International Journal of Computer Applications (0975 – 8887)
Volume 32– No.6, October 2011

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Iris recognition using Partial Coefficients by applying Discrete Cosine Transform, Haar Wavelet and DCT Wavelet Transform

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ABSTRACT
Iris recognition systems are unavoidable in emerging security and authentication mechanisms. In this paper, we make a comparative study of performance of image transforms Discrete Cosine Transform (DCT), Haar wavelet and DCT wavelet, when they are used for iris verification. Initially, the entire 256x256 feature co-efficient matrix, obtained after applying DCT, Haar wavelet or DCT wavelet transform to the image, is considered. The coefficients from bottom right of the image matrix, transformed using DCT, Haar wavelet or DCT wavelet, which contain minor information, are discarded gradually and the performance is recorded for all iterations.

General Terms
Security, Algorithms

Keywords
Iris recognition, biometrics, DCT, Haar Transform, DCT wavelet, Partial Coefficients

1. INTRODUCTION
Security has become a major concern nowadays. One of the important techniques used in security systems is iris recognition. Iris recognition is the analysis of the coloured ring that surrounds the pupil[1]. The iris has unique structure and these patterns are randomly distributed, which can be used for identification of human being. This makes it comparatively more reliable and stable for identification than the other biometric features such as face and voice[2]. With the development of highly sophisticated techniques for iris image acquisition, iris recognition is expected to become an important and widely used form of identification its applications ranging from national identification card, biometric passport and forensics to banking, e-commerce, welfare distribution, etc.

2. REVIEW OF LITERATURE
Many approaches are available in literature for iris recognition based on various approaches for feature extraction. Feature extraction is the process of extracting subset of features from the entire feature set. The basic idea behind the feature extraction is that the entire feature set is not always necessary for the identification process.

Improper iris image preprocessing can also influence the subsequent processes like feature vector extraction and enrollment/recognition[10]. Consequently, the iris preprocessing step needs to be robust and perform iris localization accurately. Daugman[11] applied integro-differential operators for iris localization. It searches the path circularly to detect the iris boundary. Tisse *et al.*[2] implemented Hough transform for the same process. A generalized Hough transform was implemented by Wildes[12] to detect local boundaries of an iris. Ma *et al.*[13] proposed a new algorithm which locates the center of pupil and uses it to approximate iris region before executing edge detection and Hough transform. Cui *et al.*[14] made use of the low frequency information from wavelet transform for pupil segmentation and localized the iris with integro-differential operator. Moreover, the eyelids detection was also performed after the eyelashes detection. These methods are used to define the area of iris which is later segmented for the feature extraction.

One of the most common techniques used for feature extraction is Discrete Cosine Transform (DCT). Donald Munro et al.[3] have proposed an iris coding method based on differences of discrete cosine transform (DCT) coefficients of overlapped angular patches from normalized iris images.

Kekre, Sarode, et al.[4, 19] have proposed an iris recognition system based on vector quantization (VQ) techniques and have compared its performance with the discrete cosine transform (DCT). They have tested Linde-Buzo-Gray (LBG), Kekre's fast codebook generation (KFCG) algorithm and Kekre's proportionate error (KPE) algorithm for the clustering purpose. Kekre, Sarode et al [15] have also done a performance comparison of Iris Recognition Techniques using Wavelet Pyramids of Walsh, Haar and Kekre Wavelet Transforms.

Tze Weng et al.[16] have created an Iris Recognition System based on Haar Wavelet decomposition with help of Hamming Distance and Segmentation. Abdel Alim, O.; Sharkas, M [17] have fed the features obtained to a neural network and compared the performance of DCT with Gabor. Kumar et al.[18] present a comparative study of the performance from the iris identification using log-Gabor, Haar wavelet, DCT and FFT based features.

In this paper, we present Iris Recognition using partial coefficients after performing DCT, Haar wavelet and DCT wavelet transform and their performance are compared.

3. EXISTING TRANSFORMS
3.1 DCT Transform
The discrete cosine transform[5] (DCT) represents an image as a sum of sinusoids of varying magnitudes and frequencies. The DCT function for a 2-D image is given by Equation 1 and 2

$$B_{pq} = \alpha_p \alpha_q \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} A_{mn} \cos\frac{\pi(2m+1)p}{2M} \cos\frac{\pi(2n+1)q}{2N} \quad ...1$$

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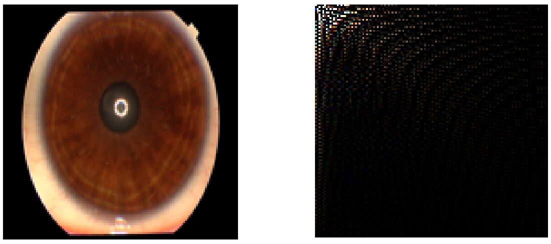
$$\alpha_p = \frac{1}{\sqrt{M}} \quad \text{if } p = 0 \qquad \alpha_q = \frac{1}{\sqrt{N}} \quad \text{if } q = 0$$

$$= \sqrt{\frac{2}{M}} \quad \text{if } 1 \leq p \leq M\text{-}1 \qquad = \sqrt{\frac{2}{N}} \quad \text{if } 1 \leq q \leq N\text{-}1 \quad ...2$$

where B_{pq} are called the DCT coefficients of A which can be an image data A(m, n). The DCT decomposes a signal into its elementary frequency components.



Original Iris **Result of DCT**

Figure 1. Result of applying DCT Transform to the image. The concentration of white spots on the top left corner shows concentration of energy.

When applied to a MxN matrix, the 2D-DCT compresses all the energy information of the image and concentrates it in a few coefficients located in the upper-left corner of the resulting MxN DCT/frequency matrix[6]. This is shown in Figure 1.

3.2 HAAR Transform

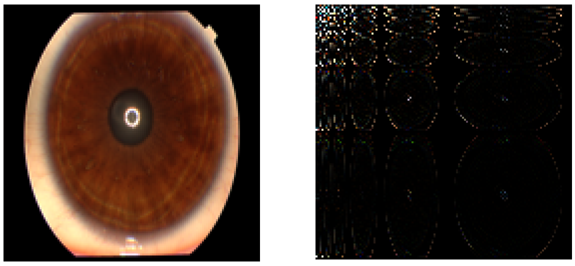
The family of N Haar[7] functions $h_k(t)$, (k = 0, 1,2,3,...,N-1) are defined on the interval $0 \leq t \leq 1$. The shape of the specific function $h_k(t)$, of a given index k depends on two parameters p and q:

$$k = 2^p + q - 1 \qquad ...3$$

For any value of $k \geq 0$, p and q are uniquely determined so that 2^q is the largest power of 2 contained in $k(2^p < k)$ and q-1 is the remainder $q-1 = k - 2^p$.

- When $k = 0$, the Haar function is defined as a constant

$$h_0(t) = 1/\sqrt{N} \qquad ...4$$



Original Iris **Result of Haar**

Figure 2. Result of applying Haar Transform to the image. Concentration of white spots on the top left corner shows the concentration of energy.

- When $k > 0$, the Haar function is defined as

$$h_k(t) = \frac{1}{\sqrt{N}} \begin{cases} 2^{p/2} & when \quad (q-1)/2^p \leq t < (q-0.5)/2^p \\ -2^{p/2} & when \quad (q-0.5)/2^p \leq t < q/2^p \\ 0 & otherwise \end{cases} \quad ...5$$

From the definition, it can be seen that p determines the amplitude and width of the non-zero part of the function, while q determines the position of the non-zero part of the function.

3.3 DCT Wavelet Transform

Wavelet Transform matrix of size P^2xP^2 can be generated from any orthogonal transform matrix of size PxP[9]. The DCT Wavelet matrix also, is obtained in a similar fashion from the 2-dimensional DCT transform matrix. As an illustration of the construction of a wavelet from a transform, consider an orthogonal transform matrix M of size PxP as shown in *Figure 3.*

M_{11}	M_{12}	…	$M_{1(P-1)}$	M_{1P}
M_{21}	M_{22}	…	$M_{2(P-1)}$	M_{2P}
. .	. .	…	. .	. .
M_{P1}	M_{P2}	…	$M_{P(P-1)}$	M_{PP}

Figure 3. PxP orthogonal transform matrix (M)

1st column of M Repeated P times — 2nd column of M Repeated P times — pth column of M Repeated P times

M_{11}	M_{11}	…	M_{11}	M_{12}	M_{12}	…	M_{12}	…	M_{1P}	M_{1P}	…	M_{1P}
M_{21}	M_{21}	…	M_{21}	M_{22}	M_{22}	…	M_{22}	…	M_{2P}	M_{2P}	…	M_{2P}
. .	. .	…	. .	. .	. .	…	. .	…	. .	. .	…	. .
M_{P1}	M_{P1}	…	M_{P1}	M_{P2}	M_{P2}	…	M_{P2}	…	M_{PP}	M_{PP}	…	M_{PP}
M_{21}	M_{22}	…	M_{2P}	0	0	…	0	…	0	0	…	0
0	0	…	0	M_{21}	M_{22}	…	M_{2P}	…	0	0	…	0
…	...	…	...	…	...	…	...	…	...	…	…	...
0	0	…	0	0	0	…	0	…	M_{21}	M_{22}	…	M_{2P}
. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
M_{P1}	M_{P2}	…	M_{PP}	0	0	…	0	…	0	0	…	0
0	0	…	0	M_{P1}	M_{P2}	…	M_{PP}	…	0	0	…	0
. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
0	0	…	0	…	0	0	…	0	M_{P1}	M_{P2}	…	M_{PP}

Figure 4. P^2xP^2 wavelet transform generated from PxP orthogonal transform

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Figure 4 shows P^2xP^2 wavelet transform matrix generated from PxP orthogonal transform matrix. For generating a wavelet matrix, the first P rows are obtained by repeating every column of the orthogonal transform matrix P times. After this, the second row is translated P times to obtain the next P rows. Similarly, all rows are translated to generate P rows corresponding to each row of the orthogonal transform matrix. Eventually, the wavelet matrix of size P^2xP^2 is obtained.

4. PROPOSED APPROACH

Discrete Cosine Transform, Haar wavelet transform and DCT wavelet transform concentrate the energy co-efficient of the image in the upper left corner of the transformed matrix. Hence, we propose a system which uses only these upper-left coefficients and discards the remaining coefficients. These fractional coefficients are further studied to find the optimum fraction that will result in the highest accuracy. It should also be noted that these fractional coefficients would reduce the complexity of the system as the number of coefficients would reduce as the size of the fractions reduce as given in Figure 5.

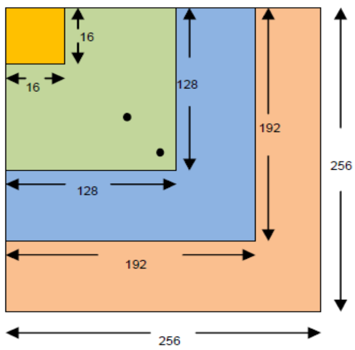

Figure 5. Selection of varying size portion

The Phoenix database [8] consisting of 6 images (3-right eye and 3-left eye) each of 64 individuals is used in the system (total 384 images). Out of these 6 images of each individual, 4 images i.e. 2 of the left eye and 2 of the right eye were used as training set and the remaining images i.e. 1 of the left eye and 1 of the right eye were used for testing. Thus, the training set constituted of 256 images and the test data constituted of 128 images (ratio 2:1).

No pre-processing of the images was done to separate the iris.

4.1 Algorithm

The algorithm that we have used for our study on iris recognition is as given below:

1. Creation of feature vector database
   - 1.1. Read the database image (Size=256x256x3).
   - 1.2. Extract the Red, Green and Blue component of that image such that each is of size 256x256.
   - 1.3. Apply DCT / Haar wavelet / DCT wavelet to the Red, Green and Blue components of the image so that we get 256x256x3 entries. This is the Feature Vector (FV) of that image.
   - 1.4. Repeat steps 1 through 3 for every database image.
2. Testing phase
   - 2.1. Read the Query image.
   - 2.2. Repeat step 1.2 and 1.3 for the query image so as to obtain its Feature Vector.
   - 2.3. For every Database image 'i' and a Query image 'q' the Mean Squared Error (MSE) is calculated using Equation 6.

$$MSE(i) = \frac{1}{3M^2}\sum_{m=0}^{M-1}\sum_{n=0}^{M-1}\sum_{d=0}^{2}\left[FV_i(m,n,d) - FV_q(m,n,d)\right]^2 \quad ...6$$

where initially M = 256.

   - 2.4. The trainee image with the least MSE is declared as the identified user.
   - 2.5. Repeat steps 2.3 and 2.4 decreasing the value of M gradually from 256 to 1 and record the error obtained in user identification for every fraction of the original feature vector.

5. RESULTS AND DISCUSSION

In this section, accuracy analysis and complexity analysis are presented.

5.1 Accuracy Analysis

Table 1 and Figure 6 show the identification accuracy obtained for the fractional feature vectors for DCT, Haar wavelet and DCT wavelet transforms. The size of the feature coefficients is reduced as shown in Figure 5.

Table 1. Accuracy variation for different sizes of feature coefficients for DCT, Haar wavelet and DCT wavelet

Size of feature coefficients (MxM)	Accuracy (in %)		
	DCT	Haar	DCT Wavelet
256x256	67.1875	67.1875	67.1875
192x192	67.1875	67.1875	67.1875
128x128	66.4063	66.4063	65.6250
96x96	66.4063	67.1875	65.6250
64x64	66.4063	67.9688	66.4063
32x32	67.1875	70.3125	68.7500
16x16	72.6563	75.7813	75.7813
15x15	74.2188	75.0000	76.5625
14x14	74.2188	76.5625	76.5625
13x13	75.7813	76.5625	77.3438
12x12	75.7813	75.7813	76.5625
11x11	78.1250	75.7813	77.3438
10x10	78.1250	75.7813	76.5625
9x9	78.9063	77.3438	78.1250
8x8	76.5625	79.6875	75.7813
7x7	**79.6875**	**80.4688**	**78.9063**
6x6	77.3438	76.5625	78.1250
5x5	78.9063	75.7813	78.6875
4x4	70.3125	76.5625	71.0938
3x3	71.0938	62.5000	71.8750
2x2	42.1875	46.8750	42.1875
1x1	50.0000	50.0000	50.0000

From Table 1 it can be seen that as the size is decreased from 256x256 to 1x1, there is a gradual increase in identification accuracy. The accuracy steadily increases till the size is reduced to 7x7 where the peak accuracy for DCT, Haar wavelet as well as DCT wavelet transform is achieved.

Thus, we have obtained maximum accuracies of 79.6875% for DCT, 80.4688% for Haar wavelet and 78.9063% for DCT wavelet, using only 0.075% of the feature coefficients located in the top left corner of the coefficient matrix. This is because of the property of DCT, Haar wavelet and DCT wavelet to concentrate the energy in the top left corner of a 2-D matrix. Thus, by comparing only that part which contains the maximum information, we have achieved a 13% improvement in accuracy compared to using the entire feature coefficient matrix.

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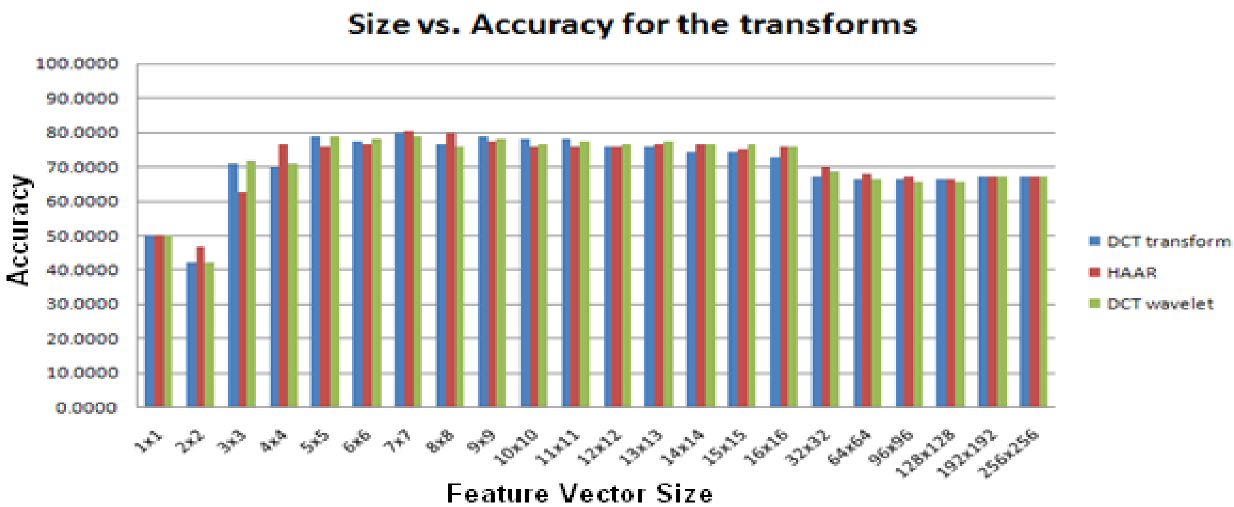

Figure 6. Bar chart showing variation in accuracy for different sizes of feature coefficients for DCT, Haar wavelet and DCT wavelet transforms

5.2 Complexity Analysis

The main operation while matching the image is calculating the Mean Squared Error. Calculation of difference between corresponding elements of two NxN matrices involves N^2 subtractions. Similarly, squaring of the elements of the difference matrix involves N^2 multiplications. So, to compute entire NxN answer matrix would involve N^2 multiplications and N^2 additions. As each matrix is 3-D, having one dimension each for Red, Green and Blue components, the total number of required operations would be:

$$3N^2 \text{ additions} + 3N^2 \text{ multiplications} \qquad ...7$$

The calculation of the mean of an NxNx3 matrix would involve $3N^2$-1additions and 1 division. Therefore the total operations to calculate the Mean Square Error would be:

$$6N^2\text{-1additions} + (3N^2 + 1) \text{ multiplications} \qquad ...8$$

Considering one CPU unit for one addition operation, the multiplication operation would require 8 CPU units. The size of the feature matrix and the total number of CPU units required are given in Table 2:

Table 2. Number of CPU units required for iris recognition for different size of feature matrix

Size of Feature Matrix	256x256x3	7x7x3
Total additions	393215	293
Total Multiplications	196609	148
Total CPU units	1966088	1478

Thus, it can be seen the number of CPU units required are only 0.07517% of the original CPU units, and therefore the complexity has dropped dramatically.

6. CONCLUSION

In this paper, we have discussed Iris Recognition using DCT, Haar wavelet and DCT wavelet transform. We have applied these transforms on the iris images and have considered fractional coefficients of the transformed images for Iris Recognition. Results of this experiment have shown that the accuracy in recognition increases as the size of the feature coefficients decreases. A maximum value of 79.6875% accuracy for DCT, 80.4688% for Haar wavelet and 78.9063% for DCT wavelet is obtained when the size of the feature coefficients is 7x7. Therefore, number of calculations is reduced by 99.924% along with increased identification accuracy of approximately 13% in each case. Thus, by discarding 99.925% coefficients, or using only the most significant 0.075% coefficients after applying DCT, Haar wavelet or DCT wavelet transform, we achieve better performance as well as accuracy. Thus, fractional feature coefficients technique provides better accuracy coupled with lower complexity.

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Dr. H. B. Kekre has received B.E. (Hons.) in Telecomm Engineering from Jabalpur University in 1958, M. Tech (Industrial Electronics) from IIT Bombay in 1960, M.S.Engg. (Electrical Engg.) from University of Ottawa in 1965 and Ph.D. (System Identification) from IIT Bombay in 1970 He has worked as Faculty of Electrical Engg. and then HOD Computer Science

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