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BRAINWAVE TYPE DETECTION IN MATLAB WITH EEG SIGNALS

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Abstract: The electroencephalography is a method for detection of the human brain impulses as time series rows. By doing so, we can detect with sensors the type of the brain activity according to the power spectrum main signal frequency. This makes the electroencephalography suitable for having the potential to be used for sleep/awake detection, for lie/truth detector, for analysis of mental illness, for telekinetic remote control and many more useful applications. In this paper is presented a procedure for brainwave type detection in MATLAB with electroencephalography signals extracted with EPOC Neuroheadset from a human test subject.

Keywords: electroencephalography, brainwave, EEG signal processing, Emotiv EPOC Neuroheadset, research in MATLAB.

1. Introduction

The human brain is the most complex organ of the planet. Every human physical and mental task is processed in the brain in nonlinear fashion. The electroencephalography (EEG) is a method for detection of brain impulses and signals that have been used for quite some time now. By now EEG signals have been measured and analyzed for more than a century.

In 1875 the English scientist Richard Caton have discovered and made the first recording of electrical activity in the brain of an experimental animal. Later on, in 1924 the German neurologist Hans Berger carried out the first human EEG recordings of the electrical activity directly by two electrodes over the scalp of a subject. He called it “electroencephalogram”. From 1929 to 1938 Berger published several scientific papers on his discoveries on EEG [1].

Electroencephalography or EEG is mainly used in the medicine. Up to date EEG is one of the main diagnostic tests for epilepsy. It also can be used for the diagnosis of other brain disorders as tumors, brain death in a coma, sleep disorders, changes in brain function (encephalopathy) or memory impairment.

EEG signal detection is done with usage of electrodes, which are placed on the scalp in order to detect electrical activity in the human brain. The neural cells in the human brain communicate by electrical impulses at all instances of time, even when we sleep. This activity is monitored in form of brainwaves.

Nowadays the human brainwaves are not only used for medical diagnosis but in the therapy process as well. EEG is beginning to be used also for a remote control. With EEG signals one can control robots, musical instruments and heroes in games, using only “thought power”. With this telekinetic technology can allow people to control many different devices that can be managed only by the mind. For example, a car that gets into the thoughts of human before they appeared in his mind, thus reducing reaction time.

Today in the consumer market there are many EEG recording devices in different price ranges, based on the number of simultaneously extracted EEG signals. A device called “Emotiv EPOC” was been chosen for EEG signal extraction, as it is one of the cheapest solutions presenting at user disposal more than 10 electrodes, amplifier and PC USB interface as an integrated easy to manage package.

The paper is organized in the following way: In the next Section the EEG data description is presented. Then the variety of the brainwave types and the EEG data recording device used are presented in Sections 3 and 4. A procedure in MATLAB for detection of the brainwave activity type, depending of the signal frequency is presented in Section 5.

2. EEG Data Properties

Electroencephalography (EEG) is the recording of electrical activity of the human brain [2]. EEG refers to the recording of the brain’s instant electrical activity for short periods of time, usually for 20–30 minutes, as recorded from multiple electrodes placed on the scalp. That is, the type of neural oscillations that can be observed in EEG signals. In neurology, the main diagnostic application of EEG is in the case of epilepsy, as the epileptic activity can create clear abnormalities on a standard EEG study. A secondary clinical use of EEG is in the diagnosis of coma, encephalopathies, and brain death. A third clinical use of EEG is for studies of sleep and sleep disorders where recordings are typically done for one full night, sometimes even longer.

Understanding the neural functions and neurophysiologic properties of the human brain together with the mechanisms underlying the generation of signals and their recordings is, however, vital for those who deal with these signals for detection, diagnosis, and treatment of human brain disorders and the related diseases.

There have been many algorithms developed so far for processing EEG signals. The operations include, for example, time-domain analysis, frequency-domain analysis, time-frequency analysis and multiway processing.

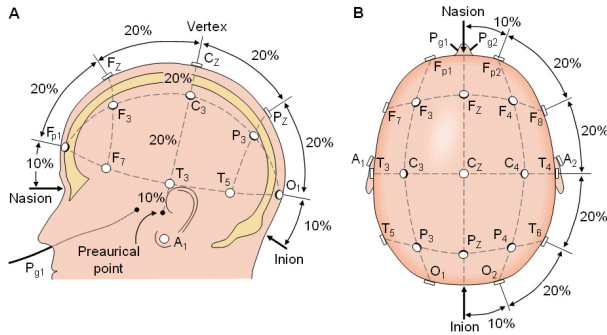


Figure 1. The international 10-20 system of electrode placement.

Modelling the neural activities is presumably much more difficult than modelling the function of any other organ as these signals are non-stationary and it is impossible to define reference.

Localization of brain signal sources is another very important research field. The sources of electromagnetic waves might be considered as magnetic dipoles for which the well-known inverse problem has to be solved, or they can be considered as distributed current sources.

The International so-called 10-20 system is usually employed to record the spontaneous EEG [3]. In this system 21 electrodes are located on the surface of the scalp as shown in Figure 1. The electrode placement positions are determined by dividing the skull into perimeters by connecting few reference points on human head. From these points, the skull perimeters are measured in the transverse and median planes. Electrode locations are determined by dividing these perimeters into 10% and 20% intervals.

3. Brainwave Types

Many human brains can be diagnosed by visual inspection of the EEG signals. The experts in clinical field are familiar with appearance of different brainwaves in the EEG signals.

There are five major brainwaves distinguished by their different frequency range. These frequency bands varied from low to high frequencies respectively are called

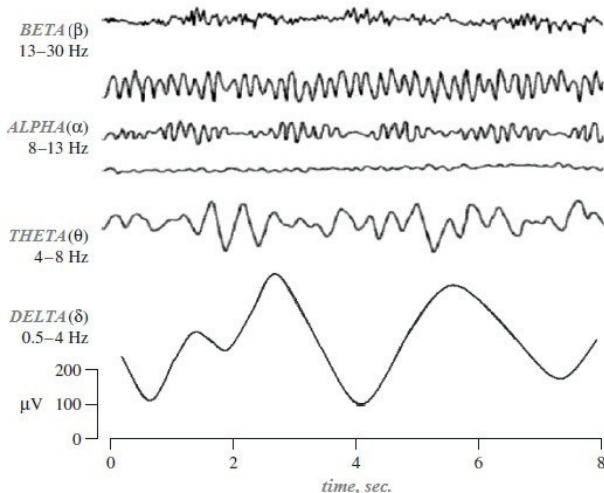


Figure 2. Typical brainwave types.

delta (δ), theta (θ), alpha (α), beta (β), and gamma (γ), as shown in Figure 2 [2].

The delta brainwaves lie in the range of 0.5 to 4 Hz. This brainwave type is associated with deep sleep and may be present in an awake state. These signals are very likely to be confused with the large muscle signals. Delta brainwave is decreased with age, and it is not normal to detect delta waves in healthy people while they are awake.

The theta brainwaves type lie in the range of 4–8 Hz. Theta waves are associated with access to unconscious materials, creative thinking and deep meditation. Furthermore, there is a link between emotions such as disappointment and frustration.

Alpha brainwaves type lies within the frequency range of 8–13 Hz. These waves have comparatively higher amplitude to other brainwave types. It is best seen when eyes are closed and the patient is in mental relaxation. This brainwave type is useful to trace mental effort because of its higher amplitude.

The beta brainwaves have a larger range in the frequency spectrum as they are observed between 13–30 Hz. Beta waves can be measured from frontal and central regions of the brain. The central beta wave can be blocked by motor activity and operation of the planning to make a move.

The gamma brainwaves are sometimes called fast beta waves and lie within the range of frequency higher than 30Hz. They are used to detect high cognitive activities and give some clues about mental diseases.

4. EEG Signal Extraction Hardware

Based on the latest developments in neuro-technology, one Swiss based company called “Emotiv” developed a cheap new interface for human interaction with the computer wirelessly.

The “Emotiv EPOC” device [4] has 16 sensors which come into contact with the scalp of the head and using the conventional technology - electroencephalography, by detecting electric signals from the surface of the scalp and making them appear on the screen.

The “Emotiv EPOC” is an EEG Headset which supplies 14 channels EEG data and 2 gyros for 2 dimensional controls. The advantage is that it is wireless cable free solution with long autonomous operation time. The “Emotiv EPOC” sends EEG data to computer with USB receiver via Bluetooth interface.

The academic version of the “Emotiv” software can access the raw data which is decrypted using Control Panel and can save the extracted data. The “Research Edition SDK” includes a research headset: a 14 channel (plus CMS/DRL references, P3/P4 locations). The channel names based on the International 10-20 locations are: AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4 (shown in Figure 3). Other specifications are listed below (Table 1).

The system can record offline data in the standard for medical database records European Data Format “.edf”, which can be used from other programs like MATLAB [5].



Figure 3. Emotiv EPOC neuroheadset [4].

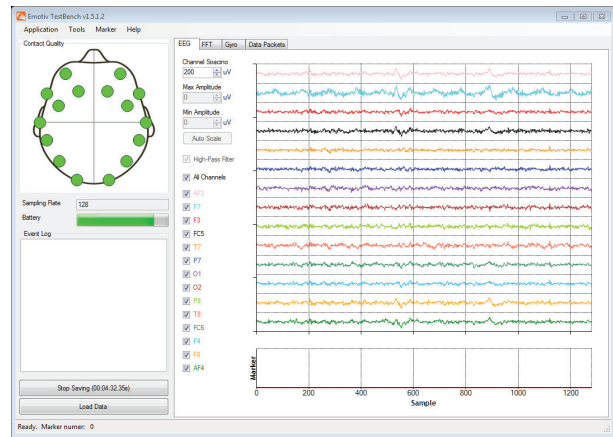


Figure 5. Emotiv EPOC testbench.

Table 1. Emotiv EPOC Specifications [4]

	EMOTIV EPOC HEADSET
Number of channels	14 (plus CMS/DRL references, P3/P4 locations)
Channel names (International 10-20 locations)	AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4
Sampling method	Sequential sampling, Single ADC
Sampling rate	128 SPS (2048 Hz internal)
Resolution	14 bits 1 LSB = 0.51 μ V (16 bit ADC, 2 bits instrumental noise floor discarded)
Bandwidth	0.2 - 45Hz, digital notch filters at 50Hz and 60Hz
Filtering	Built in digital 5th order Sinc filter
Dynamic range (input referred)	8400 μ V (pp)
Coupling mode	AC coupled
Connectivity	Proprietary wireless, 2.4GHz band
Power	LiPoly
Battery life (typical)	12 hours
Impedance Measurement	Real-time contact quality using patented system

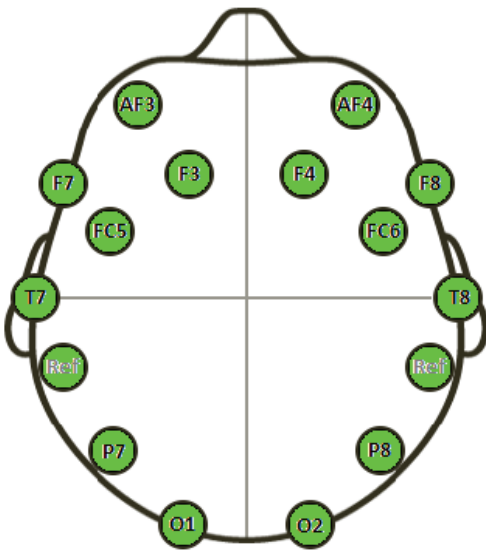


Figure 4. Emotiv EPOC's sensors layout.

The signal sample rate is 128 Hz, meaning that for one second there are 128 data points stored for 16 vectors, every one presenting one of the electrode channels with two of them being the reference.

The display screen “Emotiv EPOC” during one experiment is shown in Figure 5. At the time of recording the research subject solves sudoku with a medium level of difficulty. Recording is stopped when the final result is obtained.

5. EEG Signal Processing in MATLAB

European Data Format (“.edf”) is the European standard file format designed for the exchange and storage of medical data. This is a format for the exchange of polygraph records in digital format. The extracted off-line data from the system can be imported in MATLAB workspace.

A plot window of the obtained EEG signals from all of the channels in MATLAB, using pre-recorded data from one experiment with solving sudoku for the time of 17 seconds is shown in Figure 6.

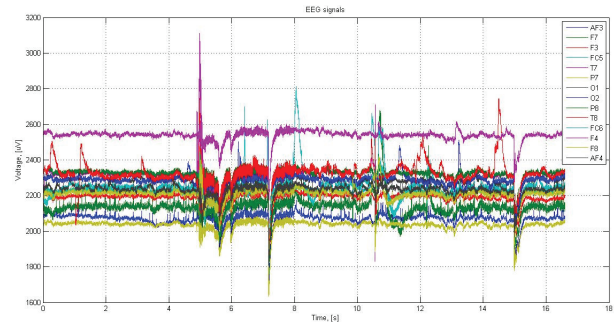


Figure 6. EEG signals in time domain obtained from all 14 channels in MATLAB for 17 s.

The following graph of Figure 7 displays only EEG data obtained from channel “T7”. This is necessary, because in further research the signal data is to be considered separately.

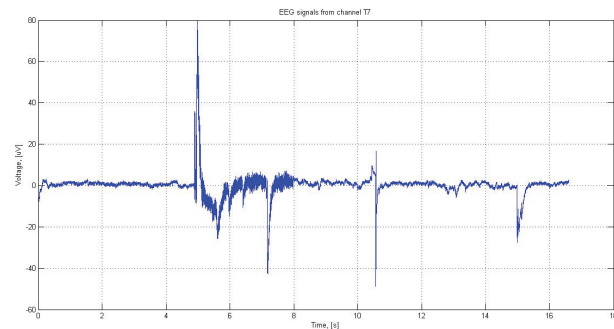


Figure 7. EEG data obtained from channel “T7” in MATLAB for 17 s.

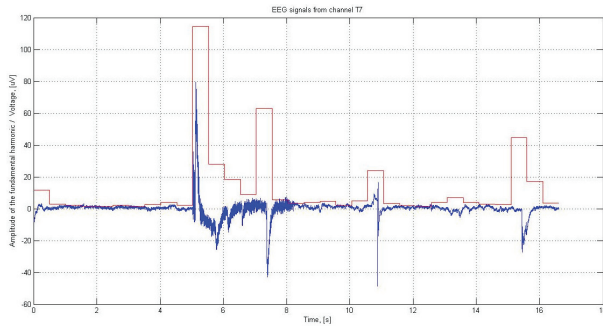


Figure 8. Amplitude of the fundamental harmonic of the EEG signal from channel “T7”.

On every separate signal type from every channel a fast Fourier transform is performed and the power spectrum is obtained in predetermined intervals with equal length in time with a moving window function. From the spectrum domain we are interested in the dominating frequency, and for this reason the DC component term, the zero frequency term, is omitted and the signal frequency bin with maximum value for the window is stored as index (frequency) and value (amplitude).

One such an example with extraction of the amplitude of the fundamental harmonic component of the EEG signal from channel “T7” in MATLAB is shown in Figure 8.

In Figure 9 is shown the frequency of EEG research signal of channel “T7” that varies between 4 and 11 Hz for every window interval. Based on the mean average value of the main frequency on the spectrum from all of the channels we can conclude that brain waves are alpha or theta depending on the resulting value.

Also, by doing so we can ignore the impact of malfunctioning sensors if they are not dominant. Finally, the obtained results are compared, generalized in order to determine the terminal state of the subject during the entire experiment. Data observation showed that large variations sometimes are occurring and they must be isolated, which has been believed to be due to the insufficient or bad contact between the electrode tampon and the skin of the human scalp. As above were described Alpha waves corresponding to intellectual relaxation and Theta waves of stronger mental activity. Both types of brainwaves are characterized by increase attention and mind activity.

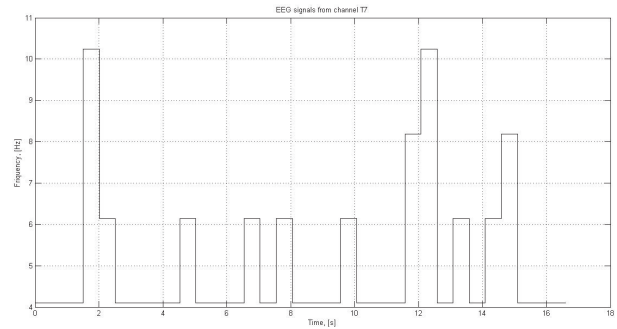


Figure 9. Frequency of the EEG signal from channel “T7”.

6. Conclusion

We can determine easily the brainwave type automatically, based on the magnitude of the frequency of these signals. This provides us with the option at a given time to detect the type of brainwaves, corresponding to a specified activity. If the frequency of the brainwave signals is obtained and known, one can determine the mental state activity, without any spoken words. There tends to be an interesting future for such a technologies.

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