Personal Identification algorithm based on Retinal Blood Vessels Bifurcation

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Abstract

Biometric identifiers are the unique, measurable characteristics used to tag and describe individuals. Physiological characteristics are related to the shape of the body. Examples of biometric identifications are, fingerprint, face, DNA, Palm print, hand geometry, iris recognition, and retina. Human retina is another source of biometric system which provides the most reliable and stable means of authentication. We propose a new algorithm for the detection and measurement of blood vessels of the retina and finding the bifurcation points of blood vessels for personal identification. A minutiae technique for finding bifurcation points of the extracted blood vessels and according to bifurcation points identifies the individual person. Performance of these techniques is tested using the database from Dr. Manoj Saswade and Dr. Neha Deshpande (300 Images). This algorithm achieves a true positive rate of 98%, false positive rate of 20%, and accuracy score of 0.9702 and also classification down through Statistical Techniques.

Keywords

Blood Vessels Extraction, Bifurcation Points.

1. Introduction

Biometrics offers greater security and convenience than traditional methods of personal recognition. Biometrics are used in automated personal recognition and identification systems especially at high security regions in some applications, biometrics can replace or supplement the existing technology. In others, it is the only viable approach[1]. Biometric identifiers are the unique, measurable characteristics used to tag and describe individuals. Commonly used Biometric identifications are, fingerprint, face recognition, DNA, Palm print, hand geometry, iris recognition, and retina. Human retina contains vascular pattern which is unique in every individual and can be used in biometric system. The foundation of retinal recognition is the pattern of blood vessels present in human retina [2]. Retinal images are captured using digital fundus camera, in Saswade eye clinic Topcon TRC 50 EX is used. In order to scan retina, the person must position his eye very close to the lens of camera and should remain still during scanning procedure. Once the scanner is activated, the green light moves in a complete circle and captures the fundus region containing blood vessels[3]. Proposed algorithm shows the blood vessels extraction and detection of the bifurcation points of the vessels to identify the person. For observing the result we have taken the database form Dr. Manoj Saswade and Dr. Neha Deshpande, in this database total three hundred high resolution fundus images.

2. Methodology

Consider figure 1, it shows the flow of proposed algorithm for extraction of retinal blood vessels from high resolution fundus image. Initially preprocessing is done on the captured high resolution fundus image. Green channel is separated from rgb image. Histogram equalization for enhancement of image is done, then intensity transformation function for image contrast adjustment is carried out. Complement function is used for enhancement of intensity transformation image. After enhancement of blood vessels threshold function is performed for extraction of retinal blood vessels. Morphological Skeletonozation is done for calculating the centerline of blood vessels and minutia technique is used for labeling the bifurcation points. A database formed after collecting the image from Dr. Manoj Saswade and Dr. Neha Deshpande. This database has total 300 fundus images. Through the system bifurcation points for all 300 images are calculated and stored in one dataset. Whenever an image is entered, its bifurcation points are calculated and they are matched with the bifurcation points available in the dataset. If match is found then for the system, person is authenticated otherwise not.

2.1 Preprocessing

The Preprocessing is done to remove noise (pixel whose color is distorted) from background and to enhance the image. In the first stage of preprocessing green channel is taken out, because green channel shows high intensity as compare to red and blue.

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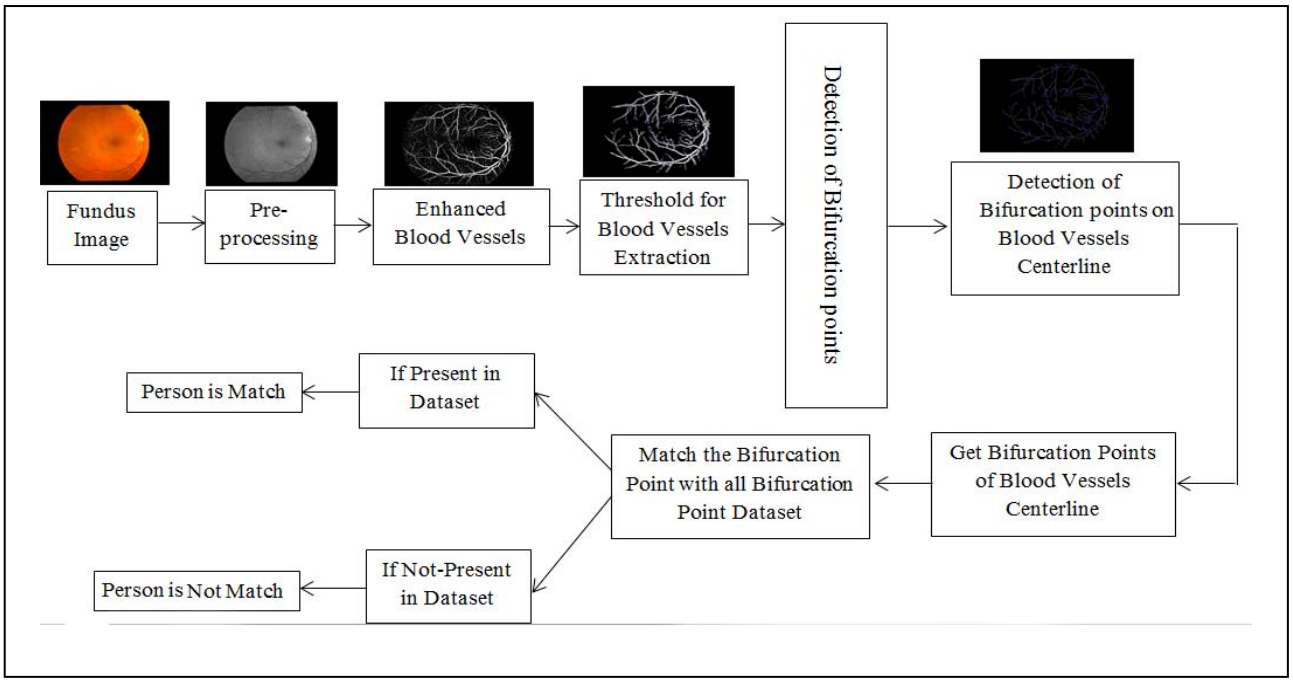

Figure 1: Flow chart for proposed algorithm of Extraction of the Retinal Blood Vessels and Detection of the Bifurcation Points for Person Identification

Mathematical formula for finding green channel is as follows

$$g = \frac{G}{(R + G + B)} \qquad (1)$$

Here g is a Green channel and R, G and B are Red, Green and

Blue respectively.

2.2 Blood Vessels Extraction

Use the complement function for enhancing the blood vessels of the retina. Following formula is the mathematical representation of Complement function.

$$A^c = \{\omega \mid \omega \notin A\} \qquad (2)$$

Here A^c is a complement, ω is the element of A, $\notin$ stands for not an element of A and A is set.

Then use Histogram equalization function for enhancing the complementary image to adjustment of contrast for better quality of an image. Histogram equalization is very important method for enhancement, the following mathematical equation elaborate the histogram equalization

$$h(v) = \text{round}\left(\frac{cdf(v) - cdf_{min}}{(M \times N) - cdf_{min}} \times (L - 1)\right) \qquad (3)$$

Here cdf_{min} is the minimum value of the cumulative distribution function, M × N gives the image's number of pixels and L is the number of grey levels.

After enhancement, use the Morphological structuring element for enhancing the blood vessels of the retina. The following mathematical formula shows the dilation and erosion function.

$$I_{dilated}(i,j) = \max_{f(n,m)=true} I(i+n, j+m) \qquad (4)$$

$$I_{eroded}(i,j) = \min_{f(n,m)=true} I(i+n, j+m) \qquad (5)$$

Perform erosion and dilation for joining the corrupted blood vessels.

2.3 Detection of Bifurcation Point

Then use the Morphological open function for thickening the retinal blood vessels. The following mathematical formula shows the Morphological open function.

$$A \circ B = (A \ominus B) \oplus B \qquad (6)$$

Here $A \circ B$ is morphological opening, $\ominus$ is Erosion and $\oplus$ is Dilation.

Then use 2D median filter for highlighting and removing noise from the Morphological open function. The following mathematical formula shows the 2D Median Filter

$$y[m,n] = \text{median}\{x[i,j], (i,j) \in \omega\} \qquad (7)$$

Here ω Represents a neighborhood centered around location(m,n) in the image.

Then use the Threshold function for extracting the retinal blood vessels.

2.4 Centerline Bifurcation Point

$$T = \frac{1}{2}(m1 + m2) \quad (8)$$

Here m1 & m2 are the Intensity Values.

After threshold function we get blood vessels then perform morphological skeletanization function for calculating the centerline of extracted blood vessels.

Then used Minutiae Techniques for finding the bifurcation points of the extracted centerline of blood vessels of the retina

$$D_0(p) = \{\{(\beta_{l,k}, \omega_{l,k})\}_{k=0}^{K_l-1}\}_{l=0}^{L-1} \quad (9)$$

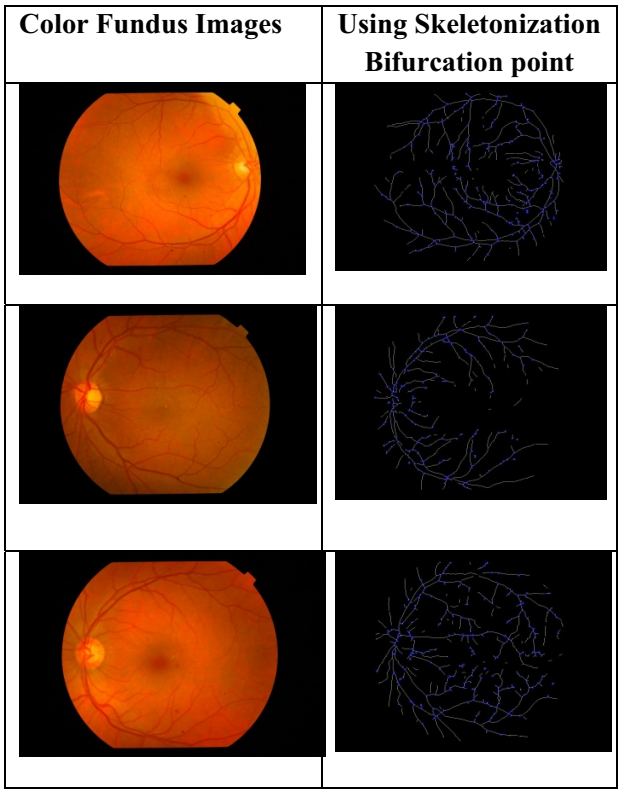

Figure 2: Fundus images and Images obtained using Skeletonization to detect bifurcation point

3. Result

For this algorithm we designed one graphical user interface (GUI) in MATLAB shown in the figure 7. For result analysis we have used Receiver Operating Characteristic (ROC) curve, this algorithm achieves a true positive rate of 98%, false positive rate of 20%, and accuracy score is 0.9702. For result analysis, statistical techniques like finding mean, variance, covariance, coefficient, normalization curve are performed. For performing the statistical technique ground truth of blood vessels bifurcation points and bifurcation points by proposed algorithm is considered. For calculating the retinal blood vessels bifurcation point we have taken 300 high resolution fundus images from doctors and extract the blood vessels by using proposed algorithm and label the bifurcation points to the extracted blood vessels. By the statistical techniques product moment correlation coefficient shows the output result as 1.63 ,thus it is proved that, this system generated output is similar to the ground truth.

$$Sensitivity = \frac{TP}{TP + FN} \quad (10)$$

$$Specificity = \frac{TN}{TN + FP} \quad (11)$$

Table 1: Bifurcation points manually and by algorithm

Sr No	Name of High Resolution Fundus Image	Bifurcation Ground Truth	Bifurcation by proposed algorithm
1	1	605	605
2	2	944	944
3	3	304	304
4	5	649	649
5	7	1431	1431
6	8	675	675
7	10	147	147
8	12	306	306
9	14	616	616
10	16	500	500
11	18	187	187
12	19	405	405
13	21	930	930
14	1	203	203
15	3	421	421
16	5	903	903
17	7	415	415
18	9	605	605
19	11	944	944
20	27	500	500
21	29	187	187
22	31	405	405
23	33	930	930
24	35	203	203
25	37	421	421

Perform Statistical Techniques for result analysis

- Calculate Mean

$$\text{Mean (X)} = \frac{113843.2}{204} = 558.0549$$

$$\text{Mean (Y)} = \frac{113843.2}{204} = 558.0549$$

- Calculate Variance

$$\text{Variance} = \frac{\sum(x - \bar{X})}{N} = \frac{113259.236}{204} = 555.192334$$

$$\text{Variance} = \frac{\sum(y - \bar{Y})}{N} = \frac{113259.236}{204} = 555.20701$$

- Calculate Standard Deviation

Standard Deviation (x):

$$\sqrt{\text{Variance(x)}} = \sqrt{555.192334} = 23.5625$$

Standard Deviation (y):

$$\sqrt{\text{Variance(y)}} = \sqrt{555.20701} = 23.5629$$

- Calculate Correlation

Correlation: $s = \frac{1}{N-1}\sum_{i=1}^{n}(x_i - \bar{X})(y_i - \bar{Y})$

$$S = \frac{1}{203}(113259.236)(113259.236)$$

$$S = \frac{1}{203}(226518.472)$$

$$s = 1110.38467$$

- Calculate Coefficient

Pearsons Coefficient of Correlation:

$$r_{xy} = \frac{\sum xy}{N\sigma_x\sigma_y}$$

Where,

xy = 86116547.99 N = 204

$\sigma_x = 23.5625$ $\sigma_y = 23.5629$

$$r_{xy} = \frac{86116547.99}{204 \text{ X } 23.5625 \text{ X } 23.5629}$$

$$= \frac{86116547.99}{23.919} = 9613.5$$

- Calculate correlation coefficient
Product moment correlation coefficient:

N = 204 $\sum y = 113843.2$

$\sum x = 113843.2$ $\sum y^2 = 227686.4$

$\sum x^2 = 227686.4$ $\sum xy = 86116547.99$

$$S_{xy} = \sum xy - (\sum x \sum y \div N)$$

$$= 86116547.9 - (113843.2 \times 113843.2 \div 204)$$

$$= 86116547.99 - (1116.11)$$

$$= 86115431.88$$

$$S_{xx} = \sum xx - (\sum x \sum x \div N)$$

$$= 227686.4 - (113843.2 \times 113843.2 \div 204)$$

$$= 227686.4 - (1116.11)$$

$$= 226570.29$$

$$S_{yy} = \sum yy - (\sum y \sum y \div N)$$

$$= 227686.4 - (113843.2 \times 113843.2 \div 204)$$

$$= 227686.4 - (1116.11)$$

$$= 226570.29$$

$$r = \frac{S_{xy}}{\sqrt{S_{xx}\, S_{yy}}} = \frac{86115431.88}{\sqrt{226570.29 \times 226570.29}}$$

$$= \frac{1093.87}{673.16} = 1.63$$

According to Product moment correlation coefficient shows the strong positive correlation. Hence it is clear that ground truth bifurcation are equal to proposed algorithm bifurcation. After calculating of these techniques, perform normalization curve on the basis of Z Score of ground truth and verses algorithm bifurcation to see whether both bifurcations are same or not.

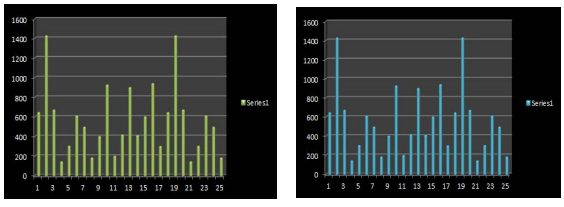

Figure 3: Blood Vessels Bifurcation Ground Truth and proposed algorithm

4. Conclusion

In this paper a biometric algorithm is presented for personal recognition based on retinal blood vessel bifurcation point of human retina. This algorithm has three stages consisting of preprocessing, Vessels extraction and matching according to bifurcation point. The first stage preprocesses the image. The second stage enhanced the blood vessels and segmented it using 2-d median filter. In the third stage minutiae technique is used for finding bifurcation point. In order to use vascular pattern for matching, the proposed system used bifurcations points as feature points. For performing these techniques we have used database from Dr. Manoj Saswade and Dr. Neha Deshpande. This algorithm achieves a true positive rate of 90%, false positive rate of 0%, and accuracy score of 0.9902.

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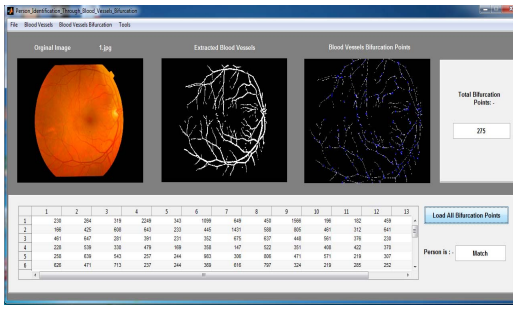

Figure 4: GUI for Person Identification through Retinal Blood Vessels Bifurcation Points