International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

An Innovative Technique for Biometric Recognition of Face and Palm-Print Multimodal using Matching Level Fusion

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Submitted: 02/01/2024 **Revised**: 02/02/2024 **Accepted**: 10/02/2024

Abstract: This paper gives a innovative method for the Recognition of Face and Palm-Print. Main motive of this paper is ti increase robustness of the recognition systems. Traits are combined with different biometric fusion techniques and results are very innovative. Fusion technique can be implemented by two approaches, Combination like wavelet transformation, HOG, DCT, etc. and Classification like k-Nearest Neighbors (kNN), Random Forest, etc. Biometric fusion was implemented on matching score level. Database used for experiments were, faces94, faces95, faces96 and IITD Palmprint Database using various Face recognition and Palm recognition algorithms. Results of which are discussed further in the paper.

Keywords: *Combination and Classification based approaches, HOG, Hamacher Product, Lukasiewiez t norm, Face recognition, Palm recognition, Biometric fusion, Matching score level,*

I. Introduction:

From the starting of the 20th century, data generated from the different resources in the field of technology. With the enormous availability of data, question arises about its security, for this purpose different technologies are invented. Security must be errorless, and Alpha-numeric passwords were easy to decrypt. Therefore, an automated, most safely, and non-decryptable, individual specific system was the need. To solve this we came to automatic biometric recognition systems.

Biometric being a unique characteristic of an individual, it proves for verification and authentication problems. Humans have many of its own biometrics for disposable, like face, iris, fingerprint, palmprint, DNA, gait, etc. Research work in biometric recognition is at its peak. Many different algorithms and state of the art are coming onto picture. As technology is advancing, mocking are becoming stronger and stronger. In the work published by to Shervin Rahimzadeh Arashloo et al, "it has been observed that face recognition systems are quite vulnerable to spoof attacks, nearly 80% of the spoofing attempts successfully passed the authentication stage" [1].

Main security threat emphasizes that, before giving any acess of information to any subject, proper identification and authentication of that subject is very important. This can be done by using many different robust algorithm implemented. This paper emphasizes, basically on two modalities, palmprint and face. Standard databases have been used for testing. As robustness is to be increased, biometric fusion was implemented. Collection of biometric information is taken by various sensors like digital camera, fingerprint sensors, etc. Used sensor take biometric modality and give output in some form, like Camera gives images as output. Now, we are using two modalities, we will get data for both face and palmprint. Biometric fusion is done by taking these sensors information and fusing will occur using it for authentication and verification purposes. Basically, there are different levels of fusion, i.e. Sensor, Feature, Matching score, Decision level. In sensor level fusion technique output of the sensor, is taking directly without any prepossessing. After this, preprocessed data send to classifier for authentication. Followed by Feature level fusion takes place in this step data extraction takes place, important features processed by sensor used for fusion of both modalities. Then immediately data transfer to classifier for classification. Next to this step Matching score level fusion takes place, here some unique features are compared with a template and generate score, which gives the amount of match of the test image with template, which is calculated for both modalities and fused with fusion technique. Last step for the level fusion is Decision level fusion which is implementing two separate classifiers for two modalities and fusing the decisions of the classifier using fusion techniques. [2].

This paper emphasis on deployment of Matching score level fusion. For implementing the fusion level technique, much experimentation was carried out on face and palm recognition techniques, best results are used for implementation. Algorithm used for implementation during experimentations is Confidence-based and classification-based algorithm. Confidence-

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based algorithms give amount of similarity between template and query image. Techniques like Random Forest, kNN, etc. are used for classification, give outputs based on the classes, it gives plots and the hyperplane it calibrates while training. For fusion techniques, Fuzzy logic is good conceptual and mathematical tool for combination purposes. Also, we can use algorithms like weighted sum, product rule, max rule, etc. These fusion techniques add much more robustness and thus security of the sensitive and vital information.

II. Literature Survey: Today with rapid development going on in the field of biometric, different efficient algorithms were developed o different biometric models like EAR, FINGERPRINT, FACE, PALM PRINT IRIS etc.. Many of the new algorithms are invented and has a best results. By Yong Xu et al., previous work on recognition based on edges, ridges, lines and different methods like edge detection, gradient calculation also used. In Gabour filter for getting 5 orientation vector for encoding, 5 orientations and convoluted input images were required. At the matching state, matching takes place by using Hamming and Euclidean tec. distance metrics along with this dimensional reduction technique also used like LDA, PCA etc. called as sub-spaced based method. And classification based algorithms like kNN, SVM etc. exhibited their advantages.[3].

III. Preprocessing Technique:

Grey Scale Method: For preprocessing technique, first is grey scale conversion, image taken by camera contain main basic three colors RGB. When we are working on Colored image it means we are working on these three colors or channels. Experimentally this is an expensive and time consuming process to overcome this, we convert image into Grey scale image, and it have only one intensity channel.

$$\text{Grey} = 0.299 * \text{R} + 0.587 * \text{G} + 0.114 * \text{G} \quad (1)$$

Secondly, Contrast Limited Adaptive Histogram Equalization, to improve the contrast in computer image processing generally histogram technique is used, which is differing from normal histogram equalization. AHE has a tendency to overamplify noise in relatively homogeneous regions of an image. A variant of adaptive histogram equalization called contrast limited adaptive histogram equalization (CLAHE) in which the contrast amplification is limited, prevents this by limiting the amplification.

IV. Biometric Modality:

Face: Most common trait for human identification is Face. Every human has unique features like its eyes, nose, ears, lips etc. Many researchers were implements different techniques, robust algorithms for getting accuracy in research work.

Histogram of Oriented Gradients (HOG) :HOG is a popular feature descriptor technique used due its accurate description. "The orientation computation is not affected by lighting conditions as histogram is computed. Lighting condition is just a bias added to whatever original intensity of the image possess, and histogram is invariant to added bias" [4]. Techniques such as sobel gardients or Cartesian mask such as [1 0 -1] , [1 0 -1]T . First step in HOG analysis is the calculation of the magnitude and direction of gradient of the local image. Next step is kernel histograms calculation. Kernal used for calculation of intensity histograms of image. After this these kernals are arranged in clocks called descriptor block. These have shape like Circular, Square etc. When the histogram calculated, they correspond to the local scale of that kernel. Hog can be given in fig.

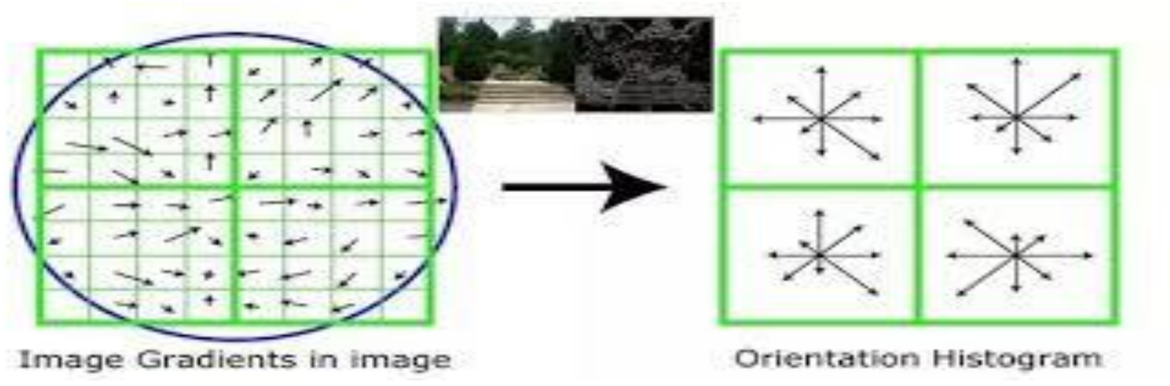

Fig 1: Descriptor block

Database used for this algorithm has been tested on faces94, faces95, faces96 [6]. In this training data contains used one subject per subject class. Pearson correlation coefficient is calculated between query images and trained images. Recognition output level is given on the basis of the confidence level, and for that HOG is the best.

Local Binary Pattern Histogram: LBPH algorithm generally starts from dividing input image into kernels of 16x16 pixels, LBPH is a texture spectrum. Every pixel in the kernel have eight neighbors and also have 8 Traverse the neighbors in either clockwise or counter-clockwise direction. If the center pixel value is less than the traversing pixel value, then that traversed pixel value is replaced by "1" and if the center pixel value is greater than the traversed pixel value then the traversed pixel value is replaced by "0". In this pattern, we will get 8 values for each pixel, which we will call as 8-bit value for each pixel. Later this 8-bit binary value is converted to decimal value for plotting purposes. This gives decimal value for the entire input image. Compute histogram after all values have been calculated.

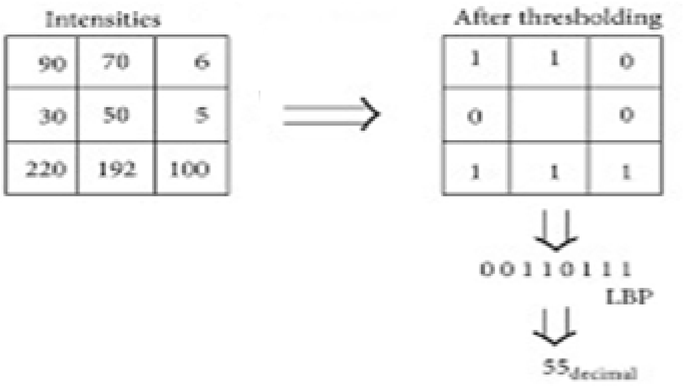

Fig 2: Query image to decimal value conversion.

This algorithm was tested on faces94, faces95, faces96. Also, the trained data for LBPH contains only one image per subject class. The single image per class was selected for training based on majority containment of variants available. LBPH was implemented as a classification-based algorithm using face recognizer available in OpenCV. The predictor gives the output label.

Fisher's Linear Discriminent Analysis The basic idea behind the Fisher's linear discriminent analysis is used for pattern recognition, dimensionality reduction to design an optimal transform, which can maximize the ratio of between-class to within class scatter matrices so that the classes can be well separated in the low-dimensional space [21]. This is similar to Principal Component analysis, only difference is PCA is an unsupervised algorithm. For reducing computational cost and dimensionality it projects the data onto an inferred axis. During this process PCA ignores the labels of the given data therefore FLDA used. [7-8].

$$J(W) = \frac{W^T S_B W}{W^T S_W W} \qquad (2)$$

Where:

S_B: Scatter matrix between classes,

$S_B = \sum_c (\mu_c - \bar{x})(\mu_c - \bar{x})^T$

S_W- Scatter matrix within classes,

$S_w = (x_i - \mu_c)(x_i - \mu_c)^T$

$\bar{x}$ -Overall means of the test cases,

$J(W)$ = Image feature vector,

Discrete Cosine Transform (DCT): Discrete Cosine Transform (DCT) an image was represented as a sum of sinusoids of varying frequencies and magnitudes. As stated by Surya Kant Tyagi et al., DCT is used in signal processing and in image processing due to its energy compacting property. It converts most signal information into some coefficient. When DCT is applied on an image, we get low frequency and high frequency feature matrix. If DCT is to be applied to an image called $f(x, y)$ we get low frequency and high frequency feature matrix of size M×N, then transformed image will be $F(u, v)$.[9-10]

$$F(u, v) = \alpha(u)\alpha(v)\mathrm{Cos}\left(\frac{(2x-1)un}{2M}\right) * \mathrm{Cos}\left(\frac{(2x+1)un}{2M}\right) \qquad (3)$$

Where,

$u = 0,1,2, \ldots M$

$v = 0,1,2, \ldots N$

$\alpha(w) = \frac{1}{\sqrt{2}}$ When $w = 0$

$\alpha(w) = 1$ otherwise

Here, DCT is confidence-based algorithm. DCT is applied on the input image and compared with the trained data using Mean Square Error and the corresponding labels are given as output. Here, also, only one input image is given for training.

Wavelet Transformation: For the dimensionality reduction and computation time, decomposition of image into components corresponding to different frequency spectrum bands. This technique is called as 1-D wavelet transformation, which is applied on image, and it becomes, 1- D. It works on basis function, similar to PCA. [11,12]

As per recursive definition algorithm, suppose we have 1-D array of 8 elements, take sum of average of 2 elements. Now we are taking 4 sum averages and also take 4 difference average. Repeat this process until 2 sum average and 2 difference average remain and use them as feature vectors. For 2-D wavelet transformation , it applied on 2-D image, then resize it up to fourth of same images are fitted into its original size, further division takes place by recursively.[13] Wavelets are of two types, discrete transformation and continuous transformation. And, are many filters like Frequency B-spline, Meyer, Bi-orthogonal, etc. In discrete wavelet transform, the wavelets of the image are discretely sampled. Wavelet transform consider time and frequency information, as compared to Fourier transform, which is used as confidence-based approach and Pearson correlation coefficient is used to calculate confidence values and gives label as output.

2. Palm-print: Palm-print is a unique to every subject can be used biometric modal. Main part of the palm-print recognition is based on the basic lines on the palm. Palm-print recognition is quite complex compared to face recognition due to complex features on the palm. The algorithms were tested on IITD palmprint database. The database contains the images of complete palm. We used a ROI extraction technique just to extract the palmprint.[17] Some of the techniques applied on face were applied to palm. The techniques were applied on IITD-Palmprint database.

1. Discrete Cosine Transform..

2. Histogram of Oriented Gradients

3. k-Nearest Neighbors.

4. Wavelet Transformation.

5. Random Forest

The accuracies results of palm print recognition are discussed in Table 1.

Table 1: Accuracy results of Classifiers with feature descriptors.

Sr. No.	Algorithms	Accuracy on faces94	Accuracy on faces95	Accuracy on faces96
1.	kNN-HOG	96.66%	90.11%	80.11%
2	kNN-DCT	95.11%	81.33%	74%
3.	kNN-LBPH	91.2%	87.4%	81.43%
4.	kNN-Wavelet	94%	90%	76%
5.	kNN-Fisher	85%	82.5%	70.86%
6.	Random Forest-HOG	78.33%	91.45%	88%
7.	Random Forest-DCT	84.66%	75%	69.23%
8.	Random Forest-LBPH	81%	82.56%	75.44%
9.	Random Forest-Wavelet	89.33%	77.78%	65%
10.	Random Forest-Fisher	85.5%	84.66%	78.34%

Biometric Fusion: As discussed earlier, Biometric fusion's main aim is to increase robustness to such extent that the spoofing attacking should fail. Matching Score level fusion is used in the implementation part. Matching score level fusion can also be called as confidence-level fusion. Template is matched with each query and the amount of matching which is the confidence level is shown. After the fusing the confidence levels, we get a score which if greater certain threshold is verified else discarded. Many algorithms for individual recognition were implemented and the best one was taken for fusion. As it is a score level fusion, confidence-based algorithms are to be used for both face and palm-print. [19]

Weighted Sum: It is one the simplest and widely used fusion technique. The scores of two modalities are fused using a linear equation and weights given to the scores.

$$\text{Fued Score} = \alpha * c_1 + \beta * c_2 \quad (4)$$

Where,

α- Weight of matching score of modality1,

c1= Matching Score of modality 1,

β- Weight of matching score of modality 2,

c2=Matching Score of modality 2.

Hamacher Product: It is one of the triangular normalization techniques used in fuzzy logic. It is used in probabilistic spaces and multi-leveled logic problems. It is a strict Archimedean t-norm. Fbsp wavelet transformation was used for face recognition and HOG was used for palm-print recognition [20]. It is defined as below,

α- Weight of matching score of modality1,

c1= Matching Score of modality 1,

$$T_{H_\theta}(a,b) = \frac{ab}{a+b-ab} \qquad \text{for } a,b \neq 0 \qquad (5)$$

$$T_{H_\theta}(a,b) = 0 \qquad \text{for } a = b = 0$$

Where,

T_{H_θ} – Hamacher Product of scores a and b.

Score of modality 1.

Score of modality 2.

Lukasiewiez t norm: It is conjunction, nil-potent Archimedean t-norm. It is used when we have a n-level logic problem. Here the classed used in the database are analogous to the n-level logic problems. It is defined as,

$$T_{Luk}(a,b) = \max(0, a+b-1) \qquad (6)$$

V. Metrics and Classifiers:

Pearson's Correlation coefficient and mean squared error are the main two metrics used in this paper.

Pearson Correlation Coefficient: Pearson correlation coefficient is the covariance of the two images divided by the product of the standard deviations.

$$\rho_{X,Y} = \frac{\text{conv}(x,y)}{\sigma_x \sigma_y} \qquad (7)$$

Where, $\text{conv}(x,y)$-Covariance of X, Y,

σ_x-Standard deviation of image X,

σ_y-Standard deviation of image Y

Here ρ can be expressed in terms of mean and exception.

$$\text{conv}(X,Y) = E[(X-\mu_x)\ (Y-\mu_y)] \qquad (8)$$

$$\rho_{x,y} = \frac{E[(X-\mu_x)\ (Y-\mu_y)]}{\sigma_x \sigma_y} \qquad (9)$$

Here, μ_x- is mean of Image X,

μ_y- is mean of Image Y,

E- is the Exception

The Pearson correlation coefficient is the measure of the linear relationship between two images. Pearson's correlation requires the pixel intensities of the image with normal distribution. Like other correlation coefficients, this one varies between -1 and +1 with 0 implying no correlation. Correlations of -1 or +1 imply an exact linear relationship. Positive correlations imply that the first variable is directly proportional to the other variable. Negative correlations imply that as x increases, y decreases.

Mean squared error: It is defined as average of the squares of the deviation. It is the error between the estimator value and the estimated value. Smaller the value of Mean Squared Error more similar is the two compared images.

This value of MSE can be used to compare two images. This metric gives more of a structural similarity between two images.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(\hat{X} - X_i)^2 \qquad (10)$$

Here; $\hat{X}$ – Number of predictions,

X_i-Number of true values.

MSE value, compares two images, and gives more structural similarity between two images.

Random Forest: It is an ensemble learning method used for regression and classification problems. Ensemble learning is using multiple algorithms to improve the accuracy and robustness of the classifier or repressor. Random Forest constructs multiple layers of decision trees while training. Each decision tree gives its decision about the test image and the mode of all the results is given as the output of the whole algorithm. This algorithm is much robust compared to other algorithms as it uses multiple decision trees. It means that multiple recognition algorithms are used, and majority of its output is given as final output. The algorithm uses tree bagging. Tree bagging is selecting random samples with replacement and training the decision trees. After training, prediction on the test samples is made by taking mode of the outputs of the decision trees. Let c(f) be a decision tree and p(f) be the prediction. [16]

$$\text{Output} = \max\{pi(f)\} \qquad (11)$$

Here i have 1,2,3,…n and n is the number of decision tree.

HOG features are calculated and given to the classifier. This is a classification-based approach. Thus, 5 instances of the subjects are given for the training.

K-Nearest Neighbors: KNN is one of the fastest algorithms used for classification purposes. It is also one of simplest algorithm used in machine learning. Euclidean distance is calculated between the test image and the images in the training data, the label of the image with the least distance is considered as the label of the test image. kNN classifier takes an important hyper-parameter of „n_neighbors‟, which is the number of closest neighbors to be checked for the test image. If n_neighbors is set to 5, it means the test image will look for the labels of 5 closest images and majority of the labels in the group of 5 will be considered as the label of the test image. [14-15] It is quite easy and straightforward algorithm and is used widely. HOG features are calculated first and then given to the classifier. kNN is used as a classification approach. Five instances of The techniques discussed in Table 2 are the intelligent classifier techniques. These techniques use more than one image for training as the techniques are clustering techniques. These techniques require some feature to classify into classes.

VI. Experiments on Modalities:

Face: All discussed techniques were applied on Faces94, Faces95, Faces96. The accuracies are as shown in Table 1. The techniques shown in Table 2 only use one image in its training. Technique discussed in Table 2 are the intelligent classifier technique .These techniques are clustering techniques and applied on one image for the technique.

Table 2: Accuracies of various algorithms used on Face

Sr. No.	Algorithms	Accuracy on faces94	Accuracy on faces95	Accuracy on faces96
1.	HOG	95.61%	75%	84.80%
2.	LBPH	89.33%	85.5%	83.5%
3.	Fbsp wavelet	94.33%	86.4%	81%
4.	DCT	80.6%	79.4%	70%
5.	Fisher	84.8%	78.56%	72.5%

Palm-print: The discussed techniques were applied on IITD-palmprint database and the accuracies were calculated [18]. Only one image was given for training for HOG, DCT, Wavelet Transformation, and Radon-Gabor Transform. Five images were given for training in kNN and Random Forest. The techniques with their accuracies shown in Table 3 use only one image for training.

Table 3: Accuracies of algorithms used for palm print

Sr. No.	Algorithms	Accuracy on IITD Database
1.	HOG	82%
2.	DCT	67%
3.	Fbsp Wavelet	70.55%

The techniques shown in Table 4 are classifier-based technique. These techniques use more than one image for training.

Table 4: Feature descriptor for classifier

Sr. No.	Algorithms	Accuracy on IITD Database
1	kNN-HOG	82.77%
2	kNN-DCT	70.10%
3	kNN- Wavelet	80.11%
4	Random Forest- HOG	68.00%
5	Random Forest- DCT	40.50%
6	Random Forest -Wavele	44.22%

Biometric Fusion: Biometric fusion was the best method for measuring each biometric trait. For Face and plan wavelet and HOG are the best transformation respectively.

Table 5: Feature descriptor for classifier

Sr. No.	Algorithms	Accuracy on Face94 + IITD	Accuracy on Face95 + IITD	Accuracy on Face96 + IITD
1	Weighted Sum	90.01 %	94.88%	91%
2	Hamacher Product	95.10%	95%	93%
3	Lukasiewiezt norm	90.00%	94.10%	95.55%

VII. Conclusion:

Data being a ranked priority nowadays, need for accurate and moreover robust authentications techniques is called for. Hacking and spoofery methods are getting stronger and penetrable than ever. The controlled access given sensitive data using biometric recognition systems is a strong method used against misuse of information. Biometric fusion of two or many biometric entities proves to be more robust to attacks as it checks for multiple biometrics. Using a confidence-level based fusion technique in systems can be even more robust than the existing systems.

We discussed various techniques which can be used for biometric recognition. With only one training image in most of the algorithms, it proves the robustness of each algorithm. Now, if all image instances are given for training, we can imagine how robust the system would become. One of the purpose of using only single image for training is not to require more biometric information for a human being. Mathematical and probabilistic fusion open doors for more and more robust and accurate techniques.

References:

[1] Shervin Rahimzadeh Arashloo, Josef Kittler and William Christmas," Face Spoofing Detection Based on Multiple Descriptor Fusion Using Multiscale Dynamic Binarized Statistical Image Features", IEEE Transactions on Information Forensics and Security, Vol. 10, Issue11, pp. 2396 – 2407, 2015.

[2] Muhtahir O. Oloyede and Gerhard P. Hancke, "Unimodal and Multimodal Biometric Sensing Systems: A Review". IEEE Access, vol.4, pp. 7532 – 7555, 2016.

[3] Yong Xu, Lunke Fei, and David Zhang, "Combining Left and Right Palmprint Images for More Accurate Personal Identification", IEEE Transactions on Image Processing, Vol. 24, No. 2, pp. 549 – 559, Februaury 2015.

[4] Shu Chang, Ding Xiaoqing, Fang Chi, "Histogram of the Oriented Gradient for Face Recognition", Tsinghua science and Technology, Vol. 16, No. 2, pp. 216 – 224, April 2011.

[5] Richard Szeliski, "Computer Vision: Algorithms and Applications," 2010.

[6] Spacek, L.2008.Computer Vision Science Research Projects [Online]. http://cswww.essex.ac.uk/mv/allfaces/index.html

[7] Max Welling, "Fisher Linear Discriminant Analysis", University of Toronto, Department of Computer Science, Tech, Rep, 2005.

[8] Yishu Liu, Zhihua Yang, Ching Y. Suen, and Lihua Yang, "A Study on Performance Improvement Due to Linear Fusion in Biometric Authentication Tasks", vol. 46, issue. 9, pp. 1252 – 1264, Sept. 2016 .

[9] Surya Kant Tyagi and Pritee Khanna, "Face Recognition Using Discrete Cosine Transform and Nearest Neighbor Discriminant Analysis". IACSIT International Journal of Engineering and Technology, Vol. 4, No. 3, June 2012.

[10] Md Saiful Islam, Nassim Ammour, Naif Alajlan, and M. Abdullah Al-Wadud. "Selection of Heart-Biometric Templates for Fusion". IEEE Access, vol 5, pp. 1753 – 1761, 2017.

[11] Duraisamy Sundararajan, "Fundamentals of the Discrete Haar Wavelet Transform," 2011.

[12] Christos Georgakis, Stavros Petridis, and Maja Pantic, "Discrimination Between Native and Non-Native Speech Using Visual Features Only". IEEE Transactions on Cybernetics, vol 46, issue 12, pp. 2758 – 2771, 2015.

[13] Yazhuo Gong, David Zhang, Pengfei Shi and Jingqi Yan, “Handheld System Design for Dual-Eye Multispectral Iris Capture with One Camera”. IEEE Transactions on systems, man, and cybernetics: systems, vol. 43, no. 5, sept 2013.

[14] Dhriti and Manvjeet Kaur, “K-Nearest Neighbor Classification Approach for Face and Fingerprint at Feature Level Fusion”. International Journal of Computer Applications vol. 60,no.14, December 2012.

[15] Anne M.P. Canuto , Fernando Pintro, João C. Xavier-Junior, “Investigating fusion approaches in multi-biometric cancellable recognition”. Expert Systems with Applications, vol. 40, pp.1971–1980, 2013.

[16] Emir Kremic and Abdulhamit Subasi, “Performance of Random Forest and SVM in Face Recognition”. The International Arab Journal of Information Technology Vol. 13, No. 2, March 2016.

[17] Milind E. Rane, Umesh S Bhadade, “Comparative Study of ROI Extraction of Palmprint,” IJCSN International Journal of Computer Science and Network, Volume 5, Issue 2, April 2016.

[18] “Palmprint Image Database version 1,” IIT, Delhi, India, 2007, http://www4.comp.polyu.edu.hk/~csajaykr/IITD/Database_Palm.html

[19] Aleksandr Sizov, Elie Khoury, Tomi Kinnunen, Zhizheng Wu,and Sebastien Marcel, “Joint Speaker Verification and Anti-Spoofing in the i-Vector Space”. ”, IEEE Transactions on Information Forensics and Security, vol.10, issue 4, pp. 821 – 832, 2015.

[20] Madasu Hanmandlu , Jyotsana Grover , Ankit Gureja , H.M. Gupta, “Score level fusion of multimodal biometrics using triangular norms”, Pattern Recognition Letters, vol. 32 pp. 1843–1850, 2011.

[21] Qian Du, Senior Member, IEEE, “Modified Fisher’s Linear Discriminant Analysis for Hyperspectral Imagery”, IEEE GEOSCIENCE AND REMOTE SENSING LETTERS, VOL. 4, NO. 4, October 2007.