Hybrid Multimodal Biometric Recognition using Kekre's Wavelets, 1D Transforms & Kekre's Vector Quantization Algorithms Based Feature Extraction of Face & Iris

H B Kekre, V A Bharadi
Computer Science Department
MPSTME, NMIMS University
Mumbai, India

V I Singh, V Kaul, B Nemade
IT Department, TCET
Mumbai University
Mumbai, India

ABSTRACT
Face Recognition Systems are becoming ubiquitous and inevitable in today's world. Being less intrusive and universal face recognition systems serve as good option for access control and surveillance. Iris recognition enjoys universality, high degree of uniqueness and moderate user co-operation. This makes Iris recognition systems unavoidable in emerging security & authentication mechanisms.

Various unimodal system implement face & iris based biometric authentication are available. In this paper a multimodal system which is a combination of a unimodal face recognition and multi-algorithmic iris recognition is proposed, the proposed system is combination of unimodal face and multi-algorithmic iris recognition system hence the name hybrid multimodal. Multimodal biometric systems are becoming more and more popular, they have more accuracy as compared to unimodal biometric systems. On the other hand these systems are more complex.

Face features are extracted using multilevel decomposition of face image using a new family of wavelet called kekre's wavelet and the iris features are extracted using 1 D transform of row & column mean, kekre's wavelet based texture features and Kekre's Fast Codebook Generation (KFCG) & Kekre's Median Codebook Generation (KMCG) algorithms based VQ codebooks.

The proposed system gives 99% correct classification rate (CCR) as compared to 85% CCR of face recognition system and 96% CCR of iris recognition system.

General Terms
Pattern Recognition, Security, Algorithms, Biometrics.

Keywords
Hybrid Multimodal Biometric Systems, Face Recognition Iris Recognition, KFCG, KMCG, Kekre's Wavelets

1. INTRODUCTION
Biometrics comprises methods for uniquely recognizing humans based upon one or more intrinsic physical or behavioral traits. In computer science, in particular, biometrics is used as a form of identity access management and access control. It is also used to identify individuals in groups that are under surveillance [1].

Biometric characteristics can be divided in two main classes:

• **Physiological** are related to the shape of the body. Examples include, but are not limited to fingerprint, face recognition, DNA, Palmprint, hand geometry, iris recognition, which has largely replaced retina, and odor/scent.

• **Behavioral** are related to the behavior of a person. Examples include, but are not limited to typing rhythm, gait, and voice & handwritten signatures. Some researchers have coined the term behaviometrics for this class of biometrics [2][3].

Biometric systems based on one (Unimodal) biometric are often not able to meet the desired performance requirements, and have to contend with a variety of problems such as noisy data, intra-class variations, restricted degree of freedom, non-university, spoof attacks and unacceptable error rates [1][3]. Some of these limitations can be addressed by deploying multimodal biometric systems that integrate the evidence presented by multiple sources of information.
Multimodal biometrics refers to the use of a combination of two or more biometric modalities in a verification/identification system [5][6][7]. Identification based on multiple biometrics represents an emerging trend. The most compelling reason to combine different modalities is to improve the recognition rate. This can be done when biometric features of different biometrics are statistically independent. There are other reasons to combine two or more biometrics. One is that different biometric modalities might be more appropriate for the different applications. Another reason is simply customer preference.

In this paper a Hybrid Multimodal Biometric System is proposed, the system is based on fusion of face and iris based unimodal systems. In the next sections face & iris biometrics are briefly discussed and then the multimodal biometrics and proposed architecture is discussed.

2. FACE RECOGNITION
Face recognition extracts facial characteristics. It requires a digital camera to develop a face image of the user for authentication. With security and surveillance cameras presents in variety of public places facial recognition is a viable option for biometric identification. Accuracy of face biometric is relatively low but requires low user co-operation. With advancement in technology variations such as facial thermogram (temperature distribution on a face) and 3D face mapping are

also being implemented [1], [2]. In current time where the world is facing increasing threats from terrorist attacks face recognition systems serve key role in security systems of public areas like airports, railway stations etc.

In [10] authors have proposed a face recognition technique based on a new family of wavelets called kekre's wavelets [8][9] for multiresolutoin analysis of face images. Different variants of feature vectors are generated and their performance for face recognition has been analyzed. The analysis shows that kekre's wavelets are faster than Haar wavelets and the feature vector based on these wavelets gives good accuracy. The Correct Classification Rate (CCR) is 87.53%. Authors have tested various variants of the feature vector and distance measures such as Euclidian distance and relative energy entropy (REE) are used. In this paper the proposed system is combining this system with a Multi-algorithmic iris recognition system.

3. IRIS RECOGNITION

Iris recognition is one of the important techniques due to its rotation and aging invariant nature [1][[3][11][12]. Compared with other biometric features (such as face, voice, etc.), the iris is more stable and reliable for identification [1]. Iris is the central part of the eye surrounding the pupil. Iris Recognition is the analysis of the coloured ring that surrounds the pupil [1][3]. The iris has unique structure and these patterns are randomly distributed; which can be used for identification of human being.

Authors have proposed use of DCT and Vector Quantization with clustering using Linde-Buzo-Gray (LBG) Algorithm, Kekre's Proportionate Error Algorithm (KPE) & Kekre's Fast Codebook Generation Algorithm (KFCGA) in [13][14][15][16]. These approaches are using Kekre's Vector Quantization Algorithms. In another variation Row & Column mean and its 1D transform is used for Iris feature vector generation [15]. In this paper some of the above mention feature vector extraction methods are combined to implement a multi-algorithmic iris recognition system. The proposed architecture will be discussed in the next sections.

4. MULTIMODAL BIOMETRICS SYSTEMS & PROPOSED ARCHITECTURE

In general, the use of the terms multimodal or multibiometric indicates the presence and use of more than one biometric aspect (modality, sensor, instance and/or algorithm) in some form of combined use for making a specific biometric verification/identification decision.

The goal of multibiometrics is to reduce one or more of the following:

- False accept rate (FAR)
- False reject rate (FRR)
- Failure to enroll rate (FTE)
- Susceptibility to artifacts or mimics

To further the understanding of the distinction among the multibiometric categories [6][7][17][18] they are briefly summarized in the following:

Multimodal biometric systems take input from single or multiple sensors measuring two or more different modalities of biometric characteristics.

Multi-algorithmic biometric systems take a single sample from a single sensor and process that sample with two or more different algorithms. The technique could be applied to any modality. Maximum benefit would be derived from algorithms based on distinctly different and independent principles and conditions.

Multi-instance biometric systems use one sensor (or possibly multiple sensors) to capture samples of two or more different instances of the same biometric characteristics. For example, systems capturing images from multiple fingers are considered to be multi-instance rather than multimodal.

Multi-sensorial biometric systems sample the same instance of a biometric trait with two or more distinctly different sensors. Processing of the multiple samples can be done with one algorithm or some combination of multiple algorithms. For example, a face recognition application could use both an infrared camera and a visible light camera coupled with specific frequency (or several frequencies) of infrared illumination.

In the paper a unimodal face recognition system is combined with a Multi-algorithmic Iris recognition system. The proposed architecture is shown in Fig. 1.

4.1 Feature Vector Extraction Using Kekre's Wavelets [10]

With the development of wavelet theory, Wavelet Analysis has been valued highly in various domains of research. It is a powerful tool of multi-resolution analysis. Here wavelet energy feature (WEF) by the high frequency to describe the palmprint images' texture and use it to describe the ridges & principle lines is constructed. Kekre's Wavelet (KW) Transform of the selected palmprint ROI is taken. The wavelets will capture localized spectral information from the ROI. We have the ROI of Size 256 X 256 Pixels. At each level Mth order KW matrix (of MXM Size) is generated by M/2 order Kekre's Transform Matrix (N=M/2, P=2).

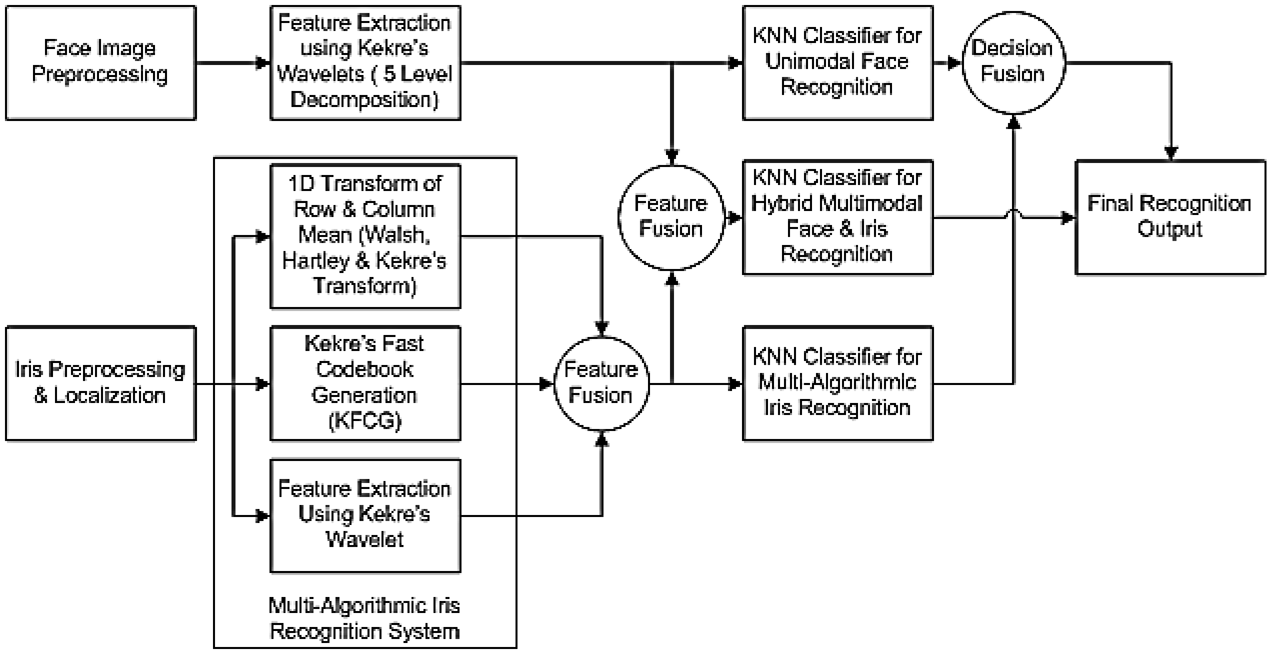


Figure 1. Architecture of Proposed Hybrid Multimodal Biometric System

$$E_i^h = \sum_{x=1}^{M}\sum_{y=1}^{N}(H_i(x,y))^2 \qquad (1)$$

$$E_i^v = \sum_{x=1}^{M}\sum_{y=1}^{N}(V_i(x,y))^2 \qquad (2)$$

$$E_i^d = \sum_{x=1}^{M}\sum_{y=1}^{N}(D_i(x,y))^2 \qquad (3)$$

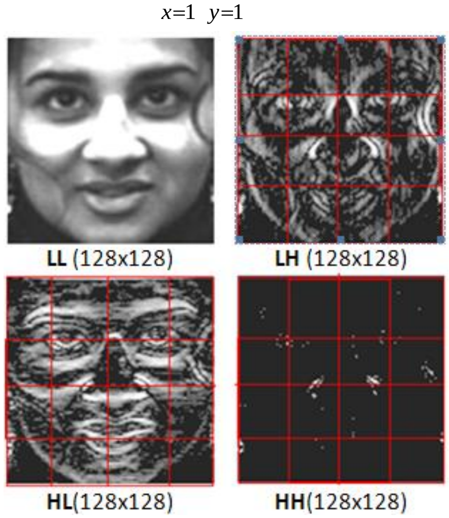


Figure 2. Dividing Wavelet Components into 4x4 non overlapping blocks

Only Horizontal, Vertical and Diagonal Components are divided into 4x4 blocks. Each component gives 16 values and per level we get 48 values of wavelet energy [10].

These energies reflect the strength of the images' details in different direction at the *i*-level decomposition. Hence the feature vector $(E_i^h, E_i^v, E_i^d)_{i=1,2,3,...,k}$ where K is the total number of wavelet decomposition level, can describe the global details feature of palmprint texture. Only Horizontal, Vertical and Diagonal Components are divided into 4x4 blocks. Each component gives 16 values and per level we get 48 values of wavelet energy

Using above mentioned vector, the features extracted from the whole ROI don't preserve the information concerning the spatial location of different details of facial features, so its ability to describe face uniqueness is weak. In order to deal with this problem, we divide the detail images into S×S non-overlap blocks equally, and then compute the energy of each block. Then, the energies of all blocks are used to construct a vector. This is shown in Fig 4. Finally the vector is normalized by the total energy. We are also normalizing this vector each level and Component wise also. These normalized vectors are named as wavelet energy feature. WEF has a strong ability to distinguish palmprints. According to these figures, WEFs of the same face are very similar while those of different faces are quite dissimilar. This is helpful for face recognition.

Each component is divided into 4x4 (SxS) non overlapping blocks; hence for a single component (LH, HL or HH) we have 16 wavelet energy values. In a single decomposition we have 3 components (LH, Hl & HH) hence we get total 48 components. We normalize the feature vector by dividing energy of components at each level by the sum of all the components energy at that level. We have such 5 levels (J) of decompositions hence we have total 3xSxSxJ i.e. 240 (3*4*4*5) values in the wavelet energy feature vector. We call this feature vector as KWEFV.

KWEFV = {WE0, WE1, ….., WEn)   n=3xSxSxJ.   (4)

For the face shown in Fig 2, the plot of Wavelet Energy Coefficients (KWEFV) is shown in Fig. 3. Total 15 Components (3*J) are generated, total energy of each component for analysis is also calculated. The component energy is normalized by total energy at the level. The distribution is a coarser estimate of spectral content.

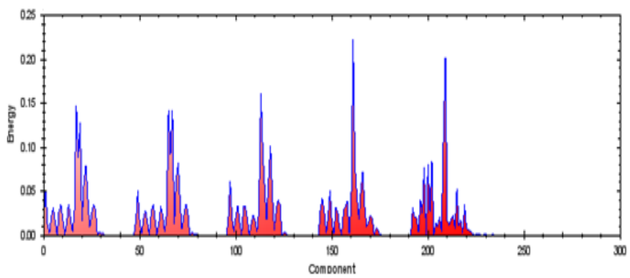
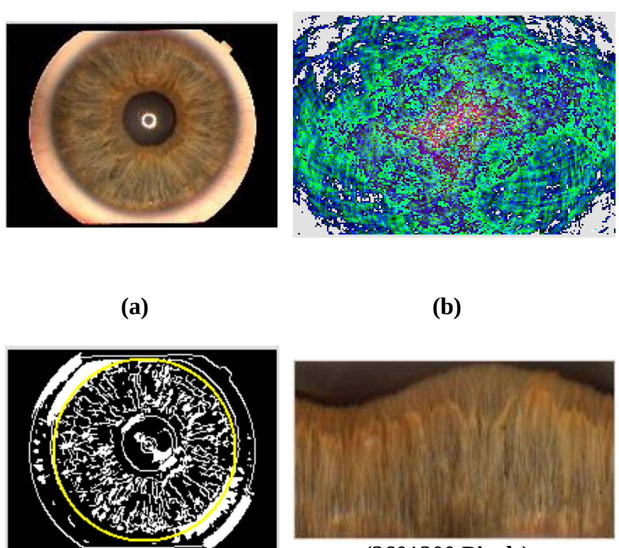


Figure 3. Kekre's Wavelet Energy Feature Vector Wavelet coefficients normalized level wise

4.2 Multi -algorithmic Iris recognition

Phoenix Iris database [19] is used for Iris recognition; we are using iris localization method based on circular Hough transform. The normalization process involves unwrapping the iris image and converting it into its polar equivalent. Daugman's Rubber sheet model [20]. The center of the pupil is considered as the reference and a remapping equation is used to convert the points on the Cartesian co-ordinates to the polar co-ordinates.



(a) (b)

(360*200 Pixels)

(c) (d)

Figure 4. Iris Normalization Process (a) Input Iris Image (b) Corresponding Hough Magnitude (c) Localized Iris Region (d) Unwrapped Iris

Iris Preprocessing improves the performance of the system. The extracted Region of Interest (ROI) is then used for feature extraction. We are using three different algorithms for texture feature extraction.

4.2.1One Dimensional Transform of Row & Column Mean [15]

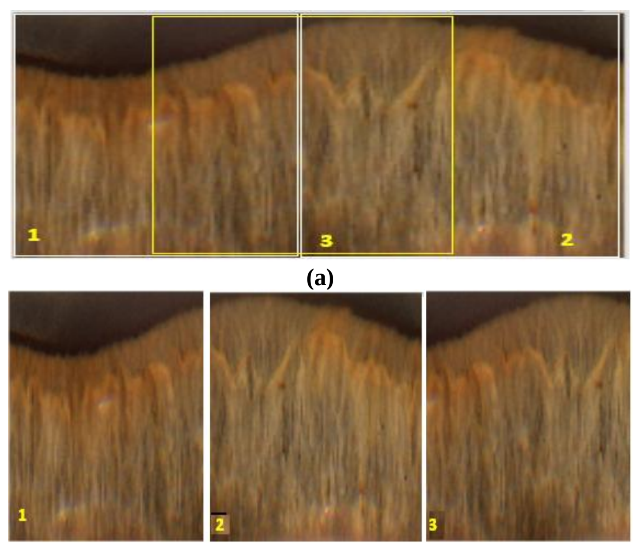
The ROI is used to generate row and column mean of the grey levels. The row and column mean correspond to the texture information. The row mean and column mean vectors are then operated by 1D transform. Walsh, Hartley, Kekre's Transform are used to generate the coefficients. These coefficients are stored in database as feature vectors.

4.2.2 Codebook Generated by KFCG[13][14][15][16]

Here the ROI is used and R, G & B Planes are used to generate codebook. Clustering is performed by Kekre's Fast Codebook Generation Algorithm [21]. The final codebook size is 128*12. This is used as a feature vector.

4.2.3 Multiresolution Analysis by Kekre's wavelets [8][10]

The selected Iris ROI size is 360 * 200 Pixels. We divide the ROI into three regions as follows. Region 1 & 2 are non-overlapping and region 3 is the central 180*180 pixels region overlapping with region 1 & 2. This arrangement is used for capturing localized texture information. Each block is the subjected to multiresolution analysis using kekre's wavelet up to three level of decomposition. Feature vector is extracted in same way as discussed for face in section 4.1. The normalized wavelet coefficients are stored in the database.



(a)

(b)

Figure 5. Three Blocks for Multiresulution Analysis (a) Iris ROI (360*180 Pixels scaled) (b) Three Regions of 180*180 Pixels each

The feature vector generated by above mentioned three algorithms are fused together to form a composite feature vector, this is called feature fusion. **This fusion is an example of multi -algorithmic iris recognition system**. As we are considering Left as well as right eye iris image for recognition purpose the system is also an example of **multi-instance** biometric system.

4.3 Hybrid Multimodal System

Kekre's wavelet based unimodal feature vector is fused with the multi-0algorithmic & multi-instance iris recognition system to form a fused feature vector of Face+ Iris. The feature vector size is 2156 Bytes of face + 81408 Bytes of Iris Composite features = 83564 Bytes total). This is a novel feature fusion scheme having combination of Unimodal + Multi-algorithmic + Multi-instance biometric modalities hence it is called as Hybrid Multimodal biometric System. Though the system is complex the accuracy is higher than individual modalities.

Each feature vector is given to respective K- Nearest Neighborhood Classifier, total three K-NN classifiers are implemented. One each for face & Iris feature vector and one for final hybrid feature vector. Besides this the decisions from face & iris classifiers are also fused to implement decision fusion based multimodal system. The proposed system implements both the feature fusion as well as decision fusion [17[18].

5. RESULTS

The proposed system is programmed into Visual C# 2.5 (MS Visual Studio 2005). The system is tested on PC with AMD Athlon FX 64 processor running at 1851MHz, 1.5 GB RAM with Windows XP SP3 – 32 bit Operating System.

For testing Phoenix iris database [19] and Computer Vision Research Projects Face Database-Faces94 [22] are used. Each user from Phoenix database is associated with one user from Face database to implement multimodal system. Three left iris and three right iris images are takes for training and six face images are taken for training. System is tested in both Authentication as well as Recognition (Identification) mode. Total 101 face users and 64 iris users were enrolled. The hybrid system consists of 64 individuals with total 768 biometric samples and 384 hybrid feature vectors.

On this test bed total 4041 genuine as well as forgery tests are performed.

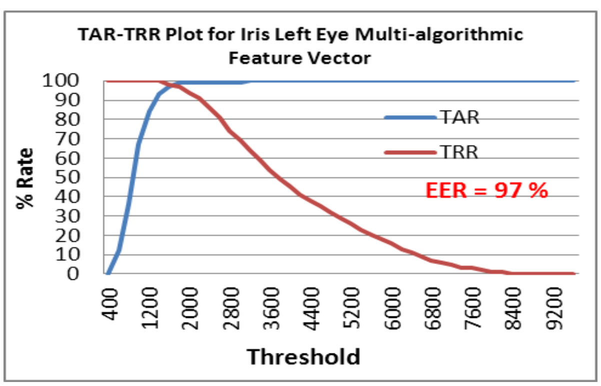


Figure 6. TAR-TRR Plot for Multi-algorithmic Iris Recognition with only left eye testing.

Iris testing is performed on left & right eye samples individually as well as in combination. In case of Iris only (without fusion with face biometrics) three different test set are analyzed. In case of Left eye iris only the Equal Error Rate (EER) of TAR-TRR analysis [1][2][4] is 97%. In case of right eye only the EER is 96%. When both the feature vectors are combined in a multi-instance iris recognition system the EER has marginally increased to 97.5%. The TAR-TRR analysis plots are shown in Fig. 6 to Fig. 8.

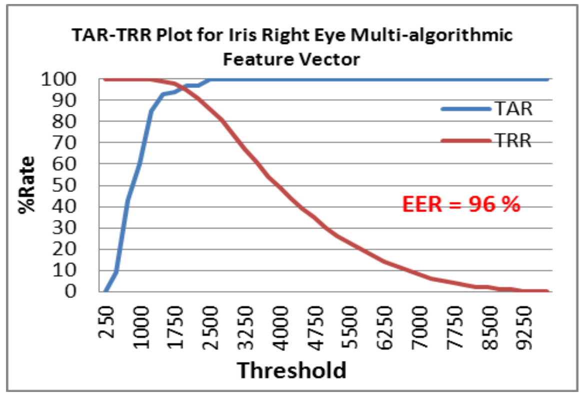


Figure 7. TAR-TRR Plot for Multi-algorithmic Iris Recognition with only Right eye testing.

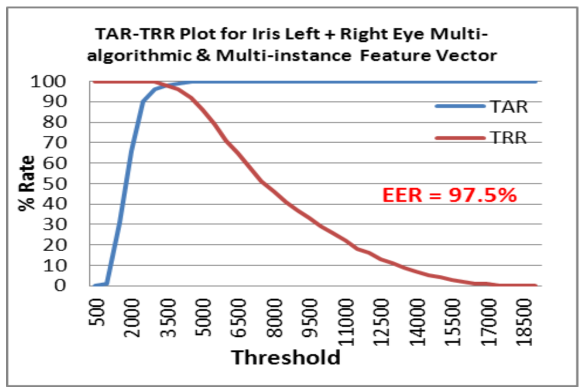


Figure 8. TAR-TRR Plot for Multi-algorithmic & Multi-instance fusion of Iris Recognition with Left + Right eye testing.

As discussed in the previous section this feature vector is fused with face feature vector to form the composite Hybrid Feature Vector. When this fusion is performed the final system give EER of 98 %. This is shown in Fig. 9.

Face Recognition system has EER of 95 % [10] and corresponding Correct Classification Rate (CCR) is 85 %. But the final system has CCR of 99% in case of Feature Fusion and 97% in case of Decision Fusion. The proposed hybrid system gives highest CCR as compared to the individual Systems.

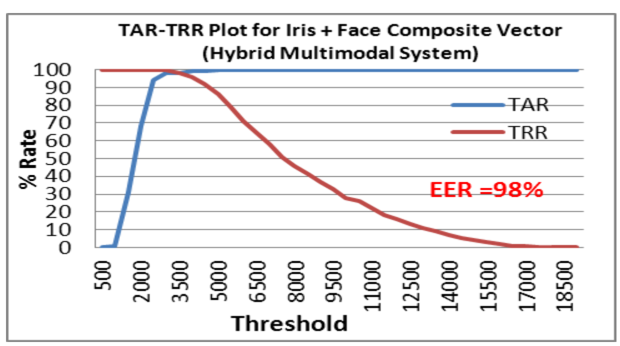


Figure 9. TAR-TRR Plot for Final Hybrid Multimodal System with Fusion of face & Iris.

6. CONCLUSION

In this paper authors have proposed a novel multimodal architecture called as Hybrid Multimodal System. This system is actually combination of Unimodal Face & Multi-algorithmic as well Multi-instance iris recognition systems.

Authors have used Kekre's Wavelets for Multiresolution Analysis of Face and Iris images, besides this Walsh-Hadamard Transform, Kekre's Transform, Hartley Transform of Row and Column mean of Iris image & KFCG based codebook are also used to generate the composite feature vectors.

Feature Fusion as well as Decision fusion are implemented in proposed hybrid multimodal system. Final System gives 99% CCR with Feature Fusion and 97% CCR with Decision Fusion. The individual face recognition system has CCR of 85%, this clearly indicate that the fusion has increased the performance of the system.

7. REFERENCES

[1] A. K Jain, P. Flynn, A. Ross, "Handbook of Biometrics", Springer, 2008.

[2] C. Tisse, L. Martin, L. Torres, and M. Robert, "Person Identification Technique using Human Iris Recognition", in Proc. Vision Interface, pp. 294-299, 2002.

[3] 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.

[4] A. Ross and A.K. Jain, "Information Fusion in Biometrics", *Pattern Recognition Letter* 24, pp.2115- 2125, 2003.

[5] H B Kekre, V A Bharadi, "Multimodal Biometrics" , International Conference & Workshop on Emerging Trends in Technology 2010 (ICWET 2010), 26-27 Feb 2010

[6] H B Kekre, V A Bharadi, "Adaptive Feature Set Updating Algorithm for Multimodal Biometrics", ACM International Conference (ICAC3'09), ACM Conference, Jan 2009

[7] H B Kekre, V A Bharadi, "Ageing Adaptation for Multimodal Biometrics using Adaptive Feature Set Update Algorithm", IEEE International Conference (IACC 2009), Thapar University, Patiala- Punjab, India. March 2009,

[8] H. B. Kekre, A. Athawale, D. Sadavarti, "Algorithm To Generate Kekre's Wavelet Transform from Kekre's Transform", IJSET, June 2010 (In Press)

[9] H. B. Kekre, S. D. Thepade, "Image Retrieval using Non-Involutional Orthogonal Kekre's Transform", International Journal of Multi-disciplinary Research And Advances in Engineering, IJMRAE, Vol.1, No.I, November 2009,pp189-203.

[10] H B Kekre, V A Bharadi, "Face Recognition using Kekre's Wavelets Energy & Performance Analysis of Feature Vector Variants" , ACM International Conference & Workshop on Emerging Trends in Technology 2011, ICWET 2011, TCET, Mumbai, India

[11] J. Daugman, "How iris recognition works", IEEE Trans, Circuits and Systems for Video Technology, vol 14, Issue 1, pp. 21-30, Jan.2004.

[12] R. Wildes, "Iris Recognition: An Emerging Biometric Technology", in Proc. IEEE, vol 85, no.9, pp. 1348-1363, 1997.

[13] H B Kekre, V A Bharadi, "Iris Recognition Using DCT & Vector Quantization", The 2010 IEEE International Conference on Signal Acquisition and Processing (ICSAP 2010), 9-10 February, 2010, Bangalore, India

[14] H B Kekre, V A Bharadi, "Iris Recognition Using Discrete Cosine Transform and Kekre's Fast Codebook Generation Algorithm", International Conference & Workshop on Emerging Trends in Technology 2010 (ICWET 2010), Mumbai, India, 26-27 Feb 2010

[15] H B Kekre, V A Bharadi, "Performance Comparison of Full 2-D DCT, 2-D Walsh and 1-D Transform over Row Mean and Column Mean for Iris Recognition", International Conference & Workshop on Emerging Trends in Technology 2010 (ICWET 2010), India, 26-27 Feb 2010

[16] H B Kekre, V A Bharadi, T K Sarode, "Performance Comparison of DCT and VQ based Techniques for Iris Recognition, Journal of Electronic Science and Technology (JEST) (International), vol. 8, no. 3, Sept. 2010

[17] A. Ross, AK. Jain,"Multimodal Biometrics: An Overview", In Proc. of 12th European Signal Processing Conference (EUSIPCO), (Vienna, Austria), pp. 1221-1224, September 2004.

[18] Teddy Ko , "Multimodal Biometric Identification for Large User Population Using Fingerprint, Face and Iris Recognition" , Proceedings of the 34th Applied Imagery and Pattern Recognition Workshop (AIPR05) ,2005.

[19] http://phoenix.inf.upol.cz/iris/download/, (refferred on 10-09-2009, 10:00 a.m.).

[20] J. Daugman, "High Confidence Visual Recognition of Persons by a Test of Statistical Independence", IEEE Trans. Pattern Analysis and Machine Intelligence, vol. 15, pp. 11481161, 1993.

[21] Kekre H., Sarode T., "An Efficient Fast Algorithm to Generate Codebook for Vector Quantization," IEEE CNF , ICETET-2008, Nagpur, India, pp.: 62- 67, 16-18 July 2008.

[22] Computer Vision Research Projects Face Database : Faces94 – available at: http://cswww.essex.ac.uk/mv/allfaces/faces94.html