International Journal of Engineering &Technology, 7 (4) (2018) 6970-6976

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i4.26010
Research paper

Combination of SVM, LDA, PCA and linear regression under fuzzy system in human face recognition

Bulbul Ahammad [1] *, Liton Jude Rozario [2], Anup Majumder [1]*, Md. Imdadul Islam [2]

[1] *Lecturer, Department of Computer Science and Engineering, Jahangirnagar University, Dhaka, Bangladesh*
[2] *Professor, Department of Computer Science and Engineering, Jahangirnagar University, Dhaka, Bangladesh*
**Corresponding author E-mail: anupju.cse20@gmail.com*

Abstract

One of the main applications of image processing is recognition of human face. In this paper, we worked on several benchmark databases of human face to identify a person based on Linear Regression, SVM (Support Vector Machine and Viola-Jones Object detector), LDA (linear discriminant analysis) and PCA (Principal Component Analysis). All the four methods are combined under Fuzzy system and we get the accuracy of 96.4% which is higher than any individual method.

Keywords: *Viola-Jones Object Detector; Fuzzy Rules; Surface Plot; Eigen Vector; RBF.*

1. Introduction

Biometric is an automated recognition system used in person identification, which has versatile applications in real life shown in [1-2]. The major fields of application of Biometric are: commercial, government and forensic. In commercial field it is used in: credit cards, cellular phones, AIMS, medical records, managerial, e-commerce, electronic data security and network login. In government sector its application is found in: PAN card, driving license, passport control, border control and social security. Finally, in forensic we can apply it in: corpse identification, criminal investigation, terrorist identification, parenthood, determination and missing children. In this paper we only emphasized on human face recognitions. It is obvious that face recognition has been used to a great extent in recent years and much importance is placed on further research and innovativeness. As the representation of information using image is the more reliable key to Biometric system, an application of image analysis and understanding have become a great concern to our study [3]. So, developing an efficient technique for identification of faces is unavoidable. For this reason, many researches have built a reliable recognition system for past few recent years and the majority of them focused on the degree of accuracy of face recognition system, which is divided into two groups. One group emphasized on developing a more effective feature extraction module to minimize the influence of illumination, position, orientation, scale and expression, whereas the other concentrates on the classification technique to improve the quality of the end results of face recognition [3]. Classification is a very common task in machine learning and its objective is to decide on which class a data point will be in, where some data points belonging to one of two classes are given [4]. Many classification methods have been used in many research works such as – Back Propagation Neural network, SVM Classifiers, Nearest Neighbor Classifier and Hidden Markov Model [5]. Face recognition refers to matching an input image against a database of images in order to verify if the input image is already present or not in the database. Face recognition system comprises of three modules – Face Detection, Feature extraction and Face recognition or Classification. According to [6], face detection modules can be broadly categorized as feature based and image based detection techniques. Feature based methods focus on the information of –edges, gray levels, color, motion and point distribution models to detect and localize the faces i.e. they utilize the visual features of human faces such as skin color, contour, nose, eyes, mouth and so on as the basis for detection. Feature extraction refers to extracting required features from the detected face in an input image. Many feature extraction techniques such as PCA (Principal Component Analysis), LBP (Local Binary Pattern), Viola-Jones and so on, have been proposed for this reason. In this paper, we employed the Viola-Jones object detection framework to detect if an image contains a face and to identify the required facial feature points [7]. Here four widely used algorithms in human face identification: regression of facial images, principal component analysis (PCA), linear discriminant analysis (LDA) and support vector machine (SVM) are used and we combined the result using Fuzzy system. Theoretical analysis of each algorithm is given in next section. Combination of all four methods gives accuracy of 96.4%, actually this accuracy depends on quality of facial image.

The rest of the paper is organized as: section 2 deals with the theory of four methods of image identification: Linear Regression, PCA, LDA and SVM then four methods are integrated together using Fuzzy Logic system to enhance the accuracy of human face detection, section 3 provides results based on analysis of section2 and section 4 concludes entire analysis.

2. System model

2.1. Linear regression on facial image

In linear regression a set of scattered points (x_i, y_i); i = 1, 2, 3…, n are plotted on a straight line based on least square distance algorithm. The coefficients of the straight line$y=a+bx$ are evaluated as,

Copyright ©2018 Bulbul Ahammad et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

$$b=\frac{n\sum_{i=1}^{n}y_ix_i-\sum_{i=1}^{n}y_i\sum_{i=1}^{n}x_i}{n\sum_{i=1}^{n}x_i^2-\left(\sum_{i=1}^{n}x_i\right)^2} \text{ And } a=\frac{\sum_{i=1}^{n}y_i-b\sum_{i=1}^{n}x_i}{n} \quad (1)$$

Under linear regression model of object detection, N facial image of same person with background is read form a database then background is eliminated using Viola-Jones algorithm. The serial number of images, i = 1, 2, 3…, N is taken as abscissa and the resized image is considered as the ordinate of the Cartesian co-ordinate system. The vertical distance of a test image from the regression line is evaluated and if the distance is above the threshold then it is considered as the image of different person otherwise it is of the same person as explained in [8].

2.2. PCA algorithm

1) First of all we consider images,I_1, I_2, I_3, …, I_M each of size N×N are converted to column vector as: Γ_1, Γ_2, Γ_3,…, Γ_M each of size of $N^2\times1$.
2) Calculate the average vector, $\boldsymbol{\psi}=\frac{1}{M}\sum_{i=1}^{M}\boldsymbol{\Gamma}_i$ (known as average face) and difference vectors, $\boldsymbol{\Phi_i}=\boldsymbol{\Gamma_i}-\boldsymbol{\psi}$; i = 1, 2, 3,.., M
3) Construct a matrix, $\mathbf{A}=[\boldsymbol{\Phi_1} \quad \boldsymbol{\Phi_1} \quad \cdots \quad \boldsymbol{\Phi_M}]$ and the covariance matrix, $\mathbf{C}=\mathbf{AA}^T$. The covariance matrix can also be derived as: $\mathbf{C}=\frac{1}{M}\sum_{i=1}^{M}\boldsymbol{\Phi}_i^T\boldsymbol{\Phi}_i$. The size of matrix C or A is $N^2\times N^2$.
4) Select the M orthogonal Eigen vectors U_k (where $\mathbf{U}_k^T\mathbf{U}_j=\delta_{k,j}$) and corresponding Eigen values λ_k which specify the principal components of data are from the covariance matrix C.
5) Select a new test image and find its vector Γ. The projection of Γ on face space is: $\mathbf{U}_k^T(\boldsymbol{\Gamma}-\boldsymbol{\psi})=\boldsymbol{\omega}_k$ is called weight of face k. Let us define weight vector, $\boldsymbol{\Omega}=[\boldsymbol{\omega}_1 \quad \boldsymbol{\omega}_2 \quad \cdots \quad \boldsymbol{\omega}_M]$.

Measure the Euclidean distance: $\varepsilon_k=\|\boldsymbol{\Omega}-\boldsymbol{\Omega}_k\|$ is and if the distance is greater than a threshold value θ then the test image is unknown otherwise it is under the class of same database; where $\boldsymbol{\Omega}_k$ is the weight vector of the image k. Detailed analysis of PCA is found in [9].

Numerical example:

As an example, let us take 4 matrices of 4×4 as shown below,

$$\mathbf{I}_1=\begin{bmatrix}2&5&9&12\\9&12&0&15\\7&9&1&36\\15&19&12&25\end{bmatrix}, \mathbf{I}_2=\begin{bmatrix}3&5&38&5\\13&22&39&2\\21&15&7&10\\18&13&17&16\end{bmatrix},$$

$$\mathbf{I}_3=\begin{bmatrix}9&5&9&12\\11&22&0&19\\17&9&1&26\\15&19&29&32\end{bmatrix} \text{ and } \mathbf{I}_4=\begin{bmatrix}33&15&14&22\\38&12&33&15\\7&23&25&16\\6&22&33&16\end{bmatrix}$$

The average vector,

Ψ = [11.7500 7.5000 17.5000 12.7500 17.7500 17.0000 18.0000 12.7500 13.0000 16.5000 8.5000 22.0000 13.5000 18.2500 22.7500 29.7500] ^{T}

Four difference vectors,

Φ_1 = [-9.7500 -2.5000 -8.5000 -0.7500 -8.7500 -5.0000 -18.0000 2.2500 -6.0000 -7.5000 -7.5000 14.0000 1.5000 0.7500 -10.7500 -4.7500] ^{T}

Φ_2 = [-8.7500 -2.5000 20.5000 -7.7500 -4.7500 5.0000 21.0000 -10.7500 8.0000 8.5000 -1.5000 -12.0000 4.5000 -5.2500 -5.7500 -13.7500] ^{T}

Φ_3 = [-2.7500 -2.5000 -8.5000 -0.7500 -6.7500 5.0000 -18.0000 6.2500 4.0000 -7.5000 -7.5000 4.0000 1.5000 0.7500 6.2500 2.2500] ^{T}

Φ_4 = [21.2500 7.5000 -3.5000 9.2500 20.2500 -5.0000 15.0000 2.2500 -6.0000 6.5000 16.5000 -6.0000 -7.5000 3.7500 10.2500 16.2500] ^{T}

First four rows of covariance matrix normalized by 1000 is evaluated as,

0.6308 0.2125 -0.1475 0.2737 0.5757 -0.1150 0.3600 0.1027 -0.1500 0.1575 0.4575 -0.1700 -0.2175 0.1163 0.3558 0.5058

0.2125 0.0750 -0.0350 0.0925 0.2025 -0.0500 0.1500 0.0225 -0.0600 0.0650 0.1650 -0.0600 -0.0750 0.0375 0.1025 0.1625
-0.1475 -0.0350 0.5770 -0.1785 -0.0365 0.1200 0.6840 -0.3005 0.2020 0.2790 0.0390 -0.3780 0.0930 -0.1335 -0.1155 -0.3175

0.2737 0.0925 -0.1785 0.1467 0.2357 -0.0850 0.0030 0.0978 -0.1160 0.0055 0.1755 0.0240 -0.1065 0.0742 0.1427 0.2587

The elements of matrix of eigen vectors are,

0.3703 0.3046 0.0862 -0.0432 0.0201 0.2517

0.1333 0.0923 -0.0696 0.0289 0.0780 0.1679

0.1565 -0.4709 0.0149 0.2499 0.0229 -0.1069

0.1117 0.2171 -0.0816 0.0030 -0.0140 0.1033

0.3859 0.2066 -0.1092 0.0232 0.3033 0.4231

-0.0350 -0.1263 0.4461 -0.1125 0.2801 0.1132

0.5609 -0.3909 -0.1628 0.0031 -0.1165 -0.1281

-0.0667 0.2526 0.1493 0.0018 0.0871 0.2244

-0.0226 -0.1976 0.4529 -0.0758 0.2135 0.1271

0.2363 -0.1561 -0.0700 -0.0855 -0.0426 -0.0822

0.3386 0.1145 -0.1567 -0.0796 -0.1894 -0.0172

-0.2813 0.2271 -0.3343 0.2514 -0.2432 -0.0210

-0.1107 -0.1365 0.0678 -0.0478 0.0827 -0.0433

0.0214 0.1347 -0.0312 -0.8550 -0.0718 -0.2970

0.1834 0.1930 0.5916 0.1556 -0.6768 -0.0660

0.2060 0.3906 0.1387 0.2856 0.4345 -0.7139

Finally the weight vectors,

Ω_1 = [-30.0209 7.7104 -11.3792 0.0000]

Ω_2 = [9.4559 -40.3733 0.5181 -0.0000]

Ω3 = [-20.1262 11.7706 12.9644 0.0000]

Ω_4 = [40.6912 20.8924 -2.1033 -0.0000]

2.3. LDA method in object identification

LDA utilizes two matrices: 'within-class scatter matrix' and 'between-class scatter matrix' to calculate the orthogonal components of an image i.e. components of the image matrix along different mutual orthogonal vectors. The notion is similar to the eigen vectors of PCA method. Let us suppose that the database of a facial image has c different folders where each folder contains n facial images of an individual. The set of images of i^{th} person is [11], $Y_i = \{y_1, y_2, y_3, \ldots \ldots \ldots y_n\}$; where $y_j \in Y_i$ is the j^{th} image of person i. The set of entire images is, $Y = \{Y_1, Y_2, Y_3, \ldots \ldots \ldots Y_c\}$. The within-class scatter matrix is expressed as,

$$\mathbf{S}_w = \sum_{i=1}^{c} \sum_{x_k \in X_i} (\mathbf{x}_k - \mu_i)(\mathbf{x}_k - \mu_i)^T \quad (2)$$

The between-class scatter matrix is expressed as,

$$\mathbf{S}_B = \sum_{i=1}^{c} N_i (\mu_i - \mu)(\mu_i - \mu)^T \quad (3)$$

Where μ_i is the mean of i^{th} group and μ is the overall mean. The next step is to find out m unitary matrices of $\mathbf{S}_w^{-1}\mathbf{S}_B$ corresponding to m largest eigen values. Let the orthogonal eigen vectors or unitary matrices be: $w_1, w_2, w_3, \ldots \ldots \ldots, w_m$. The component of y_k along j^{th} eigen vector is, $z_k = y_k.w_j$; where $k = 1, 2, 3, \ldots, m$. The projection vector will identify the facial image or person.

As an example, we take two persons; each one has four images as shown in FIGURE. 1(a)-(b). Applying Viola-Jones algorithm the region of interest of both set of images is shown in FIGURE. 1(c)-(d). Next the profile of two largest eigen vectors of two persons under LDA is shown in FIGURE.2 (a)-(b) like [10]. The curves of same person are much closed; where as that of different person are widely separated visualized from the figure also. The cross correlation co-efficient of eigen vector of same person is very closed to unity but that of different person is found less than 0.8.

(A)Person-1 **(B) Person 2** **(C) ROI of Person 1** **(D) ROI of Person 2**

Fig. 1: Images of Two Persons and ROI.

(A) First Eigen Vector **(B) Second Eigen Vector**

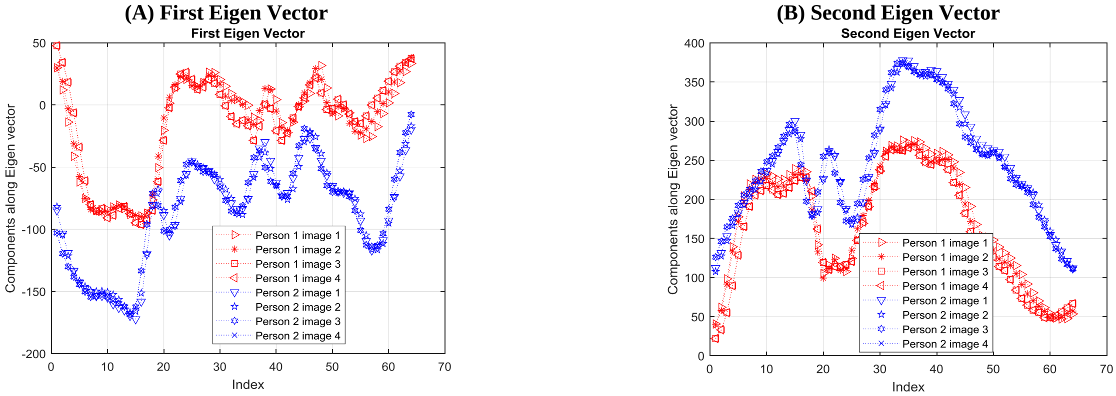


Fig. 2: Profile of Eigen Vectors of 4 Images Per Person.

2.4. SVM in face recognition

The SVM is a learning algorithm, classifies objects taking decision boundary called hyperplane where the optimum hyperplane separates the points corresponding to objects with widest margin. The generalized equation of a hyperplanelike [11],

$f(x) = b + w^Tx$; where w is known as the weight vector and b as the bias. (4)

The SVM determine the constants: w^T, b, τ such that $w^Tx + b \geq \tau$ for one group of points and $w^Tx + b \leq \tau$ for another group of points. The SVM uses Kernel function to provide the best trajectory of decision boundary.

Here we first consider a numerical example of SVM of traffic data of two network. Probability density function of interarrival time of traffic follows negative exponential distribution like, $f(t) = \lambda e^{-\lambda t}$; where λ is call arrival rate and t is inter-arrival time.

Integrating over [0, t] gives the cdf, $F(t) = \int_0^t \lambda e^{-\lambda t} dt = \frac{\lambda}{-\lambda}\left[e^{-\lambda t}\right]_0^t = 1 - e^{-\lambda t}$ is a random number in the range [0, 1]. Solving for the interarrival time,

$$t = -\frac{1}{\lambda}\ln(1 - F(t)) \quad (5)$$

Here we consider an example of two traffic stream with arrival rate of λ_1=1/6 calls/ min and λ_2=1/12 calls/min. Let us now take data D = [t_1 t_2] for 200 interarrival time of traffic 1 and traffic 2. The scatter plot of SVM corresponding to radial basis function and radial sigma function is shown in FIGURE 3.

Algorithm-1

1) Read the RGB image.
2) Convert it to gray scale image I.
3) Apply Viola–Jones object detection algorithm on the image I to detect facial region, I_F.
4) Convert the image I_F into vector V_F.
5) Determine a vector G with Gaussian random variable with, mean μ = mean(V_F) and variance σ^2 of V_F. Provided the length of G and V_F are equal and mean of G falls on the center of the vector V_F.
6) Determine the normalized parameter, $G^T.V_F/255^2$ of the face image.
7) Use 100* $\sigma^2$and $G^T.V_F/255^2$as the point P of SVM.

8) Repeat steps 1 to 8 for N images of first kind. The corresponding matrix of points is M_P.
9) Repeat steps 1 to 8 for N images of second kind. The corresponding matrix of points is M_Q.
10) Apply the point matrices M_P and M_Q to SVM for both radial basis and sigmoid Kernel.

Determine the percentage of error from the results of SVM.

(A) (B)

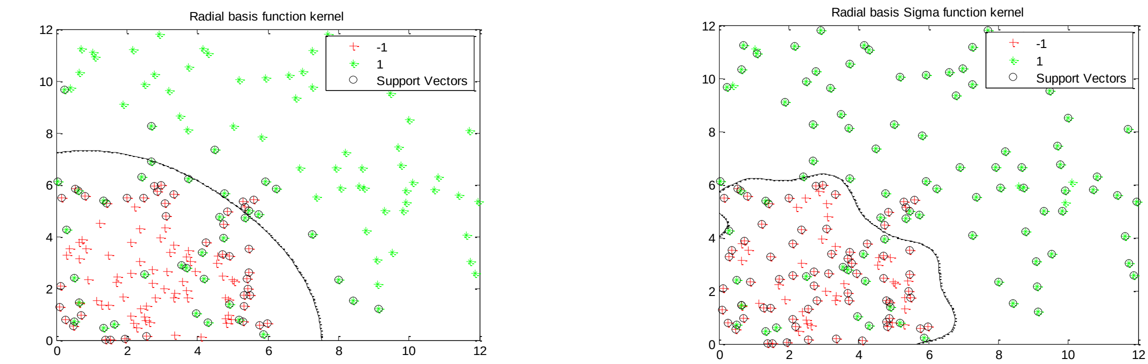


Fig. 3: Points of Inter-Arrival Time of Two Traffic Stream.

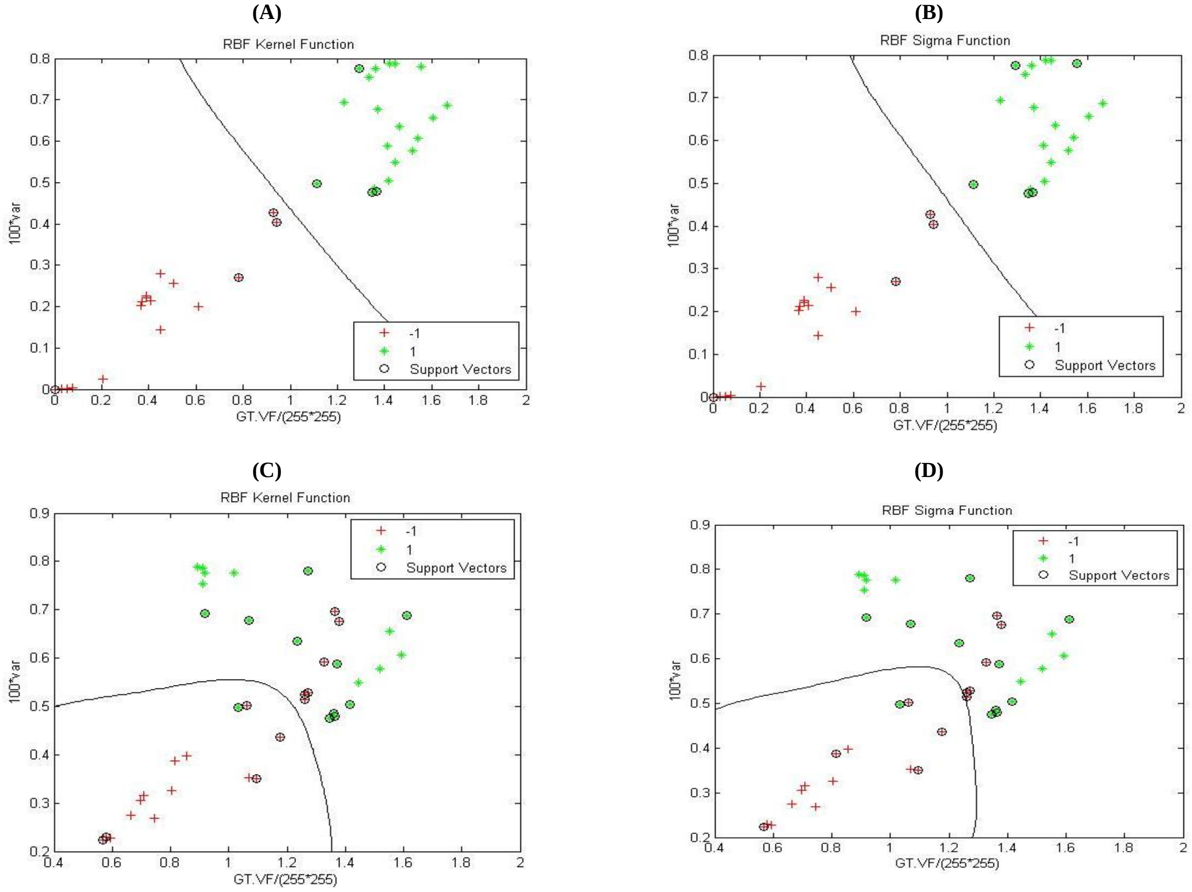


Fig. 4: Points of Facial Points for 'RBF Kernel Function' and 'RBF Sigma Function' (N = 20).

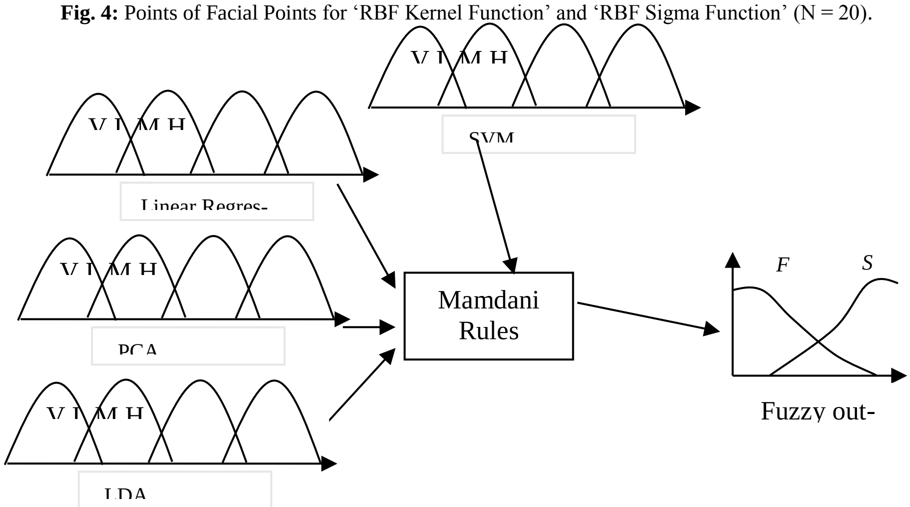


Fig. 5: Fuzzy Face Recognition System.

As an example, the scatter plot of 20 facial images taken from database 1 and 20 images from database 2 under 'RBF Sigma Function' is shown in FIGURE 4. (a) - (d).

2.5. Fuzzy Logic system

In this paper the accuracy of four methods is combined with Fuzzy system where four membership functions are used named as: very low (V), low (L), medium (M)and high (H). The range of membership functions are shown in Table 1.

Table 1: Fuzzy MF Range (REGRESSION, PCA, LDA, SVM)

Accuracy	Very Low	Low	Medium	High
Range in %	10-50	50-70	70-85	85-100
Symbol of MF	V	L	M	H

(A) Few Rules of Failure

1. If (Linear-Regression is V) and (PCA is V) and (LDA is V) and (SVM is V) then (output is F) (1)
2. If (Linear-Regression is V) and (PCA is V) and (LDA is V) and (SVM is L) then (output is F) (1)
3. If (Linear-Regression is V) and (PCA is V) and (LDA is L) and (SVM is V) then (output is F) (1)
4. If (Linear-Regression is V) and (PCA is L) and (LDA is V) and (SVM is V) then (output is F) (1)
5. If (Linear-Regression is L) and (PCA is V) and (LDA is V) and (SVM is V) then (output is F) (1)
6. If (Linear-Regression is L) and (PCA is L) and (LDA is V) and (SVM is V) then (output is F) (1)
7. If (Linear-Regression is V) and (PCA is L) and (LDA is L) and (SVM is V) then (output is F) (1)
8. If (Linear-Regression is V) and (PCA is V) and (LDA is L) and (SVM is L) then (output is F) (1)
9. If (Linear-Regression is V) and (PCA is L) and (LDA is V) and (SVM is L) then (output is F) (1)
10. If (Linear-Regression is L) and (PCA is V) and (LDA is V) and (SVM is L) then (output is F) (1)
11. If (Linear-Regression is L) and (PCA is L) and (LDA is V) and (SVM is L) then (output is F) (1)
12. If (Linear-Regression is L) and (PCA is L) and (LDA is L) and (SVM is L) then (output is F) (1)

(B) Few rules of success

20. If (Linear-Regression is H) and (PCA is V) and (LDA is V) and (SVM is V) then (output is S) (1)
21. If (Linear-Regression is H) and (PCA is L) and (LDA is V) and (SVM is V) then (output is S) (1)
22. If (Linear-Regression is H) and (PCA is M) and (LDA is V) and (SVM is V) then (output is S) (1)
23. If (Linear-Regression is H) and (PCA is V) and (LDA is L) and (SVM is V) then (output is S) (1)
24. If (Linear-Regression is H) and (PCA is V) and (LDA is H) and (SVM is V) then (output is S) (1)
25. If (Linear-Regression is H) and (PCA is V) and (LDA is M) and (SVM is V) then (output is S) (1)
26. If (Linear-Regression is H) and (PCA is V) and (LDA is V) and (SVM is L) then (output is S) (1)
27. If (Linear-Regression is H) and (PCA is V) and (LDA is V) and (SVM is H) then (output is S) (1)
28. If (Linear-Regression is H) and (PCA is V) and (LDA is V) and (SVM is M) then (output is S) (1)
29. If (Linear-Regression is M) and (PCA is H) and (LDA is V) and (SVM is V) then (output is S) (1)
30. If (Linear-Regression is H) and (PCA is H) and (LDA is V) and (SVM is V) then (output is S) (1)
31. If (Linear-Regression is L) and (PCA is H) and (LDA is V) and (SVM is V) then (output is S) (1)
32. If (Linear-Regression is V) and (PCA is V) and (LDA is H) and (SVM is V) then (output is S) (1)
33. If (Linear-Regression is V) and (PCA is L) and (LDA is H) and (SVM is V) then (output is S) (1)
34. If (Linear-Regression is V) and (PCA is M) and (LDA is H) and (SVM is V) then (output is S) (1)

Fig. 6: Fuzzy Rules of the System.

The basic diagram of the Fuzzy system is shown in FIGURE.5; where we have four types of Fuzzy input and they are combined by Mamdani rules of 'and' and 'or' laws. The only one Fuzzy output gives the result of success (S) and fail (F). Few fuzzy rules correspond to failure and success is shown in FIGURE 6. (a) and (b) based on [12].

3. Results and discussion

In this paper we worked on 20 databases of facial image each containing 100 RGB images. We first converted them into gray scale image then resized the images as 64×64. The background of the images was eliminated using Viola-Jones algorithm. Few original RGB images with background and removal of background after application of Viola-Jones algorithm are shown in FIGURE.7 and 8 respectively. The feature vectors of four methods (SVM, LDA, PCA and Linear Regression) are compared to take the decision whether the image is of the same person under a database or not.

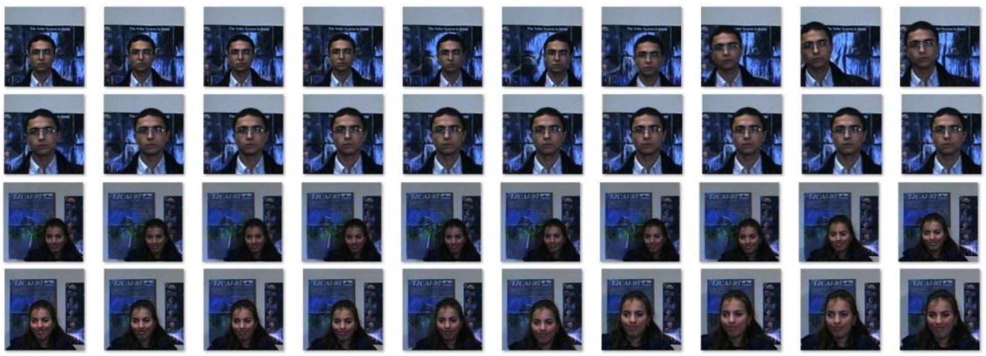


Fig. 7: Sample Facial Images From Database with Background.

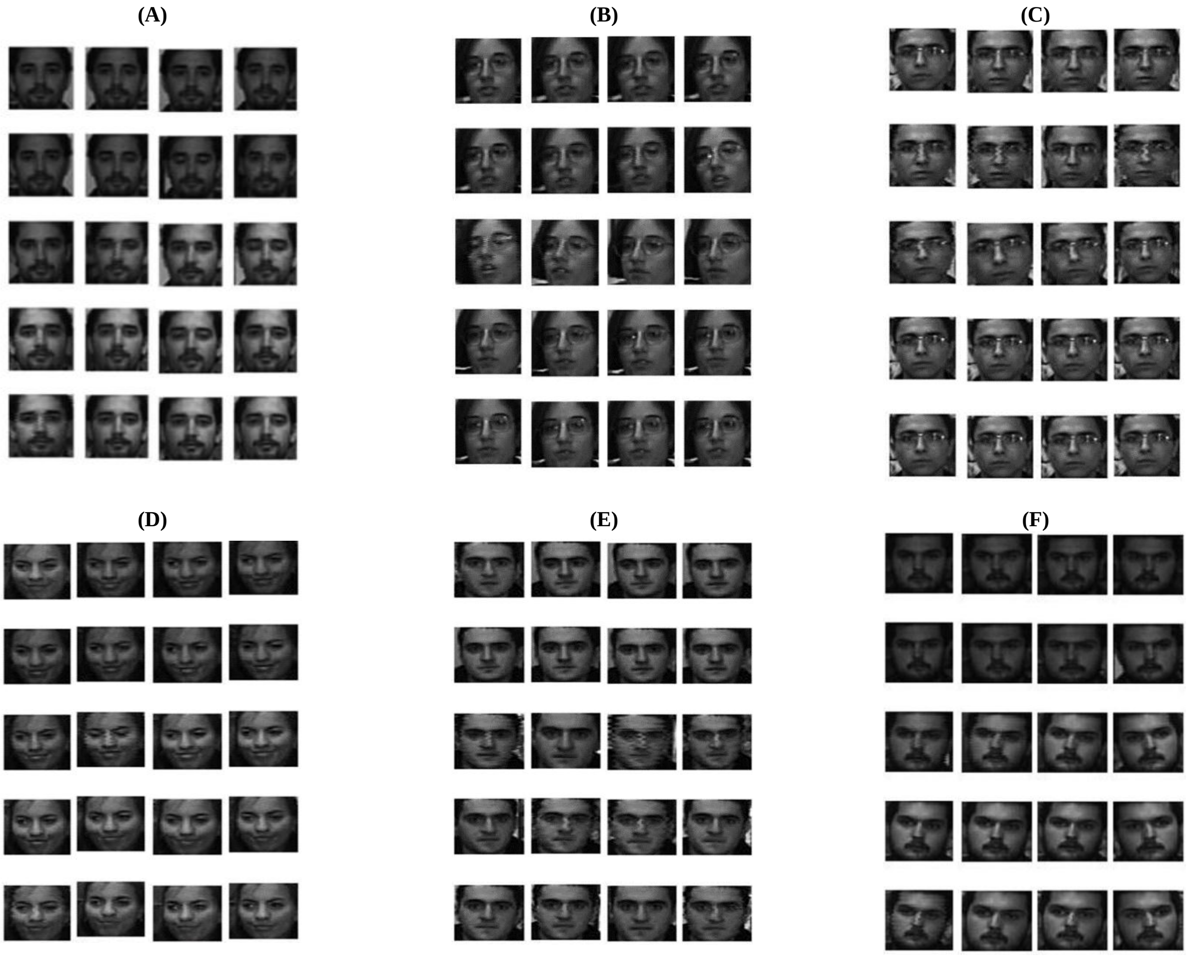


Fig. 8: Sample Facial Images from Database After Application of Viola–Jones Algorithm.

As an example the accuracy of 8 databases is shown in Table 2. under SVM where two functions: RBF Kernel and RBF Sigma functions are used. Here RBF Sigma function provides better result. Few numerical data of four systems are shown in Table 3. as a comparison, only five databases are shown here.

Table 2: Comparison of Accuracy

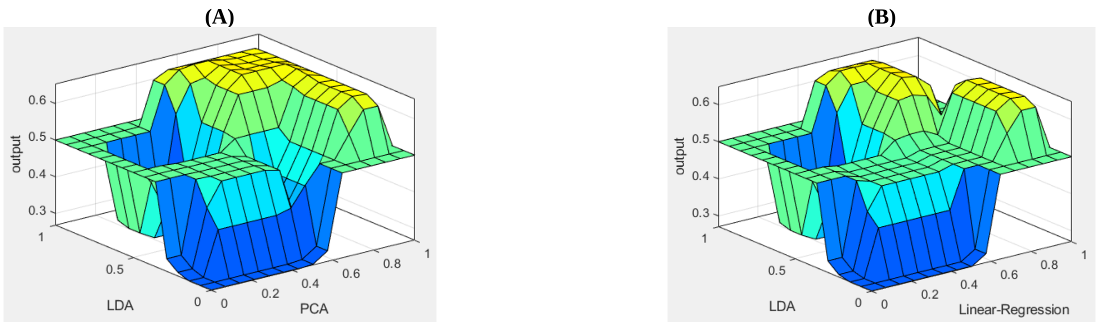
Sample Facial Database	RBF Kernel Function Accuracy	RBF Sigma Function Accuracy
1	0.742	0.772
2	0.903	0.922
3	0.884	0.884
4	0.732	0.732
5	0.842	0.881
6	0.802	0.831
7	0.798	0.803
8	0.823	0.825

Table 3: Numerical Data of Accuracy

Database	LDA	PCA	SVM	Linear Regression
1	0.782	0.867	0.742	0.684
2	0.867	0.776	0.903	0.785
3	0.834	0.812	0.884	0.792
4	0.716	0.692	0.732	0.742
5	0.822	0.917	0.842	0.784

Table 4: FUZZY Data of Accuracy

Database	LDA	PCA	SVM	Linear Regression
1	M	H	M	L
2	H	M	H	M
3	M	M	H	M
4	M	L	M	M
5	M	H	M	M



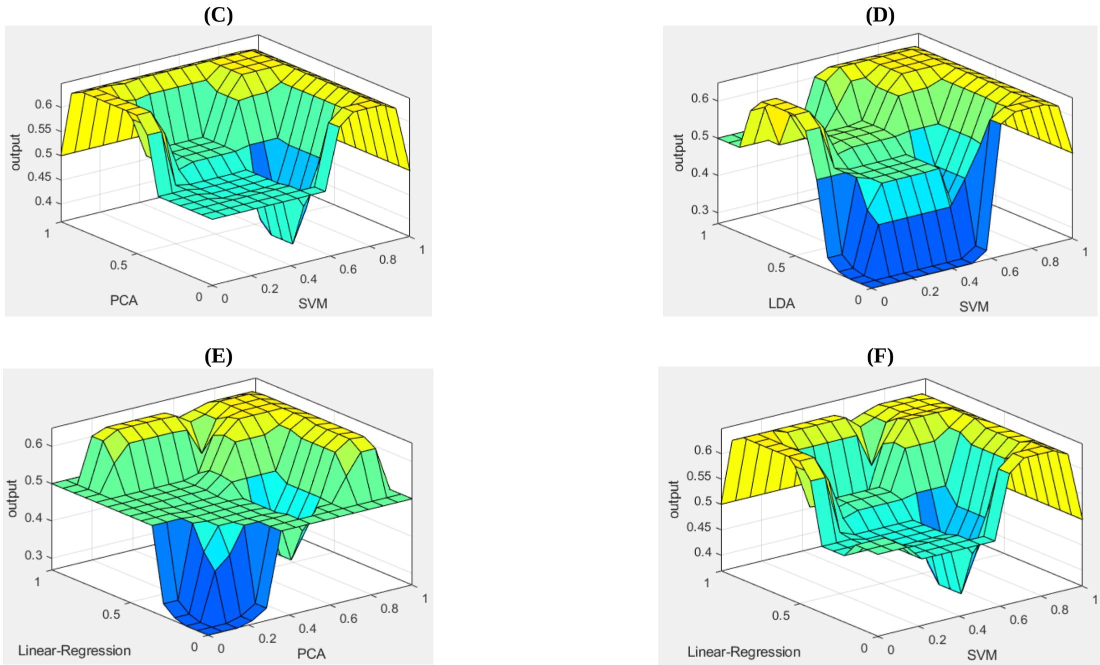


Fig. 9: Surface Plot of Different Methods.

The Fuzzy values of Table 3. are shown in Table 4. under the range of membership function of previous section. Applying Fuzzy rules of previous section, we get the surface plot of six combinations shown in FIGURE.9. After de-fuzzification using centroid method, we get the accuracy of 96.4% which is greater than the individual methods.

4. Conclusion

In this paper four frequently used algorithms of object detection are used then they are combined using Fuzzy rules which provide higher accuracy than individual way. Still we have the scope of inclusion of additional algorithms like: wavelet based feature detection, BNP (Binary Local Pattern), local gradient method etc. Even instead of fuzzy combining scheme, we can train a neural network (Deep Learning system or Convolutional network) using the feature vectors of different methods to acquire similarity or dissimilarity of human face.

References

[1] Shruti Y. Bhirud and V.V.Gohokar, 'Face Recognition Based on SVM and GABOR Filter,' International Journal of Current Engineering and Technology, vol.2, issue 4, pp.1517-1518, Nov 2015.

[2] YuktiBakhshi, Sukhvir Kaur, Prince Verma, 'A Study based on Various Face Recognition Algorithms,' International Journal of Computer Applications, vol. 129, no.13, pp.16-20, Nov 2015 https://doi.org/10.5120/ijca2015907066.

[3] Chuan-Wei Tsai, Keng-Mao Cheo,Wei-Shang Yang, Yi-ChingSu,Chu_Sing Yang and Ming-Chao Chiang, 'A Support Vector Machine Bases Dynamic Classifier for Face Recognition,' International Journal of Innovative Computing, Information and Control, vol. 7, no 6, pp.3437-3440,Jun 2011.

[4] S.Vijayarani and M.Vinupriya,'Facial Image Classification and Searching –A Survey,' International Journal of Information Technology, Modeling and Computing (IJITMC), vol.2, no.2, pp.145-147, May 2014. https://doi.org/10.5121/ijitmc.2014.2203.

[5] Navin Prakash, YashpalSingh, 'Support Vector Machines for Face Recognition,' International Research Journal of Engineering and Technology (IRJET), vol.2, issue 2, pp.19-23, Nov 2015.

[6] Ruchida S. Sonar,P.R. Deshmukh, 'Support Vector Machines for Human Face Detection: A Review,' International Journal on Recent and Innovation Trends in Computing and Communication,vol.2,issue 11,pp.16-18, Dec 2014.

[7] JuliansonBerueco, Kim Lopena, Arby Moay, Mehdi Salemiseresht, and ChuchiMontenegro, 'Age Estimation Using Support Vector Machine–Sequential Minimal Optimization,' Journal of Image and Graphics, vol.2, no.2, pp.3422-3425, Dec 2014. https://doi.org/10.12720/joig.2.2.145-150.

[8] Anup Majumder, Md. Mezbahul Islam, RahminaRubaiat and Md. Imdadul Islam, 'Human Face Detection Based on Combination of Logistic Regression, Distance of Facial Components and Principal Component Analysis,' International Journal of Computer Science and Information Security, vol. 16, no. 2, pp. 34-41, February 2018.

[9] Pingping Tao, XiaoliangFeng andChenglinWen, 'Image Recognition Based on Two-Dimensional Principal Component Analysis Combining with Wavelet Theory and Frame Theory,' Journal of Control Science and Engineering Volume 2018, pp.1-7, Article ID 9061796 https://doi.org/10.1155/2018/9061796.

[10] R. M. Amin, S. S. Khan and Md. Imdadul Islam, 'Human Face Detection Using Combination of LDA and DWT,' International Journal of Computer Science and Information Security, Vol. 15 No. 7, pp.87-94, JULY 2017.

[11] Ying Zhang ,1 Qingchun Deng,2 Wenbin Liang,3 and Xianchun Zou, 'An Efficient Feature Selection Strategy Based on Multiple Support Vector Machine Technology with Gene Expression Data,' BioMed Research International, Volume 2018, pp.1-11, Article ID 7538204 https://doi.org/10.1155/2018/7538204.

[12] Md Abul Kalam Azad, Sanjit Kumar Saha, Md. Imdadul Islam, Jugal Krishna Das, 'Detection of Primary User at Fusion Center of a CRN Using Fuzzy-Logic Rules,' International Journal of Computer Science and Information Security, vol. 16 no. 8 AUG 2018, pp. 84-92.