Implementation of Human-Machine Interface via Measurement and Treatment of Bio-Potential

Valentin Nikolov, Georgi Chipov

Emails: val_niko@yahoo.com   georgichipov@gmail.com

Abstract: A system for human-machine interface through a module for amplification of muscular bio-potentials (electromyography) and eye position registration (electrooculography) is presented. The ability of catching up objects is demonstrated, using an electro-mechanical gripper, managed by the bio-potentials of the forearm. Through software application the horizontal eye movements in real time are displayed on a monitor. Some applications of the module are discussed.

Keywords: Human-machine interface, bio-robotics, cyborg, bio-potentials, EMG, EOG, prosthesis.

Introduction

The rapid development of the computing equipment on one hand, and the more than ever demanding and seeking perfection (or capital) human spirit on the other, face us with a new type of dilemma. Should we reconcile with the results of the evolution or let our imagination take us beyond the boundaries of what we call admissible for thousands of years? Even today in our modern and open society the idea of interference in the human body provokes heavy controversy. Regardless of the price that many anxious minds assure us that we will pay in the indeterminate future, the first steps in trying to go beyond the limitations of our physical bodies are already a fact.

There is no need to fall into details in order to see that our life has already been obsessed by information technology. Computers are everywhere and they fill up even the most unsuspected corners of our live. Since we exist in such electronic environment, it is logical that more and more new methods that could stimulate and

make easier the access to the endless amount of information, will be created The idea of direct connection between the human body and a machine which overcomes the disadvantages of the popular indirect access (keyboard, mouse, display, etc.) is not new. The achievements in modern medicine provide us with lots of alternatives of how a person could become a cyborg, without having a particular medicine problem. Many actual examples could be given. One of the world-famous achievements are the experiments of Professor Kevin Warwick from Reading University, England. He calls himself the world's first cyborg (Fig. 1).
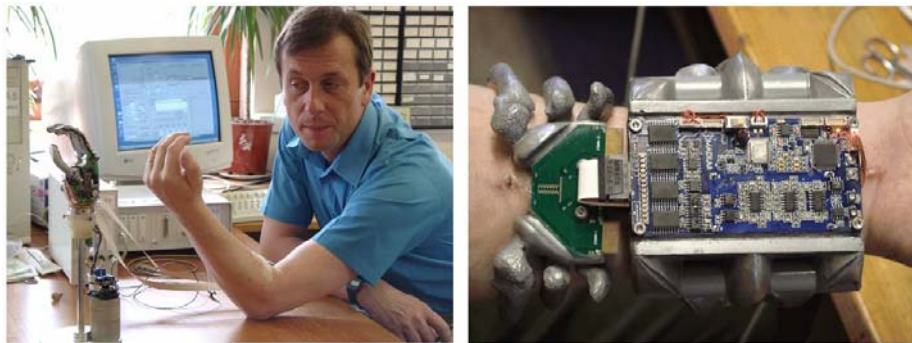

Fig. 1. Professor Kevin Warwick with an implanted module for registration the activity of the peripheral nervous system in the forearm

After a surgical intervention, electrodes have been placed in Warwick's hand. Thus the registration of the activity in the peripheral nervous system in the area of the forearm is significantly facilitated. This interface allows the experimenter to control electro-mechanical devices from a considerable distance [1].

The efficiency of such methods is indisputable but it raises the question of how this can be done easily and painlessly, without the need of invasive surgical methods? What are the options of realization of such interface without any pain and risk for one's health?

Systems for non-invasive registration and analysis of Bio-Potentials (BP) are not only well-known for a long time, but are also an integral part of modern medical equipment for prophylaxis, diagnostics, treatment and rehabilitation of many diseases (Fig. 2). Their relatively low price and good repeatability of the measured values makes them a valuable tool with many applications outside medicine. In most of the cases the registration of BP is performed through electrodes, attached to the skin's surface in the area of the body which is being examined. The amplitude and the nature of the signals are different and they depend on the observed organs. This requires also specific processing and treatment of the raw data, but common for all cases here is the need of amplifying the low potential before entering the data for analysis.

The object of this project is exactly the realization of a module for surface measuring of bio-potentials and its application in the building of an interface between a man and a machine (computer).
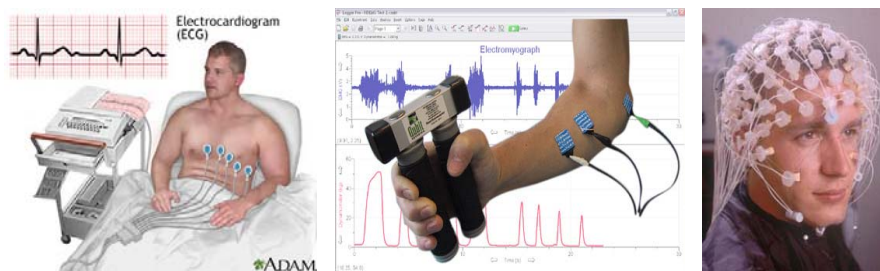
Fig. 2. Noninvasive registration and processing of bio-potentials

A module for registration of bio-potentials

The main purpose was the realization of a module that is able to register the muscle activity in the forearm − ElectroMyoGraphy (EMG) and to amplify the potentials which are generated by the movement of the eyeballs − ElectroOculoGraphy (EOG). The same module has been used for both experiments, as the differences are in the filter units only. For better illustration, both interfaces will be examined separately.

Emg interface

The idea here is to be analyzed the signals generated by the forearm's muscles as a result of the movement (open/close) of the palm. The goal here is: the collected data to be processed by a computer and to be used for the control of the electromechanical gripper. The complete module is presented in Fig. 3.
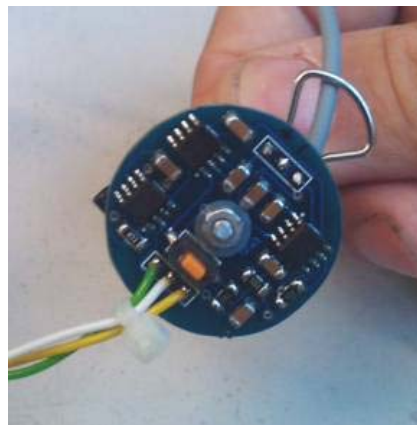

Fig. 3. EMG module

A classical solution (Fig. 4) with four main blocks has been chosen. The BP's amplification by the muscles is an essential stage of the registration. In literature [2] it is indicated that the amplitude of the generated voltage goes from 0.5 up to

10 mV depending on the density of the muscle group. The frequency range is 20-2000 Hz. A typical EMG signal is presented in Fig. 5. An instrumental amplifier AD620 with a gain of 105 has been selected. The second block of the scheme is a high-RC filter through which the signals with a frequency below 0.5 Hz are filtered. An active low pass filter has also been added. The 3-pole Butterworth filter has a band pass of 30 Hz. After filtration the signal is being re-amplified by inverted OPA2177 operational amplifier with a gain of 47. The power in the scheme is of 5 V and the necessary bipolar power for amplifiers (±2.5 V) is provided through the implementation of a virtual middle point (ground) with TLE2426.
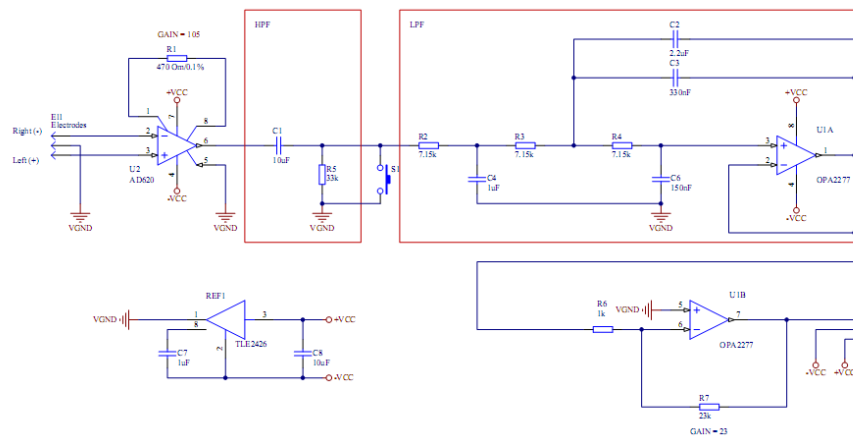

Fig. 4. EMG module

Fig. 5. EMG signal

After this pre-processing the signals are with amplitude that can also be measured by conventional instrumentation. The complete system is illustrated on Fig. 6. Three medical surface electrodes have been used (Fig. 6-1). One is sticked to the wrist area and the neutral (ground) of the EMG module is connected to it. The other two are fixed over a muscle of the forearm's area which is playing the major role in opening/closing of the palm (hand). The palm movement is registered by the realized EMG module (Fig. 6-2). In order a processing by a computer to be enabled, the analog data needs to be converted in a digital form. A multifunctional USB device of National Instruments − NI USB-6009 (Fig. 6-3), has been used. The periphery has 8 analog inputs (14-bit, 48 kS/s), 2 analog outputs (12-bit, 150 S/s), 12 digital inputs/outputs, 1×32-bit counter. The EMG signal is fed to one of the analog inputs. The visualization and the data processing are done through software (Fig. 6-4) written with LabView. The software application analyzes the amplitude of the incoming signals, as the criteria of an occurred event (opening/closing of the hand) are the threshold changes of the first derivative. When this happens, an

63

enabling signal (bit) by one of the digital outputs of NI USB-6009 is sent. This single bit information is used by the controller of the electro-mechanical gripper (Fig. 6-5) which is being opened or closed, depending on the condition of the palm. At this stage of development, the force applied by the gripper is not controlled. Gripper's drive is performed via an ordinary hobby-servo motor and the movements of the clips are performed in discrete steps.

Fig. 6. Control of the electromechanical gripper by registration of the signals
generated by movement of the palm

Fig. 7 presents a fragment of a software application for processing, analysis and gripper control. The top graph shows the amplified EMG signal during closing of the hand and on the bottom figure the results for the first derivative have been presented.
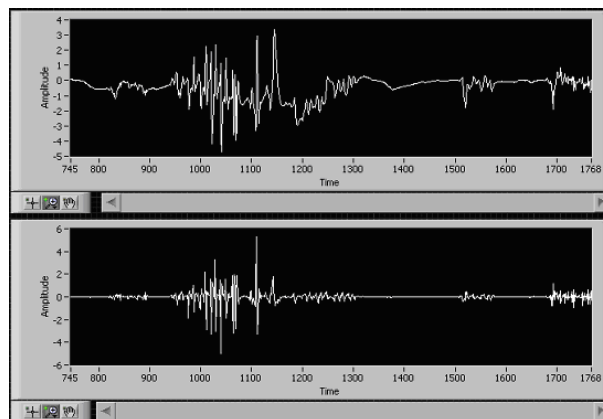

Fig. 7. Software for processing, analysis and gripper control: the amplified
EMG signal (above); the first derivative of the signal (below)

Eog interface

In this experiment (Fig. 8) the same circuit solution is used as above described, only the filters parameters are changed. A High Pass Filter is used solely to remove the DC component. The Butterworth filter is limited to 10 Hz. Again three medical electrodes are used here. The neutral electrode is attached between the two eyes and both active electrodes are sticked in the area of the temples. The task here is to register the horizontal movement of the eyes. To register the vertical movement also it is necessary to add a second EOG module and the active electrodes have to be sticked above and below the eye (Fig. 9).
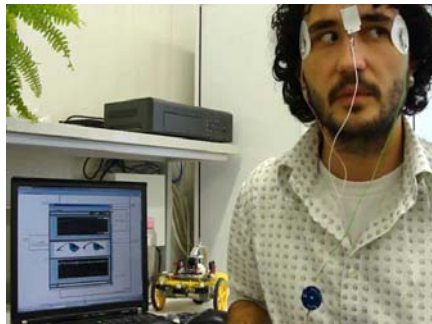

Fig. 8. Registration of the horizontal movement of the eyes
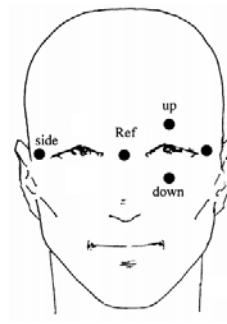

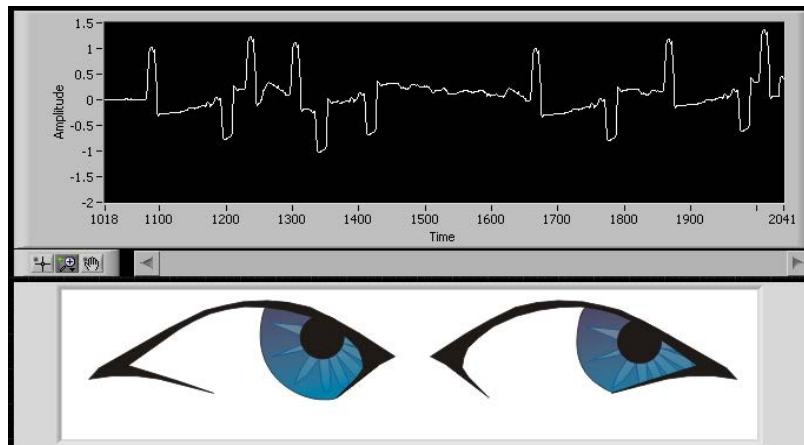Fig. 9. EOG – electrode attachment

Fig. 10. Fragment of software for processing and analysis of EOG: EOG signal characteristic (above); animation showing the actual position of the eyes (below)

Similarly, the amplified signal is fed to an analog input of NI USB-6009 for conversion and then the data are analyzed by LabView software. As can be seen in Fig. 10 (above) the typical EOG signals are almost rectangular. When moving the eyes to the end, the horizontal position pulse is registered and its polarity

determines the direction in which the gaze is diverted. When the eyes move to the opposite end position, a new impulse is generated, but in opposite polarity. The pulse duration depends on the time in which the eyes remain in their respective final positions. To make the interpretation of the results easier, the actual position of the eyes is presented by using an animation in real time (Fig.10 – below).

A video material presenting the described experiments can be seen in [11, 12].

Future work

It is intended to develop software environment for computer's mouse control and cursor movement, done by eye movements. Such a development could be useful for people with disabilities, allowing them access to a computer. The application can easily be extended to allow control of various electromechanical devices (wheelchairs).

At the date of submission of the paper a project was launched for realization of artificial, five-finger hand which will be controlled by registered EMG potentials.

R e f e r e n c e s

1. **http://www.kevinwarwick.com/**
2. T h a k o r, N. V. Bipotentials and Electrophysiology Measurement. Copyright 2000, CRC Press LLC.
   http://www.engnetbase.com
3. B a r r, R. C. Basic Electrophysiology. – The Biomedical Engineering Handbook. J. Bronzino, Ed. Boca Raton, FL: CRC Press, 1995, 101-118.
4. We b s t e r, J. G. Reducing Motion Artifacts and Interference in Biopotential Recording. – IEEE Trans.Biomed. Eng., Vol. **31**, 1984, 823-826.
5. E n d e r l e, J. D., S. M. B l a n c h a r d, J. B. B r o n z i n o. Introduction to Biomedical Engineering. San Diego, Academic Press, 2000.
6. C r o f t, R. J., R. J. B a r r y. Removal of Ocular Artifact from the EEG. – Neurophysiol Clin, Vol. **30**, 2000, 5-19.
7. W e b s t e r, J. G. Reducing Motion Artifacts and Interference in Biopotential Recording. – IEEE Trans. Biomed. Eng., 1984, p. 31, 823-826.
8. M a r m o r, M. F., E. Z r e n n e r. Standard for Clinical Electro-Oculography. – Doc. Ophthalmol, Vol. **85**, 1993, 115-124.
9. C o h e n, A. Biomedical Signals: Origin and Dynamic Characteristics; Frequency Domain Analysis. – Biomedical Engineering Handbook. J. Bronzino, Ed. Boca Raton, CRC Press, 1995.
10. Y a t h u n a n t h a n, S., L. U. R. C h a n d r a s e n a, A. U m a k a n t h a n, V. V a s u k i, S. R. M u n a s i n g h e. Controlling a Wheelchair by Use of EOG Signal. – In: 4th International Conference on. Information and Automation for Sustainability, 2008, ICIAFS 2008.
11. **http://www.youtube.com/watch?v=z5gdD0WnEaU**
12. **http://www.youtube.com/watch?v=pIYqfJkodRE**

Применение интерфейса „человек–машина" для измерения и обработки биопотенциалов

Валентин Николов, Георги Чипов

Emails: val_niko@yahoo.com   georgichipov@gmail.com

(Р е з ю м е)

Предложена система интерфейса „человек–машина" с модулем для усиления мускульных биопотенциалов (элекромиография), и для регистрации позиций глаз (элекроокулография). Демонстрируется способность захватывания обьектов, используя электро-механический захват, управляемый био-потенциалами руки. На мониторе показаны горизонтальные движения глаз в реальном времени при помощи софтуерным применением. Дискутируются некоторые возможные применения модуля.