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Classification of Retinal Images for Diabetic Retinopathy at Non-Proliferative Stage using ANFIS

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Abstract— Digital Retinal Fundus image is analyzed for the classification and stages of Diabetic Retinopathy (DR).This imparts importance, since many of heart, lung, and kidney related problems could be predicted well in advance, by analyzing the fundus image itself which is an cost effective technique. Also, Later stages of DR causes abnormal changes in human retina and vision loss is occurred in most of the patients. The aim is to extract the abnormal features like Microaneurysms, exudates, and blood vessels, to classify DR at its proliferative stage itself. At the same time, the healthy or normal features like optic disk, blood vessel map is to be removed by suitable enhancement technique (Morphological technique) .The abnormal features and its normal ground features are trained for classification. The classification is done using ANFIS architecture. The detection and classification method , surely provide an additional and promising data and information to ophthalmologists and to the analyst for further treatment. The proposed method will give a promising accuracy when compared with the methods available in the literature.

Keywords— Retinal fundus image,Normalfeatures, Microaneurysms , Exudates, Statistical features, ANFIS architecture

I. INTRODUCTION

Diabetic retinopathy is a complication of diabetes that affects the eyes. It is caused by damage to the blood vessels of the light sensitive tissue at the back of eye (Retinal).[1]At first, Diabetic Retinopathy may have no symptoms or only mild vision problems.[8] Early detection of diabetics plays a major role in the success of such disease treatment, so that the worst case can be anticipated.[6]. There are three major types of diabetes: Type 1 diabetes, type 2 diabetes, gestational diabetes. They have the same basic characteristics: the body’s inability either to make or to use insulin. Our body needs insulin, a hormone, to be able to use glucose, which comes from the food. We eat for energy without enough insulin glucose stays in the blood creating high level of blood sugar. This leads to cause damages in kidneys, heart, nerves, eyes and other organs.[8] Early detection of diabetes is achieved by following symptoms: Increased hunger, itching blurry vision, fatigue, increased urination and thirst, headaches, unusual weight changes, dry mouth, irritability.

Diabetic Retinopathy, the most common diabetic eye diseases occurs when blood vessels in the retinal change sometime these vessels swell and leak fluids or even close off completely. In other cases abnormal new blood vessel grow on the surface of the retina.[8]. The retina is a thin layer of the light sensitive tissues that lines the back of eye. The light rays focused onto the retina where they are transmitted to the brain and interpreted as the images we see. The macula is very small area at the center if the retina, which is responsible for pinpoint vision allowing us to read, see or recognize a face. Diabetic Retinopathy affects usually both eyes. Types of diabetic retinopathy: Non-proliferative Diabetic Retinopathy (NPDR) and Proliferative Diabetic Retinopathy (PDR).

A. Non Proliferative Diabetic Retinopathy

NPDR is the earliest stage of Diabetic Retinopathy. This stage can detect the abnormal features namely Microaneurysms, Exudates etc.. Sometimes deposits of cholesterol or other fats from the blood may leak into the retina. In NPDR, depending on the presence and extent of the features such as hard exudates, microaneurysms or cotton wools spots due to leakage of fluid and blood from the blood vessels, can be classified to mild, moderate or severe stages as followings:

- **Mild NPDR:** This is the earliest stage of retinopathy and vision is usually normal except in some cases. However, deterioration of the blood vessels in the retina has already started. Blood vessels erupt when there is not enough oxygen in the blood because of high levels of glucose. Small swellings known as Micro-aneurysms or flame-shaped hemorrhages start to develop in the fundus quadrants.
- **Moderate NPDR**: As the disease progresses, some of the blood vessels that irrigate the retina become blocked. It is more than “mild” but less than “severe” stage. There will be micro-aneurysms or hemorrhages of greater severity in one to three quadrants and leakage might occur, resulting cotton wool spots and exudates etc. to be present in the retina.
- **Severe NPDR**: As more blood vessels are blocked, those areas in the retina will be deprived of blood supply. Signals will then be sent to the body for the growth of new vessels in order to compensate for the lack of nourishment.

B. Proliferative Diabetic Retinopathy

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It is mainly occurs when many of the blood vessels in the retina close, preventing enough blood flow. In an attempt to supply blood to the area where the original vessels closed. The retina responds by growing new blood vessels. This is called neurovascularization. These new blood vessels are abnormal and do not supply the retina with proper blood flow [7]. The new vessels are also accompanied by scar tissue they may cause the retina to wrinkle or detach. It cause more severe vision loss then non proliferative diabetic retinopathy because it can affect both central and peripheral vision [6]. **Cotton wool spots** are an abnormal finding on funduscopic exam of the retina of the eye. They appear as fluffy white patches on the retina. They are caused by damage to nerve fibers and are a result of accumulations of axoplamic material within the nerve fiber layer.[7]. The paper is organized as follows. Section I describes about Introduction, Section II focus is on literature survey of related works in DR, In Section III, proposed method is explained followed by Results and Discussion on Section IV. In Section V feature extraction part is well described and Retinal fundus images are classified as Normal and Abnormal. In Section VI Conclusion and future enhancements are discussed.

II. LITERATURE SURVEY

David et.al. [1] , presented an automated system to analyze the retinal images classifier based on artificial neural network which classify the images according to the diseased condition. The consistent identifying and quantifying of changes in blood vessels and different findings such as exudates in the retina over time can be used for the early detection of Diabetic Retinopathy . In [2], the Complexity of the vertical vascular network is quantified through the measurement of fractal dimension. A computerized approach enhances and segments the retinal vasculature in digital fundus images with an accuracy and comparison gold standard of manual tracing, fractal analysis was performed on skeletonized version of the network. J.Anitha et.al.[3], explained about the hybrid neural network (CPN) which is highly desirable since it comprises the advantages of supervised and unsupervised training methodologies. Neural Network is proposed to tackle the problem which eliminates the iterative training methodology which accounts for the high convergence time. Methods of 2-D fundus imaging and technique for 3D optical coherence tomography imaging are reviewed. Special attention is given to quantitative technique for analysis of fundus photograph with a focus on clinically relevant assessment of retinal vasculature identification of lesions. Assessment of optic nerve need shape building retinal atlases and to automated methods for population screening for retinal layers is explained by Michael D.Abram et.al. [5]. Akara sopharak.et.al [6], implemented and investigated the benefit of both traditional automatic exudates detection and machine learning methods and comparative analysis. Mathematical morphology fuzzy c means clustering, nerve Bayesian classifier, support vector machine and nearest neighbor classifier is presented. Detected exudates are validated with expert ophthalmologists hand drown, ground truths. The sensitivity, specify precision and accuracy of each methods is also compared. In [7], an Automated method for the detection of exudates in retinal images with high accuracy. First the image is converted to HIS model. After preprocessing possible regions containing exudates using grey scale morphology are identified. Diptoneel kayal et.al [8], described the detection of exudates in early stages of the diseases is extremely difficult only by visual inspection because of small diameter of human eye. But an efficient automated computerized system can have the ability to detect the disease in very early stage .Md.mohid ahmed et.al [9], proposed an clustering based methodology to Exudates are a category of lipid retinal lesions visible through optical fundus imaging and indicative of DR. we tend to propose clustering bases methodology to phase exudates using multi space clustering and color space options. Srilatha and roe et.al.[10] presented the automated system for the analysis of the retinal images by using image processing techniques. These features are utilized by the classifier to grade DR into different stages according to disease and thus indicating the severity.

III. PROPOSED SYSTEM

The proposed method consists of three main phases. The first step is preprocessing followed by proper Image enhancement techniques. The next phase is removal of healthy features like optic disc and blood vessels followed by detection and extraction of Non-proliferative stage(NPDR) , features namely Microaneurysms and exudates . The third phase is the classification stage of DR namely the classes of Normal and abnormal data using ANFIS architecture.

A. Database

Database are an essential resource in the development of eye fundus image analysis algorithms that considerably help the medical imaging researchers to evaluate and compare state-of-the-art methods. The Fundus database image is received from a Ophthalmology clinic located in Tirupathi. Clinical Validation is done by an expert Ophthalmologist from the same hospital.

B. Preprocessing

The normal fundus photographs, taken for the diagnostic processes, basically, contain many noises present in them. If the detection is made with those same images it may lead to malicious results. Hence to improve the image quality, uneven illumination, insufficient contrast between the exudates and the image background pixels and to remove the noises present in the input fundus images. Thus the preprocessing step has to be done initially.

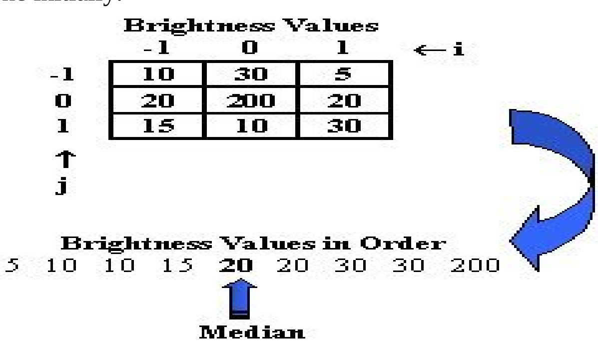

Fig.1.Median Filtering Technique

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i) HIS Color Space Conversion

In case of the Digital Image Processing, the images used are either indexed images or RGB (Red, Blue, and Green) images. The choice of the RGB to HIS is based on the fact that the intensity matrix of the image can be disassociated from other components such as hue and Saturation.

ii) Median Filtering

For better feature extraction it is necessary to perform a high degree of noise reduction in an image before performing higher-level processing steps, such as edge detection. Median filter, is a non-linear filtering technique, used to remove noise by preserving its edge. Median filter is a sliding window spatial filter. For every pixel, a 3x3 neighborhood with the pixel centre is calculated and the value of each pixel is replaced by the median pixel value of 3x3 neighborhoods.

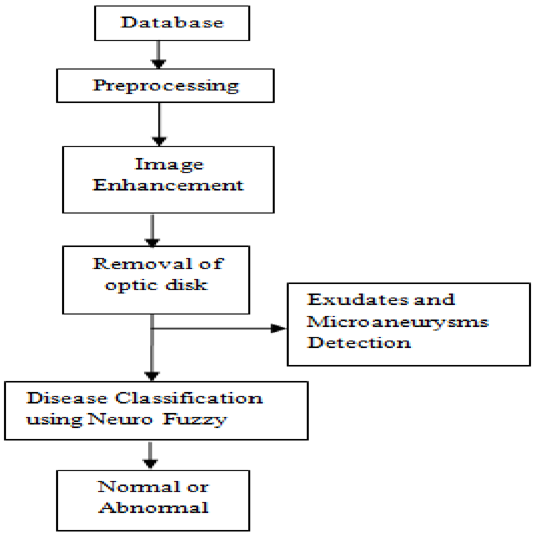

Fig.2.Flow Diagram of the Proposed System

iii)Image Enhancement by Adaptive Histogram Equalization

Adaptive histogram equalization is a computer image processing technique used to improve contrast in images. The method is useful in images with backgrounds and foregrounds that are both bright or both dark. The operation can be expressed as P(M(I)) where I is the original image, M is histogram equalization mapping operation and P is a palette. If we define new palette as P'=P(M) and leave image I unchanged then histogram equalization is implemented as palette change. On the other hand if palette P remains unchanged and image is modified to I'=M(I) then the implementation is by image change. In most cases palette change is better as it preserves the original data. This method usually increases the global contrast of many images, especially when the usable data of the image is represented by close contrast values. Through this adjustment, the intensities can be better distributed on the histogram. This allows for areas of lower local contrast to gain a higher contrast without affecting the global contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values.

C. Removal of optic disk

As the optical disk is made up of a group of bright spots, it is not suitable to use loops and locate the largest value The exudates are obtained after the removal of the circular border. The Optic disk and exudates show high intensity values compared with the other features. Almost, both possess similar characteristics. Optic disk is characterized by the largest area, high contrast, circular shape areas. Column matrix of vessel removed image is taken as input for further processing. Largest value of the column value is calculated by suitable method and its corresponding median value is calculated. The highest row and column value of optic disk is derived using the corresponding matlab function. A mask of radius =90 is generated by using the following equation which is the equation of the circle.

Equation of Circle:

$$R^2 = (X - a)^2 + (Y - b)^2 \qquad (1)$$

where a and b is the offset , which fix the maximum row and column value, which matches with the size of the optic disk. R is the radius of the circle.

D. Disease Classification using ANFIS

Adaptive Neuro-Fuzzy Inference System is a common approach in which the two techniques such as a neural network and a fuzzy logic get combined to create a complete shell .Basically the system of ANFIS applies the technique of the artificial neural network learning rules to determine and tune the fuzzy inference systems' structure and parameters. A number of important features of ANFIS can help the system accomplish a task brilliantly; these features are characterized as easy to implement, fast and accurate learning, strong generalization abilities, excellent explanation facilities through fuzzy rules, and easy to incorporate both linguistic and numeric knowledge for problem solving .

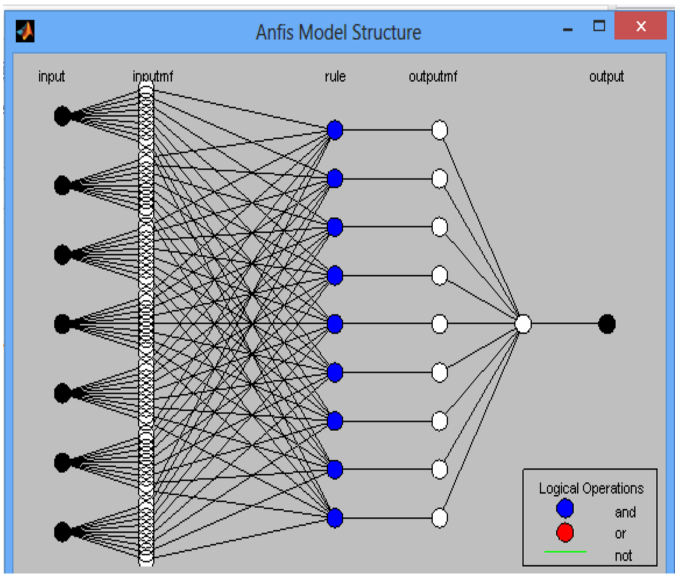

Fig.3Anfis model Structure

In Neuro-Fuzzy technique a neural network is introduced to devise the fuzzy system so that the structure and parameters which identify the fuzzy rules are accomplished by adopting and optimizing the topology and the parameters of corresponding the neuron fuzzy network based on data sets.

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The system is considered to be an adaptive fuzzy inference system with the capability of learning fuzzy rules from data and as a connectionist architecture provided with linguistic meaning. This is called ANFIS.

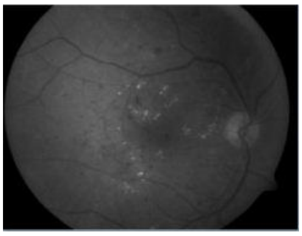
Both the Feed forward neural network and ANFIS have a similar structure but the links in an ANFIS only indicate the flow direction of signals between nodes and no weights are associated with the links. The architecture of the ANFIS consists of five layers. Among those layers both the first and the fourth layers consist of adaptive neurons despite the fact that the second, third and fifth layers consist of fixed neurons. The adaptive neurons are related with their respective parameters, and get duly updated with each in subsequent iteration, while the fixed nodes are devoid of any parameters.

IV. RESULTS AND DISCUSSION

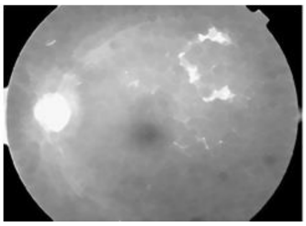
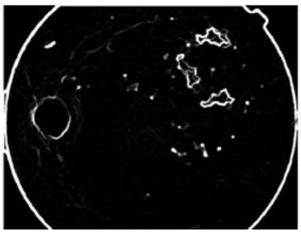
The proposed system is tested and evaluated on publicly available databases, namely DRIVE and DIARETDB1 database. DIARETDB1 provides 89 images with a variety of diagnoses captured by a Topcon TRV-50 fundus camera at 45 degree FOV in PNG format. DRIVE photographs are obtained from DR screening program in Netherlands, used for clinical diagnoses. Images acquired using Canon CR5 non-mydriatic 3 CCD cameras with a 45 degree FOV, in TIFF format.

A. *Exudates Detection*

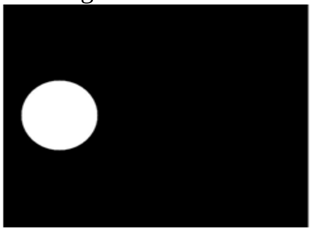
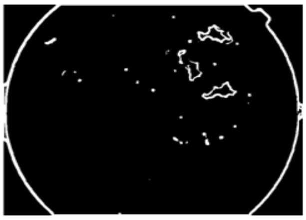
Figure 4.a) shows the original input RGB image, whose size is made in to its standard size. Figure 4. b) shows the intensity adjusted image, which has a better contrast when compared to its back ground. Figure 4.c) is the closed image, in which the thin blood vessels are removed by a suitable morphological operator. Figure 4.d) shows the image after filtering with median filter. 4.e) shows the mask generated for optic disk and is AND with the filtered image to remove the optic disk by using the equation of circle equivalent to optic disk diameter. Figure 4.f) is the image with optic disk removed. Figure 4.g) shows the final exudates extracted image. The final output of the sample image shows the abnormality condition of DR. This patient is to be further examined and better treatment could be done.

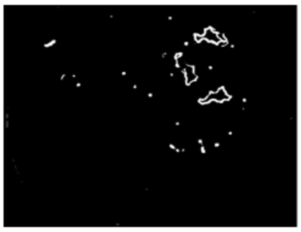
4.a) Original Image 4.b) Intensity Adjusted Image

4.c) Closed Image 4.d) Image after Filtering

4. e) Mask for Optic disk 4. f) Optic disk Removed Image

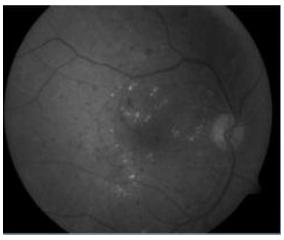


4.g) Region of Exudates

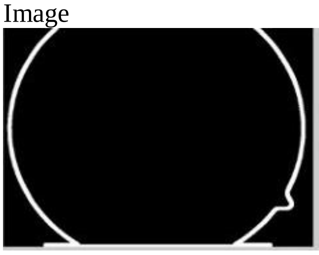
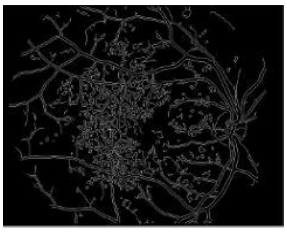
Fig. 4 Result for Sample Input Image

B. *Microaneurysms Detection*

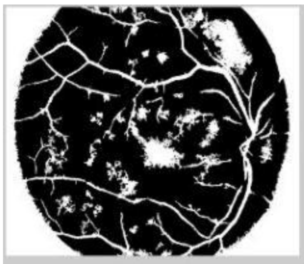
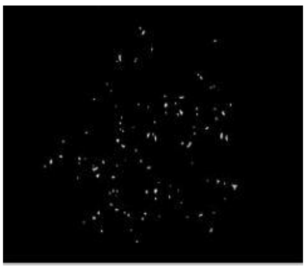
The Microaneurysms(MAs) is the first sign of Diabetic Retinopathy (DR) and it is the primary symptom. MAs are characterized by rounded structure and is red color in nature.

5.a) Original Image 5.b) Gray Scale Image

5.c) Circular Border 5. d) Edges without Border

5.e) Blood vessels and noise Removal 5.f) Microaneurysms after removal of Exudates

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5. g) Microaneurysms

Fig. 5 Result for Sample Input Image 2

Figure 5.a) shows the original input RGB image, whose size is converted to the standard size. Figure 5.b) shows the gray scale converted image, which is a single channel conversion of the RGB image. Figure 5.c) shows the circular bordered image which is to be superimposed on the preprocessed image , to remove the circular border. Figure 5.d) is the image free from circular border with blood vessels and exudates to be removed and MAs. to be retained. Figure 5.e) shows the blood vessels and noise present, which is to be removed. Figure 5.f) shows the MAs present with the exudates removed structure, with the help of the intensity variation between MAs. and Exudates. The final output image is shown in Figure 5.g) in which Microaneurysms alone are present and extracted based on the roundness metric whose value is one. The number of MAs, shows the severity of the disease, those could be further examined and investigated for future diagnoses and treatment in the early stage itself.

V. FEATURE EXTRACTION

Feature extraction is a special dimensionality reduction step, in which feature contributing to diagnose DR well in advance are extracted. Also, the feature extraction simplifies the amount of resources used to describe the large data set accurately. The following statistical features namely, mean, variance, energy, skewness and kurtosis are evaluated and tabulated. The table I and table II, shows the features extracted for Normal and Abnormal cases of DR.

TABLE I. Extracted Statistical Feature Values of Normal Image

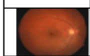
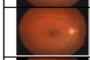
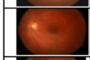
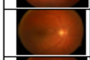
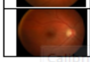
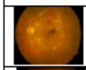
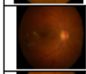
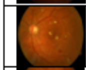
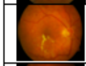
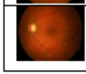
IMAGE	MEAN	VARIANCE	ENERGY	SKEWNESS	KURTOSIS	MAs	EXUDATES
	32.9	295.5	0.018	1.9	10.6	193	70
	56.4	438.9	0.039	0.3	5.08	28	66
	35.6	426.8	0.012	2.5	12.3	64	131
	39.4	331	0.019	1.9	12.4	5	0
	33.6	368.9	0.015	2.4	12.7	20	0

Table I, Shows the extracted statistical feature values of normal images . The number of MAs are less and area of exudates are having low values which shows the initial stage of DR.

Table II, Shows the extracted statistical feature values of abnormal images . The number of MAs are more and area of exudates are having higher values which shows the next stage of DR, but which lies in Non-Proliferative Stage only. In this stage of DR also, the patient vision could be safeguarded and further progress of disease could be avoided.

TABLE II. Extracted Statistical Feature Values of Abnormal Images

IMAGE	MEAN	VARIANCE	ENERGY	SKEWNESS	KURTOSIS	MAs	EXUDATES
	64.8	652.75	0.011	0.83	4.96	447	3290
	24.2	215.24	0.016	2.56	12.3	409	2921
	50.6	370.03	0.019	1.80	12.3	511	4129
	52.8	571.17	0.0122	1.22	6.71	640	3834
	34.8	462.0	0.012	2.84	17.4	127	1040

VI. CLASSIFICATION

The features extracted from the input fundus images is fed as the input to the ANFIS architecture. The statistical features particularly texture features namely MAs count and Exudates area are analyzed. Depends on the texture features, ANFIS classifies the images into normal and abnormal case. Hybrid optimization and 100 epochs are selected for training.

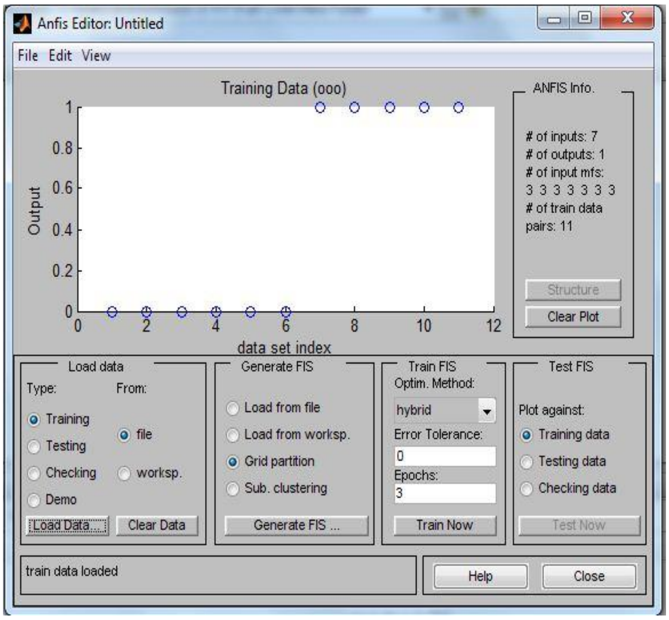


Figure. 6. Training Data

Figure.6 shows the training phase, in which the number of input is 7, number of output is one and membership of 3 is chosen. The input data is trained using this phase. Figure 7. shows the input selection parameters namely, accept ratio and reject ratio. In Figure. 8, Training error is shown after the required epochs of training phase and testing is based on the best training. The ANFIS output, namely the classification output as normal and abnormal is shown in Figure. 9. Rule viewer is shown in the Figure 10, in which 9 rules are chosen. Figure. 11, shows the output of ANFIS as surface viewer.

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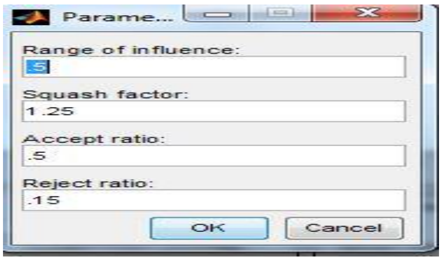

Figure 7. Input selection parameters

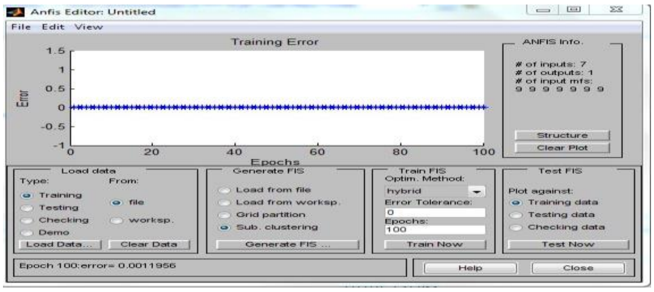

Figure 8. Training Error

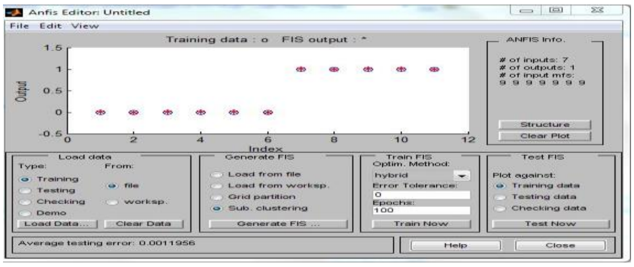

Figure. 9 ANFIS Output

Figure. 10 Rule Viewer

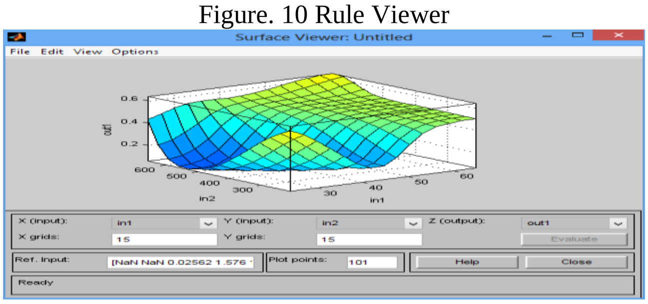

Figure 11. Surface Viewer

VII. CONLUSION AND FUTURE WORKS

An automated system has been successfully developed which is able to detect the microaneurysms and exudates in the fundus photographs with the performance approaching that of trained clinical observers. It has been found that the exudates can be detected irrespective of the stages of its growth. The fuzzy and the morphological methods have been employed to detect this complication caused due to diabetic retinopathy. This method is found to reduce the manual effort required for the detection and also the accuracy gets increased. The performance is measured by forming tables and plotting graphs comparing methods. The detection can be made with high sensitivity and specificity for different photographic modalities. The proposed algorithms are computationally powerful to detect and diagnose the diseases from the fundus images. This system is complicated for diagnose the soft exudates. Sometimes there might be exudates occurring in the optic disk which might be left undetected because of its elimination. As, Future enhancement work can be concentrated to diagnose the soft exudates as well as detect the exudates which are present in the optic disk. Also , the total software for DR can be devised and implemented in hospitals to reduce the vision loss by helping the human environment with low cost.

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