British Journal of Applied Science & Technology
14(2): 1-13, 2016, Article no.BJAST.23442
ISSN: 2231-0843, NLM ID: 101664541

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A New Approach for Automatic Human Recognition Based on Retinal Blood Vessels Analysis

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/BJAST/2016/23442
Editor(s):
(1) Samir Kumar Bandyopadhyay, Department of Computer Science and Engineering, University of Calcutta, India.
Reviewers:
(1) Romany Fouad Mansour, Assiut University, Egypt.
(2) Diana Bilkova, University of Economics, Prague, Czech Republic.
Complete Peer review History: http://sciencedomain.org/review-history/12989

Original Research Article

Received 1st December 2015
Accepted 24th December 2015
Published 15th January 2016

ABSTRACT

Retinal biometric is one of the newest biometric technologies that increasingly being used, especially in critical areas that require tight security measures, in order that retinal is one of the most robust and most accurate biometrics methods to recognize a person, the retinal recognition technique is yet another step in biometrics, it deals with very distinct physical property of exceptionally very low false acceptance and false rejection rates, and features that are found in the retina of eye are more reliable and stable features than those found in other biometrics. Retinal biometric is one of the newest biometric technologies that increasingly being used, especially in critical areas that require tight security measures, in order that retinal is one of the most robust and most accurate biometrics methods to recognize a person, the retinal recognition technique is yet another step in biometrics, it deals with very distinct physical property of exceptionally very low false acceptance and false rejection rates, and features that are found in the retina of eye are more reliable and stable features than those found in other biometrics.
This paper presents a new system for personal recognition based on retinal vascular pattern. This system is insensitive to rotation and robust to noise and brightness variations. The presented system consists of three main stages (i.e., preprocessing, feature extraction, and matching stage). Preprocessing is used for enhancement and segmentation the vascular network (i.e., Region of Interest), as discriminating feature the set of local average of vascular densities have been used in

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feature extraction stage, finally Euclidean distance measure used in matching stage. The proposed system is evaluated on the two publicly available databases: (i) STARE (Structured Analysis of the Retina) and (ii) DRIVE (Digital Retinal Images for Vessel Extraction). The test results indicated that the attained recognition accuracy of the proposed method is 100% for both datasets.

Keywords: Retinal vessels; human identification; vascular extraction; retina recognition system, biometric technology.

1. INTRODUCTION

Biometric is the science of identifying and verifying the identity of a person based on physiological or behavioral characteristic [1,2]. Biometric security system are widely used which mostly include face recognition [3], fingerprint [4], speech recognition [5], iris [6] and etc. The retina is considered as the most accurate and reliable biometric [7], because of the complex structure of capillaries which supply the retina with blood, each person's retina and also person's eye is unique and has unchanging nature. Retina based identification systems are mostly used in high security area (e.g., sensitivity center, biological laboratory, and POW reactors).

There are two famous studies which confirmed the uniqueness of retina blood vessel pattern, the first was published in 1935 by Dr. Carleton Simon and Dr. Isodore Goldstein [8]; they discovered that every individual has unique and different vascular pattern. Later, they published a paper which suggested the use of photographs of these vascular patterns of the retina as a tool to identify people. The second paper was published in 1950 by Dr. Paual tower [9]; he discovered that even among identical twins. Retina scan technology captures and analyzes the pattern of retinal blood vessel on thin nerve of the back of the eyeball [10]. Because retina is not directly visible, so retina scanner is used to take image of vascular pattern. The retina scanning system was launched first by in 1985 [11].

This paper is organized into five sections. Section 2 presents the related literature review, section 3 illustrates the proposed methodology, and section 4 shows some of results attained during the tests applied on the taken two datasets. Finally, some conclusions are given in section 5.

2. LITERATURE REVIEW

During the last years, an increase is noticed in the research efforts toward developing systems dedicated to recognize humans through retinal images due to the increased need for the system to identify the person that is more reliable and stable with low error rate. Many researches have been appeared in the literature. These studies introduced different methods which vary in terms of processing time and efficiency. Some of the previous works relevant to recognize the people using blood vessels analysis are listed below:

Frazin et al. [12] presented a novel retinal identification method; it consists of three modules; which are: (i) vascular grids segmentation, (ii) feature extraction, and (iii) matching stage. First, localization the optical disc and remove its effect in retinal image by using template matching technique, vascular and background contrast was enhanced via by using local contrast enhancement(LCE), then morphological operation applied to fill the blank space between the two parallel curves after LCE process, and histogram thresholding technique used to achieve binary image containing the vascular pattern. In the next stage, generated the features (i.e., vascular diameters and their relative angles and locations) by using four sub modules: (i) vascular masking in the vicinity of optical disc, (ii) planar transformation to obtain a rotation invariant binary image containing major retinal vascular, (iii) multiscale analysis of the polar image by using wavelet transform in order for separating vascular according their diameter sizes, and finally (iv) feature vector construction from three image, each containing vascular with specified range of diameter size. In the last stage, modified correlation (MC) measure in order to obtain the similarity index between the feature vectors for each scale, then computed the total value of the similarity index by summing scale weight similarity indices. Their proposed method was evaluated on DRIVE database, and the obtained identification accuracy rate was 99%.

Barkhoda et al. [13] proposed a new retinal identification system using angular partitioning. The first stage of the proposed system is the preprocessing step in which the extra margins of the retinal image are cropped and the boundary box of retina is extracted from the input retina to achieved translation invariant features then the cropped image is normalized to achieve the scale invariant, and the adopted a similarity approach applied to extract the vascular pattern. Then, the extracted vascular pattern is passed through a morphological thinning process. After thinning, the produced vascular network is fed to features extraction stage to produce the features vectors depending on the angular partitioning of the pattern image. The extracted feature vectors have been analyzed the discrete Fourier transform and the Manhattan metric was used in order to measure the closeness of the feature vector. This proposed system tested on 360 images from DRIVE dataset, their proposed system had achieved accuracy rate 98%.

Cemal et al. [14] presented a person identification system using retinal vasculature in retinal images which tolerates scaling, rotation, translation through segmenting vessel structure and then employ similarity measurement along with the toleration. They tested their system on Four hundred retinal images, and the best obtained recognition rate was 95%.

Sabaghi et al. [15] proposed a new biometric identification system based on combination of Fourier transform and special partitioning and wavelet transform. At first, optical disc was localized using template matching technique in order to rotate the retinal image to reference position, then used wavelet transform and angular partitioning of the frequency spectrum information of retinal image for feature extraction. Finally Euclidean distance used for feature matching. This proposed system was tested using DRIVE dataset, and the achieved 99.1% for accuracy rate.

Rubaiyat et al. [16] presented a biometric scheme based on color retinal images. The scheme includes three stages (i.e., preprocessing, feature extraction and vessel matching). In first stage, the green plane of retina image is chosen while the other two bands are discarded. Then, the preprocessing steps are applied; they are localization of the field of view, translation adjustment, enhancement of blood vessel by grey level homogenization, then localizing the vascular pattern by Thresholding, and finally apply morphological operations. In second stage, the energy feature of vesicular blood vessel is determined from the polar transformation of prominent vascular extracted image. Finally, feature matching stage is applied using fast normalized cross correlation. This method was tested on DRIVE and STARE database, and the obtained recognition accuracy was 100% for STAER DB and 99.71 for DREIVE DB.

Monisha et al. [17] presented a robust method of human authentication based on the retinal vascular patterns. First, top halt and bottom halt filtering are applied, and median filtering was applied repeatedly for smoothing. Then, thresholding process is used to segment the vascular network from the retinal image. After that, thinning is performed to extract the skeleton of the blood vessels based on the morphological image analysis. Feature points (i.e., blood vessel bifurcation and ridge ending) are extracted for classification using crossing number method. Finally, Euclidean distance measure was used for matching between all the feature vectors. The proposed method was tested on DRIVE, STARE datasets. The attained recognition rate was 96% for STARE dataset, 97.5% for DRIVE dataset.

3. THE PROPOSED METHODS

The proposed approach aims to recognize people by analysis of retinal blood vessel pattern extracted from their retina images. The proposed system offers high recognition accuracy and enough stability for brightness variations and rotation. It consists of many stages; they are: (i) image preprocessing stage to enhance the vascular relative to its surrounding objects, (ii) segmentation of vascular pattern, (iii) post preprocessing stage to enhance the extracted vascular, (iv) features extraction; and finally (vi) features matching. Fig. 1 shows the layout of the proposed retina recognition system. Each module of the developed system is described in the following sub-sections.

3.1 Preprocessing

The preprocessing stage is a primary stage in any recognition system; it is developed to manipulate the image data and making it in more suitable for features extraction task. In the proposed system the pre-processing stage covers the tasks: (i) prepare the proper gray image variant, (ii) allocate the retina field of view (FOV) in the image, and (iii) enhance the image brightness in order to ensure the success of extracting blood vessels pattern (region of interest) process. The applied preprocessing stage consists of the following steps:

3.1.1 Gray image preparation

At first the input bitmap color image is converted to gray image, because it carries just the intensity information that is required to perform the allocation of the retina FOV step. The colored image is converted to a gray image using the following equation [18]:

$$I(x,y) = \frac{1}{3}\left(I_{red}(x,y) + I_{green}(x,y) + I_{blue}(x,y)\right) \quad (1)$$

Where, I() is the generated gray image. Fig. 2 shows a sample of the retina image, and the produced gray variant.

3.1.2 Allocation of the retina field of view (FOV)

Since, the retinal image does not contain only the retina area, it also holds the surrounding background. So, the field of view of retina area must be isolated (as retina FOV) from other areas in the image. This step is accomplished by calculating the image histogram at the boundaries of whole image. A scanning for the histogram within the dark region that lay at the four image corners is done in order to determine the proper threshold for isolating the retina field of view. From the determined histogram, at first the local peak value of the histogram (MaxHis) at the dark side (i.e., close to black gray side) is detected. MaxHis has the highest frequency of occurrence relative to the neighbors. Next, the first valley (MinHis) coming after MaxHis is detected. MinHis has the lowest histogram value relative to its neighbors. Then, the corresponding gray value (T) for MinHis is taken as the threshold value to do image binarization and making a binary mask for defining the retina FOV region. The binarization process is accomplished using the following equation:

$$M_{bin}(x,y) = \begin{cases} 0 & if\ Gry(x,y) < T \\ 1 & Otherwise \end{cases} \quad (2)$$

Where $M_{bin}()$ is the produced binary image (mask). A sample of the resulting mask is shown in Fig. 3B.

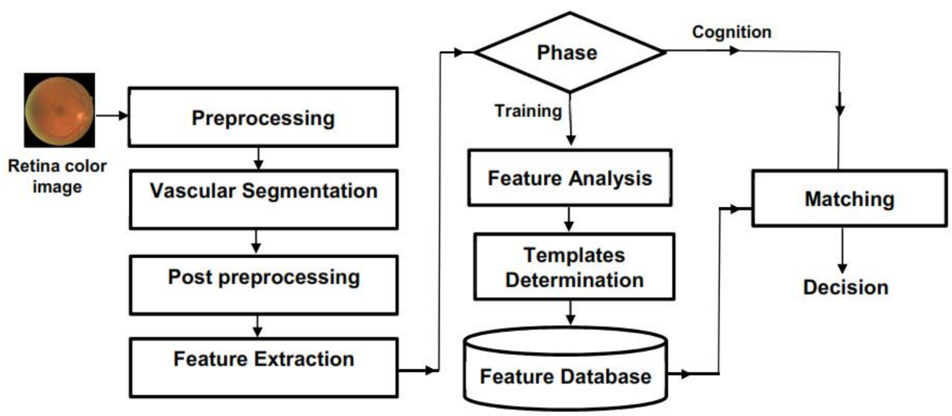


Fig. 1. The layout of the proposed method

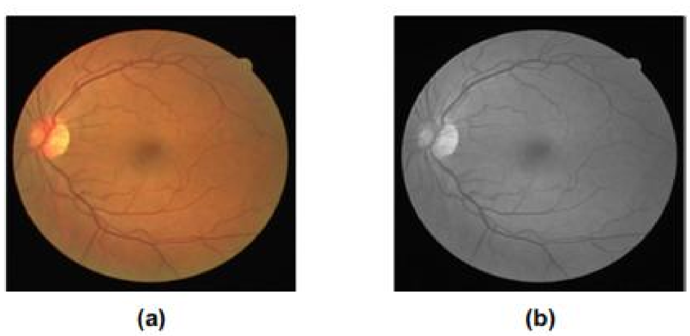
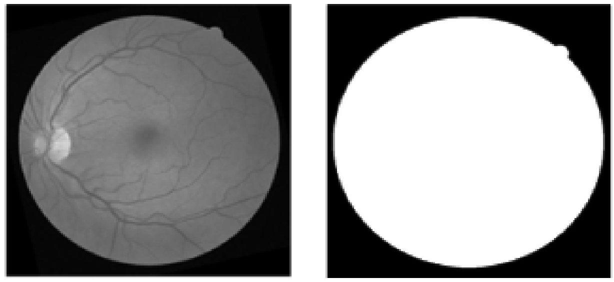


Fig. 2. Gray image preparation: (a) Before, (b) After



(A) Green channel **(B) Mask image**

Fig. 3. The extracted binary mask image

3.1.3 Compensation of brightness

Retinal images have low noise and non-uniform spatial brightness. This processing stage aims to remove the existing low noise and to handle the non-uniform illumination appeared in the gray image variant of the input retinal image. This stage implies the following steps:

(1) The gray level of the retinal image, Gr_Img(), is filtered using mean filter in order to eliminate the low noise that may exist in Gr_Img (). Then, the output image is divided into small non-overlapping blocks. The size of each block is set (wxw). The mean value, M(k,m), for each part is calculated and assigned as the mean value for all pixels belong to the block, then a new image array M_Img() is generated by replacing each pixel value belong to certain block with the corresponding computed mean value of that block. In this work, the value of block size (wxw) was taken (11x11), because around this value successful segmentation results are attained.
(2) Then, the subtraction process is applied by subtracting each pixel value in M_Img() from the corresponding pixel value in Gr_Img (). This step suppresses, up to suitable extent, the local lighting variation and, consequently, reduces the appearance of unwanted areas (including the optical disc). For this reason the local mean compensation process is more suitable to be used instead of the global mean compensation, as illustrated in Fig. 4.

3.1.4 Background compensation

A mapping process was applied to more reduce (i.e., smooth) the small local intensity variations inside the retinal area (e.g., background, optic disc, fovea, and macular area), this step is to facilitate the process of segmentation and avoid the occurrence of false blood vessels segments. The proposed mapping process is applied by feeding each pixel output from the previous process to the following equation:

$$\Delta' = \frac{A * Exp\big(\alpha(\Delta - T)\big)}{Exp\big(\alpha(\Delta - T)\big) + 1} \tag{3}$$

Where, Δ represents the brightness difference of pixel (relative to the corresponding local mean); α represents the rate coefficient of transition from bright area to the dark area; A represents the strength coefficient, when it is given high value it works on bleaching vascular areas to increasing the appearance of blood vessels; T is a percentage to hide some area. Fig.5 shows the result of this process. In the proposed system the used (α, A & T) values are set (0.3, 600, 15), respectively.

3.1.5 Low noisy background remover

Due to the emergence of distortions in the background area of retina FOV the process of low noise removal is needed in order to solve. At first, the mean brightness of all pixels lay inside FOV retina area is calculated. Then, a certain percentage (p) from the calculated mean value is taken as ambient background, and it is subtracted from all pixel values Bc_img(). In this work, the value of (p) was taken (0.1). This process will darken the circular area while keeping the vascular areas bright and visible, an example result of this process is shown in Fig. 6.

3.1.6 Emphasis of the edge contrast

Blood vessels usually have poor local contrast. Due to this weakness, contrast stretching step was applied to increase blood vessels contrast from the background of the retinal image. As next step the local contrast of the dark pixels is increased using non-linear gamma contrast stretching method. The process of contrast emphasis was done by computing the mean (μ) and standard deviation (σ) values. The average of low (L) pixels values and the average of high (H) pixels values of the image are assessed using statistical bases. These two values are less affected by the impulsive noise which may appear in the image. Taking into consideration that the output values of applying both minimum & maximum operators on the image array are greatly affected by impulsive noise, this causes bad reflectance on the process of brightness stretching. So, the use of statistically-based assessed values (i.e., L & H) leads to more robust brightness stretching results. In this paper work, the values of L and H are assessed using the following equations:

$$L = \mu - \alpha_1 \sigma \; ; \quad H = \mu + \alpha_2 \sigma \qquad (4)$$

Where, α is the dispersion ratio from the mean (μ) in terms of standard deviation (σ), in this work its value is set (0.8). The below non-linear gamma mapping equation is applied just on pixels belong to fundus area:

$$I'(x,y) = \begin{cases} 0 & if\ Gry(x,y) \le Min \\ 255\left(\dfrac{Gry(x,y) - Min}{Max - Min}\right)^{\gamma} & if\ Min < Gry(x,y) < Max \\ 255 & Otherwise \end{cases} \qquad (5)$$

Where, Gry() is the grey image, I'() is the produced image, γ is the predefined exponent value (in this work, its value is set 0.9). Fig. 7 shows an output sample of this non-linear gamma stretching process.

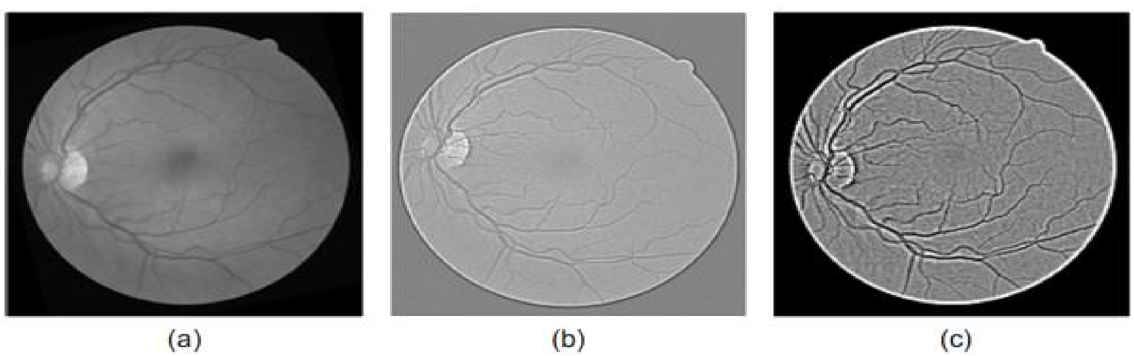


Fig. 4. Local mean compensation: (a) Input image, (b) After global mean compensation, (c) After local mean compensation process

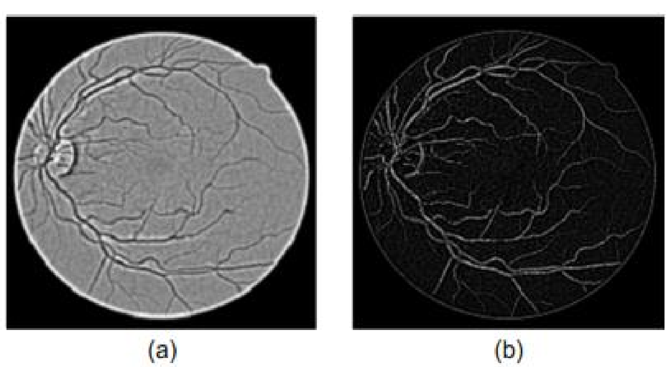
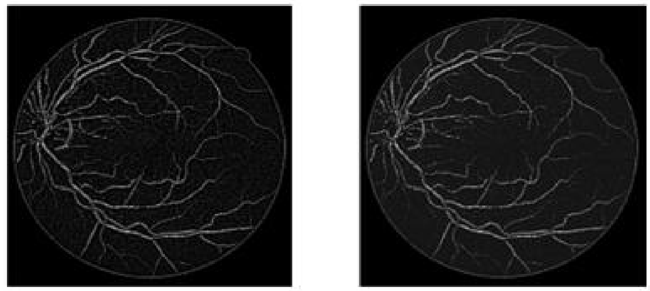
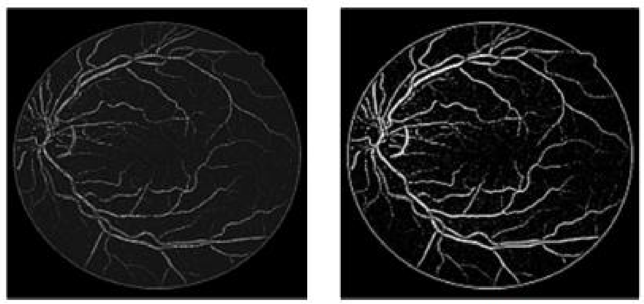


Fig. 5. Background compensation: (a) Before, (b) After



(a) (b)

Fig. 6. Low noisy background removal: (a) Before, (b) After



(a) (b)

Fig. 7. Emphasis the edge contrast: (a) Before, (b) After

3.2 Extraction of Connecting Blood Vessels

This stage is vital for extracting the blood vessels from retina image; therefore, the region growing methodology can be used to collect the pixels of connected blood vessels, since, the pixels belong to blood vessels network are connected with each other. In this proposed method, the seed filling algorithm [19] was used as region growing tool for extracting the blood vessel patterns from retina image. The applied seed filling steps are:

(1) Start vertical-horizontal sequential scan to all pixels of the produced binary mask image, and check each one, if it is a black pixel (0) then this pixel is considered as a seed point of a segment; and add it to a temporary buffer (called Segment Buffer).
(2) Then, test the four connected (i.e., up, down, right and left) neighbors of the pixel added to the segment buffer. If each one of the four connected pixels is black then add it to the segment buffer. Each added point is flagged in the image array as visited point (i.e., assigned a value 3) in order to avoid visit repeat.
(3) Step (2) is repeated, sequentially, to all points listed in segmented buffer, till the last pixel in the buffer is scanned and no further neighbors pixels are added to the buffer.
(4) After collecting a segment that contains all connected black pixels to the seed point. Then, the size of the segment is checked. In case the size (i.e., number of pixels listed in segment buffer) is small then all points of this segment are flagged as visited white pixels, otherwise they flagged as black visited points.
(5) Then continue the vertical-horizontal pixels scanning till finding a new seed that belong to new segment. Otherwise the scanning is continued till reaching the last pixel in image mask array and no new seed point is met.

Fig. 8 presents a sample of results after applying seed filling algorithm. In the proposed system the threshold value for acceptable segments size is taken 15.

3.3 Post Preprocessing

In the previous stage a rough attempt toward blood vessels extraction is taken; it provides the true segments of the blood vessels network with some false segments (e.g., small islands and outer boundary edge), as shown in Fig. 8b. Due to the appearance of these false segments, this stage is added in order to improve the shape of the vascular network; it reduce the effect of these undesired segments pieces via removing small island pixels (white), and removing outer boundary edges to achieve better vascular extraction results. These overhaul tasks was accomplished through applying the following tasks: (a) outer boundary removal, (d) vascular thinning, and (e) cleaning of small islands.

3.3.1 Outer boundary removal

The outer boundary region of the retina area is flagged as part of target area (i.e., blood vessels segment) in the segmentation stage. Its existence leads to an increase in the false positive rate of segmentation stage accuracy; thus some additional steps are needed to remove this false region in order to achieve high segmentation and recognition accuracy.

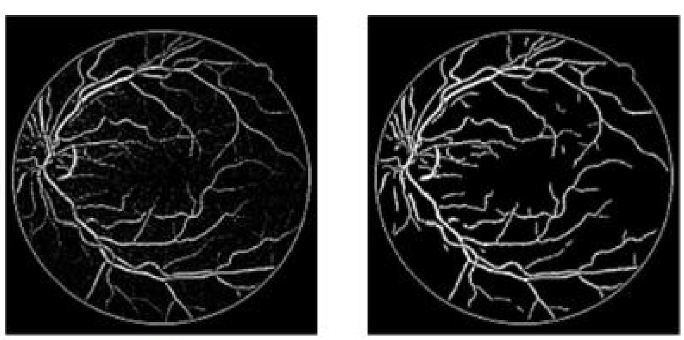
This removal task is done via searching for the white pixels exist in image that produced after implementing the tiling process; then for each met white pixel open a window of size (L×L) around it, and check if there is any pixel lay inside the opening window and was already flagged as not belong to the surrounding background area (i.e., outside FOV; in other words if the pixel has value (0) in mask image array Mask_Img). if the non-FOV pixel(s) is found in the scanned window then the tested white pixel is considered as outer boundary pixel and remove by converting its value from white pixel (1's) to black pixel (0's). Fig. 9b shows the output image after the outer boundary removal process.

3.3.2 Vascular thinning

The thickness of extracted blood vessel patterns may be different because of the physiological status and/or may due to some processing operations. So, the thickness of the blood vessels in the segmentation image does not show stable pattern which in turn causes degradation in recognition accuracy. Therefore, there is a need for thinning process in order to make the thickness of allocated blood vessels more uniform while retaining the essential spatial features of the vascular network. In the proposed system, thinning process is done using fast parallel thinning algorithm [20]. A sample of the input and output of thinning process is shown in Fig. 10.

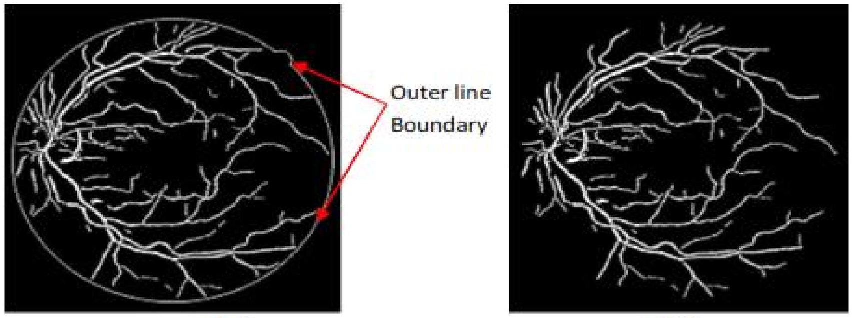
3.3.3 Cleaning of small islands

This step is essential to eliminate the small islands in the generated vascular thinned image; these islands are considered as noise patches and they are parts of the background; they classified as vascular due to miss thresholding. Seed filling algorithm was applied for handling the removal process of these islands to give more acceptable vessels allocation results in comparison with the results produce by applying erosion operations for many times. The process was adjusted to remove the small objects from the image without altering the overall shape and size of the large objects (blood vessels object). The test results indicated that the best value for the threshold of size segment is 30. Fig. 11b shows the result of cleaning small islands process.



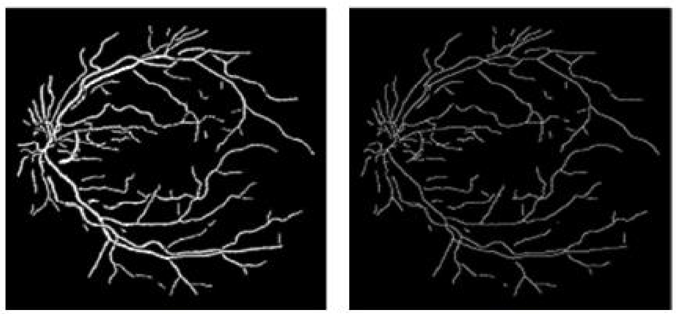
`(a) (b)

Fig. 8. The effect of region growing: (a) Before, (b) After region growing



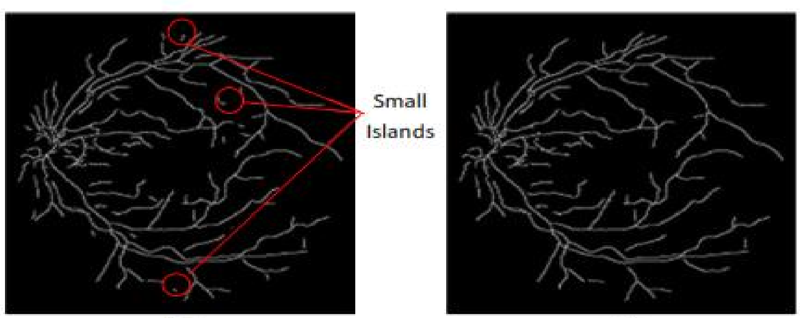
(a) **(b)**

Fig. 9. Outer edge removal: (a) Before, (b) After



(a) (b)

Fig. 10. Thinning process: (a) Before, (b) After



(a) **(b)**

Fig. 11. Cleaning small islands: (a) Before cleaning small islands, (b) After cleaning small islands process

3.4 Feature Extraction

In our proposed retina recognition system, a set of features of local average of vascular density is chosen as discriminating features for recognition purpose. This method has less computational cost, it is applicable in spatial domain, and reflects the vascular structure density in each part of image. Also, it can reflect the vascular structure density at different scales. So, to extract this set of features from the retina image the following steps have been applied:

1. The image of the extracted blood vessels from preprocessing stage is divided into overlapped blocks. The choice of overlap partitioning is to compensate the probable shifting of the blood vessels that may occur during capturing the retinal image due to the movement of head / eye. The degree

of overlapping between blocks is controlled by the overlapping ratio parameter which represents the ratio among the extracted block length and the original block length. Fig. 12 illustrates how the image is divided into overlapped blocks (green bounded blocks); firstly the image is partitioned into non-overlapped blocks (red bounded blocks), then overlapping margins are added at the area surrounding the original block to define the overlapped blocks.

2. Then, the average energy of each block is calculated by dividing the sum of computed number of blood vessels points (i.e., the number of non-zero valued, 1's, pixels) by the block size. Although many features can be used to represent the spatial distribution of the edges (vessels) network, the average density values of all blocks have been used to construct the feature vectors that representing each vessel sample for two reasons:

   (a) They passed the inter / intra scattering ratio test; which in turn proved that this kind of features has enough discrimination capabilities to lead for successful recognition decisions.
   (b) The determination of this set of features require low computation load.

3. After calculating the average vessels points' density of each block, then the average density list is assembled in feature vector.

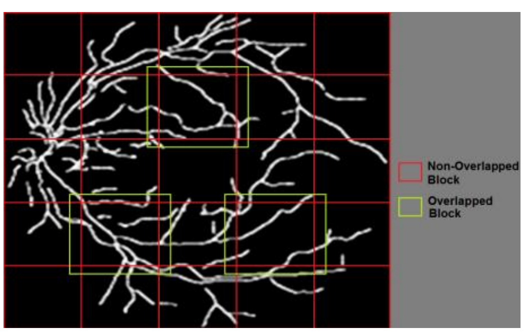


Fig. 12. Image partitioning into overlapped block

3.5 Matching Process

Feature matching is the most crucial part of any biometric system. It is used to calculate the degree of similarity between two blood vessels patterns; the distance is computed between the features vector of the template stored in the DB and of the tested image. In the proposed method the degree of similarity is determined using Mean Absolute Distance (MAD) metric; it is defined as follows:

$$MAD(F_i, T_j) = \sum_{k=1}^{N} |F_i(k) - T_j(k)| \qquad (6)$$

Where, F_i represents the tested i^{th} feature vector extracted from the retina input image, T_j represents the j^{th} template feature vector registered in the database.

4. RESULTS

Two datasets have been used for performance evaluation of the proposed method, they are: DRIVE [21] and STARE [22,23] datasets. The DRIVE dataset consists of 40 images with (768×587) pixels of resolution, they divided into 20 for training and 20 for testing. The STARE dataset consists of 20 RGB color images of retina, the images are of size (605×700) pixels of resolution. The 60 images (40 from DRIVE and 20 from STARE) have been used for identification/ verification purpose, each image was subjected to four levels of brightness variation and are add noise (i.e., pepper and salt) noise also generating other two samples by little changing the rotation of the original image; such that a total of 9 images variants have been produced from each retina image. Thus a dataset consists of simulated 540 images (i.e., 360 for DRIVE and 180 for STARE) is established.

The proposed system achieved high accuracy of vascular segmentation; achieved 0.9495% for DRIVE dataset, while 0.9583% for STARE dataset. Also, our proposed method gave better recognition rate results when compared with the methods listed in literature review section. As shown in the following table, the proposed method is more accurate in recognition rate in comparison with other published methods in literature. The need of thinning stage before feature extraction stage, in order to get the skeleton of an image through removing all redundant pixels and producing a new simplified image with the minimum number of pixels possible, so feature analysis could be done easily. Additionally, the idea of partitioning retinal image into overlapping blocks is suitable, because it improved the recognition accuracy; it helps to overcome the partial loss in low quality retinal images. The recognition rate is highly

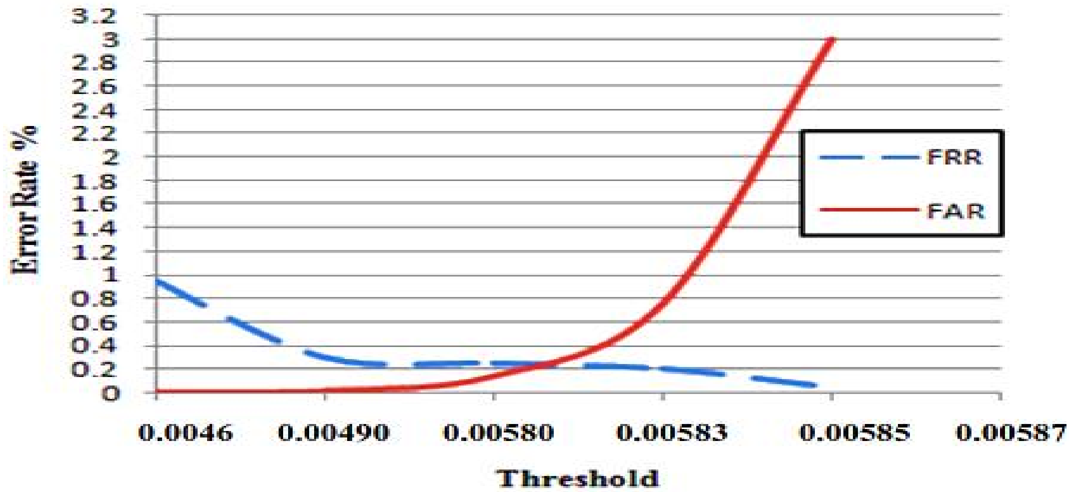


Fig. 13. Relation curve between FAR, FRR and accuracy versus different threshold values for the SDLAVDE method

affected by the variation of the number of blocks and overlapping ratio. The best attained recognition rate occurs when the number of blocks is 14 and the overlapping ratio is (0.3). The proposed method requires 6.9 seconds to accomplish accurate personal recognition for DRIVE dataset and 8.1 seconds for STARE dataset. For purpose of performance evaluation of the developed authentication system, the verification accuracy was analyzed using false rejection rate (FRR) and false acceptance rate (FAR) in addition to their two complementary rates (i.e., TRR & TAR). These parameters have been determined at various threshold values that required for making matching decisions. For purpose of performance evaluation of the proposed authentication system, the verification accuracy was analyzed using false rejection rate (FRR) and false acceptance rate (FAR) in addition to their two complementary rates (i.e., TRR & TAR). These parameters have been determined at various threshold values that required for making matching decisions. Fig. 13 illustrates the relation between FRR and FAR versus different threshold values for the verification method that based on Spatial Distribution of Local Vascular Density (SDLVDE). From the figure, we can notice that the value of EER point is equal to 0.21% at the threshold value 0.0058. Table 1 presents the recognition rate achieved by some previously published works and our proposed work. The listed results in both tables indicate that the proposed method leads to less false detection rate, and can capture both thick and thin blood vessels with less computational requirement. Also, the comparison with manually labeled images indicated that some parts of thin blood vessels cannot be extracted it. So, in future an enhancement for the pre-processing stage is required to raise its capability to collect the thin and small vascular segments.

Table 1. Comparison of different methods results using recognition accuracy criteria for the DRIVE database and STARE database

Method	DRIVE	STARE
Frazin et al. [12]	99.00%	-
Barkhoda et al. [13]	98%	-
Rubaiyat et al. [15]	100%	99.71%
Sabaghi et al. [16]	99.1%	-
Monisha et al. [17]	97.5%	96%
Proposed method	100%	100%

5. CONCLUSION

Vascular network in human retina have high degree of singularity (uniqueness) which making the founded retina biometrics methodology as an emerging security and authentication technique. Retin1as biometric are robust and steady for human authentication more than other biometric technologies. Retina contains a complicated structure of capillaries which feeding the retinal with bloods to all retina regions. In this paper, an efficient approach is proposed for individual recognition system based on retinal vascular, because among several available biometric system, retina recognition are said to be the most secure system and stable because the vascular patterns are unique and it is hard to be lost or making a copy of it. The proposed system consists of three main stages (i.e., preprocessing, feature extraction and finally matching stage). In comparison with other retina recognition methods appeared in the literature; the concept of spatial distribution of the local distribution of vascular density offers high discrimination feature. The results of the tests conducted on the two public datasets (i.e., DRIVE and STARE) indicated that the performance of the proposed method is too high (i.e., 100% recognition rate) for both datasets.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/12989