БІОЛОГІЧНІ ТА МЕДИЧНІ ПРИЛАДИ І СИСТЕМИ

A NEW MEASURE OF ELECTROENCEPHALOGRAM SYMMETRY

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Brain is the most complex part of human body; it is the origin of our senses, intelligence, and memory. One of the prominent anatomical characteristics of brain structure is its division into two separate hemispheres which are connected to each other and have common basic parts like brainstem, commissures etc. Hemispheres are mainly identical from the morphological point of view, but are very different in their functional purposes. Left hemisphere is responsible for analytic thoughts, logics and exact derivations, while right hemisphere is mainly responsible for holistic thoughts, interaction with environment, perception, orientation and memory. The difference in motor and sensor impairs from focal and generalized injuries of different hemispheres is reported. Thus the task of various brain function localization and patterning arises as well as the need of separate estimation of hemispheres' functioning and interhemispheric dynamical interactions.

Among methods of direct brain activity investigation (in terms of morphology, metabolism, electrophysiology) only studying of brain electrical activity can provide objective information about the brain functioning. Electroencephalography is a direct method for studying brain function based on recording and analysis of multi-channel signal of potential differences that accompany its functioning.

It is known [1] that one of the characteristics of a healthy brain activity is synchrony, which causes considerable similarity of characteristics of signals originating from two hemispheres. An important task is to develop methods to assess symmetry in the functioning of the brain in normal and pathological conditions. The aim of this work is the development and study of quantitative characteristics of symmetry and synchronization of electroencephalogram.

The main idea of the paper is to consider the hemispheres as two distinct systems that generate electroencephalogram signals and whose work is synchronized by certain internal or external mechanisms. Synchronization of two hemispheres leads to similarity of activity between different hemispheres. Among all possible numerical characteristics of the synchronization of two systems (generalized synchronization, phase synchronization, bi-directional influences synchronization of "impact-response" type) this paper focuses on phase synchronization.

Phase synchronization is used to estimate nonlinear relationships in signals. Even if signal amplitudes are noncorrelated, phases can vary synchronously, and this can be quantified by so-called phase-locking value (PLV). In general, phase synchronization can be regarded as the stability of instantaneous phase's difference over some time interval [2]. Among the possible ways of calculating the PLV, Hilbert transform was chosen in this work [3, 4] due to convenience of instantaneous phase fluctuations calculation simultaneously for all frequencies in the range of interest, and the availability of standard software, which facilitates the comparison of results from different studies.

While analyzing nonlinear characteristics and connections between signals from two systems there is the difficulty associated with the fact that spontaneous phase synchronization can be observed also in a completely random signal, particularly in white noise. In the application of mathematical methods to calculate the PLV between two noise signals which are generated independently of each other, one can get a non-zero PLV value which is not meaningful. Therefore, the direct use of PLV values might lead to false or noncostintent conclusions. Thus developing of objective quantitative characteristics of PLV is an important task.

In this paper to construct measure for PLV the use of surrogate signals is proposed. These signals have the same linear characteristics (amplitude spectrum) as those for real electroencephalogram signals. But all non-linearity, which is reflected in phase spectrum, is eliminated. Such signals are noise counterparts to real signals, among which phase synchronization is to be calculated.

To calculate the degree of synchronicity the following expression is proposed:

$$Q = \frac{\overline{PLV_{real}} - \overline{PLV_{surrogate}}}{\sigma_{surrogate}},$$

where $\overline{PLV_{real}}$ and $\overline{PLV_{surrogate}}$ – mean values of PLV for real and surrogate signals, $\sigma_{surrogate}$ – variance of surrogate signlals.

Experimental work has been organized as follows [5]. For real electroencephalogram signals that were registered at 10–20 system, PLV was calculated for two cases: for leads from symmetrical sites on the head, and for all possible leads pairs but not symmetric (Fig. 1). For each case, the value of synchronicity was calculated as explained above.

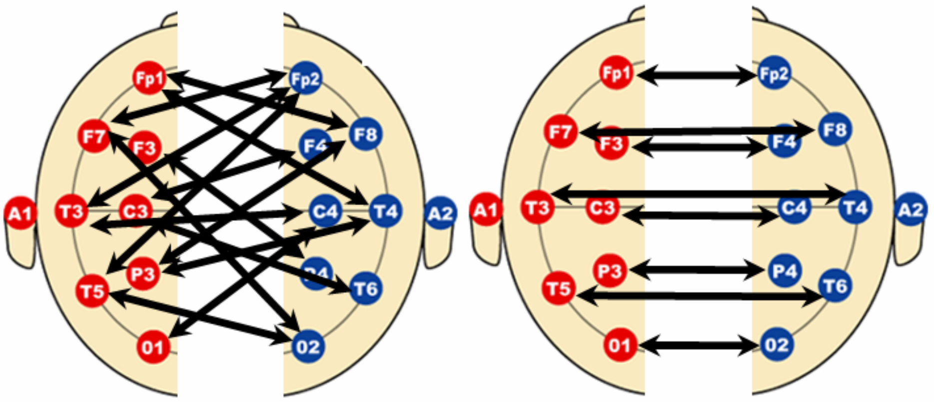

Figure 1 – Choosing electrode placement for calculating degree of synchronicity

The experimental results showed that the choice of electrode placement sites, as well as proposed measure for synchronicity of brain activity in different hemispheres, provide a way to assess the spatial and functional brain activity asymmetry.

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SYSTEM OF REGISTRATION BRAIN POTENTIALS WITH SYNCHRONIZATION FROM RESPIRATORY ACTS

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The recording of the evoked potentials (EP) of the spinal cord (SC) has a number of important circumstances. First – this is the place of registration of potentials. Second – is the value of the potential. Third – is noise sources or generators of internal signal. The value of evoked potentials during their registration from the spine surface is an average of 0,8–1 mV. However, if the registration is done in the surface of the body the amplitude of the EP is significantly reduced (30–50 mkV). All case requires a good electrical contact of electrodes with the skin. The first factor, that reduces the information content of the recorded signal – is a cardiogram. Actually, if the registration point of the EP closer to the sternum and the heart – then the more cardiogram is the "noise" and "mask" to EP. This fact requires application cardiosynchronizer in scientific work [1].

The second factor that affects the quality of registered EP SC, is reliable attachment of electrodes to the skin of the subject and the lack of his movements. In this sense, the respiratory movements had a negative impact on the information content of the studied signals. This is especially important when recording potentials from the surface of the back of man, as in this case he has to lie on his stomach. That's why registration processes brain potentials and respiratory acts need to be synchronized in time to reduce the effects of the shift of the electrodes and the emergence of "transient process" in the electrical circuit of registration system. Earlier, for the detuning of the first factor, we have used cardiosynchronizer in our study. But this problem is relatively of respiratory synchronization has not been studied. This