SAPPLICATION OF NEURAL NETWORK BY EEG SIGNAL CLASSIFICATION

M. Gála[1)], J. Mohylová[1)], V. Krajča[2)]

[1)] *VSB-Technical University of Ostrava, Department of Measurement and Control,*
17. listopadu 15, 708 33 Ostrava-Poruba, Czech Republic, mail: michal.gala@vsb.cz, jitka.mohylova@vsb.cz

[2)] *Teaching Hospital Na Bulovce*
Budínova 2, 180 81 Praha 8, Czech Republic

Summary Analysis of long-term EEG requires that it is segmented into piece-wise stationary sections and classified. Neural network architecture is introduced for the problem of classification of EEG signals. This paper deals with basic signal classification into two classes. This work is a ground towards creating an algorithm to sleep status analysis. Signal is first worked by signal segmentation and then is used a neural network to classification into two class.

1. INTRODUCTION

Computer processing and biological signal classification has great value for better diagnosis resulting. Therefore is it a strong tool in doctor hands. The effectivity rest on: software read the signal and mark only significant element of signal, that it important for result diagnosis. The doctor will get so a time saving. One of possibilities for signal classification is use a neural network. Neural networks are possible use for signal segmentation too. For example will be an 8 seconds long real record of brain activity used as a test signal. This signal is segmented. For signal segmentation is used a software with name EEGsegmentation. With this program we can display all EEG channels, ECG channel if exist too and many more.

2. NEURAL NETWORKS (NN)

A biological neural network is composed of a group or groups of physically connected or functionally associated neurons. A single neuron can be connected to many other neurons and the total number of neurons and connections in a network can be extremely large. Connections, called synapses, are usually formed from axons to dendrites, though dendrodentritic microcircuits and other connections are possible. Neural networks are extremely complex. Artificial intelligence and cognitive modeling try to simulate some properties of neural networks. An artificial neural network is an interconnected group of artificial neurons that uses a mathematical or computational model for information processing based on a connectionist approach to computation. In most cases an artificial neural network is an adaptive system that changes its structure based on external or internal information that flows through the network.

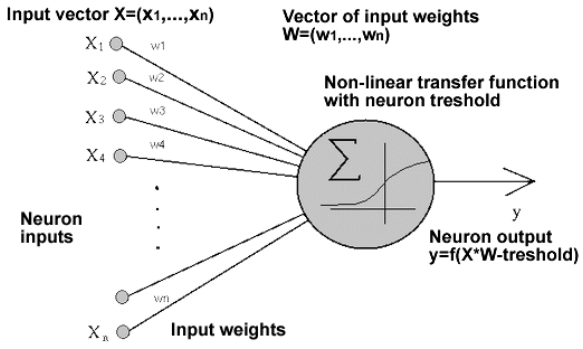

Fig. 1. Neuron model

Neural network have more good attributes. For example teach ability: the network changes its structure following information for better artificial neural network performance. According to propagation of signal, two main groups of neural networks are possible:

- Feed-forward – Data enters at the inputs and passes through the network, layer by layer, until it arrives at the outputs. During normal operation, that is when it acts as a classifier, there is no feedback between layers.

- Recurrent - a network of neurons with feedback connections between layers.

Learning classify into: learning with teacher and learning without teacher. Learning is a systematic process, where knowledge's are saved into synaptic weights of neural network. In learning state:

$$\frac{\partial W}{\partial t} \neq 0 \qquad (1)$$

W is a matrix of all synaptic weights of neural network. After learning is the network learnt and then:

$$\frac{\partial W}{\partial t} = 0 \tag{2}$$

3. BACKPROPAGATION ALGORITHM

90% applications from neural networks are based on backpropagation algorithm. It is a basic algorithm for controlled teaching. Backpropagation is recursive gradient method for neural network weights adjusting with heed on learning error *J* minimalization.

$$J = \frac{1}{2}\sum_{i=1}^{N_0}(e\upsilon_i - x_i)^2 \tag{3}$$

N_0 is number of input neurons, $e\upsilon_i$ is required activation value of i-neuron, x_i is activation of i-neuron and p index means that it belongs to p-pattern. For each neuron hold:

$$x_i = f_i(i_i) \qquad i_i = \sum_{j=1}^{M} w_{ij}x_j + \theta_i \tag{4}$$

i_i is input of i-neuron, f_i is activation function of i-neuron, M is number of i-neuron inputs, w_{ij} is weight from z-neuron to i-neuron and θ_i is threshold value of i-neuron. Backpropagation is gradient method and therefore for weight change Δw_{ij} hold:

$$\Delta w_{ij} = -\gamma\frac{\partial J}{\partial w_{ij}} = -\gamma\frac{\partial J}{\partial i_i}\frac{\partial i_i}{\partial w_{ij}} = \gamma\delta_i x_j \tag{5}$$

Calculated synaptic weight change between neuron from hidden layer and output neuron is then increment with current weight value:

$$w_{ij} = w_{ij} + \Delta w_{ij} \tag{6}$$

For learning rate γ (5) hold:

$$\delta_i = -\frac{\partial J}{\partial i_i} = -\frac{\partial J}{\partial x_i}\frac{\partial x_i}{i_i} = -\frac{\partial J}{\partial x_i}f'(i_i) \tag{7}$$

If is i-neuron output neuron, then hold:

$$\delta_i = -\frac{\partial J}{\partial x_i}f'(i_i) = (e\upsilon_i - x_i)f'(i_i) \tag{8}$$

If is it not output neuron:

$$\delta_i = -f'(i_i)\sum_{h=1}^{N_h}\frac{\partial J}{\partial i_h}\frac{\partial i_h}{\partial x_i} = -f'(i_i)\sum_{h=1}^{N_h}\frac{\partial J}{\partial i_h}\frac{\partial}{\partial x_i}\sum_{l=1}^{N_l}w_{hl}x_l =$$
$$= -f'(i_i)\sum_{h=1}^{N_h}\frac{\partial J}{\partial i_h}w_{hi} = f'(i_i)\sum_{h=1}^{N_h}\delta_h w_{hi} \tag{9}$$

Formula 9 is main backpropagation relationship and shows recursive propagation of error signal δ from output neurons to network input.

4. ADAPTIVE SEGMENTATION

In the course of automatic analysis of EEG signal with use computer equipment, one of the primary tasks is the extraction of informative symptoms with maximum discriminatory ability. By obtaining spectral appearance of stage of signal with constant length is able to arrive to deformation of signal characteristic. It is due to non-stationary character of EEG signal. Just this necessity fixes adaptive segmentation with easy test method. Easy test method uses mechanism of signal scanning with movable window and computes divergence of autocorrelation function between reference window and movable window.

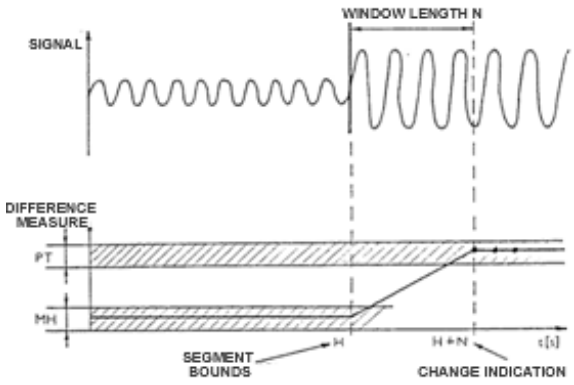

Fig. 2. Autocorrelation function based on easy test method

The bound of a segment will be set by searching a place where is measure of ACF difference constant. We can for example proceed so that we testing if 3 (or more) values of consecutive points of difference measure are enough near, whether are situated in narrow tolerance band (PT) and are at the same time larger as a minimal value (MH).

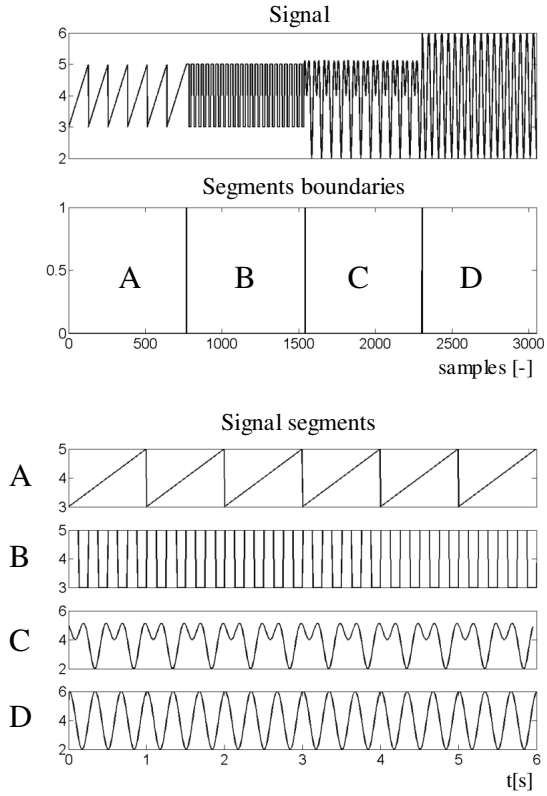

Fig. 3. Example of adaptive segmentation using on basic signal

5. EEG SEGMENTS CLASSIFICATION BY NEURAL NETWORK

A 20 channels (19 + marker), 8 seconds long real record of brain activity is used as a test signal. From this record are 15 segments of various channel extracted (Fig. 4.). All segments are defined by using an adaptive segmentation algorithm with easy test method to segments boundaries indication. These 15 segments are in two classes (A and B) separated. Each class has training signals and testing signals. In class A are 5 signals, 3 training signals (FP1, F7, F3) and 2 testing signals (FP2, FZ). In class B are 10 signals, 8 training signals (PZ, P3, C4, CZ, C3, F4, F8, *F3*) and 2 testing signals (*FZ*, *F7*).

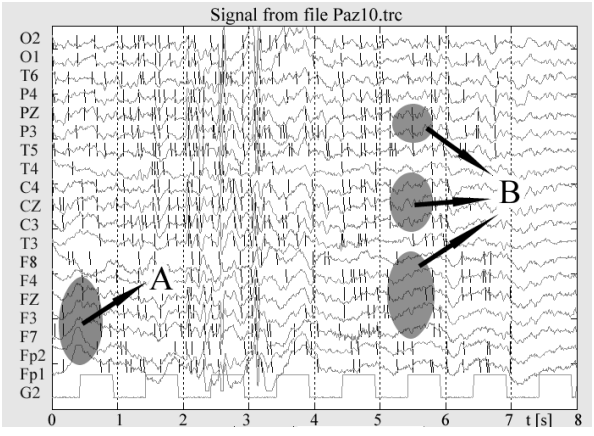

Fig. 4. Real record of brain activity with two class of used segments

5.1. NEURAL NETWORK REALIZATION

Neural network is based on backpropagation algorithm. The network has one secret layer with 20 neurons, 40 input neurons and one output. This network is network with teacher. For network creating and training is a MATLAB algorithm used. As activation function is log-sigmoid function used. Before is the neural network trained, must be the signal edited. First must be the signal transferred from time domain to frequency domain by using fast Fourier transform. So is a problem with displacement between signals solved.

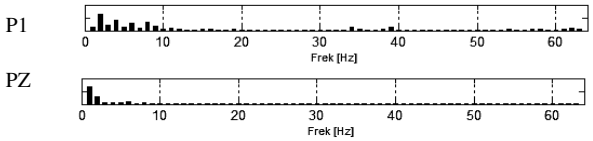

Fig. 5. Frequency domain of FP1 and PZ signal

This frequency range is then narrowing down to 0 – 40 Hz and at 40 elements dissociated. For EEG computer processing are these frequencies important:

- Delta (0,5 – 4Hz) – total unconsciousness, deep, dreamless sleep
- Theta (4 – 8Hz) – daydreaming, fantasy, imagination, ideas
- Alfa (8 – 13Hz) – occur an adult who is awake but relaxed with eyes closed
- Beta (13 – 22Hz) – occur during deep sleep, REM sleep when the eyes switch back and forth.

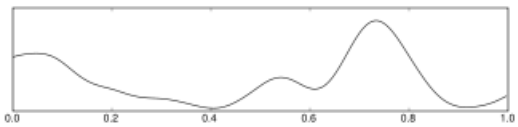

Fig. 6. Delta activity

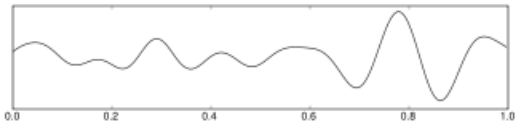

Fig. 7. Theta activity

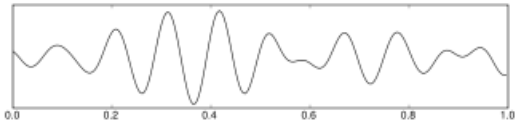

Fig. 8. Alfa activity

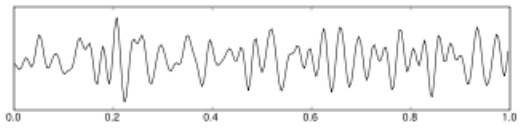

Fig. 9. Beta activity

Next are the signals normalized, 1 has a max value of the signal and 0 has a min value of the signal, a log-sigmoid function is used. I tried to learn the neural network following way:

- Output equals 1 in the case of signal from group A (FP2, FZ) as input signal.
- Output equals 0 in the case of signal from group B (*FZ*, *F7*) as input signal.

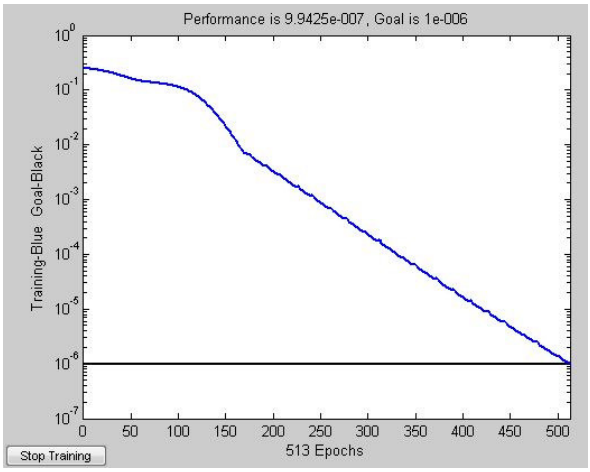

Fig. 10. Neural network training

Table 1. Outputs values of neural network by testing signals using

	FZ	**FP2**	***FZ***	***F7***
1	0,9107	0,9982	0,0032	0,0001
2	0,2860	0,8100	0,0001	0,0065
3	0,0962	0,9560	0,0007	0,0017
4	0,0246	0,9706	0,0002	0,0484
5	0,1786	0,9672	0,0026	0,0001
6	0,8552	0,9431	0.0001	0,0466

The table show if work the network correct or not. By using test signals from class B (*FZ, F7*) as input signal, output equals 0. Network is learnt and works correct. Problem is if I used test signals from class A (FZ, FP2). Network is learnt but works not correct (signal FZ, line 1 and 6). The output value by class A should be 0 but by signal FZ is output in two cases 0, 9107 (line 1) or 0, 8552 (line 6). It is due to small training group. Training group A is not so large to right network learning and correct signal classification.

6. CONCLUSION

This paper presents the application method of neural network by signal classification in two classes. The network has one secret layer with 20 neurons, 40 input neurons and one output. The network classifies signal in two classes. It has wrong applicability in praxis, because it is only basic network. There are about 120 classes of segments on the present. For this number of classes the neural network should be bigger and should have bigger training set of signals. By neuron count reduction the network is faster but it results in knowledge generalization. It is very big optimization problem. If there are a small number of neurons, network may not be able to classify signals correctly. Other way, if there are big numbers of network neurons, network may overload the system. Training set largeness is important too. When using small training set, the network is not able to learn and classify signals correctly. In the future work the neural network will be used to sleep status analysis.

REFERENCES

[1] VONDRÁK, I.: *Umělá inteligence a neuronové sítě. Skriptum VŠB - TU Ostrava,* 1994

[2] Neural Networks, *http://www.aiit.sk/source/publications/thesis/phd_thesis_prospectuses/1999/bundzel/html/node1.html, 12.10.2007*

[3] ARBIB, MICHAEL A.: *The Handbook of Brain Theory and Neural Networks,* 1995.

[4] WILKES, A.L. & WADE, N.J.: *"Bain on Neural Networks". Brain and Cognition* 33: 295–305, 1997.

[5] KVASNIČKA V., BEŇUŠKOVÁ L.: *Úvod do teórie neurónových sietí*

[6] MOHYLOVÁ, J., KRAJČA,V.: *Aplikace shlukové analýzy pro zpracování EEG záznamů, Ostrava:, Katedra teoretické elektrotechniky, FEI, VŠB - TU Ostrava,* 2001, 80-7078-922-6

[7] MATLAB,*http://www.mathworks.com/ 6.2.2007*