GRAPHICAL USER INTERFACE
FOR EEG SIGNAL SEGMENTATION

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Abstract

Multi-channel signal processing forms one of fundamental problems of data analysis. The paper is devoted to selected problems related to segmentation of such signals based upon changes of their frequency components. The main part of the contribution presents the use of the moving window to find signal change-points using discrete Fourier transform to detect the evolution of average spectral components in selected frequency bands. The paper presents both the mathematical background of this problem and description of the proposed MATLAB graphical user interface for multi-channel signal de-noising and segmentation. Methods proposed are applied for EEG signal analysis.

1 Introduction

Signal segmentation [3, 1] forms a basic mathematical problem allowing the following feature extraction and classification of signal components. The paper presents a specific method to find signal change-points based on differences of its frequency components in selected frequency bands fundamental for EEG signal analysis.

The initial part of the paper is devoted to EEG data acquisition and its preprocessing using digital filters to remove its undesirable frequency components. The proposed algorithm allows processing of general multi-channel signals in the graphical user interface enabling selection of filter structure and having possibilities of different kinds of visualization. Methods of signal segmentation using signal frequency components form the main part of the contribution. Associated graphical user interface is designed to allow signal segmentation with the use of the moving window for estimation of its average frequency components in specific frequency bands.

Mathematical methods for signal analysis and processing are verified for simulated sequences and applied for multi-channel signals. Proposed graphical user interface allows import of any signals of this kind stored in the corresponding MATLAB structured variable with all associated information and the paper illustrates its use for EEG signal processing.

2 EEG Data Properties

Electroencephalography [4] is the neurophysiologic measurement of the electrical activity of the brain using electrodes placed on the scalp. The resulting traces are known as electroencephalogram (EEG) and they represent an electrical signal (postsynaptic potentials) from a large number of neurons. The EEG is a brain non-invasive procedure frequently used for diagnostical purposes. Instead of electrical currents the voltage differences between different parts of the brain are observed.

The EEG consists of a set of multi-channel signals. The pattern of changes in signals reflects large-scale brain activities. In addition the EEG also reflects activation of the head musculature, eye movements, interference from nearby electric devices, and changing conductivity in the electrodes due to the movements of the subject or physicochemical reactions at the electrode sites. All of these activities that are not directly related to the current cognitive processing of the subject are collectively referred to as background activities below. Formerly the problem with the interferences of other electric devices was solved by A Faraday cage which is an enclosure formed by conducting material, or by a mesh of such material. Such an enclosure blocks out

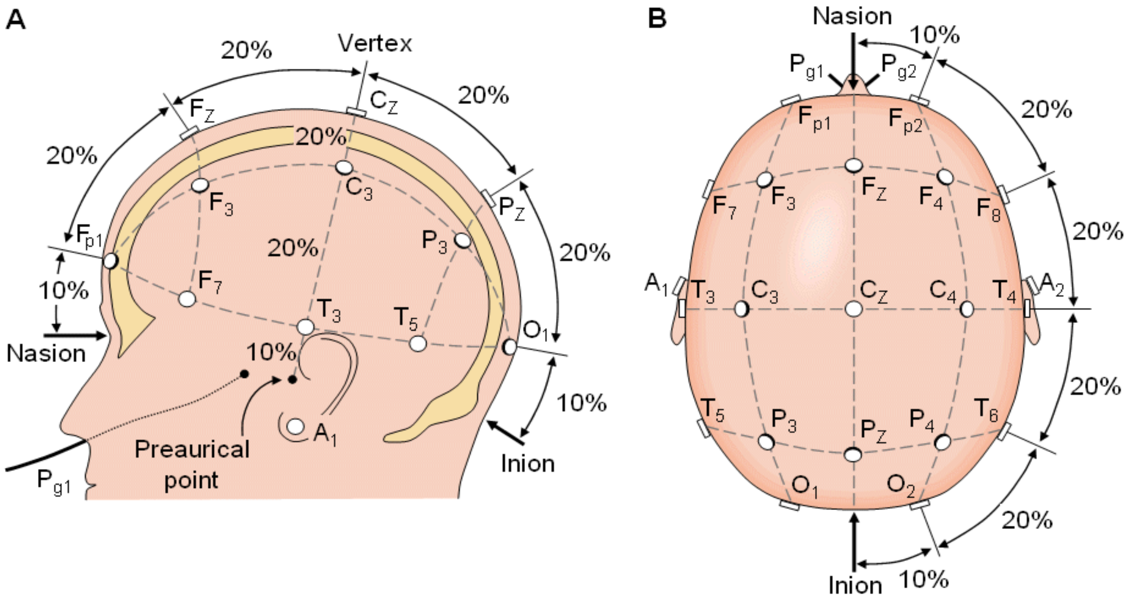

Figure 1: The international 10-20 system seen from **(a)** left and **(b)** above the head. A = Ear lobe, C = central, Pg = nasopharyngeal, P = parietal, F = frontal, Fp = frontal polar, O = occipital [5]

external static electrical fields. But this realization proved to be expensive and digital filtration is preferred [6] now.

The internationally standardized 10-20 system is usually employed to record the spontaneous EEG. In this system 21 electrodes are located on the surface of the scalp (19 electrodes in our case), as shown in Fig. 1. The positions are determined by dividing the skull into perimeters by connecting few reference points on human head. Reference points are nasion, which is the delve at the top of the nose, level with the eyes, and inion, place on the middle on the back of the 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.

EEG data provided were saved in structured arrays with their fields containing information about measuring conditions and data observed. In the specific case used the structure variable *Data* has seven elements which their fields accessible by commands

```
data.wanted_element
data(position of field).wanted_element
```

Thanks to this it is possible to store not only data values but also labels of the different channels, sampling frequency, number of channels and further information according to Fig. 2.

EEG measurements allow both their time-domain and frequency-frequency analysis. Analysing their frequency components the following frequency bands are studied

data

Field	Value
vzorkfrekv	128
pocetkanalu	25
citlivost	4
label	<25x6 char>
pocetdatovychzaznamu	902
pdni	16289
zaznamy	<25x115456 int16>

Figure 2: The EEG structured data

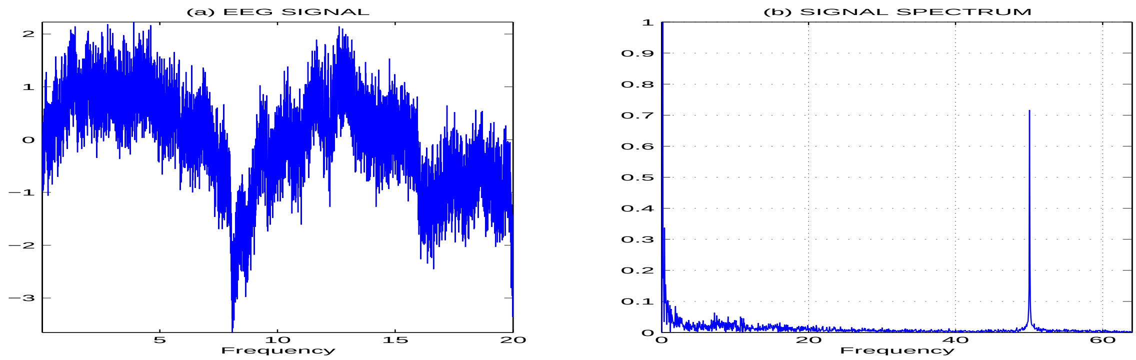

Figure 3: Analysis of a given signal presenting **(a)** part of the EEG signal and **(b)** its spectrum

- DELTA - 3 Hz and less (deep sleep, when awake pathological)
- THETA - 3.5 - 7.5 Hz (creativity, falling asleep)
- ALPHA - 8 - 13 Hz (relaxation, closed eyes)
- BETA - 14 - 30 Hz and more (concentration, logical and analytical thinking, fidget)
- GAMMA - greater than 30 Hz (simultaneous processes)

3 Mathematical Methods

Spectral analysis is a basic mathematical tool based on the Fourier transform allowing the study of the signal frequency spectrum. Representation of the original selected channel of the EEG signal is on Fig. 3 (a) with its frequency spectrum on Fig. 3(b) showing the additive undesirable component of 50Hz.

Discrete Fourier transform forming the basis of spectral analysis is a transform of finite sequences of complex or real numbers with its result in the finite sequences of generally complex numbers. Having the finite sequence $\{x(n)\}$, $n = 0, 1, 2, ..., N-1$ of N samples the discrete Fourier transform and its inverse are defined by relations

$$X(k) = \sum_{n=0}^{N-1} x(n)\, e^{-\,j\,k\,n \frac{2\,\pi}{N}}, \quad k = 0, 1, ..., N-1 \tag{1}$$

$$x(n) = \frac{1}{N} \sum_{k=0}^{N-1} X(k) e^{\,j\,k\,n \frac{2\,\pi}{N}}, \quad n = 0, 1, ..., N-1 \tag{2}$$

Discrete Fourier transform demands the signal to be sampled with sufficient frequency regarding the contained noise, which is generally composed by harmonic functions of higher frequencies than the clean signal is.

Difference equations form a basic tool for description of discrete systems [7]. A general system of this kind can be described by relation

$$y(n) + \sum_{k=1}^{M} a(k)\, y(n-k) = \sum_{k=0}^{M} b(k)\, x(n-k) \tag{3}$$

where sequences $x(n)$ and $y(n)$ represent input and output signals and M stands for the order of the difference equation. This mathematical structure can be used to evaluate output values of the infinite impulse response (IIR) filter

$$y(n) = -\sum_{k=1}^{M} a(k)\, y(n-k) + \sum_{k=0}^{M} b(k)\, x(n-k) \tag{4}$$

which can be simplified in the case of zero coefficients $\{a(k)\}$ to finite impulse response (FIR) filter in the form

$$y(n) = \sum_{k=0}^{M} b(k)\, x(n-k) \tag{5}$$

Digital filters defined usually by difference relations mentioned above enable selection of specified signal frequency components properly defining their coefficients. In the case of EEG signal processing it is necessary to filter out the 50Hz noise and also it is desirable to filter frequencies bellow 1Hz and above 60Hz, that are considered not to contain any important information. These cut off frequencies must be recalculated to values between zero and one for the Matlab `fir1` function and they represent the `Wn` variable for the evaluation of the filtration coefficients. Using variable `M` for the order of the filter it is possible to use the following commands.

```
b1=fir1(M,Wn1,'stop');
b2=fir1(M,Wn2,'bandpass');
```

The first line stand for the evaluation of the stopband filter to filter out component of 50Hz while the second one evaluates coefficients of the bandpass filter. Fig. 4 presents the given and filtered signal representing a selected EEG channel.

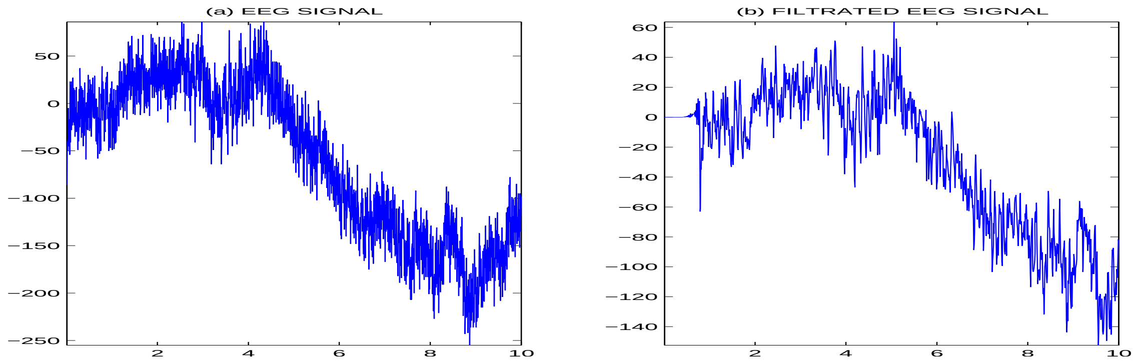

Figure 4: Comparison of **(a)** unfiltered EEG signal and **(b)** filtered EEG signal

4 EEG Data Processing

The study has been devoted to the EEG signal consisting of 19 channels each of them representing one electrode. These signals contain noise that can be clearly seen in signal spectrum on 50 Hz and which must e rejected at first. To achieve this goal we can use either time domain or frequency domain filtering. For EEG signal processing the GUI has been proposed with selected results given in Fig. 5.

Segmentation is another step in data processing and analysis. Segmentation of EEG allows further studies of the given signal and searching for pathological sequences that might help with determination of diagnosis. This paper studies the possibilities of segmentation using time windows applied for EEG signals analysed by the DFT using the average value of energy in the selected frequency band.

Proposed GUI presented in Fig. 6 allows application of two methods of dividing the signal sequence into windows. The first one uses consequent widows while the second one distributes data into windows that overlay each other by half of their length. The size of the window can be adjusted manually as well.

5 Conclusion

The paper presents selected results of multi-channel signal segmentation using frequency components change in windows of the given length. The following work will be devoted to more sophisticated structures allowing the use of more complex information about given signals both in the time and frequency domains. Further methods of signal preprocessing and wavelet transform use [2] for its segmentation will be studied as well.

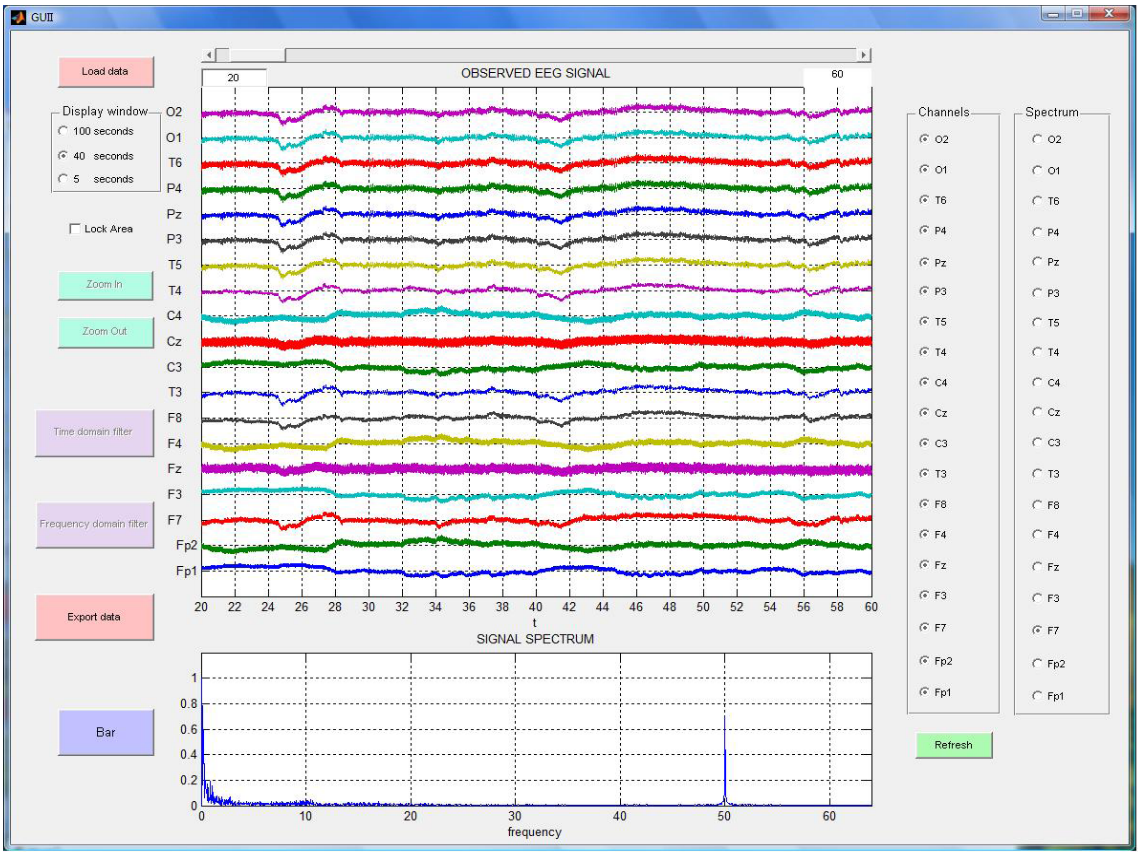

Figure 5: GUI for signal pre-processing

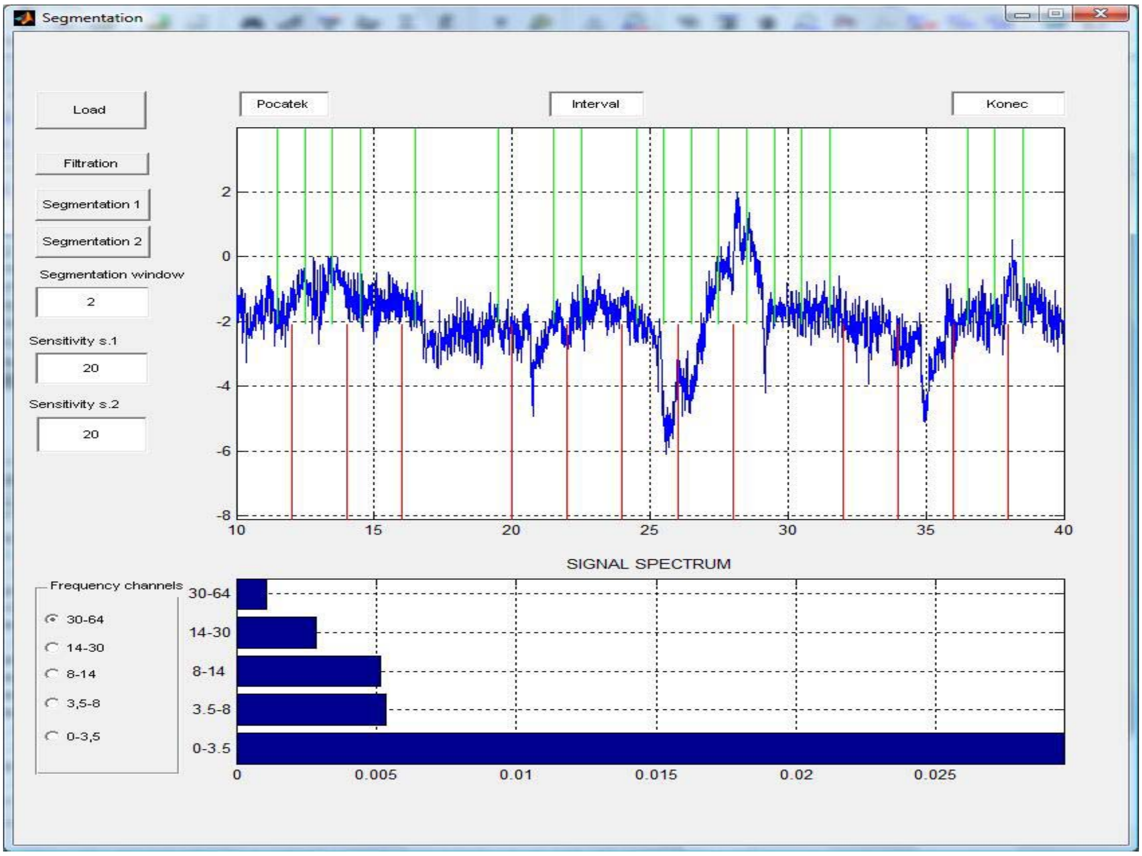

Figure 6: GUI for signal segmentation

Ackowledgement

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References

[1] B. E. Brodsky and B. S. Darkhovski. *Nonparametric Methods in Change-Point Problems.* Kluwer Academic Publishers, Boston, U.S.A., 1993.

[2] Nazareth P. Castellanos and Valeri A. Makarov. Recovering EEG Brain Signals: Artifact Suppression with Wavelet Enhanced Independent Component Analysis. *Journal of Neuroscience Methods*, 158(2):300–312, 2006.

[3] W. J. Fitzgerald, J. J. K. O. Ruanaidh, and J. A. Yates. Generalised Changepoint Detection. Technical report, University of Cambridge Engineering Department, Cambridge, U.K., 1994.

[4] Saeid Sanei and J. A. Chambers. *EEG Signal Processing.* Wiley - Interscience, 2007.

[5] Sharbrough, Chatrian, Lesser, Lders, Nuwer, and Picton. *American Electroencephalographic Society Guidelines for Standard Electrode Position Nomenclature.* 1991.

[6] Josef Svatoš. *Biologické signály I.* Vydavatelství ČVUT, Prague, second edition, 1998.

[7] S. V. Vaseghi. *Advanced Digital Signal Processing and Noise Reduction.* John Wiley & Sons Ltd, West Sussex, 2006.

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