Early Detection of Adult Valve Disease–Mitral Stenosis Using The Elman Artificial Neural Network

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Summary
In complex, data-based prediction problems, such as medical diagnosis, the Elman Neural Net (ENN) has been applied for the automated detection of various diseases, such as mitral valve stenosis. This paper discusses the design and implementation of an automated classification system for heart diseases, based on ultrasonic devices. M-mode class images are applied to classify the degree of stenosis in the mitral valve. An artificial neural network (ANN), trained by the ENN, demonstrated good performance of the designed system. The system is applied in adult patients 20-60 years old, both male and female. Matlab software is used to design the system used to diagnose. The objective of the system used in our work is to diagnose mitral valve stenosis in samples of echocardiograph images for which there are difficulties in practical experiments in finding the optimal features by specialists who work in laboratories.

Key words:
Image classification, Artificial neural network, Feature selection, Neuro-medical system, Kernal PCA, Elman Neural Net

1. Introduction

Artificial neural networks, which are commonly referred to as "neural networks" (NNs), are simulations of the biological neural networks of the human brain that consist of a number of simple, highly interconnected elements to process information in its dynamic state and deliver it to external inputs; therefore, they are called "computing systems." Artificial neural networks have been studded to understand and imitate human performance in solving complex problems. With incomplete or unrelated data that cannot be solved easy by conventional programming techniques or by human diagnosing, artificial neural networks (ANNs) are extremely useful for this type of information in the input data [1] because of the capability of ANNs to classify features, which refers to its ability to approximate functions and generalized them. [2]

All physicians are confronted during their training by the task of learning to diagnose. They must solve the problem of deducing certain diseases or of formulating a treatment based on more or less specified observations and knowledge, which is the standard knowledge provided by seminars, courses, and books. On one hand, medical knowledge becomes outdated quickly; on the other hand, this knowledge does not replace the surgeon's own experience. For these tasks, certain basic difficulties must be taken into account.

As the basis for a valid diagnosis, a sufficient number of experienced cases is reached only in the middle of a physician's career, so that number has therefore not yet been reached by the end of academic training. This is especially true for rare or new diseases, with which experienced physicians are in the same situation as newcomers.

Principally, humans do not resemble statistical computers, but they do have pattern recognition systems. Humans can recognize patterns or objects very easily, but they fail when probabilities must be assigned to observations. These principal difficulties are not widely understood by physicians. Also, studies revealing that approximately 50% of diagnoses are wrong have not impeded the self-conscience of some physicians [3].

2. ARTIFICIAL NEURAL NETWORK (ANN) WITH MEDICAL IMAGES

Neural network applications in computer-aided diagnosis represent the mainstream of computational intelligence in medical imaging. [4] Their penetration and involvement are almost comprehensive for all medical problems due to neural networks having the nature of adaptive learning from input information, and using a suitable learning algorithm, they can improve themselves in accordance with variety and changing in input content. Furthermore, neural networks have the capability to optimize the relationship between inputs and outputs via distributed computing, training, and processing, resulting in reliable solutions that are desired by specifications.

Medical diagnosis often relies on visual inspection, and medical imaging provides the most important tool for facilitating such inspection and visualization [5-6]. The medical imaging field is very important because it offers much useful information for diagnosis and therapy. There are also many applications that use neural networks with Bayesian statistics (which can estimate the probability density of model parameters given the available data).

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A schematic diagram of an ANN, based on the principles of definition, is shown in Figure 1, in which the cell body within it is modeled by a linear activation function. The activation function attempts to enhance the signal contribution received through different dendrons. This action is assumed to be undertaken via signal conduction through resistive devices. The synapse within it is modeled by a non-linear inhabiting function to limit the amplitude of the signal processed by the cell body [7].

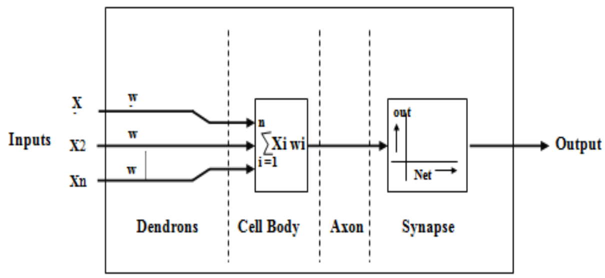


Figure 1. An ANN based on the human brain [7]

Artificial neural networks have been successfully used to recognize objects from their feature patterns. For the classification of patterns, neural networks should be trained prior to the phase of recognition. These processes of training can be classified into three typical categories, namely supervised, unsupervised, and reinforcement learning. These learning rules work with different structures of ANNs, as shown in Figure 2.

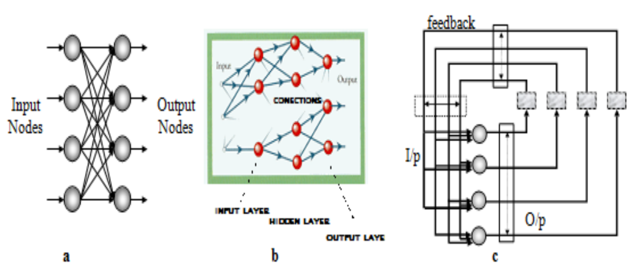


Figure 2. Different taxonomies of Anns: a. one-layer NN; b. multi-layer NN; c. Recurrent NN

Elman Artificial Neural Networks are among the neural network learning algorithms widely used in medicine because they are conceptually simple and computationally efficient, and they often work successfully with noisy data. The use of ANNs in ultrasonic images (echocardiography), which is an important non-invasive methodology in clinical cardiology, helps the user to diagnose whether the tested object is normal or abnormal [8].

3. Pattern Recognition in Neural Networks

Human beings do not analyze different real-world situations as isolated facts, but they try to describe them in terms of patterns of related facts. Sometimes these relationships are implicit because they all refer to the same object. Other times, it is necessary to connect these characteristics explicitly to find relationships, because this skill is not only used for the perception of facts. In addition, methods of providing computers with this same pattern-processing skill of human beings have been sought. In some applications, pattern characteristics are best described by structural relationships, which depend on the size and location of information.

The use of NN allows the operator to obtain a suitable choice for trainable pattern classification because of the NN's capability of generalizing information, as well as its tolerance of noise and its power in computational systems, which consists of many simple processing elements connected together to perform tasks analogously to the performance of biological brains.

Thus, like other machine learning problems, the data are divided into training set and a random testing set. The training data are used for feature selection; the testing data are used for the evaluation of the accuracy of the finally selected feature set [9].

4. MITRAL VALUVE STENOSIS

Cardiovascular diseases are the most frequent cause of adult deaths in our time. These diseases can be divided into two main groups:

1. Congenital diseases (arterial septal defects, ASDs; ventricle septal defects, VSDs; tetralogy of Fallot, TTF; and heart failure, HF); and
2. Rheumatic disease (valvular disease: regurge and stenosis), as well as hypertensive and coronary diseases, which occur at different ages.

Valvular heart disease is an important subject for study not only because it is often the primary cause of heart failure but also because there is much unnecessary confusion associated with it in the medical literature and in minds of many physicians. Among the most common rheumatic valve diseases is mitral stenosis (MS), which occurs when there is resistance to the flow of blood through the mitral aperture during diastolic filling of the left ventricle. This occurs if there is congenital stenosis, a thrombus, a trial myxoma, bacterial vegetation, or calcification of the valve [10].

In normal adults, the cross-sectional area of the mitral valve is 4-6 cm2, but when this area is reduced to approximately 2 cm2, then it represents mild MS. When the mitral opening is reduced to 1 cm2, then it is severe

MS. Between 1 and 2 cm2 of indicates moderate MS. This disease never occurs before 20-30 years after rheumatic fever during childhood [11].

5. Recognition BY Medical Image SystemS

A research line of NNs is applied to recognize patterns in our images, which taken at Ibn Albetar and Ibn Alnafees hospitals. These images are shown in Figure 3.

The computer imaging systems consisted of two primary component types, hardware and software. The hardware components can be divided into image acquisition system (Probe of Echocardiography - Voluson 530D; transducer) and a display and recording system (monitor). The software allows for manipulation of the images and performs any desired processing of the image data, which is in digital form. These images (100 images for training and100 images for testing) are obtained from patients and are compressed into a group at the size of 256 x 256 pixels. Thus, the analog images are converted into digital shapes, which are suitable for computing in a research program and which are represented as two-dimensional arrays of data with pixel values [12, 13, 14].

The developed system used an ANN to distinguish three sets of echocardiography images obtained for mitral valve stenosis (M-mode). These images describe the degree of stenosis (mild, moderate, or severe).[15].

6. Extract Features

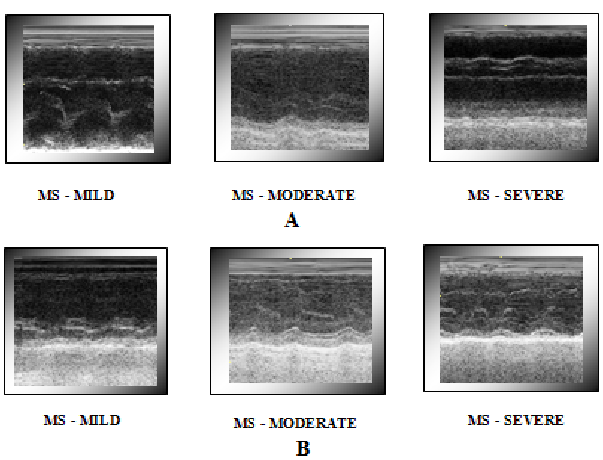


Figure 3. Types of learning and training data: A. Learning set; B. Testing set

The selection of adequate features plays an important role in the field of image segmentation, and with these techniques, it is possible to assess the dimensions of the problem with the objective of reducing its computational complexity. The small size and more relevant feature set will increase the classification accuracy and reduce the computation time. The output of feature selection algorithms is optimal, but such optimal feature sets may perform badly in some practical problems because minimal feature sets depend too heavily on the classification problem and the known data set [9].

Feature selection must be based on the separability of classes. Features that make possible greater separability of classes are more significant and must be chosen for the implementation of the image segmentation process. Kernel principal component analysis (Kernal PCA) is used to assist the segmentation process by reducing segmented images' (256 x 256) pixels to 3 PCA values.

The main algorithm of PCA is:

$$\sum_{i=1}^{N} X_i = 0. \quad (1)$$

It operates by diagonalizing the covariance matrix.

$$\frac{1}{N}\sum_{i=1}^{N} X_i X_j^T \quad (2)$$

In other words, it gives an Eigen decomposition of the covariance matrix

$$\lambda_v = C_V, \quad (3)$$

which can be rewritten as

$$\lambda_X {}_i^T v = X_i^T C_V$$
$$\forall i \in [1, N] \quad (4)$$

In PCA $d \geq N$ dimensions if N points are used.

X_i, if it can map to N-dimensional space with Kroneker's delta $\phi(X_i)$

$$\phi(X_i) = \delta_{ig}, \quad (5)$$

where $\phi : R^d \rightarrow R^N$ & δ_{ig} is Kroneker's delta (ϕ creates Elman-ly independent vectors).

In PCA $\phi(X_i)$ are not independent in R^N so

$$K = k(x, y) = (\phi(x), \phi(y)), \quad (6)$$

where k is the Grammian matrix in high-dimensional space.

$$v_1 = \arg\max \mathrm{var}\{v^T x\} = \arg\max E\{(v^T x)^2 \quad (7)$$

where $\|v\| = 1$. We only need to compute the inner products in the high-dimensional space [12].

7. SUGGESTED SYSTEM

7.1 METHOD AND EXPERIMENT

Artificial neural networks are currently an important research area in medicine, and they can be useful in biomedical system application, especially in disease diagnosis and classification. Thus, we suggested a system consisting of Elman's Neural Net divided into four layers, which are the input layer, hidden layer, connecting layer, and output layer, as shown in Figure 4. The architecture of Elman's Neural Net allows for the enabling of the network to distinguish separate input patterns from the same input sequence, and the addition of the interior (connection) layer increases the capability of the processing of dynamic information by the network itself. Elman's Neural Net must adapt to time-varying characteristics because it has the function of mapping dynamicity, resulting in simplifying of training the topology structure of Elman's Neural Network shows that there are input (n), output (m), and (r) neurons in the hidden layer and connecting layer. The weight between the connecting layer and hidden layers are (w1,1), and the weight from the hidden layer to output layer is (w2,1); u(k-1) represents the input of the neural network, x(k) represents the output of the hidden layer, xc(k) represents the output of the connecting layer, y(k) represents the output of the neural network, and (f) represents the transfer function of the hidden layer [10].

6.2 ALGORITHM OF ELMAN'S NEURAL NETWORK

The algorithm of Elman Neural Net can be represented as follows

$$X(k) = f(w_2 x_c(k) + w_1(u(k-1))) \quad (8)$$

$$X_c(k) = x(k-1) \quad (9)$$

$$y(k) = g(w_3 x(k)) \quad (10)$$

g is the transfer function of the output layer and it is usually a linear function.

S type function is commonly used and can be defined as:

$$f(x) = (1 + e^{-x}) \quad (11)$$

E is the error, and t_k is the output vector of the object

$$E = \frac{1}{2}\sum_{k=1}^{m}(t_k - y_k)^2 \quad (12)$$

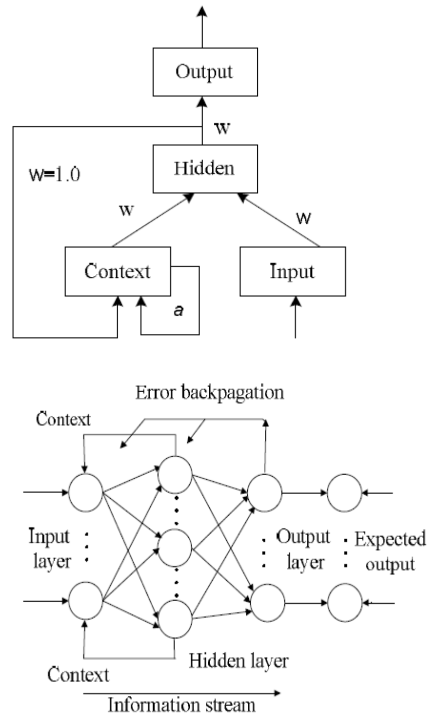


Figure 4. The main architecture of Elman's Neural Network

8. TRAINING PROCEDURE

To evaluate the performance of any neural network recognition system, the accuracy of the system can be calculated as:

$$Accuracy\% = \frac{Number\ of\ correctly\ classified\ patterns}{Total\ number\ of\ paterrns}$$

(13)

The performance of the suggested system has been tested on data obtained from echocardiography device-type volution of 530 D with a 3.5 MHz central frequency transducer. Elman's Neural Network is used for the training and testing classification process, in which 100 images are used for training, and 100 images used for testing, so Elman's Neural Net and its efficiency can evaluate the performance of the microscope in testing images in greater detail. The median filter is also used to remove noise from each image; then, canny detection is used to detect their edges, while region growing is used to segment the images and to reduce segmentation by PCA from 256 x 256 pixels to 3 Kernal (PCA) values, as shown in Table 1.

Table .1. The Kernal PCA values for research images

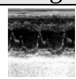
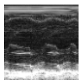
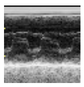
Type	Image	3-Kernal		
MILD		-0.0623	-0.0560	0.0514
MODERATE		-0.0382	-0.0587	0.0800
SEVERE		-0.0441	-0.175	0.0596

Table 2 shows the recognition rates (classification results of training and testing images) of the ENN used in diagnostic systems of research for different iterations.

Table 2. The recognition rates and iterations of one of ENNs

Tmax	5000	5500	10000	10500
R%	90.32	90.51	89.67	89.91

Tmax	1500	15500	20000	20500
R%	91.92	93.54	96.80	96.97

Elman's Neural Network gives the following error values:

* Training data error = 0.098468
* Testing data error = 0.084284

The classifying results of training and testing images gave total classification accuracy of approximately 100% for training and 96.979% for testing images.
The Elman Neural Network used provided both fast training and powerful mapping. Using the Matlab package (R 2009 a), this neural network has three input nodes, three hidden nodes, and one output node as shown in Figure 5.

The combination of any two images with different types the same arrangement features led the diagnosing step to move away from its goal, and this situation referred to the behavior of the NN in its arrangement. The NN arrangement of any two objects, each of them equal in general features decreased the recognizing of training images; in addition, the error rate did not decrease to a suitable rate. To avoid this problem, which occurred in the beginning of the computing program used in this work, an increasing number of training images is used. As we mentioned earlier, the research used 100 images for training.

A three-layer neural network with one hidden layer, each layer in both input and output, contained one neuron for input data and output response, while five neurons in the hidden layer are for processing, as shown in the figure above.

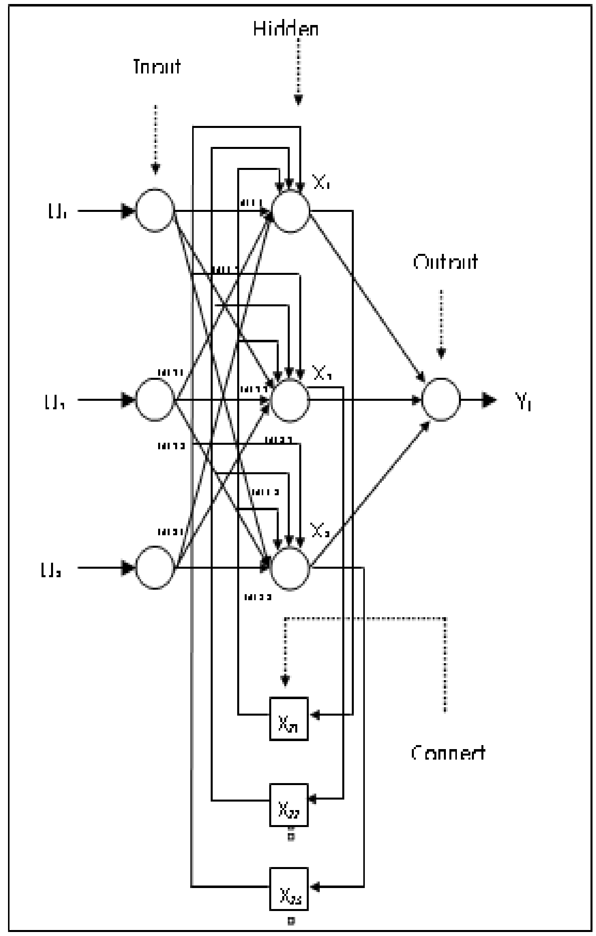


Figure 5. The main architecture of the neural net used

We used two neural networks for recognition and classification of diseases. The recognition network is used to identify the normal and abnormal cases; the classification network is used to classify the degree of abnormality.
The input represented actual processing units, rather than the simple input ports, as would be the case with a strictly fed forward network. This network was trained alternatively from case data, which acted as continuous values.
The relationships between the number of iterations and the learning rate for group A are shown in Figure 6.

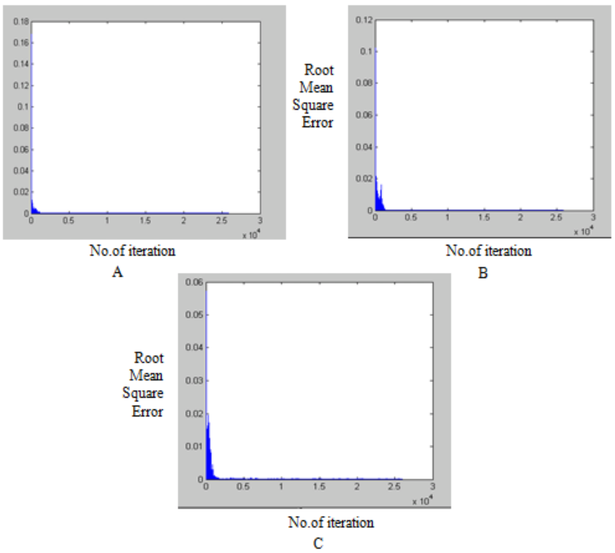


Figure 6. The performance of an artificial neural network during learning: A. MS-MILD; B. MS-MODERATE; C. MS-SEVERE

9. CONCLUSION

The field of diagnosis is very important and covers a wide area of work. The implemented system provided good results and can applied in a good number of patients, so one advantage with the use of ANNs, compared to rule-based criteria, is the enhanced diagnostic performance and easy adjustability of the network outputs when used in different clinical situations.

Several concluding remarks can be made according the provided results as follows.

1- Although it is difficult to train hall images, it is very important to do this in the diagnosis of human diseases with regard to the degree of any disease because it must be the same degree in all patients who also have in common age, tall height, weight, health, etc.

2- Early diagnosis has several advantages, so using an ANN helps to diagnosis easily, especially when it is compared to programming and when using it in a package.

3- It is important to make a comparison between artificial and biological values to know the accuracy of the ANN'S work.

4- The classification technique that is used gave the highest accuracy, so Elman's Neural Network shows the possibility of reducing input data to a learning step by extracting features dependent on regional grouping. This technique facilitates much research into image classification, especially when diagnosis is difficult for humans, as with medical images, which are increasingly being used in health care and medical research.

REFERENCES

[1] Lee, Jay, and Ben Wang. Computer-Aided Maintenance. New York: Kluwer Academic Publishers, 1999.

[2] Gaetano, P. "Artificial Neural Networks in the Assessment of Respiratory Mechanisms," unpublished doctoral dissertation, Faculty of Medicine, University of Uppsala, 2004.

[3] Ge, J., Sahiner, B. Hadjiiski, L. M., Chan, H. P., Wei, J., Helvie, M. A., and Zhou, C. "Computer Aided Detection of Clusters of Micro Calcifications on Full field Digital Mammograms." Medical Physics 33.8 (2006): 2975-88.

[4] Chang, C. Y. "Contextual-based Hopfield neural network for medical image edge detection." Optical Engineering 45.3 (2006): Art. No. 037006.

[5] Qing Song. On the Weight Convergence of Elman Networks. IEEE Transactions on Neural networks, vol. 21, no. 3, March 2010

[6] Middleton, INITIALS, and Damper, R. I. "Segmentation of Magnetic Resonance Images Using a Combination of Neural Networks and Active Contour Models." Medical Engineering & Physics 26.1 (2004):71-86.

[7] Suzuki, Kenji. "Artificial Neural Networks — Methodological Advances and Biomedical Applications." Tech Janeza Rijeka, Croatia, 2011.

[8] Cunn, Yann Lee et al. "Pattern Recognition & Neural Networks." Bell Labs. 1998.

[9] Salih, Ghaidaa K. "Early Detection of Disease — Viral Hepatitis Type-C Using Elman Artificial Neural Net. Eng Tech Journal 30.12 (2012): PAGES.

[10] Paulraj M. P, Mohd Shuhanaz Zanar Azalan, "Image Quality Assessment using Elman Neural Network Model and Interleaving Method" International Journal of Human Computer Interaction (IJHCI), Volume (3) : Issue (3) : 2012

[11] Braun, Walt. " Valvular Heart Disease" Text Book of Cardiovascular, 5th ed., 2001

[12] Hymer P., "Extraction and Application of Secondary Crease Information in Fingerprint Recognition." Dept. of Science and Technology, Linkopings Univ., Sweden, 2005.

[13] L. Whei-Min and H. Chih-Ming, "A New Elman Neural Network-Based Control Algorithm for Adjustable-Pitch Variable-Speed Wind-Energy Conversion Systems," Power Electronics, IEEE Transactions on, vol. 26, pp. 473-481, 2011.

[14] Luse, M., and Binstock A. Bitmapped Graphics Programming in C++. New York: Addison-Wesley, 2004.

[15] Jie, INITIALS, Yao, INITIALS, and Cald, INITIALS. "Feature Selection for Flourscan Image Classification." http://www.daneprairie.com, 2002.