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SYSTEM FOR READING AND ANALYZING SIGNALS OF THE HUMAN BRAIN

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Abstract. The given work is devoted to the methods for analysis of signals of the encephalograph by neural networks. A system for analysis of read brain signals using a handheld computer Raspberry Pi 3b+ is proposed. On the basis of this system it is proposed to create a neural network which will analyze the received signals. Analytical review of a device for reading and analysis of human brain signals using an encephalograph was performed. The parameters of the components were calculated and described the necessary components. The existing methods of receiving signals of the human brain are analyzed. Methods of analysis for additional algorithms of machine analysis are looked at.

The basis of Neurocomputer Interface is the recognition of patterns of brain biopotentials. If the subject can change the nature of his biopotentials, for example, by performing certain mental tasks, the NCI system could translate these changes into control codes, such as by moving the mouse cursor on a computer screen or the hand of a robot manipulator. You can also use these codes to select letters on a "virtual keyboard" or to control a wheelchair.

The most of current Neurocomputer Interfaces are preprogrammed. Firstly, that means that it is not consider brain characteristics of each user. This causes difference in work for each person so it may be very easy for one user and really hard for other. Secondly, a device can do built in tasks only. It can be really hard and even impossible to add new functionality to device.

These restrictions can be removed by a device that can collect signals of human brain, label them and create the model that represents their connections and then use this model to recognize current state of human brain. This problem can be solved by connecting neurointerface to the pocket PC Raspberry pi 3b+ because it is compact enough and already have all needed data interfaces on RPi bus. Although, it can use

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python programming language that allows us to use tensorflow package that have already have a lot of functionality in using of neural networks.

Keywords: Encephalograph, neurointerface, neural networks, human brain signals, Raspberry Pi 3b+.

Section: Information Technology in medicine.

Introduction. The possibility of record any movement, perception or internal mental activity is associated with a certain pattern of activation of neurons that interact with each other through electrical impulses [1]. These currents create an electromagnetic field that can be registered outside the head using electroencephalography (EEG) and magnetoencephalography (MEG).

In 1988, Farvel and Donchin first implemented a "virtual keyboard" system, which made it possible to type text by recognizing the P300 component when capturing visual evoked potentials (EPs). After that, many different modifications of NCI were developed: systems with increasing capabilities, which have already found their application both in the clinic for communication with patients who have completely lost the ability to move [2] and as innovative technological projects for remote control [3].

The speed of information transfer of this new communication channel is still low. However, constant advances in EEG recording techniques, signal processing algorithms and pattern recognition, a deeper understanding of neurophysiology and the involvement of more and more scientists in these works provide a steady increase in this speed, increasing the number of applications and dynamic progress in general.

If in 1994 there were only 6 research groups engaged in NCI, then the first international congress on NCI in 1999 was attended by researchers from 2 dozen laboratories. At the second congress in 2002, there were researchers representing 38 research groups, including the United States, Germany, China, Finland, Switzerland, England, Canada, and others.

The EEG method, developed by Hans Berger in 1929, has been used successfully for many years for 3 purposes:

– diagnosis of neurological disorders in clinics and hospitals;
– to study brain functions in neurophysiological laboratories;
– for the therapeutic purposes based on biological feedback.

Also, EEG can also be used to control external devices directly. This 4th application of EEG is called the Neurocomputer Interface (NCI). Examples of such devices are:

– manipulator, analog of a computer mouse and keyboard;
– device for entering data into augmented reality glasses;

– a signal reading module for exoskeleton and prostheses.

But the most of common NCI now are preprogramed to make one or few tasks so this imposes such restrictions on these devices:

– It is impossible or really hard to add new functionality to a device;

– Most of devices are programmed to work fine with a group of people so it can work better on one person and worse on other.

These restrictions can be removed by a device that can collect signals of human brain, label them and create the model that represents their connections and then use this model to recognize current state of human brain. This problem can be solved by connecting neurointerface to the pocket PC Raspberry pi 3b+ because it is compact enough and already have all needed data interfaces on RPi bus. Although, it can use python programming language that allows us to use tensorflow package that have already have a lot of functionality in using of neural networks.

This device is also useful because it allows a person to monitor the health of the brain. It can be used constantly so it can be used to prevent diseases on early stages when they are easier to cure.

Objective. The basis of NCI is the recognition of patterns of brain biopotentials. If the subject can change the nature of his biopotentials, for example, by performing certain mental tasks, the NCI system could translate these changes into control codes, such as by moving the mouse cursor on a computer screen or the hand of a robot manipulator. You can also use these codes to select letters on a "virtual keyboard" or to control a wheelchair.

The most of current NCI are preprogrammed. Firstly, that means that it is not consider brain characteristics of each user. This causes difference in work for each person so it may be very easy for one user and really hard for other.

Secondly, a device can do built in tasks only. It can be really hard and even impossible to add new functionality to device. For example, adding “additional button” for keyboard or speed control for wheelchair can cause a lot of trouble for user.

Materials and methods. The definition of NCI given in the work of Walpal and others [4] received the greatest recognition:

NCI is a communication system in which messages or commands sent by an individual to the outside world do not pass through the normal normal output channels of the brain in the form of peripheral nerves and muscles.

According to this definition, blinking cannot be used by the NCI system. Either the biopotentials of the brain recorded from the surface of the scalp - EEG, or from the surface of the cortex -

electrocorticograms (ECoG), or intracerebral leads are used. The last two methods relate to invasive NCI. There are also other definitions of NCI, for example:

NCI is a human-computer interface that receives commands directly from the brain without making any physical movement. NCI uses electrophysiological signals to control external devices.

A neurocomputer interface (also called a direct neural interface, a brain interface, a brain-computer interface [5]) was created. It is a system designed to exchange information between the brain and electronic equipment (such as a computer). In unidirectional interfaces, external equipment can either receive signals from the brain or send signals to it. Bidirectional interfaces allow the brain with external equipment to exchange information in both directions. At the heart of the neurocomputer interface, the biological feedback method is often used.

The NKI systems include (Fig. 1.):

1. Electrodes for drainage of biopotentials. The minimum number is 2, more often they record using 21, 64 and even 128 channels. With a large number of electrodes, electrode helmets are used for the speed of establishing and increasing the positioning accuracy of the electrodes over certain brain fields, as well as the reproducibility of their location from experiment to experiment.

2. A biopotential enhancer that connects to a computer or directly (for example, via a USB port) or via an interface card using an operational amplifier.

3. Personal computer for recording signals and processing them. Because many systems use feedback elements, either the same computer or an optional PC that shows the test incentives and produces recognition results, such as the text that was entered.

4. Software for EEG registration and processing, pattern recognition, inducement and output recognition.

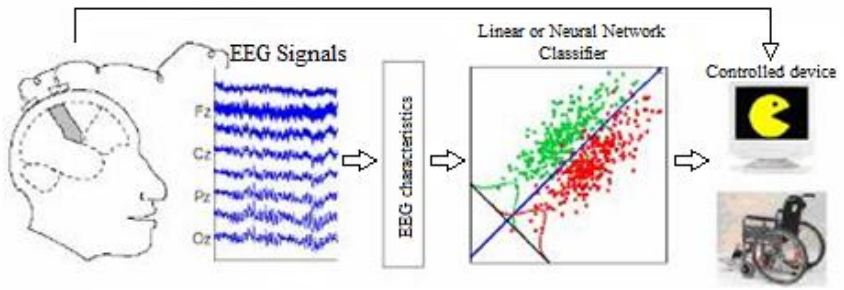

Fig. 1 – Structure scheme of NCI.

When conducting EEG measure the total postsynaptic currents. The action potential (PD, short-term potential change) in the presynaptic axon membrane causes the release of the neurotransmitter into the synaptic cleft [6].

A neurotransmitter, or neurotransmitter, is a chemical that transmits nerve impulses through synapses between neurons. After passing through the synaptic cleft, the neurotransmitter binds to the receptors of the postsynaptic membrane. This causes ionic currents in the postsynaptic membrane. As a result, compensatory currents occur in the extracellular space. It is these extracellular currents that form the potential of the EEG. EEG is insensitive to axonal PD.

Although the formation of the EEG signal responsible postsynaptic potentials, surface EEG is not able to capture the activity of a single dendrite or neuron. It is more correct to say that superficial EEG represents the sum of synchronous activity of hundreds of neurons having the same orientation in space, located radially to the scalp. Currents directed to the scalp are not recorded. Thus, during the EEG activity of radially located apical dendrites is recorded. As the voltage of the field decreases in proportion to the distance to its source in the fourth degree, the activity of neurons in the deep layers of the brain is recorded much tighter than the currents directly near the skin.

Currents registered for EEG are characterized by different frequencies, spatial distribution, and interconnections with different brain states (eg, sleep or wakefulness). Such potential fluctuations represent the synchronized activity of an entire network of neurons. Only some of the neural networks responsible for registered oscillations (eg, thalamocortical resonance underlying "sleepy spindles" - accelerated alpha rhythms during sleep) have been identified, whereas many others (eg, the system that forms the occipital main rhythm) not installed [3].

To obtain traditional surface EEG recording is made using electrodes placed on the scalp with the use of electrically conductive gel or ointment. Usually before the electrode is placed, it is possible to remove dead skin cells that increase resistance [4]. The technique can be refined using carbon nanotubes that penetrate the top layers of the skin and help improve electrical contact. This sensor system is called ENOBIO; however, the technique presented in general practice (neither in scientific research nor in the clinic) has not yet been used. Usually, many systems use electrodes, each with a separate wire. Some systems use special hats or mesh helmet designs that incorporate electrodes; most often this approach justifies itself when using a kit with more tightly spaced electrodes.

For most applications in the clinic and for research purposes (except kits with more electrodes), the location and name of the electrodes are defined by the International "10-20%" system. The use of this system ensures that the names of the electrodes between different laboratories are strictly consistent. The clinic most commonly uses a set of 19 discharge leads (plus grounding and reference electrode).

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Generally, fewer electrodes are used to register EEG infants. Additional electrodes can be used to obtain the EEG of a particular brain region with a higher spatial resolution. A set with more electrodes (usually in the form of a hat or mesh helmet) can hold up to 256 electrodes located on the head at more or less the same distance from each other.

Each electrode is connected to one input of a differential amplifier (ie one amplifier is a pair of electrodes); in the standard system, the reference electrode is connected to the other input of each differential amplifier. Such an amplifier increases the potential between the measuring electrode and the reference electrode (usually 1,000-100,000 times, or the voltage gain is 60-100 dB). In the case of an analog EEG, the signal then passes through the filter. At the output the signal is registered. For clinical surface EEG, the frequency of analog-to-digital conversion occurs at 256-512 Hz; Up to 10 kHz conversion rate is used for scientific purposes.

In order to obtain a compact portable structure that does not need to be greased with a gel, it is necessary to perform a preliminary amplification of the signal by means of a differential amplifier made directly on the sensor (Fig. 2) [7]. This will also filter out the noise and increase the quality of the read signal.

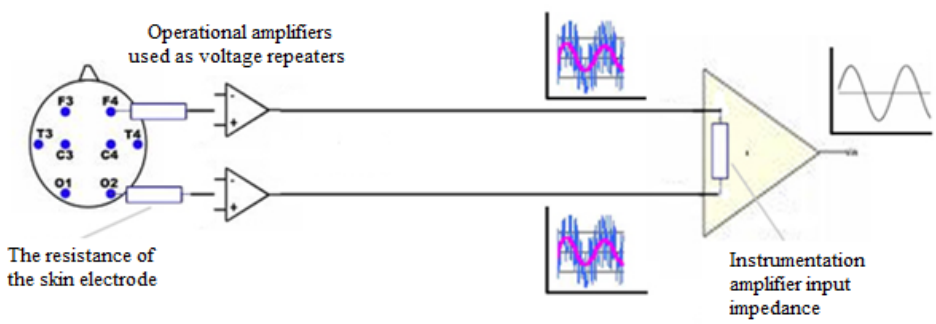

Fig. 2 – Functional scheme for connecting dry electrodes.

This system is implemented on a pocket PC Raspberry Pi 3b+. This device can control the transmission or through interfaces such as I2C, SPI and OneWire using RPI bus. The signal is read by a four-channel ADC ADS1115 connected via the I2C interface on a monopolar circuit. Scheme of electrode of encephalograph is presented in fig. 3 and structural scheme of a NCI is presented in fig. 4.

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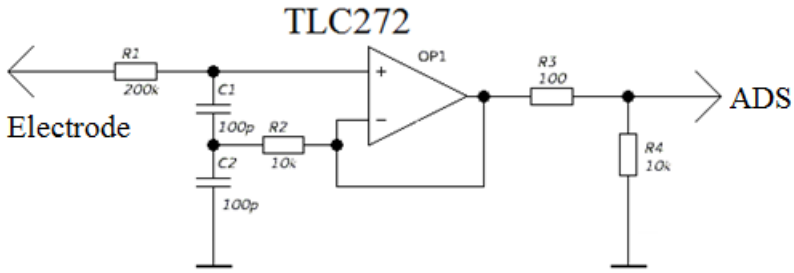

Fig. 3 – Scheme of the electrode of the encephalograph.

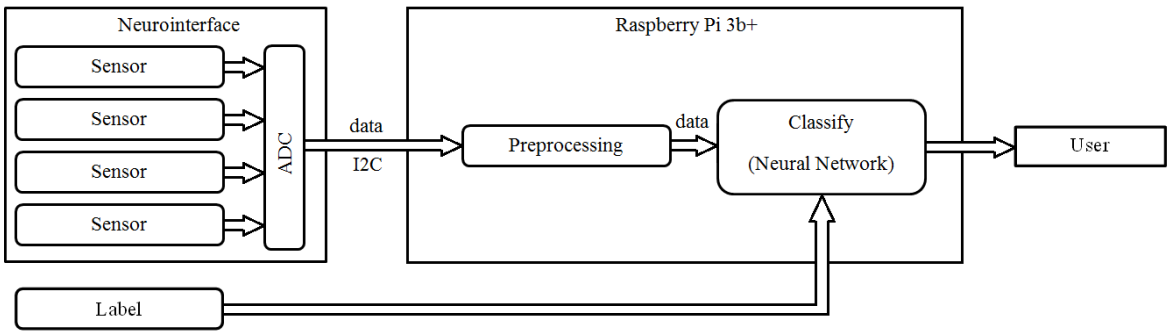

Fig. 4 – Structural scheme of a NCI.

The difference between the signals between the electrodes is calculated by subtracting one signal from another using a program. Thus, there is no loss of data. The result of the survey of sensors using the ADC is presented in Fig. 5.

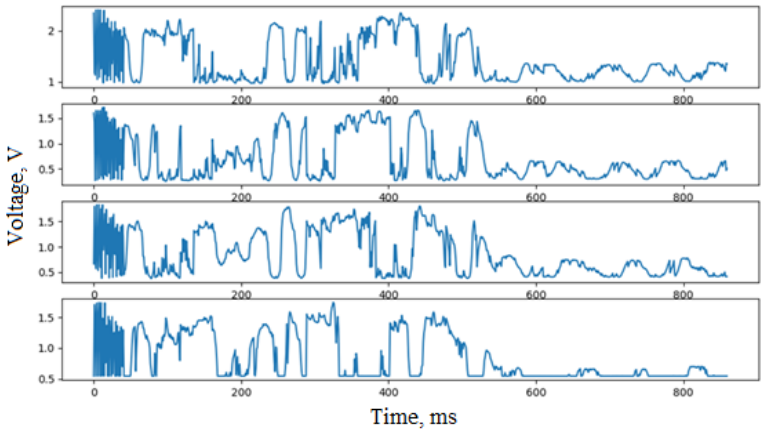

Fig. 5 – The result of the survey of encephalograph sensors using ADC ADS1115.

Conclusions. Analytical review of a device for reading and analysis of human brain signals using an encephalograph was performed. The parameters of the components were calculated and described the necessary components. The existing methods of receiving signals of the human brain are analyzed. Methods of analysis for additional algorithms of machine analysis are looked at. The efficient methods of rejection of signals in the human brain have been analyzed and a compact 4-channel system has been implemented for reading the samples on a pocket PC Raspberry Pi 3b+.

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