, blow sensors or voice interfaces can take advantage from the described universal mono-command software interface.

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