International Journal of Engineering Research & Management Technology

ISSN: 2348-4039

November- 2014 Volume 1, Issue-6

Email: editor@ijermt.org www.ijermt.org

Knowledge-Based Inference System for Biometrics "Retinal Vascular Pattern Recognition Using ANFIS"

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ABSTRACT—
Biometric is the most important trait for identifying the human with authentication and authorization. Biometric identification system is the only way of avoiding forgery because of its significant aspects. The pattern recognition of any biometric image is an essential process in image processing for its uniqueness in accordance with the level of its usage. In this article, the GLCM, which are focused on texture features and WT, which focused on energy features used for extracting features from the funds image along with its enhancement by CLAHE techniques? An innovative optimization algorithm is designed for the functionalities of this proposed system. Through the aspects of this system, the performance Evaluation Metrics with Receiver Operating Characteristics (ROC) such as True Positive (TP), False Positive (FP), False Negative (FN), True Negative (TN), Positive Predictive Value (PPV), Negative Predictive Value (NPV), Sensitivity (Se), Specificity (Sp) and Accuracy (Acc) are measured. These retinal vascular structured pattern recognition processes are implemented using ANFIS.

Key Words — Biometric Image, CLAHE, Performance Evaluation Metrics, ROC, ANFIS

I. INTRODUCTION

The Greek term 'Biometric' is the combination of two words like 'Bios' and 'Matron' with the meaning 'Life' and 'Measure' respectively. The characteristics of Biometric can't be lost, theft and forgotten. It is available at anytime with the human being can be used anywhere for their own usage [7,8]. The significance of the Biometric is it's uniqueness and stability [9]. The various image processing systems and its implementation play important roles in different fields. The human entry into the working place or interaction with machine can be restricted through the authentication and authorization particularly for the security. It is for obtaining the accuracy in the performance and time-complexity based processes. Various Technical Systemic processes, approaches, methodologies, techniques are used in various articles related to retinal images published recently. The Systems such as Support Vector Machine (SVM), Linear Discriminate Analysis (LDA), Artificial Neural Networks (ANN) and Adaptive Neuro-Fuzzy Inference System (ANFIS) are mostly used for implementing Image-based tasks. In this article the Back Propagation Technique is applied on ANN. The efficient results of the proposed processes are produced by the system named as ANFIS1 with Grid Partitioning Technique and ANFIS2 with Subtractive Clustering Technique [14]. The Retinal Images, which are extracted from Original Retinal Fundus Image DB Set-1 and Original Retinal Fundus Image DB Set-2 have been processed by using all these systemic techniques for obtaining the Percentage of Average Classification Error, which is the core value for identifying the efficiency of a System among multiple systems [3].

II. SYSTEMIC PROCESSING

This article focuses a sequential systemic processing as follows: (i) Inputting the fundus image (ii) Extracting the components as Red channeled components and Green channeled components (iii) Enhancing the image (iv)

Clearing the noise (v) Segmenting the image (vi) Optimizing the features of image (vii) Evaluating the performance and metrics.

The overall sequential systemic processes followed in this proposed system are as follows:

Step 1: Image Acquisition
(Input Image: Color Retinal Fundus Image)

Step 2: Channel Extraction of an image
(Red Channel-based Image & Green Channel-based Image)

Step 3: Image Enhancement (using CLAHE)

Step 4: Retinal Optical Disk Removal.

Step 5: Noise Removal from the Image.
(Using Median Filtering)

Step 6: Image Border Removal
(Morphological Operation)

Step 7: Edge Detection with AdaptiveThreshold Value.

Step 8: Defining the structural element for image Segmentation.

Step 9: Segmentation by taking Difference between Erosion and Dilation processed images. (By Morphological Operation)

Step 10: Calculating Area of Border of the Image.

Step 11: Removing Border of an image.

Step 12: Alternate Processes:
(i) Extraction of Complement-based Retinal Blood Vessels.
(ii) Binary conversion on image
(Image to Black and White)
(iii) Image Segmentation
(MATLAB: Erosion and Dilation processes)
(iv) Difference between Erosion and Dilation processed images.

Step 13: Performance of AND operation.

Step 14: Output Image: Retinal Blood Vessels with Fine Fibers and without Border

Step 15: Calculating Area of Blood Vessels.

Step 16: Identification process on Output Image.

III. IMAGE PROCESSING

The two main processes such as (i) Preprocessing (ii) Enhancement.

(i) Preprocessing:

The retinal fundus image source is inputted for extracting it's component in respect to Red Color Channeled components and Green Color Channeled components.

(ii) Enhancement:

The extracted components of the image is enhanced using Contrast Limited Adaptive Histogram Equalization (CLAHE).

CLAHE:

This algorithm is an improved version of Adaptive Histogram Equalization (AHE), which is developed for processing the medical images with the further enhancement of low-contrast images. The processes such as (i) Partitioning of Images into the Contextual Regions. (ii) Applying Histogram Equalization to portioned Contextual Region. The full gray spectrum distributes the gray values to the hidden features of the image as visible [1].

Various Adaptive Contrast Limited Adaptive Histogram Equalization (Adaptive CLAHE) is used to sharpen the field edges of the image.

CLAHE is used for enhancing the extracted image. J = adapthisteq(I) enhances the contrast of the grayscale image I by transforming the values using CLAHE. CLAHE operates on small regions in the image, called tiles, rather than the entire image. Each tile's contrast is enhanced, so that the histogram of the output region approximately matches the histogram specified by the 'Distribution' parameter. The neighboring tiles are then combined using bilinear interpolation to eliminate artificially induced boundaries. The contrast, especially in homogeneous areas, can be limited to avoid amplifying any noise that might be present in the image [6].

Sequential Noise Clearing Process: The Median Filtering Technique is used for removing the existing noise in the image. It is mandatory to remove some kind of noise to involve some noiseless and high signaled image for processing the image.

The median can be used as a measure of location when a distribution is skewed, when end-values are not known, or when one requires reduced importance to be attached to outliers, e.g., because they may be measurement errors.

Formula: MEDIAN = { (n + 1) / 2 }th item;

n = number of values.

The noiseless fine fibers of retinal blood vessels are produced for the authentic processes [5].

The combination of CLAHE, Median Filtering and Edge Sharpening by Adaptive CLAHE are applied for reducing noise of the image. This process is usually known as 'Sequential Processing'.

IV. IMAGE ANALYSIS

Image Segmentation is an important process of image analysis in the domain of image processing. The Mathematical Morphological processes are used for segmenting the image in the following way [5,15].

The area of the Blood Vessels are calculated by using the MATLAB process. The following codes are used for it.

```
for (x=1; x<=500; x++)
    for (y=1; y<=750; y++)
        if (a_bloodvessel[x,y] ==1) then
                area=area+1.
```

V. IMAGE CLASSIFICATION

(i) Feature Extraction:

The features of an image is extracted using ANFIS algorithm.

ANFIS:

Adaptive Neuro Fuzzy Inference System (ANFIS), which is based on Takagi-Sugeno Fuzzy Inference System was developed in the early 1990s [10,11]. It is a Neural Network based Fuzzy Inference System, which integrates both the principles of Neural Networks and Fuzzy Logic. The fuzzy IF-THEN rules with learning capability helps the inference system to go for performing the appropriate nonlinear functions [12]. So, ANFIS is known as a 'Universal Estimator' [4,13].

ANFIS with Subtractive Clustering:

It is a fast, one-pass algorithm to estimate the total number of clusters and the cluster centers in a set of data. This clustering technique is to avoid the rule-base explosion problem. The subtractive clustering equation is used to calculate the number of cluster and the cluster center in a set of data by assuming that each data point is a potential cluster center and calculate some potential measures [4].

(ii) Feature Ranking and Selection:

Feature Selection:

Gray Level Co-occurrence Matrix (GLCM):

The GLCM technique consists of 23 features such as Autocorrelation, Contrast, Correlation, Cluster Prominence, Cluster Shade, Dissimilarity, Energy, Entropy, Homogeneity, Homogeneity, Maximum probability, Sum of squares, Sum average, Sum variance, Sum entropy, Difference variance, Difference entropy, Information measure of correlation1, Information measure of correlation2, Inverse difference (INV), Inverse difference normalized (INN), Inverse difference moment normalized. Out of them, the features such as Autocorrelation, Sum Entropy, Inverse-Difference Normalization (INN), Inverse-Difference Moment Normalized and Homogeneity are selected as the top high rated features for our image processing [2].

Wavelet Transformation (WT):

The WT technique consists of 53 features such as haar, db1, db2, db3, db4, db5, db6, db7, db8, db9, sym2, sym3, sym4, sym5, sym6, sym7, sym8, coif1, coif2, coif3, coif4, coif5, bior1.1, bior1.3, bior1.5, bior2.2, bior2.4, bior2.6, bior2.8, bior3.1, bior3.3, bior3.5, bior3.7, bior3.9, bior4.4, bior5.5, bior6.8, rbio1.1, rbio1.3, rbio1.5, rbio2.2, rbio2.4, rbio2.6, rbio2.8, rbio3.1, rbio3.3, rbio3.7, rbio3.9, rbio4.4, rbio5.5, rbio6.8, dmey. Out of them, rbio1.1, rbio1.3, bior3.7, bior1.3 and coif1 are considered for the image processing of our proposed system [2].

Feature Ranking (GLCM and WT):

The five out of twenty three features selected from GLCM and five out of fifty three features from WT are selected. Totally ten out of seventy six combined features of both GLCM and WT are considered. The selected ten features are again ranked to select the five top-ranked features for the enhancement of the image to be processed in our proposed system. The top-ranked features named Autocorrelation, Homogeneity, Sum Entropy, bior1.3 and rbio1.1 are selected from both GLCM and WT are considered [2].

The following Equation is used for feature ranking and selection using the features of GLCM and WT.

$$Y = \sum_{F=1}^{M} \left[\sum_{I=1}^{N} \left[\begin{array}{l} [(\alpha = \min(F(I))), \\ \quad (\beta = \max(F(I))), \\ \quad (\gamma = \alpha \sim \beta) \,\forall\, I1{:}N \textit{ and } F1{:}M\,] \end{array} \right] \right] \quad \text{-- Eq. (1)}$$

where, 'F' indicates 'Feature' of either 'GLCM' or 'WT' and 'I' indicates 'Image (Fundes Image Source) [2].

VI. RESULTS AND DISCUSSIONS

The 10-fold cross validation technique is followed to divide the images of the database.
The Database, which is used in our proposed system consists of 1050 retinal fundus images.
The images of the database are processed in the following manner.

Step 1: The main database is divided into 10 sets of databases such as DB01, DB02,……,DB10.

Step 2: The total number of images 'n' are classified into 10 data sets ie. n/10. Hence, each data set consists of 105 images.

Step 3: Each data set is assigned to each Database.

Step 4: Among the 10 data sets, 9 data sets are considered as 'Training Data Sets' and 1 data set is considered as 'Testing Data Set'.

Step 5: The mean accuracy value is obtained at the end of every data set is processed.

Step 6: This process is repeated for 10 times because of the total number of data sets in the form of 10 databases.

The following table represents the resultants values obtained by implementing the 10-fold cross validation techniques. This has produced all the performance measures such as True Positive, False Positive, False Negative, True Negative, Positive Predictive Value, Negative Predictive Value, Sensitivity, Specificity and Accuracy.

TABLE 1 DB with Performance Measures

Database	TP	FP	FN	TN	PPV(%)	NPV(%)	Sensitivity(%)	Specificity(%)	Accuracy(%)
DB01	64	1	0	40	98.5	100	100	97.6	99.0
DB02	67	1	3	34	98.5	91.9	98.7	97.1	96.2
DB03	69	1	2	33	98.6	94.3	97.2	97.1	97.1
DB04	64	1	2	38	98.5	95.0	97.0	97.4	97.1
DB05	65	0	1	39	100	97.5	98.5	100	99.0
DB06	75	0	2	28	100	93.3	97.4	100	98.1
DB07	65	2	3	35	97.0	92.1	95.6	94.6	95.2
DB08	72	2	2	29	97.3	93.5	97.3	93.5	96.2
DB09	59	8	0	38	88.1	100	100	82.6	92.4
DB10	73	2	0	30	97.3	100	100	93.8	98.1
Average	67.3	1.8	1.5	34.4	97.38	95.76	98.17	95.37	96.84

TABLE 2 DB with Performance Measures

Particulars	Value of Accuracy	Database
Lalli et al [1]	≅ 99.5%	Own Database
Lalli et al [2]	≅ 99.5%	Diaret DB0 and DB1
Lalli et al [3]	≅ 99%	Diaret DB0 and DB1
Lalli et al [4]	98.75%	Diaret DB0 and DB1
Lalli et al [5]	≅ 99%	Diaret DB0 and DB1
Proposed System $Y = \sum_{F=1}^{M} \left[\sum_{I=1}^{N} \left[\begin{matrix} [(\alpha = \min(F(I))), \\ (\beta = \max(F(I))), \\ (\gamma = \alpha \sim \beta) \forall I1{:}N \text{ and } F1{:}M] \end{matrix} \right] \right]$	96.84%	Stare + Drive + Messidor + Diaret DB0 and DB1 [10-Fold Cross Validation]

ROC Curve with purposes:

You may want to inspect the classifier performance more closely, for example, by plotting a Receiver Operating Characteristic (ROC) curve. By definition, a ROC curve [7,8] shows true positive rate versus false positive rate (equivalently, sensitivity versus 1–specificity) for different thresholds of the classifier output. You can use it, for example, to find the threshold that maximizes the classification accuracy or to assess, in more broad terms, how the classifier performs in the regions of high sensitivity and high specificity.

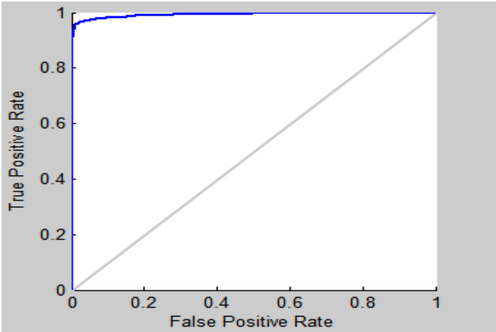
The confusion matrix, C, is defined as

$$\begin{pmatrix} TP & FN \\ FP & TN \end{pmatrix} \qquad \text{-- Eq. (2)}$$

Where,

- TP stands for "True Positive".
- FN stands for "False Negative".
- FP stands for "False Positive".
- TN stands for "True Negative".

The function then applies the scales as multiplicative factors to the counts from the corresponding class: perfcurve multiplies counts from the positive class by scale(P) and counts from the negative class by scale(N). Consider, for example, computation of positive predictive value, PPV = TP/(TP+FP).



Area Under Convergence (AUC): 0.0320

Figure 1. ROC Systemic Processes

The above Figure 1, the X-axis represents the False Positive Rate and the Y-axis represents the True Positive Rate.

VII. CONCLUSION

The pattern recognition of retinal vascular structure is a significant process in accordance with the concern of the biometric traits for identifying the human in an effective manner to determine the uniqueness, authentication and authorization. Recognizing the pattern of the biometric helps this process a lucrative way. The innovative optimization algorithm performs the operations to measure the performance metrics through the aspects of GLCM, WT concern with the feature extraction from Retinal Vascular Structures using ANFIS. Hence, the resultant values such as True Positive (TP)=67.3, False Positive (FP)=1.8, False Negative (FN)=1.5, True Negative (TN)=34.4, Positive Probability Value (PPV)=97.38, Negative Probability Value (NPV)=95.76, Sensitivity (Se)=98.17, Specificity (Sp)=95.37 and Accuracy (Acc)=96.84.

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Ms. G. Lalli born on 27-06-1977 has completed M.C.A., M.Phil. and pursuing Ph.D. She is currently working as an Assistant Professor (Selection Grade-II) with 12 years of experience in the Department of Computer Applications, Erode Sengunthar Engineering College, Erode. She has published 2 Research Papers in International Journals. She has presented 12 papers in various International Level Conferences and 7 papers in various National Level Technical Conferences organized by various esteemed Educational as well as Technical Institutions and Research Centres. She has attended various Technical and Development programmes such as Technical Seminars, Workshops, Faculty Development programme, Personality Development Programmes, etc.,. She has submitted 5 projects for various competitions and sponsorship. Her project entitled 'Ballot Automation using Satellite Links and Biometric Systems' has achieved the Cash Prize and Shield in TECH TOP' 08, which is a National Level Project Competition. The Projects guided by her entitled "Vehicle Tracking System" got sponsorship from ICTACT, India and "Automatic EB Billing System" has won the 'Best Project Award' in the International Project Exhibition cum Competition during 2012 organized by Stella Maris College, India. She is '**Senthamizh Thilagam'** awardee by Tamizhayya Palkalaikazhagam for the 1st Place won in the State-level Inter-Collegiate Essay Writing Competition. **'Silver Medalist'** in the Inter-District School level Hand Writing Competition. Got 2nd Place in the Long-jump Inter-District Sports. 'Cash Prize' and 'Shield' for Centum Result in Maths and higher Percentage in SSLC Public Exam.

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