

Evaluation Of The Neurosky MindFlex EEG Headset Brain Waves Data

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Abstract—In human brain, either in the state of wakefulness or sleeping, different frequency changes are observable in the spectrum of measured electric signals of the brain. Regarding the frequency components of these signals that occur as a consequence of this electric activity, different brain waves can be distinguished. The electric impulse alternations that generated during the operation of neurons can be measured by the EEG (electroencephalograph) device. In the past, devices that could measure these brain signal alterations were mainly used in medicine. However, in the past few years cheaper and user friendly brainwave signal processing units have become available and the use of this technology has expanded. In this paper, the so-called Brain Computer Interface unit will be presented that was developed for further brain wave analysis and ensures the detection of brain waves. Moreover, an application for visualization and further procession of the measured and processed signals will also be described. The application can be used for EEG data acquisition, processing and visualization which could be the base of several further researches.

I. INTRODUCTION

According to Galvani's thesis published in 1791, brain could generate electricity. Thanks to the work of Fritsch and Hitzig (1870) and later Ferrier (1875), it became clear that movement and perceptive phenomena could be generated by the electric stimulation of the cerebral cortex. Hans Berger (1929), a psychiatrist working at the University of Jena, was the first person who used EEG leads. The EEG signal is a complex, multi-component periodic curve which is dominated by relatively large amplitudes ranging between 8-12 Hz waves in relaxed state. It is called Alpha activity. Berger observed that, as a result of light stimulus, mental activity or intensive emotional influence, the alpha activity is replaced by a lower amplitude but higher frequency component called Beta activity.

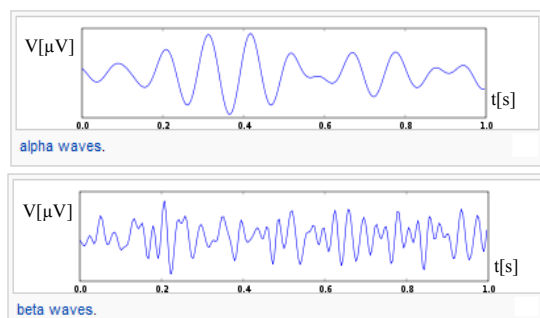


Figure 1. Example alpha and beta brain wave signals [6]

The traditional EEG analysis facilitates the graphical illustration of the temporal and spatial features of electric brain activity. The mathematical procession of the EEG signals could nowadays easily be done by digital signal processing units. The so-called quantitative EEG (QEEG) signal evaluation method, i. e. the frequency analysis of EEG signals with the application of computer processing, could be simply accomplished. With the use of Fourier transform, the digital EEG signals using QEEG are converted so that frequency bands and brain wave intensity can be defined and visualised in an exact way according to their frequency spectra. The frequency and amplitude range of each brain wave type is shown in Table 1 and the time functions of alpha and beta waves are shown in Figure 1 [1].

TABLE I.
FREQUENCY COMPONENTS OF BRAIN WAVES [2]

Brain Wave Type	Frequency Spectrum (Hz)	Amplitude (μV)	Significance
Delta	0,1-0,3	100-200	• deepest, dreamless sleep • unconscious state • cognitive tasks by frontal lobe
Theta	4,0-7,5	<30	• REM sleep, dreaming • physiological at the age of 1-6 • cognitive task by frontal lobe (Fourier analysis) • Intuitivity, creativity
Alpha	8,0-12,0	30-50	• the "basic" wave of the brain • when stimulated high frequency rhythm occurs (alpha block) • relaxed, but non-sleepy state
Beta	13,0-30,0	<20	• sensory and emotional influences • harmonic, wide awake, excited, conscious state
Gamma	30,0-50,0	<10	• high mental activity

II. REGISTRATION OF EEG SIGNALS

To detect EEG signals, electrodes are placed on the hairy scalp. These electrodes are of low resistance. Two methods - bipolar and monopolar- could be used to lead voltage. In the former case, the voltage difference is measured between adjacent points, while in the other case, there is a reference point, also referred to as a null point, and the voltage difference is measured to this. This null point electrode should be placed in an area where its potential is not influenced by brain activity, for example on the earlobes. For clinical and diagnostic examinations, the bipolar lead is used generally. The monopolar lead is particularly applied in different research and tests, as it gives a general information about brain activity. The main advantage of this method is that the null point makes the comparison of signals possible in several electrode pairing. On the contrary, there is not an ideal null point area and that is the main disadvantage of this method. The bipolar version is a better choice for local analysis, as the neighbouring areas can be compared, and that is the reason why it is more likely to be used for diagnosing. In this method, the brain signals measured on the two active halves of the skull are compared. Any activity together with these signals is subtracted and only the difference is registered. [3]

A. EEG Headsets

The detection of brain signals and their transmission to the signal processing – possibly instant processing – unit is implemented with the use of the EEG signal measuring sensors that are placed on the head and the signal processing and transmitting electrical units. In most cases the EEG devices capable of EEG signal transmission via wireless connection.

In the past few years, EEG headsets, which besides the brain signal detecting unit, also contains the analog-digital converter to convert the detected brain signals to digital ones, a signal processor unit for further processing (e. g. FFT algorithm) and a communication unit that can send these signals through the communication channel, have become available. To make these devices more mobile, they can gain energy from their own energy supply, either from batteries or an accumulator.

B. MindFlex EEG Headset

MindFlex is a brain trainer device based on the ThinkGear technology that was developed by NeuroSky. The device contains a controlled unit and a wireless EEG headset (Figure 2). This MindFlex EEG headset can be fixed on the head thanks to its rubber design. Its energy supply is ensured by three pieces of 1,5 V AA batteries. Brain signals are detected by a metal electrode constricted to the forehead by monopolar method and the null point is the electrode clipped on the earlobes (null reference).

The signal processing unit, also developed by the ThinkGear technology of NeuroSky, can determine the value of concentration or attention. The NeuroSky MindFlex EEG headset transmits the processed signals to the controlled unit through a wireless network, but non-standard WiFi connection.



Figure 2. MindFlex EEG Headset

C. Data Communication with EEG Headset

As the MindFlex EEG Headset does not use a standard wireless communication channel the way of communication had to be solved to read the information provided by the headset, i.e. the connection with the headset had to be established differently. To do this, it was necessary to implement the receiver of wireless signals and the procession of the received data. To achieve this communication, an interface unit that could be applied with the computer and the knowledge of the communication protocol were required. To produce or provide such an interface unit that can be used with the computer and is able to communicate with the headset, the wireless communication method of the headset had to be determined. The case containing the electronics of the EEG headset had to be disassembled to examine the type of wireless chip used in the headset. Unfortunately, the exact type of the chip providing wireless transmission in the headset could not be read; therefore, the read of the information processed by the headset had to be solved in another way. Examining the internal construction of the EEG electrical unit, the power adapter providing 3,3 V supply voltage and a pin with a Tx label could be noticed. Having examined this Tx signal, a serial line information could be retrieved. The internal construction of the EEG headset is shown in Figure 3.

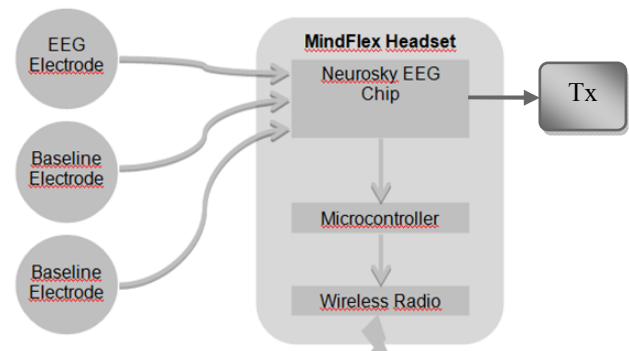


Figure 3. Electronic units of MindFlex EEG Headset

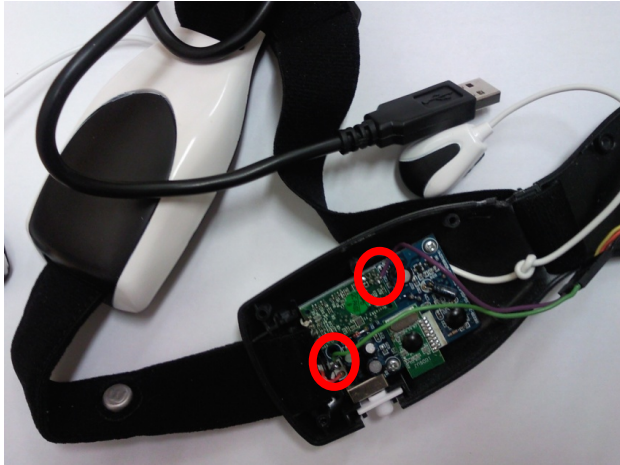


Figure 4. Installation of FTDI USB-UART interface

To process the data coming from this serial communication with a computer, a converter was needed that could convert the information of a 3,3 V serial port signal to an input available on the computer. The simplest solution is to use an USB-3,3 V UART converter, for example the FTDI TTL-232-3V3 type. Its installation is shown in Figure 4. Using the converter, the noise of the measured signals increased greatly; therefore, an optical isolation unit had to be applied to prevent the noise coming from the computer. The Windows driver of the converter hardware unit was necessary to be able to use the cable, which could be downloaded from the FTDI's official site. The converter can be used as a virtual serial port with this driver. The sample of this serial data is shown in Table II.

TABLE II.
SAMPLE OF SERIAL LINE DATA [4]

[0]: 0xAA	[SYNC]
[1]: 0xAA	[SYNC]
[2]: 0x20	[PLENGTH] (payload length) of 32 bytes
[3]: 0x02	[POOR_SIGNAL] Quality
[4]: 0x00	No poor signal detected (0/200)
[5]: 0x83	[ASIC_EEG_POWER_INT]
[6]: 0x18	[VLENGTH] 24 bytes
[7]: 0x00	(1/3) Begin Delta bytes
[8]: 0x00	(2/3)
[9]: 0x94	(3/3) End Delta bytes
[10]: 0x00	(1/3) Begin Theta bytes
[11]: 0x00	(2/3)
[12]: 0x42	(3/3) End Theta bytes
[13]: 0x00	(1/3) Begin Low-alpha bytes
[14]: 0x00	(2/3)
[15]: 0x0B	(3/3) End Low-alpha bytes
[16]: 0x00	(1/3) Begin High-alpha bytes
[17]: 0x00	(2/3)
[18]: 0x64	(3/3) End High-alpha bytes
[19]: 0x00	(1/3) Begin Low-beta bytes
[20]: 0x00	(2/3)
[21]: 0x4D	(3/3) End Low-beta bytes
[22]: 0x00	(1/3) Begin High-beta bytes
[23]: 0x00	(2/3)
[24]: 0x3D	(3/3) End High-beta bytes
[25]: 0x00	(1/3) Begin Low-gamma bytes
[26]: 0x00	(2/3)
[27]: 0x07	(3/3) End Low-gamma bytes
[28]: 0x00	(1/3) Begin Mid-gamma bytes
[29]: 0x00	(2/3)
[30]: 0x05	(3/3) End Mid-gamma bytes
[31]: 0x04	[ATTENTION] eSense
[32]: 0x0D	eSense Attention level of 13
[33]: 0x05	[MEDITATION] eSense
[34]: 0x3D	eSense Meditation level of 61
[35]: 0x34	[CHKSUM] (1's comp inverse of 8-bit Payload sum of 0xCB)

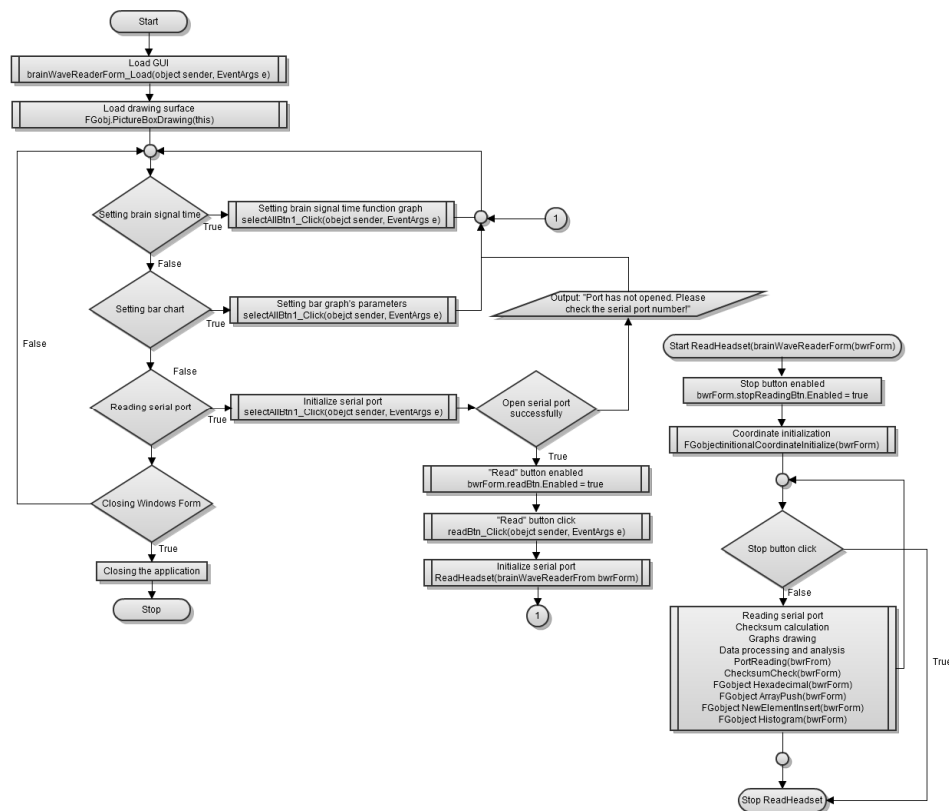


Figure 5. The simplified flowchart of the program

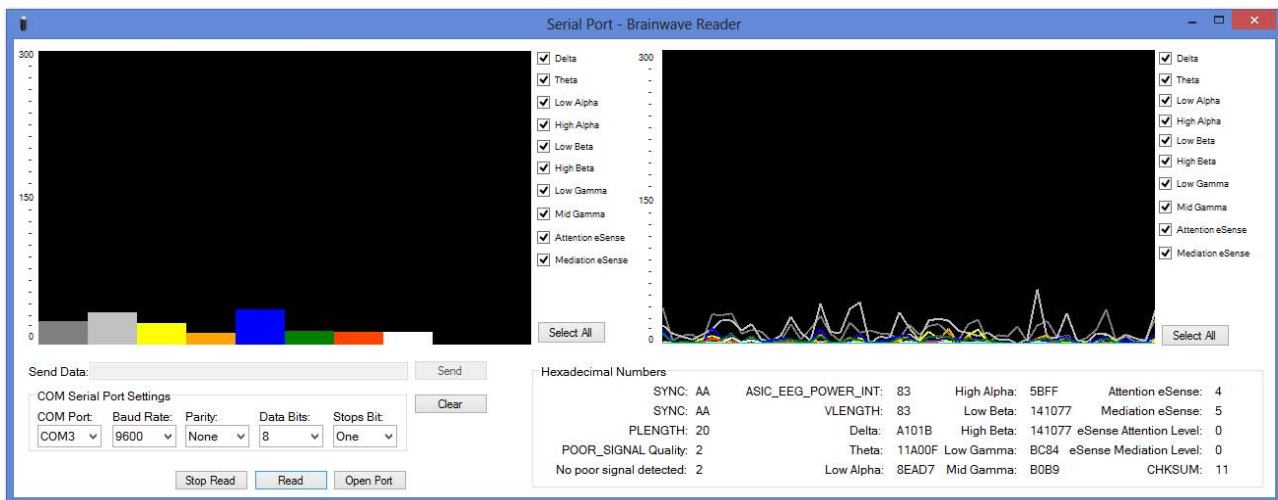


Figure 6. User interface and measured brain waves

III. BRAIN COMPUTER INTERFACE

The brain computer interface (BCI) is also called neural interface or brain machine interface (BMI), which is a direct communication channel between the brain and a separate device. [5]

A Windows Forms Application has been developed to evaluate and visualize the brain wave data of the MindFlex EEG headset, described in the previous chapter. This BCI program can run on a PC and has been written in C#. Microsoft Visual Studio was used to implement the program, which is a developing environment that supports modern object-oriented programming and has been used in Windows operating systems.

The program can be divided into two main parts functionally: the data processing and the visualization parts. The data processing part reads, converts, processes data received from the headset through serial connection, and the visualization part displays given signals by a column chart and a time chart. The user interface can be seen on Figure 6.

After starting, the user has to give serial port settings, for instance, the serial port number, parity bites, etc. Once successful setting is finished, the serial connection has to be opened for reading. After the beginning of reading, the components of different frequency spectra can be observed. The values of brain wave signals can be viewed in the column charts, while if you want to see signal changes in time, just simply click on the brain wave types in the line styled diagram on the right side and the software will visualize it. Of course, more than one brain wave type can be checked. The reading procedure can be stopped or restarted any time.

The source code contains three classes: one of them is the so-called BrainWaveReaderForm, which deals with events and derives from the Form class which derives from the source of all classes named Object. The second class is called the FormGraphics class and is responsible for data visualization and is in connection with BrainWaveReaderForm class. The third class is the SerialPortManager, which manages serial port. In Figure

5, you can see a flowchart and a class chart illustrating the main parts of the operation of the program. [7]

IV. CONCLUSIONS

The novelty of this development is the universal measuring, data collecting, data processing and visualizing software which could be the base of several further researches. The program described above enable users to investigate how brain wave signals - measured by the EEG headset - alternate in time and how they depend on the changes of brain activity. On the basis of the results, the information obtained by the processed brain waves can be used in several research areas, for instance medical research, multimedia applications, games etc. The program can easily be further developed and added new functions due to its modular build. The program allows the development of individual processing algorithms. On the other hand, the EEG headset could be interfaced to other devices owing to this application and the control of these devices can also be solved, for instance, the speed control of a mobile robot, so it can be claimed that the developed BCI can be the basis of future application developments.

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