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Intelligent System using Neural Network Classifier for Glaucoma Diagnosis

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Abstract: ***Glaucoma is one of the principal causes of blindness in the world[1]. It is a condition of eye disease which leads to irreversible blindness in advanced stages. Early diagnosis is an important objective in Glaucoma diagnosis to maintain the best visual acuity throughout the life of the people with Glaucoma. A Neural Network approach is proposed for the diagnosis of Glaucoma. Automated analysis of information from various diagnostic techniques was performed to improve Glaucoma detection in the clinic. This paper discusses the inclusion of neural networks in Glaucoma diagnosis. Data from clinical examination, pachymetry, perimetry and analysis of the retinal nerve fiber layer were integrated in a system of Artificial Intelligence. Analysis of 106 eyes obtained from practicing ophthalmologist, which represent various stages of glaucoma is used to develop an ANN. In Multilayer perceptron, the learning was carried out with 66% of the data and with the training function of gradient descent with momentum backpropagation. The classifier accuracy was. This method provides an efficient and accurate tool for the diagnosis of Glaucoma in the stages of glaucomatous illness by means of ANN.***

Keywords: Neural Network, Glaucoma, Multilayer Perceptron, Artificial Intelligence, Back propagation, Artificial Neural Network, Feed Forward Neural Network.

I. INTRODUCTION

Glaucoma is a term used to describe a group of diseases of the eye characterized by progressive and irreversible damage to the optic nerve (nerve of the eye responsible for vision) and which if untreated can lead to blindness. Though raised pressure of the eye (pressure maintained by fluid in the eye) is an important risk factor, a few individuals can develop glaucoma even with normal pressure of the eye. Glaucoma is the second leading cause of blindness in the world accounting for upto 8% of total blindness. In India, glaucoma is the leading cause of irreversible blindness with atleast 12 million people affected and nearly 1.2 million people blind from the disease. More than 90 percent of cases of glaucoma remain undiagnosed in the community.[2]

Artificial neural networks are finding many uses in the medical diagnosis application. Artificial neural networks provide a powerful tool to analyse and model complex clinical data for a wide range of medical applications. Most applications of artificial neural networks to medicine are classification problems; that is, the task is on the basis of the measured features to assign the patient to one of a small set of classes.[3] An artificial neural network a part of artificial intelligence, with its ability to approximate any nonlinear transformation is a good tool for approximation and classification problems.[4-6] Multilayer perceptron (MLP), a feed-forward, back-propagation network, is the most frequently used ANN technique in glaucoma research.[7]

Artificial Neural Networks (ANNs) have discrete advantages over statistical classification methods. Traditional classification methods fail because of noisy or incomplete data but ANNs are useful for such cases also. Neural networks are also useful in multivariable classification problems having high correlation degree. The diagnosis of diseases also involves such complex classification. By correct application of artificial neural networks in this area, in order to obtain the interdependence of symptoms and proper diagnosis, this dependence can be generalized.[8-10] Input patterns representing various symptoms are classified based on this generalized model. The proposed system classify 18 input parameters based on a generalized ANN model.

II. GLAUCOMA

Glaucoma is a group of diseases that damage the eye's optic nerve and can result in vision loss and blindness. With early detection and treatment, eyes can be protected against serious vision loss.[11] Glaucoma is characterized by a particular pattern of progressive damage to the optic nerve that generally begins with a subtle loss of peripheral (side) vision. An elevation in the pressure within the eye (the intraocular pressure, or IOP) is generally, but not always, associated with the development of glaucoma, although additional factors are also likely to play a role in its development. In some cases, glaucoma may occur in the presence of normal eye pressure. This form of glaucoma is believed to be caused by poor regulation of blood flow to the optic nerve. Glaucoma is the diagnosis given

to a group of ocular conditions that contribute to the loss of retinal nerve fibres with a corresponding loss of vision. Glaucoma therefore is a disease of the optic nerve, the nerve bundle which carries images from the eyes retina to the brain.

Glaucoma is said to be one of the leading causes of blindness in people with a family history of glaucoma, people over the age of 40 in Indian and African American population and 60 in Mexican American population.[11] The patients present complains about pain in eye, redness of eye, headache, blurring of vision etc. at various stages of glaucoma progression.

The first and primary variation in eye because of glaucoma is in the intraocular pressure of eye. Glaucoma is said to be a disease due to elevation in eye pressure.[12] The value of intraocular pressure is usually varies between 10 to 20 mmHg. But in case of patients, who present glaucoma it sometimes may increase. The nerve fibres begin to die due to this pressure increase. Because of dying of these fibres, the light that falls on these regions do not induce any sense of vision. Thus the spot becomes blind.[13]

Different stages of glaucoma in the proposed system is classified as,

1) *No Glaucoma:* The diagnosis of presenting symptoms is other than glaucoma.
2) *Primary Open Angle Glaucoma:* It is also known as primary or chronic glaucoma. It is caused by the slow clogging of the drainage canals, resulting in increased eye pressure. It has a wide and open angle between the iris and cornea. It develops slowly and is a lifelong condition. It is most common form of glaucoma, accounting for at least 90 % of all glaucoma.
3) *Primary Normal Tension Glaucoma:* It is also known as low tension or normal-pressure glaucoma. It leads to the damage of optic nerve, even though the eye pressure may not very high.
4) *Primary Ocular Hypertension*
5) *Angle Closure Glaucoma:* It is caused by blocked drainage canals, resulting in a sudden rise in intraocular pressure. It is a result of the angle between the iris and cornea closing. It is comparatively a less common form of glaucoma.
6) *Secondary Glaucoma:* This disease causes increased eye pressure, that result in optic nerve damage and vision loss. It may occur as the result of an eye injury, inflammation, tumor, advanced cases of cataract or diabetes, or it can also be caused by certain drugs such as steroids.[14]

Glaucoma affects about 70 million people worldwide, of whom about 10 per cent are believed to be bilaterally blind. It is estimated that by the year 2020, this number would rise to around 79.6 million. Statistics gathered by the World Health Organisation (WHO) show that glaucoma is the second leading cause of blindness globally, after cataract. Glaucoma, however, presents greater health challenge than cataract because the blindness it causes is irreversible. India has the third largest number of glaucoma patients, after China and Europe/USA. Glaucoma is the third leading cause of blindness in India, but the alarming thing is that by the time a patient is detected to be having glaucoma, 90 % have lost 50 % of their sight In India, it is estimated that glaucoma affects 12 million people accounting for 12.8 % of the countries blindness and by 2020; this is expected to be 16 million. Population-based studies report a prevalence between 2 to 13 % in India. In India, more than 90 % of glaucoma in the community is undiagnosed. Statistics say one in eight persons above the age of 40 years in India is either suffering from glaucoma or is at risk of the disease. Glaucoma can affect any age group, including newborn, infants, children, and elderly.[14-17]

Glaucoma is detected through a comprehensive dilated eye exam that includes the following:

7) *Visual acuity test:* This eye chart test measures how well you see at various distances.
8) *Visual field test:* This test measures your peripheral (side vision). It helps your eye care professional tell if you have lost peripheral vision, a sign of glaucoma.
9) *Dilated eye exam:* In this exam, drops are placed in your eyes to widen, or dilate, the pupils. Your eye care professional uses a special magnifying lens to examine your retina and optic nerve for signs of damage and other eye problems. After the exam, your close-up vision may remain blurred for several hours.
10) *Tonometry:* It is the measurement of pressure inside the eye by using an instrument called a tonometer. Numbing drops may be applied to your eye for this test. A tonometer measures pressure inside the eye to detect glaucoma.
11) *Pachymetry:* It is the measurement of the thickness of your cornea. Your eye care professional applies a numbing drop to your eye and uses an ultrasonic wave instrument to measure the thickness of your cornea.[11]

Immediate treatment for early-stage, open-angle glaucoma can delay progression of the disease. Therefore, early diagnosis plays a very important role. Glaucoma treatments include medicines, laser trabeculoplasty, conventional surgery, or a combination of any of these. These treatments may save remaining vision, they do not improve sight already lost from glaucoma.[11]

III. ARTIFICIAL NEURAL NETWORK

Artificial neural networks (ANN) have emerged as a result of simulation of biological nervous system, such as the brain on a computer. Artificial Neural networks are represented as a set of nodes called neurons and connections between them. The

connections have weights associated with them, representing the strength of those connections. Neural network can be applied to problems that do not have algorithmic solutions or problems for which algorithmic solutions are too complex to be found. In others words the kind of problems in which inputs and outputs variables does not have a clear relationship between them, a neural networks is an efficient approach in such problems. Most neural network architecture has three layers in its structure. First layer is input layer which provides an interface with the environment, second layer is hidden layer where computation is done and last layer is output layer where output is stored. Data is propagated through successive layers, with the final result available at the output layer.[18] Figure 1 show multilayer perceptron structure with N number of inputs neurons corresponding to N number of hidden and output neurons.

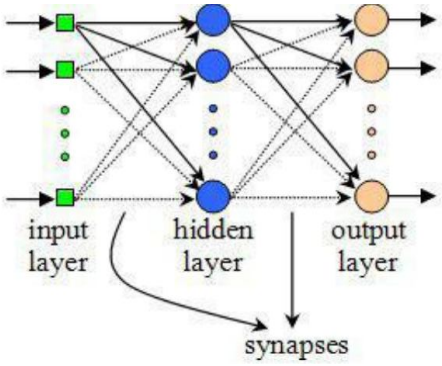


Fig. 1 A Multilayer Perceptron architecture[18]

Artificial neural network has become most widely used tool for diagnosis of diseases. Because of the capabilities of Artificial neural networks such as Fault tolerance, Generalization and Learning from environment, it is becoming more and more popular in medical diagnosis and many more others areas. One of the network structures that have been widely used is the feed forward network where network connections are allowed only between the nodes in one layer and those in the next layer. Feed-forward back propagation neural network is used as a classifier to distinguish between infected or non-infected person. [15]

Medical Diagnosis using Artificial Neural Networks is currently a very active research area in medicine and it is believed that it will be more widely used in biomedical systems in the next few years. This is primarily because the solution is not restricted to linear form. Neural Networks are ideal in recognizing diseases using scans since there is no need to provide a specific algorithm on how to identify the disease. Neural networks learn by example so the details of how to recognize the disease is not needed.[19]

Based on the way they learn, all artificial neural networks are divided into two learning categories: supervised and unsupervised. In supervised learning, the network is trained by providing it with input and output patterns. During this phase, the neural network is able to adjust the connection weights to match its output with the actual output in an iterative process until a desirable result is reached. An ANN of the unsupervised learning type, such as the self-organizing map, the neural network is provided only with inputs, there are no known answers. The network must develop its own representation of the input stimuli by calculating the acceptable connection weights. That is self-organization by clustering the input data and find features inherent to the problem.[20]

IV. THE PROPOSED NEURAL NETWORK DIAGNOSTIC MODEL

Different types of neural networks are available and multilayer neural networks are the most popular for disease diagnosis. Popularity of MLP is due to more than one hidden layer in its structure which helps sometimes in solving complex problems which a single hidden layer neural network cannot solve.[18]

In this paper, a typical MLP back propagation neural network is proposed to diagnose glaucoma. A basic model-Model-1 with 4 glaucoma diagnostic classes are trained and tested first. This model is then optimized further as Model-2 for diagnosis of more specific type of glaucoma with 7 different glaucoma diagnostic classes.

A. Model-1 consists of three layers

1) The input layer with 18 input parameters
2) Two hidden layers with 16 and 13 nodes respectively
3) The output layer with 4 diagnostic classes

A network with two hidden layers with 16 and 13 nodes is created and trained. Training continues as long as the network continues improving on the validation set. The test set provides a completely independent measure of network accuracy. The information

moves in only one direction, forward, from the input nodes, through the hidden nodes and to the output nodes. There are no cycles or loops in the network. The proposed neural networks are shown in Fig.2 and Fig.3.

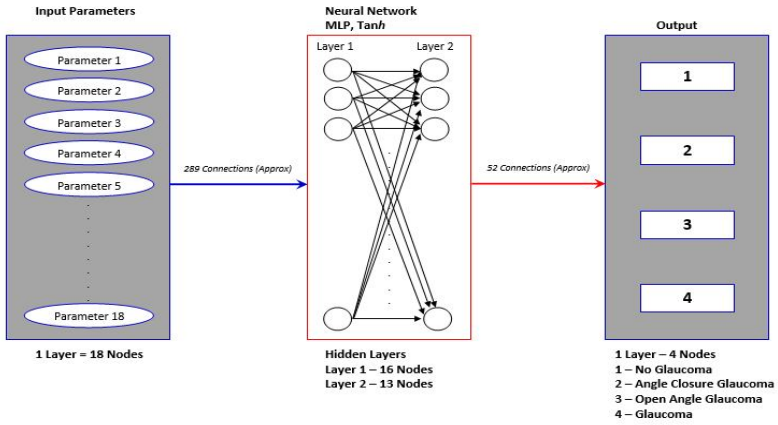


Fig 2. Proposed model-Model-1 for glaucoma diagnosis using MLP

B. Model-2 consists of three layers

1) The input layer with 18 input parameters
2) Two hidden layers with 16 and 13 nodes respectively
3) The output layer with 7 diagnostic classes

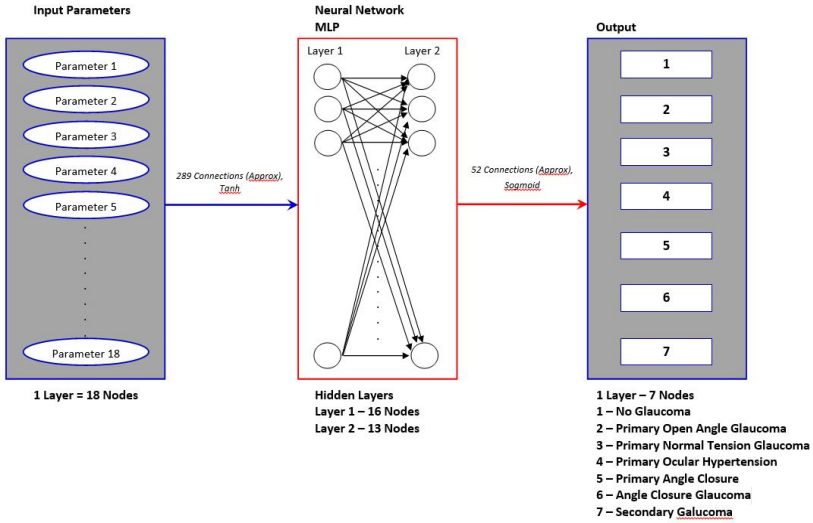


Fig 3. Proposed model-Model-2 for glaucoma diagnosis using MLP

The output of the hidden layer can be represented by,

$$YNx1 = f(WNxM\ XM,1 + bN,1\ )$$

where Y is a vector containing the output from each of the N neurons in a given layer, W is a matrix containing the weights for each of the M inputs for all N neurons, X is a vector containing the inputs, b is a vector containing the biases and f(·) is the activation function.21

V. EXPERIMENTAL RESULTS

The input parameters include various parameters such as patient history, age, complaints and clinical examinations, such as, CDR, IOP, Pachymetry result, Gonioscopy result, different OCT parameters and Perimetry test result.

First model-Model-1 is used for classification of 18 parameters for glaucoma diagnosis in 4 different classes of classification using MLP, No Glaucoma, Open Angle Glaucoma, Angle Closure Glaucoma and Other Glaucoma (for types of glaucoma other than the two classes). Second model-Model-2 is using the 18 input parameters and diagnosis is in 7 different classes using MLP, namely, No

Glaucoma, Primary Open Angle Glaucoma, Primary Normal Tension Glaucoma, Primary Ocular Hypertension, Primary Angle Closure, Angle Closure Glaucoma and Secondary Glaucoma. The model is build using SPSS.

The input and target samples are divided into 66% training and remaining 44% validation and testing sets. The training set is used to teach the network. The learning rate of the network is 0.2 with momentum 0.8. The network is optimized and trained using gradient descent algorithm.

The data was created by a medical expert as a data set to test the proposed system of MLP, which will perform the presumptive diagnosis of eye disease-glaucoma. The data set contains 106 patients. Fig. 4 and Fig. 5 are the neural networks for Model-1 and Model-2. Model-1 classify the symptoms into 4 diagnostic classes. Model-2 classify the symptoms into 7 diagnostic classes.

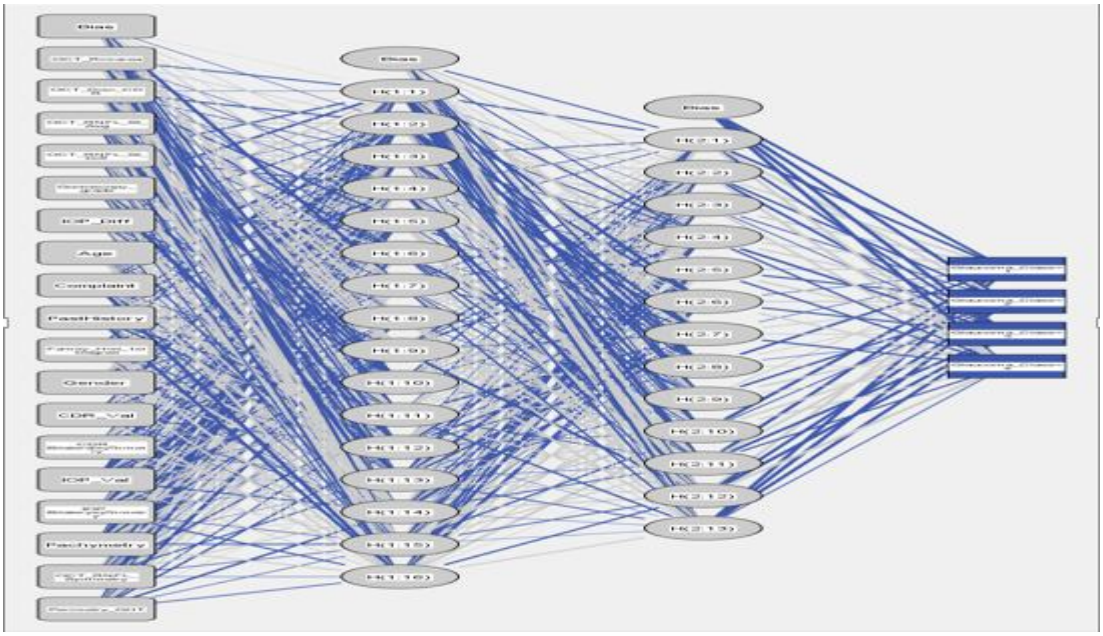


Fig. 4 Neural Network Model-1

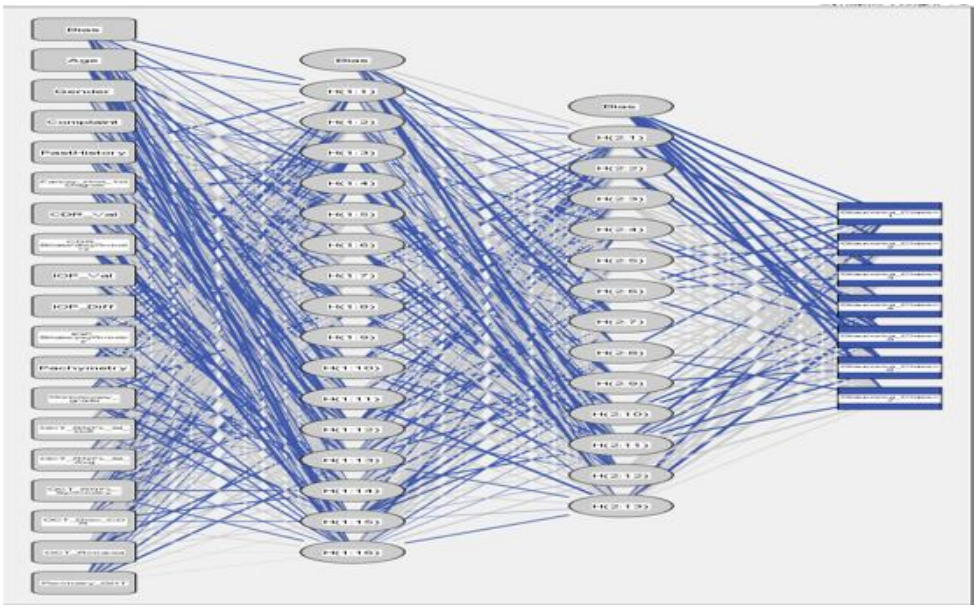
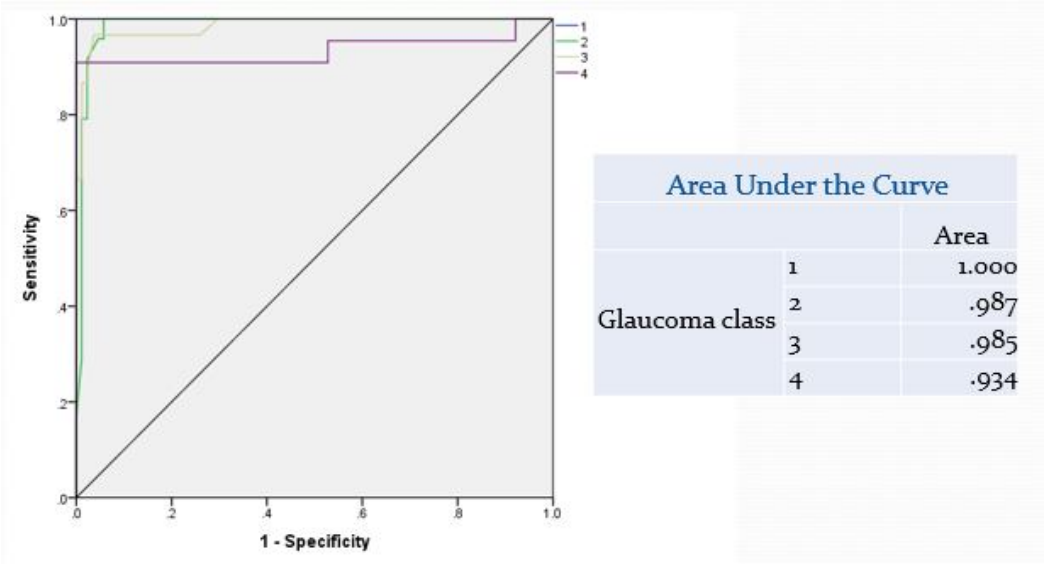


Fig. 5 Neural Network Model-2

Model-1 has classification accuracy 97.6%. Fig. 6 shows the area under ROC curve for Model-1. The values for different classes being >0.9 shows that the classifier quality is 'Excellent'. It discriminates the symptoms very well and classify it into respective diagnosis class.

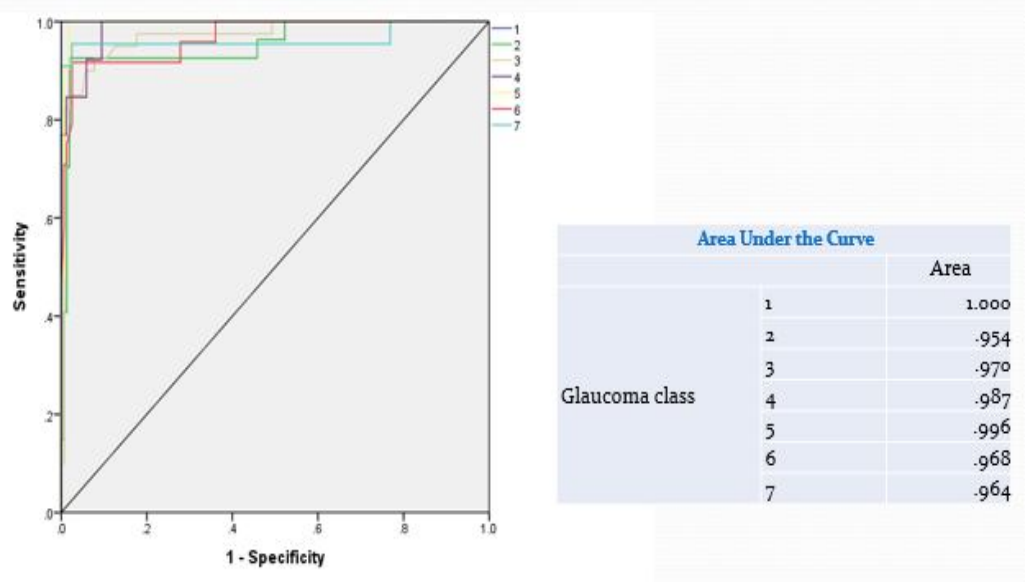


Area Under the Curve

		Area
Glaucoma class	1	1.000
	2	.987
	3	.985
	4	.934

Fig. 6 ROC Curve for Model-1

Model-2 has classification accuracy 94.9%. Fig. 7 shows the area under Experimental results ROC curve for Model-1. The values for different classes being >0.9 shows that the classifier quality is 'Excellent'.



Area Under the Curve

		Area
Glaucoma class	1	1.000
	2	.954
	3	.970
	4	.987
	5	.996
	6	.968
	7	.964

Fig. 7 ROC Curve for Model-2

VI. CONCLUSIONS

This paper intended to evaluate artificial neural network in glaucoma disease diagnosis. The Multilayer Perceptron back propagation neural network with supervised learning is proposed to diagnose the disease. Artificial neural networks shows significant results in dealing with data represented as symptoms for glaucoma. Results shows that the proposed diagnosis neural network could be useful for identifying the person with glaucoma.

VII. ACKNOWLEDGMENT

The heading of the Acknowledgment section and the References section must not be numbered.
Causal Productions wishes to acknowledge Michael Shell and other contributors for developing and maintaining the IEEE LaTeX style files which have been used in the preparation of this template. To see the list of contributors, please refer to the top of file IEEETran.cls in the IEEE LaTeX distribution.

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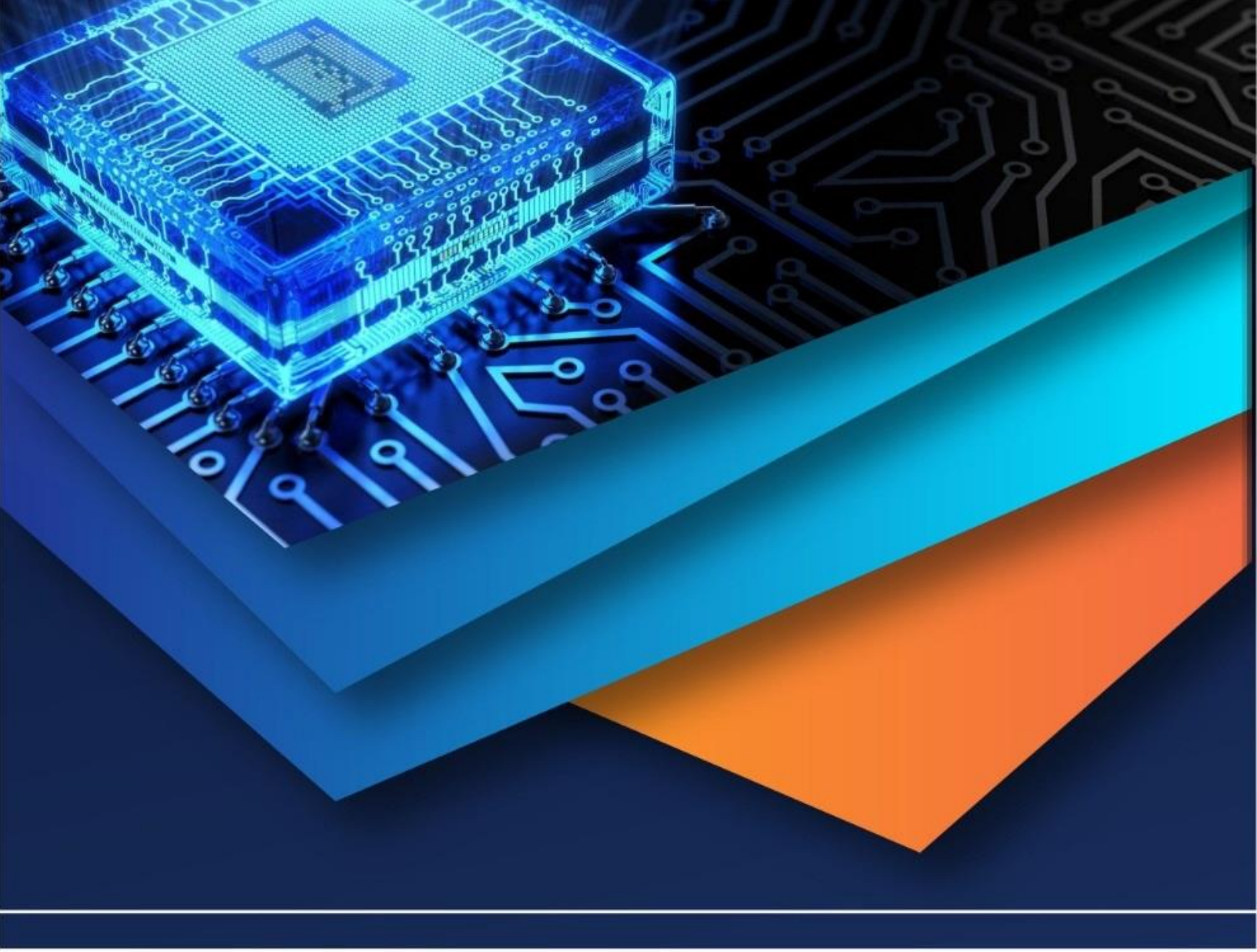

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