

# Unimodal Biometric Based Security Application by Exploiting Retina

T.S. Sasikala , K. Siva Sankar

**Abstract:** *Biometrics based security is one of the current research trends. Though there are several prominent biometrics, retina is one of the biometrics that is literally difficult to alter or duplicate. However, the retinal based biometric systems are scarce in the existing literature. Hence, this article presents a unimodal biometric system, which relies on the retina of the human eye. This work accepts the retinal images from the DRIVE and VARIA datasets and the images are pre-processed. The geometrical and textural features are then extracted from the retinal images to build the feature vector. The feature vectors are stored in the database. In the testing phase, the retinal image is collected from the user and the same processes such as image pre-processing, feature extraction are performed and the feature vector is built. This feature vector is compared against the feature vector in the database by means of the similarity measure. The user is given access when a perfect match is encountered.*

**Keywords:** *Biometrics, retina, user recognition.*

## I. INTRODUCTION

A biometric system extracts the physiological or mannerism based features from the intended individual, based on which the system decides whether to give access permission or denial. There are several biometrics, which are utilized for ensuring security to any sensitive system. Some of the prominent biometrics are face, voice, iris, fingerprint, palm print and so on.

In spite of the presence of numerous biometric based security applications, retinal image based biometric systems are quite rare in the literature. Retinal biometric systems are quite rare, due to its complex structure and intricate details available in it.

Retina is present in the human eyes and it is composed of a thin layer of cells behind the eyeball. The purpose of retina is to convert light to nervous signal and is achieved by photoreceptors. These converted signals are passed on to the brain. Some of the important parts of retina are optic disc, fovea and blood vessels. The arrangement of blood vessels is unique for every individual and with this arrangement, the individual can be identified.

Based on this nature of retina, the humans can easily be differentiated and the main advantage of retina based

security system is that retinal pattern cannot be impersonated by any means. Besides this, the retinal pattern is considered to be so unique than other biometrics.

Additionally, retina based security systems are very scarce in literature, when compared to other biometrical systems. Understanding the potential and scarcity of retinal recognition system, this chapter intends to present a retinal biometric based security application that provides or denies access to the users. The proposed approach consists of two main processes, which are conscription and verification.

In the conscription phase, the users are captured with the retinal pattern and the features are extracted from the retina. The system is trained with the user's retinal pattern with the help of feature vector. During the phase of verification, the system extracts the retina and matches the extracted data with the conscribed data. When the data is matched, then the user is given access else, the access is denied for the user.

The proposed retina recognition system is decomposed into three important phases, which are retinal pre-processing, feature extraction and recognition. The pre-processing activity removes the noise and improves the contrast of the retinal area. This step is followed by the extraction of features and based on the extracted features, the recognition is done. The pre-processing activity of this work involves colour transformation and edge detection.

Certain geometrical and texture features of the retina are then extracted and stored in the database. This work employs curvelet for extracting texture features from the retina image. Finally, the user recognition is performed by similarity measures to reduce the time consumption of recognition. Some of the contributions of this work are listed below.

- Retinal biometric based security applications are very limited in the existing literature. Hence, this chapter presents a novel retinal biometric based application that relies on both geometric and texture features.
- This work focuses more on feature extraction, as the retina is comprised of more intricate details. Both the geometrical and textural features are extracted to form the feature vector.
- Finally, Euclidean distance is employed as the similarity measure to perform the retina recognition.
- The performance of the proposed approach is tested in terms of accuracy, precision, recall, F-measure and time consumption analysis.

Manuscript published on 30 December 2018.

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The rest of the article is organized as follows. The related review of the unimodal biometric system is presented in section 2. The proposed unimodal biometric system based on retina is presented in section 3. The performance of the proposed approach is evaluated in section 4. The conclusions of the article are summarized in section 5.

### II. REVIEW OF LITERATURE

This section reviews the related literature with respect to unimodal biometric systems.

In [1], a retinal blood vessel segmentation based on Mathematical morphology and K-Means Clustering is proposed. Maximum response is obtained by convolving the retinal image with linear structural elements with different directions. K-Means Clustering which minimizes variance within-group is used to classify the pixels as image or background. This approach is tested on a DRIVE database and achieves 87.99% sensitivity, 97.99% Specificity and 96.25% accuracy.

The authors of [2] developed a three stage blood vessel segmentation algorithm. During first stage binary image is extracted by applying high-pass filtering to the original fingerprint image. Also extract another binary image by reconstructing the morphologically enhanced blood vessel regions. Obtain the major vessels common to both the binary images. During the second stage classify all the pixels in both the binary images using Gaussian Mixture Model (GMM). During the final stage combine the vessels and classified vessel pixels. This method gives an accuracy of 95.2% on DRIVE database and 95.15% on STAR database.

In [3], a neural network based scheme is deployed for pixel classification. Multilayer feed forward neural network with five layers are considered, among this input layer consist of seven neurons, output layer consist of one neuron and other three layers are hidden. This method gives 70.67% sensitivity, 98.01% specificity and 94.5% accuracy on DRIVE.

A morphological multi-scale enhancement methods for blood vessel segmentation is proposed in [4]. This technique used fuzzy filter and watershed transformation. Background of the retinal image is estimated by applying Multi-scale non-linear morphological opening operators with structuring elements. Normalize the contrast of the image by Subtracting the existing background from the image. Then apply fuzzy morphological operator on the normalized image with twelve linear structuring elements of nine pixels length. Filtered image is threshold to obtain vessel region and thinned to obtain approximate vessel centre lines. Finally vessel boundaries are detected by applying watershed technique on vessel center lines.

A technique that combines unique vessel centerlines detection with morphological bit plane slicing is presented in [5]. Centre lines are extracted by applying first order derivatives of a Gaussian filter in four directions. Orientation map and shape are obtained by applying morphological multi direction top-hat operation of the gray scale retinal image. Then subject the enhanced vessels to bit plane slicing. Combine these maps with the centerline for segmenting the blood vessels from the retinal image and

achieves 71.5% sensitivity, 97.7% specificity and 94.3% accuracy.

In [6], a Fast Discrete Curvelet Transform (FDCT) for contrast enhancement is proposed. Multi structure morphological transformation is applied for detecting edges of blood vessels. False edges are removed by applying morphological opening and connected adaptive component analysis is applied to obtain complete blood vessels. This method achieves 73.5% sensitivity, 97.9% Specificity and 94.6% accuracy.

In [7], a three stage process for retinal blood vessel segmentation is proposed. During first stage retinal image preprocessing is done using adaptive histogram equalization to enhance blood vessels and to separate green channels from the image. During second stage dilation and erosion operations are performed on the image with different structuring elements of radius three to detect retinal blood vessels. Finally SVM classifiers are used to segment the Blood vessels from the retinal image.

The authors of [8] presented an automated enhancement and segmentation of blood vessels. Here blood vessels are emphasized by applying morphological multidirectional top-hat transform with rotating structuring elements to the background of the retinal image. Improved multi-scale line detector is applied to produced Vessel response and final blood vessel. Also multi scale line detectors have different line response, more vessel responses are produced from longer line detectors when compared to shorter line detector. This method achieves 73.5% sensitivity, 96.9% specificity and 94.2% accuracy.

A graph based approach for delineating boundary of blood vessels is proposed in [9]. Edges of blood vessels are segmented based on the width of blood vessels and weight of vessels is used to construct graph. This method lacks in detection of clear blood vessel detection.

A supervised vessel segmentation methods for extraction of images ridges is presented in [10]. From the ridges construct various primitives in the form of line elements. Then K-nearest neighbor classifier and sequential forward feature selection are used to compute feature vectors for every pixel and classified them as vessel or background.

In [11], a method to extracts blood vessels from fundus images using a computerized technique is presented. This is a three phase process. During initial stage retinal images are enhanced using Contrast Limited Adaptive Histogram Equalization (CLAHE) and median filter. Then mean-C thresholding based segmentation is applied for extraction of blood vessels and finally isolated pixels in the segmented blood vessels are removed using morphological cleaning operations

The authors of [12] implemented blood vessel segmentation based on structure element. Apply Hessian method to the rescaled image for blood vessel segmentation. Then back sample the rescaled image to original size. Hysteresis thresholding method is used to take out subsequent blood vessels.

Finally blood vessels are segmented using image fusion method. In [13], vectorial tracking (pixel tracking) method using neural network to segment structure or branches of retinal blood vessels is proposed. Initial blood vessel is tracked by detecting the initial seed points and rest of the vessel pixels are tracked by measuring the continuity of blood vessel characteristics.

The authors of [14] implemented two neural network trainers and Random Forest Classifier for hierarchical retinal blood vessel segmentation process. Neural network trainer is named as convolution neural network (CNN) and is a trainable hierarchical feature extraction and RF is used as a trainable classifier for classifying vessels and non-vessels.

A retinal blood vessel segmentation first enhances the retinal image using multiple scales filtering technique based on eigenvalue analysis of the Hessian matrix is presented in [15]. After enhancing the contrast apply Otsu's thresholding iteratively, until exact blood vessels are detected.

The authors of [16] presented a novel blood vessel segmentation. After estimating the Green channel of the retinal image invert the intensity of the image and illumination is equalized. Enhance the resultant image using adaptive histogram equalizer, apply morphological open process to prune the enhanced image. Calculate the direction and magnitude of the vessel gradient using distance transform. Finally Graph cut technique is used to segment the blood vessels.

In [17], an automated segmentation of optic nerve head for diagnosis of glaucoma is proposed. By this method distance map algorithm is used to remove blood vessels, then morphological operations are combine to segment the optic disc from the blood vessels.

In [18], a method to segment optic nerve head boundary using deformable contour model. Specialized templates are used to localize the optic disk and dimensionally sensitive gradient is used to eliminate the obstruction of the vessels in the optic disk region before performing the segmentation.

An adaptive morphological operation to segment optic disk from color fundus image is presented in [19]. Formally optic disc boundary is defined using watershed transform marker and morphological erosion is used to minimize the vessel obstruction.

Motivated by these existing works, this work intends to present a unimodal biometric system based on retina.

### III. OVERVIEW OF RETINAL STRUCTURE

Retina is the psychological biometric trait which has minutiae and it is used for authentication and identification. Retinal scanning is used by several applications like Federal Bureau of Investigation (FBI), Central Intelligence Agency (CIA) and National Aeronautics and Space Administration (NASA). Retinal scanning procedure is also used in prison, ATM authentication for preventing fraud [90].

Retina is a sensory tissue that consists of multiple layers and millions of photo receptors namely rods and cones. Rods are located throughout the retina, whereas cones are concentrated in a small central area of the retina called macula. A small depression present at the center of

the macular is named as fovea, which contains only cone photo receptors.

Retina also includes blood vessels called vasculature pattern with little curvature, branches from optic disc and have tree shape. Usually, the size of retina ranges from 0.5 mm thickness with mean diameter of the blood vessels of about 250 μm and optic disc of about 2 × 1.5 mm thickness.

During 1935 simon and Goldstein discovered that every eye has a unique vasculature pattern in the retina. This vasculature pattern provides higher level of security because it cannot be easily changed or altered.

Retina has two sources of oxygen and nutrients; the retinal blood vessels and the choroid. Out of these, retinal blood vessels are unique and are mainly used for authentication. The nerve which transmits visual information from the retina to the brain is named as optic Nerve or optic Disc. Retinal blood vessel and optic disc are segmented from the retina to carry out authentication. Figure 1 shows the parts of retina and segmented parts of retina being used for authentication.

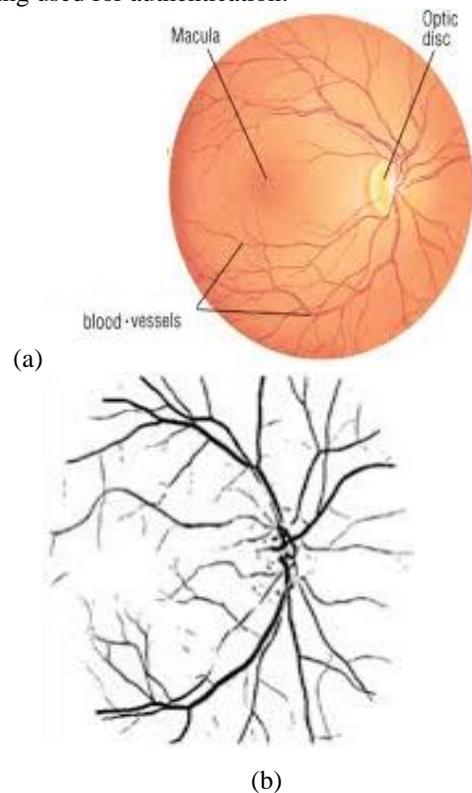


Fig.1. (a) Retinal parts (b) Sample segmented retina

Blood vessels, Optic Disc, macula and fovea are the main components of retina. Bifurcation and crossover are the unique features of the retina. Ridge ending and bifurcation are the key features extracted from retina and are named as minutiae. A single curved segment present in the blood vessel is termed as ridge and the region between two adjacent ridges are called valley.

There are several bifurcation points, which can be selected during minutiae extraction such as ending, bifurcation, crossover, island, lake and spur points from the retinal image. Hence, the overview of retinal structure is presented in this section and the proposed retinal biometric recognition system is presented in forthcoming section.

**IV. PROPOSED UNIMODAL BIOMETRIC SYSTEM BASED ON RETINA**

The main objective of this chapter is to present a reliable unimodal biometric system based on retina. The retinal images are quite unique and difficult to duplicate, such that retina alone is utilised as a biometric to analyse the performance. The main goal of any recognition system is to attain greater precision and recall rates, while consuming reasonable time period.

Greater precision rates indicate that the false negative rates of the system is minimal, whereas greater recall rates shows the false positive rates of the system is very low. A recognition system must show minimal false positive and negative rates. False positive rates of a recognition system means that the system provides access to the illegitimate users and the false negative rates of the recognition system denote that the legitimate users are denied access to the system.

The proposed unimodal biometric system based on retinal images involve three important phases, which are image pre-processing, feature extraction and recognition phases. The image pre-processing phase attempts to transform the colour of the image and enhances the information available in the retinal images.

The feature extraction phase relies on geometrical and texture based images. The feature vector is formed out of these features and the recognition is done by Euclidean distance measure. All the involved phases are described as follows. The overall flow of the work is depicted in figure 2.

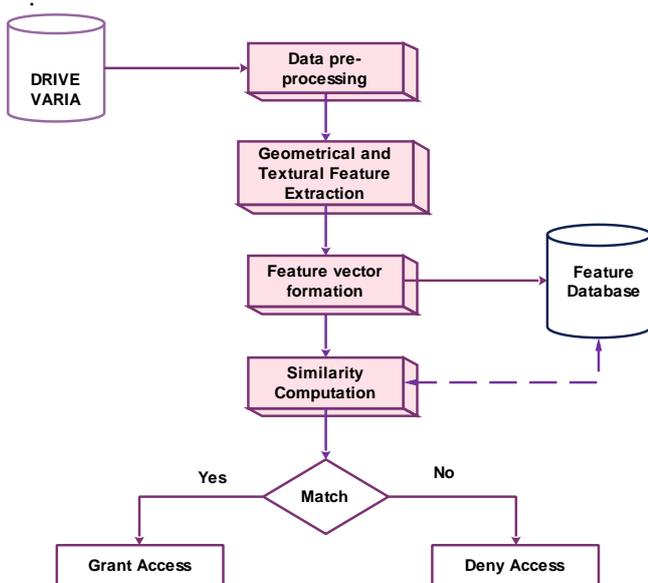


Fig.2 Overall flow of the work

A. Retinal Image Pre-processing

The retinal image pre-processing phase performs two important steps, which are color model conversion and contrast enhancement. Usually, the retinal images are based on Red, Green, Blue (RGB) model, which is the most basic color model. However, RGB color model cannot ensure the uniformity and hence, YCbCr model is employed for better processing.

The YCbCr model represents the available color information in three channels which presents the brightness and two color channels with difference. Y channel indicates the brightness, Cb is computed by subtracting the blue channel (B) from the brightness channel (Y), Cr is the difference between the red channel (R) and brightness channel (Y). The Y component represents the retinal image in a better way. Some of the sample channels of a sample retinal image are presented in figure 3.

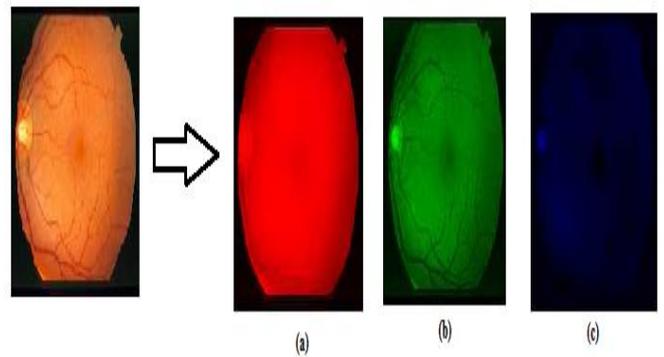


Fig.3. (a) Red (b) Green (c) Blue component of a sample retinal image

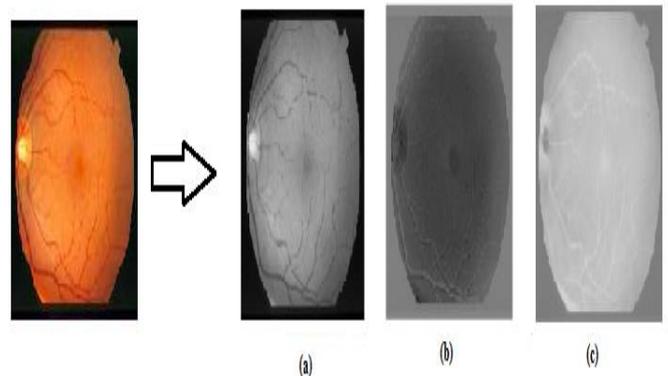
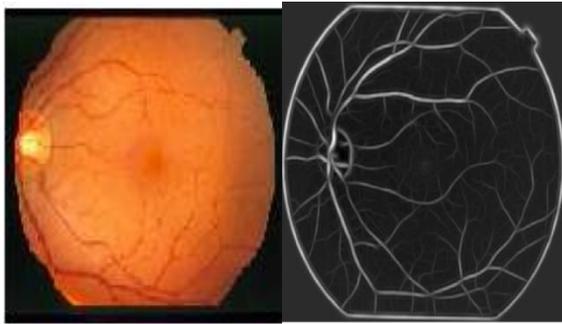


Fig.4. (a) Y (b) Cb (c) Cr component of a sample retinal image

The Y component is considered by this work for further processing. This step is followed by enhancing the blood vessels available in the retinal images. The gabor filter is utilized for enhancing the blood vessels, which paves way for detecting edges, corner and spots.





(a) (b)

**Fig.5. (a) Original image (b) Enhanced retinal image**

As soon as the retinal images are enhanced, the blood vessels are segmented, the blood vessels are detected from the retinal images by means of gabor filter. 2D gabor filters are utilized for better localization in spatial and frequency domains. The size of the gabor filter is needed to be fixed by considering the different parameters such as wavelength, bandwidth and aspect ratio.

The parameters are set in the following way. Wavelength is varied from 9 to 11 and the orientation is fixed as 0 degree. The aspect ratio and the bandwidth is fixed as 0.5 and 1 respectively. The orientation count is 24. With these inputs, the  $\sigma$  is computed by

$$\sigma = SLR \times wavelength \quad (1)$$

$$SLR = \frac{1}{\pi} \sqrt{\frac{\ln(2)}{2} \times \frac{2^b + 1}{2^b - 1}} \quad (2)$$

In the above equation,  $b$  is the bandwidth. The size of the gabor kernel is computed by

$$s = 2.5 \times \frac{\sigma}{A_r} \quad (3)$$

The value of  $s$  is rounded off with the least possible number and the kernel matrix is computed by

$$k_m = 2s + 1 \quad (4)$$

This step is followed by creating a mask of size  $-s$  to  $s$ . The 2D gabor filter is formed as follows.

$$g_f = p \times e^{(-q \times (x a^2 + A r^2 \times y a^2))} * \cos_{f_n} \quad (5)$$

where

$$f = \frac{2\pi}{wavelength} \quad (6)$$

$$q = \frac{1}{2 \times \sigma^2} \quad (7)$$

$$p = \frac{q}{\pi} \quad (8)$$

$$x a = x \cos \theta + y \sin \theta \quad (9)$$

$$y a = -x \sin \theta + y \cos \theta \quad (10)$$

$$\cos_{f_n} = \cos((f \times x a) - \pi) \quad (11)$$

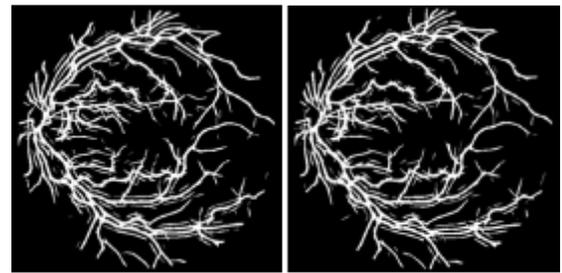
The next step is to obtain the positive and negative values to perform normalization, which is done by

$$pst = summation(+ve \text{ values in kernel}) \quad (12)$$

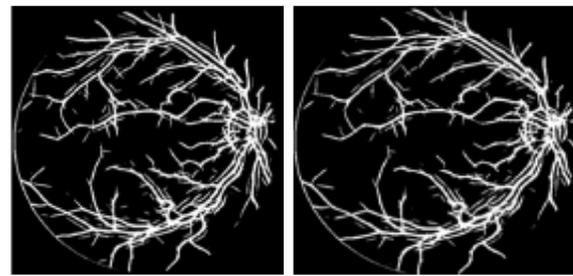
$$ngt = abs(summation(-ve \text{ values in kernel}))$$

(13)

All the positive and negative values of the kernel are then divided by the  $pst$  and  $ngt$  values respectively. The image is convolved by means of the filter kernel and this process is repeated for 24 iterations. In all the iterations, the greatest outcome is obtained and the resultant image is formed. This process is carried out by varying the wavelength from 9 to 11. The sample results of detected vessels in the retinal image are presented in figure 6.



(a) (b)



(c) (d)

**Fig.6. Sample retinal vessel detection of (a,b) left eye (c,d) right eye**

The resultant images for all the three wavelengths may visually appear to be similar to each other. However, greater wavelengths may hide thinner blood vessels and on the other hand, least wavelengths show fake structure that resembles vessel.

Hence, the resultant images of all the three different wavelengths are collected and added together, which is used for feature extraction. The process of feature extraction is presented as follows.

### B. Geometrical and Texture Feature Extraction

This work intends to extract both geometric and texture features from the retinal images, in order to improve the recognition ability of the proposed biometric system. When the retinal blood vessels are detected, features are extracted from the retina and the blood vessels strongly indicate the bifurcation and cross points. The bifurcation and cross points are computed with respect to a point  $pt$ . Consider  $pt = 1$ , such that the connected pixels ( $N_c$ ) from  $pt$  is defined by

$$N_c^4 = \sum_{u \in R} (pt_u - pt_u pt_{u+1} pt_{u+2}) \quad (14)$$

$$N_c^8 = \sum_{u \in R} (\overline{pt}_u - \overline{pt}_u \overline{pt}_{u+1} \overline{pt}_{u+2}) \quad (15)$$

In the above equation,  $R=(1,3,5,7)$  and  $\overline{pt} = 1 - pt$ . When the value of  $N_c^4$  or  $N_c^8$  is 3, it denotes that it is a branching point. Suppose when the value is 4, then it is a crossing point. The coordinates of all the significant points are stored in the database. The texture features are extracted by means of curvelet, as presented as follows.

Curvelet is the enhanced version of ridgelet transform. The main goal of ridgelet is to detect lines and is represented by

$$RT_f(a, b, \theta) = \iint \psi_{a,b,\theta}(x, y) I(x, y) dx dy \quad (16)$$

$I(x, y)$  and  $\psi$  denote the image and the ridgelet function respectively, as denoted in eqn. (17).

$$\psi_{a,b,\theta}(x, y) = a^{-1/2} \psi\left(\frac{xcos\theta + ysin\theta - b}{a}\right) \quad (17)$$

The curvelet sub-bands of the image are established by modifying the ridgelet in various scales and orientations. The curvelet subbands are evaluated with respect to energy by the following equation.

$$E(a, \theta) = \sum_x \sum_y |Sb_{a,\theta}(x, y)| \quad (18)$$

By this way, the geometrical and texture features are extracted from the retinal images and the feature vector is formed and stored in the database for future comparison. The overall algorithm of this work is presented as follows.

As stated earlier, the retinal recognition system is classified into two classes, which are conscription and recognition. During the process of conscription, the acquired retinal images are pre-processed and enhanced. The enhanced images are passed on to the feature extraction system, which extracts the geometrical and texture features. Both these extracted features are stored in the database for future processing activity.

During the phase of recognition, the retinal image of the user is acquired and the image is performed with the earlier activities such as pre-processing, feature extraction. The so computed feature vector is matched with the feature vectors in the database. When the feature vectors match with each other, then the user is granted access to the system and vice versa.

### C. Retina Recognition

This work makes the matching process simpler by employing distance measure. Euclidean distance is utilized as the distance measure, which compares the feature vector formed from the user and the feature vector in the database. The Euclidean distance is computed as follows.

$$E_{dis} = \sqrt{\sum_{i=1}^n (U_i - DB_i)^2} \quad (19)$$

The comparison is done by the Euclidean distance and is defined as

$$com = dis_{min}(U_{fv}, DB_{fv}) \quad (20)$$

$U_{fv}$  is the feature vector formed out of the data of the user and the  $DB_{fv}$  is the feature vector in the database.  $dis_{min}$  is the least possible distance between the feature vector of the

user and the one in the database. When the feature vector matches with each other, then the access is given. As this work relies on both geometrical and textural features, the performance of the work is reasonable and is discussed in the following section.

## IV. RESULTS AND DISCUSSION

The performance of the proposed approach is analysed over the DRIVE and VARIA databases, which can be down loaded from <http://www.isi.uu.nl/Research/Databases/DRIVE/> and <http://www.varpa.es/research/biometrics.html#databases> respectively. Both these databases are publicly available. The DRIVE database consists of 40 images totally, out of which 20 images are meant for training and the remaining are for testing purposes. The VARIA database is exclusively meant for retinal authentication and the database contains 233 images, which are collected from 139 candidates. The images of both the datasets are of  $768 \times 584$  pixels.

The proposed approach is implemented in MATLAB 2013B version upon a standalone computer with i7 processor and 16GB RAM. The performance of the proposed approach is analysed in two perspectives such as by considering feature extraction techniques and existing techniques. The The performance of the proposed approach is compared in terms of accuracy, sensitivity, specificity and time consumption.

Accuracy is the most important performance metric that proves the reliability of the recognition system. The accuracy rate of the recognition system must be greater and is computed by the following equation.

$$accu = \frac{T_p + T_n}{T_p + T_n + F_p + F_n} \quad (21)$$

where the true positive, true negative, false positive and false negative rates are represented by  $T_p, T_n, F_p$  and  $F_n$  respectively. Sensitivity and specificity rates of the approach are based on the false positive and false negative rates.

The greater the false positive and false negative rates, the minimal are the sensitivity and specificity rates. The sensitivity and specificity are inversely proportional to the false negative and false positive rates.

Most of recognition approaches in the existing literature focus on attaining better accuracy rates but fail to prove reasonable sensitivity and specificity rates. The sensitivity and specificity rates are computed as follows.

$$sen = \frac{T_p}{T_p + F_n} \quad (22)$$

$$spe = \frac{T_n}{T_n + F_p} \quad (23)$$

The F-measure of a proposed approach relies on the sensitivity and specificity rates of the approach. The F-measure of the system is computed by

$$F_{msr} = \frac{2 \times sen \times spe}{sen + spe} \quad (24)$$



The F-measure is directly proportional to sensitivity and specificity rates. The greater the F-measure, the better is the performance of the recognition approach with minimal false positive and false negative rates.

#### A. Performance Analysis by Varying the Feature Extraction Techniques

Initially, this section intends to analyse the performance of the proposed approach by varying the feature extraction techniques. The potential of the combination of geometrical and textural features is justified by comparing it with the individual feature extraction techniques. The attained experimental results are presented as follows.

Results attained for DRIVE dataset			
Performance Metrics/Feature extraction techniques	Geometric al Features	Textural Features	Geometrical + Textural Features
Accuracy (%)	82	86	<b>89.6</b>
Precision (%)	76	78.3	<b>86.3</b>
Recall (%)	71.8	74.3	<b>84.2</b>
F-Measure (%)	73.84	76.24	<b>85.23</b>
Time Consumption (s)	<b>11.8</b>	21.6	32.8
Results attained for VARIA dataset			
Accuracy (%)	79	83	<b>87.9</b>
Precision (%)	72	79	<b>84.7</b>
Recall (%)	68.3	75.8	<b>81.74</b>
F-Measure (%)	70.1	78.77	<b>83.29</b>
Time Consumption (s)	<b>14.4</b>	23.6	36.2

**Table 1: Experimental Results by Varying Feature Extraction Techniques**

The experimental results prove that the combination of geometrical and textural properties perform well than when the feature extraction techniques are employed individually. The main reason is that the geometrical features consider the structural feature of the retinal image. On the other hand, texture features collect the intricate surface details of the image, which boosts up the recognition ability.

When the geometrical features alone are applied over the DRIVE dataset, the sensitivity and specificity rates are not up to the mark. The F-measure rate shown by the geometrical features is 73.84%. However, some improvement is observed on the system when the textural features are utilized and is proven by increased F-measure with 76.24%.

This work intends to analyse the performance of the system, when both the geometrical and textural features are combined together. The F-measure of the combination of geometrical and texture features is 85.23%. The average performance of the feature extraction techniques over both DRIVE and VARIA datasets are presented in table 2.

Average Results attained for DRIVE and VARIA datasets			
Performance Metrics/Feature extraction techniques	Geometrical Features	Textural Features	Geometrical + Textural Features
Accuracy (%)	80.5	84.5	<b>88.75</b>
Precision (%)	74	78.65	<b>85.5</b>
Recall (%)	70.05	75.05	<b>82.97</b>
F-Measure (%)	71.97	77.5	<b>84.26</b>
Time Consumption (s)	<b>26.1</b>	28.6	31

**Table 2: Average results of the proposed approach for DRIVE and VARIA datasets**

From the experimental analysis, it is evident that the proposed approach proves better performance when the geometrical and textural features are combined together. The main reason for the better performance is the effective utilization of the available details in the retinal image. Though the time consumption seems to be greater than the other two techniques, the F-measure and the accuracy rates are far better than the comparative techniques. Hence, the choice of the combination of geometrical and texture features is justified. The following section presents the performance analysis of the proposed approach by comparing it with the existing approaches.

#### B. Performance Comparison with Existing Approaches

This section compares the performance of the proposed approach with the existing approaches such as biometric authentication system based on geometric hashing proposed by Bhuiyan A. et al. [20], retinal feature based system proposed by Hussain A. et al. [21] and Gabor+SIFT based system proposed by Meng X. et al. [22]. The performance of all the systems are analysed in terms of sensitivity, specificity, F-measure, accuracy and time consumption rates. The experimental results are presented in the following section.

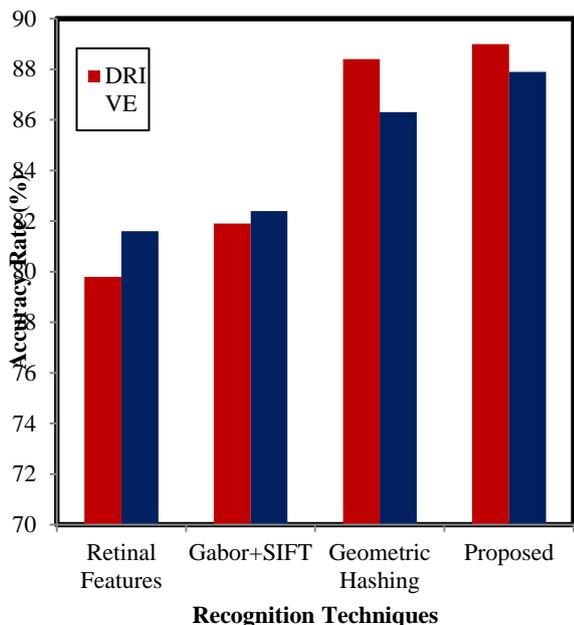


Fig.7: Accuracy rate analysis w.r.t existing approaches

Accuracy is the main performance metric of any recognition system, as the accuracy rates denote the recognition of the correct candidate. Suppose, when the recognition system shows minimal accuracy rates, then the system is not capable of recognizing the correct candidate. On analysing the performance of the proposed approach and on comparison, it is observed that the existing approaches show comparable results, yet minimal than the proposed work.

The maximum accuracy rate is attained by the proposed approach with 88.4%. The recognition system based on geometric hashing gives tough competition to the proposed approach, yet the combination of geometrical and textural features performs better. The following section presents the sensitivity and specificity rate of the retinal recognition techniques.

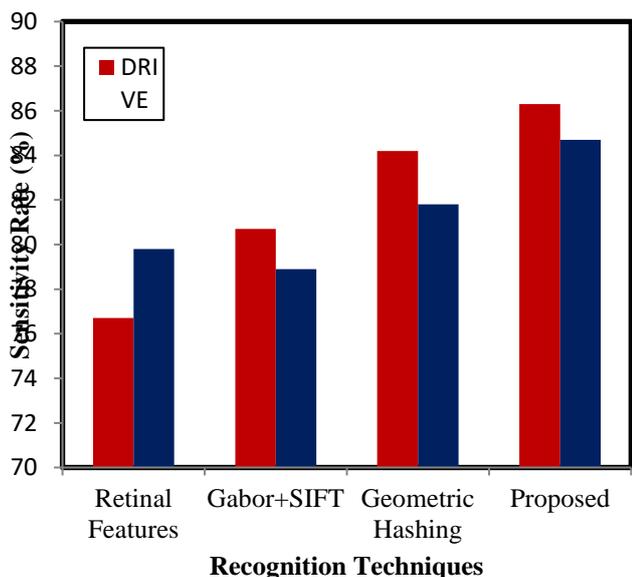


Fig.8: Sensitivity rate analysis w.r.t existing approaches

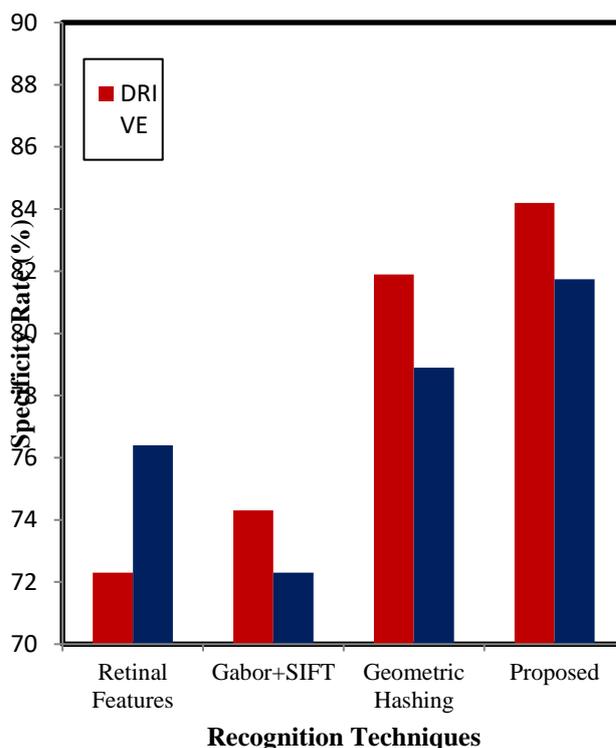


Fig.9: Specificity rate analysis w.r.t existing approaches

The sensitivity and specificity rates of the retinal recognition system indicate the reliability of the system. Maximal sensitivity and specificity rates show that the false negative and false positive rates are minimal. False negative rates mean that the legitimate users are denied access, as they are considered to be illegitimate by the retinal recognition system. Similarly, false positive rates represent that the illegitimate users are granted access by the system, as the system considers the illegitimate users as legitimate. This causes a serious security issue and hence, it is an absolute necessity for the recognition system to attain maximal sensitivity and specificity rates.

The experimental results show that the proposed approach shows better sensitivity and specificity rates. The reason behind the reasonable results is the effective pre-processing of images, which paves way for accurate detection of blood vessels and the combination of geometrical and textural features. The maximal sensitivity and specificity rates are attained by the proposed approach with 86.3 and 84.2% for DRIVE database and 84.7%, 81.74% are the sensitivity and specificity rates shown by the proposed approach for VARIA dataset. The following result shows the f-measure rate of the proposed approach.

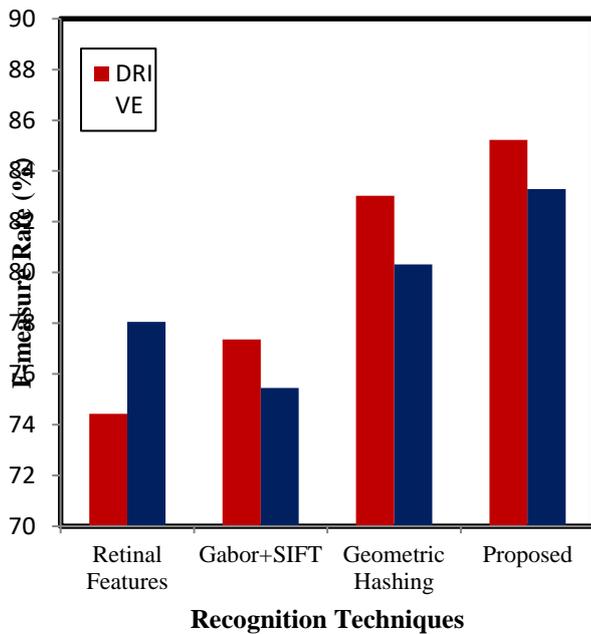


Fig.10. F-measure analysis w.r.t existing approaches

F-measure strongly relies on the sensitivity and specificity rates. Hence, it is obvious that the proposed approach shows greater F-measure rates, when compared to the existing approaches. The f-measure rate of the geometric hashing based technique proves the second best F-measure and the least f-measure rate is shown by the basic retinal feature based recognition rate system. The following section analyses the time consumption of the proposed approach and compares with the existing approaches.

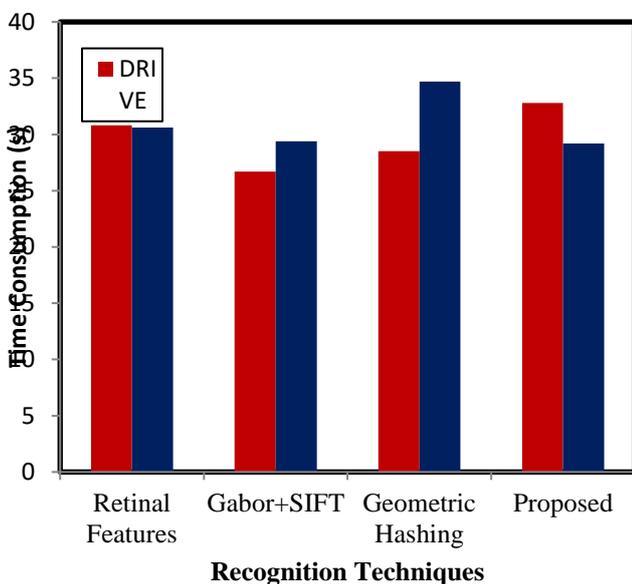


Fig.11. Time consumption analysis w.r.t existing approaches

The proposed approach proves better performance in terms of accuracy, sensitivity and specificity at the cost of time consumption. The average time consumption of the proposed approach is 31 seconds. However, the geometric hashing based approach consumes slightly more time than the proposed approach with 34.8 seconds. The least time consumption is observed with the Gabor+SIFT approach

with 28.05 seconds. Hence, the performance of the proposed approach is better with reasonable accuracy, sensitivity, specificity rates.

## V. CONCLUSION

This paper presents a unimodal biometric system that relies on retinal features. The proposed unimodal system involves minimal complexity in terms of time and computation. The retinal based unimodal biometric system is presented for ensuring the better recognition of the users, as the retina based biometric systems are quite rare in the existing literature. On the negative side, the unimodal system relies on a single biometric, which may affect the reliability of the system. In future, this article is planned to be enhanced by considering multiple biometrics.

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