Retinal recognition: Personal identification using blood vessels

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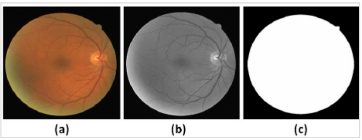
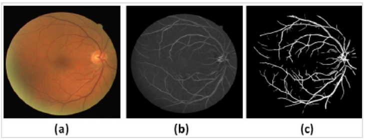
Abstract

Biometrics are used for personal recognition based on some physiologic or behavioral characteristics. In this era, biometric security systems are widely used which mostly include fingerprint recognition, face recognition, iris and speech recognition etc. Retinal recognition based security systems are very rare due to retina acquisition problem but still it provides the most reliable and stable mean of biometric identification. This paper presents a four stage personal identification system using vascular pattern of human retina. In first step, it acquires and preprocesses the colored retinal image. Then blood vessels are enhanced and extracted using 2-D wavelet and adaptive thresholding respectively. In third stage, it performs feature extraction and filtration followed by vascular pattern matching in forth step. The proposed method is tested on three publicly available databases i.e DRIVE, STARE and VARIA. Experimental results show that the proposed method achieved an accuracy of 0.9485 and 0.9761 for vascular pattern extraction and personal recognition respectively.

Figures





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6th International Conference on Internet Technology and Secured Transactions, 11-14 December 2011, Abu Dhabi, United Arab Emirates

Retinal Recognition: Personal Identification using Blood Vessels

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***Abstract*—Biometrics are used for personal recognition based on some physiologic or behavioral characteristics. In this era, biometric security systems are widely used which mostly include fingerprint recognition, face recognition, iris and speech recognition etc. Retinal recognition based security systems are very rare due to retina acquisition problem but still it provides the most reliable and stable mean of biometric identification. This paper presents a four stage personal identification system using vascular pattern of human retina. In first step, it acquires and preprocesses the colored retinal image. Then blood vessels are enhanced and extracted using 2-D wavelet and adaptive thresholding respectively. In third stage, it performs feature extraction and filtration followed by vascular pattern matching in forth step. The proposed method is tested on three publicly available databases i.e DRIVE, STARE and VARIA. Experimental results show that the proposed method achieved an accuracy of 0.9485 and 0.9761 for vascular pattern extraction and personal recognition respectively.**

I. Introduction

Biometrics are used to improve security, convenience and accountability while detecting and deterring frauds [1]. The biometric technologies include fingerprint recognition [2], iris recognition [3], facial recognition [4], hand geometry [5] and speech recognition [6]. In field of biometrics, there is always a confusion between iris and retina. They may be in same class of biometrics 'eye biometrics' but they are completely different in terms of their functions and patterns [7]. A colored region between the pupil and sclera is known as iris whereas retina is located at back region of eye. Main components of retina are blood vessels, optic disc, macula and fovea. The foundation of retinal recognition is the blood vessel pattern. Unlike other biometric technologies retinal recognition is the most reliable and stable due to its rich and unique vascular pattern. It is almost impossible to forge a human retina as it is located at back of eye and is not exposed to external environment [7].

Retina is scanned using fundus camera which is normally used by ophthalmologists for treatment of retinal diseases. In order to scan retina, the person must position his eye very close to the lens of camera. During scanning process, he must remain still and also must remove glasses to avoid signal interference. Once the scanner is activated, the green light moves in a complete circle and vascular pattern of retinal is captured [7]. Due to a complicated acquisition process, retinal recognition systems are not used widely but due to their stability and reliability, retina biometrics systems are suited for maximum security areas such as Government and military.

The uniqueness of retinal vascular pattern was introduced by two ophthalmologists, Dr Carleton Simon and Dr. Isodore Goldstein in 1935 [8]. They were studying on eye disease when they made this discovery that every eye has its own unique vascular pattern and it can be used for personal identification. Later in 1950s, Dr Paul Tower discovered that vascular patterns are unique even among identical twins [9]. His study showed that, among resemblance factors typical of twins, retinal vascular patterns are the one that have the least similarity.

An approach similar to landmark-based image registration can be applied to retina authentication [10, 11]. In these methods feature extraction and matching have an essential role when it comes to distinguishing between impostors and genuine persons. Ortega et al. [10] and Xu et al. [11] have recently proposed methods in which feature points present the positions of blood vessel bifurcations and crossovers. In addition to the landmark-based registration methods, retina authentication can be performed based on a circular area of a reference point [12]. These methods depend on locating the reference point, the optic disc.

In this paper, we present a retinal recognition system for personal identification using blood vessels pattern. The paper proposes a four stage system consisting of preprocessing, vascular pattern extraction, feature extraction and filtration and finally feature matching. It extracts bifurcation points from vascular pattern just like fingerprint minutiae points. The accuracy of retinal recognition systems depend upon vascular pattern and feature extraction. In order to improve the accuracy, the paper presents a method for filtration of false bifurcation points caused by spurs. We also compare the blood vessel segmentation with already proposed systems. Experimental results show that the proposed system achieves a high accuracy for vascular pattern extraction and for retinal recognition.

The paper consists of four sections. Section 2 consists of proposed system. It explains the complete four stage system followed by experimental results in section 3. Section 4 provides conclusion.

II. Proposed System

The proposed retinal recognition system consists of four stages i.e preprocessing, vascular pattern extraction, feature extraction and filtration and biometric pattern matching. Background and noise from retinal image are removed in preprocessing step to ensure that no false feature should be detected due to presence of noise. Blood vessel enhancement and segmentation is done in vascular pattern stage and it is very important as the whole system depends upon accurate segmentation of vascular pattern. Prominent feature of vascular pattern are the bifurcation points. They are extracted and filtered to eliminate false points in third stage. Last stage performs a matching process between the features vectors stored in database and the features from acquired image. Figure 1 shows the complete flow diagram for proposed system.

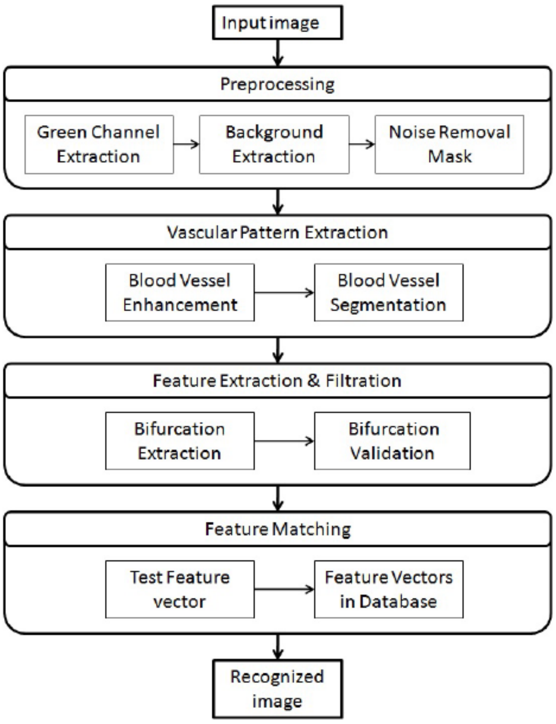

Fig. 1. Flow diagram of proposed retinal recognition system

A. Preprocessing

Preprocessing is done to extract retinal image from background and to remove noisy area from retinal image. In a fast and real time identification system, it is necessary to process foreground only. Cutting or cropping out the region that contains the retinal image feature minimizes the number of operations on the retinal image. We used a preprocessing technique which uses green channel from colored retinal image and creates binary masks of 1's and 0'1 for background and noisy areas [13] where 1 is for true retinal image pixels and 0 is for background or noisy pixels. Background subtraction uses gradient mean and variance based method and separates the original retinal image area from dark background whereas noise removal uses HSI (Hue, Saturation and intensity) color space and removes the noisy area from retinal image [13]. Final mask is then created by adding both masks and applying morphological operations. Figure 2 shows colored retinal images and their respective preprocessing masks.

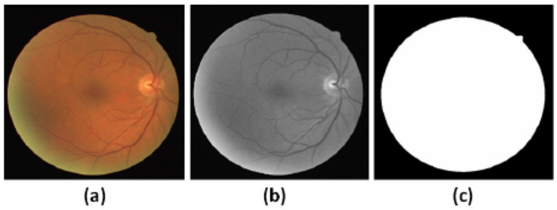

Fig. 2. Preprocessing: a)Original retinal image; b)Green Channel; c)Preprocessing mask

B. Vascular Pattern Extraction

Retinal recognition solely depends upon vascular pattern and their features so it is very important that blood vessels should be segmented accurately. In proposed retinal identification system, blood vessels are enhanced and segmented using wavelets and adaptive thresholding techniques [14]. Gabor wavelet is famous due to its directional selectiveness capability of detecting oriented features and fine tuning to specific frequencies [15], [16].

1) The continuous wavelet transform (CWT) $T_\psi(\mathbf{b}, \theta, a)$ is defined in terms of the scalar product of f with the transformed wavelet $\psi_{\mathbf{b}}, \theta, a$ using equation 1 [17]
$W_\psi(\mathbf{b}, \theta, a) = C_\psi^{-1/2}\langle \psi_{\mathbf{b}}, \theta, a | f \rangle$
$$= C_\psi^{-1/2} a^{-1} \int \psi^*(a^{-1} r_{-\theta}(\mathbf{x} - \mathbf{b})) f(x) d^2\mathbf{x} \quad (1)$$
where $f \in L^2$ is an image represented as a square integrable (i.e., finite energy) function defined over $\mathbf{R}^2$ and $\psi \in L^2$ be the analyzing wavelet. C_ψ, ψ, $\mathbf{b}$, θ and a denote the normalizing constant, analyzing wavelet, the displacement vector, the rotation angle, and the dilation parameter respectively.
2) It is easy to implement wavelet transform using the fast Fourier transform algorithm. Fourier wavelet transform is defined using equation 2 [16].
$$W_\psi(\mathbf{b}, \theta, a) = C_\psi^{-1/2} a \int \exp(j\mathbf{k}\mathbf{b}) \hat{\psi}^*(a r_{-\theta}\mathbf{k}) \hat{f}(\mathbf{k}) d^2\mathbf{k} \quad (2)$$
where $j = \sqrt{-1}$, and the hat ($\hat{\psi}^*$ and $\hat{f}$) denotes a Fourier transform.
3) The 2-D Gabor wavelet is defined as [17]

$$\psi_G(\mathbf{x}) = \exp(j\mathbf{k}_0\mathbf{x})\exp(-\frac{1}{2}|\mathbf{A}\mathbf{x}|^2) \quad (3)$$

where k_0 vector defines the frequency of the complex exponential and $\mathbf{A} = diag[\epsilon^{-1/2}, 1], \epsilon \geq 1$ is an elongation diagonal matrix in any desired direction.

4) The Gabor wavelet transform, for each pixel location and chosen scale value, is computed using equation 4 [16], for θ spanning from 0^o up to 170^o at steps of 10^o and the maximum is taken.

$$M_\psi(\mathbf{b}, a) = max_\theta |W_\psi(\mathbf{b}, \theta, a)| \quad (4)$$

This gives us the enhanced vascular pattern for the retinal image and vascular pattern is segmented using adaptive thresholding method [18]. Figure 3 shows the enhanced and segmented vascular pattern from preprocessed image.

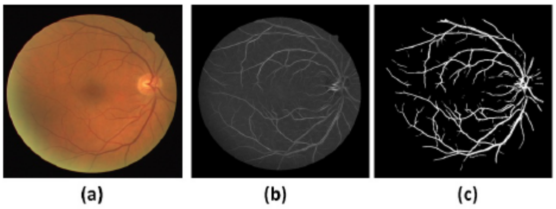

Fig. 3. Vascular pattern extraction: a)Preprocessed image; b)Enhanced blood vessels; c)Segmented blood vessels

C. Feature Extraction and Filtration

Main feature of vascular pattern is vessel bifurcation point where a vessel splits into two vessel branches(fig. 4).

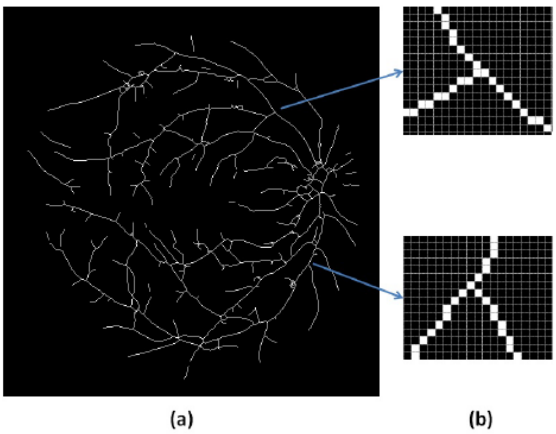

Fig. 4. Vascular pattern features: a) Thinned vascular pattern; b) Bifurcation points

Prior to feature extraction, morphological thinning operation is performed on segmented vascular pattern to get one pixel wide blood vessels [18]. In order to extract features from thinned vascular pattern, crossing number method is used given in equation (5) [19]. For every vessel pixel p in thinned image I_{thin}

$$C(p) = \frac{1}{2}\sum_{i=1}^{8} |I_{thin}(p_{imod8}) - I_{thin}(p_{i-1})| \quad (5)$$

Where p_0 to p_7 are the pixels belonging to an clockwise ordered sequence of pixels defining the 8-neighborhood of p and $I_{thin}(p)$ is the pixel value. $I_{thin}(p) = 1$ for vessel pixels and zero elsewhere. $C(p) = 3$ and $C(p) = 1$ correspond to vessel bifurcation and vessel endings.

The bifurcations obtained from this algorithm must be filtered to preserve only the true feature points. In order to eliminate false bifurcation due to spurs, take a window of size 9×9 and place the candidate bifurcation point at the center of window. If there exists any connected vessel ending point within the window then remove that candidate bifurcation as it is because of spur (fig. 5). In bifurcation validation, again take a window of size 9×9, place candidate bifurcation point at center of window and initialize it with a value of -1. As each bifurcation has three connected branches, assign 1,2 and 3 to all pixels traveling along three different branches respectively (fig. 5). Now move along the border of the window in clockwise direction and count transitions from 0 to 1, 0 to 2 and 0 to 3. For a valid bifurcation, count should be equal to 3 otherwise eliminate that bifurcation. Figure 5 shows the case of false bifurcation and validation of true bifurcations.

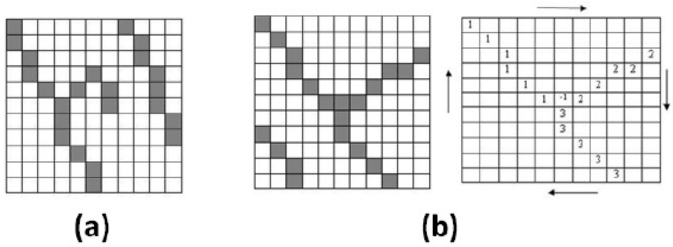

Fig. 5. Feature filtration: a) False bifurcation due to spurs; b) True bifurcation point

D. Feature Matching for Retinal Recognition

Feature matching is the most crucial part of any biometric system. In order to make matching invariant to translation and rotation, we calculated the relative angles ϕ_{ij} between every bifurcation and its four nearest bifurcation points and also their relative distances d_{ij} as shown in figure 6.

Here a is the candidate bifurcation having b orientation whereas c, d, e and f are its four nearest bifurcation points. $orient1$, $orient2$, $orient3$ and $orient4$ are relative angles between orientation of a and orientations of c, d, e and f respectively. Angles are computed by using orientation of vessel to which bifurcation point belongs to and distances are calculated using pixel coordinates of each bifurcation point [19]. For every bifurcation point, template feature set for

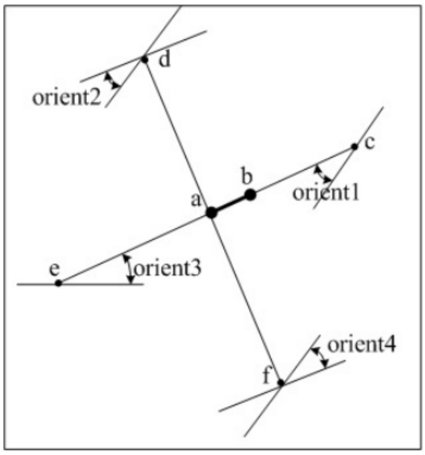

Fig. 6. Four nearest bifurcation points and their relative orientations for center bifurcation

matching is $< \phi_{11}, \phi_{12}, \phi_{13}, \phi_{14}, d_{11}, d_{12}, d_{13}, d_{14} >$. Now if a and b are bifurcation points from two retinal images of same person then their feature vectors will be similar. Matching is done by calculating euclidian distance between feature vectors of all bifurcation points in test image and templates stored in database.

III. Experimental Results

In biometrics based system, the accuracy of implemented algorithms is very important and they must be tested properly. In this paper, three datasets i.e DRIVE, STARE and VARIA are used in order to check the validity and accuracy of proposed system. Figure 7 shows different images from three databases.

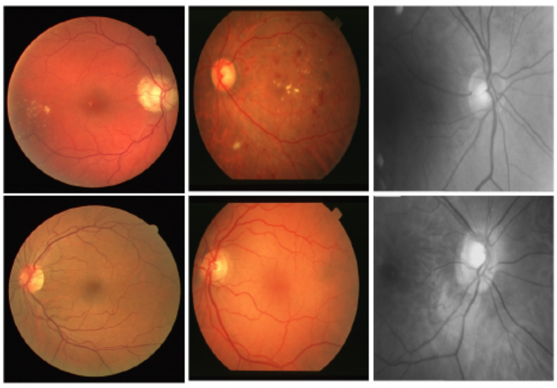

Fig. 7. Retina images: a) Drive database images; b) STARE database images; c) VARIA database images

DRIVE [20] and STARE[21] databases are publicly available databases to check the accuracy of vascular pattern extraction and these databases also include ground truth for vascular segmentation. There are 40 images with resolution of 768x584 and 81 image with a resolution of 700x605 in DRIVE and STARE respectively. We tested our vessel segmentation method on these two databases and compared the proposed technique with Jiang et al. [23], Staal et al. [20] and Soares et al. [17]. Table-1 summarizes the comparison results for vessel segmentation in terms of accuracy using DRIVE and STARE databases.

TABLE I
Blood vessel segmentation comparison results

Method	Accuracy (DRIVE)	Accuracy (STARE)
Jiang et al.	0.8911	0.9009
Staal et al.	0.9441	0.9516
Soares et al.	0.9466	0.9480
Proposed	**0.9469**	**0.9502**

VARIA [21] is a database that is formed for retinal recognition systems. It includes 233 retinal images with a resolution of 768x584, from 139 different persons. The proposed retinal recognition system is tested on total 354 images. Table II shows the recognition rate of proposed method on three databases.

TABLE II
Recognition rate of proposed method

Database	Total images	Correctly recognized	Wrongly recognized	Recognition rate
DRIVE	40	40	0	100%
STARE	81	77	4	95.06%
VARIA	233	231	2	99.14%
Total	**354**	**348**	**6**	**98.30%**

It shows that proposed method achieves a recognition rate of 100%, 95.06% and 99.14% for DRIVE, STARE and VARIA databases respectively. In case of STARE database, recognition rate is a bit low as it contains 51 images with severe eye disease and it was difficult to extract feature points in presence of different lesions but still the proposed method achieves an overall high recognition rate of 98.30%.

IV. Conclusion

Retinal image consists of a unique pattern in each individual and it is almost impossible to forge that pattern in a false individual. However, its high cost and acquisition related drawbacks have prevented it from making a commercial impact. This paper presented a retinal vascular pattern based biometric system. In proposed system, the acquired retinal image is preprocessed to remove background and noise and then vascular pattern is extracted using Gabor wavelet and adaptive thresholding technique. A feature vector is formed using relative angles and distance between each bifurcation points and its four nearest bifurcation points. A comparison for vascular pattern extraction and matching is given. Results demonstrated that the proposed system can be used in a biometric based personal identification system.

REFERENCES

[1] S. Prabhakar, S. Pankanti, and A. K. Jain, Biometric recognition: Security and privacy concerns", IEEE Security and Privacy, vol. 1, no. 2, pp. 33-42, Mar, 2003

[2] A. K. Jain, L. Hong, S. Pankanti, and R. Bolle, An identity-authentication system using fingerprints", Proceedings of the IEEE, vol. 85, no. 9, pp. 1365-1388, 1997.

[3] Daugman, J., Complete Discrete 2-D Gabor Transforms by Neural Networks for Image Analysis and Compression", *IEEE Transactions on Acoustics, Speech, and Signal Processing*, Vol. 36, no. 7, July 1988, pp. 1169-1179.

[4] W. A. F. Abate, M. Nappi, D. Riccio, and G. Sabatino, 2D and 3D face recognition: a survey", Pattern Recognition Letters, vol. 28, no. 14, pp. 1885-1906, 2007.

[5] R. Zunkel, Hand geometry based verification", in BIOMETRICS: Personal Identification in Networked Society, pp. 87-101, Kluwer Academic Publishers, Dordrecht, The Netherlands, 1999.

[6] S. Young, "Large vocabulary continuous speech recognition: A review", *IEEE Signal Processing Magazine*, vol. 13, no.5, pp.45-57, 1996.

[7] Ravi Das, "Retinal recognition Biometric technology in practice", *Keesing Journal of Documents & Identity*, no. 22, pp.11-14, 2007.

[8] Simon, C., Goldstein, I., "A New Scientific Method of Identification", *New York State Journal of Medicine*, vol. 35, no.18, pp. 901-906, 1935.

[9] Tower, P., "The Fundus Oculi in Monozygotic Twins: Report of Six Pairs of Identical Twins", *Archives of Ophthalmology*, vol. 54, pp. 225-239, 1955.

[10] M. Ortega, M.G. Penedo, J. Rouco, N. Barreira, and M.J. Carreira, Retinal verification using a feature points-based biometric pattern", *EURASIP J. Adv. Signal Process*, vol. 2009, pp. 1-13, 2009.

[11] Z.W. Xu, X.X. Guo, X.Y. Hu, X. Chen, and Z.X. Wang, The identification and recognition based on point for blood vessel of ocular fundus", *In: Proc. ICB 2006, LNCS 3832, Heidelberg*,2006, pp. 770-776.

[12] H. Farzin, H. Abrishami-Moghaddam, and M.-S. Moin, A novel retinal identification system", *EURASIP J. Adv. Signal Process*, vol. 2008, pp. 1-10, 2008.

[13] M.U. Akram and A. Khanum, "Retinal Images: Blood Vessel Segmentation by Threshold Probing", *IEEE Symposium on Industrial Electronics and Applications (ISIEA 2010)*, pp.475-479, Malaysia, 2010.

[14] M.U. Akram, A. Tariq and S. A. khan, " Retinal Image Blood Vessel Segmentation", *3rd IEEE International conference on Information and Communication Technologies*, pp. 181-186, Pakistan, 2009.

[15] A. Arnodo, N. Decoster and S. G. Roux, "A wavelet-based method for multifractal image analysis. I. Methodology and test applications on isotropic and anisotropic random rough surfaces", *Eur. Phys. J. A.*, vol. 15, pp. 567-600, 2000.

[16] J.P. Antoine, P. Carette, R. Murenzi, and B. Piette, "Image analysis with two-dimensional continuous wavelet transform", *Signal Process.*, vol. 31, pp. 241-272, 1993.

[17] J. V. B. Soares, J. J. G. Leandro, R. M. Cesar, H. F. Jelinek and M. J. Cree., "Retinal vessel segmentation using the 2-D gabor wavelet and supervised classification", *IEEE Trans. on Med. Imag.* vol. 2, no. 9, pp.1214-1222, 2006.

[18] R. C. Gonzalez and R. E. Woods, *Digital image processing, Prentice hall*, second edition, 2002.

[19] A. K. Jain, R. Bolle, and S. Pankanti, "Biometrics: Personal Identification in a Networked Society", eds., Springer- Verlag New York Inc (C),1999.

[20] J. Staal, M. D. Abramoff, M. Niemeijer, M. A. Viergever and B. van Ginneken,"Ridge-based vessel segmentation in color images of the retina", *IEEE Trans. Med. Imag.*, vol. 23, no.4, pp. 501-509, Apr. 2004.

[21] A. Hoover, M. Goldbaum, "Locating the optic nerve in a retinal image using the fuzzy convergence of the blood vessels", *IEEE Trans. on Medical Imaging*, vol. 22, no. 8, pp. 951-958, August 2003.

[22] VARIA,"Varpa retinal images for authentication", http://www.varpa.es/varia.html.

[23] X. Jiang and D. Mojon,"Adaptive local thresholding by verificationbased multithreshold probing with application to vessel detection in retinal images",*IEEE Trans. Pattern Anal. Mach. Intell.*, vol.25, no.1, pp. 131-137, 2003.

Citations 6 References 25

Identity Verification of Individuals Based on Retinal Features Using Gabor Filters and SVM

"In a retinal authentication system proposed by Bevilacqua et al. [17], the accumulation matrix is utilized for detecting vascular bifurcation and cross over point. Akram et al. [18] presented a retina recognition method in which they represented feature points by bifurcations and endings vessel. For generating a feature vector, relative angles and distances between a candidate feature point and its four closet feature points are computed. "

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