Performance Comparison of Face Recognition using DCT and Walsh Transform with Full and Partial Feature Vector against KFCG VQ Algorithm

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ABSTRACT
Aim of this paper is to compare the performance of transform based face recognition technique with vector quantization (VQ) based face recognition technique. Transform based face recognition technique considers full and partial feature vector of an image. 2D-DCT and Walsh transform is applied on the resized image of size 128x128, to obtain its feature vector. Partial feature vector is obtained by selecting 75% rows and columns of feature vector, 50% rows and columns of feature vector and so on. The smallest size of partial feature vector is selected as 4x4. Transform based technique is tested on two different databases. Georgia Tech Face Database contains JPEG color images and Indian Face Database contains bitmap color images of varying size. Recognition rate is calculated for varying size of selected feature vector using DCT and Walsh transform. Also computational complexity in terms of number of CPU units is calculated in both the cases: with full feature vector and with partial feature vector. Then KFCG-VQ algorithm is applied on both the databases. Results of above transformation techniques and computational complexity are compared with the results obtained by KFCG-VQ algorithm. Results show that, KFCG outperforms both transformation techniques with full and partial feature vector consideration and gives less computational overhead by reducing it by 600 times than DCT and by 70 times than Walsh transform.

General Terms
Performance, verification, security.

Keywords
Face recognition, DCT, Walsh, KFCG, Vector quantization.

1. INTRODUCTION
Widespread use of an internet is making access and transmission of the information much easier. This access must be restricted in such a way that only intended user can access the required information. Various security measures have been provided to limit this access to the information. Face recognition is one of the important techniques and is preferred over other techniques like fingerprint recognition, iris recognition because it does not require explicit cooperation from users. Also special equipments are not required to capture the image [1,2,3]. A face recognition is an computer application for automatically identifying or verifying a person from a digital image or a video frame from a video source.

A face recognition system can operate in following two modes:

Verification: A one to one comparison of a captured biometric with a stored template to verify that the individual is who he claims to be.

Identification: A one to many comparisons of the captured biometric against a biometric database in attempt to identify an unknown individual. The identification only succeeds in identifying the individual if the comparison of the biometric sample to a template in the database falls within a previously set threshold [4,29].

General steps in Face Recognition [4]:

1. Capture the image: First step is to capture the image of the person who is to be recognized.

2. Face detection: Next is detection of actual face in the image.

3. Feature extraction: After a face has been detected, the task of feature extraction is to obtain features that are fed into a face recognition system. These features can be local features such as lines or fiducial points, or facial features such as eyes, nose and mouth.

4. Face Recognition: The last step is face recognition, where extracted features of input image are compared with the features in the database.

Depending on the nature of the application, sizes of testing and training databases, clutter and variability of the background, noise, occlusion and speed requirements some of the subtasks can be very challenging.

This paper compares accuracy and computational complexity of transform based face recognition technique with that of VQ based face recognition technique. Remaining paper is organized as follows: in section 2 we present related work carried out in the field of face recognition. DCT, Walsh transform and vector quantization is discussed in brief in section 3. In section 4 our proposed approach is presented. Section 5 elaborates the experiment conducted. Results are tabulated in section 6. Conclusion has been outlined in section 7.

2. RELATED WORK
In face recognition system feature extraction plays an important role to create more robust systems [1]. Various techniques have been proposed till now to extract feature vector from the image. PCA [15], Wavelet analysis, LDA[16], EBGM [15] are to name

the few. Principle Component Analysis (PCA) approach is used to reduce the dimension of data by means of data compression basics and reveals the most effective low dimensional structure of facial patterns [17]. This reduction in dimension removes information that is not useful and precisely decomposes the face structure into orthogonal components known as eigenfaces. Each face image is represented as a feature vector which is stored in a 1D array. A distance between the respective feature vectors of images is compared to find the match [18]. In LDA samples of unknown classes are classified based on training samples of known classes. Nonlinear characteristics of face are considered in EBGM. DCT [22,26,27] has been used as a feature extraction step in various studies on face recognition. Other transforms like Walsh- Hadamard transform [5,31,32], Wavelet transform also have been proposed [9, 24, 25, 28, 12].

For Recognizing objects from large image databases, histogram based methods were proposed in last decade. Initially, this idea was based on color histograms that were launched by Swain and Ballard [18]. Following this idea numerous developments were made by different people, exploiting this idea, such as texture histograms for 2D object recognition suggested by Gimelfarb and Jain [19], shape-index histograms for range image recognition proposed by Dorai and Jain [20] and relational histograms used by Huet and Hancock [21] for line-pattern recognition. Similarly, one dimensional (ID) and two dimensional (2D) histograms are also proposed with diverse variations like ID shape index histogram, 2D maximum and minimum curvature histogram, 2D mean and Gaussian curvature histogram and 2D shape index and curvedness histogram in [23]. Based on vector quantization algorithm, VQ histogram method is proposed by kotni [1].
Closest distance between histograms of different face images can be used for recognition purposes. Different distance measures may affect the recognition rate [22]. Euclidean distance can be used as it produces stable and satisfactory results [23].

3. DCT, WALSH TRANSFORM AND VECTOR QUANTIZATION

3.1 Discrete Cosine Transform

The discrete cosine transform (DCT) [5,30] represents an image as a sum of sinusoids of varying magnitudes and frequencies. The DCT function for 2-dimensional image is given by Eq. 1 & 2.

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

Eq...(1)

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

$$= \sqrt{\frac{2}{M}} \quad \text{If} \quad 1 \le p \le M-1 \qquad = \sqrt{\frac{2}{N}} \quad \text{If} \quad 1 \le q \le N-1$$

Eq… (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. When applied to an MXN image/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 real-valued MXN DCT/frequency matrix [8,10.1213,14].

3.2 Walsh Transform

Walsh transform matrix is defined as a set of N rows, denoted Wj, for j = 0, 1, ... , N - 1, which have the following properties:

- Wj takes on the values +1 and -1.
- Wj[0] = 1 for all j.
- $W_j x W_k^T$=0, for j~=k and $W_j x W_k^T$ =N, for j=k.
- Wj has exactly j zero crossings, for j = 0, 1, ..., N-1.
- Each row Wj is either even or odd with respect to its midpoint.

Walsh transform matrix is defined using a Hadamard matrix of order N. The Walsh transform matrix row is the row of the Hadamard matrix specified by the Walsh code index, which must be an integer in the range [0, ..., N - 1]. For the Walsh code index equal to an integer j, the respective Hadamard output code has exactly j zero crossings, for j = 0, 1, ……... , N – 1 [6, 23].

3.3 Vector Quantization

VQ can be defined as a mapping function that maps k dimensional vector space to a finite set CB= $\{C_1, C_2, C_3, \ldots, C_N\}$. The set CB is called codebook consisting of N number of codevectors and each codevector $C_i = \{c_{i1}, c_{i2}, c_{i3}, \ldots\ldots, c_{ik}\}$ is of dimension k. The key to VQ is the good codebook. There are various codebook generation algorithms available in literature [7,].

Vector quantization is composed of three operations: Codebook design, Encoding and Decoding. The input to the encoder is a vector and output is the index of the codevector that shows closest matching with that of input vector. In this case the closest match is found by evaluating the Euclidean distance between the input vector and each codevector in the codebook. Once the closest codevector is found, the index of that codevector is sent through a channel. When the decoder receives the index of the codevector, it replaces the index with the associated codevector[3]. Various techniques to generate the codebook are available. Codebook can be generated in spatial domain by clustering algorithms or using transform domain techniques [11].

4. PROPOSED APPROACH

DCT and Walsh transformation techniques have been applied on full image in following different ways:

DCT and Walsh Transform With All Transform Coefficients

In this method, 2-D DCT and Walsh transform is applied on the full image resized to 128 * 128 (Here n=128). This gives feature vector of size 128*128 (i.e. n*n) as shown in Figure 1. Algorithm for this technique is as given:

Step 1: Resize each trainee image to size 128 * 128.
Step 2: Apply DCT / Walsh transformation technique on resized image and obtain its feature vector.
Step 3: Save these feature vectors to create the trainee database.

Step 4: Resize each test image in the database to size 128*128.

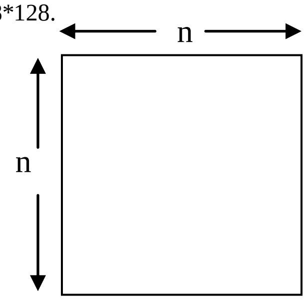


Figure 1: Full feature vector

Step 5: Apply DCT / Walsh transformation technique on resized image and obtain its feature vector.

Step 6: Save these feature vectors to create the test database.

Step 7: Calculate Euclidean distance between feature vectors of each test image with each trainee image feature vector.Direct Euclidian distance is computed using Eq. (1) given below:

$$d(x_i, cv_j) = \sqrt{\sum_{p=1}^{n} (x_i - cv_j)^2} \quad \text{.....Eq. (3)}$$

Step 8: Select the trainee image whose feature vector gives minimum Euclidean distance with the feature vector of test image. This is the recognized image.

DCT and Walsh Transform With Partial Transform Coefficients

In this method, 2-D DCT and Walsh transform is applied on the full image resized to 128*128 and selected portion of feature vector is used for Euclidean distance calculation. Algorithm for this technique is as given:

Step 1: Resize each trainee image to size 128 * 128.

Step 2: Apply DCT / Walsh transformation technique on resized trainee image and obtain its feature vector.

Step 3: Select first 64 (50%) rows and first 64 columns of feature vector as shown in Figure 2. Save these partial feature vectors (partial coefficients) to create the trainee databa

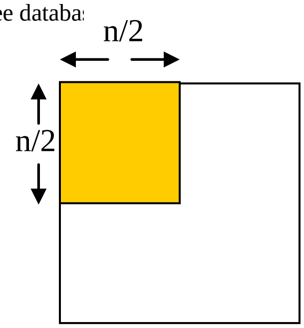


Figure 2: Partial feature vector

Step 4: Resize each test image in the database to size 128 * 128.

Step 5: Apply DCT / Walsh transformation technique on resized image and obtain it's feature vector.

Step 6: Select first 64 (50%) rows and first 64 columns of feature vector. Save these partial feature vectors (partial coefficients) to create the test database.

Step 7: Calculate Euclidean distance between feature vectors of each test image with each trainee image feature vector.

Step 8: Select the trainee image whose feature vector gives minimum Euclidean distance with the feature vector of test image. This is the recognized image.

Similarly, feature vector of size 96*96, 32*32,16*16, 8*8 and 4*4 is selected and Euclidean distance between corresponding feature vectors of test image and trainee image is calculated. The trainee image which gives smallest Euclidean distance, is chosen as closest matching image.

Kekre's Fast Codebook Generation Algorithm (KFCG)

Before applying KFCG-VQ algorithm, following steps are performed:

1. Images are divided into windows of a fixed size say X rows and Y columns.
2. The pixels in these windows are arranged in a row to get XY pixels in a row vector.
3. The first 2 steps are repeated for all non-overlapping windows to get the Training set.

Steps for KFCG algorithm are as follows:

Step 1. Let T contains M vectors, T={X_1, X_2, …., X_M}. Each vector is of dimension K. i.e. X1={$x1_1$, x12,…….$x1_K$}.

Step 2. Set N1=1 and Compute the initial codevector as

$$C = \frac{1}{M} \sum_{m=1}^{M} Xm \quad \text{…. Eq. (4)}$$

Step 3. Set i=1, m=1, Q1(1)=T where Q denotes set of N clusters for N codevectors.

Step 4. For n=1 to N1

Begin
  For j=1 to number of vectors in Q1(n)
    Begin
      Compare xji with cni
        If xji≤ cni then put xj in Q(m)
        Else put xji in Q(m+1)
    End
  Compute codevectors C_m and C_{m+1} by taking mean of all vectors in set Q (m) and Q(m+1) respectively.
End

Step 5. N1= 2N1, Q1=Q

Step 6. Set m=1, i=i+1, If i= =K then i= 1

Step 7. Go to step 4 until codebook of size N is generated. i. e. N1=N

Figure 3 shows clustering after first iteration using KFCG whereas Figure 4 represents clustering in second iteration using KFCG.

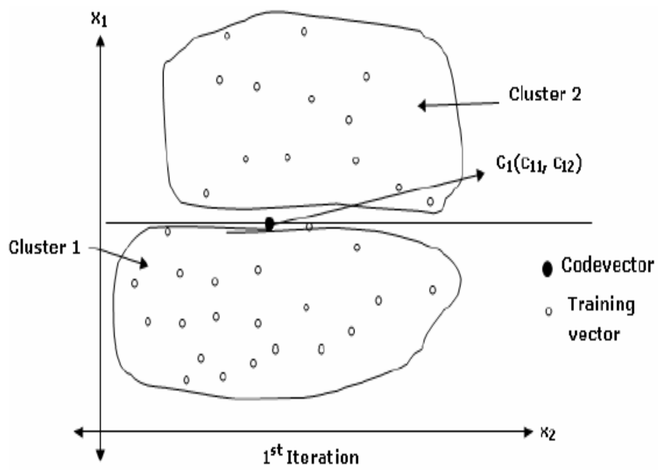


Figure 3: KFCG for two dimensional case with first iteration

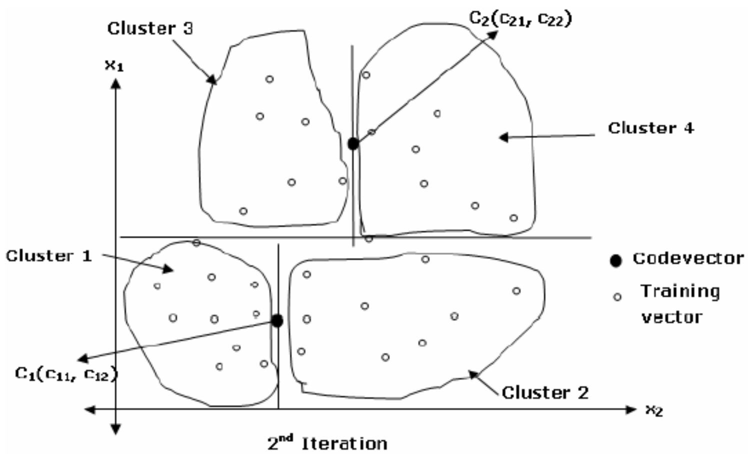
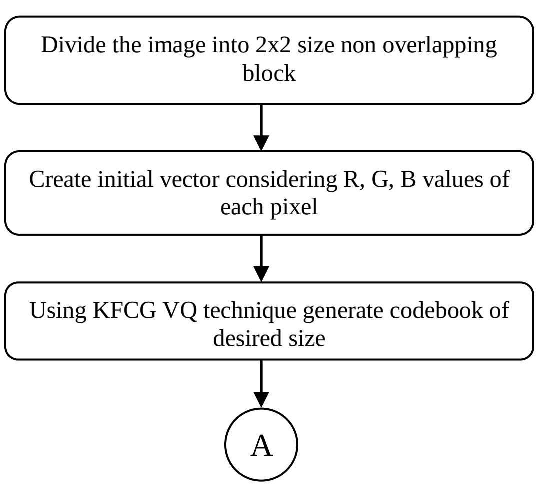


Figure 4: KFCG for two dimensional case with second iteration

Figure 5 shows flowchart for the proposed method.



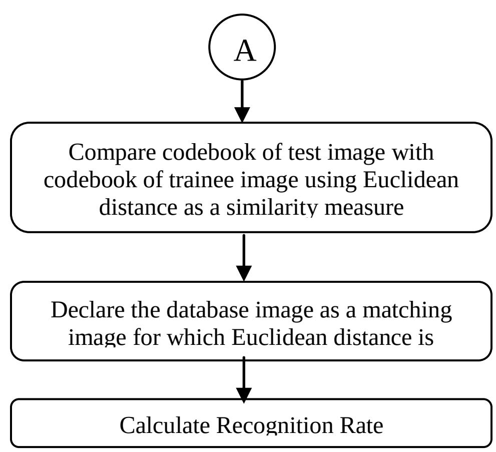


Figure 5: Flowchart for face recognition system using proposed VQ techniques

5. EXPERIMENTS

To study proposed transformation techniques and KFCG-VQ technique, we have used two different databases: Georgia Tech Face Database and Indian Face Database.

5.1 Georgia Tech Face Database [33]:

This database contains images of 50 people stored in JPEG format. For each individual, there are 15 color images captured and all are of different size. Most of the images were taken in two different sessions to take into account the variations in illumination conditions, facial expression, and appearance. In addition to this, the faces were captured at different scales and orientations. Figure 6 shows some of the sample images from Georgia Tech Face Database. This database is divided into two different sets, each containing different number of test and trainee images. First set contains 7 test images per person. Such 50 individuals are included in database. Hence total 350 test images are there in the database. In the first set, number of trainee images used for each person is 8, so total 400 trainee images and 350 test images are there in the first set. In second set, 10 images per person have been used for training purpose. Thus there are 500 trainee images and 250 test images in the second set.

Figure 6: Sample images from Georgia Tech Face Database

5.2 Indian Tech Face Database:

This database contains images of 50 persons stored in bitmap format. There are 10 color images of each person. These images are with rotation of face at different angles, different facial expressions and with considerable difference in illumination. Images are taken at different locations. Similar to Georgia Tech Face Database, two sets of images have been formed from this database also. The first set contains 3 test images and 7 trainee images per person, i.e. total 150 test images and 350 trainee images. Second set contains 2 test images and 8 trainee images per person, i.e. total 100 test images and 400 trainee images.
Figure 7 shows some sample images from Indian Face Database. Recognition rate is calculated for both the databases, using DCT and Walsh transform with full and partial feature vector and then by applying KFCG-VQ algorithm.

Figure 7: Sample images from Indian Face Database

6. RESULTS AND COMPLEXITY ANALYSIS

Table 1 shows the recognition rate for two sets of Georgia Tech Face Database using 2D-DCT. First set contains 350 test images and second set contains 250 test images.

6.1 Results of DCT and Walsh Transform

Table 1. Recognition rate for Georgia Tech Face Database with 350 test images and 250 test images for varying size of feature vector using DCT

Size of feature vector selected	Georgia Tech Face Database	
	350 Test images	250 Test Images
128 * 128	70	68.35
96 * 96	71.14	70.8
64 * 64	72	71.2
32 * 32	72.57	73.6
16 * 16	73.45	74.4
8 * 8	**75.12**	**76.4**
4 * 4	70.23	76.4

It can be seen that, as we decrease the size of selected feature vector, recognition rate increases. It reaches to the peak value for some size of feature vector and then again decreases. Using the first set of 350 test images, maximum recognition rate obtained is 75.12% for 8*8 size codebook. As number of test images is decreased to 250 and trainee images is increased to 500 in the second set, recognition rate increases to76.4% for same codebook size.
Results for Walsh transform for Georgia Tech Face Database are tabulated in Table 2.

Table 2. Recognition rate for Georgia Tech Face Database with 350 test images and 250 test images for varying size of feature vector using Walsh Transform

Size of feature vector selected	Georgia Tech Face Database	
	350 Test images	250 Test Images
128 * 128	69.71	70
96 * 96	71.14	71.8
64 * 64	72	72.4
32 * 32	73.71	74.4
16 * 16	74	74.8
8 * 8	**74.57**	**75**
4 * 4	73.21	73.78

It can be observed from the table 2 that, as number of trainee images is increased, recognition rate also increases. For the set of 350 test images, as the size of feature vector under consideration is reduced, Recognition rate is increases. Highest recognition rate obtained is 74.57% for 8*8 size feature vector. Then recognition rate decreases. For the set of 250 test images peak value of recognition rate obtained is 75% at 8*8 size feature vector.
In Table 3, results of recognition rate for two sets of Indian Face Database, using DCT are presented.

Table 3. Recognition rate for Indian Face Database with 150 test images and 100 test images for varying size of feature vector using DCT

Size of feature vector selected	Indian Face Database	
	150 Test images	100 Test Images
128 * 128	83.57	84

96 * 96	85.57	86
64 * 64	86.42	88
32 * 32	**88.67**	**89**
16 * 16	88.67	87
8 * 8	88.67	84
4 * 4	87.57	83

For first set maximum accuracy obtained is 88.67 for feature vector size 8*8 and remains constant for 16*16 and 32*32 size of feature vector and then decreases. Similarly, for second set maximum accuracy obtained is 89% at 32*32 size feature vector and then it decreases.

Table 4. Recognition rate for Indian Face Database with 150 test images and 100 test images for varying size of feature vector using Walsh Transform

Size of feature vector selected	Indian Face Database	
	150 Test images	100 Test Images
128 * 128	88	**90**
96 * 96	88	90
64 * 64	88	89
32 * 32	**88.67**	88
16 * 16	87	85
8 * 8	86.67	84
4 * 4	82.42	80

Table 4 shows the results for two sets of Indian Face Database using Walsh transform. When different size of feature vector is considered, accuracy increases with decreases in size of feature vector. It reaches to some peak value and then again starts decreasing. Maximum 90% accuracy is obtained for the set of 100 test images. For the first set of 150 test images, recognition rate is 88.67% when 32*32 size feature vector is considered.
Table 5 shows

6.2 Results of KFCG

Table 5 shows the results of KFCG algorithm on Georgia tech face database when image is divided into 2x2 non overlapping block. It shows that with 350 test images, maximum recognition rate obtained is 78.57% for 8x12 size codebook and with 250 test images, it is 84.4% for 256x12 size codebook.

Table 6 represents the results when image is divided into 1x2 non overlapping block. With the set of 350 test images, it gives maximum accuracy of 78.85% for codebook size 8x12 and with 250 test images 84.8% accuracy is obtained for 16x12 size codebook.

Table 5. Recognition rate for Georgia Tech Face Database with 350 test images and 250 test images for varying size of codebook with 2x2 image block using KFCG

Size of Codebook	Georgia Tech Face Database	
	350 Test images	250 Test Images
4x12	78.28	82.8
8x12	**78.57**	84
16x12	74.57	82.4
32x12	75.71	83.2
64x12	76	82.8
128x12	76.86	84
256x12	76.86	**84.4**
512x12	76.28	82.8

Table 6. Recognition rate for Georgia Tech Face Database with 350 test images and 250 test images for varying size of codebook with 1x2 image block using KFCG

Size of Codebook	Georgia Tech Face Database	
	350 Test images	250 Test Images
4x12	78.28	82.4
8x12	**78.85**	84.4
16x12	73.42	**84.8**
32x12	78	83.8
64x12	76	83.2
128x12	75.71	82.8
256x12	75	82.8
512x12	74.85	80.2

Table 7 represents the results for Indian Face Database when image is divided into 2x2 non overlapping block. With the set of 150 test images, it gives maximum accuracy of 90.66% for codebook size 128x12 and with 100 test images it is 90% for same codebook size.

Table 7. Recognition rate for Indian Face Database with 150 test images and 100 test images for varying size of codebook with 2x2 image block using KFCG

Size of Codebook	Indian Face Database	
	150 Test images	100 Test Images
4x12	79.33	80
8x12	80.66	82
16x12	84.66	88
32x12	86	89
64x12	86.66	89
128x12	**90.66**	**90**
256x12	84	84
512x12	77.33	76

The results obtained by dividing the image into 1x2 non overlapping block are tabulated in table 8. As shown in the table highest accuracy is obtained as 91% for the set of 100 test images. Codebook of size 128x12 is generated to get this result.

Table 8. Recognition rate for Indian Face Database with 150 test images and 100 test images for varying size of codebook with 1x2 image block using KFCG

Size of Codebook	Indian Face Database	
	150 Test images	100 Test Images
4x12	79.33	81
8x12	81.33	85
16x12	84	88
32x12	86.66	88
64x12	87.33	89
128x12	88	**91**
256x12	**88.66**	89
512x12	87.89	89

6.3 Complexity Analysis

Table 9. Comparison of number of calculations and CPU units required for applying DCT, Walsh and KFCG-VQ technique on Georgia Tech Face Database with 400 trainee images.

Parameter	Algorithm applied on Georgia Tech Face Database with 400 Trainee Images with image size 128x128		
	DCT	WALSH	KFCG

Codebook size giving maximum recognition rate	-	-	8x12
Number of multiplications required	4210688	16384	108
Number of additions required	4194303	4194303	49331
Number of comparisons required	0	0	12288
Number of CPU units required	37879807	4325375	62483

Table 9 presents number of calculations required when 2D DCT, Walsh transform and KFCG-VQ algorithm are applied on the image. In the table number of multiplications/divisions required, number of additions required, number of comparisons required and total number of CPU units required for all these calculations by each of the algorithm are tabulated. It is observed that, using KFCG algorithm, maximum recognition rate is obtained for codebook size 8x12 and 62483 CPU units are required by KFCG which is the least of all algorithms and almost 600 times less than the CPU units required by DCT algorithm.
According to table 10, maximum accuracy obtained by KFCG is at codebook size 256x12. Number of CPU units required by KFCG are 112723 respectively. Here also, KFCG requires least number of CPU units to perform all calculations.

Table 10. Comparison of number of calculations and CPU units required for applying DCT, Walsh and KFCG-VQ technique on Georgia Tech Face Database with 500 trainee images.

Parameter	**Algorithm applied on Georgia Tech Face Database with 500 Trainee Images with image size 128x128**		
	DCT	**WALSH**	**KFCG**
Codebook size giving maximum recognition rate	-	-	256x12
Number of multiplications required	4210688	16384	3084
Number of additions required	4194303	4194303	55283
Number of comparisons required	0	0	32768
Number of CPU units required	37879807	4325375	112723

For Indian Face Database, highest recognition rate obtained by KFCG-VQ algorithm is at codebook size 128x12. Size of the codebook is same even if 150 test images are used or 100 test images are used. Number of calculations required for both the sets are tabulated in table 11.

Table 9,10 and 11 shows that, KFCG has overall less computational complexity as compared to DCT and Walsh Transform.

Table 11. Comparison of number of calculations and CPU units required for applying DCT, Walsh and KFCG-VQ technique on Indian Face Database with 350 and 400 trainee images.

Parameter	**Algorithm applied on Indian Face Database with 350 Trainee Images with image size 128x128**		
	DCT	**WALSH**	**KFCG**
Codebook size giving maximum recognition rate	-	-	128x12
Number of multiplications required	4210688	16384	1548
Number of additions required	4194303	4194303	52211
Number of comparisons required	0	0	28672
Number of CPU units required	37879807	4325375	93267

7. CONCLUSION

In this paper, face recognition using transformation technique and KFCG-VQ algorithm are compared. In transformation techniques, DCT and Walsh transforms are considered with all transform coefficients and partial transform coefficients. In case of partial transform coefficients, it has been observed that, recognition rate increases as the size of feature vector under consideration decreases. Recognition rate reaches to some peak value and then decreases as size of partial feature vector is reduced.

For the first set of Georgia Tech Face Database i.e. with 350 test image set, when DCT is used, number of CPU units required is 37879807. With Walsh transform this number reduces to 9 times less than DCT. Use of KFCG algorithm reduces the number of CPU units to 62483 which are 600 times less than that of required in DCT and 70 times less than that of Walsh transform. With the set of 250 test images, number of CPU units required using KFCG is 336 times less than required using DCT and 38 times less than that of Walsh transform. For Indian Face Database, KFCG algorithm requires 93267 CPU units which are 400 times less than required in DCT and Walsh transform. In KFCG, Codebook size at which highest accuracy is obtained varies as number of test images vary. It varies number of CPU units required in each case. From table 9, 10 and 11 it is clear that, overall computational complexity in KFCG is drastically reduced and KFCG gives highest recognition rate of 91% for Indian Face Database at 128x12 size codebook. For Georgia Tech Face Database maximum recognition rate of 84.8% is obtained for 16x12 codebook size.

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