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An Intelligent Method Based On Hough Transform and Support Vector Machine to Diagnose Retinal Detachment in Ultrasound Images

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Abstract - ***One of the problems that exist in some eye patients is the recognition procedure. To detect eye diseases, ultrasound imaging is used, but in some cases, due to the poor quality of ultrasound images and also incoming noises, some of the image details disappear and similarities in diagnostic features of the diseases come into existence. It is important for ophthalmologists to detect the retinal detachment. Moreover, finding a way to diagnose the detachment can have useful role in on time diagnosing it from other diseases. In this paper, first, digital sonography image are preprocessed to reduce its noise. Then, by use of principal components analysis method (PCA) and Hough transform, image features are extracted and finally support vector machine (SVM) will be used for diseases diagnosis. In addition, a comparison of the performance of SVM with multilayer perceptron neural network (MLP) and retinal with Radial Basis Functions (RBF) is carried out. The results of this study shows that SVM achieves a correct diagnosis of 98.1 percent, while, in the best situation, the percentage of correct diagnosis using MLP and RBF are 72 and 90 percent, respectively. So SVM has more effective performance, compared to neural networks method, which for the medical diagnosis can be of the great importance.***

Key Words: *Image Processing, Automatic diagnosis, SVM, Neural Network, principal components analysis, Retinal detachment*

1. INTRODUCTION

Ultrasound imaging method can be used as an effective diagnostic method for diagnosis of eye diseases. Eye diseases can be diagnosed by using two types of amplitude and intensity scanning in ultrasonography. In A-Mode method that is known as *amplitude modulation*, the reflection waves are shown as a vertical deviation in the baseline scope and altitude of deviation is proportional to the amplitude of the reflection wave [10]. In B-Mode Method that is called *light intensity modulation*, the reflection waves can be seen in the form of luminous points during the zero line. Here, we use B-Mode images to diagnose the disease. Reflection is produced by the interaction of the ultrasound wave to interface surface of environments with different audio impedance, and reflection wave amplitude is proportional to the difference of impedance of two environments. Dissimilar environments (as the humor and lens) produce great reflections, while the outer objects such as glass and metal create a slight reflection (less than 10 percent of the original waves), so they can be easily detected by sonography [10].

But some items such as small hemorrhages of posterior vitreous accumulate on a half-carved or fully-carved posterior surface of vitreous and produce a discoid reflection such as retinal detachment. Since the retinal detachment is considered as an emergency disease and needed an emergency surgery, the opportune diagnosis is of the very great importance for the ophthalmologists.

This article is organized as follows: In section 2, the methods for removing image noise are discussed. In section 3, the methods of feature extraction are addressed. In section 4, the new methods are proposed. In section 5, the experimental results obtained from implementation of the proposed methods are examined, and finally in section 6, some conclusions are presented.

2. PREPROCESSING

Due to the low quality of images, incoming noises from imaging devices and environment, image opacity and its low contrast, preprocessing is an essential step in the design of intelligent systems. The purpose of this step is to enhance the image quality, noise removal, smoothing, and so on. In the preprocessing stage, in order to highlight the edges and sharp transitions in intensity, the algorithms based on the intensity [13], the threshold measurement to extract the region of interest (ROI) and edge detection algorithms [14, 15, and 16] can be used.

2-1. Smoothing filter maker

Major application of the averaging filters (smoothing) is the reduction of noises and image irrelevant details. Local averaging although reduces noise but, at the same time, it reduces the amount of high frequency image which cause blurring around the edges and image details. To avoid this problem, the selective averaging is used.

In the selective averaging method, first, some edge detection methods is used and then the local average is implemented. Edge detection condition at any point x of the image matrix is as follows.

$$X' = 1/8\sum_{i=1}^{8} O_i, |x - x'| \geq T \quad (1)$$

where T is the desired threshold that is selected through trial and error. The following algorithm is used for the local averaging.

$$y = \frac{1}{9}(\sum_{i=1}^{8} O_i + x) \quad (2a)$$

$$Y = \begin{Bmatrix} y \to if |x - x'| \prec T \\ x \to else \end{Bmatrix} \quad (2b)$$

With the use of this algorithm, the removal of image details and its blurring near the edges are prevented. In the above equation, it is assumed that the noise amplitude is less than T (average of image edge size).

3. EXTRACTION OF IMAGE FEATURES

The first step in any project is the pattern recognition, feature extraction and formation of feature vectors. To this aim, various methods have been applied [1, 4, 5, and 6].
In Ref. [12], the combination of statistical correlation method with PCA methods and discrete cosine transform (DCT) are used for the extraction of facial image feature. Here, we used the two methods. PCA and Hough transform, to extract the features of images.

3-1. principal components analysis

If we have R images of B-Mode in training set and each image $\mathbf{x}_i$ is a two-dimensional array with intensity matrix of m*n size, each $\mathbf{x}_i$ image can be converted to a vector with D (*D=m*n*) pixels, while $X_i = (x_{i1}, x_{i2}, ..., x_{iD})$. The set of R images that are used for training are defined in the form of $\mathbf{x}_i = (x_1, x_2, ..., x_R)$ in which $X \subset R^{D*R}$.
Covariance matrix is defined as follows:

$$y = \frac{1}{R}\sum_{i=1}^{R}(x_i - \bar{x})(x_i - \bar{x})^T = \phi\phi^T \quad (3)$$

where

$$\phi = (\phi_1, \phi_2, ..., \phi_R) \subset R^{D*R}$$

and $\bar{x} = \frac{1}{R}\sum_{i=1}^{R} x_i$ is image of training set average. Therefore values and eigenvectors are defined by the covariance matrix γ.
If we define $Q = (Q_1, Q_2, ..., Q_r) \subset R^{D*R}, (r \prec R)$ as the eigenvectors proportional to r out of the largest eigenvalues, the matrix that is made by these vectors of training images is called Coefficients Matrix (PCA). Using this matrix, one can obtain the correct primary images. The main idea of PCA is to reduce the image dimensions without deleting its important information and to find a canonical representation of data and to keep its variance. To obtain the primary image through the PCA, the following relation is used

$$z_i = Q^T y_i, i = 1,2,...,R \quad (4)$$

while $z_i \subset R^{r*R}$ and y_i is the image of x_i from which the average image value is subtracted.

3-2. Hough transform

Hough transform uses mapping of image lines from Cartesian or polar space to parameter space. If the equation of the normal line in the polar space is as follows:

$$x\cos\theta + y\sin\theta = \rho \quad (5)$$

in which ρ is equal to positive *x* latitude of origin. We know that the horizontal line has θ = 0, and similarly, vertical line has an angle of 90 degrees that ρ is equal to the y positive latitude of origin or θ = −90. Each sinus curve shows a set of lines passing thorough a specific point of (x_k, y_k) in (x, y) plane. The point of intersection in (ρ', θ') is correspondent to a line that passes through the points (x_i, y_i) and (x_j, y_j). Thus, a point in Cartesian space is coincident with a sinus wave in r-θ space. The point having the most share of sinuses is considered as the candidate of the main line. To use Hough transforms in line detection, first, we should consider the peak detection. [18]

3-2-1. Extract of Hough transforms peaks

Hough transform is a method to detect complex patterns by determining the specific values of parameters that distinct patterns. In this method, each image point is examined in terms of the parameters that are involved in it and final result determines belonging or not belonging of point of intersection to the desired shape. Hough transform method can describe many properties in the image. First, independent combination of the evidences in this transform can help to detect the shapes which have a slight or special deformation. The size and location of peaks fitted as criteria for similarity of the shape and the model in the image [19].
On the other hand, this method is resistant against the random data that have been generated by poor quality images.

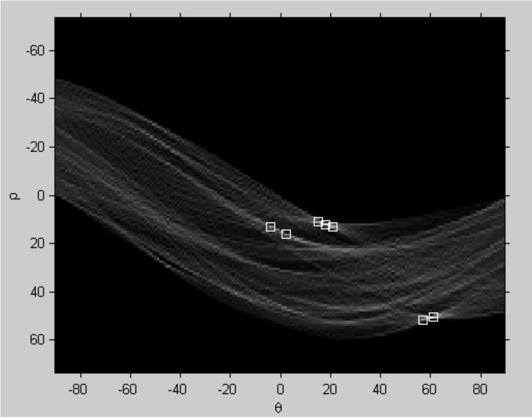

Fig-1: Hough transforms peaks corresponding to a sample image

4. CLASSIFICATION

4-1. Neural Networks

In recent years, neural networks have been widely used in diagnosing diseases; neural networks have the advantages such as high-speed in computation, the ability to analyze complex nonlinear problems, resistance against parameters change and ability to learn and generalization [2].

In [1, 3, 5] the neural network with radial basis functions (RBF) is used for face recognition. In [15] an optimized back-propagation neural network is used in edge detection which leads to much better result than normal back-propagation neural network. In [17] the multilayer perceptron neural network (MLP) is also used for diagnosis of liver diseases. In this article, we analyze performance of the two types of neural networks RBF and MLP in the diagnosis of retinal detachment of other diseases of the eye from the sonography images.

4-1-1. Multilayer Perceptron Neural Network

This network is consists of three input, hidden and output layers while numbers of neurons in each layer are selected by trial and error and network is trained based on back-propagation error algorithm.

For the ρ-th input pattern, the squared of output error for all neurons in the output layer comes in the form below [2].

$$E_p = \frac{1}{2}(d^p - y^p)^2 = \frac{1}{2}\sum_{j=1}^{S}(d_j^p - y_j^p)^2 \qquad (6)$$

in which d_j^p and y_j^p are the desired output and the actual output for j-th neuron in the output layer, respectively. Moreover, S is the dimension of the output vector. y^p and d^p are the actual and ideal output vectors, respectively.

In order to minimum the cost function E, the weights are justified by gradient descent method [2].

4-1-2. RBF Neural Network

Due to the simple structure and high speed training, RBF neural networks are widely used to classify images. The number of cells in the output layer is equal to the number of outputs, and their weights are set based on the gradient descent method, in accordance with the minimum sum of squared error and the appropriate function centers [2].

RBF Networks usually has a hidden layer that this layer uses a Gaussian transfer function. Unlike the multilayer perceptron neural networks that usually use the sigmoid functions in their hidden layer.

K-th neuron output of the output layer is obtained by the following linear function.

$$z_{ik} = \sum_{j=1}^{n} \varphi_j(x_i) w_{kj} + b_k w_k \, , \; k = 1,2,\ldots,m \qquad (7)$$

in which w_{kj} is weight of the link between the j-th hidden layer neuron and k-th output layer neuron. b_k and w_k are the positive bias and the weight of k-th output layer neuron link of bias neuron, respectively, and m is the number of actual classes in the problem at hand.

Zhimin Yanget [3] examined structure and function of the automatic detection system, based on RBF. His experience results show that RBF network is better than BP network, in terms of estimating the optimal characteristics, classification capability and high-speed computation. In Ref. [1], a PCA based on the RBF neural network is also used for facial recognition.

4-2. SVM

SVM is a classifier that obtains samples making up the border of classes by using all bands and an optimization algorithm. These samples are called support vectors. The number of training places with the smallest distance to the border of the decision can be considered as a subset for defining the boundaries of decision making and as a backup vector.

Models of SVMs are divided to the SVM classification model and SVM regression model. The classification model is used for resolving the problems related to the classification of the information and data, while the regression model is applied on the forecasting-based problems. The most important properties of the SVM are as follows: classification with maximum extension, reach to the global optimization and automatically determining the optimal structure of classifier.

If training points are defined as (x_i, y_i) and the input vector as $x_i \subset \mathbf{R}^n$ while the data are linearly separable, we have:

$$(\mathbf{X}) = sign[\sum_{i=1}^{N} y_i \alpha_i \langle x_i, \mathbf{x} \rangle + b] \qquad (8)$$

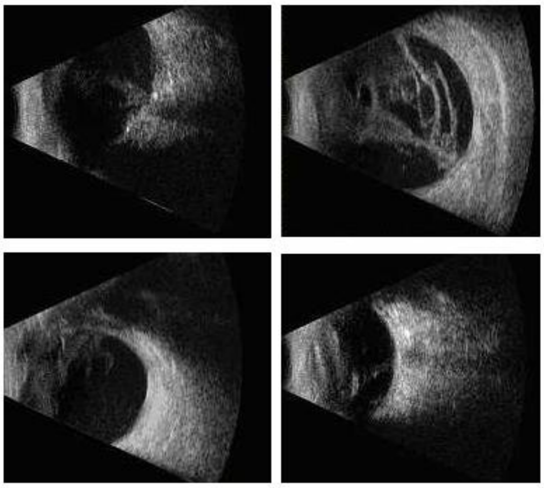

Fig-2: Eye sonography images. The first two images are related to the eye with retinal detachment and in the last two ones related to the eye without retinal detachment.

in which y is the output and y_i is the cost of sample x_i. Vector $\mathbf{x} = (x_1, x_2,\ldots, x_n)$ represents the input data and vectors $\mathbf{x}_p$, $p = 1,2,\ldots, N$ are support vectors.

If the data is not linearly separable, samples can be taken to higher space by applying a pre-process. In designing a model of SVM, the parameters: type of kernel function, kernel function and adjustment parameter C should be adjusted optimally. Three types of kernel functions that are used in modeling the SVM are as follows:

1. Polynomial machine with kernel function

$$k(x_i, x_j) = (x_i.x_j)^d \tag{9}$$

in which: d is the degree of a polynomial kernel.

2. Radial basis function machine with kernel function

$$k(x, x_i) = \exp(-\frac{(x - x_i)^2}{\delta^2}) \tag{10}$$

in which: δ is the bandwidth of radial basis function kernel

3. Dual NN machine with kernel function

$$k(x, x_i) = s[(x.x_i)] = 1/[1 + \exp\{v(x.x_i) - c\}] \tag{11}$$

in which C and V are sigmoid function parameters [20].

4-3. The proposed method

In the proposed method, in order to improve the images' quality, we use the average windowing, to as much as possible reduce noise in the image which leads to more uniformity in the image. In order to extract the desired area, for each of the images, an area (ROI) with 50×50 pixels is selected. ROI area was chosen so that it includes only the area between the lens and retinal embrace and the area of optic nerve and all the other areas are removed.

Figure 1 shows a sample of studied images in this paper. The PCA algorithm is used for extraction of images features, the obtained matrix coefficients has the dimensions 2750 × 2750. Since the main features are located in the first rows or columns of coefficient matrix (which are proportional to the most effective eigenvalues that are the same as the largest eigenvalues of images), we considered only the first 50 columns of the matrix coefficients PCA. Then the Hough transform is applied to images and peaks were extracted. Ultimately, the created final vector in the above steps as the feature vector of each image used to train classifiers and after parameters setting optimal, tests images is evaluated to check the results of the performance of the designed system. Vector of the algorithm diagram block described is mapped in Figure 3.

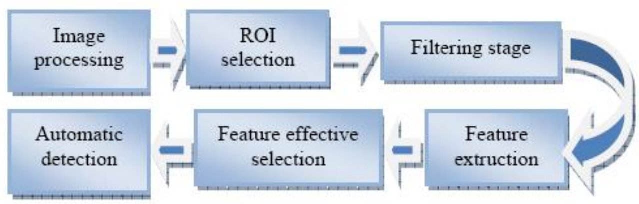

Fig-3: Block diagram of the system for the diagnosis of retinal detachment in the other eye sonography images

5. EXPERIMENTAL RESULTS

In this study, we used 120 eye sonography image including 70 cases of retinal detachment (which was fixed after surgery) and 50 cases other diseases such as vitreous opacities. In the first step after applying PCA algorithm and Hough transform extracted of classifieds desired characteristics took place by perceptron three-layer neural network and RBF network and then network test took place with 30 percent of the database images. The number of neurons in the hidden layer was selected by trial and error and described network per 3 neurons in the hidden layer and *logsig* operation function in hidden layer reached to the best answer 72 percentage. In Table 1, the results of the change of neurons number and hidden layer operation function is shown in output response percent. In the second step of this study same characteristics were obtained from the PCA for classifieds for RBF neural network that 90percent found the correct diagnosis. In the last step was used from of the SVM algorithm type 2 to intelligent detect that in addition, the detection rate is higher than the neural networks, correct diagnosis percent arrived also to the 98/1 percent.

6. DISCUSSION AND CONCLUSION

In this article, a detection method based on Hough transform was suggested to diagnose retinal detachment of the other eye diseases with use of digital sonography images of the eye. The results of SVM algorithm were compared with the proposed classifier with two neural networks MLP and RBF in correct diagnosis. The results show that the proposed method in this article is high potential in retinal detachment dissociation from other diseases.

Table-1: The results of the different classifiers

Classifier	Maximum percent of Correct Training	Average percent of Correct Training
perceptron neural network	95	72
RBF neural network	95	90
Maximum distance Algorithm	95	79.2
SVM classifier	100	98.1

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