Research Article
An Efficient Method for Automatic Human Recognition Based on Retinal Vascular Analysis

Saba A. Tuama and Dr. Loay E. George

Department of Computer Science, College of Science, Baghdad University, Baghdad, Iraq

Abstract: Biometric security has become more important because of the Increasing activities of hackers and terrorists. Retinal biometric system is one of the most reliable and stable biometrics for the identification/verification of individuals in high security area rather than other biometric. Also no two people have the same retinal pattern and then cannot be stolen or forget. Due to these reasons this study presents a system for individual recognition based on vascular retina pattern. This approach is robust to brightness variations, noise and it is insensitive to rotation. The proposed method consists of three main stages (i.e., preprocessing, feature extraction and finally matching stage). Preprocessing is done to make the required color band separation, remove the rotation appearance which might occur during the scanning process and modify the image brightness to simplify the process of extracting vascular pattern (region of interesting) from input retina (i.e., feature vector) in the feature extraction stage. Finally, the discrimination process of features is evaluated and the results utilized in matching stage. The proposed method is tested on the two publicly available datasets: (i) DRIVE (Digital Retinal Images for Vessel Extraction) and (ii) STARE (Structured Analysis of the Retina). The achieved accuracy of recognition rate was equal to 100% for all datasets.

Keywords: Biometric security, human recognition, retina biometric, rotation invariance, vascular analysis, vascular patterm

INTRODUCTION

Biometric is the science of identifying and verifying the identity of a person based on physiological or behavioral characteristic (Jain *et al*., 2004; Al-Hamdani *et al*., 2013). Biometric security system are widely used which mostly include fingerprint (Ross *et al*., 2003), face recognition (Park *et al*., 2005), iris (Ibrahim, 2014), speech recognition (Plannerer, 2005) and etc. 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. The retina is considered as the most accurate and reliable biometric (Dwivedi *et al*., 2013). Retina based identification systems are mostly used in sensitivity center, biological laboratory and POW reactors which demands high amount of security (Jain *et al*., 2000).

There are two famous studies which confirmed the uniqueness of retina blood vessel pattern, the first was published in 1935 by Simon and Goldstein (1935); they discovered that every individual has unique and different vessel pattern. Later, they published a paper which suggested the use of photographs of these blood vessel patterns of the retina as a tool to identify people. The second paper was published in 1950 by Tower (1955); he discovered that even among identical twins, the patterns of retina vascular are unique and different.

This study presents a system for individual recognition depending on the vascular pattern of his/her retina images. The features extracted from retina images are more reliable and stable than other biometrics features.

REVIEW OF RETINA TECHNOLOGY

Anatomy of retina: The retina covers the inner side at back of the eye it is approximately 0.5 mm thick (Tabatabaee *et al*., 2006). The retina consists of many important parts, they are: Optic Disc (OD), blood vessel, macula and fovea. Figure 1 shows the elements of human retina. OD is the center of retina and it is about (2×1.5 mm) (Godse and Bormane, 2013), blood vessels that are connected patterns like tree with OD as root over the surface of retina, the diameter of these blood vessels about 250 mm (44 of retina diameter) (Goh *et al*., 2000), macula has 5-6 mm diameter, the fovea is the center of macula has diameter 0.25 mm. The retina contains two types of photoreceptors that are cones and rods; which are responsible for daytime and night vision.

Corresponding Author: Saba A. Tuama, Department of Computer Science, College of Science, Baghdad University, Baghdad, Iraq
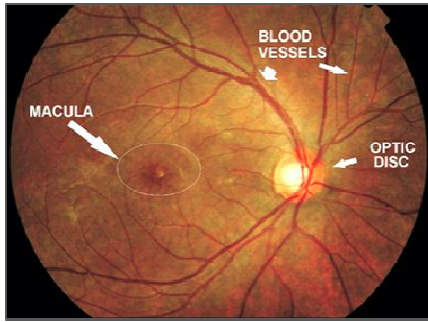
Fig. 1: Human retina

Retina scan technology: This technology captures and analyzes the pattern of retinal blood vessel on thin nerve of the back of the eyeball (Hájek *et al*., 2013). Because retina is not directly visible, so retina scanner is used to take image of vascular pattern. The retina scanning system were launched first by in 1985 (Farzin *et al*., 2008) and it was too uncomfortable for the user and too bright.

Retina scan requires persons to remove their glasses, place their eye close to scanner and look into particular device and concentrate on small point within it (Spinella, 2003). The retina scanner uses infrared light source to illuminate the retina. The infrared energy is immersed more rapidly by blood vessels in the retina rather than by the surrounding tissue (Wayman 2001; Mali and Bhattacharya, 2013). Then, the capturing image of retinal blood vessel is analyzed for characteristic points within pattern.

The strengths and weakness of retina scanning: Retinal recognition has strengths and weaknesses just like all other biometric technologies; but it has its own unique strengths and weaknesses. The strength of retina recognition technology may be summed as the follows:

* The vascular pattern of the retina unchanged during a person's life unless he/she affected by an eye diseases (such as: cataracts, glaucoma, etc.) (Qamber *et al*., 2012)
* The generated feature vector for a template representing a retina pattern is small; it is one of the smallest templates of biometric technologies (Hadi and Hamid, 2014)
* It has occurrence of false positive and offer extremely low (close to 0%) error rates (Sasidharan, 2014)
* As mentioned the retina is located inside the eye, so it is not exposed to threats as other biometrics (such as; fingerprint, hand geometry, iris, etc…)

But the weakness of retina scanning technology can be described as follows:

* The public perceives that retinal scanning is a health threat; some people believe that retina scan damage the eye and user unease about the need to position the eye in close proximity of the scanner lens (Qamber *et al*., 2012)
* Retina scanning device are very expensive to implement and procure
* An individual may be afflicted with some disease of the eye (such as cataracts, glaucoma and so on) which complicate the identification process (Farzin *et al*., 2008)
* Of all biometric technologies, successful retina scanning demands the highest level of user motivation and patience (Spinella, 2003)
* Retina scanning technology cannot accommodate people wearing glasses (which must be removed prior to scanning) (Dwivedi *et al*., 2013).

LITERATURE REVIEW

Many research works have been done to differentiate human according to their human retina. Some of the previous works relevant to recognize the people using blood vessels analysis are listed below.

Barkhoda *et al*. (2009) presented algorithm for detection and measurement of human blood vessels and finding the bifurcation points of vessel in order to personal identification, these bifurcation points considered as feature points to identifies the individual person. This algorithm tested on 300 images from Dr. Nanojswda and Dr. Dehadespir and achieved true position rate 98% accuracy of classification 0.9702.

Cemal and İki (2011) 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%.

Qamber *et al*. (2012) proposed a system for personal identification by blood vessels. The system consists of four stages which are: capturing of retinal image, preprocessing, feature extraction and finally matching stage. In the first stage, the retinal image is acquired, then, the preprocessing steps are applied. In the second stage, the blood vessels are enhanced and extracted using 2-D wavelet and adaptive thresholding operation. In third stage, the features are extracted and filtered. Finally, at the fourth stage the matching steps for the vascular pattern features are applied. The proposed method was tested on three publicly available databases (i.e., DRIVE, STARE and VARIA). The test results showed that the proposed method achieved an accuracy of 0.9485 and 0.9761 for vascular pattern extraction and personal recognition, respectively.

Dehghani *et al*. (2013) proposed method for human recognition based on retinal images. This method consists of the steps: feature extraction, phase correlation and finally feature matching. In feature extraction step they used Harris corner detector, then, the phase correlation technique was applied to estimate the rotation angle of eye movement. Finally, a

similarity function is used in matching step to compute the degree of similarity between features of different retina images. This method evaluated using both DRIVE and STARE datasets (including 480 retinal images). The test results referred that the system can reach high average true recognition.

Rubaiyat *et al*. (2014) presented 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 and 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 obtained 100% on STAER DB and 99.71 on DREIVE DB.

Farzin *et al*. (2008) presented a novel retinal identification method based on features extracted from retinal images. This method includes three modules which are blood vessels segmentation, feature generation and finally matching stage. First, the blood vessels are localized in the color retinal image. The output is passed through the feature generation module; it includes Optic Disc (OD) detection and, then, a circular region around OD is selected. After that polar transformation is applied and then a rotation invariant template is created. These templates were analyzed in three different scales using wavelet transform to separate blood vessel according their diameter sizes. The blood vessel position and orientation in each scale were used to define the feature vector for each subject in the dataset. Finally in matching stage, a modified correlation measure was proposed to obtain a similarity index of each scale of the feature vector. Their proposed method was evaluated on DRIVE database and the obtained identification accuracy rate was 99%.

THE PROPOSED METHOD

In this section, a simple and robust method for retina recognition system is introduced. The proposed method aims to recognize the people by analysis of retinal vascular pattern in retina with high accuracy and offers enough stability for rotation and brightness variations. It consists of six main stages:

- Image preprocessing stage to enhance the blood vessels relative to its surrounding objects
- Vesicular network extraction of blood vessels
- Morphological operations to enhance the extracted vascular network
- Extraction of spatial distribution of vessels directions to be used as vessels network features
- Features evaluation and templates establishment; and finally
- Features matching based on Euclidean distance measure.

Figure 2 shows the layout of the proposed method of retina recognition system. Each module of the developed system is described in the following subsections.

Preprocessing, blood vessels extraction and post processing stages: This stage aims to compensation the rotation variation problem and to enhance and segmentation processes for extraction the vascular network which is Region Of Interest (ROI) from color retinal image via applying many steps. Figure 3 presents the steps of this stage. Many of these steps have been explained in our previous article (Tuama and George, 2016) except the following sections.

Rotation compensation: One of the most challenging issues facing the cognition tasks relevant to retina blood vessels is the rotation of head or eye relevant to camera references. The rotation causes some problem in feature extraction and/or matching stages. So, it is important to address the impact of rotation by directing (i.e., rotating) the image such that the relative line passes
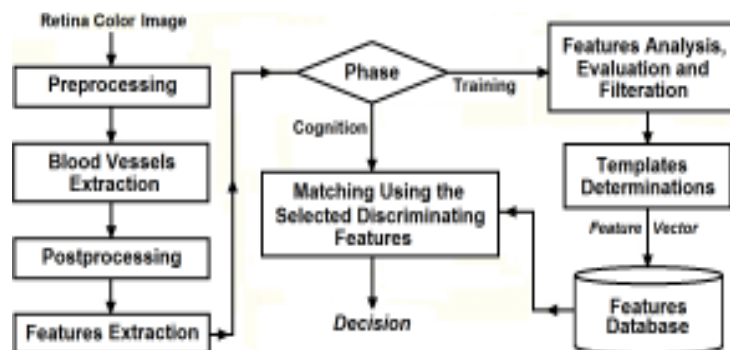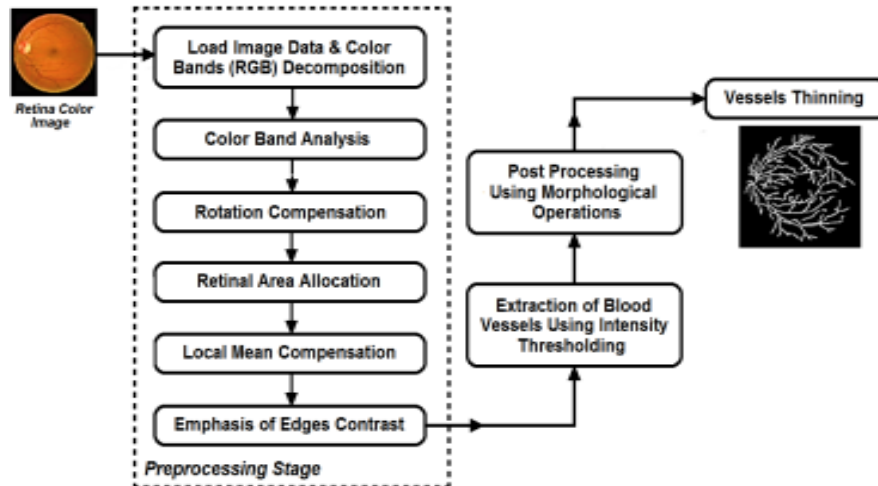

Fig. 2: The layout of the proposed method

Fig. 3: The steps of the first three stages (preprocessing, vessels extraction and post processing)

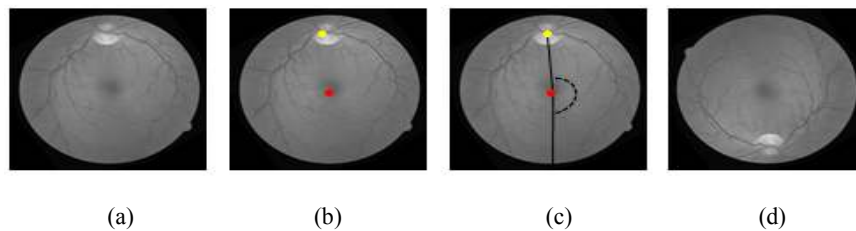(a)   (b)   (c)   (d)

Fig. 4: Rotation compensation; (a): Gray image; (b): Localized center of retina area and optical disk; (c): Obtain the angle of rotate; (d): The results after the rotation compensation process
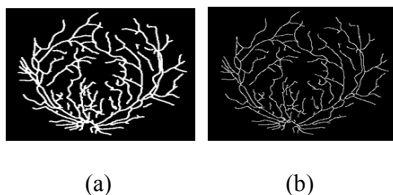

(a)   (b)

Fig. 5: The effect of thinning process; (a): Before; (b): After

between two certain reference objects, appeared in image, to be directed along certain direction. In our proposed system the line passes through the center of Optical Disc (OD) and the center point of the view of the retina image is directed down. The main two reference points are (Fig. 4a):

- **The center point of the retina image:** As the first reference point (Fig. 4b)
- **The center of optic disc:** It is localized by finding the brightest big region, then, select the center point of this region as the second reference point (Fig. 4c and d).

Thinning of extracted vessels: Thinning process is applied for reducing a shape body to its core components, while retaining the essential features of the original object. Because the extracted blood vessel patterns from previous stages have variable thickness,

so thinning is needful to make the width of vascular network equal to single pixel; it can be accomplished by deleting, iteratively, the outer edge points until the skeleton points of vessels remain. Thinning process can be done using fast parallel thinning algorithm (Zhang and Suen, 1984). A sample of the input and output of thinning process is illustrated in Fig. 5.

Feature extraction: In this stage, a set of discriminating information is extracted from the final processed image. The extracted information represents the required feature vector to distinguish between persons. Different sets of features have been suggested in the literature for purpose of retina recognition; some of the published works (Bevilacqua *et al.*, 2008; Xu *et al.*, 2005; Ortega *et al.*, 2009) suggested the use of blood vessel bifurcation and crossover points as feature points, while some other methods (Farzin *et al.*, 2008) have used the location of optic disc.

In our proposed method used two different sets of discriminating features have been used to achieve high accuracy for identification/verification. The used features are:

- Spatial distribution of the local average of vascular direction
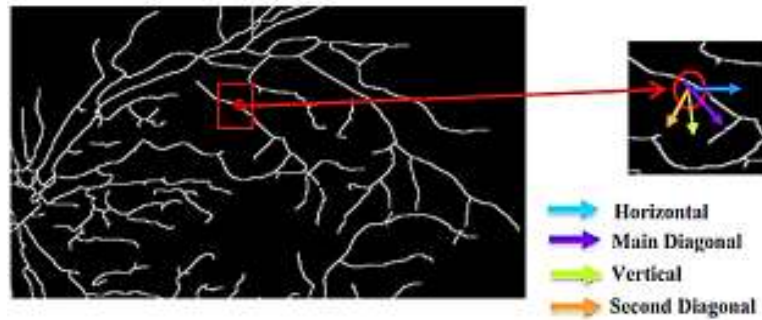- Spatial distribution of local average of vascular density.

Fig. 6: The process of checking the pixel direction

Spatial distribution of the local average of vascular direction: This set of features depends mainly on the distribution of blood vessels directions at different parts of the image. The steps of determining this set of features are:

- The direction of each vascular pixel in the image is determined by checking if the pixel is located in the blood vessel segment along the vertical, horizontal, main diagonal or second diagonal direction. Figure 6 illustrated the checked directions for each pixel.
- The resulting (2D) array of vessel directions is divided into overlapped blocks. The choice of overlap partitioning is to compensate the probable shifting of the blood vessel. The degree of overlapping between blocks is controlled by the overlapping ratio parameter which represents the ratio between the extracted block length and the original block length.
- The resulting (2D) array of vessel directions is divided into overlapped blocks. The choice of overlap partitioning is to compensate the probable shifting of the blood vessel. The degree of overlapping between blocks is controlled by the overlapping ratio parameter which represents the ratio between the extracted block length and the original block length.
- The average of local direction is determined for each block separately and the average values for all blocks are assembled as elements of the feature vector.

Spatial distribution of the local average of vascular density: Each image of the extracted blood vessel is divided into overlapped blocks with predefined overlapping ratio. Then the average energy of each block is calculated through dividing the sum of computed number of vessels points (i.e., the number of non-zero valued, 1's, pixels) by the block size. After calculating the average vessels points' density of each block, then the average density list is assembled in feature vector.

Matching vessels: Feature matching is the most crucial part of any biometric system. It is used to calculate the degree of similarity between two vessels patterns, the distance are computed between features vectors of the templates stored in the DB and the patterns 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:

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

where, F_i represents the tested i^{th} feature vector extracted from retina input image, T_i, represents the jth template feature vector registered in the database.

TEST RESULTS

Two datasets have been used for performance evaluation of the proposed method, they are: DRIVE (http://www.isi.uu.nl/research/databases/DRIVE/) and STARE (http://www.ces.clemson.edu/ahoover/Stare/ Probing/Index.html) (Hoover *et al.*, 2000) 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 35 RGB color images of retina, the images are of size (605×700) pixels of resolution. The 75 images (40 from DRIVE and 35 from STARE) have been used for identification/verification purpose, each image was subjected to two levels of brightness variation and are rotated 5 times (with rotation steps of five degrees) in both clockwise and anticlockwise direction, such that a total of 13 images variants have been produced from each retina image, Thus a dataset consists of simulated 975 images (i.e., 520 for DRIVE and 455 for STARE) is established.

The results of the tests conducted on the recognition method based on the spatial distribution of the local average of vascular density and spatial distribution of the local average of vascular direction show the need of the 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. The experimental results indicate that each individual

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

Method	STARE	DRIVE
Farzin *et al.* (2008)	99.00%	-
Sabaghi *et al.* (2012)	99.1%	-
Aich and Al-Mamun (2013)	100%	98.64%
Qamber *et al.* (2012)	96.29%	100%
Rubaiyat *et al.* (2014)	100%	99.77%
Proposed Method	100%	100%

feature is not powerful by itself, the combination features led to an optimal recognition performance. At feature extraction stage the two sets of proposed features led to high recognition performance, the recognition rate for the first set of features alone (i.e., spatial distribution of vascular density) is 99.608%. While in combination with the second set (i.e., spatial distribution of vascular directions) has led to perfect recognition rate 100%. Additionally, the idea of partitioning retinal image into overlapping blocks is suitable, because it has been improved the recognition accuracy through; it helps to overcome the partial loss in low quality retinal images. The system performance can be speed up by decreasing the number of blocks but this will lead to a decrease in the accuracy rate of the system and it is also possible to get less templates storage space when using a single template, but also at the expense of accuracy and computation complexity. The recognition rate is highly affected by the variation of the number of blocks and overlapping ratio. The best attained recognition rate occurs when the number of blocks is 12 and the overlapping ratio is 0.4.

This method is robust to rotation and noise; in addition, in our proposed method have small useful features extracted which is blood vessel density and blood vessels direction, in order that, this proposed method has simple and low computational complexity. The recognition methods, published in the literature, have less accuracy, more complexity and require more computational effort when they compared with the proposed method. Table 1 presents the accuracy of recognition rate achieved by some of the previously published works and the proposed work. The listed results in Table 1 indicate that our method leads to high average accuracy in comparison with other published methods.

CONCLUSION

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. In this study, an efficient and simple method is proposed for individual recognition system based on retinal blood vessels. In comparison with other retina recognition methods appeared in the literature. The introduced system proposed a simple module for rotation compensation and to make the method robust against face rotation.

Also, the concept of spatial distribution of the edge directional density is used as discrimination feature.

The results of the tests conducted on the two public datasets (i.e., DRIVE and STARE) indicate that the performance of the proposed method is too high (i.e., 100% recognition rate) for both datasets and also same when the extracted vesicular patterns of both data sets have been assembled in one datasets.

REFERENCES

Aich, S. and G.M. Al-Mamun, 2013. An efficient supervised approach for retinal person identification using Zernike moments. Int. J. Comput. Appl., 81(7): 34-37.

Al-Hamdani, O., A. Chekima, J. Dargham, S.H. Salleh, F. Noman *et al.*, 2013. Multimodal biometrics based on identification and verification system. J. Biometrics Biostat., 4(2): 1-8.

Barkhoda, W., F.A. Tab and M.D. Amiri, 2009. Rotation invariant retina identification based on the sketch of vessels using angular partitioning. Proceeding of the International Multi Conference on Computer Science and Information Technology (IMCSIT'09). Poland, pp: 3-6.

Bevilacqua, V., L. Cariello, D. Columbo, D. Daleno, M.D. Fabiano, M. Giannini, G. Mastronardi and M. Castellano, 2008. Retinal fundus biometric analysis for personal identifications. In: Huang, D.S. *et al.* (Eds.), ICIC, 2008. LNAI 5227, Springer-Verlag, Berlin, Heidelberg, pp: 1229-1237.

Cemal, K. and C. İki, 2011. A personal identification system using retinal vascular in retinal fundus images. Expert Syst. Appl., 38(11): 13670-13681.

Dehghani, A., Z. Ghassabi, H.A. Moghddam and M.S. Moin, 2013. Human recognition based on retinal images and using new similarity function. EURASIP J. Image Video Process., 58: 1-10.

Dwivedi, S., S. Sharma, V. Mohan and K.A. Aziz, 2013. Fingerprint, retina and facial recognition based multimodal systems. Int. J. Eng. Comput. Sci., 2(5): 1487-1500.

Farzin, H., H.A. Moghaddam and M. Shahrammoin, 2008. A novel retinal identification system. EURASIP J. Adv. Sig. Pr., 2008: 1-10.

Godse, D.A. and D.S. Bormane, 2013. Automated localization of optic disc in retinal images. Int. J. Adv. Comput. Sci. Appl., 4(2): 65-71.

Goh, K.G., W. Hsu and M.L. Lee, 2000. Medical Data Mining and Knowledge Discovery. Springer, Berlin, Germany, pp: 181-210.

Hadi, J. and T. Hamid, 2014. Retinal identification system using Fourier-mellin transform and fuzzy clustering. Indian J. Sci. Technol., 7(9): 1289-1296.

Hájek, J., M. Drahanský and R. Drozd, 2013. Extraction of retina features based on position of the blood vessel bifurcation. J. Med. Res. Dev., 2(3): 55-58.

Hoover, A., V. Kouznetsova and M. Goldbaum, 2000. Locating blood vessels in retinal images by piecewise threshold probing of a matched filter response. IEEE T. Med. Imaging, 19(3): 203-210.

Ibrahim, A.A., 2014. Iris recognition using Haar wavelet transform. J. Al-Nahrain Univ., Sci., 17(1): 180-186.

Jain, A.K., L. Hong and S. Pankanti, 2000. Biometric identification. Commun. ACM, 43(2): 91-98.

Jain, A.K., A. Ross and S. Prabhakar, 2004. An introduction to biometric recognition. IEEE T. Circ. Syst. Vid., 14(1): 4-20.

Mali, K. and S. Bhattacharya, 2013. Comparative study of different biometric features. Int. J. Adv. Res. Comput. Commun. Eng., 2(7): 2776-2784.

Ortega, M., M.G. Penedo, J. Rouco, N. Barreira and M.J. Carreira, 2009. Retinal verification using a feature points-based biometric pattern. EURASIP J. Adv. Sig. Pr., 2009: 1-13.

Park, U., H. Chen and A.K. Jain, 2005. 3D model-assisted face recognition in video. Proceeding of the 2nd Canadian Conference on Computer and Robot Vision (CRV'05), 3: 322-329.

Plannerer, B., 2005. An Introduction to Speech Recognition. E-Books Directory, Retrieved from: http://sistemic.udea.edu.co/wp-content/uploads/2013/10/introSR.pdf.

Qamber, S., Z. Waheed and U. Akram, 2012. Person identification system based on vascular pattern of human retina. Proceeding of the Cairo International Biomedical Engineering Conference (CIBEC).

Ross, A., A. Jain and J. Reisman, 2003. Hybrid fingerprint matcher. Pattern Recogn., 36(7): 1661-1673.

Rubaiyat, A.H., S. Aich, T.T. Toma, A.R. Mallik, R. Al-Islam and A.H. Mohammad, 2014. Fast normalized cross-correlation based retinal recognition. Proceeding of the 17th International Conference Computer and Information Technology (ICCIT, 2014), pp: 358-361.

Sabaghi, M., S.R. Hadianamrei, M. Fattahi, M.R. Kouchaki and A. Zahedi, 2012. Retinal identification system based on the combination of fourier and wavelet transform. J. Signal Inform. Process., 3(1): 35-38.

Sasidharan, G., 2014. Retina based personal identification system using skeletonization and similarity transformation. Int. J. Comput. Trends Technol., 17(3): 144-147.

Simon, C. and I. Goldstein, 1935. A new scientific method of identification. New York State J. Med., 35(18): 901-906.

Spinella, E., 2003. Biometric Scanning Technology: Fingers, Facial and Retinal Scanning. SANS Institute, San Francisco, CA.

Tabatabaee, H., A.M. Fard and H. Jafariani, 2006. A novel human identifier system using retina image and fuzzy clustering approach. Proceeding of the 2nd IEEE International Conference on Information and Communication Technologies (ICTTA, 2006). Damascus, pp: 1031-1036.

Tower, P., 1955. The fundus oculi in monozygotic twins: Report of six pairs of identical twins. Arch. Ophthalmol., 54(2): 225-239.

Tuama, S.A. and L.E. George, 2016. A hybrid morphological based segmentation method for extracting retina blood vessels grid. Brit. J. Appl. Sci. Technol., 12(2).

Wayman, J., 2001. Using biometric identification technologies in the election process. Int. J. Image Graph., 1(1): 93-113.

Xu, Z.W., X.X. Guo, X.Y. Hu and X. Cheng, 2005. The blood vessel recognition of ocular fundus. Proceeding of the 4th International Conference on Machine Learning and Cybernetics (ICMLC, 2005). Guangzhou, pp: 4493-4498.

Zhang, T.Y. and C.Y. Suen, 1984. A fast parallel algorithm for thinning digital patterns. Commun. ACM, 27(3): 236-239.