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V. Gaidar, post grad. stud.,
S. Radchenko, Ph.D., O. Sudakov, Ph.D.
Department Medical radiophysics, Faculty of Radiophysics, electronics and computer systems,
Taras Shevchenko National University of Kyiv

REMOVAL EMG AND EOG ARTIFACTS FROM EEG SIGNAL

One of the main problems in electroencephalography analysis is artifacts: electromyogram (EMG) and electro - oculogram (EOG). Considered removal methods are based on blind source separation techniques (BSS) with the Second Order Blind Identification (SOBI). We applied the modified SOBI algorithm with asymptotically optimal weights (WASOBI).

Keywords: *electroencephalogram, electromyogram, electro – oculogram, blind source separation techniques.*

Introduction. Electroencephalography (EEG) is a common method of research of the brain [7]. EEG non-invasive and safe method of direct mapping of functional activity of the central nervous system that allows us to monitor those signals in real time. EEG is based on getting the bioelectric potentials from the surface of the scalp. We get signals due to the electrical interaction of a large number of neurons (which include action potentials, the electrical synaptic transmission of information and other). So we can say that the signal at each electrode is based on the summation of elementary processes, actually occurring at the level of individual neurons. Electroencephalograph used in clinical practice for the detection of various pathologies and malfunction of the brain function, and it is save method for learning about brain functionality. If we could create the database with data, which would contain a large number of electroencephalographic researches, so in the future it would allowed to us analyzing various pathologies for a large data set and picking up some statistics to create a classifier.

However electroencephalogram is very sensitive to different artifacts. Among them the most distorted the real data are: motor artifacts (also called miogramm (EMG) [2], that caused by muscle reduction) and oculogramm artifacts (EOG) arising from motion of eyes and blinking. The systematic approach of recognition, source identification and elimination of artifact is an important process to reduce the chance of misinterpretation of the EEG and limit the potential for adverse clinical consequences.

Therefore, without the prior automatic processing data and removal of artifacts does not make sense to do some analysis, because, the signal will be distorted by EOG and EMG artifacts. That is why in this work we focus on solving the problem of the artifacts removal.

When we talk about EEG data taken from specific electrodes, we must consider that this signal is weighted linear mixture of underlying cortical source signal [1, 4]. The weights of each recorded mixture are determined by the distance of cortical sources domains from the electrodes pair, the electrical properties of underlined tissues etc. The method of Blind Source Separation (BSS) [5] allows separate a set of sources from a set of mixed signals without the aid of information about signals or mixing process. BSS technique is able to separate EEG signal into spatial components and then identify the artifacts components by using the proper criterion. After that we can remove artifact components and reconstruct the signal free of artifacts. BSS relies on the assumption that the signals are not correlated and statistically independent from each other. The main idea of the method can be represented as follow [5, p. 164]: $g(t) = As(t) + n(t)$ .The data from i electrode $g_i(t)$ can be obtained by mixing a large number of independent sources $s_j(t)$, where mixing can be expressed in $[n \times m]$ matrix A called the mixing matrix, here n - number of electrodes, m - number of sources (the assumption $n = m$) and $n(t)$ - white noise. Thus can find signals solving the inverse problem of finding unmixing matrix $[m \times n] - W$: $s(t) = Wg(t)$. For these purposes, we used algorithm SOBI [9] and reformulating the problem as a weighted least - squares (WLS) problem [10]. Thus, we achieve two main goals: minimizing the mean square error (MSE) of the estimated matrix A ; second, rather than estimate A from M vectors we estimate A from a small number of estimated correlation matrices. The true correlation matrices have the structure [9] $R_x[\tau] = AR_S[\tau]A^T \ \forall\tau$ where due to the spatial independence of the sources, their correlation matrices $R_s[\tau] = diag[\lambda_\tau^{(1)}, \lambda_\tau^{(2)}...]$ are diagonal matrices.

After obtained matrix A we can identify columns of A corresponding to EOG and EMG sources by using the criteria that marks as artifacts the components with smaller fractal dimension [6]. Conceptually, components with low fractal dimensions are those who are composed of few low-frequency components. This is often the case of ocular activity and therefore this is a suitable criterion for detecting ocular (EOG) components.

Now that we have defined a set of independent signals $s_j(t)$ we can remove by equate to null some of the weight coefficients mixing matrix. We talk about the weights because on different electrodes these independent signals will be represented in different ways.

But for remove signals that corresponding to the artifacts, we need to have some criteria [3]. So going directly to the removal of artifacts we can define a general algorithm:

1. Background EEG decomposed into a set of spatial components.
2. Provision artifact components using the appropriate automatic criteria.
3. EEG reconstructed, but without the selected artifacts. We can write the obtained from *j*-electrode signal:

$$x_j(t) = \sum_{i \in r_{EEG}} a_{ji} s_i(t) + \sum_{i \in r_{EEG}} a_{ji} s_i(t) \quad X(t) = A_{EEG} s_{EEG} + A_{EOG} s_{EOG}$$

where $x_{EEG}(t) = A_{EEG} s_{EEG}$ and $x_{EOG}(t) = A_{EEG} s_{EOG}$.

Experimental. In our case we had a real EEG signal that was collected from 21 scalp electrodes placed according to the international 10–20 System at the Department of Medical Radiophysics (Faculty of Radiophysics, Electronics and Computer Systems).

EEG records the potential between two electrodes. Electrodes are placed on the skin of head, so that the multi-channel system covers all major parts of the brain.

Two types of EEG montages are used: monopolar and bipolar [8]. The monopolar montage is when the "input 1" amplifier is supplied from the electrode potential, which stands on the brain, and to "input 2" – from the electrode which is removed from the brain.

Electrode located above the brain, often called active electrode. The removed from the brain tissue electrode, called the reference: As the reference electrode often used electrodes that placed on the left (A1) or right (A2) earlobe. The active electrode is connected to "input 1", the reference electrode connected to the "input 2".

Since EEG recorded the potential between two electrodes, the position of a point on the curve will display changes under each of the pair of electrodes.

Electrode location under active electrode generates an alternating of brain potential. In reference electrode located far from the brain, there is a constant potential that does not affect on the record. However, the region of the head between the active and reference electrodes forming part of an electrical circuit "power object".

If the "input 1" and "input 2" electrodes both are active we talk about bipolar montage. In this case EEG recording monitor equally changes in potentials under each of the pair of electrodes, and recorded curve a potential difference reflects each electrode.

In our case we use the bipolar montage and experimental conditions provided the opportunity for display EOG and EMG signals on the obtained data (Fig. 1).

Movement during the recording of an EEG may product artifact through both the electrical fields generated by muscle and through a movement effects on the electrode contacts and their leads. It is the most common and significant source of noise in EEG. EMG activity almost always obscures the concurrent EEG because of its higher amplitude and frequency.

In our case we can see the EMG artifact in the right circle and the EOG in the top circle. With bipolar montage, positive and negative phase reversals of EOG are seen at the frontal electrodes, because they placed near the eyes. Observe that original EEG frame contains few blinks and well defined EMG signal (designated in the right and left circles respectively). As we can see the WASOBI algorithm using with fractal dimension criteria gives desirable result of remove EOG and EMG data from EEG data and wherein applied method do not distort real EEG signal.

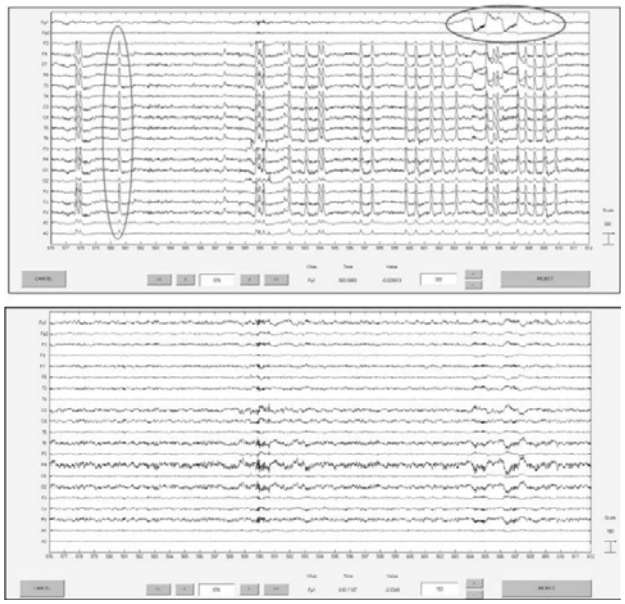

Fig. 1 Original EEG (the top frame) and corrected frames respectively

In order to make sure that, after using this method of artifacts remove, our data, that did not consist artifacts has not changed significantly we used Kolmogorov – Smirnov test. We have chosen the range between 104.5–107.5 seconds, which doesn't consist the artifacts before we using the WASOBI method (Fig. 2).

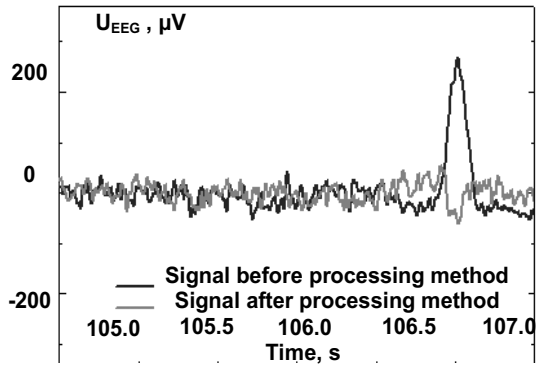

Fig. 2. EEG signal before (blue) and after EMG removal (red)

As the result, the function of the probability that a signal obtained specific amplitude range was built (Fig. 3).

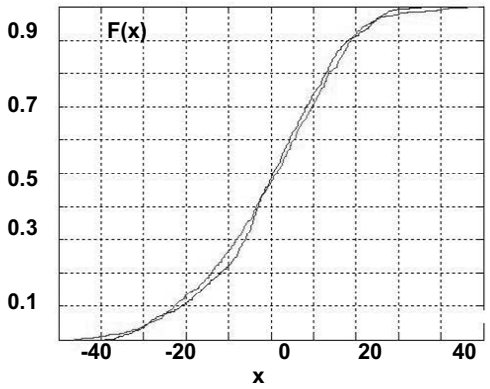

Fig. 3. Cumulative distribution function

Obtained value of the parameter p: $p = 0.18$ enables us to say that the method can be used for processing EEG data. The suggested algorithm of remove artifacts of oculogram and miogram provides low distortion of signal that does not contained artifacts, which was confirmed by the Kolmogorov-Smirnov test. Thus, in further it provides an opportunity to create expert systems for classification and analysis of EEG signals.

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Гайдар В. О., Радченко С. П., Судаков О. О.
кафедра медичної радіофізики, факультет радіофізики, електроніки та комп'ютерних систем
Київський національний університет імені Тараса Шевченка

ВИДАЛЕННЯ АРТЕФАКТІВ ЕЛЕКТРООКУЛОГРАМИ ТА ЕЛЕКТРОМІОГРАМИ З ЕЕГ СИГНАЛУ

Однією з основних проблем при аналізі електроенцефалограм є артефакти: електроміограми (ЕМГ) і електроокулограми (ЕОГ). Були розглянуті методи видалення основані на методі сліпого розділення джерел (BSS) із використанням статистики другого порядку (SOBI). Ми застосували модифікований алгоритм SOBI з підбором асимптотично оптимальних вагових коефіцієнтів (WASOBI).

Ключові слова: *електроенцефалограма, електроміограма, електроокулограма, метод сліпого розділення компонент.*

Гайдар В. О., Радченко С. П., Судаков О. О.
кафедра медицинской радиофизики, факультет радиофизики, электроники и компьютерных систем,
Киевский национальный университет имени Тараса Шевченко

ВЫДЕЛЕНИЕ АРТЕФАКТОВ ЭЛЕКТРООКУЛОГРАММЫ И ЭЛЕКТРОМИОГРАММЫ С ЭЭГ СИГНАЛА

Главной проблемой при анализе электроэнцефалограмм есть артефакты, которые сильно искажают ЭЭГ сигнал. Наибольшое проявляються: артефакты электромиограммы (ЭМГ) и электроокулограммы (ЭКГ). Были рассмотрены методы выделения и дальнейшего изъятия этих сигналов с выходных электроэнцефалограмм. Нами был применен метод "слепого разделения компонент" (BSS) с использованием статистики второго порядка. Мы применили модифицированный метод SOBI с подбором асимптотических коэффициентов (WASOBI).

Ключевые слова: *электроэнцефалограмма, электромиограмма, электроокулограмма, метод слепого разделения.*

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O. Gaidar, Ph.D, V. Tryshyn, Ph.D,
O. Svarichevska, Ph.D, I. Pavlenko, Ph.D,
Institute for Nuclear Research National Academy of Sciences of Ukraine
V. Gaidar, post grad. stud.,
Taras Shevchenko National University of Kyiv

ENVIROMENTAL IMPACT ASSESSMENT OF OPERATION OF POSITRON EMISSION TOMOGRAPHY CENTER

Impact assessment for centre of positron emission tomography has been carried out. It has been shown that risks, that arise due to the radiation impact factor, are acceptable. The adequacy of protective measures to ensure radiation safety of personnel, population and environment is analysed.

Keywords: *fluorodeoxyglucose, medical cyclotron, radionuclides, source term, radioactive waste.*

Introduction. The oncology illnesses are placed second in the mortality structure of the population after the heart-vessel system. The early diagnose is the very important moment in treatment of these illnesses what is explained the importance of creation of modern centre nets in the Ukraine for the positron-emission tomography (PET).

Today radiopharmaceuticals (RPhP), which include short-half-life radionuclides ^{11}C, ^{13}N, ^{15}O, ^{18}F, are generally recognized. The short period of life of these radionuclides demands location of cyclotron (for theirs production) and laboratories of radiopharmaceutical synthesis (RPhP) in close proximity to diagnostics centers, which often are located in dense population districts of the large towns. This requires the careful approaches to create reliable systems of engineering barriers to prevent unreasonable release of radioactive substances to the environment and to protect from irradiation personnel and population.

The modern center for early diagnostic of cancer by positron emission tomography (PET-center) will be built in Donetsk, where for manufacturing of fluorodeoxyglucose (FDH), based on short-lived radionuclides ^{18}F, the medical cyclotron MINITrace of GE Medical systems company is used.

Production is based on the irradiation of the target (with water, enriched by isotope ^{18}O) by protons, accelerated to the energy of 9.6 MeV. The produced radionuclide ^{18}F further is used for the synthesis of FDH radio-pharmaceutical, its dosage and transfer to the block of radio diagnostic department of PET-center.

PET center has several blocks, first is the cyclotron unit, block of radiopharmaceutical synthesis and block of radio diagnostic studies.

The block of cyclotron unit includes: cyclotron tank, utility room of cyclotron, the cyclotron control room, sanitary gateway in the output of the cyclotron block.

The block of radiopharmaceutical synthesis includes: laboratory of synthesis, clean changing rooms; laboratory of quality, passageway to transmit radiopharmaceutical to the diagnostic department of PET-center, sanitary gateway at the output of the block.

Also available support facilities, technical service corridor for the hot cells of laboratory of synthesis and interim storage of radioactive waste, emergency shower at the exit from the technical corridor to the corridor; space for calculations, documentation and personnel office room, and others.

Block of radio diagnostic studies is on the 2-nd floor and provides the facilities for receiving and preparation of radiopharmaceuticals based on ^{18}F, procedural for introduction of radiopharmaceuticals to patients; waiting rooms for patients after introduction of radiopharmaceuticals with a bathroom connected with the system of special sewage as well as procedural and console of PET/KT system.

During the operating the PET Center main factor of negative impact on the environment is the radiation one, namely:

- pollution of the surface layer of air in the surrounding PET-center territory by radioactive airborne emissions;
- formation and accumulation of solid radioactive waste (RW);
- formation of radioactive liquid radioactive waste (radioactive runoff).

In normal mode, the PET-center radioactive substances will be localized by system of protective barriers (containers, protective screens, elements of process equipment) that prevent their direct contact with the environment.

For this purpose we have developed the system of stationary biological barriers and appropriate calculations have been made. In this calculations as base was selected the request of non-exceeding of acceptable levels of design dose, which provide non-exceeding of the established limits of effective dose of irradiation for different categories of people: the staff category A and B, and