Artificial Neural Networks for Evaluation of Psychophysiological State

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***Abstract*—In this document, we make an analysis of the possibility of using neural networks in the development of tests to evaluate the psychophysiological state of a human. Also, in this paper, the developed system of psychophysiological diagnostics is presented. This system will automate the execution and processing of results of the express testing methods for evaluation the psychophysiological state.**

The described model of evaluation the human's psychophysiological state using a neural network has the following advantages: remote diagnostics, stability and accuracy of the results, the ability to self-training by detecting complex dependencies, identification of typical trends for people of a certain profession or in a particular area.

It has been proved that the usage of neural networks for processing the results of psychophysiological tests will improve the accuracy of diagnosis.

***Keywords*—diagnosis, human physiological state, brain asymmetry, physiological tests, decision-making support, neural network.**

I. Introduction

Nowadays, psychophysiology has a lot of methods and tools for evaluation of the human psychophysiological state. This branch of psychology is rapidly developing and adjusting under the ever-changing requirements. The results obtained from psychophysiological diagnostics are used in different fields of human activity, ranging from career counseling up to monitoring the condition of the person prior to admission to work. The tools used for diagnosis have come a long way from the old techniques with paper blanks and patient monitoring to hardware and software systems and mobile applications. One of the ways to improve the quality of diagnosis and the search for new patterns is the use of neural networks.

Artificial neural networks are one of the artificial intelligence technologies used for solving such complex problems. Today neural networks are widely used in science and technology with applications in various areas of chemistry, physics, and biology [1].

For example, artificial neural networks are used in chemical kinetics [2], prediction of the behavior of industrial reactors [3], modeling kinetics of drug release [4], optimization of electrophoretic methods [5], classification of agricultural products such as onion varieties [6], and even species determination [7][8][9].

An analysis of the use of neural networks for medical diagnosis has given the following result: in many cases, neural networks have been able to diagnose the disease two times more accurately than the expert. Using of the neural networks has a few significant advantages, such as:

- The ability to conduct remote diagnostics, which is quite an important criterion for a lot of people who do not have the opportunity to visit a good specialist;
- The stability of the diagnostic results, regardless of the expert mood and interpersonal interaction;
- The ability to process large amount of data;
- The ability to find complex dependencies in an input data;
- Reduction of diagnosis time.

It is proved [13], that the use of neural networks has a number of drawbacks. For example, a neural network can inherit specialist's knowledge gaps if they are into the training sample. Consequently, the high quality of input data is vital. Accordingly, using data obtained from several experts in different (but related) profiles, we can assume that the neural network will diagnose more accurately than the average medical consultant.

The purpose of this paper is an analysis of the existing solutions that use neural networks in medical diagnosis and attempt to use one of the considered models for the evaluation of human psychophysiological state using the data obtained from the developed tests.

II. Using neural networks for solving the problems of medical diagnostics

A. An analysis of the applications of neural networks for the diagnosis of myocardial infarction

Neural networks are used for medical diagnosis because each person has a unique, specific set of peculiarities. This makes it difficult to develop a universal method of diagnosis for all people. The approach of using neural networks in this case allows to increase the accuracy of diagnosis, as compared with

the results obtained by using amplitude-time methods [12]. In a training sample, the final estimate of psychophysiological state was based on the solutions of several experts, according to the majority decision. Every decision can correspond with two propositions:

- Suspected myocardial infarction;
- Signs of a heart attack are not detected.

Learning Vector Quantization (LVQ) Neural Networks has been used for implementation of this analysis (Fig. 1).

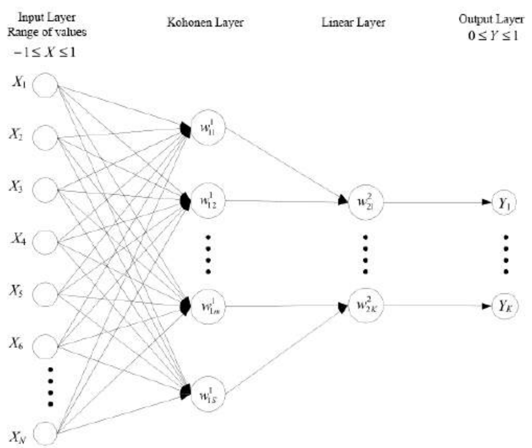

Figure 1. The structure of the LVQ Neural Networks

The value of the output signal of the LVQ neural network determined by using this formula:

$$S = \sqrt{\sum_{i=1}^{N} * (x_i - w_{im}^1)}^2 .$$

$$Y_k = F_{lin} + \left(\sum_{j=1}^{s} w_{jk}^2 * F_{compet}(S) \right) .$$

where x_i – i-th element of the input vector, w_{im}^1 – i-th element of the vector of weight m-th neuron in kohonen layer, w_{jm}^2 – j-th element of the vector of weight k-th neuron in linear layer, F_{compet} – the function of kohonen layer, F_{lin} – the function of linear layer, N – the number of elements in input vector, S – the number of elements in the kohonen layer, Y_k – k-th value of the output vector.

B. An analysis of the applications of neural networks for the recognition and expression of emotions based on physiological parameters

The necessity of using neural networks [11] is due to the complexity of the relationships between physiological and psychological states, which are based on the interaction of the various systems of the body and are characterized by non-linear and multi-layered structure.

To display the relationship between physiological and psychological states, the neural network with backpropagation method of training was used. This neural network is composed of several layers of neurons, wherein each neuron of layer *i* is connected to each neuron of layer *i + 1*. In this case, three layers have been realized:

- The first layer contains basic physiological parameters;
- Second – physiological functional systems;
- Third, depending on the first two, the cognitive and regulatory abilities.

Twelve factorial estimates calculated from the primary physiological parameters are used as input parameters. The rhythm of the front and lateral cortex of the brain, the reactivity of the nervous system, vascular reactions, changes in blood pressure and other emotional pressure are examples of physiological parameters. Parameters of the emotional competence are the output data. The relationship between physiological parameters and varying functional system was revealed during the analysis of the model of the neural network, that will accordingly formalize the diagnosis of emotional competence, taking into account the physiological characteristics.

Diagnosis of psychological indicators using physiological parameters with help of neural networks promotes the creation of an instrument to consolidate existing psychological and physiological methods of diagnosis psychophysiological state [11]. To date, the problem lies in the fact that the physiological and psychological techniques were developed in isolation from each other without considering the relationship of psychic and physiological systems of a human. The use of neural networks for solving this problem would integrate the existing psychological and physiological methods of diagnosis of psychophysiological state of a human. In this case, backpropagation is used for training of neural network. One of the improvements of this model is the method of steepest descent at the training.

C. Using neural networks for diagnosis of psychophysiological state of a human

Successful using of neural networks in the field of medical diagnosis was the basis of research on the use of neural networks for the classification of psychophysiological states, using data that was obtained from psychological tests.

The system of analysis of a psychophysiological state of a human contains a set of tests of a different kind for identification of psychophysiological characteristics of a human. To date, the system has two psychophysiological tests: the reaction to a moving object and a tapping rate.

Designed reaction to a moving objects test suggests that the subject will respond at the moment when the moving object crosses fixed marks as fast as possible. Initially, the test was used to determine the ratio of excitation and inhibition processes. Prevalence of correct answers indicates a high functional condition of the nervous system, the high number of outrunning errors proves the predominance of excitation processes, and a high number of lag errors shows predominance of inhibitory processes. Realized test also helps to evaluate the functional asymmetry of the human brain.

The tapping rate is used to identify the strength of the nervous system of a human by analyzing their psychomotor performance [10]. This test monitors changes of the maximum rate of wrist movements and provides the following data for the analysis: number of errors, the average time of pressing, the duration of the test, the number of taps every five seconds.

To collect statistical data, a sequence of five experiments with pupils from sports school and students has been conducted. A total of 30 people were tested. The age of subjects varied from 14 to 22 years of age. The final decision on the psychophysiological state of a human is based on the assessment of several experts. The resulting experimental data is a training database for the neural network.

The database is a table (or matrix) of data concerning persons for whom the psychophysiological state is already known. Each row of the matrix refers to one person (Fig. 2). The first m elements of the row are test data and the last n elements represent the output (results). The term "test data" indicates results of tests and other information provided by the person.

Person code	TEST DATA			RESULTS
1	$data_{1,1}$ ...	$data_{1,i}$ ...	$data_{1,m}$	POSITIVE
2	$data_{2,1}$ ...	$data_{2,i}$ ...	$data_{2,m}$	POSITIVE
3	$data_{3,1}$ ...	$data_{3,i}$ ...	$data_{3,m}$	POSITIVE
...	...	...	...	...
k	$data_{k,1}$ ...	$data_{k,i}$ ...	$data_{k,m}$	NEGATIVE
k+1	$data_{k+1,1}$ ...	$data_{k+1,i}$ ...	$data_{k+1,m}$	NEGATIVE
...	...	...	...	...
n	$data_{n,1}$ ...	$data_{n,i}$ ...	$data_{n,m}$	NEGATIVE

Figure 2. Example of training database structure. Each row refers to a different person labeled with a numerical code.

Let's determine the number of neural networks. Since each test involves a different dimension of the input vector to the neural network and is used to determine a different number of psychological parameters, it is advisable to use the number of the neural networks that is equal to the number of tests. Also, unique parameters of each individual test should be taken into account during the training.

D. A generalized description of the neural network to process the results of various psychophysiological tests is offered

The neural network that was discussed in details in [10] was implemented to solve this problem. This neural network is a multilayer backpropagation network. The structure of a neural network is formed by an "input" layer, one or more "hidden" layers, and the "output" layer (Fig. 3).

The neurons in the input layer receive the data and transfer them to neurons in the first hidden layer through the weighted links. Here, the data are mathematically processed and the result is transferred to the neurons in the next layer. Ultimately, the neurons in the last layer provide the network's output.

By the final user, the neural network can be viewed as a "black box" that receives a vector with m inputs and provides a vector with n outputs (Fig. 4) [1].

For each of the tests, we established its own neural network, because the dimension of the input and output vectors are different.

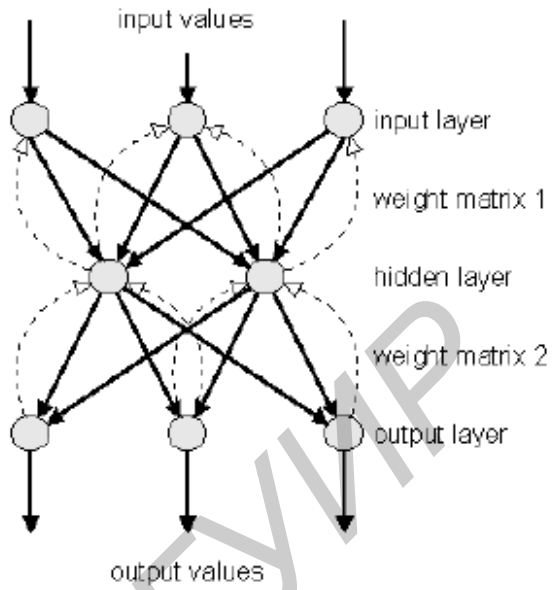

Figure 3. A multilayer neural network with backpropagation error and one hidden layer

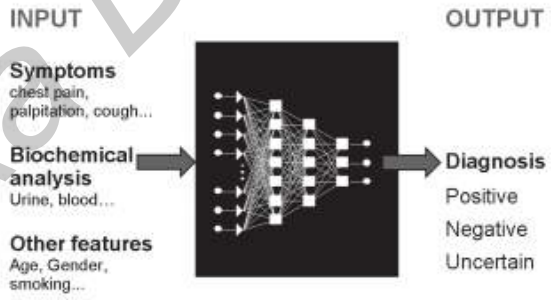

Figure 4. Details of input and output items concerning neural networks based diagnosis

An example of the input and output vectors for neural network used to process results of reaction to a moving objects test is presented here. Six test results are given to neural network. Results contain 2 parameters and 16 discrete values. Here is an example of one of this test results:

- The velocity of the object 100 pixels/sec;
- Direction of the object: from left to right;
- Difference between the position of the label and the fixed object (15 values): -1, -4, -3, -3, -4, 5, -3, -4, -4, -3, 1, -4, 0, -6, -2.

Thus, the dimension of the input vector N = 17 * 6 = 102.

The neural network is able to identify the following properties of the human nervous system:

- Strength of the nervous system: strong / weak;
- Functional asymmetry of the brain: the left / right / not expressed;
- Ratio of excitation and inhibition: excitation / inhibition / balanced.

The dimension of the output vector K is defined as a composition of the number of options and the count of values of each of the recognized properties of the nervous system; and is equal to K = 2 * 3 * 3 = 18.

III. Conclusions

The article shows that neural networks are an effective tool for the study of a stochastic system, such as a person. The usage of neural networks in the psychophysiological diagnostics improves accuracy by identifying the hidden relationships between different human systems. In addition, their use makes the diagnosis more reliable and therefore increases patient satisfaction. It is worth to remember that the psychophysiological state of a person depends on many factors such as physiological condition, emotional area, behavioral sphere.

This hierarchy corresponds to a multilayer structure of the neural network shown in Fig. 3 and has the following properties:

- The presence of a nonlinear relationship between the first and last layers can determine the number of layers and the number of neurons in each layer;
- Each intermediate layer represents one level of the system and is interpreted separately.

The ability to use the neural networks for processing the results of psychophysiological tests was confirmed with the help of a generalized description of the neural network, and examples of input and output vectors for processing results of the reaction to moving objects test. Thus, it justified that the use of neural networks for the processing of the results in the developed tests will improve the accuracy of diagnosis. However, despite their wide application in modern diagnosis, they must be considered only as a tool to facilitate the final decision of a clinician, who is ultimately responsible for critical evaluation of the artificial neural network output.

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ИСКУССТВЕННЫЕ НЕЙРОННЫЕ СЕТИ ДЛЯ ОЦЕНКИ ПСИХОФИЗИОЛОГИЧЕСКОГО СОСТОЯНИЯ ЧЕЛОВЕКА

Порядин А. Е., Сидоркина И. Г.

В работе исследуется возможность использования нейронных сетей при разработке тестов для оценки психофизиологического состояния человека. Описана компьютерная система психофизиологической диагностики человека, позволяющая автоматизировать выполнение и обработку результатов экспресс-методик. Представленная модель оценки психофизиологического состояния человека, использующая нейронную сеть, имеет следующие преимущества: возможность проведения диагностики удаленно, стабильность и точность результатов, способность к самообучению путем обнаружения сложных зависимостей, выявление типичных тенденций для людей определенной профессии или в той или иной области, обработка большого количества данных и снижение времени диагностики.