Multilayer neural network in differential diagnosis of balance disorders

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Abstract: - The aim of this study was the differential diagnosis of balance disorders thus a clear distinction between the patient with balance disorders and the patient without balance disorders. The data used in this article was measured under the static conditions on the posturography platform. The patients were split to three groups, peripheral, central and normal based on doctor's diagnosis. These patients were used as input to neural network. Was selected the multilayer network with Backpropagation algorithm. The network was learned the combination of the particular diagnosis thus, the network was learned the combination of normal-peripheral, peripheral-central and central-normal diagnosis. The test set contained 10 normal, 10 peripheral, and 10 central patients, who were evaluated already learned the multilayer neural networks with Backpropagation algorithm. From the results was found out that the proposed multilayer network was able to correctly determine the diagnosis of the particularly patients of 67%.

Key-Words: - posturography, Romberg test, Backpropagation algorithm, differential diagnosis, balance disorders, peripheral, central

1 Introduction

Differential diagnosis of peripheral and central vestibular syndrome and exclusion of non-vestibular vertigo is the basic vestibular question. At its result depends other diagnostic procedures, treatment and forecasting.

Peripheral Vestibular Disorders (PVD) includes pathology of inner ear vestibular structures as well as the vestibular portion of the eighth cranial nerve. Such pathology diminishes available sensory information regarding head position and movement. These disorders include neuritis, labyrinthitis, bilateral vestibular loss, Meniere’s, BPPV, and vestibulopathy following surgical procedures (e.g. labyrinthectomy and acoustic neuroma). [5]

Central Vestibular Disorders (CVD) primarily involves the vestibular nuclear complex and the cerebellum, as well as structures of the reticular activating system, midbrain, and higher centers of cortical function. Pathology of the central vestibular structures affects integration and processing of sensory input from the vestibular, visual, and somatosensory systems. The most common CVD include brainstem strokes, head trauma, migraine-related vestibulopathy, multiple sclerosis, and cerebellar degeneration. [5]

Both PVD and CVD reduce the appropriate neural output for spatial orientation, postural control, and eye movement control. Individuals with either disorder might report problems of dizziness, imbalance, falls, and/or visual blurring (oscillopsia).

There are many studies deal with the differential diagnosis of balance disorders of the human but there are not many studies using modern methods of artificial intelligence. This article deals with the differential diagnosis of balance disorders using a multilayer neural network with the Backpropagation algorithm.

2 The Backpropagation algorithm

Backpropagation is one of the most popular and known algorithms for multi-layer neural network learning. Initially, it was described in 1974, and from that time, it was extensively studied and applied to a broad range of different tasks. Because the algorithm is able to train multi-layer neural networks, the range of its applications is very great, and includes such tasks as approximation, prediction, object recognition, etc.

Backpropagation is an algorithm that was created for training multilayer neural networks with the teacher. This algorithm adjusts the weights of individual connections reverse, so that their sizes were in terms of the problem if possible optimal – is looking for the global minimum of error function. Setting the weights is thus in the opposite direction of the spread input.

2.1 Phases in Backpropagation Technique

The back propagation learning algorithm can be divided into two phases: propagation and weight update.

Phase 1: Propagation
Each propagation involves the following steps:

1. Forward propagation of a training pattern's input through the neural network in order to generate the propagation's output activations.
2. Back propagation of the propagation's output activations through the neural network using the training pattern's target in order to generate the deltas of all output and hidden neurons. [4, 17]

Phase 2: Weight Update
For each weight-synapse:

1. Multiply its output delta and input activation to get the gradient of the weight.
2. Bring the weight in the direction of the gradient by adding a ratio of it from the weight. [4, 17]

This ratio influences the speed and quality of learning; it is called the learning rate. The sign of the gradient of a weight indicates where the error is increasing; this is why the weight must be updated in the opposite direction.
Repeat the phase 1 and 2 until the performance of the network is satisfactory.

2.2 Derivation of the Backpropagation algorithm

Three-layer network with the training set consisting of pairs of vectors "$T_s\{x[k], d[k]\}_{k=1}^{N}$", where N is the number of vectors, x [k] is k-th input vector and d [k] is output vector.

Error in one vector:

$$\mathrm{E(k)} = \frac{\sum_{j=1}^{m}\left[y_j(k)-d_j(k)\right]^2}{2} \qquad (1)$$

Where:

y_j (k) is a response to the k-th input vector
d_j (k) is the desired output pattern

Global error for the epoch in BP:

$$\mathrm{E}_T = \sum_{k=1}^{N} E(k) \qquad (2)$$

Partial differential equations for the calculation of the error correction:

$$\frac{\partial E(k)}{\partial w_{ij}^0} = \frac{\partial E}{\partial w_i^0}\frac{\partial y_i^0}{\partial \Psi_i^0}\frac{\partial \Psi_i^0}{\partial w_{ij}^0} \qquad (3)$$

The variable ψ is the sum of all inputs and w_{ij} is the weight of the respective joints.

The difference between the original and output:

$$\frac{\partial E}{\partial y_i^0} = y_i^0 - d_i \qquad (4)$$

Derivative of the sigmoid:

$$\frac{\partial y_i^0}{\partial \Psi_i^0} = y_i(1-y_i) \qquad (5)$$

The output of the neuron:

$$\frac{\partial \Psi_i^0}{\partial w_{ij}^0} = y_j^1 \qquad (6)$$

Delta for the output layer:

$$\frac{\partial E(k)}{\partial w_{ij}^0} = \left(y_i^0 - d_i\right)y_i(1-y_i)y_j^1 = \frac{\partial E(k)}{\partial \Psi_i} y_j^1 = \delta_i^0 y_j^1 \qquad (7)$$

Delta weights:

$$\Delta w_{ij}^0(t) = \eta \delta_i^0(t) y_j^1(t) + \mu \Delta w_{ij}^0(t-1) \qquad (8)$$

Correction weights:

$$w_{ij}^0(t+1) = w_{ij}^0(t) + \Delta w_{ij}^0(t) \qquad (9)$$

3 Methods of posturography

Posturography is the clinical study of a patient's ability to remain upright. It involves the use of noninvasive medical testing to quantitatively measure a patient's balance and motor control. Various devices are used for posturography evaluations, including specialized platforms with sensors to provide feedback during the test [1, 8, 12, and 13].

In a posturography test, the patient wears a safety harness in case of falls and is positioned on a platform. The most basic test involves asking the patient to stand up and hold the position as long as possible. Sensors in the platform provide information about how the patient's weight is distributed and will update when the patient loses balance and the weight shifts or becomes destabilized. Other tests can involve tilting or moving the platform to see how well a patient adapts to changing conditions [1, 8, 12, and 13].

Posturography as an examination method is measuring of postural balance in static or dynamic conditions.

Static methods are mostly judging standing balance, when is the patient placed in a standing posture on a fixed instrumented platform connected to sensitive detectors, which are able to detect the tiny oscillations of the body [15, 16, 18]. See Fig. 1.

Fig. 1 Static posturography platform [2]

Dynamic posturography differentiates from static posturography in that it usually involves perturbing the subject’s posture by means of a foam cushion or a special apparatus with a movable horizontal and tilting platform. As the subject makes small movements, the sensitive detectors transmit this time-varying information in real time to a computer. Thus, the dynamic posturography test protocols can quantify the ability of a subject to maintain balance in non-static conditions. Usually coupled with the ability to test the subject either with or without visual references (eyes open or closed) or with a moving environment that gives conflicting visual information, dynamic posturography makes it possible to quantify a subject's vestibular functions. This is because, in certain testing conditions, the visual and proprioceptive systems cannot be used, and the subject must rely only on the vestibular system to maintain balance [15, 16, and 18].

Dynamic methods generally used a special apparatus with a movable horizontal platform [15, 16]. See Fig.2.

Fig. 2 Computerized Dynamic Posturography [11]

4 Vestibular function testing

The spectrum of diseases causing vertigo is very broad, hence the first visit a doctor you have to try to provide him as much information as possible. The exact description of the symptoms helps doctors diagnose, determine the strategy of further examination and plays an important a role in treatment.

It is useful to know in particular:

- at which time the dizziness occurs
- what it causes (changes in atmospheric pressure, emotional or physical stress, premenstrual period)
- symptoms, such as (nausea, tinnitus, increase in arterial pressure, sweating, headache, tendency to fall, etc.)
- what medicines you are taking, because dizziness can be caused by the use of certain drugs
- if you have recently suffered a head injury or neck. For example, cervical spine injury in a car accident when the head when braking or crash the car reversed rapidly forward and back

After gathering the data history and measure blood pressure the doctor performed a number of simple tests of balance function testing. [6, 8, 12, 13]

4.1 Romberg test

Romberg's test or the Romberg maneuver is a test used by doctors in a neurological examination, and also as a test for drunken driving. The exam is based on the premise that a person requires at least two of the three following senses to maintain balanced while standing:

- proprioception (the ability to know one's body in space)
- Vestibular function (the ability to know ones head position in space)
- vision (which can be used to monitor changes in body position)

A patient who has a problem with proprioception can still maintain balance by using vestibular function and vision. In the Romberg test, the patient is stood up and asked to close his eyes. A loss of balance is interpreted as a positive Romberg sign.

The Romberg test is a test of the body's sense of positioning (proprioception), which requires healthy functioning of the dorsal columns of the spinal cord [6, 8].

5 Measurement results

Posturograph STP-03 software (widely use in Czech Republic) calculates the value of the way (10) and area (11) of the patient center of gravity circumscribed over the posturography platform. Evaluates the ratio between these values for the examination with open and closed eyes are important parts of vertigo assessment.

Parameter Way, W (cm/s) describes the path of moving center of gravity, but because the examination time given a constant number, Way is characterized as the speed of center of gravity. Parameter Way for open eyes is marked with postfix f; (Wf) - visual fixation. Way for the closed eyes is marked with postfix s; (Ws) – visual suppression.

$$M_i = \sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2}$$
$$W = \frac{T^{-1}}{n} \sum_{i=1}^{n} M_i \ [mm/s] \qquad (10)$$

Where:

M_i particular element of way calculation
T measure period [s]
x,y center of gravity coordinates
n number of measured samples

Parameter Area, *A* (cm^2/s) indicates the area, which describes variation of center of gravity during the examination. Like the parameter Way, Area for the visual fixation is marked *(Af)* and for visual suppression *(As)*. [4]

$$N_i = \frac{\left| \begin{matrix} (y_{i+1} - y_0) * (x_i - x_0) \\ -(y_i - y_0) * (x_{i+1} - x_0) \end{matrix} \right|}{2}$$
$$A = \frac{1}{t} \sum_{i=1}^{n-1} N_i \ [mm^2/s] \qquad (11)$$

Where:

N_i particular element of area calculation
t length of measure [s]
x_0, y_0 average values of center of gravity coordinates *(12)*

$$x_0 = \frac{1}{n} \sum_{i=1}^{n} x_i \qquad y_0 = \frac{1}{n} \sum_{i=1}^{n} y_i \qquad (12)$$

5.1 Visual presentation of results

As mentioned earlier, the posturography examination has also visual outputs. This paper is not dealing with those results directly so outputs will be describe shortly, but information covering by them are much more wider than used numerical results.

Fig. 3 shows center of gravity trajectories (patient body motion) focus and direction of motion vector evaluation. The above charts are for open eyes, bottom for closed eyes. On the left is the trajectory of motion, in the middle motion vectors in a bar-shaped view. On the right is shown the envelope vectors.

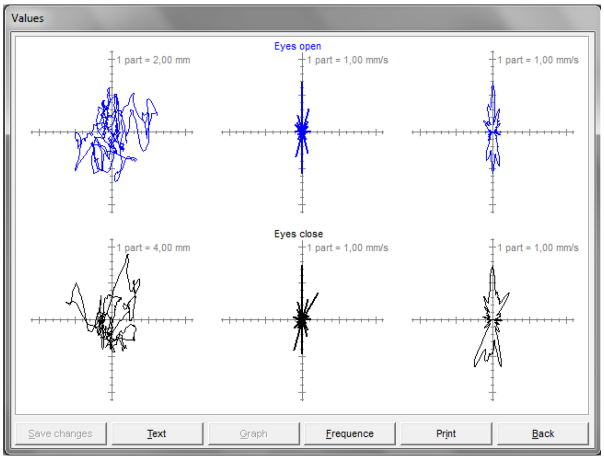

Fig. 3 Results in charts

Fig. 4 shows harmonic analysis of the patient's movements. The above charts are for open eyes bottom for closed eyes. On the left is the lateral component of movement, in the middle anteriopostural component of movement. On the right is the frequency analysis of the above mentioned components is showed. The area for the simulation analysis is highlighted by red line segments.

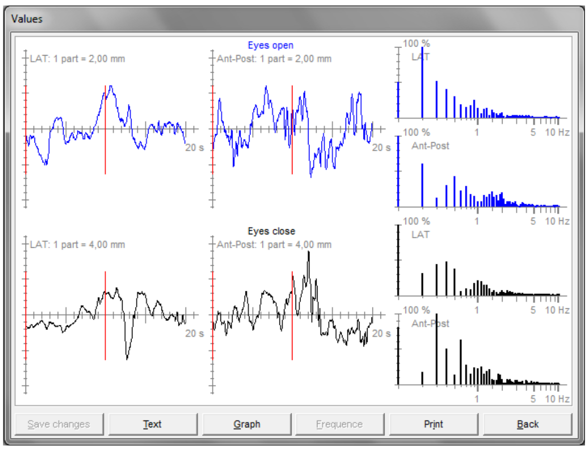

Fig. 4 Frequency analysis

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6 Subjects and method

6.1 Subjects

The patients were measured on the static posturography platform called STP-03. These patients were firstly diagnosed by doctor. The patients were split to three groups, peripheral, central and normal. Peripheral group contained 142 patients, 69 central patients and 53 normal patients. These patients were used as input to neural network.

6.2 Method

The Backpropagation algorithm was used for training of the three layer neural network.
The network contained three layers, where the input layer contained eight neurons, the hidden layer contained seven neurons and output layer contained one neuron. See Fig. 5.

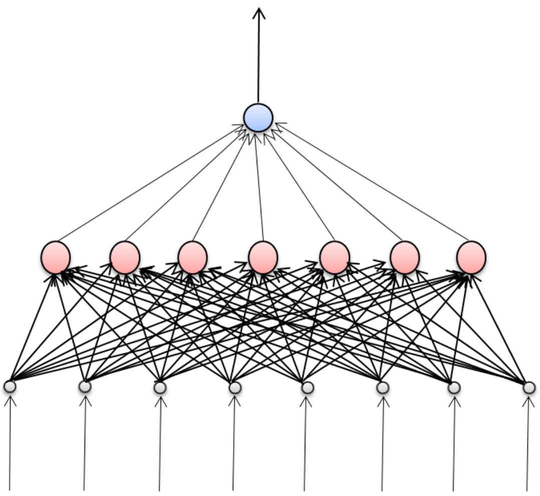

Fig. 5 Block diagram of the neural network

The network was learned the combination of the particular diagnosis. Firstly the network was learned the combination of "normal and peripheral" diagnosis. Secondly the network was learned the combination of "peripheral and central" diagnosis and then the network was learned the combination of "central and normal" diagnosis.

7 Results

The test set was contained 10 normal patients, 10 peripheral patients, and 10 central patients.
Results of normal evaluated patients show that 70% of patients were rated as normal and 30% of patients as peripheral. Results of peripheral evaluated patients show that 70% of patients were rated as peripheral and 30% as central. Results of central evaluated patients show that 60% of them were rated as the central and 40% as peripheral. See Fig. 6.

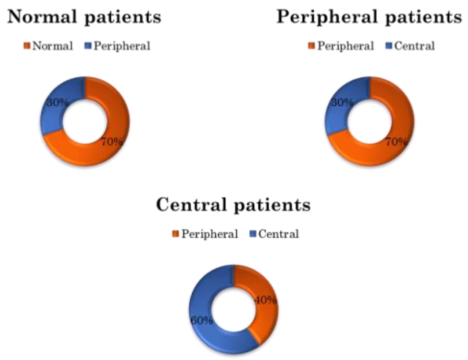

Fig. 6 The results of neural network testing

8 Conclusion

This article deals with the differential diagnosis of balance disorders in human patients. There is thus a clear distinction between the patient with balance disorders (peripheral, central) and the patient without balance disorders. The data used in this article was measured on the posturography platform called STP-03. These patients were firstly diagnosed by doctor. The patients were split to three groups, peripheral, central and normal. Peripheral group contained 142 patients, 69 central patients and 53 normal patients. These patients were used as input to neural network. Was selected the multilayer network with Backpropagation algorithm. The network comprised three layers, where the input layer contained eight neurons, the hidden layer contained seven neurons and output layer contained one neuron.
The network was learned the combination of the particular diagnosis. Thus, the first network was learned the combination of “normal-peripheral” diagnosis, the second network was learned the combination of “peripheral-central” diagnosis and last network was learned the combination of “central-normal” diagnosis. The testing set was contained 10 normal patients, 10 peripheral patients and 10 central patients.
Results of normal evaluated patients show that 70% of patients were rated as normal and 30% of patients as peripheral. Results of peripheral evaluated patients show that 70% of patients were rated as peripheral and 30% as central. Results of central evaluated patients show that 60% of them were rated as the central and 40% as peripheral.
With regard to the solved problem, it cannot say whether the results are satisfactory. During testing of individual patients was not a clear distinction between patients with central or peripheral disorders

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and patients without disorder. For a given problem is still necessary to seek new and better methods of solution, that would be able to punctually determine diagnosis of the patient.

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References:

[1] Brookside Associates Medical Education Division, BrookSidePress (2012, 05). *Neurology*, 51 pages., Available from: http://www.brooksidepress.org/Products/OperationalMedicine/DATA/operationalmed/Manuals/SeaBee/clinicalsection/Neurology.pdf

[2] Caretta s.r.o., *Posturography*, Available from: http://www.caretta.cz/software/posturograph/teorie.asp

[3] Drsata J., *Computer posturography in the diagnosis and rehabilitation of vertiginous states*, Ph.D Thesis, Hradec Kralove, 2007.

[4] DR. S. SANTHOSH BABOO AND I.KADAR SHEREEF. *An Efficient Temperature Prediction System using BPN Neural Network*., International Journal of Environmental Science and Development, 2011, Vol. 2, No. 1, p. 49-54. ISSN 2010-0264.

[5] FARRELL, Lisa. Peripheral versus Central Vestibular Disorders. *Peripheral versus Central Vestibular Disorders*. 2012, Available from: http://www.neuropt.org/files/peripheral_vs_central_vestibular_disorders.pdf

[6] I. Marinovic, D. Coko, Z. Blazevic, I. Zanchi, "*Theremin in Human Posture Identification*", Proceedings of the 3rd WSEAS International Conference on REMOTE SENSING, Venice, Italy, November 21-23, 2007, 570-570.

[7] Issing; Klein, P. .; Weiser, M. , (2005). "*The homeopathic preparation Vertigoheel versus Ginkgo biloba in the treatment of vertigo in an elderly population: a double-blinded, randomized, controlled clinical trial*". Journal of alternative and complementary medicine 11 (1): 155–160. PMID 15750375

[8] Khasnis A, Gokula RM (1 April 2003). "*Romberg's test*". Journal of Postgraduate Medicine 49 (2): 169–172. PMID 12867698

[9] Kuipers-Upmeijer, J; Oosterhuis, HJ (1994). "*Unterberger's test not useful in testing of vesitibular function*". Nederlands tijdschrift voor geneeskunde 138 (3): 136–9. PMID 8295639

[10] LEJSKA, Mojmir (2010). *Treatment of vertiginous states by vestibular rehabilitation*, AUDIO-Fon centr Brno

[11] NEUROCOM. *Setting the Standard in Balance and Mobility*: *EquiTest* [online]. NeuroCom, a division of Natus, 2012 [cit. 2012-05-09]. Available from: http://resourcesonbalance.com/neurocom/products/EquiTest.aspx

[12] Pivnickova, L., Vasek, V., Dolinay, V., *Algorithms in the examination of the postural stability*, In procceedings of the 10th WSEAS International Conference on Electronics, Hardware, Wireless and Optical Communications (EHAC'11), Cambridge 2011, pp.374-376, ISBN: 978-1-61804-004-6.

[13] PIVNICKOVA, Lucie, DOLINAY, Viliam and VASEK, Vladimir. *Examinations and algorithms to help find a cause of vertigo*, INTERNATIONAL JOURNAL OF MATHEMATICAL MODELS AND METHODS IN APPLIED SCIENCES, 2011, p. 1273-1280.

[14] UMF VBT, Practical laboratories Physiology III (2012, 05). *Exploration of the vestibular analyzer.*, Available from: http://www.umft.ro/newpage/structura/catedre/FIZIO/Physiology_III/Exploration%20of%20the%20vestibular%20analyzer.pdf

[15] Vestibular Technologies, (2012). *Posturography*, Available from: http://www.vestibtech.com/Posturography.htm

[16] (Vertigo Academy – Zavrat), MedNews (2012, 05). *Zavrat*. Available from: http://www.vertigoacademy.cz/zavrat/

[17] Wiki, *Backpropagation*, Available from: http://en.wikipedia.org/wiki/Backpropagation, 2012.

[18] Wiki, *Posturography*, Available from: http://en.wikipedia.org/wiki/Posturography, 2012.