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Comparative Study of Feature Level and Decision Level Fusion in Multimodal Biometric Recognition of Face, Ear and Iris

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Abstract This research paper investigates the comparative study of decision level fusion and feature level fusion of multi-biometric recognition system. We have designed a feature level fusion in little different way to the comparison of conventional feature fusion. We applied the whole procedure in face database from University of Essex,U.K.,AMI ear database and UPOL iris database. Experimentation has been performed using the parameters FAR, FRR and GAR. At the end we have seen that OR type feature fusion is most efficient in terms of FAR and GAR. Apart from that AND-OR type decision fusion should be used in customized level to vary the parameter FAR and FRR. High energy coefficients have been computed using DCT and Hough transformations for Face, Ear and Iris. Decision level fusion has been done using AND ,OR and AND-OR rules.

Keywords—"FAR",; "FRR"; "Multi-modal"; "Biometrics"

Introduction

Unimodal biometric system has not fulfilled the level of performance in today's advancement of technology and in higher user demand. Multimodal biometric system changed the mind set of biometric researchers, because it has impressive accuracy and reliability [1]. Apart from that, multimodal system has some important advantages like intra-class variability, interclass similarity, sensitivity to noise etc. [1] In multimodal biometric system more information is condensed and process them to recognize [2]. That is why this method is so effective in practical applications. As per the definition of multimodal biometric system [3], two or more than two biometric traits are taken into account. So to make the true and false comparison, we have to combine the extracted features from each biometrics input image. K.Nandakumar [4] discussed a detailed method for fusion of two or more than two image information's. As per the author fusion technique not only condenses the image information but also enhances the template security.

N.Poh, J.Kittler [5] also discussed about the fusion techniques. As per the authors the fusion techniques are broadly divided into two classes 1. Fusion before matching and 2. Fusion after matching. Fusion before matching is again divided into two classes: sensor level and feature level. Fusion after matching export the fusion to matching score level fusion, rank level fusion and at last decision level fusion.

D.R.Kisku, A.Rattani, P.Gupta and J.K.Sing [6] investigated the performance study of feature level fusion of a multimodal biometric system. They used DWT as a tool to fuse the feature of the input images. They got impressive results after graph matching procedure for ultimate recognition system.

B.J.Kang, K.R.Park [7] declares a different approach of fusion which is rank level fusion. They used vein, geometry of single finger as biometric trait. As a result whole recognition device is very small in size. They used Fourier descriptors to extract the feature and applied max, min and sum rule for rank level fusion. Authors demanded ERR as 1.089 and increased by 1.627% by applying the above method.

A.Tharwat, A.F.Ibrahim, H.A.Ali [8] proposed a multimodal biometric system of two traits, ear and finger knuckle. Author described two different fusion methods, first image level fusion, where input images are combined and make them as single image. After that, combined image is forwarded for the classification. The second one is multilevel fusion method, where images are combined first and then after the feature extraction classifier gives three classification results. Final decision is made after the fusion of the three classification results.

Y.Elmir, Z.Elberrichi, R.Adjoudj [9] discussed a score level fusion of a fingerprint and voice based multibiometric recognition. Authors used Gabor filter to sector wise normalization of the fingerprint and computed Mel-frequency cepstrum coefficient to make the feature matrix of a voice signal. They used the SVM to merge the score combination. They got 70% of recognition rate after the score level fusion.

K. Vishi, S.Y. Yayilgan[10] experimented the performance of a multimodal biometric system using score level fusion. Authors first extracted the feature from fingerprint and iris. Then after the comparison of the feature template to the database, each score took into account. All the score are then combined using minimum score, maximum score, simple sum and user weighted sum rules. The final decision is made after the comparison between the combined score and threshold.

P.P.Paul, M.L. Gavrilova, R.Alhajj [11] proposed a different method for decision fusion using social network analysis. First they choose Fisher Linear Discriminant analysis to extract the feature of multi-biometric traits. The similarity is measured and the result is fused with social network analysis for each traits. After getting the fused results of all traits, final result is obtained by again fusion of all the decisions.

N. T. Vetrekar, R. S. Gad [12] Introduced different types of fusion approach named hyperspectral method. This method is different from conventional fusion procedure. Authors combined hyperspectral input images into 650+710nm, 650+710+770nm spectral band of energy. At last authors got the linear improvement of ERR with the higher combination of spectral images.

Taking in account all above combinations, we have decided to compare the performance of simple feature level fusion and decision level fusion. Feature level fusion is very much popular method as compared to the other fusion, because all the computations are done over a single fused feature. So the time consumption and the amount of computation power are needed very much less due to the single level operation. But in case decision and other kind of fusion, features are not combined in primary level. So computation and the time is extended to perform all the operation for all the traits. However, time and time and computational power can be minimized by pipelining the entire procedure to short procedure.

In this research our objective is making fusion in feature level and decision level for a multimodal biometric system. After that analyze and compare the performance of all the combinationlike AND, OR, AND-OR rules used for fusion. Here we have taken FAR and FRR as the parameter to measure the system performance.

In this paper first we discussed different method for feature extraction used in our procedure, then discussed about different fusion techniques. Then we described the steps of experiment. At last we have compared the result of different approach of our paper.

Uni-modal versus Multi-Modal Biometric System

Uni-modal biometric system is the easiest method used for biometric recognition. Here a fixed biometric trait is selected and then features are extracted from that image and final decision is made after the comparing to the preloaded templates, named as database. Though, unimodal system has many drawbacks, but this system gave us the first idea how multimodal system should be designed.

Multimodal system is the modern approach of biometric recognition to combat problem of false rejection and false acceptance. This method is more practical and reliable. Here more than one biometric trait is taken into account and features are extracted from those images. Then the features are combined using various rules and final result is got after the comparison with threshold. This combination could be done in any block to the basic system of multimodal system.

Discrete Cosine Transform (DCT)

DCT[15][16][17] is considered as the adaptive transformation approach to extract the image features. In this work, the DCT is applied on the window block of the available image set as well as on input image. This method basically uses the cosine transformation to represent the original data. To obtain this NxN DCT coefficient matrix is computed for NxN size image. Here Particular matrix element is taken in the form of intensity defined for specific I and j positions. The DCT based transformation is given by

$$F(u) = \left(\frac{2}{N}\right)^{\frac{1}{2}} \sum_{i=0}^{N-1} \Lambda(i).cos\left[\frac{\pi.u}{2.N}(2i+1)\right] f(i)$$

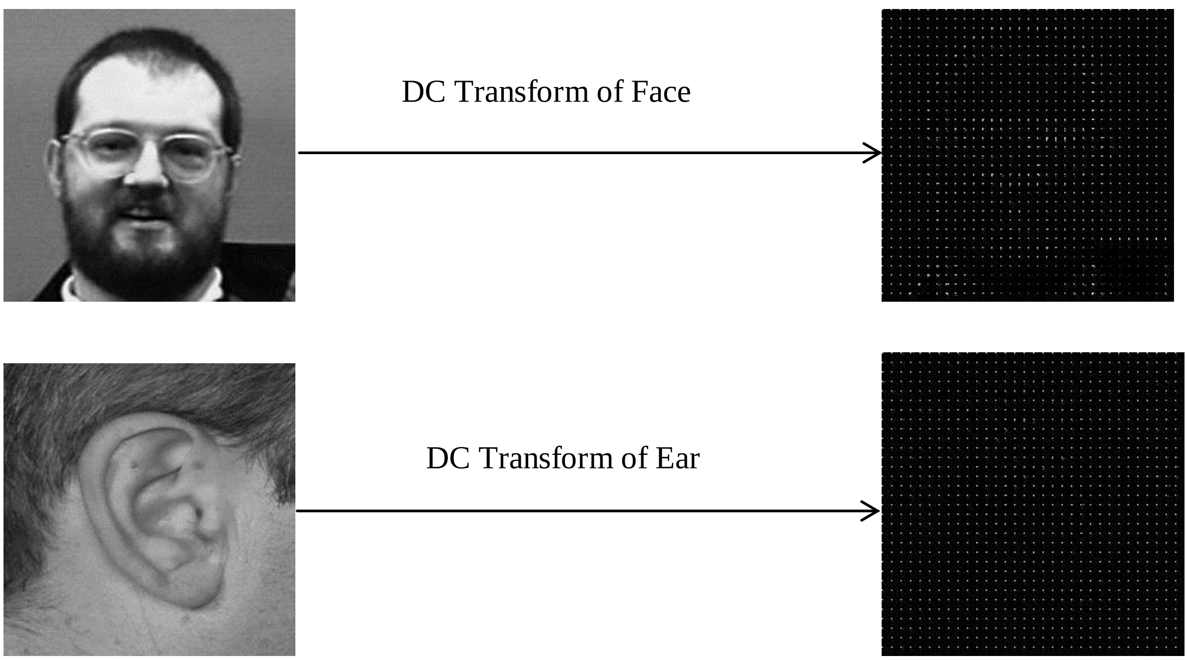

Figure 1: DCT

The discrete cosine transform (DCT) helps separate the image into parts (or spectral sub-bands) of differing importance (with respect to the image's visual quality). The DCT is quite same to the discrete Fourier transform: it transforms a signal or image from the spatial domain to the frequency domain.

Hough Transformation

This transformation[27][28] isused for line detection. That is why Hough transformation is used for primary feature extraction of iris images.The Hough transform is a feature extraction technique used in image analysis, computer vision, and digital image processing. The purpose of the technique is to find imperfect instances of objects within a certain class of shapes by a voting procedure. This voting procedure is carried out in a parameter space, from which object candidates are obtained as local maxima in a so-called accumulator space that is explicitly constructed by the algorithm for computing the Hough transform.

Fig2. Hough Transformation

Kekre Transformation

The Kekre[12][13][14] transform matrix of dimension NXN is given below:

$$K(NXN) = \begin{bmatrix} 1 & 1 & 1 & . & . & . & 1 & 1 \\ -N+1 & 1 & 1 & . & . & . & 1 & 1 \\ 0 & -N+2 & 1 & . & . & . & 1 & 1 \\ . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . \\ 0 & 0 & 0 & . & . & . & 1 & 1 \\ 0 & 0 & 0 & . & . & . & -N+(N-1) & 1 \end{bmatrix}$$

The formula for generating the element K(x, y) of Kekre transform matrix is given in the equation below:

$$K(x,y) = \begin{cases} 1, & x \le y \\ -N + (x-1), & x = y+1 \\ 0, & x > y+1 \end{cases}$$

Algorithm:

1. Construct the Kekre Transformation Matrix-K
2. Construct and pre-process the input matrix from input image-I
3. Finally generate the transformation matrix as
   T=K*I*K

Fig.3 Kekre transformation

Kekre transformation matrix should be of any size. That is why with the help of this transform image will be compressed of any size. As per the definition Kekre transformation matrix has all the upper diagonal elements are 1 and all the lower diagonal elements are zero.

Hartley Transformation

In mathematics, the Hartley transform [22][23][24] is an integral transform closely related to the Fourier transform, but which transforms real-valued functions to real-valued functions. It was proposed as an alternative to the Fourier transform, and is one of many known Fourier-related transforms. Compared to the Fourier transform, the Hartley transform has the advantages of transforming real functions to real functions (as opposed to requiring complex numbers) and of being its own inverse. Hartley transformation is a delicious choice to compress an image instead of FFT because it deals with only real value. A big advantage of Hartley transform is same matrix is used for forward and reverse Harley transform.

The two-dimensional Hartley transform can be computed by an analog optical process similar to an optical Fourier transform, with the proposed advantage that only its amplitude and sign need to be determined rather than its complex phase.

The Hartley transform of a function f(t) is defined by:

$$H(\omega) = \{\mathcal{H}f\}(\omega) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(t)\,\mathrm{cas}(\omega t)\,\mathrm{d}t,$$

Where ω can in applications be an angular frequency.

Algorithm:

1. Make the FFT of the input image

2. Subtract the imaginary value from the real value.

Fig.4 Hartley Transform

Discrete Wavelet Transformation

Here DWT applied to map the input image under time domain to wavelet domain. The vector specifications are here defined in linear with specification of the frequency conditions. The condition specific constraints are adapted from the image. The certain sampled function is applied to select the effective image features. In this work, frequency domain specific features are collected from the image so that the feature set will be obtained. The decomposition function defined under wavelet with level specification is given by

$$s(t)=\sum_i \alpha_i^n \cdot \varphi_i^n(t)+\sum_{j=1}^{n}\sum_i \beta_i^j \cdot \psi_i^j(t)=a_n+d_n+\ldots+d_1$$

Here n is number of levels.

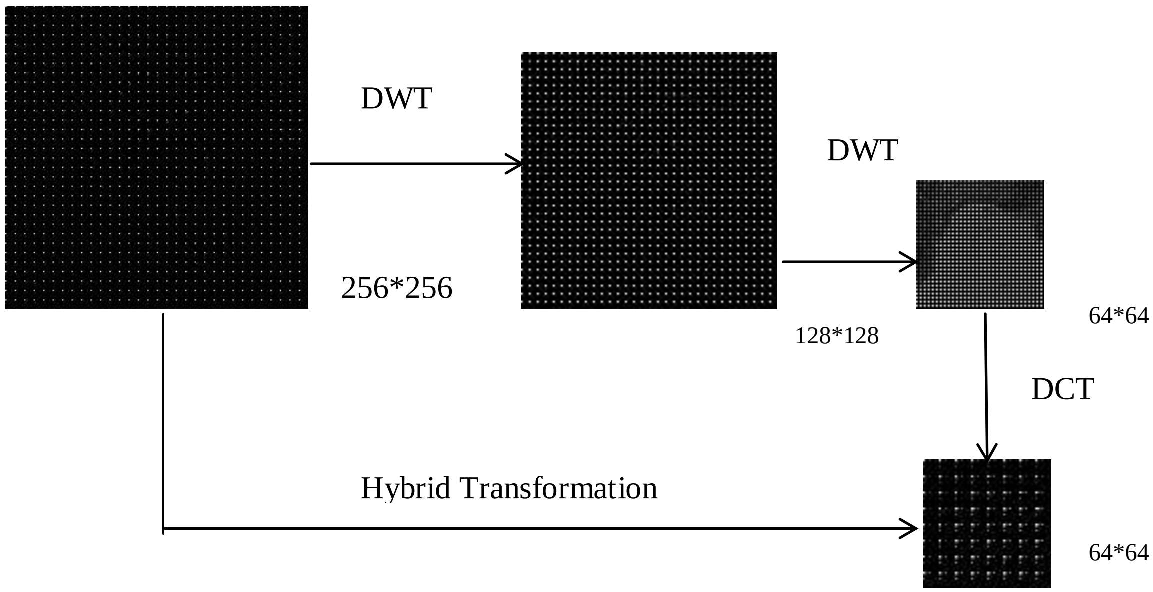

Fig5. Hybrid Transformation Using DWT-DCT

However, wavelet transform is widely used for it' perfect reconstruction property. Primarily DWT separate the high energy coefficients and low energy coefficients from a single image using the low pass filter and high pass filter tool. This transformation is very useful for low energy image compression.

Fusion Technique

Fusion is necessary for the traits, which are come from the image sensors. In multimodal system generally we get more than one feature matrix form the each biometric trait. But we cannot process or store them into database simultaneously because it takes lots of time to compute and it is also time consuming. That is why we all need to combine feature matrices, coming from different sources. This method is named as fusion method. This method is widely described by many researchers [4][5].

Fusion methods are broadly divided into two groups:

1. Fusion before matching
2. Fusion after matching.

Fusion before matching

In this case combination process is done before the matching process. This method can be applied in feature level as well as sensor level. In sensor fusion best captured image is taken into account after the combined effort of more than one image sensor. By this method, the image is full of more information and results are also very impressive. In case of feature fusion the combination is done after the feature extraction process. We all know single image in a unimodal biometric system is not very informative; to be used for recognition process with single extracted feature. That is why feature fusion is very handful in practice. This method is also provides very impressive result.

Fusion after matching

Here fusion is performed after the matching score or distances are generated. Then all the generated scores are combined using different rules like sum, min, max etc.

Then final decision is made by analyzing the combined score. This method is named as score level fusion. Another type of fusion called decision level fusion; here final decision is made after combining the decisions made by each classifier.

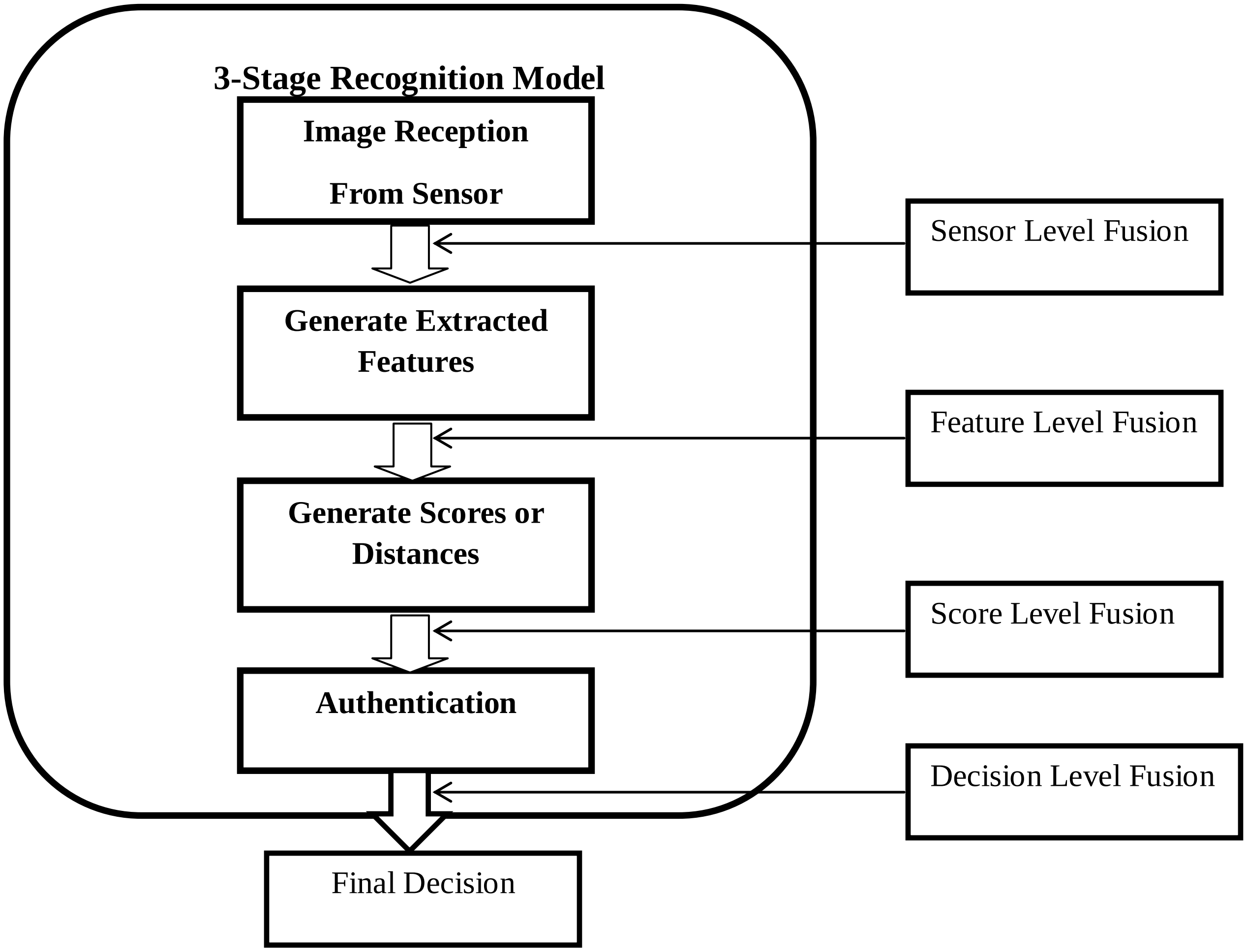

Fig6. Scope of Fusion

Research Methodology:

Steps:

1. We have taken three biometric traits face, ear and iris.
2. First features are extracted using DCT and Hough transform.
3. Then hybrid transformation is done of previous extracted features.
4. Last, extracted features are converted into Eigen space and stored in database.
5. Three types of features are combined using AND, OR, and AND-OR rule.
6. Performance is measured after getting the true distances and false distances.

7. To perform decision fusion, without combining the features distances are calculated.
8. Final decision are made after combining the raw decisions using AND, OR, AND-OR rule.
9. Again performance are measured in terms of FAR and FRR.

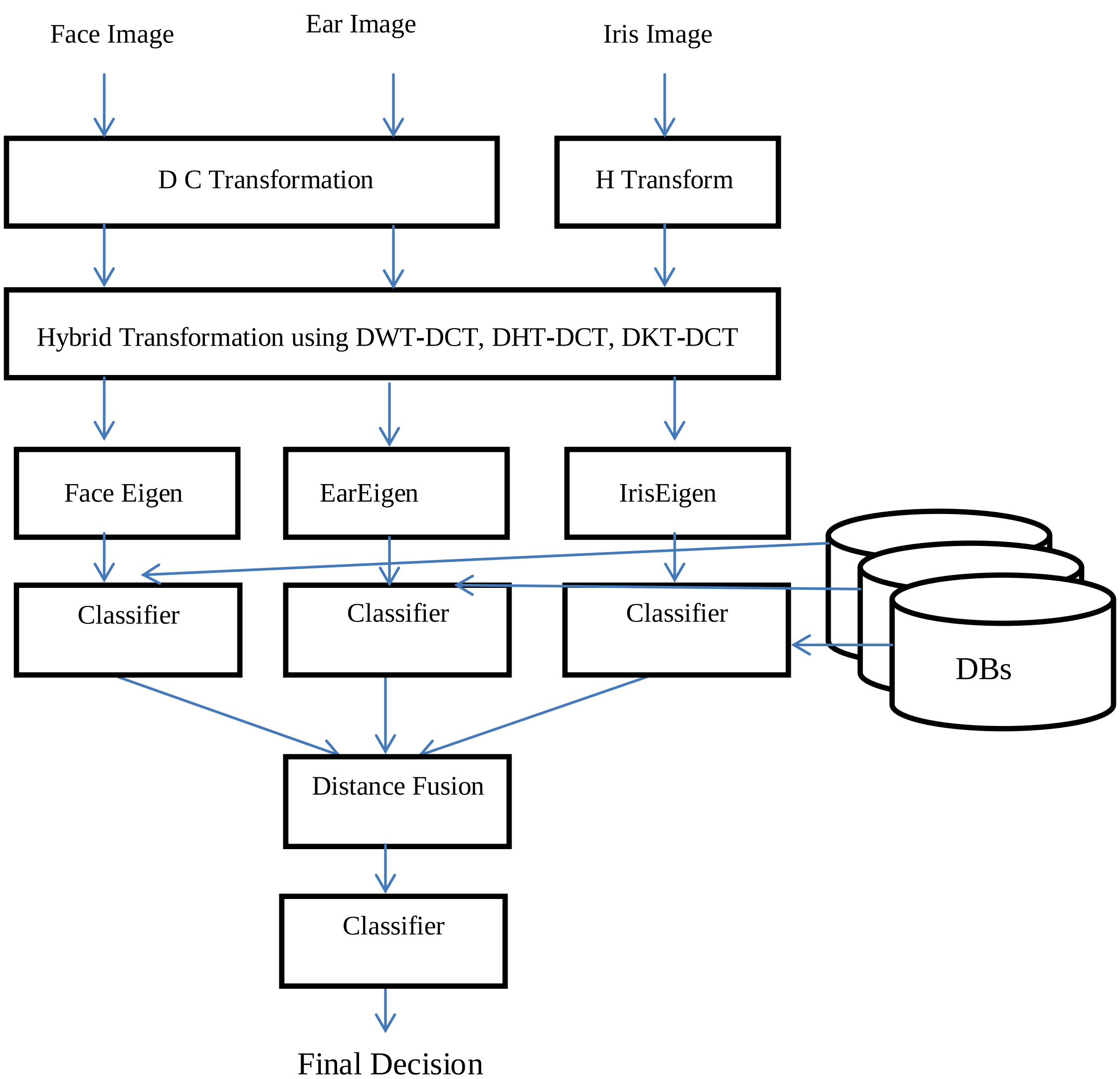

Fig.7 Multimodal Biometric System Using Feature Fusion

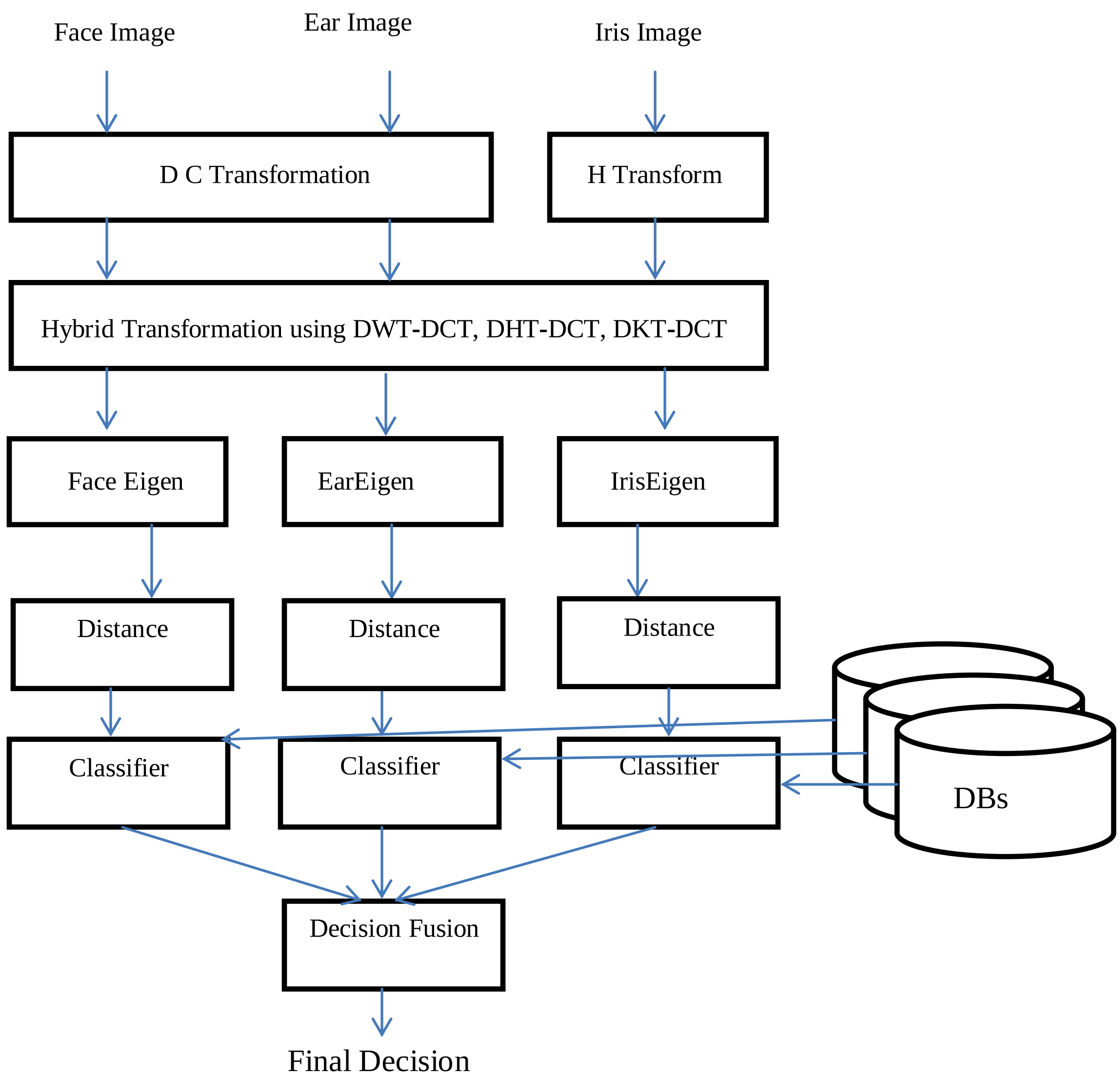

Fig.8 Multimodal Biometric System Using Decision Fusion

First, all the images are DC transformed at the primary level to retain the high energy coefficient. After that, we have use hybrid transformation to extract the features in final level. Hough transform is used for feature extraction of iris images as Hough transform is a special transform used for line detection of an input images. Hybrid transform like DCT-DWT, DCT-DKT and DCT-DHT are used here. Then all the hybrid transformed features are converted into Eigen space by evaluating normalized Eigen vector. After that all the Eigen features are stored into the database. During the recognition process test feature matrix will be compared with this template. Now to measure the system performance, we calculated true and false distances after fusing the features by AND, OR, AND-OR rule and then classification is applied.

To perform decision fusion, without fusing the features, we made the decision fusion after calculating the distances. The decision fusion is also done using AND, OR , and AND-OR rule.

Fusion Techniques used in our experiment:

Feature Level Fusion:

Feature of Face=a;

Feature of Ear=b;

Feature of Iris=c;

AND rule: (a) and (b) and (c)

OR rule: (a) or (b) or (c)

AND-OR rule: ((a) or (b)) and ((a) or (c)) and ((b) or (c))

Decision Level Fusion:

Decision of Face=a;

Decision of Ear=b;

Decision of Iris=c;

AND rule: Final decision will be passed if a,b,c all authenticated.

OR rule: Final decision will be passed if any among a,b,c authenticated.

AND-OR rule: Final decision will be passed if a,b,c all authenticated

Final decision will be failed if any among a,b,c not authenticated

Experimental Setup:

Matlab(R2009b) is used here as the simulation language that provide the interactive environment to provide quick and accurate results. Matlab is a product of Math works that includes the scientific software package integrated to provide the mathematical computation and provide graphical visualization so that result representation can be improved. For image processing, Maltab is having vast range of function to provide the effective information processing. The system is used with Intel™ core i5 processor where experiment has been performed. GUI from Matlab is used for easy performance.

The work is here defined to perform the Multimodal (Face/Ear/Iris) recognition using multiple feature vectors. To perform the recognition, the dataset is collected from external web source. The properties of this dataset is given here under

Table 1: Dataset Properties of Face

Property	**Values**
Database Name	Face Recognition Data, University Of Essex,UK
Number of Images	200
Number of Instance of a person	2
Number of Persons	100
Image Format	JPG
Type	Grey
Resolution	256x256

Table 2: Dataset Properties of Ear

Property	**Values**
Database Name	AMI Ear Database
Number of Images	200
Number of Instance of a person	2
Number of Persons	100

Image Format	JPG
Type	Grey
Resolution	256x256

Table 3: Dataset Properties of Face

Property	**Values**
Database Name	UPOL iris image database[29]
Number of Images	200
Number of Instance of a person	2
Number of Persons	100
Image Format	PNG
Type	Grey
Resolution	256x256

Experimental Result:

The experimentation of the work is here performed on different fusion approaches and before applying fusion, unimodal system performances are also analyzed. In any biometrics system the basic parameter to measure the performance is calculating the FAR and FRR. The basic definitions of FRR and FAR are showing below:

$$FAR = \frac{impostor\ scores\ exceeding\ threshold}{all\ impostor\ scores}$$

$$FRR = \frac{genuine\ scores\ falling\ below\ threshold}{all\ genuine\ scores}$$

First the FAR and FRR are calculated form simple face, iris and ear databases. Then the feature level fused databases using AND operator, OR operator and AND-OR operator are analyzed in terms of FAR and FRR. After completing the feature level fusion, FAR and FRR are also calculated having decision level fusion using AND operator, OR operator and AND-OR operator. All the best obtained FAR and FRR results are showing on the below table:

Traits/Method Used	**FAR**	**FRR**
Unimodal Biometric System		
Face Database	0.48	0.45
Ear Database	0.56	0.50
Iris Database	0.55	0.50
Multimodal Biometric System Using Feature Level Fusion		
AND Fusion	0.40	0.40
OR Fusion	0.40	0.07
AND-OR Fusion	0.49	0.52
Multimodal Biometric System Using Decision Level Fusion		
AND Fusion	0.51	0.48
OR Fusion	0.49	0.61
AND-OR Fusion	0.33	0.30

Table 4: Experimental results showing FAR and FRR applying different approaches

Here all graphical presentation of result are shown with GAR vs FAR plot, where GAR=1-FRR.

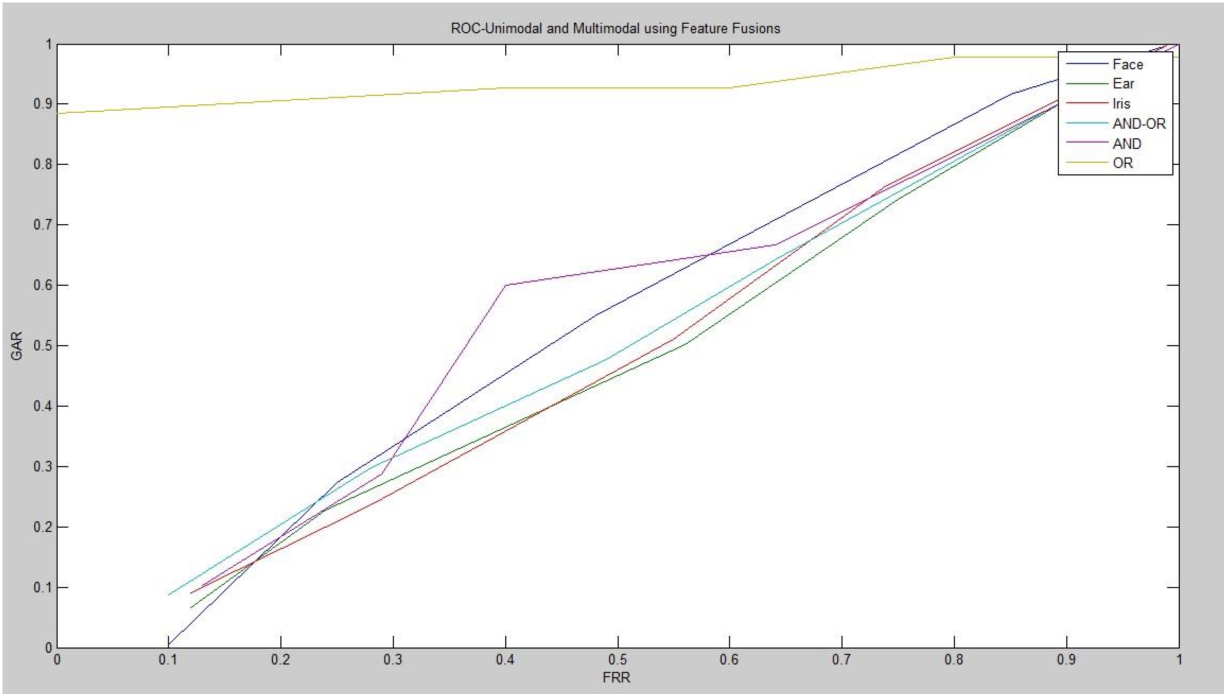

Fig.9 Performance comparison of all the feature fusion approaches.

Here performances of all the decision fusion results are shown in single plot of FAR vs FRR.

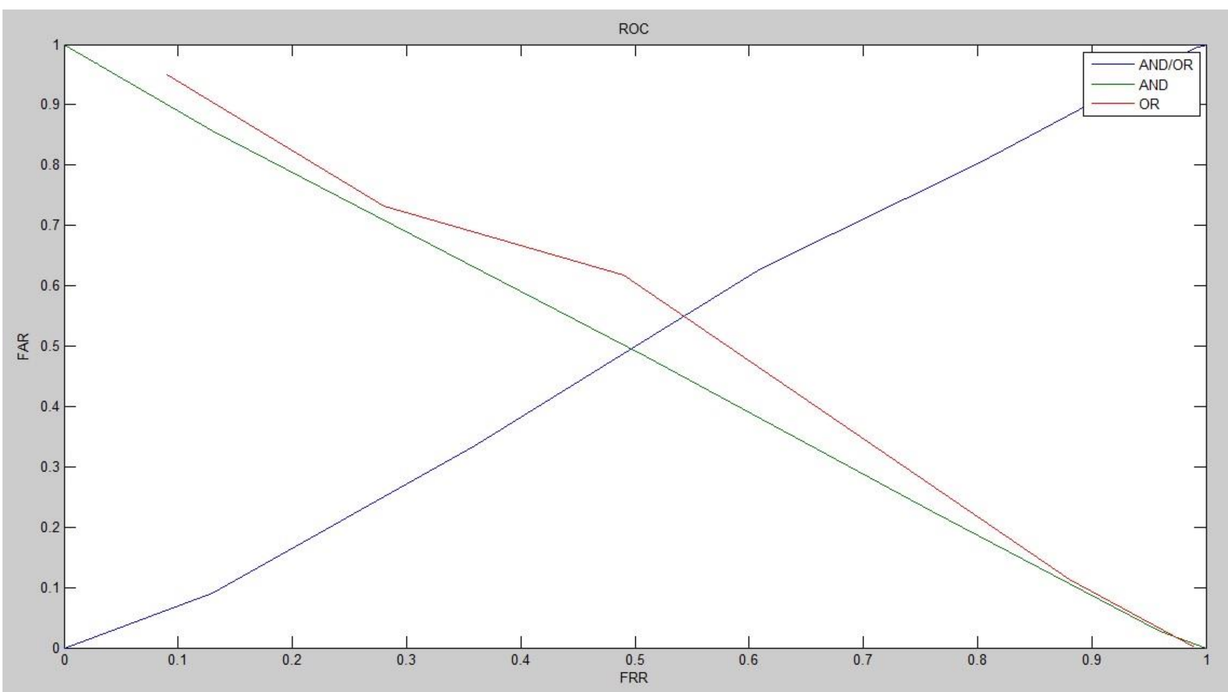

Fig.10 Performance comparison of all the decision fusion approaches.

Conclusion

One of the advanced biometric authentication types is multimodal biometric recognition. In this work, a feature adaptive approach is defined to improve the multimodal recognition. According to this proposed model, the first level features are extracted using discrete cosine transformation and discrete Hough transformation approach. In this work, three transformation approaches are applied to generate the image features. These approaches are hybrid transformation using DWT-DCT, DKT-DCT and DHT-DCT. Once the features are obtained after getting the Eigen matrices, later on the fusion image is generated by combining the two or more feature matrices using different operators. The generated fusion images are considered as the featured images on which recognition process is applied. The feature generation is here applied on training images and test image. Finally the distance adaptive approach is applied to perform the recognition and also decision level combination is applied in another approach. The results shows that the OR adaptive feature fusion provided the most accurate results.

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