ANALYSIS OF HUMAN ELECTROENCEPHALOGRAM IN MATLAB

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Abstract

In our research we analyse the influence of sound in human electroencephalogram (EEG). Our experiments are performed on subjects sitting on a chair with closed eyes relaxing in the dark inside an audiology room. They are listening to the sound sequence. Their EEG signal is monitored by four channel EEG device connected to PC. Data are stored in special software and exported to MATLAB as TXT files for other analysis. This paper deals with a processing of recorded EEG data and describes MATLAB scripts programmed for this purpose. Special functions serves for drawing diagrams in time domain, filtering signal to delta, theta, alpha, beta and gamma bands by using filters with finite impulse response, dividing recorded signal to parts using in the input the file with information about start points of segments and calculate the energy of signals.

1 Introduction to Electroencephalogram

Electroencephalogram (EEG) describes a brain activity. It is a low frequency pulsing signal. Human brain can be regarded as a signal processing unit producing actions and reactions to sensory inputs. The influence of these inputs on brain activity helps to a development of brain-computer interface (BCI) which allows for direct communication between a brain and a computer without any muscular activity. More about BCI see in [1]. Visualization and sonification of biological signals are important instruments for well working BCI. As contrasted to visualization sonification defined in [2] as a technique using data as an input and generating sound signal is not very spread and is not fully used for scientific purpose.

Sonification of EEG can be another method of EEG signal processing. The transform of EEG signal from low frequencies to audible frequencies with accent to some parameters, e. g. amplitude and energy, is very important. In the future it could help to train up human to self-regulate his brain activity in the base of listening to his sonificated EEG. First step to understand how to use sonification of EEG in the future is a detection of an influence of listening to sound on human EEG.

EEG signal is divided to six frequency bands reflecting different activities with various physiologic origins. Marginal frequencies of the bands can vary by 1 hertz. The most spread distribution is in Table 1. Delta, theta and alpha can be analysed quite well, on the other hand beta and gamma are sensitive to muscular artefacts. Slow cortical potentials (SCP) pulse on frequencies lower than 1 hertz and exact analysis of them is almost impossible.

Table 1: EEG FREQUENCY BANDS

Activity	*Behaviour*	*Frequency [Hz]*
SCP	-	0 - 1
Delta	Sleeping, change of activity	1 – 4
Theta	Falling asleep	4 – 8
Alpha	Relaxing	8 – 13
Beta	Psychical activity	13 - 30
Gamma	Stress mechanism	30 - 40

2 Idea of Our Experiments

In our research we detect changes in human EEG while listening to music. Till this time we realised three types of experiments. First experiment described in [3] was only the detection of difference between brain activities in silence and while listening to very short sound sequence

consisted of silence and three different signals. Second experiment described in [4] was listening to more tracks with different content and comparing brain activities. Now we are working on third experiment - listening to favourite and disliked music tracks selected by subjects themselves.

During the experiment conducted at the Department of Radioelectronics, CTU FEE in Prague subjects with closed eyes were relaxing and sitting on a chair inside an audiology room in the dark. While subjects were listening to selected tracks EEG was monitored by four channels. Plus, minus and reference electrodes were connected to each channel. All twelve electrodes were positioned on the scalp as parts of 10-20 system shown in Fig. 1. Selected electrodes are coloured. Character of electrodes is in Table 2.

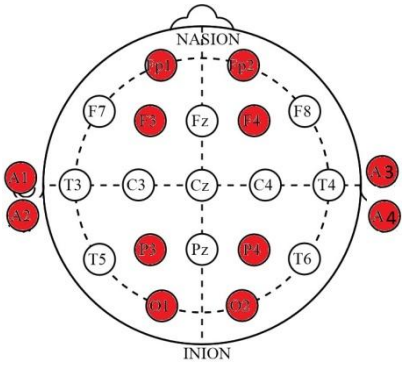

Figure 1: The system of electrodes 10-20

Table 2: USED ELECTRODES OF 10-20 SYSTEM

Channel	*Minus*	*Plus*	*Reference*
1	Fp1	F3	A1
2	P3	O1	A2
3	Fp2	F4	A3
4	P4	O2	A4

Electrodes Kendall H135 SG (diameter 35 millimeters) and conducting gel were applied. EEG was monitored by device Biopac MP35 connected to PC by USB interface. Data were stored in Biopac Student Lab PRO 3.7 and then exported to MATLAB as a TXT file. The workspace of this type of experiment is shown in Fig. 2.

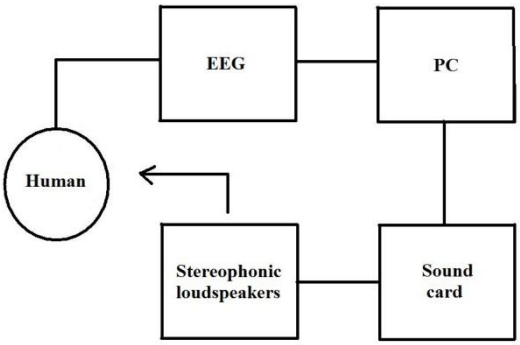

Figure 2: Workspace

3 EEG Signal Processing in MATLAB

Recorded signal is exported to MATLAB as a TXT file. It consists of matrix with four columns. Coefficients of matrix are actual amplitudes of EEG in micro-volts. When subjects listen to more tracks EEG is stored in one file, but Biopac Student PRO makes possible to append markers indicating a start of each track.

In a described MATLAB script first TXT file with EEG signal is loaded. Then the other TXT file with information about a vector of markers is also loaded. Special function "UsekyEEG" (in English "Segments of EEG") with two parameters - markers and sample frequency (in our case 500 hertz) - edits recorded EEG signals of each track to the same length and return new vector with markers characterising the start and the end of each track. Then EEG of each track is defined as a separated variable in a main script. Function "VykresleniEEG" ("Drawing of EEG") with EEG signal and sample frequency as parameters can plot all four channels to one figure such as Fig. 3.

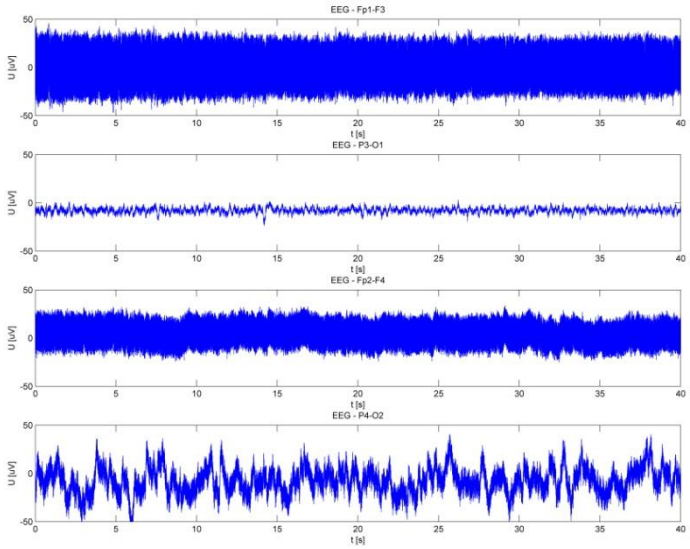

Figure 3: EEG signal (one track)

Function "SrovnaniEEG" ("Comparing of EEG") with two EEG signals and sample frequency as parameters makes possible to compare two signals in time domain, particularly EEG signal recorded while subjects was listening to his favourite track and EEG signal recorded while subjects was listening to his disliked track such as Fig. 4.

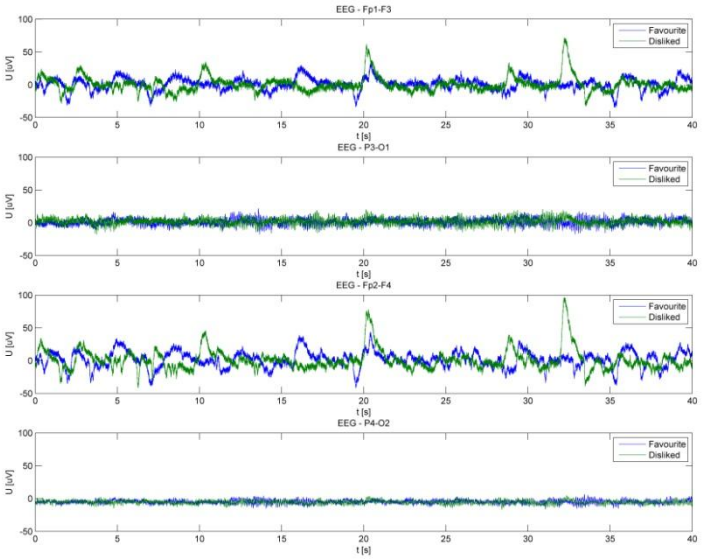

Figure 4: EEG while listening to a favourite (blue colour) and a disliked (green) music track

EEG signal is filtered to frequency bands according to Table 1. Function "FiltraceEEG" ("Filtering of EEG") with parameters EEG signal and sample frequency uses set of filters with finite impulse response (FIR). MATLAB functions fir1 and filter are used. More about filtering of EEG is described in [5]. Delta activity of selected EEG signal is shown in Fig. 5.

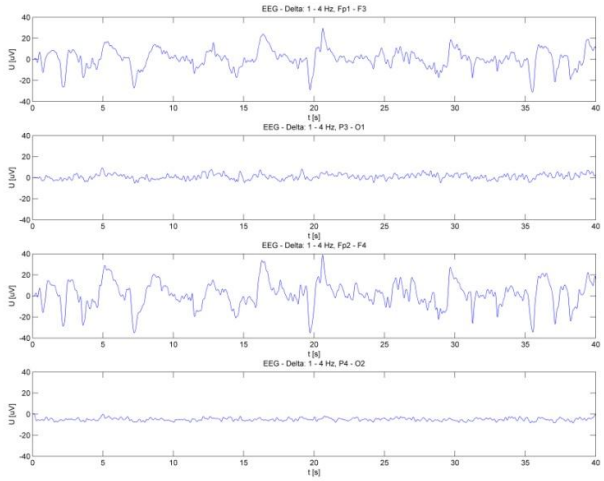

Figure 5: Delta band of selected EEG signal

Energy of signal defined by Eq. (1) is also very important value in signal processing. It can be quickly calculated by function "EnergieEEG" with EEG signal as a parameter.

$$E = \frac{1}{N}\sum_{k=1}^{N}\left|s\left(k\right)\right|^2 \tag{1}$$

4 Conclusion

MATLAB offers many possibilities of EEG signal processing and important analysis of our experiments. Combination of main script and calling other functions with strictly defined roles described in this paper is a good concept, necessary when high number of quiet similar signals is analysed. This program can be still enlarging by more functions. Some instrument for advanced spectral analysis of recorded EEG signal is in preparation.

Acknowledgment

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