VASCULAR AND NON-VASCULAR BASED RETINAL FEATURES EXTRACTION: A REVIEW

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ABSTRACT:

A biometric method is a pattern recognition system which depends up on the physiological and behavioral traits. From the last few years, biometric system has many applications like fingerprint, face, hand, palm print, retina and iris etc. Along with all these biometric systems, Retina recognition proves to be the most promising biometric system. Retinal recognition performs person identification based on two different approaches i.e. Vascular based and Non-vascular based retinal recognition. Vascular based method works on three different phases, which includes Pre-processing, Segmentation and Matching. Firstly, this method requires vascular pattern to extract region based features from retinal images. Then it segment out true vessels by removing the effects of false vessels. In matching phase input retinal picture matches with the feature vector of query image which is stored in database record. It improves the effectiveness of retinal recognition rate. Secondly, in non-vascular based approach, structural features are extracted from color retinal image which generates the similarity score by comparing two images at one single time which depends upon their structural features i.e. luminance, contrast and structure. Highest score value provides matching decision and also, it reduces time complexity.

Keywords: Biometric system, Retinal recognition, Vascular-based retinal recognition, Blood vessel segmentation, Non-vascular based retinal recognition, Structural features.
[1] INTRODUCTION

An automatic human authentication method has turned out to be a significant tool in this era of technology. The method of automatic recognition is based on individual behavior is called biometric authentication. Biometric system is that in which human features are recognized from physiological or behavioral characteristic. Depending on the application framework, a biometric system usually operates in one of two modes: verification or identification [1]. Merits of biometrics over other authentication methods are that they cannot be elapsed or misplaced. Biometrics characters are unique to individual so they are more complicated to fake. The biometric applications such as fingerprint, hand or finger geometry, face, iris, speech, retina, signature, hand vein, etc are used for verifying computation. Every human has their own individuality for perfect identification [2, 3]. In addition, biometrics such as fingerprint, hand geometry, palm print, etc. may get vague in regular contact with the surroundings. As a result, in case of biometrics, severe transformation and feature extraction based algorithms may face conflicts in establishing a match along with several images acquired from identical humankind. However, retinal identification is the absolutely free from this negative impact of the ambiance.

In human retina, blood vessels pattern is unique in every individual who used biometric system. Different traditional method uses biometric systems on vascular pattern of human retina which is most steady, unique and unforgeable source for biometrics [4]. Retina image is the distinct style form of blood vessels; it is not that much easy to be recurring between people and the updation becomes rare as well. Even though pattern of left eye and right eye of same person is distinct. Over a lifetime, many researchers have exposed that identical twins have different and unique pattern of blood vessel in retina [5]. Despite, having all these influential features, retina is failed to be used widely all around world in past few decades due to its high expenditure and user unfriendly acquisition operation.

Digital retinal images are used for identification purpose in recognition method; these images are captured by using digital fundus camera [Figure-1]. To scan retina, the person has to be placed his/her eye very near to the lens of camera. In this scanning process, person should remain still to avoid signal hindrance. The overall Retinal recognition process involves three main steps; Pre-Processing, Segmentation and Matching [6]. There are number of techniques for person identification, retinal features have been considered. Various methods use vascular pattern properties to take out retinal features for person recognition and some methods use other properties of retinal images by using either the optic disk (OD) or image organization properties.

![Figure: 1. Retinal Image](image-url)
[2] LITERATURE SURVEY

Wang et al. [15] discussed a method which is used to resolve the problems of retinal blood vessel segmentation and two different classifiers are used in this paper: RF and CNN. In this technique, Random Forest work as a trainable classifier and Convolution Neural Network executes as a trainable hierarchical feature extractor.

A new approach for blood vessel detection from digital retinal images is used by Singh et al [16]. In this paper the morphological based approach is used for background exclusion and blood vessel improvement with phase preserving noise removal algorithm. Vessel silhouette is extracted with the way of using fixed threshold procedure. Post-processing is done to take out pointless areas, eradicate spur pixels and cover gaps within detected vessel.

Emary et al. [17] used artificial bee colony optimization with fuzzy Clustering. Artificial bee colony optimization is used as a global search technique to get cluster centers of the fuzzy c-means objective function. Emary employ a pattern search approach on optimization in order to localize small vessels with a different fitness function.

D.Siva Sundhara Raja et al. [18] described a method to recognize and segment out blood vessels from retinal images with the help of the morphological operations and support vector machine classifier techniques which includes three phases, preprocessing of retinal image, blood vessel segmentation and SVM classifier.

Recognition based on vascular pattern of human retina in Personal identification system is used by Qamber et al [6]. This system is three step process- preprocessing, feature extraction and matching. Feature vector is computed with these steps from images used to perform matching with high accuracy.

A Novel Method for Person Authentication using Retinal Images developed by Latha et al [20]. In which noninvertible units construction algorithm is proposed to produce matching templates for verification purpose by using bifurcation points.

In Retina recognition, Choras [25] proposed a new method using wavelet features including minutiae features. Texture and Geometrical features are extracted from multifarious vascular pattern of retina. For the Region of interest (ROI) image preprocessing, locating, and segmentation processes are included.

A personal identification system based on minutiae matching by using human retina image is developed by Patwari et al. [26]. Patwari proposed a new algorithm for the detection and measurement of blood vessels. Bifurcation points of blood vessels are finding by using minutiae point technique.
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Lajevardi et al. [27] presented a Retina Verification System Based on Biometric Graph Matching. In this paper recognition is done on the basis of non-minutiae based retina recognition. Morphological operators and matched filters are used to extract the features from retinal vasculature structure.

Wavelet Energy Feature tool of multi resolution analysis is used by Vora et al. [28] in retinal recognition. Kekre’s wavelets are used in this method to create WEF and extract features from retinal image. For blood vessels segmentation wavelets are used and for feature extraction Energy Entropy is used.

Fast Normalized Cross-Correlation Based Retinal Recognition method is used in this paper [29]. RGB retinal fundus images are used in this simple biometric recognition system. Calculated Feature vectors generated from RGB retinal images used to perform matching.

Morphological component analysis is presented in this paper [30] to extract retinal blood vessels from retinal image. MCA algorithm is used to separate vessels and lesions from each other. After applying MCA algorithm, the Morlet Wavelet Transform is applied to enhance the retinal vessels and the final vessel structure is obtained by using adaptive thresholding.

[Table-1] shows the different methods used for retinal recognition including databases used in it. This table will help the researchers to evaluate their work performance by comparing their system working with the existing works.

<table>
<thead>
<tr>
<th>Author’s Name &amp; Year</th>
<th>Method</th>
<th>Database</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dalwinder Singh, Dharamveer Singh, Birmohan Singh (2014) [16]</td>
<td>Blood Vessel Detection</td>
<td>DRIVE &amp; STARE</td>
<td>94.60% 95.21</td>
</tr>
<tr>
<td>Eid Emary, Hossam M. Zawbaa, Aboul Ella Hassanien, Gerald Schaefer, Ahmad Taher Aza (2014) [17]</td>
<td>Artificial Bee Colony Optimization</td>
<td>DRIVE &amp; STARE</td>
<td>93.9% 94.7%</td>
</tr>
<tr>
<td>D.Siva Sundhara Raja, Dr.S. Vasuki, D. Rajesh Kumar (2014) [18]</td>
<td>Blood Vessel Segmentation</td>
<td>DRIVE and STARE</td>
<td>95.1%</td>
</tr>
<tr>
<td>Sana Qamber, Zahra Waheed, and M. Usman Akram (2012) [6]</td>
<td>Recognition based on Human Retina</td>
<td>DRIVE STARE and VARIA</td>
<td>100% 96.29% 99.57% Total 98.87%</td>
</tr>
</tbody>
</table>
Table 1. Method used for retina recognition

<table>
<thead>
<tr>
<th>Authors</th>
<th>Method</th>
<th>Database</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>L. Latha, M. Pabitha and S. Thangasamy (2010)</td>
<td>Person Authentication Based on Retina Pattern Recognition</td>
<td>DRIVE</td>
<td>100%</td>
</tr>
<tr>
<td>Manjiri B. Patwari, Ramesh R. Manza, Yogesh M. Rajput, Manoj Saswade, Neha Deshpande (2014)</td>
<td>Personal Identification based on Minutiae Matching</td>
<td>300 high resolution Fundus Images</td>
<td>97.02%</td>
</tr>
<tr>
<td>Rita A. Vora, Dr. V A Bharadi, Dr. H B Kekre (2012)</td>
<td>Retinal Scan Recog. using Wavelet Energy Entropy</td>
<td>DRIVE &amp; Messidol</td>
<td>100% 95%</td>
</tr>
<tr>
<td>Elaheh Imani, Malihe Javidi and Hamid-Reza Pourreza (2015)</td>
<td>Retinal Blood Vessel Detection using Morphological Component Analysis.</td>
<td>DRIVE &amp; STARE</td>
<td>95.23% 95.90%</td>
</tr>
<tr>
<td>Malak T. Bantan (2016)</td>
<td>Auto Segmentation of Retinal Blood Vessels.</td>
<td>MRF</td>
<td>94%</td>
</tr>
</tbody>
</table>

[3] VASCULAR BASED FEATURE EXTRACTION METHOD

Vascular-based method uses vascular properties of retinal image. The feature extraction technique is used to improve vessel segmentation. Vessel properties in retinal image are used to get better performance of retinal recognition system but it requires a neat blood vessel pattern without any pathological signs and with true vessels only however it becomes difficult in the occurrence of lesions in diseased retinal images. So this method has an improved vessel segmentation algorithm which works on true vessels as well as it will consider pathological signs as false vessels which
removes the effect of lesions to obtain good result. A vascular based feature extraction has two modules: Enrollment and Identification module as shown in [Figure-2].

[3.1] PREPROCESSING

Color fundus retinal images have some lighting variations, noise and poor contrast in it. To reduce these imperfections and produce images more appropriate for extracting blood vessels, need to know the properties of fundus image then apply preprocessing steps. Preprocessing will be performed on the colored retinal images by extracting noise and background effect from the image and then vessel segmentation of retinal image is completed by applying Log Filter and Adaptive Threshold method. Preprocessing is the first phase of retinal recognition in which system uses Gabor wavelet and multilayered thresholding technique to extracts the vascular pattern [7]. Preprocessing is completed with these two phases: Green channel extraction and blood vessel enhancement.

[3.1.1] GREEN CHANNEL EXTRACTION

Before processing the contrast of the retinal images will be improved by discarding some data from image like blue and red parts. Accordingly, the green part of image produces the clear vessels and contrast among the optic disc and tissue from background contrast of retinal image vascular pattern which is further used for processing. From particular input image green pixel values are extracted and then stored in the database in matrix form. After that grayscale image is formed from the green channel image. The blood vessels of vascular pattern present much clearness than other images in the green channel image.

[3.1.2] BLOOD VESSEL ENHANCEMENT

The final preprocessing step generates a new vessel-enhanced image, which will be most suitable for further post-processing steps used for segmentation and detection of blood vessels. Blood Vessel enhancement is achieved by estimating the homogenized opposite image, and then the morphological Top-Hat transformation is applied where morphological operation using a disc of eight pixels in radius. First and foremost, blood vessels are extracted from given input fundus image and to enhance this given image, 2-D median filtering and morpho-logical operations can be used for the extraction of blood vessels [8, 13].
[3.2] BLOOD VESSEL SEGMENTATION

Segmentation is done using multi-layered thresholding technique, which will produce a neat sample of vessels. Different ocular disorders bring defect in retinal images which results appearance of false vessels along with true vessels after applying segmentation. In order to remove all false vessels from vascular pattern of image vessels validation algorithm is required. Many algorithms have been developed to accurately segment blood vessels from images like matched filtering, supervised pattern recognition, multi-scale line-detection, scale-space analysis and morphological processing[21, 22]. Blood vessel segmentation consists of three different phases: Blood vessel extraction, region based feature extraction and classification.

[3.2.1] BLOOD VESSEL EXTRACTION

In blood vessel extraction true and false vessel appearing in vascular pattern will be extracted [14]. After this step, a false vessel appears as a round shape and bunches among true vessels. Then it will analyze and extract region based on features of true and false vessels. This blood vessel extraction phase uses various techniques to extract blood vessels from given retinal image [23].

[3.2.2] REGION BASED FEATURE EXTRACTION

A retinal image is separated into linked regions by grouping neighboring pixels of similar features. The principal approaches in this category are based on thresholding, region growing, and
region splitting/merging and clustering in feature space. Region based feature extraction method allows you to calculate local image features. Region features help you to describe: Local texture, Local intensity distribution, Local gradient, edge strength and orientation, Response of a convolution filter, Local appearance. During extraction of features, it discriminate eleven features as discussed in [9].

[3.2.3] CLASSIFICATION

Classification is a method in which individual items like objects, patterns, image regions, pixels are grouped based on the resemblance among these items and the description of the group. In classification algorithm, there are three types of classifiers: Gaussian mixture model, K-nearest neighbor and least mean square error are available to use [10]. The performance of algorithms is compared and analyzed on retinal images using different procedures which consist of accuracy, true positive rate, false positive rate, sensitivity, specificity and area under receiver operating characteristic (ROC) curve.

[3.3] FEATURE EXTRACTION

Next phase after segmentation is feature extraction. In this phase, minutiae points are extracted from retinal image using vessel properties. Minutiae points are bifurcations and ending points. Bifurcation points are those points which are divided into further two branches and Ending points are points at which vessel terminates or ends. This feature extraction phase is further divided into three phases that are feature points extraction, validation and feature set formation.

[3.3.1] FEATURE POINTS EXTRACTION

In the first phase, vessel ending points and bifurcations points are extracted from vascular pattern of retinal image [6]. Bifurcation points are those points in which vessel are divided into further two branches and Ending points are points where vessel terminates.

[3.3.2] FEATURE POINTS VALIDATION

Once all false feature points are eliminated, next step is to validate the remaining feature points. In this phase extracted features will be taken as input and then feature point validation phase results as validated blood vessels with all true vessels by removing false vessels from vascular pattern [24].

[3.3.3] FEATURE SET FORMATIONS

Feature extraction and validation is used to generate feature vector which will be further used for matching. In Feature Set Formation, for each feature point relative angle and relative distance will be calculated among four nearest features. Then system will generate a feature vector after extracting or validating features and then this feature vector will be stored in database and will compared with another query image feature vector for matching.
[3.4] MATCHING

In database, there are number of feature vectors stored for different retinal images. Each image has own feature vector which will be stored in database. The matching phase analyzes the input retinal image with matching feature vectors of query image which is placed in database. This phase finally calculates a score value in which comparison is done between two retinal images. Matching is done with two ways: genuine matching and imposter matching. In genuine matching, sample will be already enrolled in the database that is going for testing with query image. In imposter matching when we will test a query image there will be no sample present in database [11].

[4] NON-VASCULAR BASED FEATURE EXTRACTION

In vascular based feature extraction method recognition is based on vessel segmentation and minutiae point extraction which is expensive computationally and consumes too much time which results in degrading overall system efficiency. So, a simple and fast non-vascular based feature extraction method is proposed in which retina recognition is performed using structural features instead of using minutiae point’s features i.e. bifurcation and ending points. This method will use the structural information of retinal image and generate the similarity score by comparing two images at one time which depends upon their structural features i.e. luminance, contrast and structure. Highest score value is used to match the retinal images from database. This process takes less processing time to recognize images with low equal error rate. It works in two phases: Feature Extraction and Matching as shown in [Figure-3] [12].

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**Figure: 3. Work flow of Non-Vascular Based Feature Extraction**

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[4.1] FEATURE EXTRACTION

In feature extraction phase, two retinal images will be taken one as input image and second as a query image. Structural features are extracted from both the images at same time. It will extract features like luminance, contrast and structure from both the given images. The features are grouped into three categories based on the information they provide. After extraction it will produce result as a feature vector which will be stored in database.

[4.1.1] LUMINANCE

The luminance based features present information based on the intensity (gray-level or color) histogram of the pixels located in images. The histogram of an image refers to the intensity values of pixels. The histogram shows the number of pixels in an image at each intensity value. It shows the distribution of pixels among those grayscale values. The 8-bit gray scale representation of image has 256 possible intensity values. Some of the common histogram features are mean, variance, energy and median.

[4.1.2] CONTRAST

The contrast is a measure of intensity of a pixel and its neighbor over the image. It is the difference in luminance or color that makes an object distinguishable. In the visual observation of the real world, contrast is determined by the difference in the color and brightness of the object and other objects within the same field of view.

[4.1.3] STRUCTURE

The structural features provide information about the size and shape of image. To obtain structure measurement luminance and contrast functions are combined. Structure features are mostly used for finding and matching structure, recognizing objects or making measurement of structure.

[4.2] MATCHING

Matching phase will be completed after the execution of feature extraction phase from two retinal images. In feature extraction phase, features like structure, luminance and contrast are computed. Furthermore, all these features are combined to generate a single similarity score. The features functions which are computed in previous step are combined using an empirically obtained function to produce a similarity values among them. This similarity score will be generate in the form of 0 and 1. In the end, matching phase will gives result on the basis of matching score which have highest matching value.
[5] PERFORMANCE PARAMETERS

The process of measuring a performance is quantifying the efficiency and effectiveness of system. The performance of vascular and non-vascular based method is calculated by using these performance parameters. All process of measuring performance requires the use of statistical modeling to determine results. Following parameters gives the overall result of retinal recognition.

[5.1] RECOGNITION RATE (RR)

In this parameter, percentage is calculated on the basis of matched images which are correctly classified. Recognition rate is the percentage of matched images from the samples which is calculated by using the below expression.

$$RR = \frac{\text{No. of matched images}}{\text{Total no. of images}}$$

[5.2] FALSE REJECTION RATE (FRR)

False Rejection rate is the percentage of false rejections for valid inputs which are incorrectly rejected by system. This parameter is used to find out the validity of system. To compute FRR parameter each image of database is compared with all another images which are present in our database. Following is the equation which is used to measure the performance of FRR.

$$FRR = \frac{\text{Total false rejections}}{\text{Total identification attempts}}$$

[5.3] FALSE ACCEPTANCE RATE (FAR)

False Acceptance rate is the percentage of false acceptance for invalid inputs which are incorrectly accepted by the system. This parameter is also computed like false rejection rate as each image of particular person is compared with the all rest images that are stored in database. Following equation is used to measure the FAR parameter.

$$FAR = \frac{\text{Total false acceptances}}{\text{Total identification attempts}}$$

[5.4] EQUAL ERROR RATE (EER)

Equal error rate is that point where false acceptance and false rejections are equal. The lower equal error rate value will give the high accuracy and better retinal recognition system. It is also known as crossover error rate (CER).
[6] CONCLUSION

Retinal recognition method proves to be the most promising biometric system among all the biometric systems used in previous years. In this paper, vascular based method divide the extracted features of vascular pattern into true and false vessels. Then it removes false vessels by using segmentation. With this way it improves the accuracy and overall recognition rate. On the other hand Non-vascular based method reduces processing time and complexity by using only structural features of image without using segmentation. Overall, first method increases efficiency and accuracy and second method reduces time complexity but in recognition systems we should concentrate more on efficiency rather than time constraints to produce a highly secure biometric system because such systems are mostly required for security purposes.

REFERENCES


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