Diagnosis of Lumbar Disc Herniation using Multilayer Perceptron Neural Network

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***Abstract*—The aim of this study was to develop multilayer perceptron (MLP) neural network model to predict lumbar disc herniation. The age, gender, body mass index, the maximum displacement of the body center of force, left foot center of force, right foot center of force in the x and y directions have been used as the input variables for the established MLP model. The measurements were performed using the commercial software Foot Work Pro. A total of 40 patients have been divided into training and testing data sets. The study results suggested that MLP would be an efficient soft computing tool for diagnosis of lumbar disc herniation. The Pearson coefficients have been computed as 0.941 and 0.938 for training and test data sets, respectively.**

I. Introduction

Medical decision-support systems are computer systems designed to assist physicians or other healthcare professionals in making clinical decisions [1]. The decision making process is a complex mechanism that has to take under consideration a variety of interrelated factors and functions [2].

In the recent decade, soft computing techniques are widely utilized to simplify the complex uncertainties which are present in the medical data as well as in the medical decision support systems. The advantages of using such intelligent systems include increasing speed of the diagnostic process saving clinician and patient time, and, at the same time, reducing time and improving the accuracy of diagnosis.

Recent years have witnessed the development of bioinformatics and medical informatics by using computational techniques for interpretation and analysis of medical data. Yardimci [3] has described a number of soft computing methods which incorporates neural networks, evolutionary computation, and fuzzy systems and theirs applications in medicine.

There are a wide variety of techniques for medical data classification. Simple classification algorithms include the distance-based classifiers (minimum distance, nearest neighbour) and the Beyesian classifiers, while more sophisticated approaches are based on support vector machines and neural networks.

In the study of Dreiseitl and Ohno-Machado [4], logistic regression and artificial neural networks models have been compared with other machine learning algorithms in medical data classification tasks. The results and performances of these models have been summarized.

Seera and Lim [5] have developed a hybrid intelligent system that consists of the fuzzy min–max neural network, the classification and regression tree, and the random forest model, as effective decision support tool for medical data classification.

Degenerative disc disease is the major abnormality that causes lumbar disc herniation. The most common current clinically approved standard for diagnosis is the magnetic resonance imaging procedure [6].

A Bayesian-based classifier with a Gibbs distribution for diagnosing lumbar disc herniation have been designed and implemented by Alomari et al. [7]. In this study 35 cases have been used for testing and 30 data cases have been used for training. The finally an average accuracy about 92.5% has been observed.

Shamim et al. [8] have used Fuzzy Logic-based fuzzy inference system for identifying patients unlikely to improve after disk surgery and explored FIS as a tool for surgical outcome prediction.

The main objective of this paper is to investigate the accuracy of multilayer perceptron neural network for diagnosis of lumbar disc herniation. The soft computing methodology-MLP model has been designed based on experimental data.

II. Clinical Diagnosis of Lumbar Disc Herniation

The first, initial, symptom of lumbar disc herniation is usually the back pain which can be acute or chronic. In the most cases, the patients talk about localized back pain which spontaneously stops. The back pain can be very irritating. It can last for several weeks, after which it can evolve into debilitating pain which can irradiate into the legs. These symptoms can be followed with paresthesia and stiffness in the affected dermatome, as well as with muscular weaknesses [9].

Sometimes, the clinical diagnosis can be in the form of serious pains in the legs or even cramps, which come very soon after the initial symptoms. In other cases, the pain becomes intensified during the seating, standing, walking or even coughing and sneezing and any other sort of straining. The pain stops in the lying position with flexed hips and knees. The pains in the back and legs can persist at the same time, but in the most cases the back pain reduces with the appearance of sciatica [10,11]. It is likely that this phenomenon occurs due to the reduction of stretch fibers for pain in the annulus and the last ligament, which occurs with a disc extrusion. Similarly, in rare occasions, serious sciatica symptoms may suddenly withdraw, but this phenomenon is usually associated with motor weaknesses and disorder sensibilities for the interruption function seriously compressed nerve root. In elderly patients, the pain in the legs often dominates over the back pain, from the very beginning of the disease.

III. FOOT PRESSURE MEASURING

AMCUBE Foot Work Pro, presented on Fig. 1, is a platform for the detection of foot pressure distribution in both, the dynamic, as well as static mode [12]. The platform is composed of 2700 capacitive pressure sensors that measure the pressure in the range from 10 KPa to 1200 Kpa, with an error less than 5% of the full range. The dimension of a sensor amounts to 7.6 mm x 7.6 mm, which represents the spatial resolution of the measurement. The sampling frequency is 100 Hz.

Figure 1. Platform for foot pressure distribution measuring - Foot Work

The static measurements consist in the fact that the subject stands on the surface for 10 seconds. During this period the Foot Work provides information about the foot pressure distribution which is presented on Fig. 2. It also provides information about the value of displacement of the center of mass of the whole body, the left and the right foot in the frontal and sagittal plane, which is presented on Fig 3.

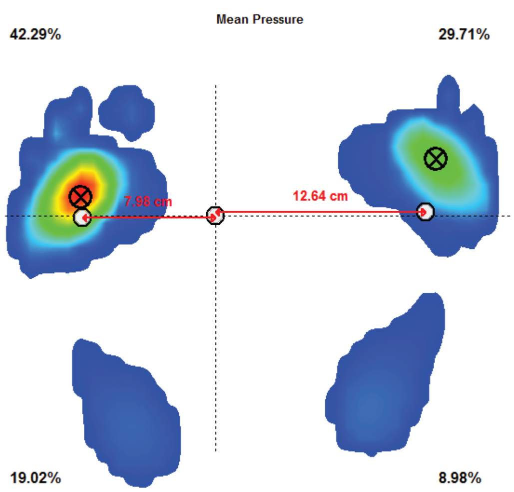

Figure 2. Distribution of foot pressure during the standing

The measurements were performed on a group of 40 subjects, aged between 18 and 73 years using the commercial software Foot Work Pro. We have presented a large number of measurements which included

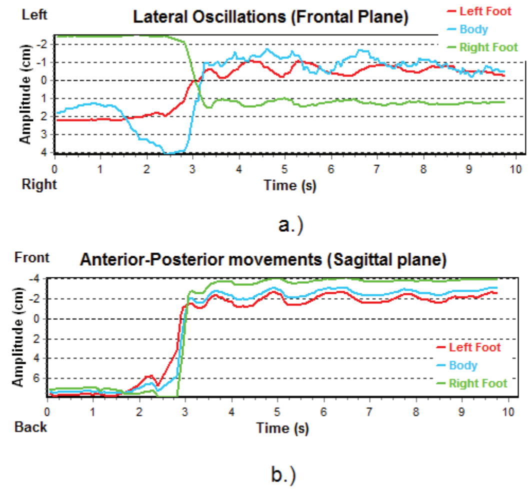

Figure 3. The value of displacement of the center of mass of the whole body, the left and the right foot in the a.) frontal plane and b.) sagittal plane

measurement of mobility during standing. Fig. 4 illustrates the domain displacement of the body center of force, left foot center of force, right foot center of force during the experiment. This domain is essentially a rectangle with sides representing the maximum displacements along the frontal and sagittal planes, respectively

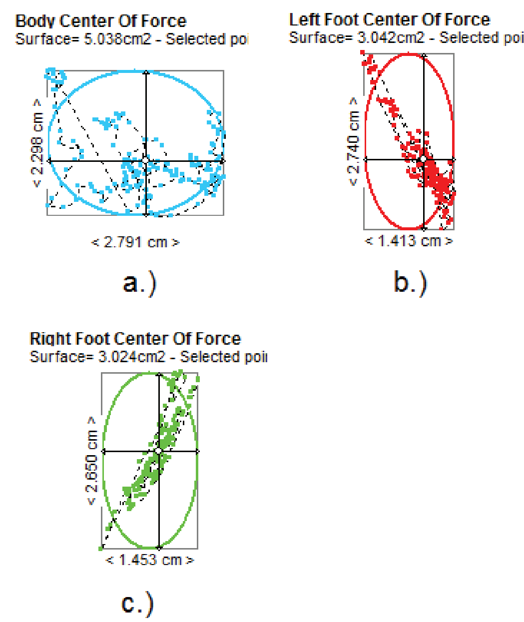

Figure 4. The spatial domain displacement of a)the body center of force, b)left foot center of force, c)right foot center of force

IV. THE ANN MODEL FOR DIAGNOSIS OF LUMBAR DISC HERNIATION

A. MLP neural network

A neural network consists of basic processing elements called neurons which are interconnected and distributed in layers. The neurons are represented by circles and the solid lines connecting the neurons represent weighting factors (Fig.5.).

The process to build MLP neural network model includes creating data sets for training and testing, training multiple MLP networks with varied parameters, and testing the models.

In this study, three-layered multilayer perceptron feedforward neural network was used and trained by the Levenberg–Marquardt algorithm. The nonlinear hyperbolic tangent sigmoid transfer function (tansig) and logarithmic sigmoid transfer function (logsig) were used in the hidden layer and the neuron outputs at the output layer. The hyperbolic tangent sigmoid transfer function and logarithmic sigmoid transfer function are described with the following equations:

$$\text{tansig}(u) = \frac{e^u - e^{-u}}{e^u + e^{-u}} . \quad (1)$$

$$\text{logsig}(u) = \frac{1}{e^u + e^{-u}} . \quad (2)$$

MLP is known to be universal approximators of the nonlinear functions, with a high degree of accuracy.

There are different algorithms for training MLP but the most often used is backpropagation rule However, backpropagation network has disadvantages of local minimum and slow convergence speed. The Levenberg–Marquardt algorithm is similar to the quasi-Newton method and one iteration of this algorithm can be written as:

$$\boldsymbol{\omega}_{k+1} = \boldsymbol{\omega}_k - \left(\boldsymbol{J}^T\boldsymbol{J} + \mu \boldsymbol{I}\right)^{-1} \cdot \boldsymbol{J}^T \boldsymbol{e} . \quad (3)$$

where $\boldsymbol{J}$ is the Jacobian matrix which contains first derivatives of the network errors with respect to the weights and biases, I is the identity matrix, μ is an adaptive factor and $\boldsymbol{e}$ is a vector of network errors.

B. Data set for lumbar disc herniation

In the MLP model for diagnosing lumbar disc herniation, one input, one hidden layer and one output layer are used as seen in Fig. 5. There are 9 inputs and 1 output for diagnosing lumbar disc herniation. Input variables names and their units are shown in Table 1. The outputs in the MLP model are LDH. The dataset has 40 observations used as training data. The first 30 data are from patients with lumbar disc herniation and others belong to people without lumbar disc herniation.

TABLE I.
INPUT VARIABLES NAMES AND THEIR UNITS.

Variable	Unit
Age	Numeric
Gender	Boolean
Body mass index	Weight (kg)'height (m)
Maximum displacement of the body center of force in the x directions	cm
Maximum displacement of the body center of force in the y directions	cm
Maximum displacement of the left foot center of force in the x directions	cm
Maximum displacement of the left foot center of force in the y directions	cm
Maximum displacement of the right foot center of force in the x directions	cm
Maximum displacement of the right foot center of force in the y directions	cm

C. Implementation of the MLP model

The optimal architecture of the MLP model for diagnosis of lumbar disc herniation was determined based on the maximum value of the Pearson coefficients of the training and test sets. The number neurons in the hidden layer was varied from 5 to 15 and the optimal number is chosen by trial and error approach, Table 2. Selection of an appropriate number of neurons in the hidden layer is very important aspect as a larger number of these may result in over-fitting, while a smaller number of neurons may not capture the information adequately.

The MLP developed in this research has 11 neurons in the hidden layer and one neuron in the output layer.

TABLE II.
THE PEARSON COEFFICIENTS OF THE ARTIFICIAL NEURAL NETWORK MODELS WITH DIFFERENT NUMBER OF NEURONS IN THE HIDDEN LAYER

MLP–structure		Pearson coefficient
9 – 5–1	Training	0.923
	Test	0.914
9 – 7–1	Training	0.934
	Test	0.927
9 – 9–1	Training	0.938
	Test	0.929
9 – 11–1	Training	0.941
	Test	0.938
9 – 13–1	Training	0.925
	Test	0.921
9 – 15–1	Training	0.923
	Test	0.92

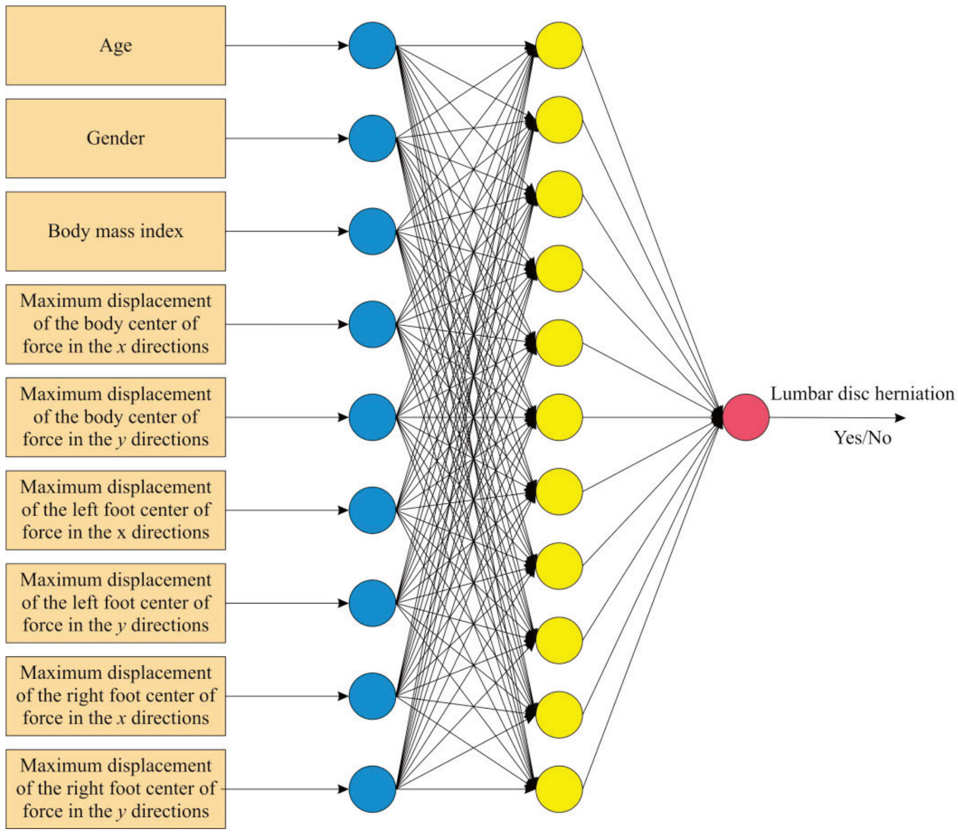

Figure 5. MLP model for diagnosing lumbar disc herniation

V. CONCLUSIONS

In this study, the applicability of the soft-computing methodology (MLP method) has been investigated for diagnosis of lumbar disc herniation. The performance of the neural network was measured using Pearson coefficient. The reported results confirmed that MLP model has good statistical performance.

The computational intelligence techniques can overcome the deficiencies of the conventional medical decision support systems that are based on statistical models. Medical decision support systems based on the soft computing technique can be seen to be a powerful alternative to traditional decision-making techniques.

Furthermore, for future research the prediction can be expanded with validation data on larger number of patients and to include other types of hybrid computationally intelligent systems (neuro-fuzzy system, genetic algorithm–fuzzy logic method, etc).

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