A robust phase information extraction using 2-D quadrature filtering (monogenic and 2D-Log Gabor) and modified HD for matching

Walid Aydi [#1], Nouri Masmoudi [*2], Lotfi Kamoun [#3]

[#] Electrical Department, University of Sfax,
Street of Soukra km 3.5 B.P. W 1173 Sfax - Tunisia
[1] walid.elaydi@gmail.com
[2] Nouri.Masmoudi@enis.rnu.tn
[3] lotfi.kamoun@isecs.rnu.tn

Abstract— The human iris recognition system is an attractive technology for identity authentication. This technology benefits from random variations in the features of the iris. Usually, an iris recognition system has 4 modules: segmentation, normalization, feature extraction and iris templates matching.

This work is mainly focused on iris texture analysis and templates matching which are 2 essential processes in the iris recognition system. The proposed approach extracts robust phase information using filtering (both monogenic and 2D log Gabor). Then, two types of distance measures such as modified HD and Jaccard distances are chosen as metrics for recognition.

We comparatively evaluate the performance of the proposed method and the fractal analysis using CASIA-V3.0 iris image databases. The obtained results with monogenic and 2D-Log Gabor filters were highly promising and led to significantly improved performance in speed and accuracy. With dissimilarity modified Hamming distance; we improved the accuracy of the iris recognition system, with a FAR equal to 3% and a speed at least 8 times..

Keyword-Feature Extraction, Monogenic Filter, Fractal Analysis, 2D log-Gabor, Jaccard distance, modified HD

I. Introduction

HUMAN iris image has more advantages than other biometric modalities such as the fingerprint, palm print, voice, retina and the face. Moreover, the iris is the most reliable and stable template of recognition which makes the iris recognition system more suitable for highly reliable human identification.

The iris contains many distinctive features such as the ridges, furrows, crypts, arching ligaments, corona, freckles, rings and the collarets [5]. These features make together a complex iris texture [5, 20] as shown in Fig. 1.

Generally, an iris recognition system has typically 4 modules: segmentation, normalization, feature extraction and matching. In the literature, there are many feature extraction methods used to generate the template. These methods are generally classified into many groups such as phase-based methods, intensity analysis, texture analysis and zero-crossing [3].

Firstly, Daugman [4, 5] used 2-dimensional Gabor wavelets to encode the iris pattern. The bit stream was then generated using the angle of each phase of the 4 quadrant techniques. The result was a template with 2048 bits long. The modified Hamming distance (HD) was then used for comparison.

After that, many researchers proposed other techniques [8, 9, 10, 11, 12, 16]. Zhafeng [17] as a phase-based method used the ordinal measure filters to encode the normalized iris regions and the HD as a metric of dissimilarity between the 2 iris templates. Li [2] as a zero-crossing approach used the zero crossing algorithm for iris feature extraction, and improved HD. KHANFIR [14] proposed to use the fractal analysis [13, 15] to encode the normalized iris and the quantization of the gradient vector of the fractal dimension to generate a 255 bits vector. It has been shown previously that the iris recognition is well to local phase-based methods which are theoretically intensity-invariant [4,5]. In this paper we focus on the feature extraction and matching which are 2 critical steps in an iris recognition system. For feature extraction, we propose to use the monogenic filter, as a local phase-based method, to encode the normalized iris region and the modified HD and Jaccard distances for template matching. The outline of the paper is organized as follows: Section 2 is a description of the fractal analysis method as a related work. Section 3 presents the proposed method. Section 4 discusses the experimental results. Finally, in Section 5 we present the conclusion and our future works.

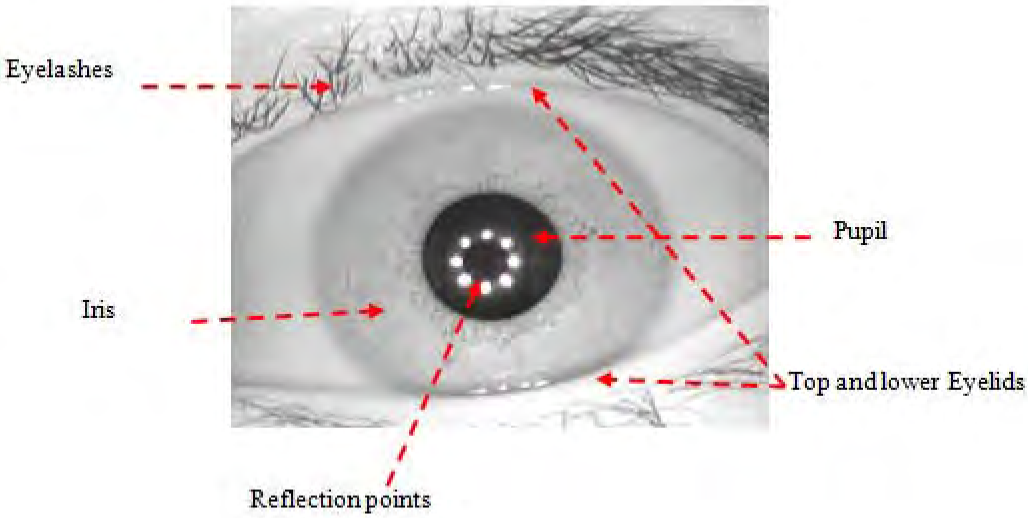

Fig. 1 Anatomy of the human eye

II. Related Work

A. Fractal Analysis

The fractal analysis is based on the quantification of the iris texture [23]. The box-counting method [21, 22, 24] is used to estimate the fractal dimension (FD) of the blocks in the normalized iris images. It is a method to gather data necessary for the analysis of complex patterns by breaking a bounded set. The texture of the iris is considered as a fractal Fig. [14]. The fractal dimension can be computed using the Hausdorff dimension. It is a real number that measures the degree of irregularity or the fragmentation of an object. Moreover it is used to measure the surface roughness [14]. To compute the fractal dimension of an object consisting of N copies and whose size had been reduced by a scale k, Hausdorff offers the relationship given by the following equation (1):

$$D = \frac{\log(N)}{\log(k)} \quad (1)$$

The fractal analysis algorithm of the normalized iris is composed of 2 steps. (1) The construction of structural edge map. (2) Automatic edge image analysis process.

- ***Construction of structural edge map:***

Let us consider a normalized iris image of size (20*240 pixels) segmented and normalized using the algorithm proposed in these papers [25, 26].

The proposed method starts with the generation of an edge map (see Fig. 2(a)) of the normalized iris. Then we remove the edges of the pupil and eyelids (see Fig. 2 (b)) which may cause errors in the feature extraction. Finally we get the edge map of the iris (see Fig.2 (c)).

(a) (b) (c)

Fig. 2. Construction of the edge map of the iris.

- ***Automatic edge image analysis process:***

The following steps describe the analysis algorithm of the iris texture:

1. Partition the edge map into non-overlapping blocks of size (s * s) (as shown in Fig. 3).
2. Subdivide each block into cells of size (n *n), where, $n < s$.
3. Compute the number of cells N containing an edge.
4. Compute the fractal dimension using equation (1).
5. Repeat from step 2 to 4 for each block.

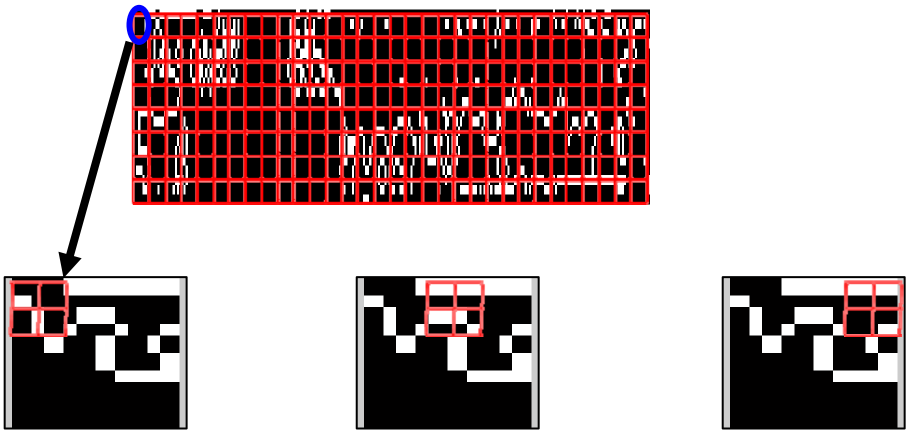

Fig. 3. Analysis of the edge map of the iris.

The biometric signature is then extracted by the threshold-gradient method of the fractal dimensions D.

B. Iris template matching

To quantify the difference between 2 iris codes A and B, the Hamming distance defined by equation (2) is used:

$$D_H = \frac{1}{N}\sum_{j=1}^{N} A(j) \oplus B(j) \quad (2)$$

Theoretically, if the 2 iris codes are identical, D_H would be zero. Otherwise, D_H would be equal to "1".

III. PROPOSED METHOD

We suggest to use the monogenic filters and 2D Log-Gabor filter for feature extraction. The monogenic filters are isotropic and have a compact representation of features with little information loss. Meanwhile, it is a framework to analyze images in terms of local orientation and local magnitude [1]. Moreover, they are more robust than the quaternionic filters which are non isotropic and more than the Gabor filters [18]. The frequency response of these filters is presented by the equation (3) [1]. More details are given in [27].

$$H_1 = i\frac{w_1}{\sqrt{w_1^2 + w_2^2}} \qquad H_2 = i\frac{w_2}{\sqrt{w_1^2 + w_2^2}} \quad (3)$$

Where, w_1 and w_2 are the horizontal and vertical frequencies grids with the same size as the input image *I*.

In order to maintain the independence between the energy (local amplitude) and structure (local phase), we suggest to use the 2D-Log Gabor filter [6, 7]. The frequency response of this filter is expressed by the following transfer function [27]:

$$2DLog\_gabor = \exp\left(-\frac{\left(\log\left(\frac{\sqrt{w_1^2 + w_2^2}}{w_0}\right)\right)^2}{2\left(\log\left(\frac{\sigma}{w_0}\right)\right)^2} \right) \quad (4)$$

Where w_0 indicates the center frequency of the filter and σ is the scaling factor of the bandwidth.

The 2D log Gabor filter possesses crucial advantages than the Gabor filter such as:

- Discarding the DC component of the signal compared to the Gabor filter [1],
- Overcoming the bandwidth limitation of the Gabor filters, and
- having a Gaussian shaped response along logarithmic frequency

To encode the normalized iris I , we take the real part of H_x and H_y :

$$H_x = \left(FFT^{-1}\left(FFT\left(I\right) * H_1 * 2DLog\_gabor\right)\right) \quad (5)$$

$$H_y = \left(FFT^{-1}\left(FFT\left(I\right) * H_2 * 2DLog\_gabor\right)\right) \quad (6)$$

Where, FFT^{-1} is the inverse Fast Fourier Transform and FFT is the Fast Fourier Transform.

The angle ϕ (equation (7)) is quantized to 1 of the 4 quadrants as shown in the Fig. 4, setting 2 bits of phase information. The result is a vector with 9600 bits long.

$$\phi = a\tan 2\left(\mathrm{Re}al\left(H_x\right), \mathrm{Re}al\left(H_y\right)\right) \quad (7)$$

Where *Real* means the real part of each element of the matrix Hx and H_y.

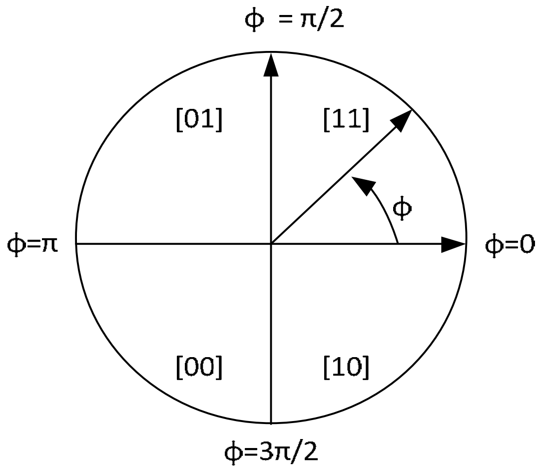

Fig. 4. Phase quadrant demodulation process

A. Iris templates matching

In this process the generated and stored templates are matched and similarity or dissimilarity scores are calculated.

In our experiments, we selected 2 similarity measures, the Jaccard and modified HD distances, to evaluate the performance of the proposed method compared with the state of the art.

- **Modified HD [20]**

The modified HD between 2 templates T_A and T_B defined by equation (8) is the number of disagreement bits over the number of the uncorrupted bits.

The modified Hamming distance also employed the noise masking (T_{AM} and T_{BM}) which corresponds to the corrupted regions (eyelashes, eyelids and the reflection points) in the iris regions, Thus, only the significant bits are considered in calculating.

The modified HD between 2 templates from the same iris has a smaller value (near zero). But it is near 0.5 for 2 templates generated from different iris.

$$d = \frac{\sum_{k=1}^{n}\left(T_{A_k}\ XOR\ T_{B_k}\right) AND \left(NOT\left(T_{AM_k}\ OR\ T_{BM_k}\right)\right)}{n - \sum_{i=1}^{n} T_{AM_i}\ OR\ T_{BM_i}} \quad (8)$$

Where, T_{A_k} and T_{B_k} are the 2 templates.

T_{AM_k} and T_{BM_k} are their corresponding noise mask bit vectors and n is the template size. The modified Hamming distance between 2 templates from the same iris consequently has a smaller value (close to zero). But it gets near 0.5 for 2 templates generated from different irises [20].

- **Jaccard distance**

It's known as the Jaccard similarity coefficient .This is also defined as the size of the intersection of two templates A and B divided by the size of the union of these sample sets [19]. The Jaccard distance is given by equation (9):

$$d_{jaccard} = \frac{\sum_{j=1}^{n} \left(\left(A_j \neq B_j \right) \cap \left(\left(A_j \neq 0 \right) \cup \left(B_j \neq 0 \right) \right) \right)}{\sum_{J=1}^{n} \left(A_j \neq 0 \right) \cup \left(B_j \neq 0 \right)} \quad (9)$$

Where, *n* is the size of the templates A or B.

IV. Experimental Results And Discussion

In this Section, a set of experiments is achieved in order to evaluate the performance of our method.

In our experiments, the enhanced Masek approach [25, 26] is adopted to segment all iris images. The proposed approach was tested on the CASIA-IrisV3-Interval database which composed by 2655 images. All iris images were acquired at infrared wavelength. They all had a size of 320 x 280 pixels.

The algorithms discussed above were implemented in Matlab 9.0 and tested using a Duo CPU 2 GHz computer with 2.99Go of RAM.

The performance of the system was estimated with the area under the ROC Curve (AUC), false accept rate (FAR), false reject rate (FRR) and time computation.

The ROC curve was constructed using (1-FAR) versus (FRR). The false acceptation rate (FAR) was the probability of accepting an imposter. On the other side the false rejection rate (FRR) was the probability of rejecting a genuine user incorrectly. A greater value for the AUC indicated a better iris recognition system.

To asses the accuracy of the proposed method using 2 types of metrics, we compared it with a fractal analysis algorithm. We can deduce from Table I that the proposed method using modified HD distance which has an AUC= 97, 85 % seems to be more accurate than the fractal analysis with AUC= 76, 47 % and the proposed method using Jaccard distance with AUC=97, 83%. The fractal analysis uses the box counting technique to compute the fractal dimension, which is related to the resolution of the input image, edge map and the number of box. We can enhance the performance of this method if we increase the number of boxes and the resolution of the normalized image but we will also increase the time execution.

Table II shows the execution time of the feature extraction and matching. We can deduce that our method using modified HD is much faster than the fractal analysis. The speed of the fractal analysis method is closely linked to the number of boxes counted used to break a dataset and image resolution [14].

TABLE I Performance Comparisons On The CASIA-IrisV3-Interval Database

Method	AUC(%)
Fractal analysis with HD similarity measure	76,47
The proposed method with Jaccard distance	97,83
Our method with modified HD distance	97,85

TABLE II Comparisons Of The Computational Cost

	Feature extraction	Iris templates matching
Fractal analysis with HD similarity measure	1.2530 (s)	0.0280 (s)
The proposed method with Jaccard distance	0.0077 (s)	0.0265(s)
Our method with modified HD distance	0.0077(s)	0.0274(s)

Fig. 5 and Fig. 6 show modified Hamming distance and Jaccard distance distributions with a slight overlap. However, the means of the intra-class and inter-class distributions are still clearly separated, so recognition is still possible. The accuracy of recognition with these distributions can be determined by calculating their false accept and false reject rates with different separation points (as shown in Table III and IV).

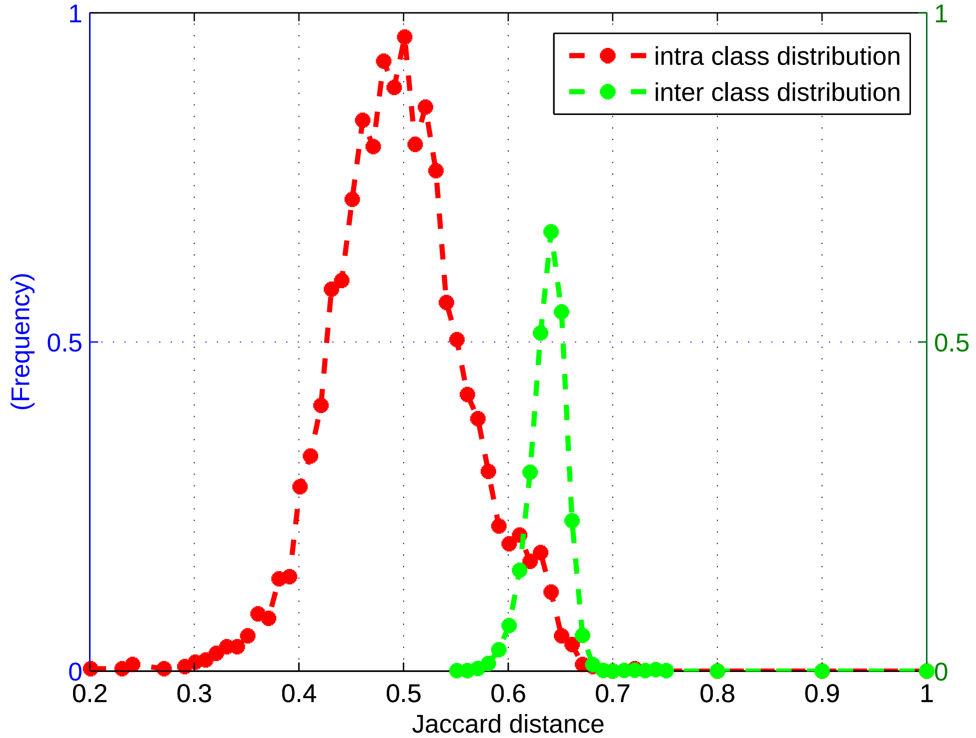

Fig. 5. Distribution of intra-class and inter-class using Jaccard distance

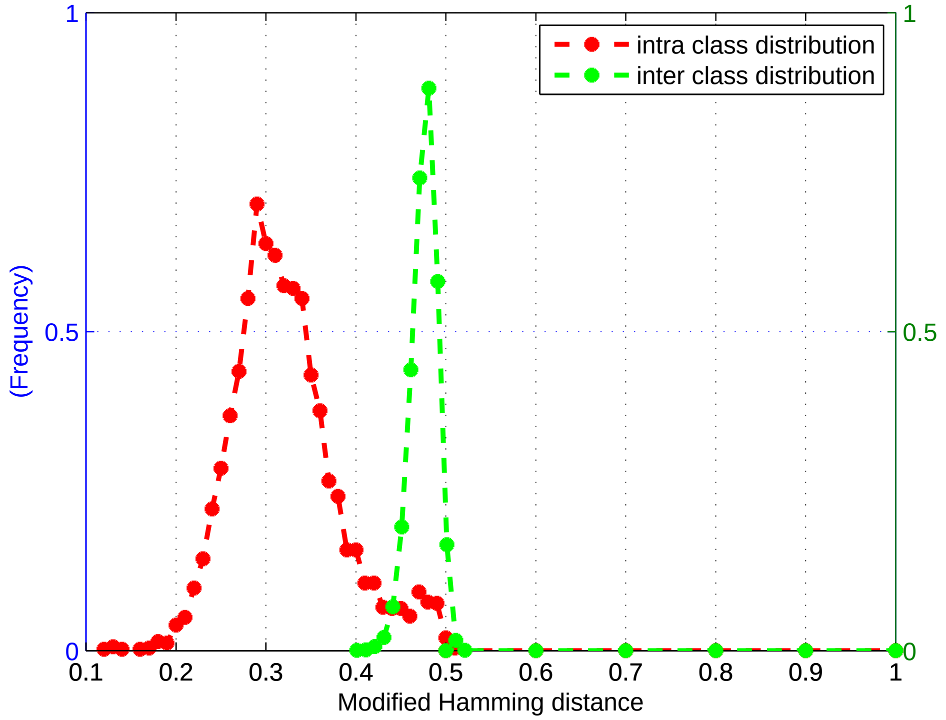

Fig. 6. Distribution of intra-class and inter-class using Modified Hamming distance

With the ‘CASIA-V3.0’ data set perfect recognition is not possible due to the overlapping distributions (inter and intra class) as shown in Fig. 5. With a separation point of 0.433 (as shown in Table III) a false accept rate and false reject rate of 4% are achieved, which still allows accurate recognition.

TABLE III. False Accept And False Reject Rates For The ‘CASIA-V3.0’ Data Set With Jaccard Distance.

Threshold	**FAR(%)**	**FRR(%)**
0.622	20	2
0.613	10	3
0.605	4	4
0.602	3	5
0.598	2	6
0.594	1	6
0.584	0.9	8

With the ‘CASIA-V3.0’ data set perfect recognition is not possible due to the overlapping distributions as shown in Fig. 6. With a separation point of 0.445 (as shown in Table IV) a false accept rate and false reject rate of 3% are achieved, which still allows an accurate recognition.

TABLE IV. False Accept And False Reject Rates For The ‘CASIA-V3.0’ Data Set With Modified Hamming Distance.

Threshold	**FAR(%)**	**FRR(%)**
0.448	5	3
0.446	4	3
0.445	3	3
0.444	3	3.1
0.442	2	3.5
0.440	2	4
0.439	1	4

Fig. 7 shows the ROC curve of the proposed method using the 2 metrics and the fractal analysis method. The further towards the top left of the graph that the ROC curve is, the better the iris recognition system is. It’s clear from the graph in Fig. 7 that the proposed method using modified HD distance outperforms the fractal analysis.

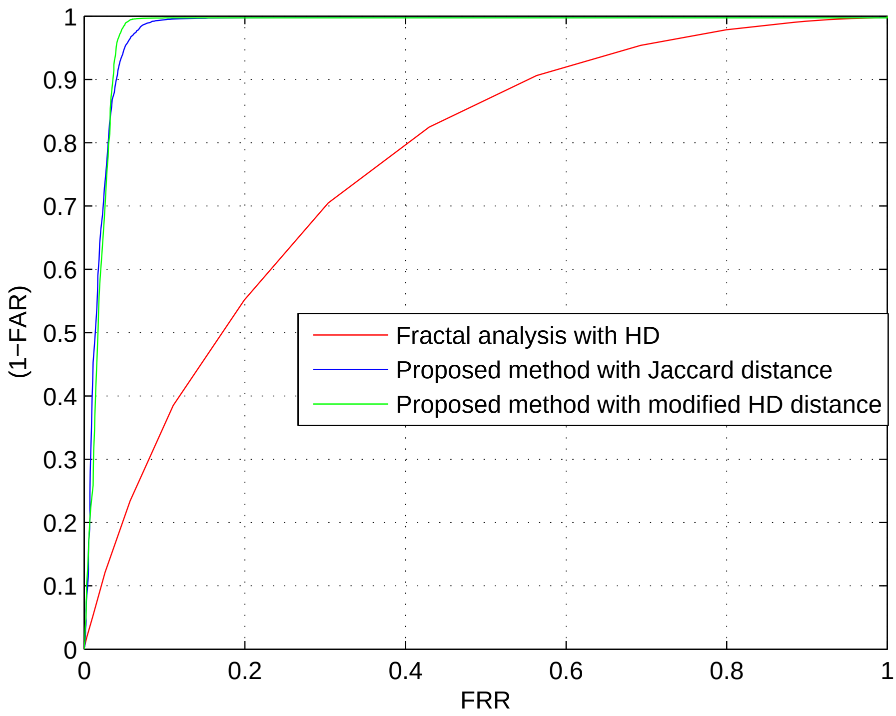

Fig. 7. ROC curves.

V. Conclusion and Future Works

In this paper we proposed a robust feature extraction method for iris recognition system based on monogenic filter. The proposed method was tested and evaluated on CASIA-IrisV3-Interval database.

The experimental results show that the proposed method using the modified Hamming distance with a recognition rate equal to 97.85% achieves fractal analyses and the proposed method using Jaccard distance in term of accuracy and time computation. Moreover, the complexity of the proposed feature extraction method is obviously low and thus achieves a considerable computational reduction.

Our future works will be focused on the implementation of the proposed method using multicore DSPs.

References

[1] M. Yang, L. Zhang, S. C. K. Shiu, and D. Zhang, “Monogenic Binary Coding: An Efficient Local Feature Extraction Approach to Face Recognition,” vol.7, pp.1738 – 1751, Nov. 2012.
[2] Li Yu, Xue Zhou, “A Novel Method for Iris Recognition Based on Zero-Crossing Detection,” vol. 127, pp. 509-517, 2012.
[3] A. Abhyankar, S. Schuckers, “ Iris Recognition Methods - Survey, International Journal of Computer Applications,” vol. 3, pp. 0975 - 8887, Jun. 2010.
[4] J. Daugman, “Biometric personal identification system based on iris analysis,” United States Patent, US5291560A, Mar. 1, 1994.
[5] J. Daugman, “How iris recognition works”, IEEE transactions on circuits and systems for video technology, vol. 14, pp.21-30, Jan. 2004.
[6] M. Felsberg and G. Sommer“, The monogenic signal,” IEEE Trans. Signal Processing, vol. 49, pp. 3136-3144, Dec. 2001.
[7] G. H. Granlund and H. Knutsson, “Signal Processing for Computer Vision,” Kluwer Academic Publishers, 1995.
[8] J. Thornton, M. Savvides, B.V.K. Vijay Kumar, “A Bayesian approach to deformed pattern matching of iris images”, IEEE Trans. Pattern Anal. Mach. Intell, vol. 29 , pp.596–606, Apr. 2007.
[9] J.Huang, T.Tan, L.Ma, Y.Wang, “Phase correlation based iris image Registration model”, Compute. Sci. Technol. vol. 20, pp. 419–425, May. 2005.
[10] W.W. Boles, “A security system based on human iris identification using wavelet transform”, Proceedings of the International Conference on Knowledge-Based Intelligent Electronic Systems, vol.2, pp.533–541, May. 1997.
[11] L.Ma, T.Tan, Y.Wang, D.Zhang, “Efficient iris recognition by characterizing key local variations,” IEEE Trans. Image Process. Vol.13, pp. 739–750, Jun. 2004.
[12] A. Azizi, H. R. Pourreza, “A New Method for Iris Recognition Based on Contourlet Transform and Non Linear approximation Coefficients”, 5th International Conference on Intelligent Computing, vol. 5754, pp. 307-316, 2009.
[13] J. Li, Q. Du, C. Sun, “An improved box-counting method for image fractal dimension estimation,” Journal Pattern Recognition, vol. 42, pp. 2460-2469, Nov. 2009.
[14] I . Khanfir, “contribution a l’identification d’individus par l’iris”, Phd thesis, university of sfax, 2010.
[15] R. B. Trabelsi, I. K. Kallel and I. Masmoudi, “multi modal biometric system based palmprint and iris,” 8th International Multi-Conference on Systems, Signals and Devices, pp.1-5, 2011.
[16] R.P. Wildes, “Iris recognition: an emerging biometric technology”, Proc.IEEE, vol. 85, pp.1348–1363, Sep. 1997.
[17] Z. He, T. Tan, Z. Sun,and X. Qiu, “Toward Accurate and Fast Iris Segmentation for Iris Biometrics,” IEEE transactions on pattern analysis and machine intelligence, vol. 31, pp.1670 – 1684, Sep. 2009.

[18] J.A. Guerrero, J.L. Marroquin and M. Rivera, “Adaptive Monogenic Filtering and Normalization of ESPI Fringe Patterns,” Depto. de Optica. Universidad Complutense de Madrid, 2841 Madrid, Spain

[19] S. Niwattanakul, J. Singthongchai, E. Naenudorn and S, “Using of Jaccard Coefficient for Keywords Similarity,” Proceedings of the International MultiConference of Engineers and Computer Scientists vol.1, Mar. 2013.

[20] L. Masek, “Recognition of human iris patterns for biometric identification,” The University of Western Australia, 2003

[21] N. Sarkar and B. B. Chaudhuri, “An efficient approach to estimate fractal dimension of textured images,” Pattern Recognition, Vol. 25, pp.1035-1041, 1992.

[22] D. Talukdar and R. Acharya, “Estimation of fractal dimension using alternating sequential filters,” in Proceedings of International Conference on Image Processing, vol. 1, pp.231-234, Oct. 1995.

[23] C. C. TSAI, J. S. TAUR AND C. W. TAO, “Iris Recognition Using Gabor Filters and the Fractal Dimension,” Journal of information science and engineering, vol. 25, pp. 633-648, May. 2009.

[24] C. Attikos, M.Doumpos, “Faster estimation of the correlation fractal dimension using box-counting,” Fourth Balkan Conference in Informatics, pp.93-95, Sep. 2009.

[25] W. Aydi, N. Masmoudi, L. Kamoun, “A fast and accurate eyelids and eyelashes detection approach for iris segmentation,” International Conference on Multi Media Processing, pp.1-6, Jun. 2013.

[26] W. Aydi, N. Masmoudi, L. Kamoun, “Improved Masek approach for iris localization,” International Conference on Microelectronics, pp. 1-5, Dec. 2011.

[27] Tak-Shing Chan, Ajay Kumar, “Reliable Ear Identification using 2-D Quadrature Filters,”Pattern Recognition Letters, vol. 33, pp.1870-1881, Oct. 2012.