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„ДНИ НА НАУКАТА НА ТУ-СОФИЯ“ Созопол’2014

юбилей
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ДЕТЕКТОР НА ЛЪЖАТА С ИЗПОЛЗВАНЕ НА ЕЕГ СИГНАЛИ ОТ ЧОВЕШКИЯ МОЗЪК И КЛАСИФИКАЦИЯ С НЕВРОННИ МРЕЖИ

Радослава Авджиева

Резюме: *Детектор на лъжата се ползва най-често от правоприлагащите агенции. Изследването в тази статия предлага нова методика за откриване на измами. С извлечени тестови ЕЕГ данни, с електроенцефалографска шапка модел "Emotiv EPOC", посредством контролиран експеримент е разработена система в среда на MATLAB, използваща апарата на невронните мрежи за класификация на входни сигнали извличани от човешкия мозък. Представен е експеримент, който да служи като обучаваща и тестова извадка с цел да се определи дали даден изследван субект е свързан с конкретно събитие или въпрос. Направена е проверка за коректността на разпознаването.*

Ключови думи: *мозъчни вълни, ЕЕГ сигнали, детектор на лъжата, невронни мрежи, MATLAB*

LIE DETECTOR WITH USAGE OF EEG SIGNALS FROM THE HUMAN BRAIN AND CLASSIFICATION WITH NEURAL NETWORKS

Radoslava Avdzhieva

Abstract: *The lie detector is used most often by law enforcement agencies. This paper proposes a new method for fraud detection. EEG test data extracted with an electroencephalograph neuroheadset "Emotiv EPOC", obtained through a controlled experiment, was used to develop a system in MATLAB that uses neural networks for classification of input signals extract from human brain. An experiment is presented for the purpose to obtain train and test samples in order to determine whether the test subject is connected to a specific event or question. An evaluation of the correctness of the classification rate recognition is performed.*

Keywords: *brainwaves, EEG signals, lie detector, Neural Networks, MATLAB*

1. Introduction

Detection of lies and fraught is an important topic in psychology and criminology [1]. The classic test involves measurements on the heartbeat pulse and some other parameters like blood pressure, respiration, skin resistance, electrodermal activity, and some others used as indicators and are called a Polygraph test [2]. The past research on the topic showed that people generally exhibit certain characteristics when they are lying.

These researches have produced the modern polygraph lie detector test. Usually when a person lies these parameters deviate slightly, so the measurements on the parameters used in the polygraph test are compared to the normal levels of the subject as reference. The main disadvantage of the Polygraph is that this test type does not detect lies directly, as it is designed to look for substantial involuntary changes, which occur in a human's body when that person is subjected to stress, such as the stress associated with deception [3].

The general idea behind a “lie detector” using electroencephalograph (EEG) signals extracted from the human brain is the simple concept, that when humans lie, they create different brain patterns. Usually the task of the pattern classification is difficult for execution. When a person lies, the system should notice that certain activities are varying from their normal parameters. These “activities” are monitored by connecting various electrodes to specific points on a human scalp which will be monitored by reception of the signals coming from the electroencephalography sensors [3].

The task of EEG signal pattern recognition is a task of signal recognition from multidimensional nonstationary signals in time and frequency domains. Neural networks are a viable tool for pattern recognition tasks. Neural networks are composed of simple computational elements called neurons, which operate in parallel [4]. If there is enough experimental data some patterns can be approximated by training a neural network so that particular inputs will lead to a specific target outputs. This is the key element of the implementation of the Lie detector by usage of EEG signals and neural networks as classifier.

The paper is organized in the following way: In the next chapter is presented a data description of the EEG signals. The EEG signals data recording device that we use for signal extraction is presented in chapter 3. A procedure for lie detection in MATLAB with electroencephalography signals extracted with “Emotiv EPOC” Neuroheadset from a human test and neural networks, which can be used as “Lie Detector”, is presented in chapter 4. The implementation of the neural network classifiers is presented in chapter 5. The conclusion remarks are given in the last chapter of the paper.

2. EEG Data Description

Electroencephalography (EEG) is the recording of electrical activity of the human brain [5]. EEG refers to the recording of the brain’s instant electrical activity for short periods of time as recorded from multiple electrodes placed on the scalp. That is, the type of neural oscillations that can be observed in EEG signals [6]. 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.

The International standard for EEE electode placement is the so-called 10-20 system, that is usually employed to record the spontaneous EEG. In this system 21 electrodes are located on the surface of the scalp as shown in Fig.1 [7].

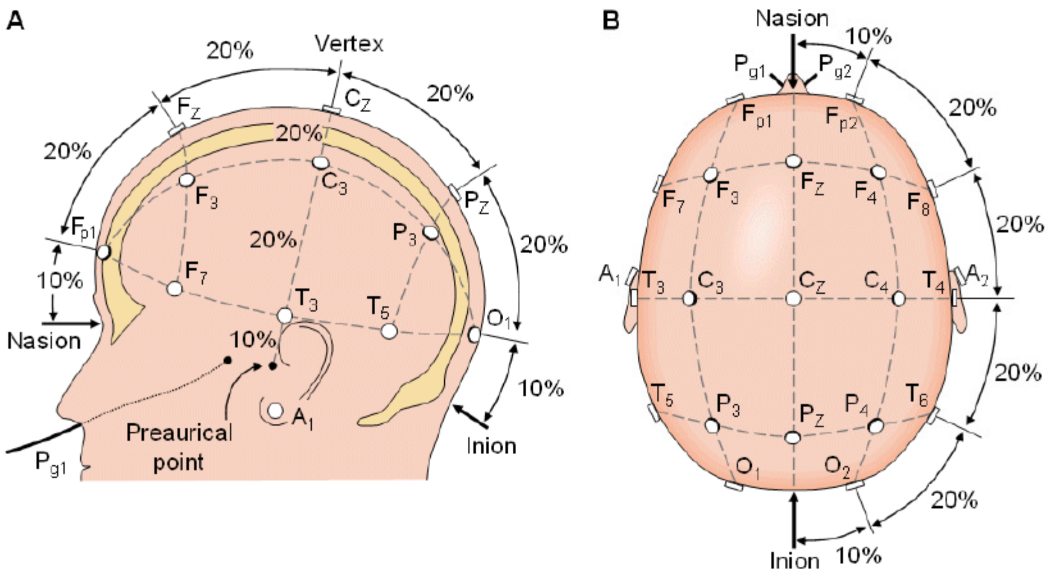

Fig.1. The International 10-20 system of electrode placement

3. EEG signal extraction system description

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 utilizes 16 electrodes that come into contact with the scalp of the head and using the conventional technology - electroencephalography, by detection of the electric signals from the surface (Fig.2) of the scalp [8].

Fig.2. Emotiv EPOC Neuroheadset

The "Emotiv EPOC" EEG neuroheadset 16 sensors are divided into groups of two for calibration purposes and 14 channels for EEG data with 2 gyros for 2 dimensional controls. The main advantage of this system is that it is wireless cable free solution, with the signal amplifier integrated in the headset, with long autonomous operation time. The "Emotiv EPOC" sends EEG data to PC with USB receiver via Bluetooth interface. 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 (Fig.3). Other specifications are listed below (Table.1) [8]. The academic version of the "Emotiv" software, the "Research Edition SDK", was used for data extraction, because with it the raw data can be accessed and saved for external program access.

Table 1 “Emotiv EPOC” Specifications:

Number of channels	14 (plus CMS/DRL references)
Channel names (International 10-20 locations)	AF3, AF4, F3, F4, F7, F8, FC5, FC6, P7, P8, T7, T8, O1, O2
Sampling method	Sequential sampling, Single ADC
Sampling rate	~ 128 Hz (2048 Hz internal)
Resolution	16 bits (14 effective) 1 LSB = 1.95 uV
Bandwidth	0.2 – 45 Hz; digital notch filters at 40 Hz and 60 Hz
Dynamic range (input referred)	256 mV (pp)
Coupling mode	AC coupled
Connectivity	Proprietary wireless, 2.4 GHz band
Battery type	Li-Poly
Battery life	12 hours
Impedance measurement	Real-time contact quality using patented system

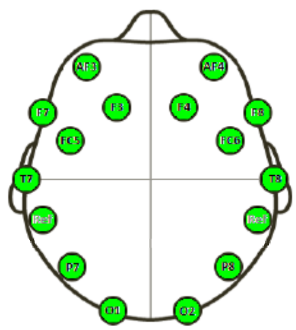

Fig.3. Emotiv EPOC’s Sensor Layout

4. General idea for the lie detector and EEG signal processing

For the purpose of the paper goals, there will be a need to calibrate and implement a “Lie Detector” in a so call polygraph test, but with EEG signals monitored. The input data will be sampled from the fourteen sensors that collect the distinct types of EEG signals from the human brain. The electroencephalography sensors with the EEG signals measure the movement of the brainwaves from a person who is being tested. After the lie detector is specified, a data gathering is to be performed from a group of volunteers. Their brainwaves are to be recorded while they are asked a series of test questions. After completing the test they will be asked which of the questions they answered were answered false. Based on these tests the data is converged. This data will be used to train an neural network, used as classifier. The trained neural network structure will essentially form, a “Lie Detector” that will acquire future readings from subjects at the input and produce the final result on the output of the neural network. If the new readings match the data used for training, the “Lie Detector” will activate indicating that the subject is telling truth or lie [3].

The EEG signals were recorded at 128Hz sampling rate from the 14 electrodes, placed at the standard positions of the International 10-20 system.

The display screen of “Emotiv EPOC” software during one experiment is shown in Fig.4. At the time of recording the test subject is asked a series of questions and the brainwaves are recorder, recorded is also and audio stream with the questions to match the questions and answers in time moments with the data samples. Signal recording is stopped when the question pool ends and then the final dataset is saved.

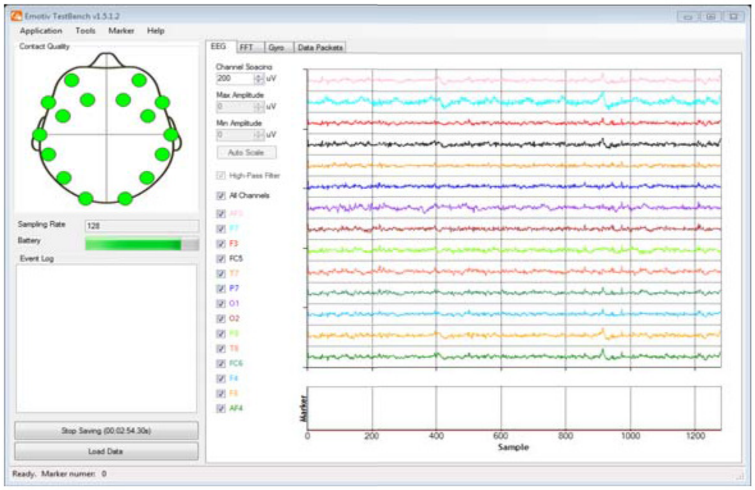

Fig.4. Emotiv EPOC TestBench

A plot window of the obtained EEG signals from all of the channels in MATLAB, using pre-recorded data from one experiment for the time of a few seconds is shown in Fig.5.

Lie detection can be represented in different ways. Depending on the situation and the kind of EEG signals information that needs to be present, one representation domain might be more appropriate than the other one.

Waveform is the most general way to represent a signal [9]. Variations of amplitude in time are presented. The biggest disadvantage of this method is that it cannot represent related information. A timedomain signal as such contains too much irrelevant data to use it directly for classification.

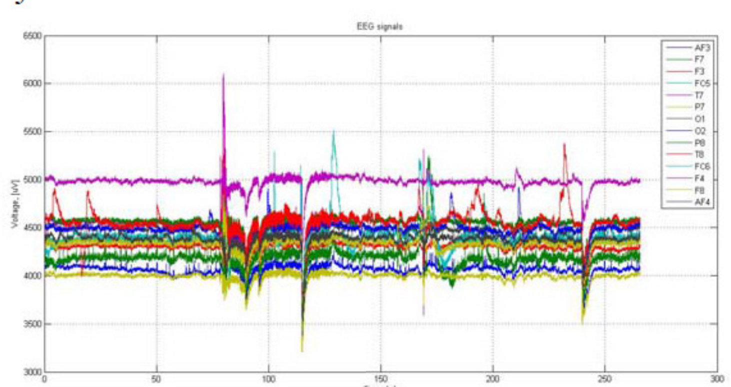

Fig.5. EEG signals in time domain obtained from all 14 channels in MATLAB

Fig.6 shows the timedomain representation of the truth and lie answer on one question. It is clear that based with this representation, it would be difficult to extract relevant information and thus cannot be used as input for the neural network classifier.

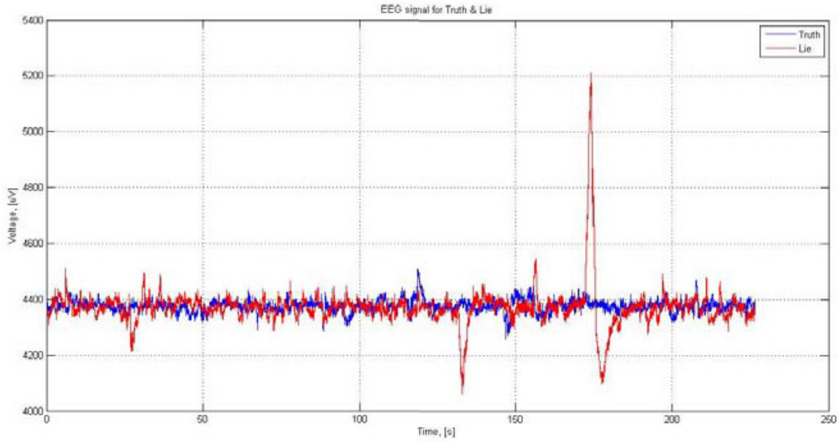

Fig.6. Timedomain representation of the truth and lie in MATLAB

On every EEG signal an 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).

On this basis, applying sets of neural networks has been developed and implemented a methodology that can effectively distinguish when a person is lying or telling the truth.

5. Neural Network classifier Implementation

The MATLAB Neural Network toolbox has been used to create, train and simulate the neural networks [10]. For every test-set we used blocks of 256 recorded samples, that was equivalent to 2 seconds, taken for all of the 14 data channels, every datasample is with length 256*14=3584 input points. For one hour of data recording there are 1800 datasamples possible. Several tests were made with 1400 datasamples vectors representatives of lie and truth events, where 700 samples were used for training, while the other 700 were be used to test the network (not included in the training dataset). The trained network can be tested in real time.

The neural nets used for the classification of input signals extract from human brain are a Feedforward Neural Networks, which use Back Propagation algorithm for training (Fig.7).

This type of NN is the most popular NN and is used worldwide in many different types of applications. The network used consists of an input layer, one hidden layer and an output layer.

To the input of the Neural network are fed a vector consisting of all data points from the "Emotiv EPOC" for one sample as it consists of 14 x 256 = 3584 data points. In this case the NN would require the same amount of inputs. In this particular design all these input ranges are put in a 'InputLayer' variable matrix.

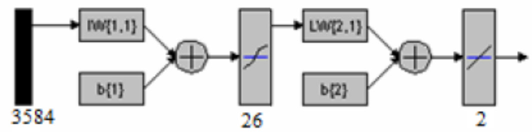

Fig.7. Example of the Feedforward Network using Back Propagation algorithm

The hidden layer consists of nonlinear sigmoidal activation function neurons using the 'tansig' MATLAB NN Toolbox function. The amount of neurons depends on some factors like the amount of input data and output layer neuron number, the needed generalization capacity of the network and the size of the training set.

Once the network is created, it can be trained for a specific problem by presenting training input EEG signals and their corresponding targets (supervised training). A set of 700 samples of each test-question is used as training data. The network is trained in batch mode which means that the weights and biases of the network are updated only after the entire training set has been applied to the network. The gradients calculated at each training example are added together to determine the change in the weights and biases. In most cases, 100 up to 200 epochs are enough to train the network sufficiently. In the training phase the network error reaches almost zero as can be seen on Fig.8.

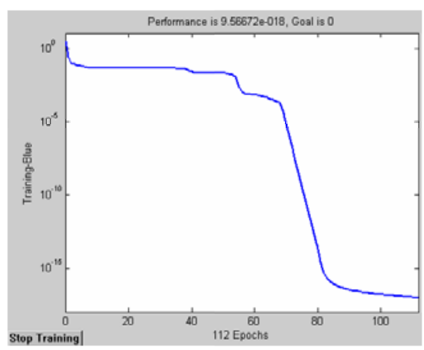

Fig.8. Training the Feedforward Backpropagation Network

The trained network was simulated with inputs that were not included in the training set. The trained network performed very well with more than 80% successful classification results.

When the number of samples that have to be recognized increases the number of hidden layer neurons also has to be increased. Increasing the number of hidden layer units causes the training time to grow sensitively. The performance of the network is mainly dependent on the quality of the signal preprocessing.

6. Conclusion

This paper presented an experiment on lie detection based on brain wavelet analysis with neural networks used as classifier in MATLAB. The results presented in this paper are part of a project with the ultimate goal of designing and developing "Lie Detector". The proposed method is suitable for integration as additional parameter or complimentary test of the standard polygraph test.

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