Game Controller Based On Bio-Signals

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Abstract**—**Interfaces have recently become very complex, but this complexity does not always lead to increased functionality or usability. When it comes to handicapped users and the application of various bio-signals as a control tool, the currently available solutions are far from satisfactory. In this paper an innovative bio-signals-controlled interface based on a gaming headset – Emotiv EPOC was presented. The main goal of this research was to design, develop and test an intuitive and user-friendly interface based on implementation of various bio-signals. The project was primarily intended for handicapped users as a replacement for traditional interfaces such as e.g. keyboard or mouse, but its potential use was extended. The proposed system differs from the existing interfaces mainly because of, as mentioned above, its versatility to work with various bio-signals, thus enabling a single interface to be controlled by different devices. Initial investigation has proven the possibility of the Emotiv EPOC headset application – as an example of an inexpensive, easily available tool for Human-Computer Interaction (HCI) for gaming purpose.

Keywords**—**Information Interfaces; Human-Computer Interaction (HCI); User Interfaces; Electroencephalography (EEG); Brain-Computer Interfaces (BCI); Control; Gaming

I. INTRODUCTION

Recent progress in Human-Computer Interface Systems design is constantly growing and engaging increasing number of researchers. Development of this research area enables to stop dividing products into those substantial and those unsubstantial. Products are most of all human-oriented [1]. Because of the rapid development of HCI systems design - building a good user interface has recently become a very complex task, although its complexity does not always lead to increased functionality or usability.

Application of various bio-signals as a control tool is a very trendy scientific area, however the currently available solutions give far from satisfactory results. In this paper an innovative bio-signals-controlled interface based on an inexpensive, easily available on an open market gaming headset - Emotiv EPOC was presented. The main aim of this research was to design, develop and test an intuitive and user-friendly interface controlled with various bio-signals. The project was primarily intended for handicapped users as an alternative for traditional keyboard or/and mouse.

The most significant difference of the proposed system, while compared to those already existing, is its versatility to work with various bio-signals - such as EMG (not yet implemented) or EEG, thus enabling a single interface to be controlled by different devices. Initial investigation has proven the possibility of the Emotiv EPOC headset application - as an example of an inexpensive, easily available tool for Human-Computer Interaction (HCI). As mentioned above - the research purpose was to improve and optimise bio-signal-based user interface.

In this paper Emotiv EPOC headset implementation as a game controller implementation was presented. Potential successful and efficient application of both EEG and speech signals for Human-Computer Interaction was shown.

Traditional devices – such as keyboard or mouse - used as a tool for our Human-Computer Interaction seem to be old-fashioned and simply limited. More and more interfaces are based on use of various bio-signals. Alternative control interface of almost any kind of media device has become a very common research subject.

The main aim of the Human-Computer Interface (HCI) is to enable direct communication between computer and human being, where no additional, traditional control device such as mouse or keyboard is needed, as various bio-signals are used as a source data [2, 3]. Design of a HCI system does not limit to its purpose, but is a whole complex process in which multiple aspects are considered, one of them involves giving a positive experience while used to the potential user [1].

Composition of a good and intuitive Human-Computer Interface is also a key aspect, which impacts gaming experience. Potential user is able to control the actions while receiving appropriate feedback. Control mechanisms should be intuitive and similar to real-world interactions - imitating human skills [4]. It is also important to mention, that a good HCI design makes the potential use of the proposed solution more comfortable [4, 5].

Optimal HCI design plays a significant role in creating any real-time system, especially in building an Augmented Reality (AR) system, where various virtual information is being mixed and used [5]. It is also important to mention, that many HCIs apply Electromyography (EMG) as a source data, where electrical activity of skeletal muscles is being analysed and used. This technology, however possible to use with the Emotiv EPOC headset, has not been applied for this study purposes, but will be implemented in the near future [3, 6].

The proposed Human-Computer Interface is based on bio-signals and involves implementation of a low cost, market available headset - Emotiv EPOC [6, 7]. The Graphical User Interface (GUI) is intuitive in operating, as it is based on graphics - with very little text involved (see: Fig. 1) [own work based on 8].

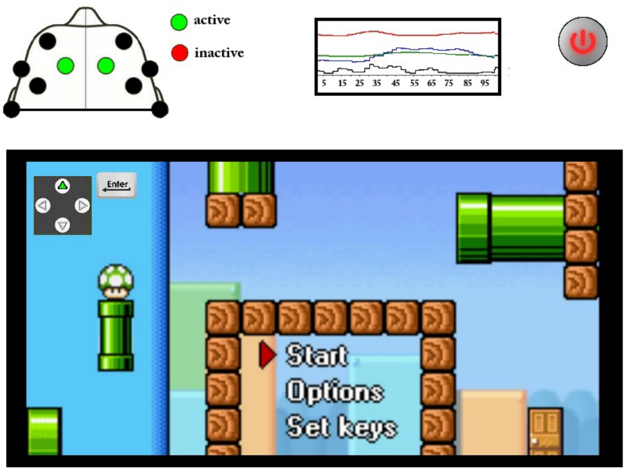

Figure 1. Graphical User Interface - prototype [own work based on 8].

Such as user-friendly GUI applied as a PC controller would enable easier access because of graphics implementation and as a result would be more versatile due to no need for a translation of the potential subtitles. It would also be more legible and easy to use for users of various generations with different physical conditions. Idea of using Emotiv EPOC headset, which supports various bio-signals, enables wider usability of the systems [6, 7, 9].

II. Emotiv EPOC-based Brain-Computer Interface

Brain-Computer Interfaces (BCIs) are a particular form of a Human-Computer Interface. It is because they enable external environment control with brain signals. Signal generated through brain's activity occurs as a result of thoughts or intentions [3]. Brain-Computer Interfaces can be divided into two main types - invasive and non-invasive. Invasive are based on surgical implantation of electrodes into the human brain [3, 10]. This research involves non-invasive, EEG-based type of BCI only. In the Fig. 2 a simplified overall scheme of a typical non-invasive Brain-Computer Interface was presented.

Recent research on potential BCI applicability for gaming purposes has proven BCI to be a good alternative to traditional

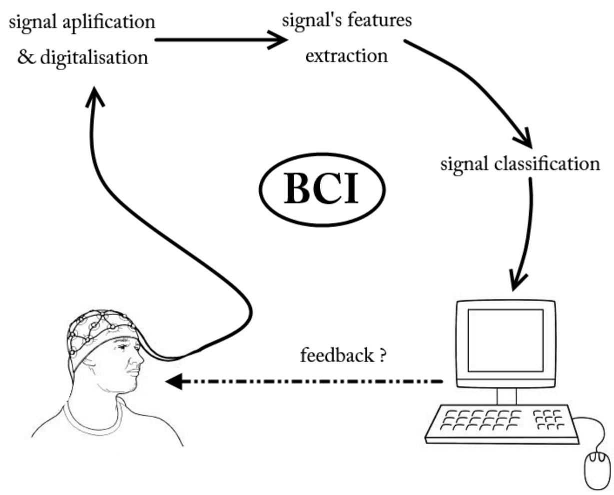

Figure 2. Overall BCI scheme [own work].

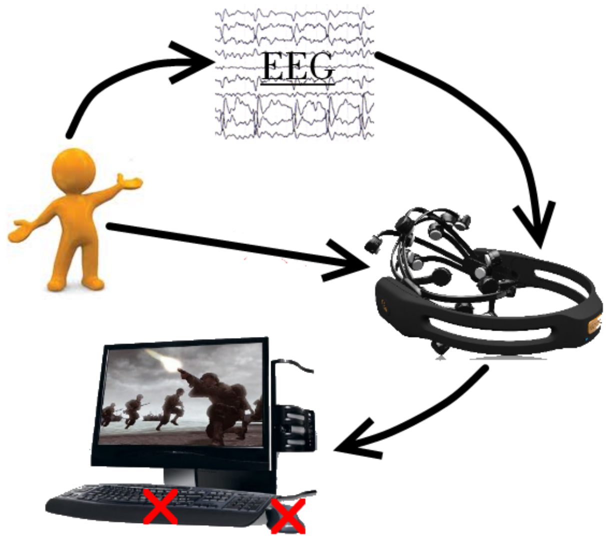

Figure 3. Simplified scheme of the project [own work].

control devices such as keyboard or mouse [9, 11, 12].

Application of an inexpensive EEG-headset - Emotiv EPOC - for the BCI gaming purpose was one of the main tasks of this project. To the advantages of the Emotiv EPOC headset belongs its implementation versatility, as it supports three types of control data sources - EEG-, EMG- and Gyroscope [3, 6, 13].

It is possible to apply Emotiv EPOC headset for gaming purposes, where potential user's emotions (meditation, excitement, engagement) are used as an input source and the brain waves are applied in order to indicate the lever of the emotions state, as the headset is able to measure voltage fluctuations resulting from ionic current flows in neurons [3, 6, 14].

One of the main goals of this project is to create an inexpensive, easy and hand-free access for a user having an ordinary PC or laptop and the Emotiv EPOC headset.

In the Fig. 3 a simplified scheme of the described project was illustrated, however the PC/laptop can be successfully replaced with any other external hardware - such as a mobile phone or a tablet. One of the biggest Emotiv EPOC headset's advantages is that it is not only inexpensive, but also easy to use and easy to wear, what plays a crucial role in successful implementation and can be used also by handicapped users [3, 9, 11].

III. Bio-Signal Based Game Control

Emotiv EPOC headset is a typical gaming device. It was not primarily designed for the clinical use and therefore some errors while registering brain signals were possible to be noticed. Despite that, it can successfully be implemented for BCI purpose and as a game controller [6, 14].

Basic game's mechanisms rely on following sequential indications in order to finish some steps by the player. Time limit was also partially estimated [5].

Initial tests conducted by the author's of this paper included inter alia implementation of a clinical EEG. Unfortunately the traditional medical equipment was too sensitive and as a result the gathered signal was very noisy and full of unnecessary artefacts. The signal processing required more sophisticated, statistical methods and these needed higher computing power.

Potential disturbances in signals analysis are caused by the 'nature' of the brain waves used for the control, which have very low frequency and the presence of the external artefact in the signal make the analysis almost impossible [14, 15].

Application written in MATLAB by the authors enables reduction the effects of the artefacts present in signals and distinction of desirable frequencies and events.

The whole analysis procedure is based on double integration and the 'mistake criteria', which can easily be set up and changed according to the test results. The authors have also taken into consideration phenomenon called 'visual stress'. 'Visual stress' affects mostly people with dyslexia. Very little interfaces take it into account.

In this 'mu' brain waves are processed. These are event-related waves, which occur only during imaginary and real motor action. They have frequency of similar to 'alpha' values – 10 Hz.

As mentioned above – the gathered signals contain a lot of disturbances, noises and unnecessary data. In order to detect the desired information it was required to design and implement appropriate filtration.

IV. Conducted Research

The whole project involved implementation of a clinical EEG device during the very first stage. However the traditional, medical equipment (16 channel EEG – Contec KT-88) was too sensitive for the purpose of the research aim and as a result – gathered signals were noisy. This was a disqualifying factor of the device as it made the potential implementation of the equipment in real-life, noisy environment impossible. It was also quite big and therefore was not handy and portable.

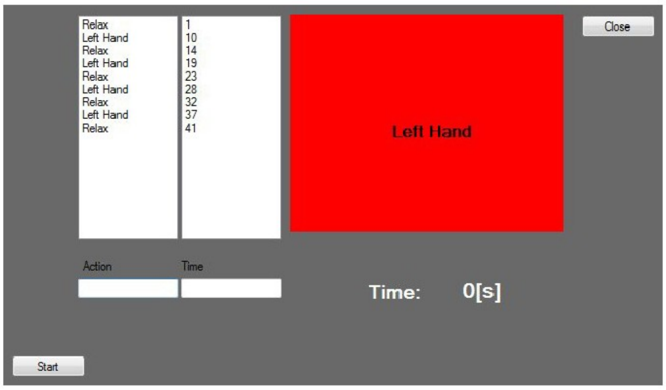

Figure 4.Visual stimuli for the appropriate hand movement [own work].

In the Figure 4 a visual stimuli application window was presented. During the research subject had to imagine a simple left- or right-hand movement according to the instruction displayed. The application and the research could be set according to the preferences.

One of the analysed signal's feature is that the brain waves (used in this case for the control purpose) have very low frequency and the presence of the external artefacts in it has made the analysis almost impossible [13, 15].

For the pattern recognition purpose signal processing application in Matlab was developed. No filtering was applied, as the initial study has proved that the applied method did not require filtering and was as simple as possible [3, 16].

The waves used for the research purpose are 'mu'-waves. These are event-related waves occurring only during imaginary and real motor action. Their frequency is similar to the frequency of the 'alpha'-waves (ca. 10 [Hz]) and therefore some of the scientist to not acknowledge their existence.

As mentioned above, the gathered signals contain a lot of disturbances, noises – which result in presence of the unnecessary data.

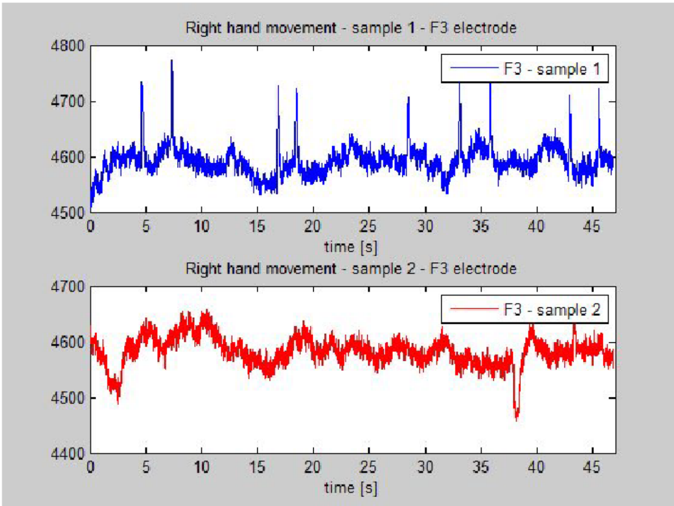

Figure 5. Imaginary right hand movement – F3 electrode – 2 samples [own work].

In the Fig. 5 two samples from two different subjects were compared. The signals were recorded from the F3 electrode during imaginary right hand movement. Signals seem to strongly differ from each other, but it is clearly visible, that they oscillate around similar values.

The proposed method is an alternative version of a mean-square method. The results of the research were satisfactory. The proposed method enables potential implementation in any programming language in almost any environment.

V. Conclusions

This research has raised some interesting questions regarding using an inexpensive, open-market available EEG amplifier – Emotiv EPOC headset. It also proved that not only complex, sophisticated signal processing methods are efficient.

The novelty of the proposed method relies on implementation of basic mathematical operations for the signal processing purpose. Similar BCI solutions have not been found. Usually traditional, statistics-based methods were applied.

During the initial stage of the research it was wrongly estimated that the information in time-progress of signals gained from the electrodes C3 and C4 were able to contain the information about pictures (visual stimulus) observed by the subject, what might have been used for the BCI design purposes. The implementation of the Morlet Wavelets (not applied for the final, described in this paper, stage) proved that this method was not suitable for Brain-Computer Interfaces due to the latency appearance.

In BCI systems very fast response is absolutely required. The first stage, although not successfully completed, provided numerous crucial information regarding construction of customised equipment, electronic and bio-signals. The proposed method has also proved that traditional statistical methods were not suitable for the implementation of the embedded systems.

It was also has proven later that the channel location should be different. Tests conducted on the customised device proved that the quality of the final design was not satisfactory and thus the accuracy was very low. The gained signals were of very poor quality, which made the further analysis impossible.

The research provided surprisingly satisfactory results. All the numeric procedures were conducted in MATLAB. This stage of research presented communication between PC and TS-7260 board and between PC and MATLAB, what resulted in building a system, which may become in the future fully working BCI. The analysed signals EEG signals did not contain the full information and the applied filtering did not improve the results significantly.

Adopted tools for signal processing could be more sophisticated, although it might lead to prohibitive computational burdens, in particular in the embedded system environment selected owing to the low-cost implementation prerequisite. Also the implementation of Emotiv EPOC headset had some disadvantages, as the device was not used for clinical applications and therefore the accuracy of the registered signal was not very high. The device also pre-processed the signals, so the obtained data was not really raw.

As mentioned above – the carried out literature study did not provide any information of using similar to proposed signal processing method.

VI. Future Work

It is planned to conduct further tests regarding usability of this solution and to implement the threshold function based analysis, which is quicker and more efficient that the one based on differentiation.

Planned future work should involve improving the accuracy of the obtained results. It would also be advisable to develop a standalone application (AE) that would not need PC, but would enable to connect the Emotiv EPOC headset with the TS-7260 with no need of MATLAB-based signal processing. Because of the implementation of the method based on basic mathematical operations, potential application of the signal processing onto the embedded platform would be possible, as the method does not require high computing or calculating power.

The further plan would be to implement the solution in order to enable efficient (and safe) control of a wheelchair.

Further plans also involve building large database with various bio-signals and their implementation. There are also plans to advance the work in the way, that various (not only EEG) bio-signals could be used in order to extend the possible application of the proposed solution. Bio-signals such as voice, eye-movements or EMG would be implemented. The result may be used in order to improve prosthetics.

The authors decided for the time being to concentrate on EMG signals analysis and to improve the signal processing method so it would be also suitable for other bio-signals, such as above mentioned EMG.

The main aim of this work was and still is the idea of improvement quality of life of handicapped-users.

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