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Performance Analysis of Subspace Methods for Robust Recognition of Facial Expressions Using Holistic Features Extraction Approach

G.P.Hegde
Professor. Dept. of Information Science and Engg.
Shree Dharmasthala Manjunatheshwar Institute of Tech.
Ujire, Mangalore, Karnataka State, India
gphegde@sdmit.in

Ashwini B
Assist. Professor, Dept. Information Science and Engg.
Shree Dharmasthala Manjunatheshwar Institute of Tech.
Ujire, Mangalore, Karnataka State, India
ashwinib@sdmit.in

Abstract— **Improvement of facial expression recognition under various occlusions for different applications is a challenging task. This paper emphasizes on fusion of holistic color and texture features of face images and dimension of feature vectors are reduced by subspace methods like Principal Component Analysis (PCA), Singular Value Decomposition (SVD), Independent Component Analysis (ICA) and Fisher Face Analysis (FFA) to improve the classification accuracy and overall facial expression recognition rate. Feature level fusion is also carried out by combining dimensionality reduced features of PCA and FFA subspace methods to improve the recognition rate compare to earlier work. Basic prototypic expressions are classified using Support Vector Machine (SVM) classifier and recognition of specific expression is carried out using distance matching score level algorithm and it is found in terms of time and space complexity measure. Subspace method is tested with Asian color database with 600 images of six different expressions classes of ten persons with different occlusions like wearing glasses, different hair styles, tints on face and poses variations. It is found that classification accuracy is increased in feature level fusion subspace model.**

Keywords-facial expressions;feature fusion; feature extraction; classifier;subspace;

I. Introduction

Facial expression variations are due to change in the movements of the muscles of certain areas of a face. These movements can express the internal emotional state of an individual to observers. These situations are primary means of conveying social information between persons [1-3]. Facial expression is a cognitive activity and behavioral exhibition of human face attributes as an immediate means of nonverbal communication media or path and social interaction. Study of automatic facial expression classification and recognition assessment under various critical conditions like illumination variations, partial occlusions, different poses, age variations, hazing effects, various noises, blurring effects and other atmospheric interferences is a demanding task and more interesting [4-8]. Facial expression recognition finds important applications in many areas such as psychological studies with human-computer interaction, mind tempering and data-driven animations, Due to its wide range of applications, automatic facial expression recognition is an effective communication channel has attracted much attention in recent years and intuitive facial expression recognition constitutes the main theoretical contribution to the video processing applications. Expression is impacted by certain attributes of each individual person Expression is impacted by certain attributes of each individual person during their exhibition of emotions [4-15]. These attributes varies from person to person and can produce different actions or behavior from each person. Research in psychology expresses by Ekman and Friesen (1978) has indicated that at least six emotions or expressions (anger, depressed, fear, happiness, sadness and surprise) are universally associated with distinct facial expressions (Lyons et al, 1999; Cohen et al, 2003; Tian, 2004; Bartlett et al, 2005). Neutral expression is considered as normal expression [16].

Features obtained from facial movements, which includes feature location and shape variations, are generally caused by the movements of facial traits, especially key elements, will frequently modify their positions when subjects are expressing emotions. As a moment, the similar feature in different images usually has different positions, in some cases; the shape of the feature may also be distorted due to the subtle facial muscle movements [19-25]. Hence, for any feature demonstrating a certain emotion, the geometric-based position and appearance-based shape normally alters from one image to another image in image databases. This kind of movement features represents a rich pool of both static and dynamic characteristics of expressions, which play a critical role for facial expression recognition. By contrast, real time recognition of facial expression systems using linear and non linear subspace methods [41][42] is often event driven with minimal feature extraction data processing. Higher dimension image have thousands of pixels it would be difficult to extract the important general features from it by decomposing high dimensional image into one dimensional vector during matching of training and testing images. Among various methods proposed to carry out this task, subspace methods are considered to be the most popular and powerful approaches, which perform poorly, even under moderate variations such as illumination. Classification of expression categories and accuracy evaluation is a learning technique which adapts the membership functions with the feature vectors as inputs to achieve the best classification. The earlier subspace methods has certain limitations like poor rate of recognition, less classification accuracy, This test condition plays a vital role in identifying an algorithm as truly robust. This in turn helps the algorithm to be adopted for many real time applications.

The rest of the paper is organized as follows: Section II focuses on brief illustration about principles of feature extraction by HSV technique and Gabor wavelets. Section III illustrates implementation of dimensionality reduction by subspace methods and Support Vector Machine classifier. In Section IV results and discussions are made. Finally conclusions are drawn in Section V.

II. Principles of Feature Extraction

Recognition rate of facial expression depends on accuracy of feature extraction and type of features extracted. In this work mainly color features and image texture features are extracted and combined both the features for robust expression recognition is illustrated below.

A. *Color Feature Extraction*

Color features are extracted initially by applying RGB to HSV conversion. The HSV values of a pixel can be transformed from its RGB components according to the following formulae

$$H=cos^{-1}\frac{\frac{1}{2}[(R-G)+(R-B)]}{\sqrt{(R-G)^2+(R-B)(G-B)}} \quad (1)$$

$$S=1-\frac{3[\min(R,G,B)]}{R+G+B} \quad (2)$$

$$V=\left(\frac{R+G+B}{3}\right) \quad (3)$$

B. *Texture Feature Extraction By Gabor Wavelets*

Holistic texture features of a face image can be extracted using Gabor wavelets. Basically group of wavelets creates a Gabor filter and each wavelet captures energy at a specific frequency and specific orientation. These properties of Gabor filter are useful for texture analysis. Design of Gabor filters is followed in [64-66]. Consider a face image $f(x,y)$ of size PxQ its discrete Gabor Wavelet transform is given by a convolution.

$$G_{mn}(x,y)=\sum_s\sum_t f(x-s,y-t)\Psi_{mn}(s,t) \quad (4)$$

In above equation s and t are the filter mask size variables, and Ψ_{mn} which is a class of self similar functions generated from dilation and rotation of the following mother wavelet.

$$\Psi_{mn}(x,y)=\frac{1}{2\pi\sigma_x\sigma_y}expp\left[-\frac{1}{2}\left(\frac{x^2}{\sigma_x^2}+\frac{y^2}{\sigma_y^2}\right)\right]exp(j2\pi Wx) \quad (5)$$

Here W is called as the modulation frequency. The self similar Gabor wavelets are obtained through the generating function,

$$\Psi_{mn}(x,y)=a^{-m}\Psi(x,y) \quad (6)$$

Where, m and n specify the scale and orientation of the wavelet respectively, with $m=0,1 \ldots\ldots\ldots M-1$, $n=0,1\ldots\ldots\ldots N-1$, and

$$\bar{x}=a^{-m}(xcos\theta+ysin\theta) \quad (7)$$

$$\bar{y}=a^{-m}(-xsin\theta+ycos\theta) \quad (8)$$

where a>1 and $\theta={}^{n\pi}/_{N}$

The variables in the above equation are defined as follows

$$a=(U_h/U_l)^{\frac{1}{M-1}} \quad W_{m,n}=a^mU_l \quad (9)$$

$$\sigma_{x,m,n}=\frac{(a=1)\sqrt{2ln2}}{2\pi a^m(a-1)U_l} \quad (10)$$

$$\sigma_{y,m,n}=\frac{1}{2\pi tan\left(\frac{\pi}{2N}\right)\sqrt{\frac{U_h^2}{2ln2}-\left(\frac{1}{2\pi\sigma_{x,m,n}}\right)^2}} \quad (11)$$

After applying Gabor filters on the image with different orientations at different scale, an array of magnitudes are obtained.

$$E(m,n)=\sum_x\sum_y|G_{mn}(x.y)|, \quad (12)$$

where, $m=0,1\ldots, M-1; n=0,1\ldots\ldots N-1$

These magnitudes represent the energy content at different scale and orientation of the image. The main purpose of texture based extraction is to search specific expression image with similar texture feature. In this work homogeneous texture feature vectors are considered. So that following mean μ_{mn} and standard deviation σ_{mn} of the magnitude of the transformed coefficients are used to represents the homogeneous texture features of the region.

$$\mu_{mn}=\frac{E(m,n)}{PXQ} \quad (13)$$

$$\sigma_{mn}=\frac{\sqrt{\sum_x\sum_y(|G_{mn}(x,y)|-\mu_{mn})^2}}{PXQ} \quad (14)$$

A feature vector f_g (texture representation) is created using μ_{mn} and σ_{mn} as the feature components. Four scales and six orientations are used in common implementation and the feature vector of length 48 is given by

$$f_g=(\mu_{00},\sigma_{00},\mu_{01},\ldots\ldots\ldots,\mu_{35},\sigma_{35}) \quad (15)$$

Texture similarity measure of test image Q and a trained image T in the database is defined by,

$$d(Q,T)=\sum_m\sum_n d_{mn}(Q,T)\text{ ,where} \quad (16)$$

$$d_{mn}=\sqrt{\left(\mu_{mn}^Q-\mu_{mn}^T\right)^2+\left(\sigma_{mn}^Q-\sigma_{mn}^T\right)^2} \quad (17)$$

$f_g^T=(\mu_{00},\sigma_{00},\mu_{01},\ldots\ldots\ldots,\mu_{35},\sigma_{35})$ denote texture feature vector of trained database image . In next section subspace coefficients are calculated using Gabor feature vectors as input by combining with HSV features of color images of both training database and testing image.

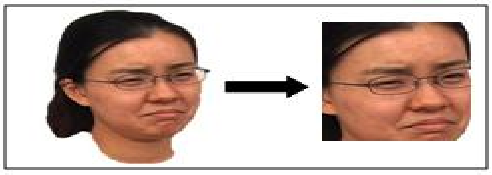


Fig 1. Actaul image from Asian datbase and cropped image

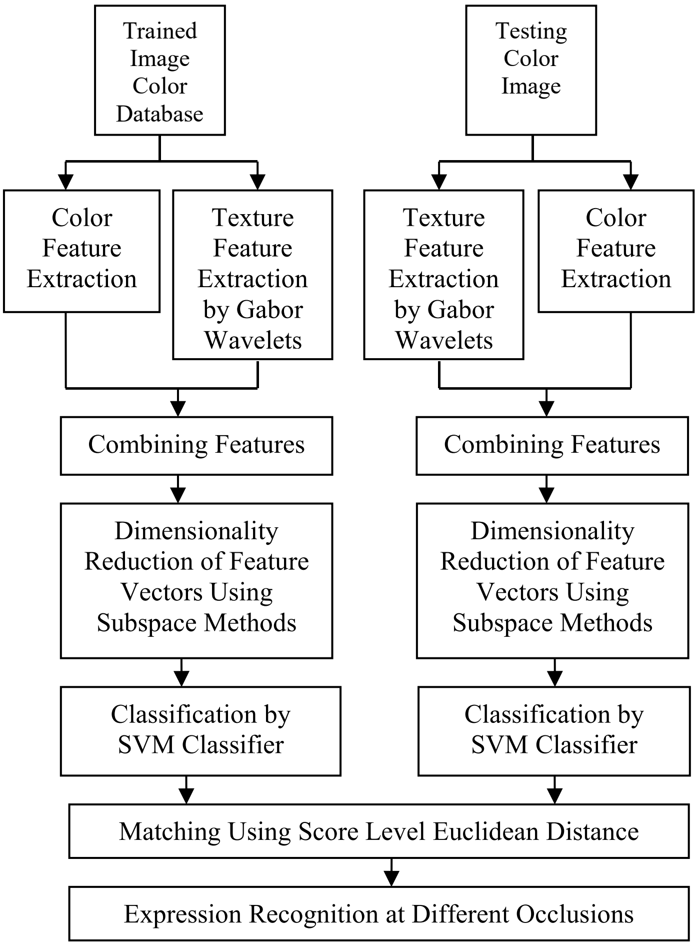


Fig 2 . Actaul image from Asian datbase and cropped image

III. Implementation of Subspace Methods And Classification Of Expressions

A. Subspace Method

In holistic features extraction approach face is recognized as a whole without using only certain fiducially points obtained from different regions of the face. Appearance based methods are holistic in nature and more sensitive to image normalization errors. Feature extraction for face representation and recognition is a core issue in face recognition [1][8][10]. Feature extraction algorithms aim at finding features from the scenes that distinguish one face from another. Human face patterns can have significantly variable image appearances and emotions. Therefore it is essential to find facial expression recognition using subspace methods that introduce low-dimensional feature representation of face objects with enhanced discriminatory power. Data reduction, redundant content removing and extraction of features are used to solve the problem of facial expression recognition at certain extent by improving the accuracy of face recognition. This paper briefly illustrates an overview of dimensionality reduction technique related to appearance based approach. It has further two sub approaches such as data driven approach and domain knowledge approach. In Data driven approach features are extracted directly from training data as holistic features, by implementing machine learning subspace methods. In case of domain knowledge approach dimensional reduction is based on knowledge of the specific pattern of recognition. Subspace methods are more efficient for both dimension reduction and projection of face images. In facial expression recognition subspace analysis makes major role for finding various features. Process of reducing the number of variables under observation is one of the properties of subspace analysis [39]-[50]. In the context of face recognition images of faces, represented as high-dimensional pixel arrays, Time and space complexity are two main problems for certain task in image. Literature survey is carried out on various linear and nonlinear subspace methods. Principal Component Analysis (PCA)[39-45][48][56], Independent Component Analysis (ICA)[53][67], Singular Value Decomposition (SVD)[54][55], Fisher Face Analysis (FFA) [61][62][63].

- After extracting the Gabor feature vectors of trained image consider the mean vector of each trained image and subtract the mean image from training images a, b, c and so on.

$$\overrightarrow{a_m} = \begin{bmatrix} a_1 - m_1 \\ a_2 - m_2 \\ . \\ . \\ . \\ a_{N^2} - m_{N^2} \end{bmatrix} \quad - - - - \quad \overrightarrow{h_m} = \begin{bmatrix} h_1 - m_1 \\ h_2 - m_2 \\ . \\ . \\ . \\ h_{N^2} - m_{N^2} \end{bmatrix}$$

- Build a matrix A which is N^2 by M dimension

$$A = [\overrightarrow{a_m} \ \overrightarrow{b_m} \ \overrightarrow{c_m} \ \overrightarrow{d_m} \ \overrightarrow{e_m} \ \overrightarrow{f_m} \ \overrightarrow{g_m} \ \overrightarrow{h_m}] \qquad (18)$$

- Compute the covariance matrix $C = AA^T$, it is a large matrix hence its computation is very high it is a N^2 *by* N^2 matrix.
- Computing the eigenvalues and eigenvectors Find eigenvalues of the covariance matrix by reducing the dimensionality of covariance matrix. Compute another matrix which is M by M.

$$L = A^T A \qquad (19)$$

- Find M eigenvalues and eigenvectors of covariance matrix L, Build a matrix V from eigenvectors of L, where eigenvectors of L are linear combination of image space with the eigenvectors of L

$$U = AV \quad (20)$$

Where V is eigenvector of L represents the variations in the faces.

- Compute the PCA coefficients A facial image can be projected in to face to 1D subspace (calculating weights only with larger eigenvalues)

$$\Omega_1 = U^T\overrightarrow{a_m}, \Omega_2 = U^T\overrightarrow{b_m} --- \Omega_M = U^T\overrightarrow{M_m} \quad (21)$$

$$W_i = [\Omega_1\,\Omega_2 ------ \Omega_M]^T \quad (22)$$

Where W_i is the projection coefficients of PCA method.

- Compute the threshold value

$$\theta = \frac{1}{2}max\{\|\Omega_i - \Omega_j\|\} \text{ for } i, j = 1---- M \quad (23)$$

By considering the testing image Gabor vector features $f_g^Q = (\mu_{00}, \sigma_{00}, \mu_{01}, \ldots\ldots\ldots, \mu_{35}, \sigma_{35})$, by referring above points

$$W_r = U^T\,(\overrightarrow{Q_m}) \quad (24)$$

Where $\overrightarrow{Q_m}$ is a average subspace image of testing image and W_i is the projection coefficients of testing image. Similarly SVD, ICA, FFA coefficients were found for both test and trained images. Gabor features vectors dimension is reduced by these methods by calculating appropriate coefficients.

B. Proposed Subspce Method

In this work extracted features are dimensionally reduced by PCA and FFA methods. Recognition rate is increased by fusing the features of PCA and FFA features coefficients are proposed. This feature level fusion subspace method classifies the expressions uniformly compared to above subspace methods.

C. SVM Classifier and Score Level Distance Matching

Based on subspace projection coefficients of Gabor feature vectors, all six expression classes are classified using SVM classifier and recognition of images is achieved using Euclidean distance matching score values. We perform the facial expression recognition by using a support vector machine (SVM) [69] to evaluate the performance of the proposed method. SVM is a supervised machine learning technique that implicitly maps the data into a higher dimensional feature space. Consequently, it finds a linear hyper plane, with a maximal margin, to separate the data in different classes in this higher dimensional space. Given training set of M labeled examples $T=\{(x_i y_i)|i=1, . . . M\}$, where $x_i \in R^n$ and $y_i \in \{-1,1\}$, the test is classified by

$$f(x) = sign\left(\sum_{i=1}^{M} a_i\,y_i K(x_i\,x) + b\right) \quad (25)$$

Where a_i ($i=1.....M$) is Lagrange multipliers of dual optimization problem b is a bias and K is a kernel function. Note that SVM allows domain specific selection of the kernel function. Although many kernels have been proposed, the most frequently used kernel function is the linear, polynomial, and Radial Basis Function (RBF) kernels. Given that SVM makes binary decisions, multi-class classification can be achieved by adopting the one-against-one or one against-all techniques. In this work, one-against-one strategy is considered, because, "one-against-one" approach is more effective than the "one-against-all" approach due to its computation simplicity and comparable performance. One against one approach constructs k(k-1)/2 classifiers, a grid-search on the hyper parameters in a 10-fold cross-validation schemes for parameters selections[69], The parameters setting producing the best cross-validation accuracy was picked. The Euclidean distance between training and test image feature vectors is given by,

Subspace Methods	FERR	Elapsed classification time in sec(SVM)
PCA	94.00%	2.604788
ICA	88.00%	8.240255
SVD	84.00%	3.151923
FFA	96.00%	7.533773
PCA+FFA	98.00%	8.234140

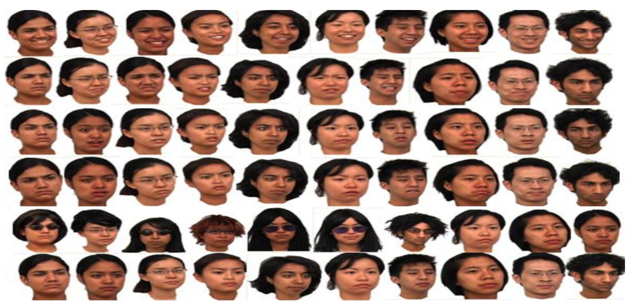
$$d = \sqrt{\|W_r - W_i\|^2} \quad (26)$$

for all $i=1$ - - - - - - - M images.

Where W_i is a vector describing the i^{th} face class of training images. If d is less than some predefined threshold value θi then images are classified in to respective classes of expressions.

IV. Results And Discussions

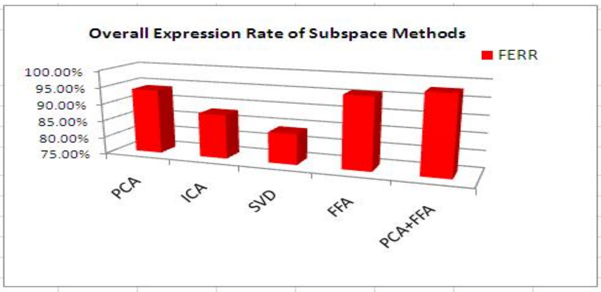
In this work Asian color database is considered for experimental testing [Michael J. Taarr face place face database



2008]. It consists of different facial expressions with face occluded by hairs, tints, glasses, goggles with different poses like 35° left, 35° right, from this database we have considered six major expressions like confusion (CO), disgust (DI), happy, sad, surprise and neutral with few occlusions. This database has 1361 face images of 250x250 resolutions. From this database we have extracted 600 images of 10 persons with 6 classes of expressions. All the images are cropped and normalized to standard size are shown in Figure. 3. In this work 10 images of each person is considered.

Fig 3. Different facial expression of Asian database

	Confusion	DI	Happy	Sad	Surprise	Neutral
Confusion	48	0	0	1	0	1
DI	2	48	0	0	0	0
Happy	0	1	49	0	0	0
Sad	0	0	0	50	0	0
Surprise	2	0	0	1	47	0
Neutral	1	2	5	2	0	40
Over all accuracy rate of PCA subspace method						94%



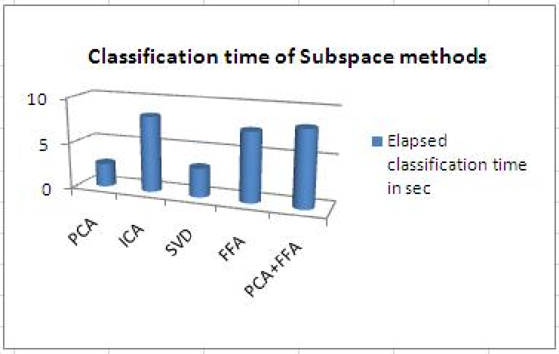


Fig 4. Cropped images of six expressions samples

TABLE I. PERFORMANCE ANALYSIS OF FERR VALUES OF SUBSPACE METHODS FOR ASIAN DATASET

Fig 4. Facial expression recognition rate of subspce methods

Fig 5. Facial expression recognition rate of subspce methods

Subspace methods like PCA and FFA yields more accurate recognition results because database images were taken at constant illumination with varying poses and expressions. FFA is more sensitive to change in poses and expressions. Hence its facial expression recognition rate (FERR) is more. ICA is more sensitive for change in illumination, but due to constant illumination its FERR value is less compare to PCA and FFA. Images in data base are varying with different poses hence SVD method gives tolerable accuracy rate. Elapsed time of ICA and FFA method is slightly high compare to other two methods because it separates the feature coefficients in to two class classification and variances. Results obtained from feature level fusion of PCA and FFA proves that facial expression rate is improved to certain extent compare to earlier work [56][60] as shown in table 6. MATLAB R2013a is used for coding the algorithms and testing the database.

TABLE II. COMPARISON OF CLASSWISE FERR VALUES USING PCA SUBSPACE METHOD

TABLE III. COMPARISON OF CLASSWISE FERR VALUES USING ICA SUBSPACE METHOD

	Confusion	DI	Happy	Sad	Surprise	Neutral
Confusion	50	0	0	0	0	0
DI	0	49	0	0	1	0
Happy	0	1	49	0	0	0
Sad	21	0	0	29	0	0
Surprise	2	0	0	0	48	0
Neutral	3	6	2	0	0	39
Over all accuracy rate of ICA subspace method						88%

TABLE IV. COMPARISON OF CLASSWISE FERR VALUES USING SVD SUBSPACE METHOD

	Confusion	DI	Happy	Sad	Surprise	Neutral
Confusion	48	0	0	1	1	0
DI	2	48	0	0	1	0
Happy	0	1	49	0	0	0
Sad	0	0	0	50	0	0
Surprise	2	0	0	1	47	0
Neutral	15	12	5	2	6	10
Over all accuracy rate of SVD subspace method						84%

TABLE V. COMPARISON OF CLASSWISE FERR VALUES USING FFA SUBSPACE METHOD

	Confusion	DI	Happy	Sad	Surprise	Neutral
Confusion	48	0	0	1	0	1
DI	2	48	0	0	0	0
Happy	0	1	49	0	0	0
Sad	0	0	0	50	0	0
Surprise	2	0	0	0	47	1
Neutral	1	1	2	0	0	46
Over all accuracy rate of FFA subspace method						96%

TABLE VI. COMPARISON OF CLASSWISE FERR VALUES USING FEATURE LEVEL FUSION PCA+ FFA SUBSPACE METHOD

	Confusion	DI	Happy	Sad	Surprise	Neutral
Confusion	49	0	0	1	0	0
DI	0	50	0	0	0	0
Happy	0	0	50	0	0	0
Sad	0	0	0	50	0	0
Surprise	1	0	0	0	48	1
Neutral	0	1	0	0	2	47
Over all accuracy rate of feature fusion of PCA+FFA subspace method						98%

V. CONCLUSION

Facial expression recognition at different critical conditions is one of the most challenging problems in the fields of image processing, biometric identification, movement tracking, computer vision, pattern recognition, physiology, psychology and so on, and it has become a hot research topic in the field of pattern recognition and artificial intelligence recently. This work mainly emphasizes on expression recognition and classification of different expressions by extracting the color and texture features of both trained dataset and testing data of Asian database. Extracted texture features are subjected to dimensionality reduction using several subspace methods. Proposed feature level fusion of PCA and FFA vector coefficients are fused together in order to increase the rate of facial expression recognition accuracy is a proposed holistic feature subspace model. Experimental results show that actual PCA methods gives higher accuracy compare to ICA and SVD methods because due to constant illumination of data in the database. Discrimination power of image classification is highly achieved in fisher face analysis method hence classification accuracy is improved by implementing this method compare to PCA method. From the results it is concluded that feature level fusion of both PCA and FFA increases the classification accuracy. In this work SVM classifier is used as a one to one classifier, it classifies the projection coefficients of subspace methods and finally expression matching is carried out using Euclidean distance measure. Classification time is very less in PCA and SVD due its unsupervised properties.

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