BIO-SIGNALS APPLICATION IN SOLUTION OF HUMAN – MACHINE INTERFACE

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Summary The article deals with the field called Human Machine Interface. It is targeted on the characteristics of the bio signals and their evaluation. Based on the results of cerebral and cephalic bio signals analysis, it is possible to evaluate the immediate physical and psychical condition of the operator of the controlling process. Timely analysis of the bio signals allows avoiding the negative consequences of the incorrect decisions resulting from the attention fatigue.

1. INTRODUCTION

The automation is widely considered the latest way of the production and services, emancipating from the routine operations and leading to a higher productivity. It is a motive power of the technical progress and industrialization. The automation assisted in the projects of the safe and efficient airplanes, ships, trains and cars, and it also contributed to the development of the chemical processes taking into account the ecologic aspects [7]. Today in industry automation area the computer supported information and control systems are intensively exercised. These systems are characterized with wide use of visualization of controlling process. Basic preview and terminology of visualization techniques is in following part of this article. The basic third part is devoted to bio-signals processing, mainly to processing of eye signals [6]. Control of safety critical processes demands to inspect a physical and psychical condition of operator too. Just eye signals analysis seems as hopeful way to make a survey about a fatigue rate of human.

2. HMI / SCADA

The part of the controlling and monitoring system for the major technologic and traffic processes constitute the operator panels or operator terminals (so-called dispatching centres), from where the staff service (operators) monitors and controls the operation, frequently and 24 hours a day. Therefore the equipment of monitoring systems, their comfort and ergonomic resolution is that important. The instruments, called in the technical literature SCADA / HMI (Supervisory Control and Date Acquisition / Human Machine Interface), should offer such comfort of monitoring and controlling of the technical process. The significant parts of these workplaces are the systems for an explanatory chart of the operational data (large-screen displays, computer monitors, projection systems). The field of HMI called Human Computer Interaction (HCI) is concerned with this issue. The work of the operators is very responsible, psychically demanding and stressing. The failure may cause serious problems, losses or even accidents. That is why as soon as during projecting HMI or HCI systems, the elements allowing the staff attention or vigilance control should be taken into consideration. For instance, in elder systems this function was performed by the mechanic bottom of the vigilance of the engine driver. For vigilance control, it is necessary to scan and consequently evaluate certain bio signals.

3. BIO – SIGNALS

The bio – signals are scanned by means of sensors [1]. The sensor is a functional element constituting the entrance block of the measurement chain, which is in the direct contact with the measured settings. The notion of sensor is equivalent to the notion of scanner or detector. Sensor as a primary source of information is scanning the monitored physical, chemical or biological quantity and according to a certain principle defined, it is transforming it into another quantity – most often into the electrical one.

A neuron is the typical infra system of central nervous system (CNS), characterized by asymmetric polarization, which creates the electrical dipole, asymmetric in accordance with the neuron asymmetry, and consequently an open electrical field. Thus, the electromagnetic signals can be recorded on the head surface, as well as the changes of electromagnetic near field and far field, which are the carriers of the information of the CNS functions. Nowadays, the developing electric cerebral activity is recorded by means of the electro-corticography and electro-encephalography. The final record is then called electro-corticogram (ECoG) or electro-encephalogram (EEG).

3.1. Cerebral Bio Signals

EEG is a continuously changing electric signal recorded from the electrodes placed on the skin of the top of the head. The signal comes from the action potentials – short-time changes in the potential differences- of the cerebral neuron cells and it measures the cerebral activity. The measured curves are summing, i.e. they are formed by the membrane potential oscillations of the tens or even hundreds of thousands neurons. Their base is constituted by the excitation and inhibition post-synaptic potentials, acting antagonistically, i.e. at the prevalence of excitation influences, the EEG curve is deflected in one direction (e.g. upwards in case of depolarisation) and at the prevalence of inhibition influences in the opposite direction (as a result of hyper polarization). EEG signals belong to the group of accidental signals, characterized by the fact that their waveform can not be expressed by time relations. In general, it is not possible to determine the precise features of EEG signals, which would be applicable to every person [2]. EEG is changing according to the activity performed at the moment; depending on the age, sex, race and many other features. The basic characteristics of EEG signal [3] include:

- amplitude level, reaching 2 ÷ 300 μV, this value may be even higher at abnormal waveforms,
- frequency range of 0,1 ÷ 80 Hz, lately the band to 30 Hz is used, where the highest signal performance is concentrated.

Tab. 1 Frequency and amplitude related distribution of EEG signals to the rhythms

Prevalent rhythm	Frequency band, Hz	Amplitude, μV
δ – delta	0,5 ÷ 4	≥ 200
θ – heta	4 ÷ 7	≥ 50
α – alfa	8 ÷ 13	10 ÷ 50
β – beta	14 ÷ 25 (sometimes to 50)	5 ÷ 10

δ-rhythm is physiological only in early childhood, in adult age in the phase of orthodox sleep and hypnosis, otherwise the phenomenon is nearly always pathological.

θ-rhythm – in physiological conditions it is recorded in small children, especially from parietal and temporal areas, otherwise it occurs rarely. If its amplitude reaches double alpha activity, or if it occurs only in one place, nidally, it is considered pathological phenomenon. Exceptionally, it may be recorded in adults in the emotional stress.

α-rhythm (Berger rhythm) - can be recorded in person with closed eyes, if the person is not solving a problem requiring the concentration. This rhythm reflects the bio-electrical activity of **"inattentive" brain** (so-called relaxed vigilation). It is best expressed above the occipital areas. It is absorbed in the consequence of visual perceptions – by opening the eyes, but also by increased attention.

β-rhythm- it is recorded in vigilant person with open eyes, or with shut eyes, if there is a mental activity, which requires "attentive" brain. It is best expressed above the frontocentral areas. Usually it is not absorbed by opening the eyes.

3.2. Eye Bio - Signals

The sight is one of the most important human receptors. By means of sight, we can perceive the light, its intensity and colour. The light comes from the source or is reflected by the objects (secondary sources) so that we can distinguish the shape, size, colour, site layout, distance and the motion of these sources. The sight allows us rich intellectual development, education, watching the beautiful things, it is essential to the most of human activities.

Human eyes are just an instrument for sight. The rest is a result of our cerebral activity. What we can see by means of eyes is transmitted by means of optic nerves to the brain in the form of neural signals. The brain consequently processes and evaluates them. In fact, the interpretation of these signals is a result of our world perception.

The sight preceptor is stimulated by the light (electromagnetic) wave in range of wavelengths 400 ÷ 700 nm. Light beams first pass through the complicated optic system of the eye: the cornea, irrigated with the lay of tears, the lens, which is surrounded by the aqueous humour and corpus vitreum. At the interface between these refractive media the light beams breaks, so that the sharp, shrinked and reverse image of the watched object is projected onto the retina. The eye is adjusted to the vision for various distances. Looking near (nearer than 5 cm), the lens elastically deforms (its suspension apparatus loosens by the contraction of ciliar muscle) and herewith its fragility increases. The amount of light entering the eye is controlled by the pigmented iris, increasing or decreasing the aperture in its centre – thus the pupil acts like a shutter. It narrows in the light and expands in the dark. All these processes take place reflexively [4].

3.3. Eye Signals Evaluation Methods

The methods of eye movements' evaluation gain ground not only in ophthalmology and HMI systems, but also in psychology, art, the projects of advertising materials (it investigates the place on the poster, as a first fixed by the sight of the viewer) [5]. The most frequently used methods of eye movement monitoring include [6]:

- videooculography (VOG)
- infrared oculography (IROG)
- electrooculography (EOG) etc.

The videooculography (VOG) has been developing in the world since the end of the sixties. The method is used for the monitoring of the eye position by the video camera. Fastening the camera directly to the head of the subject, the relative eye position to the head is measured and to determine the absolute direction it is necessary to monitor also the position of the head. If it is fastened separately, it is necessary to keep the eye in its visual field and at the same time to distinguish the eye rotation from the translation head movements. Nowadays, the monitoring algorithms are based on the digital image processing. The resolution of the decimal degrees and sampling frequency up to the hundreds of hertz is reached there.

Alongside with the Infrared oculography method it is the most spread and the most sophisticated method of the eye movement monitoring.

The infrared oculography (IROG) is the method monitoring the amount of the reflected light by means of photodetector. The principle is based on the fact that the ocular sclera reflects more falling light than sclerocornea, thus, enlightening the eye, the amount of the reflected light is changing along with the angle turn. Regarding the cover of the sclerocornea with the lid, this method can be used only for the measurement in the horizontal level.

The electro – oculography (EOG) can be used in many objective examinations. For example, it can be used for the evaluation of the functional condition of the eye strings. Further, for the evaluation of the asymmetry or the exophthalmos progression (the protrusion of an eyeball from the orbit). The elaborated records of the eye movements in sleep (polygraphic methods of sleep evaluation) and the records of the nurslings and children eye movements. Pathologic EOG is also in several blood vessel disorders and retinopathies.

During reading, the eye movements have a specific regular character. The eyes move along the lines in the form of quick steps. Between them, there is a fixation of the length 0,15s to 0,5s. Having come to the end of the line during the line spacing, there takes place an individual quick step to the beginning of the following line. The eye movement amplitude and frequency depends on the format of the text (page size, the character of the text spacing on the page and the script). Besides, these EOG parameters are influenced by the degree of the reader's text comprehension.

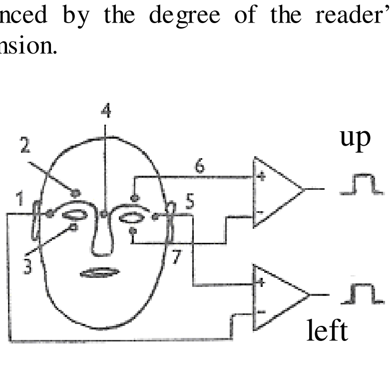

Fig. 1 Electro - Oculography

Reading well distinguishable text with a simple content, the eye movements are horizontal. If the author's style is more difficult or the content of the text is unclear or difficult for the reader, then the eyes of the reader make a quick back movements orientated against the direction of the reading. Reading aloud the amplitude of the quick steps decreases, but their number along the line is increasing. In the people having successfully passed the speed reading course, the character of the eye movement is different (instead of quite regular eye movements from the left to the right there are recorded individual quick steps in mutually opposite directions – to the left and to the right). It is probably related to the intention to increase the amount of information gained in a time unit. The lateral eye movements analysis is also used in psycho physiological methods, e.g. in logopaedia. In psychiatry, it is possible to use the electro – oculographic method for the evaluation of emotions, for the objective evaluation of the treatment efficacy etc. In a manner, the EOG modifications gain ground in criminalistics (in the investigation of the suspect persons).

3.4. EOG Signal Processing

Usually the EOG signal is evaluated according to equation

$$U_{\varphi_1} = \frac{1}{T \cdot \varphi_1} \int_0^{T_M} |u(t)| dt, \quad (1)$$

or via an impulse EOG application with using of formula

$$U_{\varphi_2} = \left(\frac{du}{dt} \right)_{\max} \cdot \frac{1}{\omega}. \quad (2)$$

For impulse EOG it is coming out from differential equation

$$\frac{du}{d\varphi} = \frac{du}{dt} : \frac{d\varphi}{dt}, \quad (3)$$

where $d\varphi / dt$ is angular speed. In equations the following drive letters are used: T is an integration constant of integrator, U_{φ_1} is potential value, corresponding to 1° eye displacement, T_M is time interval when the averaging is realised, U_{φ_2} is derivation of potential with reference to an angle, $\left(\frac{du}{dt}\right)_{\max}$ is maximum value of first derivation of EOG potential according to time (during measurement time T_M), ω is angular speed of eye motion if stimuli location is changed.

Abroad very closed relation between both measurements was determined (in pathological cases of IEOG, changes of constant potential are adequately expressed). Even if EOG tests were ineffective, the IEOG results were applicable.

Somewhere for EOG evaluation the Ardenov coefficient *R* can be used:

$$R = \frac{\max\ EOG\ value\ in\ the\ light}{\min\ EOG\ value\ in\ the\ dark} .100\ \%. \quad (4)$$

4. CONCLUSION

The evaluation of the cerebral and eye bio signals is the topical issue not only in HMI area, but also in the developing new field – the auto electronics. The basic question is a reliable perception and evaluation namely of such bio signals, which monitor the psychical condition of the control process operator, or the motor vehicle driver. The used sensors must not limit the operator (driver) in the work activity performance. The chosen methodics must offer an objective image of the operator's condition. Permanent vigilance control should contribute to the increase of the safety of the technological equipments operation.

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