# *Multi- Stage Classification of Retinopathy of Prematurity Using ANFIS*

S. Divya
*B.E. Biomedical Engineering*
*Dr.N.G.P. Institute of Technology*
Coimbatore, India.
divyasathiya29@gmail.com

M. Renuka
*B.E. Biomedical Engineering*
*Dr.N.G.P. Institute of Technology*
Coimbatore, India.
renukamani18@gmail.com

D. Vinoth
*B.E. Biomedical Engineering*
*Dr.N.G.P. Institute of Technology*
Coimbatore, India.
vinothfifa98@gmail.com

Dr.S.Prabakar
*Professor and HOD*
*Dr.N.G.P. Institute of Technology*
Coimbatore, India.
srisornaprabu@gmail.com

*Abstract*— **Retinopathy of prematurity (ROP) is a vascular disease which affects the retina of low birth weight infant (<1800g). This paper has been proposed to classify the severity stages of ROP using Adaptive Neuro Fuzzy Inference System (ANFIS) .The Median filter is used to remove the noise and green channel of image are enhanced by Contrast Limited Adaptive Histogram Equalization (CLAHE). Scale Invariant Feature Transform has been proposed to recognize the local features as key points that vary by texture, colour or intensity from its neighbouring pixels. Iterative Self-Organizing Data Analysis Technique (ISODATA) thresholding is used to identify the image globally in which the vascular structure of the foreground image is separated from the background and segmentation is performed by Expectation Maximization. The Statistical, texture and shape based features like mean, standard deviation, variance, contrast, homogeneity, entropy, energy, area, perimeter, centroid, equiv diameter, eccentricity are extracted from segmented result. Adaptive Neuro Fuzzy Inference System (ANFIS) is a feed forward neural network that classifies the image into normal, plus disease and abnormal stages.**

***Keywords— Retinopathy of prematurity, plus disease, ISODATA, Expectation Maximization, CLAHE, ANFIS***

## I. INTRODUCTION

Retinopathy of prematurity (ROP) is an eye disease which occurs in premature infants weighing less than 1800g or born before 31 weeks of gestational period. The eye starts to develop at about 16 weeks of pregnancy and the blood vessels of retina start to form from optic nerve at the back of the eye. The blood vessel begins to grow gradually towards the edges by supplying oxygen and nutrients to the developing retina [14]. During the last 12 weeks of pregnancy the eye develops rapidly and the retinal blood vessels growth will complete only when a baby born at full –gestational period but for premature infants the normal blood vessels growth may stop and may not get sufficient oxygen and nutrients to the edges of retina. As a result abnormal blood vessels will grow. The premature infants need to be examined periodically as per the guidance of ophthalmologist to determine the presence or severity of ROP.

The timing of the first assessment in any neonatal intensive care unit (NICU) must be based on the gestational age at birth. (i) If the baby is born at a gestational age of 23-24
Weeks, the first eye test should be done at the age of 27-28 weeks. (ii) If the baby is born at or beyond the gestational age of 25-28 weeks, the first test will take place during the fourth or fifth week of life. (iii) If the baby is born after 29 weeks, it is possible that the first eye exam will take place by the baby's fourth week of life.

ROP diagnosis is conducted using various screening procedures, such as Binocular Indirect Ophthalmoscope (BIO) and Ret Cam. BIO is considered the ROP gold screening standard [13]. Ret Cam is a device that has revolutionized the screening technique of ROP.A large field digital imaging equipment to examine the pediatric fundus. While indirect ophthalmoscopy requires expertise, the ret cam enables ROP screening to be performed by anyone with appropriate training and easily obtain reproducible results.

The field of view ranges between 80 degree and 130 degree. It is most commonly used for studying certain diseases. Ret cam is used most popularly in telemedicine [10]. The scanning is conducted by technicians at the peripheral centers, the images are then sent to specialists where they can study the images and prescribe treatments.

## II. Classification And Stages Of Rop

The location of the disease is referred by ICROP (International Classification of Retinopathy of Prematurity).Compared to three zones, zone I disease is the most dangerous it leads to scar tissue formation and total retinal detachment [2]. Consider eye as clock and then three zones are characterized as (Figure 2.1) is described below

Zone I is the innermost zone it covers the area of optic disc and macula at back of the eye. Zone II starts from edge of the zone I to the nasal oraserrata (3 o clock positions in the right and 9 o clock position in the left eye).It is twice the diameter of zone I. Zone III is the remaining crescent of retina anterior to zone II.

Severity Stages of ROP are categorized as Step 1-The line of demarcation is a thin, flat, white line dividing a-vascular retina from the vascular retina. Step 2 - Ridge originates from the line of demarcation and grows in height, width and volume. It turned white-pink. Step 3-Ridge with extra proliferation of the retinal fibro vascular or neo-vascularisation. Step 4-Partial retinal detachment, the step is divided into extra fovea (stage 4a) which does not affect the macula and has a relatively good vision prognosis, fovea (stage 4b) affects the fovea and typically has bad vision prognosis. Step 5 -Complete detachment to the retinal.

Plus disease features increase venous dilation and posterior retinal vessel arteriolar tortuosity. If the patient is identified with plus disease, it should be monitored and there is a high risk of developing ROP, this leads to retinal detachment and may result in blindness**.**

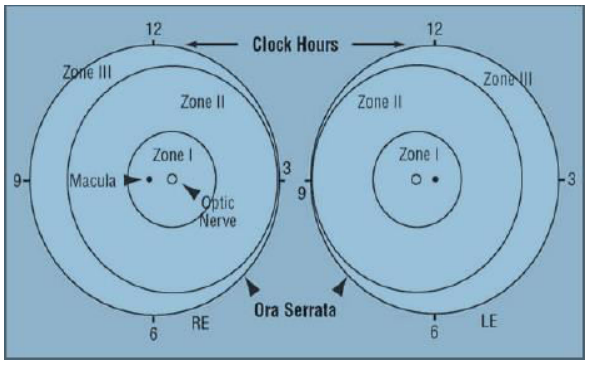


Fig.2.1 Zones of ROP

## III. Proposed System

In this section, we present the brief explanation of block diagram of Fig.3.1 discussed as follows:

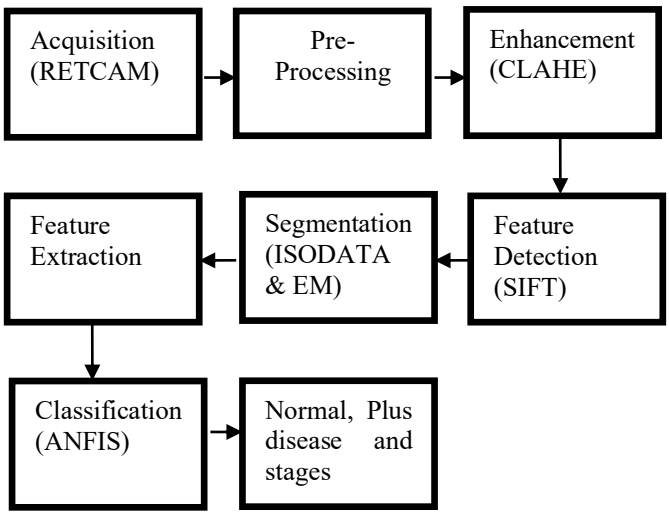


Fig .3.1 Block diagram of proposed system

Here the proposed system is explained in three phases as phase I, II and III.

*A) Phase I*

Phase I describe about the plus disease image acquisition, pre-processing and enhancement method (fig.3.2).

*i) Image Acquisition:*

The images were collected non-invasively by the Retcam that includes retinal image processing (fig 3.2a). Each image was captured in BMP format with a resolution of 640 X 480 pixels.

*ii) Pre-Processing:*

It is aimed at improving image data which enhances some important image features for further processing. Here, the size of the image is reduced by a fixed pixel value [6]. Salt-and-pepper noise presents itself as white and black pixels which occur sparsely (fig.3.2b). Median Filter can eliminate salt and pepper noise without significantly reducing the sharpness of an image (fig.3.2c).

*iii) Image Enhancement*

The RGB model's green channel provides the greatest contrast between the vessels and the background while the red and blue channels appear to be noisier. Here the green channel image is enhanced using contrast limited adaptive histogram equalization. CLAHE method is a common spatial domain enhancement technique [11]. This method operates small regions, called "tiles," rather than the whole image (fig3.2d). It was originally developed to enhance the low contrast medical images efficiently.

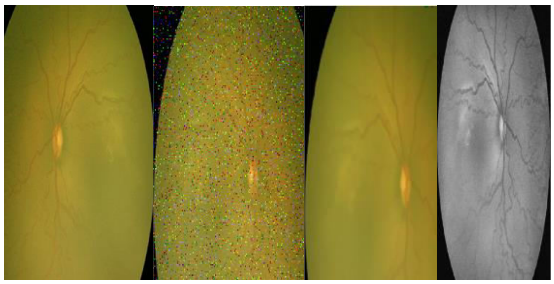

Fig. a b c d

Fig. 3.2 - Acquired, preprocessed,Enhanced image

*B) Phase II*

In phase II, feature detection, segmentation is discussed (fig.3.3).

*iv) Feature Detection:*

The Scale-invariant Transform function (SIFT) is a computer vision feature recognition algorithm for detecting and defining local features in images. Local features refer to an image pattern or distinct structure, such as a point, edge, or small patch image. Typically they are associated with an image patch that varies by texture, color, or intensity from its immediate surroundings (fig.3.3a). Local features like blobs, corners, and edge pixels are examples. An important aspect of this method is that it produces large numbers of features that cover the entire scale and position of the image.

*v) Segmentation:*

The segmentation of image is defined as the process of dividing a digital image into multiple segments. It is used primarily for identifying points and boundaries in images. Here Principal Component Analysis (PCA) is used to convert RGB to gray image. It is a well-known standard linear technique for reducing data dimension by projecting the data into orthogonal subspaces leading to maximum data spread. Further the image is enhanced by using CLAHE focusing on 64 bit pixel. Average filtering is a method of smoothing images by reducing the amount of difference in intensity between adjacent pixels [6]. Take the average filtered image and enhanced image variation to eliminate abnormalities such as optical disks, macula, and larger structures (fig. 3.3b).

One of the classification-based methods in image segmentation is the ISODATA (Iterative Self-Organizing Data Analysis Technique) method. It is an unsupervised algorithm for the Segmentation. It is a global threshold image which separates the foreground and background image by the threshold (fig. 3.3c). Here thresholding is used for blood vessel extraction.

The Expectation-Maximization (EM) algorithm is used to evaluate the parameters of maximum likelihood in the feature space [9]. Here is where the EM algorithm used to find parameters of maximum probability. The missing data is the cluster to which the points belong in the feature space (fig. 3.3d). The values are calculated to fill in for the incomplete data, then measure the estimates of the maximum likelihood parameter using this data and perform the same procedure until an acceptable stop criterion is reached.

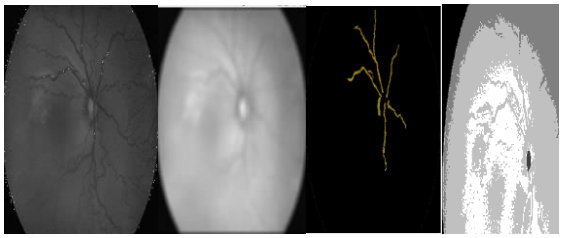

Fig. a b c d

Fig .3.3 – Feature detected and segmented image

C) Phase III

Phase III explains about feature extraction and classification

vi) *Feature Extraction*:

Feature Extraction is a form of reduction in dimensionality that essentially represents interesting parts of images as a compact vector. Various forms of features are present in an image such as color-based feature, shape feature, histogram and texture feature, chromatic feature. Statistical features, texture features and shape-based features have been taken into consideration in our project.

*Texture Feature:* Texture interpretation applies to the characterization of regions in an image by the nature of their texture. A gray level co-occurrence matrix (GLCM) tabulates how often different combination of gray level pixel occur in an image [13]. The goal is to assign unknown sample image in one set of known texture feature. It derives statistical technique for feature extraction like Correlation, Homogeneity, Entropy and Energy.

*Statistical feature*: Statistics is the research of the compilation, arrangement, examination, and interpretation of data. It deals with all facets of this, including the preparation of data collection in terms of the nature of surveys and studies. Statistics is a method that follows the concepts of statistics. The features are mean, variance and standard deviation.

*Shape Feature:* Shape is an essential basic function used to characterize the nature of the pictures. It is categorized as region based and boundary-based feature. Extract the shape-based features from the segmented optic disk. The features are area, perimeter, centroid, eccentricity, roundness, equiv diameter etc.

| stage | Case | Eye | Statistical (S) | Texture (T) | Shape (S) | Mean of STS |
|---|---|---|---|---|---|---|
| 1 | 1 | LE | 0.0256 | 0.05339 | 111.2802 | 37.2799 |
| | | RE | 0.0679 | 0.8948 | 26.9937 | 9.3188 |
| | 2 | LE | 0.01963 | 1.3703 | 11.8548 | 4.4738 |
| | | RE | 0.1089 | 0.9247 | 34.6881 | 11.9081 |
| | 3 | LE | 0.0397 | 0.6411 | 91.7792 | 30.8200 |
| | | RE | 0.0251 | 0.5261 | 69.1881 | 23.2464 |
| | 4 | LE | 0.0964 | 0.7137 | 49.8499 | 16.8867 |
| | | RE | 0.0286 | 0.6224 | 19.9173 | 6.8561 |
| | 5 | LE | 0.0274 | 0.5460 | 28.5214 | 9.6983 |
| | | RE | 0.0265 | 0.5338 | 27.8917 | 9.4840 |
| 2 | 1 | LE | 0.0334 | 0.5874 | 10.854 | 3.8252 |
| | | RE | 0.0995 | 0.6791 | 33.1881 | 11.3223 |
| | 2 | LE | 0.0253 | 0.5341 | 117.0342 | 39.1979 |
| | | RE | 0.0321 | 0.5827 | 31.9937 | 10.8695 |
| | 3 | LE | 0.1087 | 0.7114 | 28.6881 | 9.8361 |
| | | RE | 0.0658 | 0.8392 | 33.5214 | 11.4755 |
| | 4 | LE | 0.0243 | 0.5320 | 123.0204 | 41.1922 |
| | | RE | 0.1371 | 0.8299 | 22.5214 | 7.8295 |
| | 5 | LE | 0.0669 | 0.8399 | 63.4507 | 21.4525 |
| | | RE | 0.1070 | 0.7023 | 11.6881 | 4.1658 |
| 3 | 1 | LE | 0.0143 | 0.5157 | 31.6881 | 10.7394 |
| | | RE | 0.0162 | 0.5191 | 55.2797 | 18.6050 |
| | 2 | LE | 0.0174 | 0.5222 | 78.5541 | 26.3646 |
| | | RE | 0.2357 | 1.2291 | 17.8547 | 6.4394 |
| | 3 | LE | 0.1240 | 0.8891 | 39.1881 | 13.4004 |
| | | RE | 0.1602 | 1.2804 | 26.1881 | 9.2096 |
| | 4 | LE | 0.0180 | 0.5272 | 86.6154 | 29.0535 |
| | | RE | 0.1345 | 0.8401 | 29.9937 | 10.3228 |
| | 5 | LE | 0.1218 | 1.0981 | 41.0761 | 14.0987 |
| NORMAL | 1 | LE | 0.1233 | 0.9745 | 11.0214 | 4.0398 |
| | | RE | 0.0225 | 0.5335 | 41.8917 | 14.1492 |
| | 2 | LE | 0.0665 | 0.6781 | 523.5645 | 174.7364 |
| | | RE | 0.1109 | 0.9630 | 34.5440 | 11.8727 |

vii) Classification:

ANFIS is a hybrid system that combines the artificial neural network's thinking skills with Fuzzy Logic's excellent knowledge representation and inference capabilities that have the ability to self-modify its membership function to achieve a desired efficiency. Usually, it is a multi-layer feed forward network where each node performs a particular feature on incoming signals or node operation. Using ANFIS, the features extracted from the retinal images are classified. The statistical, shape, and texture-based features are fed as input. The output of classification is 1 for stage 1, 2 for stage 2, 3 for stage 3, 4 for normal and 5 for plus disease. The architecture of ANFIS is shown below (fig.3.4)

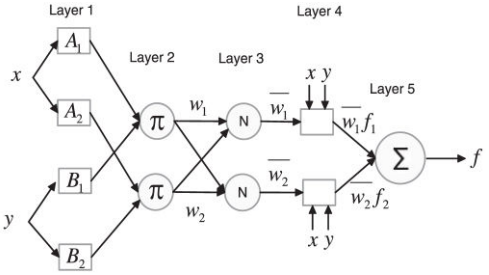


Fig. 3.4- Architecture of ANFIS

## IV. RESULT

At stages 3, 4 and 5, ROP is more prominent. The proposed method applies here only to the normal, stage 1, stage 2, stage 3, and plus disease images. Features of the texture include contrast, homogeneity, entropy, and energy. The mean, standard deviation and variance are the statistical features. Shape features include area, perimeter, equiv diameter, eccentricity are calculated. Mean of statistical texture, shape and then mean of all three features together are calculated. These features were eventually fed into MAT LAB's neural network toolbox to classify into the five stages: stage 1, stage 2, stage 3, normal and plus disease. Out of 70 images, 4 normal data, 10 data of stage 1 and 2, 9 data of stage 3 and 5 plus disease data are used for training. Remaining is used for testing and validation. The ANFIS classifier gives an accuracy of 97.368 %, Sensitivity as 98% and specificity as 99.4% in classification of the five stages. Parameter values are described in following table.

| stage | Case | Eye | Statistical (S) | Texture(T) | Shape (S) | Mean of STS |
|---|---|---|---|---|---|---|
| PLUS DISEASE | 1 | LE | 0.0838 | 0.7208 | 944.8027 | 315.204 |
| | | RE | 0.1555 | 1.5423 | 31.8270 | 11.1570 |
| | 2 | LE | 0.0801 | 0.6961 | 9.8917 | 3.5560 |
| | | RE | 0.1294 | 1.1540 | 27.7251 | 9.6695 |
| | 3 | LE | 0.1192 | 1.3072 | 6.1744 | 392.745 |

Table shows the parameter values of plus disease

## V. CONCLUSION

In order to assist in the diagnosis of the disease, a controlled classification method using ANFIS was proposed to classify the stages of ROP. The method was tested on Ret Cam wide-field images at 120 degree and the result obtained is promising. The mathematical, shape and texture parameters that were used are the key parameters that are helpful in identifying the disease stages. Compared with other algorithm like BPN and bag of words [1], [13] ANFIS classification has high accuracy and better segmentation methods can be developed in the future to remove the proliferated vessels and disconnected sections of the retina, as well as better classification methods.

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## VII. REFERENCE

[1] Mr.Amey Samant, Sushma Kadge "An Automatic approach for Detection of Retinal Disease in Premature Babies" Vishwarkarma Journal of Engineering Research- volume 1 Issue 2, 2017

[2] Dr.S.Prabakar, K.Porkumaran, Parag K. Shah and V.Narendran "Implementation of Stochastic approach for Vessel and Ridge Studies in Retinopathy of Prematurity" Current Science, VOL.112, Bo.3,2017

[3] Amanda E. Kiley, David K.Wallace, Sharon F. Freedma, and Zheen Zhao "Computer Assisted Measurement of Retinal vascular width and Tortuosity in Retinopathy of Prematurity" Arch Ophthalmol.2010; 128(7):847-852

[4] Priya Rani, Elagiri Ramalingam , Rajkumar et al "Detection of Retinopathy of Prematurity using Multiple Instance Learning" International Conferences on Advances in Computing, Communication and Informatics (ICACCI)

[5] Deepthi Badarinath , Chaitra S et al "Study of Clinical Staging and Classification of Retinal Images

for Retinopathy of Prematurity Screening" International Joint Conference on Neural Network 2018

[6] Sonal Wilson Pillai, L.T. Herlin "Retinal Blood Vessel Extraction using ISODATA clustering and Morphological operation" International Journal of Engineering Research and Technology (IJERT) Volume. 6, Issue 4 2017

[7] N.B.Prakash, D.Selvathi "Segmentation of retinal blood vessels in color fundus images using ANFIS classifier", International Journal of Biomedical Engineering and Technology, Vol. 24, No. 4, 2017

[8] Jianhua Liu, Yanling Shi "Image Feature Extraction Method Based on Shape Characteristics and Its Application in Medical Image Analysis" Springer-Verlag Berlin Heidelberg 2011

[9] Serge Belongie, Chad Carson et al "Color and Texture based Image Segmentation using EM and its application to
Content based Image Retrieval" IEEE- Sixth International Conference on Computer Vision 2006

[10] Parijat Chandra, Anil Gangwe et al "Clinical Applications in Retinopathy of Prematurity" DOS Times-
Vol.19, No.8 2014

[11] Brij Bhan Singh, Shailendra Patel "Efficient Medical Image Enhancement using CLAHE Enhancement and Wavelet Fusion" International Journal of Computer Application Volume 167 – No.5, June 2017

[12] Glen A.Gole, Anna L.Ells, Xiemena Ka et al "International classification of ROP" Jamma ophthalmology 2005

[13] Priya Rani and E.R. Rajkumar "Classification of retinopathy of prematurity using back propagation neural network" International Journal Biomedical Engineering and Technology, Vol. 22, No. 4, 2016

[14] Yifan Wang and Yuanyuan et al "Retinopathy of prematurity" National eye institute 2019

[15] K. L. Nisha, G. Sreelekha, P.S. Sathidevi, Poornima Mohanachandran et al "A computer-aided diagnosis system for plus disease in retinopathy of prematurity with structure adaptive segmentation and vessel based features" Elsevier limited 2019