Software Tools of the Brain-Computer Interface for Electroencephalograms Analysis based on Continuous Wavelet Transform

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Introduction

The paper proposes software tools of a brain-computer interface for the analysis of electroencephalograms based on a continuous wavelet transform. The implementation of software tools makes it possible to carry out wavelet analysis of signals and trace changes in the frequency of the signal over time to explore and identify details and anomalies that cannot be identified in other ways.

Algorithm for Wavelet Analysis of EEG Signals

The algorithm is represented by the following set of steps performed for all EEG channels.

Step 1. Get an array of scales: $a_i = \frac{1}{w_{min}}$ $i = 0, \ldots, N_a - 1$, where a_i is the value of the i-th scale, w_{min} is the minimum frequency, Δw is the frequency sampling interval, N_a is the number of scales.

Step 2. Calculate the values of the scaled wavelets with a shift equal to zero for each scale value. For this, the following steps are performed.

Step 2.1. Determine the number of wavelet samples for the current scale a_i that fall within the width w_t: $n_i = ent\left[\frac{w_t}{\Delta t_0} + 0{,}5\right]$, where Δt_0 is the wavelet sampling interval, ent[] is the operation of taking the integer.

Step 2.2. Calculate wavelet value: $\Psi_{i,k} = \frac{1}{\sqrt{a_i}} \Psi\left(\frac{k\Delta t_0}{a_i}\right)$, where $k = -ent\left[\frac{n_i}{2}\right] \ldots ent\left[\frac{n_i}{2}\right]$.

Step 2.3. Repeat steps 2.1 and 2.2 for each scale.

Step 3. Calculate the coefficients of the wavelet transform in the following way: $W(a,b) = \frac{1}{\sqrt{a}} \sum_{i=0}^{N-1} x(t_i)\psi\left(\frac{t_i-b}{a}\right)$, where ψ is the mother wavelet, a is the scale, b is the time shift, t_i is the i-th time sample, $x(t_i)$ is the i-th signal sample, N is the number of samples in the signal.
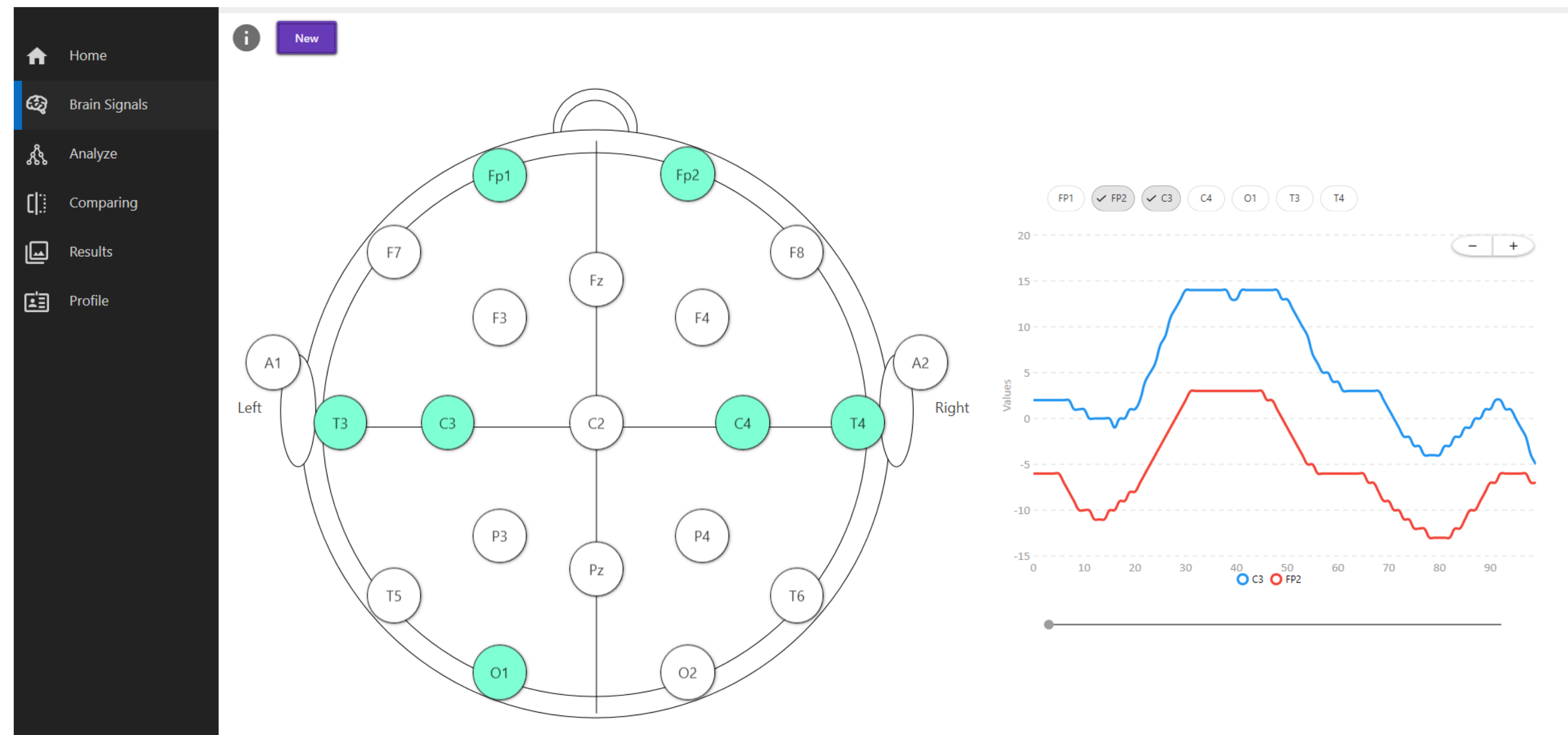
Results

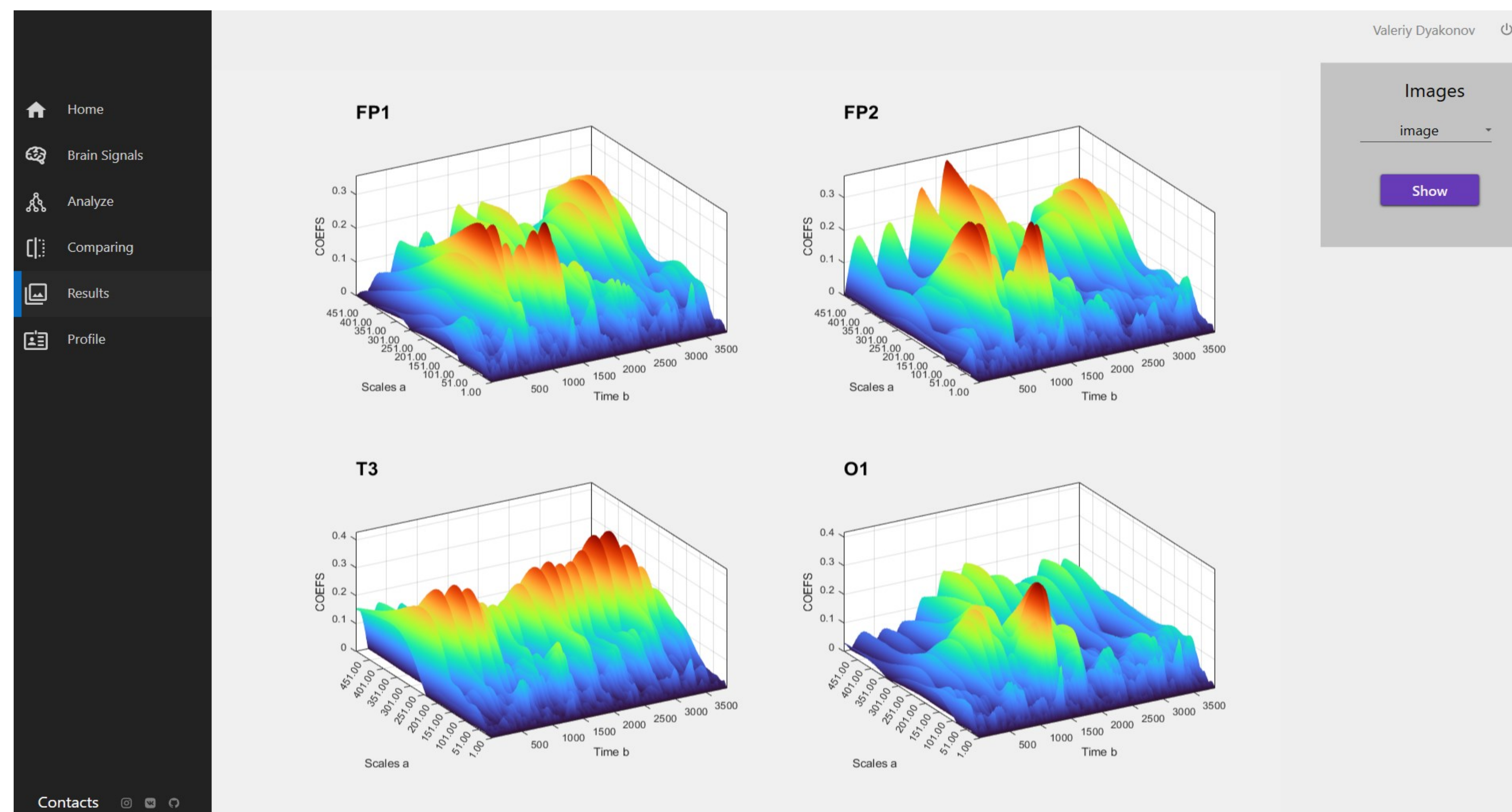Fig. 1. EEG electrodes scheme representation

Fig. 2. Software tools of the brain-computer interface

The software tools of the brain-computer interface were developed in C# using the Windows Presentation Foundation for data visualization. The software tools implement the following functions:

- user data control and user profile management;
- receiving and pre-processing of EEG signals;
- wavelet transform of EEG signals;
- comparison of EEG signals;
- analysis of the results of EEG signal processing.

Analysis of the obtained results of coherence calculation for all EEG signals allows us to draw the following conclusions:

- recording changes in the frequency of the signal over time;
- signals registered in different channels are similar in their behavior;
- when subjects use imagination, the signals are more active on large scales;
- the greatest similarity of signals falls on the frequency range 32–64 Hz;
- signals are approximately 29–35% similar.

Conclusion

Thus, the software tools of the brain-computer interface have been developed. These tools were implemented for the analysis of electroencephalograms using continuous wavelet transform. Wavelet analysis of signals acquired from various channels of EEG devices makes it possible to register changes in the frequency of the signal over time, which, in turn, makes it possible to search for and identify details and anomalies that develop over time. Our further work in this field will be aimed at creating a recommendatory mechanism for making a diagnosis based on the identified anomalies in the EEG signal.