Innovative Approach in Analysis of EEG and EMG Signals – Comparision of the Two Novel Methods

Aleksandra Kawala-Janik
and
Michal Podpora
Faculty of Electrical Engineering,
Automatic Control and Informatics
Opole University of Technology
ul. Proszkowska 76, bud. 1,
45-756 Opole, Poland
Email: a.kawala-janik@po.opole.pl,
m.podpora@po.opole.pl

Jerzy Baranowski
and
Waldemar Bauer
AGH University of Science
and Technology
Faculty of Electrical Engineering,
Automatics, Computer Science and
Biomedical Engineering
al. Mickiewicza 30, 30-059 Krakow, Poland
Email: jb@agh.edu.pl,
bauer@agh.edu.pl

Mariusz Pelc
School of Computing and
Mathematical Sciences,
University of Greenwich
Old Royal Naval College, Park Row,
SE10 9LS, London, U.K.
and
Faculty of Electrical Engineering,
Automatic Control and Informatics
Opole University of Technology
ul. Sosnkowskiego 31
45-272 Opole, Poland
Email:m.pelc@greenwich.ac.uk

***Abstract*—In this paper comparision of two, novel signal processing methods for analysis of EEG and EMG biomedical signals was presented. This is because nowadays analysis of biosignals is very popular. The first method described in this paper applies kernel density estimators, which enable densitograms construction of the examined biomedical signals. The advantage of this method is that it allowes to obtain statistically filtered signals and makes the whole process quicker. The second method presented in this paper is based on basic mathematical operations only, which also simplifies the whole process of analysis. the second method is also quick and efficient, with wide potential spectrum of use as it can also be implemented on embedded platform and the algorithm can be reqritten in any programming language.**

I. Introduction

Use of various biomedical signals, in particular EEG, but also in many cases EMG, for the control purpose has become growing concern of numerous research teams, as implementation of these signals enabels quick and direct communication betwen human and external environment [6]. Despite being excellend information source for advanced control systems, analysis of bio-signals can cause various significant issues due to the deterministic signal nature, which makes the application of these signals a very challenging task. The most difficult is implementation of both EEG and EMG signals, as the human brain and the whole nervous system have not been fully investigated and is not perfectly known by the researchers [7].

In this paper two innovative signal processing methods were presetend. Both EEG and EMG signals were tested. The first approach involves filtering of biomedical signals with implementation of statistical methods. The second method unlike the fist one uses neither traditional statisitcal methods not filtering. Both methods have advantages and disadvantages described in this paper.

II. Analysis of Biomedical Signals

One of the major aspects of biomedical engineering is analysis of biomedical signals [1]. As mentioned above for the purpose of this paper two different methods and two biomedical signals – EEG and EMG – were analysed. The EEG signals are one of the most popular biomedical signals used for the purpose of controlling an external environment. It is also important to mention, that despite quite novel approach in using these signals in various Human-Machine systems, they were reported for the first time in 1929 by Hans Berger [2]. In this paper also studies conducted on EMG signals were in short presented. This is because of wide potential use of electromyography in inter alia advanced neuroprostheses. This research direction is result of various limb amputations, which affect ca. 1.6 million of Americans, which is a very horrifying amount of people [8]. It is also imporntat to mention that the advances control systems based on myoelectric signals have become recently very popular, however the earliest mentions of EMG-based control was made in early 1950s, as it was a very simple system, where only the strength of contractions was applied. This project was improved in 1960s and later in the 1980s. It all resulted in building a commercial myoelectric prostheses [10].

A. EEG and EMG

The major difference between the EEG and the EMG signals are their frequency ranges, although both signals are sensitive prior internal and external artifacts. Amplitude of EEG signals is very low (below ca. 60 Hz), what makes the whole analysis a very compelx task. EMG-Amplitude is a bit higher, however there is a coherence between the both signals. Energy spectrum EEG-EMG coherence can clearly be visible at the frequency of β-waves, which oscillates between 15 and 35 Hz and γ – 35-50 Hz. This may give additional information regarding time-course of functional state of both brain and muscles and imrpove rehabilitation process of various movement disorders [4], [5].

Fig. 1. EMG recording.

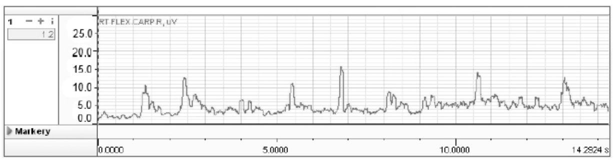

Fig. 2. Right forefinger movements.

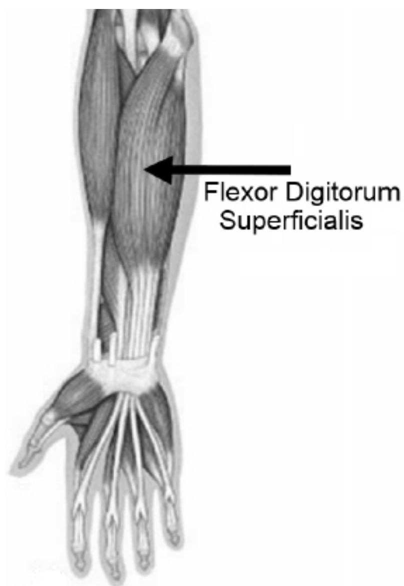

Fig. 3. EMG-electrodes location placement.

III. Research Methodology

For the purpose of this research only μ frequency range in EEG was analysed. The signals were recorded during imagery left- and right-forefinger movements. EMG signals were recorded during real movements of both forefingers (Fig. 1). In the Fig. 2 sample forefinger movements were presented.

The signals (Fig. 2) were not filtered. The electrodes were placed musculus on flexor digitorum superfcialis location (see: Fig. 3).

As the EEG signal is a measurement of currents flowing during synaptic excitations of the numerous pyramidal neurons

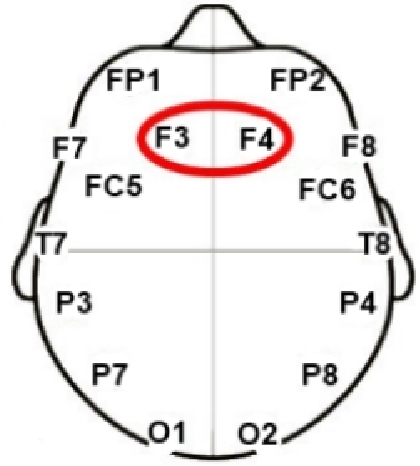

Fig. 4. Electrodes placement according to the 10-20 system.

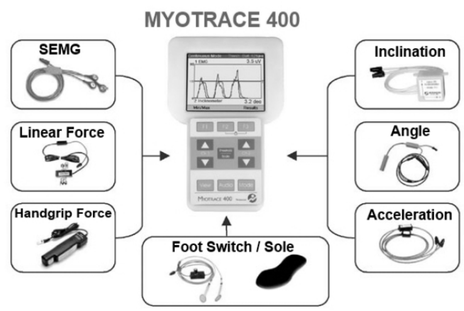

Fig. 5. MyoTrace 400 [11].

dendrides in cortes it is impossible to record activity of each neuron [2]. The electrodes in EEG system are usually placed according to the 10-20 standard system. In the Fig. 4 electrodes of the Emotiv EPOC headset were illustraded. The electrodes location corresponds with the 10-20 system. Location of the recording electrodes - F3 and F4 was marked with a red ellipse. The signals were recorded during imagery left and right forefinger movements.

A. *Equipment Used for the Study Purpose*

In order to record EMG signals – standalone, portable EMG-device – MyoTrace 400 (Noraxon) was applied. The device is able to operate in both stand-alone- and PC-modes. As it is clearly visible in Fig. 5, it can be aused with various additional equipment such as SEMG, force transducers, goniometers, inclinometers, accelerometers, hand dynamometers or foot switches. Despite handy design the equipment is designed for clinical use. It has 20-500 Hz bandwidth, sampling in real time is at 1000 sample/sec/channel [11].

For the purpose of EEG recording gaming (unlike in EMG) Emotiv EPOC headset was implemented. It is both inexpensive and easy to use. It consists of 14 saline electrodes placed on scalp and two additional reference electrodes. Sampling frequency is very low – 128 Hz only. The data is transfered wirelessly [2], [12]. In the Fig. 6 Emotiv EPOC headset was presented [12].

Fig. 6. Emotiv EPOC headset [12].

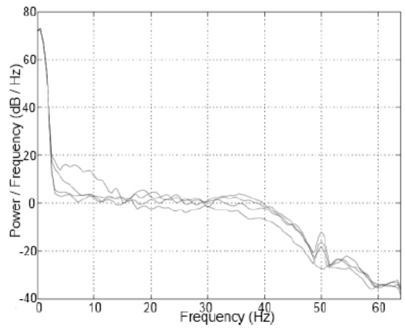

Fig. 7. F3-electrode signals spectrum.

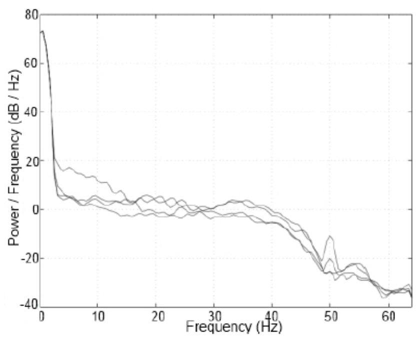

Fig. 8. F4-electrode signals spectrum.

B. Sample Results

The first method, where KSD was applied, involved using Welch method of the PSD estimators. Kaiser window was used with the width of 256 samples. Welch method was chosen because of its positive features for noisy signals. In Fig. 7 (F3-electrode) and fig8 (F4-electrode) spectra of multiople signals were presented. The difference between particular subjects is not visible. Spectrum is flat with one peak from DC part of the signal and a drop at higher frequencies obviously because of the operation of the hardware anti-aliasing filter.

In the Fig. 9 left- and right- forefinger movement was presented. This Figure is a result of used second signal processing method – the one based on mathematical opearions only.

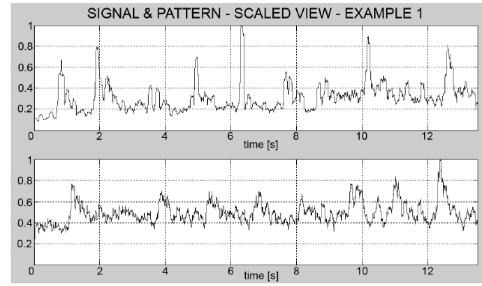

Fig. 9. Left (top) and right (bottom) forefingers – sample.

IV. Conclusion

Both signal processing methods have their advantages and disadvantages. The first one – based on Kernel Deinsity Estimators is quick and efficient, however it requires high computing power and therefore, despite its efficency, may not be implemented on systems with some limitations, such es embedded platforms. As this method belongs to the sophisticated signal processing methods – it would be hard to implement in some of the basic programming languages. It also involves filtering, what can have a negative impact on signals with limited information. However filtering used in that case is an alternative to traditional, popular filtering methiods, where initial transisional response is eliminated. Initial study results are promising.

The second method, discussed in this paper is based on basic mathematical operations only. It is because most of the applications controlled with biomedical signals rely on run-time comparison of the current muscle activity with a set of previously recorded signal patterns, which should be stored in a database. When targeting, for the potential implementation purposes in an embedded platform – the most popular and suitable application domain for this kind of the control applications – many limitations must be considered. This is because even the most technically advanced and equipped embedded system is significantly weaker then an average PC.

The above mentioned limitations excluded application of the advanced and sophisticated signal processing methods and resulted in developing a custom method of signal recognition. The proposed method is based on calculation of normalised value of signal similarity level. This method can be easily transfered into any programming language.

V. Further Work

Implementation of various bio-electrical signals, such as EMG or EEG is widely used not only in medical sciences or physiotherapy, but also in control, sport or computing [9].

Initial results of conducted research were positive and therefore promising, further research will be carried out in order to compare the efficiency of proposed methods with the approach of the most popular and with another innovative approach in order to find the most suitable signal processing method. Also other biomedical signals will be tested (EOG and speech).

REFERENCES

[1] J. Baranowski, P. Piatek, A. Kawala-Janik, M. Pelc and R.J. Anthony, *Application of Kernel Density Estimators for Analysis of EEG Signals*, 3rd ed. Ubiquitous Computing and Ambient Intelligence. Lecture Notes in Computer Science (LNCS), vol. 7656, pp. 403-406, Springer Verlag, 2012.

[2] S. Grude, M. Freeland, Y. Chenguang and M. Hongbin, *Controlling mobile Spykee robot using Emotiv Neuro headset*, 2013 32nd Chineese Control Conference (CCC). pp. 5927-5932, IEEE.

[3] A. Kawala-Janik, *Efficeincy Evaluation of External Environments Control Unisng Bio-Signals*, Doctoral Thesis. University of Greenwich, London, 2013.

[4] Q. Yang, V. Siemionov, Y. Wanxiang, V. Sahgal and G.H. Yue, *Single-Trial EEG-EMG Coherence Analysis Reveals Muscle Fatigue-Related Progressive Alterations in Corticomuscular Coupling*, IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 18, no. 2. pp. 97-106, 2010.

[5] L.M. McManus, F. Budini, F. Di Russo, M. Berchicci, F. Menotti, A. Macaluso, G. De Vito and M.M. Lowery, *Analysis of the effects of mechanically induced tremor on EEG-EMG coherence using wavelet and partial directed coherence*, 2013 6th International IEEE/EMBS Conference on Neural Engineering (NER). pp. 561-564, 2013.

[6] W. Ouyang, K. Cashion and V.K. Asari, *Electroencephalograph based brain machine interface for controlling a robotic arm*, IEEE (AIPR) Applied Imagery Pattern Recognition Workshop: Sensing for Control and Augumentation. pp. 1-7, 2013.

[7] A. Alkan and M. Gunay, *Identifcation of EMG Signals Using Discriminant Analysis and SVM Classifier*, Expert Systems with Applications, vol. 39, Issue: 1. pp. 44-47, Elsevier, 2012.

[8] S. Sikdar, H. Rangwala, E.B. Eastlake, I.A. Hunt, A.J. Nelson, J. Devanathan, A. Shin and J.J. Pancrazio, *Novel Method for Predicting Dexterous Individual Finger Movements by Imaging Muscle Activity Using a Wearable Ultrasonic System*, IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 22, Issue: 1. pp. 69-76, IEEE, 2014.

[9] Z. Borysiuk and D. Zmarzly, *Surface Electromyography (SEMG) as an Innovative System of Research Work on Information Processes in Sport*, Polish Journal of Sports Medicine, vol. 22, Issue: 1. pp. 59-66, Polskie Towarzystwo Medycyny Sportowej, MedSportPress, 2006.

[10] E. Scheme, B. Lock, L. Hargrove, W. Hill, U. Kuruganti and K. Englehart, *Motion Normalized Proportional Control for Improved Pattern Recognition-Based Myoelectric Control*, IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 22, Issue: 1. pp. 149-157, IEEE, 2014.

[11] Official Noraxon Web: *www.noraxon.com*

[12] Official Emotiv EPOC Web: *www.emotiv.com*