Hardware and Software System for Monitoring and Processing Data of Electrical Activity of the Brain

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*Abstract*— From the moment of consciousness of the human brain as the most important part of the human body, literally is all that of human being represented, his experience and knowledge, tried to know all the nuances of brain work. We have already reached certain heights in this undertaking, but we are only at the beginning of the path. To study the brain, many technologies have been created that allow you to literally look inside the process of the brain work, and sometimes even communicate with it. Nowadays, the industry of neurointerfaces is rapidly developing, perhaps in the foreseeable future there will be invasive neurointerfaces that will firmly enter the everyday life of mankind. But until this time has come, it is necessary to use what is exist and develop a basis on non-invasive interfaces until invasive ones come into our everyday life. This paper describes the prototype of brain-computer interface, describes how it will work and all stages of this project.

Keywords—Bluetooth, EEG, P300, biosignal, BCI, biopotentials, neurointerface

# Introduction

The existence of brain-computer interfaces (BCI) is due to the desire to simplify communication between humans and computers. Attempts to study the features of the human brain led to the fact that in 1849 it was discovered that the brain has electrical activity as well as muscles and nerves. In 1924, after a long time, it was possible to obtain a record of a human biosignal, which can be considered the initial first point, thanks to which the way was found not only to study the human brain more closely, but also to obtain real-time biosignal information and use it to manipulate.

These devices are called BCI or neurointerfaces, and they provide communication between the device and the brain by recording electrical activity. BCI are mainly used in medicine, but already now BCI technology is applicable in other areas, such as marketing, gaming, and others. The existing market situation is not the limit. Every year neurointerfaces are approaching the moment when they will firmly enter our life.

Some companies are developing invasive prototypes that are being successfully tested. Not so far that day, when a person with neuroimplants will become commonplace, and not a necessity due to medical indications. Therefore, it is already important to conduct development and research in this area in order to develop a basis that will help in the future when invasive interfaces are introduced into our life.

This paper describes a software and hardware complex project, a BCI that allows you to record electroencephalogram (EEG) data and transmit to a companion device over a wireless network. To understand the principles of this project, firstly need to understand how EEG technology works, how to count human biopotentials, how to convey them, how to interpret them.

# Theory

There are many types of neurointerfaces [1], most of them are based on EEG technology. An EEG is a process that detects electrical activity in your brain using small electrodes attached to your scalp. This technology has become widespread, due to the safety of use, a small number of components, small dimensions and low cost. BCIs are also divided into the method of connection, the most common now is non-invasive, that is, an interface that is not integrated into the human body but is located on it. Invasive interfaces are currently being actively studied, but are implemented only in exceptional cases, due to the too high risk of their installation into the patient's body. The data obtained by non-invasive BCI by means of electrodes is much worse than that of invasive ones and require multiple processing and filtering.

The number and location of electrodes on the user's scalp depends on the purpose of the device, on what data we want to receive. The EEG data that can be obtained now is classified into waves [2] formed by the frequency of fluctuations in the voltage of biopotentials:

* Alpha waves range in frequency from 9 to 11 Hz. Associated with calm state of mind. It can be found in the occipital and posterior regions of the brain.
* Beta waves range in frequency from 13 to 30 Hz. Associated with active concentration, busy or anxious states. Acquired from the central, frontal, parietal lobes.
* Theta waves range in frequency from 4 to 7 Hz. Occur mostly in the temporal, parietal regions. Can be found during sleep. Often found in adults during hyperventilation.
* Delta waves range in frequency from 0.5 to 4 Hz. Tend to have the slowest frequencies and the highest amplitude. Associated with slow wave sleep. Occur mostly in prominent frontally in adults and in posterior parts in children.

Waves allow you to accurately assess the work of a particular part of the brain and draw conclusions. Mostly neurointerfaces are built on waves processing, but besides this, there are other ways to implement the interaction between the BCI and the person. The human brain can respond specifically to stimulus. Not many stimuluses have been found, but those that exist work reliably enough.

P300 From the point of view of the EEG, just a burst at a certain time in a certain channel. There are many ways to cause it, if human concentrate on one object, it will be activated at the moment of state changing, a state like a shape, colour, brightness or movement. This behaviour allows a variety of interfaces to be implemented based on the P300's search in EEG data when responding to state changes.

# Task

This project involves the development of hardware and software system for monitoring and processing data of electrical activity of the brain. The purpose of this neurointerface is data collection, but within the framework of the project it is necessary that, in addition to collecting information, the BCI implements demo modes and functions of communicating with the companion application. The complete list of tasks that need to be implemented is as follows:

* Autonomous operation of the device, sleep mode, control of EEG data collection, collection of this data and transmission of this data to a companion device via a Bluetooth wireless network.
* A companion application that visualizes EEG data in real time, with the ability to record and replay work sessions. P300 point search demo mode.

Consequently, the entire project is divided into 4 subtasks:

* Hardware implementation.
* Software for the hardware.
* Companion software.
* Pre-processing of EEG data and P300 search.

# Hardware implementation

Within the framework of this project, a helmet will be implemented, under the standard international connection diagram for electrodes “10-20” [3]. But with the connection of only a small number of electrodes, at least two. In order to reduce the cost of the prototype, but with the preservation of the possibility of expanding the project. The connection of the electrodes is planned to be dry using a bipolar lead.

To solve the tasks facing the neurointerface, a prototype of the board was designed and has already been partially tested. It is based on the STM32WB55CCU6 [4] microcontroller, which consists of two cores, one of which is responsible for working with Bluetooth. The second core controls the software, which is responsible for the functioning of the neurointerface, and interacts with the Bluetooth core for data transfer.

The device hardware is divided into modules, each of which is responsible for the correct operation of the device. The device implements a power system module based on MCP1703T, L6924D, STC3100IST and TPS60403DBVR. This module provides a charge of the built into the device lithium battery and generate the required voltage for other modules. The memory module of the device has EEPROM I2C module with 1kb memory.

A module responsible for collecting data directly from the human scalp. It consists of two operational amplifiers LM358, based on which a low-pass filter and a high-pass filter are built [5]. Them cut off frequencies above 0.5 hz and below 30 hz and collects data only on those frequencies that correspond to the classification by waves. This module is necessary in order to filter out a lot of noise from human movement and other signals around. There is also a specialized amplifier AD8422 for reading the biopotential, which amplifies it by 20000 times. At the exit from this module, we receive an analog signal, which will be analysed later. Also, the device has a connection module that supports USB and SWD connections.

# Software for the hardware

Within the framework of this part, it is planned to develop software that implements the required tasks in the C ++ language, using the libraries supplied by the STMicroelectronics (microcontroller manufacturer) SPL and HAL. Also, will be using the software supplied by them to develop and debug applications based on their microcontrollers.

# Companion software

The companion application does all the work of analysing and visualizing the data received from the neurointerface. To implement the companion application, it is planned to use the C # language. The application will run on the Windows operating system. In addition to visualizing the received data, the application will have a demo mode, in particular a keyboard that will work based on the search for the P300 point among the EEG data.

# Pre-processing of EEG data and P300 search

For the correct operation of the software and hardware complex, it is necessary to accurately analyse and interpret the received EEG data. For these purposes, there are several ready-made solutions that provide mathematical algorithms [6] or neural networks.

The necessary mathematical methods, in addition to manual implementation, can be obtained through the open source MNE [7] Python package for exploring, visualizing, and analysing human neurophysiological EEG data. It is providing algorithms that cover multiple methods of data preprocessing, source localization, statistical analysis, and estimation of functional connectivity between distributed brain regions. The MNE library will allow to perform all the necessary transformations for EEG analysis: filtering, smoothing, pattern and P300 search.

# Conclusion

This project does not offer revolutionary ideas, new technologies, algorithms or methods. But it significantly lowers the threshold for entering the neurointerface industry. Often, analogues used for medical purposes cost a lot of money, while offering the same functionality that is planned in this project. The reduced entry threshold will not only increase medical accessibility, in case of high-quality project execution, but will also allow amateurs to create such devices faster and easier. This will spread knowledge about neurointerface technologies and stimulate research among amateurs. Each research is a small step not only in knowing ourselves, but also in the approach of those times when neuro-implants will become commonplace and not a fairy tale about the future.

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