Iris Recognition Based on Using Ridgelet and Curvelet Transform

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Abstract

Biometric methods have been played important roles in personal recognition during last twenty years. These methods include the face recognition, finger print and iris recognition. Recently iris imaging has many applications in security systems. The aim of this paper is to design and implement a new iris recognition algorithm. In this paper, the new feature extraction methods according to ridgelet transform and curvelet transform for identifying the iris images are provided. At first, after segmentation and normalization the collarette area of iris images has been extracted. Then we improve the quality of image by using median filter, histogram equalization, and the two-dimensional (2D) Wiener filter as well. Finally the ridgelet transform and curvelet transform are applied for extracting features and then the binary bit stream vectors are generated. The Hamming distance (HD) between the input bit stream vector and stored vectors is calculated for iris identification. The experimental results show efficiency of our proposed method.

***Key words**: Iris identification, ridgelet transform, curvelet transform.*

1. Introduction

There are different methods for personal identification with using biometric characteristics. In general, biometric is an individual identification ability based on physiological characteristics such as fingerprint, handwriting, retina, iris and face. There are many advantages of employing biometric system for identification but there are also some disadvantages. We can mention to high recognition accuracy, uniqueness, and no needs to memorize a code as advantages and low public acceptance, and complex or expensive equipments as disadvantages. Any way the advantages of using the biometric systems are more than its drawback, so using is increasing daily. Although using iris patterns for personal identification have been begun in the last 19^{th} century, it takes more attention nowadays. Fig. 1 shows different parts of eye.

Some characteristics of iris are:1) it is formed in third month and completed in eight month of fetal term, 2) not only individual persons even twins but also left and right eye belong to a person have different iris pattern, 3) changing iris pattern without surgery with high risk is impossible. In addition iris recognition system is a noninvasive method.

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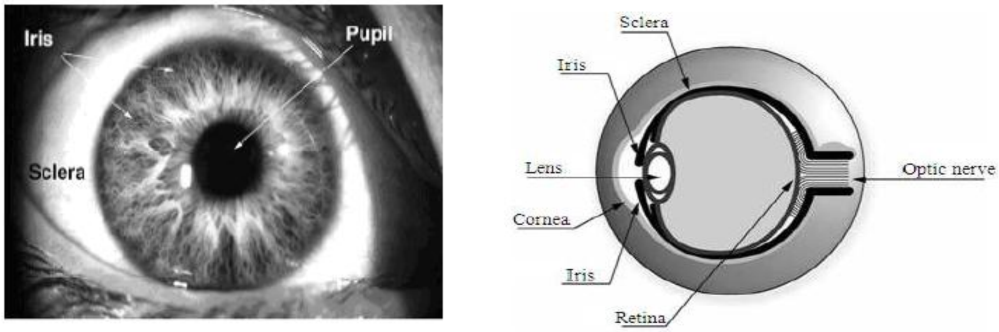


Fig. 1: Structure of Different Part of Eye [1].

Pioneer work in iris recognition was proposed by Daugman [2]. Daugman's algorithm forms the basis of today's commercially used iris recognition systems. In [3], biometrics based on the concealment of the random kernels and the iris images to synthesize a minimum average correlation energy filter for iris authentication were formulated. In [4], the multiscale Gabor filters were used to demodulate the texture phase structure information of iris. In [5], an iris segmentation method was proposed based on the crossed chord theorem and the collarette area. In [6], iris recognition technology was applied in mobile phones. In [7], correlation filters were utilized to measure the consistency of the iris images from the same eye. An iris image was decomposed in [9] into four levels by using the two dimensional (2D) haar wavelet transform, the fourth-level high-frequency information was quantized to form an 87-bit code, and a modified competitive learning neural network was adopted for classification. In [11] collarete area and daubechies in level 3 was used to extract useful features. In [12], a geometrical method for pupil detection was used. In [17] contourlet transform was applied for feature extraction. In [18] wavelet transform was used .In [19] features were extracted based on estimating the joint probability of a pair of pixel intensities in predetermined relative positions in the image. In [20] feature extraction was based on multichannel Gabor filtering. Vladan in [21]-[22] used directionlet for feature extraction and Hamming distance (HD) for classification. In [25] Gabor filter was applied to extract features according to phase specifications of iris features and finally in [26] one dimensional (1D) coiflet was used to extract features.

In this work we apply two recently introduced transforms for feature extraction, they are ridgelet and curvelet. We show that our proposed method for iris identification is more accurate in comparison with the other suggested methods for this purpose. The block diagram of our proposed method is sketched in Fig. 2.

The paper is organized as follows: Section 2 deals with image processing steps that include segmentation, normalization, and image quality enhancement. Section 3 deals with ridgelet, and curvelet transforms for feature extraction. Section 4 deals with classification and how rotation can be compensated. Section 5 deals with our experimental results and finally in section 6 the conclusion of the proposed method is presented.

2. Iris Image Processing

Iris image processing includes three stages, they are segmentation, normalization and contrast enhancement. In addition, for iris processing we need a standard database. We

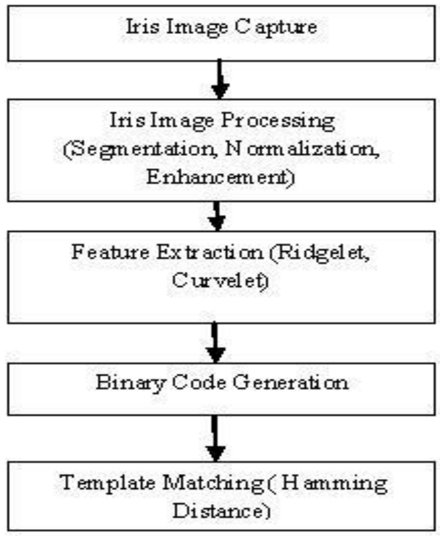


Fig. 2: The Flow Graph of Our Proposed Iris Recognition Algorithm.

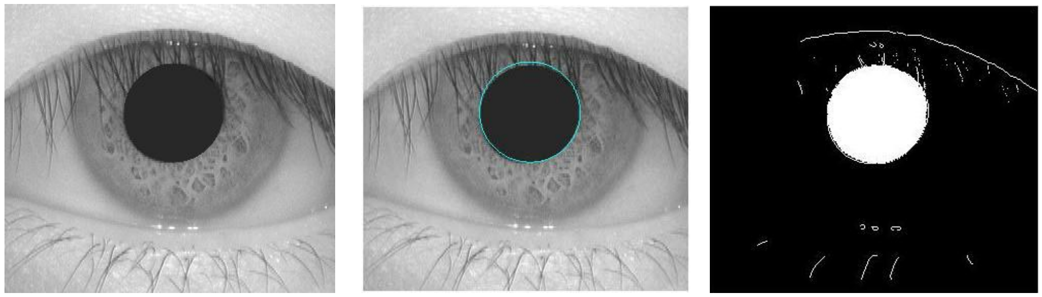
choose the standard CASIA iris image database. The CASIA iris image database includes 108 different classes. There are 7 images for each class. There by, we have totally 756 (108×7) iris images with a resolution of 320×280 pixels.

2.1. Segmentation

The iris is an annular part between pupil (inner boundary) and sclera (outer boundary) as it can be seen in Fig. 1. The inner and outer iris boundaries should be segmented to provide useful information area for identification. As pupil is black circular region, it is detected easily. The best edge results came using the canny method [10]. So we use canny edge detector for detecting eye boundaries. Then for reducing the effect of eyelids and eyelashes, we choose a window with size (3×3) and move it through the segmented image. The color values of the pixel within the window are sub threshold from the window average. If the obtained value for each pixel is less than a obtained threshold, it will be considered as zero. Otherwise it will be set to one. Fig. 3 shows an original iris image and the segmented and binary images as well. Now we should find circle contours by using a practical algorithm to segment iris boundaries.The voting procedure is realized using circular Hough transform in order to search for desired contour from the edge map. Assuming a circle with center coordinate (x_c, y_c) and radius R, each edge point on the circle casts a vote in hough space. The circular contour of interest is defined as:

$$(x_i - x_c)^2 + (y_i - y_c)^2 = R^2 \quad (1)$$

where (x_i, y_i) refers to a point on circle with radius R. The center coordinate and radius of the circle with maximum number of votes are defined as the pupil center and iris inner boundary as well. Now using circular Hough transform to find outer boundary takes obviously too much time. On the other hand we know that more complex and rich texture necessary information to identify iris area is close to pupil boundary that named collarette area, which is less sensitive to the pupil dilation. So, after detecting iris inner boundary, the iris outer boundary which has almost the same center as pupil, with predefined radius is specified.



(a) (b) (c)

Fig. 3: Original Iris Image (a), Segmented Pupil (b), and Binarized Iris Image (c).

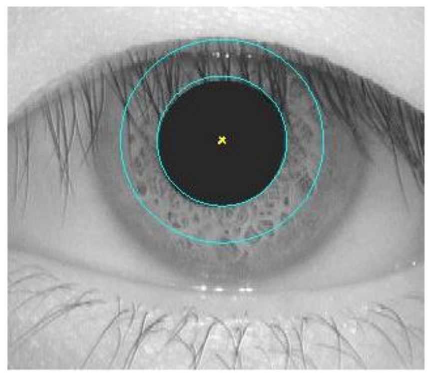


Fig. 4: The segmented inner and outer iris boundaries are shown. The center coordinate is (164.644, 104.096) and the estimated inner and outer radius are 49.542 and 77.542 pixels in order.

Table 1: Detection Accuracy of Iris Boundary.

Method	Accuracy (%)
Hanho sung [11]	98.55
Xiaofu [12]	97.67
Cui et al. [13]	97.35
Md Slim [14]	90
Our proposed method	98.64

In this way, the generated bit stream size is reduced and so it leads less computational cost for feature extraction. Fig. 4 illustrates the segmented inner and outer iris boundaries. We have run our described boundary detection algorithm on CASIA database. The accuracy achieved by the proposed algorithm and four different methods are reported in Table 1. As it can be seen, our method achieves the appropriate accuracy.

2.2. Normalization

Even iris images that are taken from the same person and in the same place are generally different, so obviously it is true for those captured at different time and different places. Pupil elastic deformation affects the iris size. Due to compensate the iris size variation, iris normalization is an obligation. As the inner and outer boundaries are approximately circle shape, we do iris normalization according to Daugman model (rubber sheet model) [15] which is shown in Fig. 5.

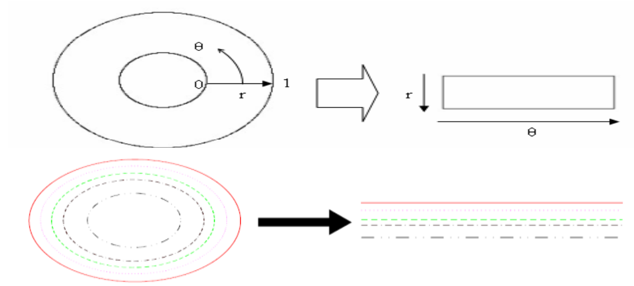


Fig. 5: Iris Normalization According to Daugman Model [15].

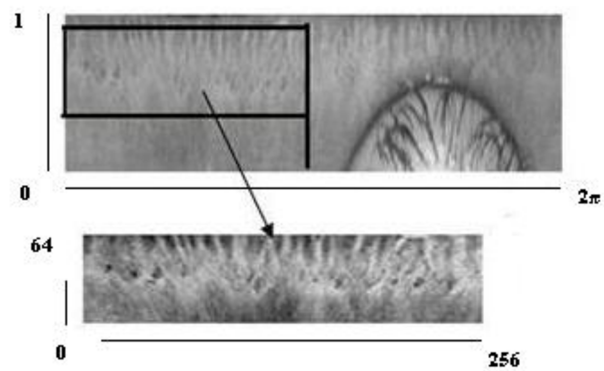


Fig. 6: Normalized Iris Image (top), Windowed Iris Image (bottom) to get rid of some existed eyelid and eyelashes.

According to the Daugman model, a linear mapping has done on each pixel of iris, and regardless its size and papillary dilation, assigns a pair of real coordinate, (r, θ). Where r is within the interval [0,1] and θ is an angle within [0,2π]. We have done normalization on the segmented iris image (Fig. 4) and show the result in Fig. 6 (top). As it can be seen, there are part of eyelid and some eyelashes effects in normalized image. So, just a part of normalized iris image that eyelid and eyelashes may not exist is chosen by windowing, Fig. 6 (bottom). The size of this rectangle window is chosen to be 64×256, and axes labels in Fig. 6 (bottom) shows the image size according to the number of pixels.

2.3. Contrast Enhancement

Iris images should be enhanced before feature extraction. For this purpose we have used median filter, histogram equalization, and the 2D wiener filter as well. No more description needs for employing median filter and histogram equalization. We just notify that the window size for using the median filter is (3×3). For applying the 2D wiener filter, at first the mean and local variance is computed according to the following equations:

$$\mu = \frac{1}{MN} \sum_{n_1, n_2 \in \eta} a(n_1, n_2) \tag{2}$$

$$\sigma^2 = \frac{1}{MN} \sum_{n_1, n_2 \in \eta} a^2(n_1, n_2) - \mu^2 \quad (3)$$

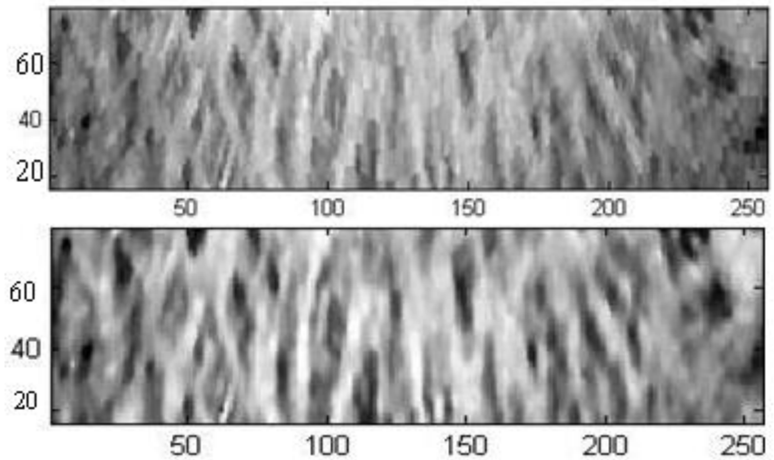


Fig. 7: Normalized Iris Image (top), enhanced iris image by using median filter, histogram equalization and wiener filter (bottom).

where η refers to the local window with size 3×3 around each pixel that is going to be processed, μ is the local mean value, and σ^2 is the local variance . The output of wiener filter is obtained as follows:

$$b(n_1, n_2) = \mu + \frac{\sigma^2 - \nu^2}{\sigma^2}(a(n_1, n_2) - \mu) \quad (4)$$

where ν^2 presents the noise variance which is considered to be equal the local mean variance. Fig. 7 (bottom) shows a contrast enhanced iris image.

3. Feature Extraction

The iris has a particularly interesting structure and provides abundant texture information. It is desirable to explore representation methods which can capture local underlying information in an iris. Here we use ridgelet and curvelet transforms to extract features. The ability of ridgelet and curvelet transforms to make sampling data in different directions caused that fewer coefficients need in comparison with using the wavelet transform and some other transforms for feature extraction. In addition our experimental results show that using ridgelet and curvelet make the iris identification system more accurate and fast.

3.1. Preliminary to Ridgelet and Curvelet Transforms

The ridgelet transform was introduced by Candes and Donoho [16] in 1999. A basic tool for calculating the ridgelet coefficients is considering the wavelet analysis in Radon domain. Fig. 8 sketches the ridgelet transform flow graph and we can find the implementation in detail in [16] as well.

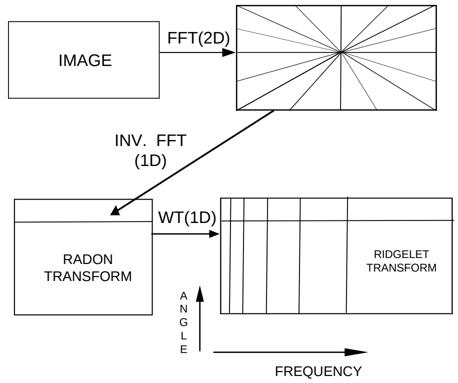


Fig. 8: Ridgelet transform flow graph. Each of the radial lines in the Fourier domain is processed separately. The 1D inverse FFT is calculated along each radial line followed by a 1D non-orthogonal wavelet transform. In practice, the 1D wavelet coefficients are directly calculated in the Fourier space [16].

The curvelet transform is a multi resolution transform which was introduced by Candes and Donoho [16] in 1999. It can detect curve boundaries better than wavelet and ridgelet transforms, or it can extract useful features that are missed in other transforms. The flow graph of computing the curvelet coefficients is sketched in Fig. 9, and we can find the implementation in detail in [16]. To capture smooth contours in images, the representation should contain basis functions with variety of shapes. A major challenge in capturing geometry and directionality in images comes from the discrete nature of the data. For these reasons, unlike other transforms that were initially developed in the continuous domain and then discretized for sampled data, the new approach starts with a discrete-domain construction and then investigate its convergence to an expansion in the continuous-domain. This construction results in a flexible multi- resolution, local and directional image expansion using curve segments. Directionality and anisotropy are the important characteristics of ridgelet and curvelet transforms. Directionality indicates that having basis function in many directions, there are only three direction in wavelet. The anisotropy property means the basis functions appear at various aspect ratios where as wavelets are separable functions and thus their aspect ratio is one. Due to these properties ridgelet and curvelet can efficiently handle 2D singularities, edges in an image**.** This property is utilized in this paper for extracting directional features for various pyramidal and directional filters.

We consider the iris enhanced image as an input image in ridgelet and curvelet transforms according to their flow- graphs to extract iris features. Now we have iris features that are more accurate than other transforms and unique for each person.

3.2. Binary Codes

After calculating the ridgelet and curvelet coefficients from iris enhanced image, they should be converted to binary codes. So for CH (horizontal coefficient), CV (vertical coefficient), and CD (diagonal coefficient), all coefficients greater than zero are replaced by 1 and all coefficients equal or less than zero are replaced by 0. In this paper we just use CV and CH coefficients. Fig. 10 shows the generated binary codes based on using the ridgelet and curvelet transforms.

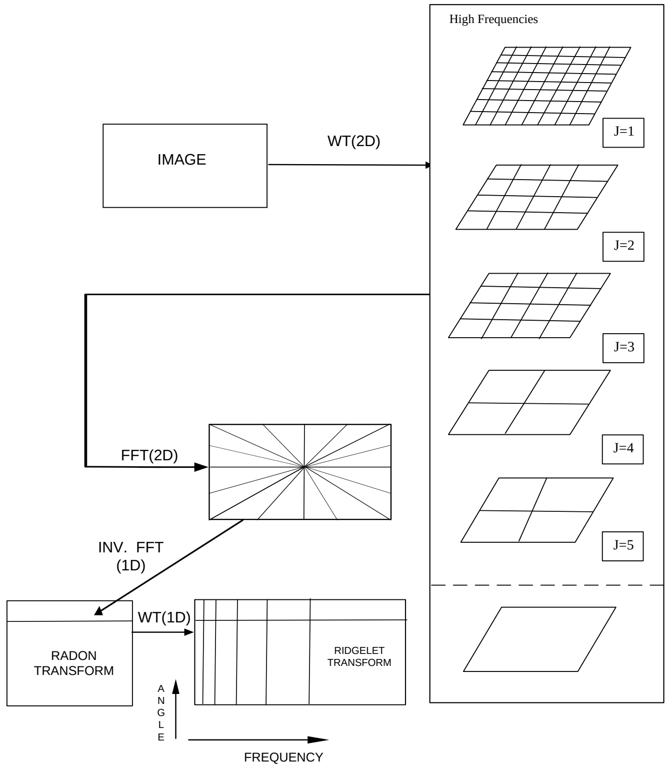
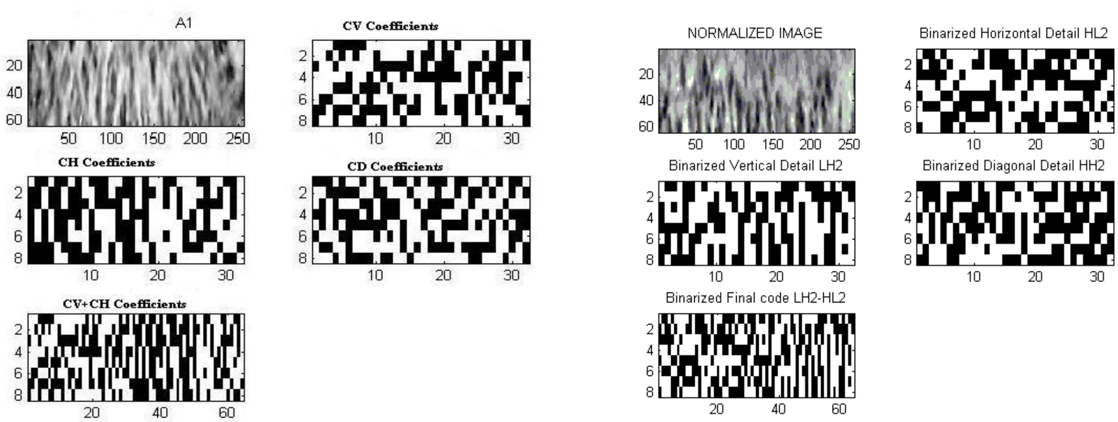


Fig. 9: Curvelet transform flow graph. It illustrates decomposition of the original image into subbands by 2-D wavelet transform and followed by the spatial partitioning of each sub band. The ridgelet transform is then applied to each block [16].



(a) **(b)**

Fig. 10: A sample Iris Binary Code Generated by using (a) Ridgelet Transform, (b) Curvelet Transform.

4. Hamming Distance Classifier and Eye Rotation

The obtained binary code should enter a comparison process to determine the user whose iris photograph was taken. So the last module of an iris recognition system is used for matching two iris templates. Its purpose is to measure how similar or different templates are and decide whether they belong to the same individual or not**.** Although there are many different methods for this purpose such as Euclidean distance, weighted Euclidean distance, and Fisher Linear Discriminate, in this work we choose HD.

4.1. Hamming Distance Classifier

The HD between two strings of bits is the number of corresponding bit positions that differ. Using the HD between two bit patterns, a decision can be made as to whether the two patterns were generated from the same iris or from different irises. HD can be made using XOR function as:

$$HD = \frac{1}{N}\sum_{i=1}^{N} X_i \otimes Y_i \tag{5}$$

where N is the number of bits in the binary code, X_i is the i^{th} feature of the tested iris, and Y_i, is the i^{th} feature of the iris template. If two bit patterns are completely independent, such as iris templates generated from different irises, the HD between the two patterns is close to 1. If two patterns are derived from the same iris, the HD between them is close to 0 (since they are highly correlated and the bits should agree between the two iris codes). According to [27] for determining the accuracy of the proposed algorithm we use $\text{Accuracy}=\frac{\text{FAR}+\text{FER}}{2}$, where FAR and FER refer to false accept rate and false reject rate.

4.2. Eye Rotation Problem

Regarding that the images are captured in different situation of the eye and head, it is possible that the head position be different in each time and we store eye images with different position of iris and pupil in them. So we should use an algorithm that is not depend on position of iris and pupil in eye image. For this purpose HD is calculated between two codes, one code on the other code is moved bit to bit to the right and left and we have several HD. In this paper we shift every binary iris code 5 bit to right and 5 bit to left. By this method for every input iris image we compare it with 11 binary codes for every 2 iris images. So we can solve eye rotation problem. After we could calculate different HDs between iris codes, we should match input image with a class in database. Here we have two methods: First, we can define an optimum threshold according to our experimental tests. We match input image with a class that their HD is sub threshold. This Method is fast but is not accurate. In another method we can match input image with a class that their HD is less than the others. This method takes time because it calculates HD between input image and all registered images, but it is more accurate. In this paper the second method is used.

5. Experimental Results

For implementing ridgelet and curvelet transform by using wavelet decomposition, we test different type of mother wavelet. Using curvelet transform we decompose an input image up to level 3, and use a combination of LH3 and HL3 that has the best performance. The algorithm performance according to 5 criteria is written in Table 2, and Table 3. The algorithm has run by using Matlab 7.6, on a Pentium 4, 2.66 MHZ, 3 Mb RAM computer. According to accuracy achieved, ridgelet transform based on using haar and curvelet transform based on using Db1 as mother wavelet have the best performance among all chosen wavelets. In addition, in order to show the efficient performance of our proposed method in comparison with others, we also report in Table 4 the achieved accuracy by 11 different methods. We mention that all chosen approaches used the same database, CASIA, and most of these methods are working based on wavelet transform. We know, wavelet transform extracts coefficients just in 3 directions (horizontal, vertical and diagonal) with angle of 45 degree, while ridgelet transform and curvelet transform extract features in more directions.

Table 2: Ridgelet Transform Based on Using Different 1D Mother Wavelets.

Mother wavelet	Code length	Runing (ms)	Accuracy (%)
Harr	399	422.6	97.965
Db1	582	499.9	96.5
Db2	584	501	97.66
Db3	586	497.3	96.55
Db4	586	499.3	97
Db5	589	500	96.55
Sym1	582	499	97
Sym2	584	500.8	97.25
Sym3	586	505	97
Sym4	588	500.6	97.015
Sym5	589	502.8	97.05
Coif1	586	501.1	97.65
Coif2	591	502	96.45
Coif3	596	509.1	96.5
Coif4	602	507.5	96
Coif5	607	513.2	96.5

Table 3: Curvelet Transform Based on Using Different 1D Mother Wavelets.

Mother wavelet	Code length	Runing (ms)	Accuracy (%)
Harr	1158	516.4	97.85
Db1	666	415.1	98
Db2	704	421.1	97.2
Db3	742	430.8	96
Db4	780	442.1	94
Db5	818	453.2	94.5
Sym1	666	415.3	97.75
Sym2	704	424.5	97.1
Sym3	742	433.4	95.6
Sym4	780	443.6	95.5
Sym5	818	452.9	95
Coif1	742	434.5	95.4
Coif2	818	464.6	95.05
Coif3	970	493.4	95.83
Coif4	1122	564.5	95
Coif5	1198	566/8	94

6. Conclusion

In this paper we proposed two effective iris recognition methods which are based on using ridgelet and curvelet transforms. In order to implement these two transforms, we have used different 1D mother wavelet such as haar, daubechies, symlet, and coiflet and investigated accuracy, binary code length, and time consuming. As we have done iris recognition on the CASIA standard database, we compared the achieved accuracy with 11 different approaches. As the ridgelet transform and curvelet transform use basis function in multiresolution, employing them for feature extraction caused our progress to provide shorter binary code and higher accuracy as well. In addition it is also shown that using curvelet transform even is better than ridgelet transform and so gets more accuracy.

Table 4: The accuracy achieved by our proposed method based on ridgelet, curvelet and other different methods for iris identification.

Different Approach	Accuracy (%)
Amir azizi [17]	96.5
k. masoud [18]	95.9
A.T zaim [19]	95
Li Ma [20]	94.9
Vladan [21]	94.7
Hanho Sung [11]	94.54
Vladan [22]	94.3
Robert w.Ives [23]	93
Boles [24]	92.64
Hao Meng [25]	87.4
Agus Harjoko [26]	84.25
Ridgelet, our method	97.96
Curvelet, our method	98

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References

[1] Ahmad M.Sarham "Iris recognition using discrete cosine transform and artificial neural network," Journal of computer science, vol 5, no5, pp 369-373, 2009.
[2] J. Daugman, "How iris recognition works," IEEE Trans. on Circuits and Systems for Video Technology., vol. 14, no. 1, 2004.
[3] S. C. Chong, A. B. J. Teoh, and D. C. L. Ngo, "Iris authentication using privatized advanced correlation filter," in Proceedings of the International Conference on Advances on Biometrics (ICB '06), vol. 3832 of Lecture Notes in Computer Science, pp. 382–388, Springer, Hong Kong, January 2006.
[4] J. G. Daugman, "High confidence visual recognition of persons by a test of statistical independence," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 15, no. 11, pp. 1148–1161, 1993.
[5] X. He and P. Shi, "An efficient iris segmentation method for recognition," in Proceedings of the 3rd International Conference on Advances in Patten Recognition (ICAPR '05), vol. 3687 of Lecture Notes in Computer Science, pp. 120–126, Springer, Bath, UK, August 2005.

[6] D. S. Jeong, H.-A. Park, K. R. Park, and J. Kim, “Iris recognition in mobile phone based on adaptive Gabor filter,” in Proceedings of the International Conference on Advances on Biometrics (ICB ’06), vol. 3832 of Lecture Notes in Computer Science, pp. 457–463, Springer, Hong Kong, January 2006.
[7] B. V. K. Vijaya Kumar, C. Xie, and J. Thornton, “Iris verification using correlation filters,” in Proceedings of the 4th International Conference Audio and Video-Based Biometric Person Authentication (AVBPA ’03), vol. 2688 of Lecture Notes in Computer Science, pp. 697–705, Guildford, UK, June 2003.
[8] E. C. Lee, K. R. Park, and J. Kim, “Fake iris detection by using purkinje image,” in Proceedings of the International Conference on Advances on Biometrics (ICB ’06), vol. 3832 of Lecture Notes in Computer Science, pp. 397–403, Springer, Hong Kong, January 2006.
[9] S. Lim, K. Lee, O. Byeon, and T. Kim, “Efficient iris recognition through improvement of feature vector and classifier,” Electronics and Telecommunications Research Institute Journal, vol. 23, no. 2, pp. 61–70, 2001.
[10] J. Canny, “A Computational Approach to Edge Detection”, IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 8, No. 6, pp. 184-201, Nov 1986.
[11] Hanho sung, jaekyung lim, “Iris localization using collarette boundary localization,” IEEE 17th international conference on pattern recognition, Cambridge UK, vol 4 , pp. 857-860, Agust 2004.
[12] Xiaofu He ,pengfei shi, “A new segmentation approach for iris recognition based on hand-held capture device,” science direct ,pattern recognition, vol 40, issue 4, pp. 1326-1333, April 2007.
[13] Richard N.F Yonh .h, “An Effective Segmentation Method for Iris Recognition System,” 5th IEEE conference on visual information Engineering, XianChina, pp. 548-553, Agust 2008.
[14] Md slim al.M, “Iris recognition:a new approach for iris segmentation,” 12th ICCIT (international conference on computer and information technology", 2009.
[15] J. Daugman, “High confidence visual recognition by test of statistical independence,” IEEE Transactions on Pattern Analysis and MachineIntelligence**,** Vol. 15, pp. 1148-1161, November 1993**.**
[16] Jean luck Starck, EmmanuelJ, “The Curvelet transform for image denoising,” IEEE trans ,vol 11 no 6, pp.670-685,June 2002.
[17] Amir azizi,Hamid reza P, “Efficient iris recognition through improvement of feature extraction and subset selection,” international journal of computer science and information security,vol2,no 1 June 2009.
[18] K Masood ,Dr M.y.J, “Iiris recognition using wavelet,” IEEE international conference on Emerging technologies, Islamabad, pp. 253-256,November2007.
[19] A.T.Zaim, “A new method for iris recognition using Gary-level coccurance matrix,” IEEE conference on information and technology, East Lansing, pp. 350-353, May 2006.
[20] L.Ma, Y.H.Wang, T.N.Tan, “Iris recognition based on multichannel Gabor filtering,”. Proceedings of the Fifth Asian Conference on Computer Vision, Australia, pp.279-283, 2002.
[21] Vladan Velisavljevic, “'Low-complexity iris coding and recognition based on directionlets,” IEEE trans. vol4,no 3,pp. 410-417, Sept. 2009.
[22] Vladan Velisavljevic, “Low complexity iris recognition with oriented wavelets,” 16th IEEE international conference on image processing, Cairo Egypt, pp. 1933-1936, November 2009.
[23] Robert W Ives,Antthony J, “Iris recognition using histogram analysis,” 38th asimolar conference on signal system and computer,vol 1, pp. 562-566,November 2004.
[24] W. Boles and B. Boashash, "A Human Identification Technique Using Images of the Iris and Wavelet Transform,"IEEE Trans. Signal Processing, vol. 46, no. 4, pp. 1185-1188, 1998.
[25] Hao Meng and cuiping Xu;"iris recognition algorithms based on gabor wavelet transform",IEEE international conference on mechatronics and automation ,Luoyang henna,pp. 1785- 1789, june2006.
[26] Agus Harjoko ,Sri Hartati ,H.D, “A method for iris recognition based on 1d coiflet Wavelet,” world academy of science , engineering and technology ,vol 56,pp.126-129, 2009.
[27] M.Vasta ,R.singh and A.N, “Reducing false rejection rate of iris recognition using textural and topological features,” international journal of signal processing ,vol 2,no 1,pp. 66-72, 2005.