Person Identification Using Parabolic Model-Based Algorithm in Color Retinal Images

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***Abstract*—Retina based person identification is perceived as the most secure and accurate authentication means among biometric systems. The superiority of this method stems from the fact that the retina is unique to every individual and it would remain the same throughout a person's life. In this paper, a novel method for person identification is presented using color retinal images. It consists of a parabolic model fitting, feature extraction and finally the matching process. A model based on parabolic fit is developed and used on the main arcade of retinal vasculature. The openness angle of the fitted parabola is calculated and named as Major Arcade angle (MAA). The parameters of the parabola and MAA are considered as features and then these undergo matching criteria for authentication. Performance of the proposed method is tested on three standard databases: DRIVE, HRF, Messidor, one local hospital database, and two authentication databases: RIDB, VARIA, and some pathological images.**

***Index Terms*—biometric system, features extraction, feature matching, main vessel arcade, parabolic model.**

I. Introduction

Now-a-days, reliable, fast and accurate person identification is an important issue for effective security control [1]. Conventional person identification systems based on possession of identity cards or information acquired from passwords is not altogether reliable [2]. Identity cards can be lost, forged or misplaced; passwords can be forgotten or compromised. Thus, a biometric person identification system is a powerful alternative means for automatically recognizing a person's identity [3]. Biometric traits used in security systems for person identification include fingerprint, hand geometry, face, voice, iris, gait, and retina. Each biometric system has its own strength and weakness and the choice depends on the application. Among all these methods, retina based person identification provides a higher level of security due to its unique and stable blood vessel pattern during one's life. Moreover, the retina lie at the back end of the eye and is not directly accessible, therefore it is very difficult to forge it [4]. A biometric authentication system is generally employed in verification and identification mode based on the application environment. The vital difference between these two modes of operation is in the testing phase. In the verification mode, a user's requested identity is being authorized by comparing the extracted biometric features with the stored biometric template of the person in the database. In the identification mode, the system validates an individual by checking the templates of all the users in the database for a match [5]. Most of the recognition methods based on retinal images are used either in identification or verification mode.

Generally, the retinal authentication system is based on the unique blood vessel pattern of retina. Two ophthalmologists, Dr. Carleton Simon, and Dr. Isodore Goldstein introduced the uniqueness of retinal blood vessel pattern in 1935 [5]. Moreover, the vascular patterns are unique even among identical twins discovered by Dr. Paul in 1950. These features of human retina make it a biometric trait for person identification. The first commercial retinal identification tool named EyeDentification 7.5 was marketed by EyeDentify Company in 1976. Then in 2001, they manufactured another device called ICAM, which can store upto 3000 templates with a storage capacity of 3300 history transactions [6]. Some companies like Retica System Inc. working on a multi-modal system using Retina and Iris for person identification.

II. Review of Existing Retina Based Biometric System

The retina is one of the most reliable, secure and stable biometric features because of its natural characteristics and low possibility of fraud. In some cases, it may change because of accident or retinal diseases. Otherwise, the retinal structures do not change.

A. Anatomy of the Retina

The retina is a thin layer of cells that lies at the back of human eye. It consists of multiple layers of sensory tissues and millions of photoreceptors; whose function is to transform light rays into electric impulses. These impulses subsequently travel to the brain via the optic nerve, where they convert into an image. The main features of a fundus retinal image are optic disc (OD), fovea and blood vessels as shown in Fig. 1.

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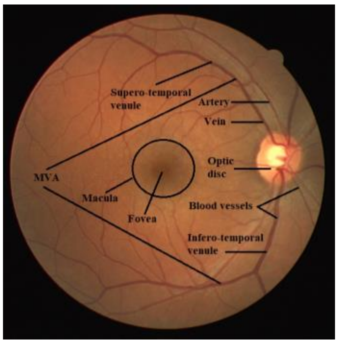

Fig. 1. Human retina with different features.

A Retina based person authentication system has mainly three stages: image enrollment, feature extraction and feature matching [6]. In the enrollment phase, a fundus camera scans and captures an image of the retina. These are then stored in digital format. The next stage is feature extraction where the features of the retina image are extracted using certain algorithms and stored as a reference template in the database. Finally, the features acquired from the query image are compared with the stored reference template by a suitable matching criterion and then the person is identified.

There are many methods that have been proposed for biometric authentication using retinal images. These methods mainly focus on the features acquired from the blood vessels of retinal images for authentication. There are a few methods that obtain features from the retinal images for authentication without performing blood vessel segmentation. The different methods are discussed below.

Farzin *et al*. [7] presented a method composed of three principal modules: blood vessel segmentation, feature generation, and modified correlation based feature matching. The wavelet transformation is used to separate vessels according to their diameter sizes. Then the vessel position and orientation were used to define a feature vector for each subject. These steps make the computational time of the system high. They have tested their method on 300 images from 60 subjects, 40 from DRIVE and 20 from STARE database and achieved an accuracy rate of 99%.

Waheed *et al*. [8] proposed a non-vascular based retina recognition system. It computes similarity measure using features based upon structural information such as luminance, contrast and structural features of an image. For matching, an empirically optimized function is used to generate a similarity score between two candidate images. They have used only 34 subjects for their experiment and obtained an identification rate of 92.5%.

C. M. Patil and K. S. Yogesh [9] have proposed a person identification system using an automatic retinal blood vessel segmentation technique. They have used three methods: Fractal Dimension method, Morphological Segmentation and Branching point method, and Watershed Segmentation method. In Fractal Dimension method, the fractal dimension of the blood vessel image is calculated using box counting algorithm. In morphological technique, the branch point, crossover point and the angles between the branch points are considered as feature set. For both the methods they have used Euclidian distance measure for identification. In Watershed segmentation method, the bifurcation points and crossover points are stored in the database as a feature vector along with the wavelets. For classification SVM is used. Using Watershed method they have achieved the best accuracy of 96% and error rate of 4%.

F. Sadikoglu and S. Uzelaltinbulat [10] designed a retinal identification system using neural network. In pre-processing, they have transformed the retina image to gray scale values and then scaled down for recognition. The extracted features are then fed to the neural network. In recognition step, the neural network classified the retina patterns. They have tested their method on DRIVE database and have achieved a recognition rate of 97.5% with neural network having 35 neurons.

J. B. Mazumdar and S. R. Nirmala [11] proposed a texture feature based retinal authentication system. They have extracted the retinal texture features using Local Configuration Pattern (LCP) and Radon transform technique. Using Radon transform they have extracted the Radon features which contain the texture information of the blood vessels of retina. Then they have formed a feature vector by combining the LCP and Radon features, which is fed to a Feed-forward Artificial Neural Network (FANN) classifier for authentication. In testing stage, they have used Euclidian distance method for matching. They have used DRIVE, HRF, Messidor, RIDB, VARIA and local hospital databases for their method and have achieved an accuracy of 99.37%.

Aleem *et al*. [12] proposed an automatic fast and accurate retinal identification system. They have used a hybrid segmentation technique to extract the retinal vasculature. To reduce the dimensionality of the large number of vessels feature they have used a Principal Component Analysis (PCA). For Identification, they have used L2-norm, which calculates the distance between the feature vectors of the query template to all the templates in the database. For segmentation, they have achieved an accuracy of 99.65% and the recognition rate of their method is 99.4%.

Jiu *et al*. [13] have proposed a biometric identification using retinal vessel structure. In their method, they have used 2D Gabor Wavelet transform to enhance the blood vessels and then segmented using Adaptive thresholding. Their feature set consists of bifurcation points and end points of vessels. Then they have used validation process to eliminate the falsely identified feature points. For feature matching, they have used Euclidian distance method. They have achieved a recognition rate of 100% using DRIVE database and for STARE and VARIA database the accuracy is 95.06% and 98.28% respectively.

Bhuiyan *et al*. [14] have proposed a biometric authentication system using retinal vasculature pattern, such as bifurcation points and crossover points. They have used a novel vessel width measurement method to characterize the major blood vessels by their width and length. Then they have developed a geometric hashing technique to make their system invariant to scale, rotation and translation. They have tested their method on 3010 retinal images and have achieved an accuracy of 98.9%.

Some authors used parabolic curve fitting method to extract retinal features and localize the eyelids for iris recognition system and are discussed below:

Li *et al*. [15] proposed a model-based approach to extract the main features of color retinal images for detection of diabetic retinopathy. At first, they have used PCA to locate the optic disc, and then a modified shape model has been proposed to extract the main course of the blood vessel, which is roughly a parabolic curve. Then they used a quadratic curve fitting technique using Hough-based and least square fitting methods. From the fitted parabola, they have localized the fovea and detected the exudates, which are then used to screen and assess diabetic retinopathy. A total of 89 images have been tested for their method and obtained sensitivity and specificity of 100% and 71%, respectively.

He *et al*. [16] presented an algorithm for accurate and fast iris segmentation. For this, they first used the Adaboost-Cascade iris detector to roughly locate the iris center. After detecting the edge points of iris boundaries the center and radius are iteratively refined by an elastic model. Then, using a spline-based edge fitting technique the non-circular iris boundaries are smoothened. The eyelids are localized by using parabolic curve fitting method. For this, they first cropped the ROI (region of interest) and filtered it with a Horizontal rank filter to get the clear eyelid boundary. A raw eyelid edge map is calculated and noisy edge points are eliminated via shape similarity calculation. Then the shape of the eyelid is fitted with a parabolic curve. Thus the exact shape of the eyelid is obtained by parabolic curve fitting.

Adam *et al*. [17] presented an eyelid localization algorithm for iris identification system based on a parabolic curve fitting technique. They have observed the shapes of eyelids are like a parabolic arc. After enhancing the boundaries they have applied a canny edge detector to get a map of edges. Then they have extracted the edges above and below the pupil for upper and lower eyelid detection. Every edge is fitted with a vertically oriented parabolic curve. By calculating the curvature of each parabola they have estimated the upper and lower eyelid. The parabolic curvature of every eyelid is refined using a gradient maximization. Finally, the edges are selected as upper and lower eyelids by the one, which is maximizing this gradient.

Oloumi *et al*. [18] designed a computer–aided diagnosis system for the detection of Proliferative Diabetic Retinopathy (PDR). They have monitored the openness of MTA (Major Temporal Arcade) and how it changes over time which could facilitate the diagnosis and treatment of PDR. At first, they have detected the blood vessels using Gabor filter then used the Generalized Hough Transform (GHT) to detect the parabolas and semi-parabolas. At last, they have used ROC and AUC to obtain the accuracy of the method.

The blood vessel structure in every retina is unique. The thick and dark vessel arcade is considered as the main vessel arcade (MVA) and is clearly visible in retinal images as shown in Fig. 1. The MVA is considered as one of the significant feature of retinal images. As the shape of the MVA resembles a parabola, we propose a parabolic model that closely fits the main vessel trajectory. All the existing works discussed in the literature on parabola fitting are for different applications such as detection of exudates, DR, PDR and to localize the eyelid but not used in retinal authentication.

In the proposed method, a parabolic model-based algorithm is used to extract different features of the MVA and a Euclidean distance method is used to match the feature for authentication. In this paper, we have extracted the features directly from the color retinal image and it does not require blood vessel segmentation step. In this way, the computational complexity of the system is also reduced.

The rest of the paper is organized as follows: Section 4 includes the proposed algorithm for person authentication using retinal features. The performance analysis and comparison with previous studies are presented in Section 5 and finally, Section 6 consists of conclusion and future work.

III. Proposed Method

In this Section, a new parabolic model based person identification method using retina images is presented and described in detail. The features are obtained directly from the color retinal image. The method consists of three steps: parabolic model fitting, feature extraction, and feature matching. The method is simple, as it does not require any blood vessel segmentation step which is generally a computationally intensive task.

There are two types of vessels- arteries and veins present in retinal images. Veins are brighter and thicker. From Fig. 1, it is observed the main thick vessel (i.e. vein) form a parabolic shape around the two sides of the OD. Though for all the retinal images the MVA is like a parabola but the shape of the parabola is different for each individual. So, the parameters extracted from the parabola can be used as features for retinal authentication purpose. The openness angle of the parabola, i.e. the major arcade angle (MAA), is also calculated for each parabola. As the shape of the parabola is distinct for each individual, the MAA is also unique and it can be taken as the feature to authenticate a person. These features are discussed in the following subsections.

A. Parabolic Model

The proposed algorithm is mainly based on curve fitting, i.e. by capturing the trend in the data by assigning a single function across the entire range. The example shown in Fig. 2 uses a straight line function described generally $f(x) = ax + b$.

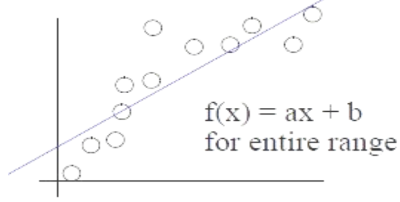

Fig. 2. Curve fitting.

The main goal is to identify the coefficients a and b such that $f(x)$ fits the data best because all the points do not lie on the straight line. There are different ways to find the optimal solution for a and b. One of them is the least square method (LSM), where to meet the condition of optimality, the square root of the sum of the squares of the deviations are minimized.

B. Feature Extraction

In the proposed work, a parabolic curve fitting model has been developed using LSM to fit the parabolic shape of the blood vessel in the retina. The method consists of the following steps:

1) The veins of retina are generally thick and bright. The vein which is crossing the optic disc and forms a parabolic shape is considered as the MVA.

2) Ten points are marked on the MVA by manually selecting 5 equidistant points on either side of the OD of the retinal image (5 points on the supero-temporal venule and 5 points on the infero-temporal venule).

3) Taking these data points, we generate the best fitted polynomial curve with degree 2 (since the curve shape is parabola) using LSM such as,

$$y = ax^2 + bx + c$$

4) The elements of the parabola i.e. vertex, focus, focal length, and MAA are considered as a feature set for authentication.

From Fig. 3 (a) it is observed that when parallel rays of light travel into a parabolic reflector, they are reflected toward a common point and this point is called focus. The vertex of the parabola is the midpoint of the line segment joining the focus and the directrix, perpendicular to the directrix as shown in Fig. 3 (b). The focal length is the distance between the vertex and the focus, measured along the axis of symmetry. These features are calculated as follows.

The equation of a parabola is given by

$$y = ax^2 + bx + c \tag{1}$$

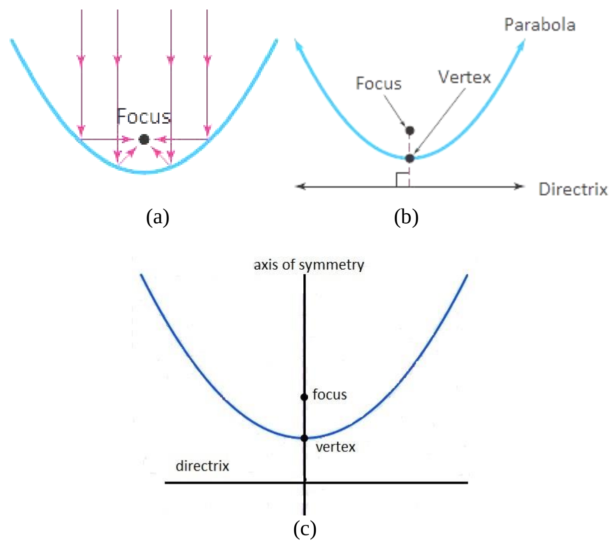

Fig. 3. (a) Focus, (b) Vertex and (c) Focal length of a parabola.

This comes from

$$(x-h)^2 = 4P(y-k) \tag{2}$$

where (h, k) are the vertex co-ordinates and (x, y) are the focus co-ordinates.

Thus equating (1) and (2) we get

$$a = \frac{1}{4P};\ b = -\frac{h}{2P};\ c = \frac{h^2}{4P} + k$$

And the vertex (h, k) is

$$h = -\frac{b}{2a},\ k = \frac{4ac - b^2}{4a}$$

We know that the discriminant D of (1) is

$$D = b^2 - 4ac$$

So, the vertex (h, k) can be written as

$$h = -\frac{b}{2a},\quad k = -\frac{D}{4a}$$

and the focus (x, y) from (2) is

$$x = -\frac{b}{2a},\quad y = \frac{1-D}{4a}$$

However, the focal length is the difference between the y-coordinate of the focus and the vertex and is given by,

$$f = \frac{1-D}{4a} - \frac{(-D)}{4a}$$

Therefore

$$f = \frac{1}{4a}$$

The vertex and focus are marked as red* and green* in all the image figures.

To calculate the MAA, a circle is drawn by considering the vertex of the parabola as center as shown in Fig. 4 (b). The radius of the circle is chosen in such a way that:

1. The circle should not be very large because the circle may not intersect the parabola.

2. The circle should not be too small to identify distinctly the point of intersection and vertex.

The points of intersection of the circle with the parabola on both supero-temporal venule and infero-temporal venule of the MVA are noted down. The MAA is the openness angle of the parabola which is $\angle AOB$ as shown in the Fig. 4 (a).

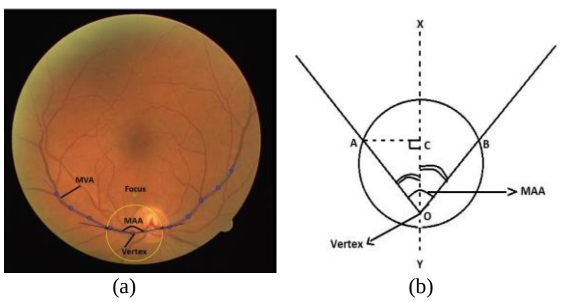

Fig. 4. (a) Openness angle of MVA (MAA) and (b) calculation of MAA

Now to calculate $\angle AOB$, we have considered the axis of symmetry XY of the parabola which is passing through vertex O as shown in Fig. 4 (b).

As XY is the axis of symmetry,

$$\angle AOX = \angle BOX$$

Then a perpendicular AC is drawn on XY which gives

$$\angle AOX = \tan \angle AOX$$

Therefore

$$\angle AOB = \angle AOX + \angle BOX = 2\tan \angle AOX = MAA$$

C. Feature Matching

After the extraction of feature sets, the next important stage is to obtain accurate corresponding individual by using an appropriate matching strategy. In our approach, Euclidean distance technique [7] is used for authentication. For feature matching, the Euclidean distance method is used. The feature set for a particular person's image is compared with feature set of all the persons present in the dataset. The comparison is done against a certain threshold. The image with minimum distance is considered as best match.

IV. Experimental Results

The proposed method is tested by carrying out three sets of experiments. The first experiment is using the three standard databases and a clinical dataset; the second is using authentication databases and lastly using the degenerated retinal images. In each experiment, the performance metrics used are: Recognition rate, false rejection rate, false acceptance rate which are defined as follows:

$$\text{Recognition Rate(RR)} = \frac{\text{Total true accepts}}{\text{Total true attempts}}$$

$$\text{False Rejection Rate(FRR)} = \frac{\text{Total false rejection}}{\text{Total true attempts}}$$

$$\text{False Acceptance Rate(FAR)} = \frac{\text{Total false accepts}}{\text{Total false attempts}}$$

For an ideal system, the RR should be very close to 100%, FRR and FAR should be 0%.

The steps of the parabolic model-fitting algorithm are shown in Fig. 5. The color retinal image taken from the DRIVE database [19] is shown in Fig. 5 (a). The 10 points are manually marked on the MVA by taking 5 equidistant points on each side of OD and is represented in Fig. 5 (b). Fig. 5 (c) represents the best-fitted parabolic curve on this retinal image. Then, taking vertex as the center a circle is drawn on the parabola to calculate MAA as shown in Fig. 5 (d). The elements of this parabola: vertex, focus, focal length, and MAA are evaluated as features of the retinal image and stored as a template for matching purpose.

The features are considered from the parabolic curve drawn over the MVA. The feature set consists of the co-ordinates of focus and vertex, the value of focal length and MAA. As we have many images for one person in every database, the features are extracted from each image and averaged to create feature template for that person. For demonstration, we have chosen 5 persons from DRIVE database and the extracted features are shown in Table I. For each person, a feature vector of length 6 is created in each database. The row index of the feature matrix represents a particular person.

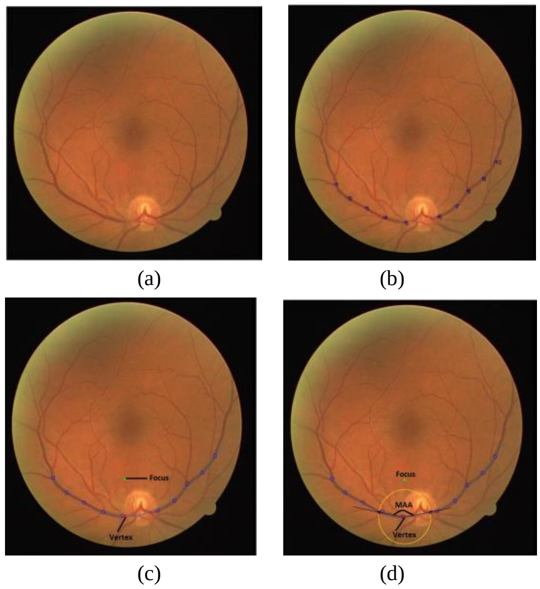

Fig. 5. Parabolic curve fitting.

TABLE I. Feature Matrix

Person	x (x co-ord. of focus)	y (y co-ord of focus)	h (x co-ord of vertex)	k (y co-ord of vertex)	Focal length	MAA (in radian)
1	282	407	282	483	75.62	2.69
2	307	399	307	442	43.4	2.46
3	293	446	293	499	53.75	2.58
4	281	169	281	123	46.28	2.54
5	304	152	304	80	71.61	2.73

In DRIVE database 40 images are there for 40 different individuals. We have generated 4 retinal images from a single image with different variation by rotating (6 and 10 degrees) and translating (5 and 8 pixel values) the images. As a result, each person has 5 images and a total of 40×5=200 images from DRIVE database are tested. HRF database [20] has 45 images and 4 generated images for each person thus a total of 45×5=225 has been tested from this database. Next, we have taken 40 images of 40 individuals from Messidor database [21] and produced 5 images for each individual with a total of 40×5=200 images for testing. The database collected from a local hospital, which has 37 images from 37 different individuals. Similar to other cases, 5 images are generated per person. So, a total of 37×5=185 images are tested from this database. Hence a total of 810 images are used in the experiment. For testing with authentication databases, RIDB [22] and VARIA [23] are considered. In RIDB, there are images of 20 different persons and each person with 5 different images. This gives 100 images in total. VARIA contains 233 images from 139 different individuals. Thus a total of 333 images are used from these sets of databases.

Fig. 6 shows the retinal images of different standard databases and their parabolic curve fitted on the images. Similarly, the parabolic curve fitted images from authentication databases RIDB and VARIA is shown in Fig. 7.

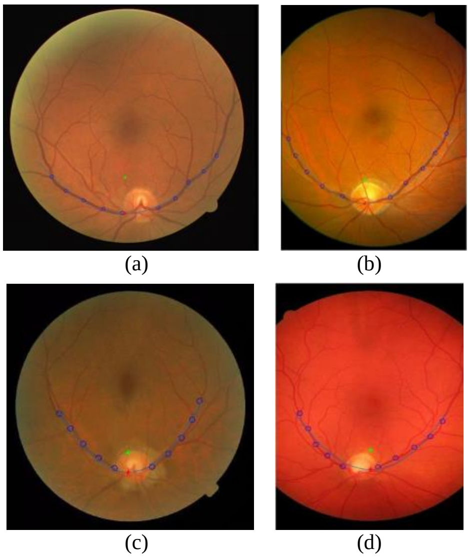

Fig. 6. Parabolic curve fitting on standard databases: (a) DRIVE, (b) Local hospital, (c) Messidor, and (d) HRF.

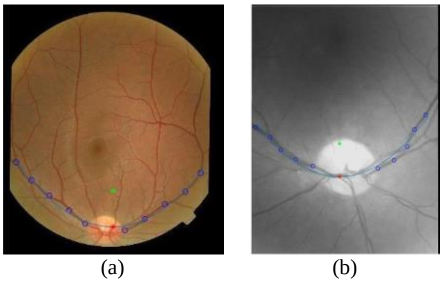

Fig. 7. Parabolic curve fitted images from (a) RIDB and (b) VARIA.

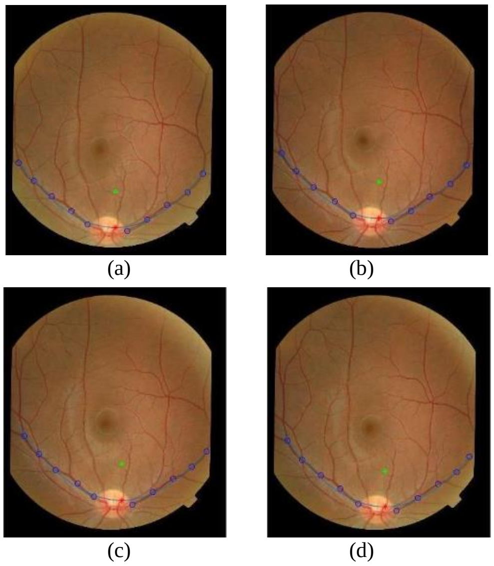

Fig. 8. Parabolic curve fitting on different images of the same person from RIDB database, (a), (b) (c), and (d) are the rotated images of a single person.

To evaluate the performance of the system on rotated images, four different images of the same person (out of five images) from RIDB database are taken. Their fitted parabolic curves on the MVA of the retina are shown in Fig. 8 (a), (b), (c) and (d). While testing with these images all are identified as the same person. The experiment is also carried out for some degenerated retinal images from HRF, Messidor and hospital images. It has been observed that the algorithm works well on these images to identify a person. As the MVA of the retina is dark and bright vessel, it is clearly visible even in the presence of pathological patches on the degenerated images. So, the features extracted from the fitted parabolic curve fitted on the blood vessel arcade can authenticate a person's identity as shown in Fig. 9.

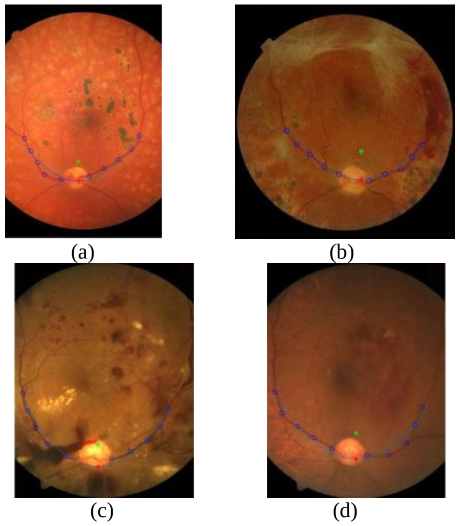

Fig. 9. Parabolic curve fitting on degenerated images from different databases: (a) HRF, (b) Messidor, (c) and, and (d) local hospital.

To evaluate the performance of the system, we have tested with 200 images from DRIVE database. All images are recognized correctly giving 100% RR and 0% FRR. From HRF database out of 225 images, 223images are correctly recognized and obtained 99.11% RR and 0.89% FRR. To evaluate RR, 200 images from Messidor and 185 images from local hospital database are also taken. In Messidor out of 200 images 197 images and from local hospital database 184 images out of 185 images are authenticated correctly giving 98.5% RR, 1.5% FRR and 99.45% RR, 0.55% FRR respectively. All the experiments are carried out on a computer with an Intel core i5-3230M processor (2.6GHz) and 4GB RAM using Matlab R2017a. The processing time of the proposed system to identify a person is calculated by taking the time total time taken by all the images for a particular database divided by the total number of images in that database. In this way the processing time of the system is calculated for all the databases. For DRIVE database images, the average time required to identify an individual is 4.2 seconds and that for the images from HRF, Messidor and local hospital are 7.4, 6.06 and 4.7 seconds respectively and shown in Table. II. The processing time for HRF database is high because of large image size (2336×3504), whereas the size of the images in DRIVE database is (584×568).

TABLE II. EXPERIMENTAL RESULT OF PROPOSED METHOD ON STANDARD DATABASES

Database used	Number of test images	Recognized images	RR (%)	FRR (%)	Processing time for identification (sec)
DRIVE	200	200	100	0	4.2
HRF	225	223	99.11	0.89	7.4
Messidor	200	197	98.5	1.5	6.06
Local Hospital	185	184	99.45	0.55	4.7

TABLE III. EXPERIMENTAL RESULT OF PROPOSED METHOD ON AUTHENTICATION DATABASES

Database used	Number of test images	Recognized images	RR (%)	FRR (%)	Processing time for identification (sec)
RIDB	100	100	100	0	5.53
VARIA	233	231	99.14	0.86	4.9

TABLE IV. EXPERIMENTAL RESULT OF PROPOSED METHOD ON DEGENERATED RETINAL IMAGES

Database used	Number of test images	Total number of test images	Recognized images	RR (%)	FRR (%)	Ave. Processing time for identification (sec)
HRF	20	100	97	97	3	6.05
Messidor	30					
Local hospital	50					

In authentication databases, 100 images from RIDB and 233 images from VARIA database are tested. All the images from RIDB database are correctly recognized giving 100 % RR, 0% FRR, whereas, 231 images are recognized correctly from VARIA database which achieves 99.14% RR and 0.86% FRR. The execution time of the proposed system using RIDB and VARIA database are 5.53 and 4.9 seconds respectively. The experimental result is shown in Table III.

Further, we have evaluated the system performance on some degenerated retinal images collected from HRF, Messidor and local hospital images as shown in Table IV. A total of 100 images are tested from these databases, out of these, 97 images are recognized correctly providing 97% RR and 3% FRR. Out of the 3 unrecognized images, 2 are from local hospital and 1 is from Messidor database. The average processing time of the system with this set of images is 6.05 seconds.

To calculate FAR, for a given database, we have tested with the images taken from other databases. It has been observed that, if we vary the threshold then sometimes the system falsely accepts the unauthorized person. As the threshold is varied, the FAR also vary accordingly.

The performance of the system is also evaluated by plotting Receiver Operating Characteristics (ROC). To obtain ROC, the threshold value set for minimum distance between feature set is varied about the optimal value and FAR is calculated each time. The results are plotted as the ROC curve as shown in Fig. 10. It is observed that, for variation in the threshold, the RR and FAR also varies. The AUC is also calculated for each database from the ROC curve. It is observed that the system gives 100% AUC for DRIVE and RIDB database. The AUC for HRF, Local hospital database and VARIA are 99.66%, 99.82%, and 99.74% respectively. For Messidor the AUC is 99% and for degenerated retinal images it is 97%. The observed result shows that the system is able to identify the authenticated retinal images effectively and at the same time rejecting the unauthorized images.

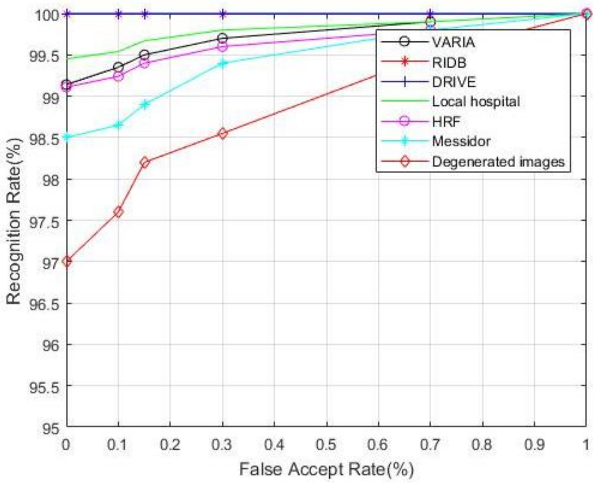

Fig. 10. ROC curve of the proposed method.

TABLE V. COMPARISON OF THE PROPOSED METHOD WITH OTHER TECHNIQUES

Method	Database used	Nos. of images	RR (%)	Processing time (sec)
Farzin *et al.* [6]	DRIVE and STARE	300	99	-----------
Waheed *et al.* [8]	DRIVE	40	92.5	-------
Sadikoglu *et al.* [10]	DRIVE	40	97.5	
Ortega *et al.* [24]	Collected from Hospital	90	100	0.144s for verification
Condurache *et al.* [25]	VARIA and DRIVERA	513	99.29	6s for both verification and identification
Lajevardi *et al.* [26]	STARE	392	99.5	6s for verification
Dehgani *et al.* [27]	DRIVE and STARE	480	100	5.3s for Identification And 0.07s for Verification
Akram *et al.* [28]	DRIVE, STARE and VARIA	354	98.3	----------------------------
Khakzar and Pourghassem [29]	VARIA	59 subjects	90.21	--------
Proposed method	DRIVE, HRF, Messidor, RIDB, VARIA and images from local hospital	1143	99.39	5.46s for Identification

Table V represents the comparative study of different methods used in the literature for retinal authentication system along with the proposed system. From the table, it is observed that [24] shows a RR of 100% and processing time of 0.144 s but the number of images used are less. In [25], the numbers of images used for authentication and

RR are less than proposed method. In [26], RR of 99.5% and processing time of 6s is obtained using 392 images from single database. The results reported in [27] shows a RR of 100% with processing time 3s for Identification and 0.07s for Verification using two standard databases only. But in the proposed method, the images are collected from standard databases, local hospitals and proper authentication databases are used. In this way, the dataset used in the present work is diverse in nature. As we have used large numbers of images, the processing time is slightly higher but the overall performance of the proposed system is better as compared to other systems.

V. Conclusion

A parabolic model based retinal authentication system is developed in this work. A parabolic curve is fitted on the MVA of retinal images. The elements of the parabola; the focus, vertex, focal length, and MAA are considered as the feature set for authentication. For feature matching, Euclidean distance method is applied to check whether the test images belong to an authorized person or not. The system is validated with a diversified dataset using standard and clinical data set images along with two authentication databases. The experimental result shows that the system is proficient at rejecting the unauthorized person and at the same time it is accepting the authenticated person efficiently. The system achieves an average RR of 99.39% and processing time of 5.46 seconds for identification. It is required to the address issue of latency, where MVA is extracted automatically which will improve the processing time of identification. The future focus is to evaluate the performance considering the multimodal biometrics system.

It is also required to investigate the use of retinal authentication system to access medical records and confidential reports, only by authorized person.

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