Efficient Facial Expression Recognition System for Tilted Face Images

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Abstract

Automatic facial expression recognition is still a hard research area with several challenges to meet. Efficient facial expression recognition system is developed to recognize the facial expressions even when the face is slightly tilted. Applications of facial expression recognition system include border security systems, forensics, virtual reality, computer games, robotics, machine vision, video conferencing, user profiling for customer satisfaction, broadcasting and web services. Initially the face localization is done using the viola jones face detector. The facial components are extracted if the facial components are properly detected and the features are extracted from the whole face if the facial components are not detected. The extracted facial features are represented by three features vectors: the Zernike moments, LBP features and DCT transform components. In order to reduce the dimensionality, a subset feature selection algorithm is used prior to training process. The paper presents a comparison between the PCA based method and Normalized mutual information selection method for reducing the dimensionality. The feature vectors are combined and reduced and then applied to SVM classifier for training process. Experiment results shows that the proposed methodology affirms a good performance in facial expression recognition.
Keywords: Facial Expression Recognition, Zernike Moments, LBP, Discrete Cosine Transform, Principal Component Analysis, Normalized Mutual Information Selection, SVM Classifier

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I. Introduction

A facial expression is a simple physiological activity of one or more parts of the face (eyes, nose, mouth, eyebrows,). Facial expression is one of the most powerful, natural and immediate means for human beings to communicate their emotions and intentions. Although much work has been done with automatic facial expression recognition task, recognizing with high accuracy remains difficult due to the complexity and variety of facial expressions. Illumination variation, rotation and facial expression are the basic existing challenges in this area.

The facial expression recognition approaches have generally attempted to recognize expression of six basic emotions named as happiness, surprise, sadness, disgust, fear and anger or to recognize Action Units (AUs) of the Facial Action Coding System (FACS). FACS defines AUs, which are a contraction or relaxation of one or more muscles.

Fig. 1: Facial Expression

Facial expression recognition system is widely used in different areas. Applications of facial expression recognition system include border security systems, forensics, virtual reality, computer games, robotics, machine vision, video conferencing, user profiling for customer satisfaction, broadcasting and web services. Facial Expression recognition is one of the topics from the field of Affective Computing. To enable a computer system to have human-like capabilities of observation, interpretation and generation of affect features the topic affective computing plays a great role. Facial expression, body movements, various gestures, voice behavior, and other physiological signals, such as heart rate and sweat etc. are some of the actions which make people express their emotions.

A variety of systems have been developed to perform facial expression recognition and each system consists of three stages: first, face acquisition; second, facial feature extraction then facial expression classification.

Face acquisition is a preprocessing stage to detect face regions in the input images or sequences. One of the most widely used face detector is the real-time face detection algorithm developed by Viola and Jones .Once a face is detected in the images, the corresponding face regions are usually normalized.

Facial feature extraction is a type of visual learning process. Existing facial expression recognition algorithms can be classified into two groups, i.e., geometric feature based and appearance based.

In the geometric features-based systems, the shape and locations of major facial components such as mouth, nose, eyes, and brows, are detected in the images. Feature-based methods find features (e.g., feature points and the motion of feature points) and track them along the images, and then, classification is carried out based on these extracted features. The approaches used in such system are

Active Appearance Model (AAM), Piecewise Bezier Volume Deformation tracker (PBVD). Feature-based methods provide good intuitive explanations for recognition, i.e., the dominant features for recognition have good physical meanings. However the geometry based methods require accurate and reliable facial feature detection, which is difficult to achieve in real time applications.

In the appearance features-based systems, the appearance changes with changes in facial expressions including skin texture changes, wrinkles, bulges, and furrows, are presented. Appearance-based methods usually use part of or the whole image as a high-dimensional vector or high-order tensor data. Then, some subspace learning methods, e.g., principle component analysis, linear discriminant analysis, locality preserving projection , and graph embedding , are carried out to obtain the subspace representation of the original input. Finally, matching is performed in the learned subspace. The existing algorithms are Principal Component Analysis (PCA), Independent Component Analysis (ICA) , Linear Discriminant Analysis (LDA) , Gabor wavelet analysis, Local Binary Patterns (LBP) , Local Phase Quantization (LPQ) , The Local Directional Pattern (LDP) ,Fisher Discriminant Analysis (FDA), Local Feature Analysis (LFA), Circular Local Binary Pattern (CLBP), Speeded Up Robust Features (SURF). Appearance-based methods are powerful in discovering both the discriminative information and the manifold structure using a subspace learning method, but their time and space costs are huge. Moreover, all the face images have to carefully be aligned and cropped. In appearance-based approaches, local texture information is important for capturing transient facial expressions.

The last step of an automatic facial expression recognition system is facial expression classification. A classifier is employed to identify different expressions based on the extracted facial features, such as Nearest Neighbor (NN), K-Nearest Neighbor (KNN), Support Vector Machine (SVM) and Hidden Markov Model (HMM).

In this paper, an enhanced facial expression recognition system is presented. Face detection is done using the well-known and efficient Viola and Jones method. Then the facial features like eyes, nose and mouth are extracted. If the face is tilted slightly, the features won't be detected. In such cases, extract the features from the whole face. Once the features are extracted, represent it using a representative vector. Three different types of information is used to enrich the representative feature vector: Zernike moments, to compact images geometric characteristics; LBP method which is considered as the most significant way to characterize texture information of the image and DCT transform to obtain its spectral components distribution. Now in order to reduce the dimensionality of the combined feature vectors, two different methods can be used. PCA based method and Normalized Mutual Information Selection tool is also being used. The paper presents a comparison between the PCA and NMIFS method. Once the reduced feature set is obtained, classification is done using the SVM classifier.

The rest of this paper is organized as follows. In section II, literature survey is briefly described. Section III describes the methodology. In section VI presents the experimental results and analysis and finally section V summarizes the system.

II. RELATED WORKS

In the literature, many Facial expression Recognition algorithms (e.g. [1]-[11]) have been proposed. . Applications of facial expression recognition system include border security systems, forensics, virtual reality, computer games, robotics, machine vision, video conferencing, user profiling for customer satisfaction, broadcasting and web services. Because of this importance in lots of areas, there are several methods have already developed in this area. Each of the methods are having its own advantages in different areas.

In [1] Ahmad Poursaberi, Hossein Ahmadi Noubari, Marina Gavrilova1 and Svetlana N Yanushkevich introduces Gauss Laguerre wavelet textural feature fusion with geometrical information for facial expression identification. In this method, both the combined texture and the geometric information of face fiducial points are used to code different expressions. For each input image, the face area is localized first. Then, the features are extracted based on GL filters. GaussLaguerre (GL) wavelets are used for texture analysis and the positions of 18 fiducial points represent the deformation of the eyes, eyebrows, and mouth. The advantage of GL filter is its rich frequency extraction capability for texture analysis, as well as being a rotation-invariant and a multiscale approach.

In [2] Mingli Song, Dacheng Tao, Zicheng Liu, Xuelong Li and Mengchu Zhou used Image Ratio Features for Facial Expression Recognition Application. Image ratio features combines both the local texture information and the geometric information to recognize facial expressions. The expression ratio at a point p is defined as the ratio of the intensity of image coordinates of p on the expression face to that of the intensity on the neutral face. It was demonstrated that image ratio features significantly improve facial expression recognition performance when there are large lighting and albedo variations.

In [3] S L Happy; Aurobinda Routray Routray, proposed a novel framework for expression recognition by using appearance features of selected facial patches. A few prominent facial patches, depending on the position of facial landmarks, was extracted which are active during the emotion elicitation. These patches are then processed to obtain the salient patches which contain discriminative features for classification of each pair of expressions. Using the appearance features from the salient patches, the system performs the one-against-one classification task and determines the expression based on majority vote.

In [4]Hong-Bo Deng, Lian-Wen Jin, Li-Xin Zhen, Jian-Cheng Huang uses a New Facial Expression Recognition Method Based on Local Gabor Filter Bank and PCA plus LDA. A Gabor filter bank with m frequencies and n orientations is used to extract the Gabor feature for face representation instead of using the entire global filter bank. For dimensionality reduction, PCA, an unsupervised learning technique and LDA, a supervised learning method was used. Local Gabor filter bank outperforms global Gabor filter bank in the aspects of shortening the time for feature extraction, reducing the high dimensional feature, decreasing the required computation and storage. However complete elimination of the sensitivity of illumination is a challenge.

In [5] Md. Hasanul Kabir, Taskeed Jabid, Oksam Chae introduces A Local Directional Pattern Variance (ldpv) based Face Descriptor for Human Facial Expression Recognition Here a descriptor named the LDP variance (ldpv), which characterizes both the spatial Structure (LDP) and contrast (variance of local texture) information is introduced. Each LDP code is computed from the relative edge response values in all eight directions, and then, the ldpv descriptor of a facial image is generated from the integral projection of each LDP code weighted by its corresponding variance. Ldpv performs stably and robustly over a useful range of low-resolution face images.

In [6] Caifeng Shan, Shaogang Gong, Peter W. Mcowan defines Facial expression recognition based on Local Binary Patterns. The operator labels the pixels of an image by thresholding a 3*3 neighborhood of each pixel with the center value and considering the results as a binary number and the 256-bin histogram of the LBP labels computed over a region is used as a texture descriptor. A limitation of this work is that the recognition is performed by using static images without exploiting temporal behaviors of facial expressions.

In [7] Rania Salah El-Sayed, Prof.Dr. Ahmed El Kholy and Prof.Dr. Mohamed Youssri El-Nahas devised Robust Facial Expression Recognition via Sparse Representation and Multiple Gabor filters. With sparse representation, each expression can be represented by a set of features, which sufficiently characterize each individual expression. Using multiple Gabor filters rendered the method robust to facial expression variations because each filter has specific property to extract.

In [8] Tran Binh Long, Le Hoang Thai, and Tran Hanh, proposed a three stage facial expression recognition system. In the first stage, the location of face in arbitrary images was detected.. ZM-ANN technique is used for face localization and for creating a sub-image which contains information necessary for classification algorithm. In the second stage, the pertinent features from the localized image obtained in the first stage were extracted. These features are obtained from the pseudo Zernike moment invariant. Finally, facial images based on the derived feature vector obtained in the second stage were classified by RBF network. The method possess orthogonality and geometrical invariance.

In [9] Irene Kotsia and Ioannis Pitas proposes a semi-automatic facial expression recognition system, in the sense that the user has to manually place some of the Candide grid nodes on face landmarks depicted at the first frame of the image sequence under examination. The tracking system allows the grid to follow the evolution of the facial expression over time till it reaches its highest intensity, producing at the same time the deformed Candide grid at each video frame. However it requires human interaction.

In [10] Ligang Zhang and Dian Tjondronegoro et.al proposes a method which increases the performance of Facial Expression Recognition system by automatically capturing facial movement features in static images based on distance features. The distances are obtained by extracting salient patch-based Gabor features and then performing patch matching operations. Patch based Gabor features have shown excellent performance in overcoming position, scale, and orientation changes, as well as extracting spatial, frequency, and orientation information.

In [11] Mohammed Saaidia, Narima Zermi, and Messaoud Ramdani introduced a Multiple Image Characterization Techniques for Enhanced Facial Expression Recognition. Three different types of information is used to enrich the feature vector: Zernike moments, LBP and DCT transform to obtain its spectral components distribution. The different feature vectors are used separately then combined to train back-propagation neural networks which are used in the facial expression recognition step.

III. PROPOSED WORK

The steps involved in the proposed algorithm are shown in Fig. 2. The proposed Facial expression recognition algorithm mainly consists of the following processes:

- Preprocessing
- Face Detection
- Facial component extraction
- Face feature's characterization
- Subset feature selection
- Classification

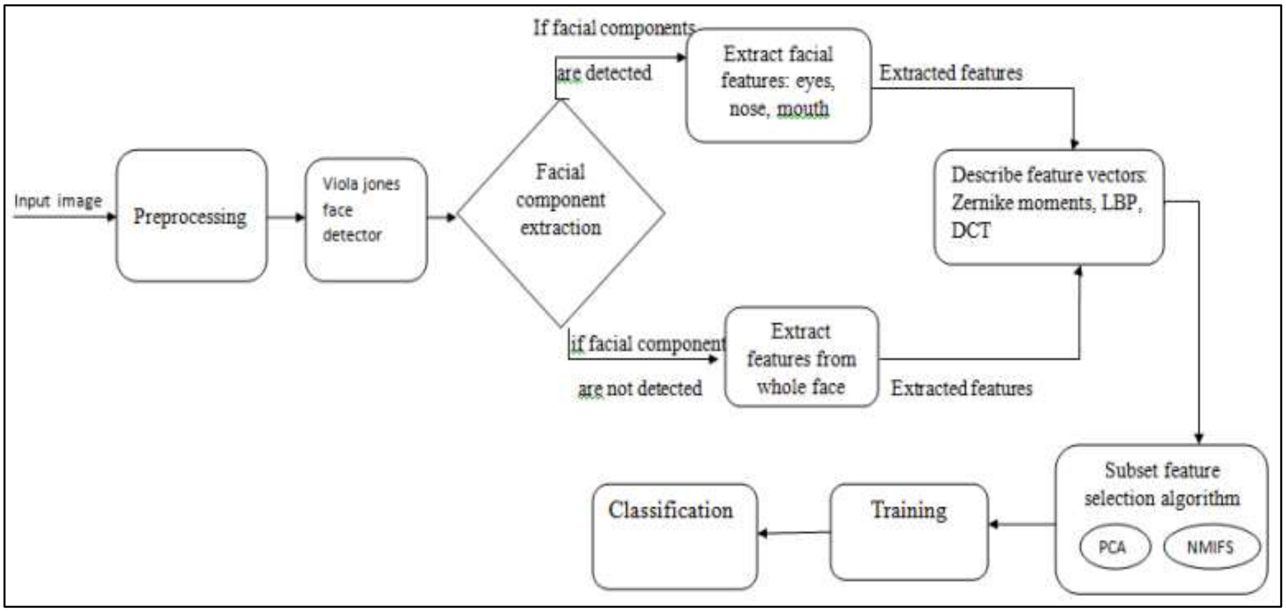

Fig. 1: Block diagram of proposed methodology

A. Preprocessing

The Recognition process begins by first acquiring the image using an image acquisition device like a camera. The image acquired then needs to be preprocessed such that environmental and other variations in different images are minimized. Hence, in order to reduce the image complexity, initially a transformation into gray-scale is applied . Gray-scale values range between 0, which represents black, and 255, which represents white.

B. Face Recognition

First, an automatic face detector (Viola-Jones face detector) is applied on the preprocessed image to extract the face region. Viola Jones face detector works based on the Haar features. The basic principle of the Viola-Jones algorithm is to scan a sub-window capable of detecting faces across a given input image. image. The obtained image is then cropped and resized to a size of 96 * 96 pixels. For enhancing the image, histogram equalization is then performed. A figure showing the input image after preprocessing and after applying viola jones face detector is being depicted in the figure 3.

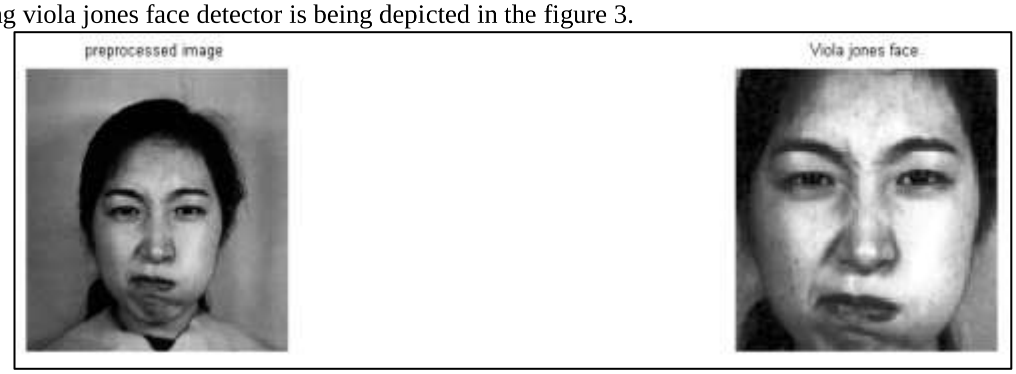

Fig. 3: preprocessed image and viola jones face

C. Facial Component Extraction

Facial components detection was widely studied and different techniques were developed. Facial features that constitute the major facial components includes eyes, nose and mouth. But there are two different cases to be considered here. The first case is when the facial components are detected. The other case is when the facial components are not detected.

1) Feature Extraction from Specific Facial Parts

Psychologists have demonstrated that the eyes, mouth and nose are the areas of the face on which appear the overall facial expressions. So, important processing time will be avoided by characterizing facial components instead of the whole face. The Viola and Jones face detector which was used for face detection is used for face feature localization also. A figure representing the detected facial features from an image is given in figure 4.

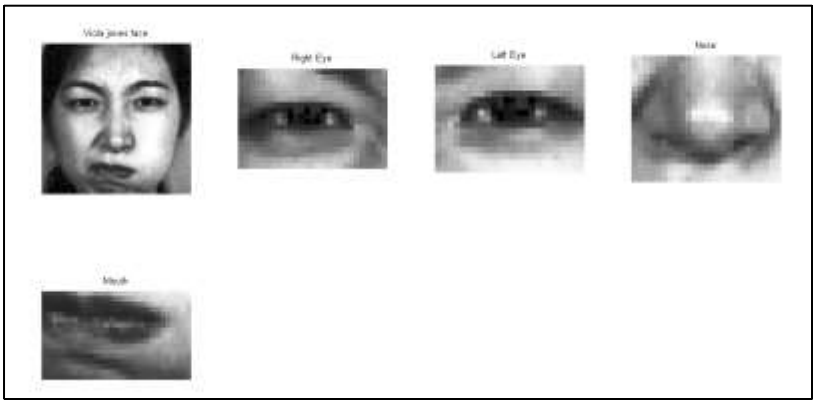

Fig. 4: Original image and detected facial features

The problem which arises while using the facial features for facial component extraction is that if the face is tilted or not exactly in the frontal position, the viola jones algorithm fails to detect the facial features. In such cases the face itself is not detected and hence not gets trained.

2) Feature extraction from whole face

DCT is used to extract features from the whole face. After applying DCT to the entire face images, some of the coefficients are selected to construct feature vectors. DCT feature extraction consists of two stages. In the first stage, the DCT is applied to the entire image to obtain the DCT coefficients, and then some of the coefficients are selected to construct feature vectors in the second stage.

$$F(u,v) = \frac{1}{\sqrt{MN}}\alpha(u)\alpha(v)\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y) \times \cos\left(\frac{(2x+1)u\prod}{2M}\right)\cos\left(\frac{(2y+1)v\prod}{2N}\right) \quad (3.1)$$

f(x,y) is the image intensity function and F(u,v) is a 2D matrix of DCT coefficients.

D. Face Feature's Characterization

Instead of the matrix of pixels, a reduced representative vector which compact the information needed for processing task is being used. Here three different ways are used to perform characterization in order to enrich the representative feature vector. Three different types of information are used ; Zernike moments, to compact images geometric characteristics; LBP method which is considered as the most significant way to characterize texture information of the image and DCT transform to obtain its spectral components distribution.

1) Face Features Characterization by Zernike Moments

Zernike moments form part of the general theory of the geometrical moments. At the difference of the general geometrical moments, those of Zernike are built on a set of orthogonal polynomials which were used as the basic elements of the construction of an orthogonal base given by the equation:

$$V_{n,m}(x,y) = V_{n,m}(\rho,\theta) = R_{n,m}(\rho).e^{j.m.\theta}$$

$$R_{n,m}(\rho) = \left(\sum_{k=|m|}^{n} \frac{-1^{\left(\frac{n-k}{2}\right)}.(n+k)!}{\left(\frac{n-k}{2}\right)!\left(\frac{k+m}{2}\right)!\left(\frac{k-m}{2}\right)!}\right).\rho^{k}$$

where

$$\rho = \sqrt{x^2+y^2}$$

$$\theta = arctg\left(\frac{y}{x}\right)$$

Zernike moments are known for their capacity to compress the geometric information of the image into a vector of reduced dimensions depending on the parameters m and n. The obtained feature vector compacts the geometric characteristics of the image such as the surface, the vertical symmetry and distribution centers masses in the horizontal and vertical directions and other image characteristics which deal with information required for such type of classification problem.

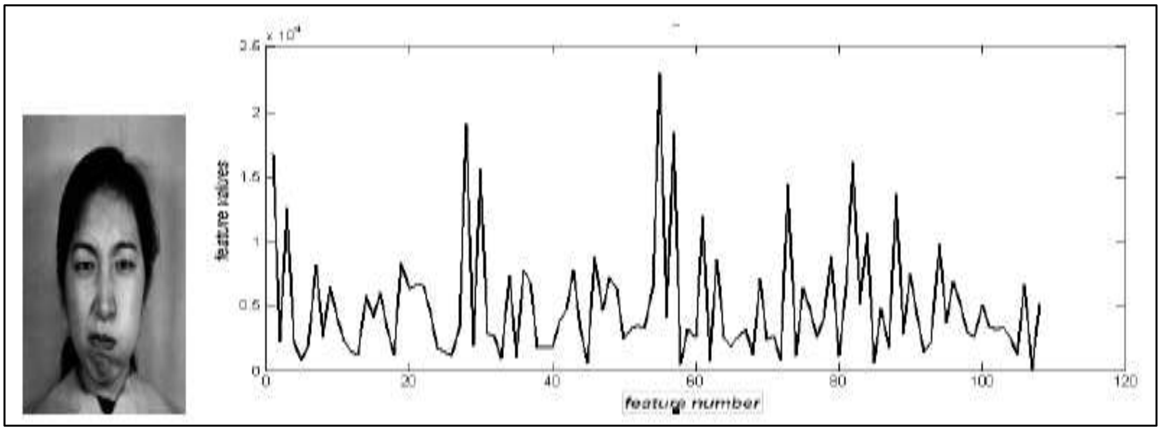

Fig. 5: Zernike moment feature vector for Anger expression

2) *Face Features Characterization by LBP*

The LBP operator is one of the best performing texture descriptors and it has been widely used in various applications. It has proven to be highly discriminative and its key advantages, namely, its invariance to monotonic gray-level changes and computational efficiency, make it suitable for demanding image analysis tasks. The operator assigns a label to every pixel of an image by thresholding the 3*3-neighborhood of each pixel with the center pixel value and considering the result as a binary number. Then, the histogram of the labels can be used as a texture descriptor. The figure 6 shows the representative scheme of the compiling process in the basic LBP method.

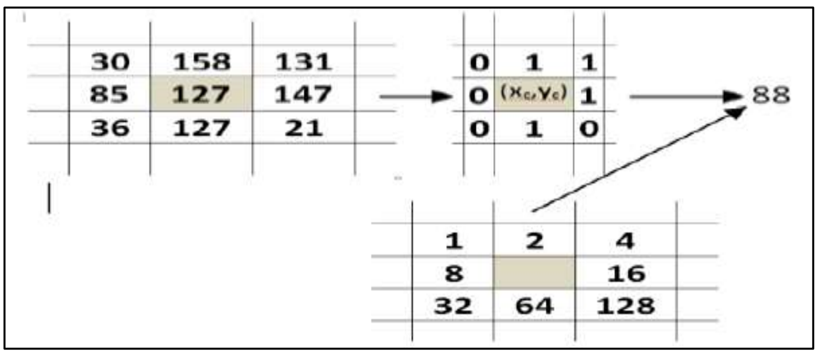

Fig. 6: Basic LBP value for the central pixel(xc,yc)

A sample of LBP feature vectors compiled for a face from JAFFE database is given in figure 7.

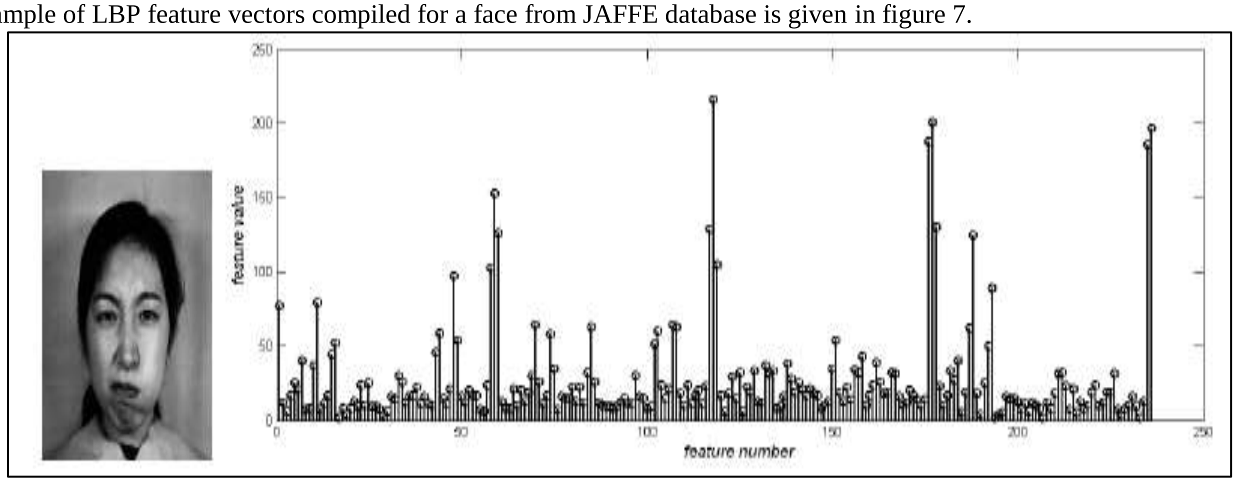

Fig. 7: LBP feature vector for anger expression

3) *Face Features Characterization by DCT*

The idea is to exploit spectral type of information brought by the image. Indeed, spectral components distribution is an important characteristic of physical signals like speech, image, etc. DCT seems to be the most preferred and most used by the researchers. This is due to the fact that it concentrates the most important visual information on a set of few coefficients which explains why it was largely used for image and video compression. In addition it leads to real coefficients. Examples of applying DCT characterization to images from JAFEE database is given in figure 8.

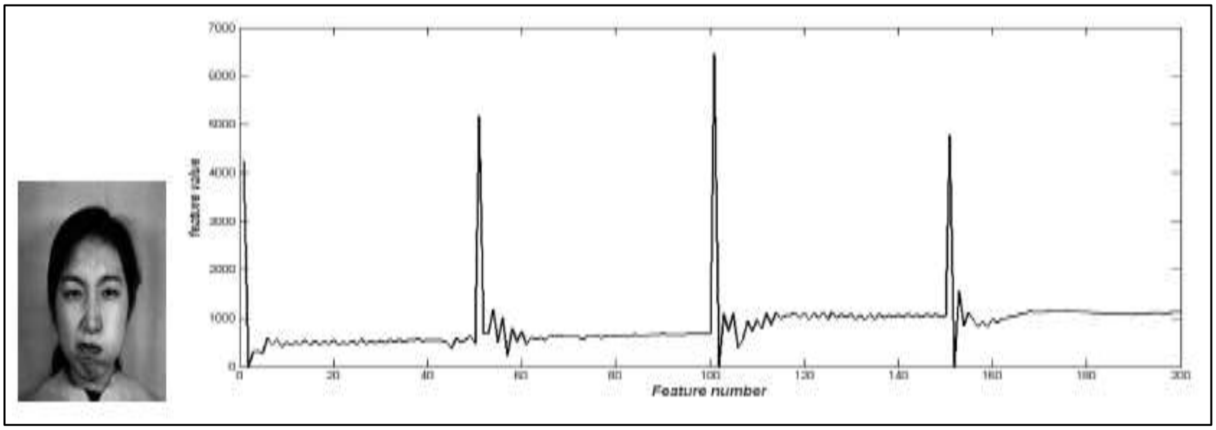

Fig. 8: DCT feature vector for anger expression

E. Subset Feature Selection

Due to the rising of dimensionality problem in classification process, a selective tool is required to compact the combined feature vectors in order to improve the classification performance, optimize the computational cost and reduce the classifier complexity. Here two important tools such as Normalized Mutual Information Selection tool(NMIFS) and PCA is used. The paper presents a comparison between the efficiency of both the methods.

1) Normalized Mutual Information Selection

Given an initial F set with n features, find subset S in F with k features that maximizes the mutual information I(C,S) between the class variable C , and the subset of selected features S. In the case of NMIFS, ones define the normalized mutual information between fi and fs , NI(fi, fs) as the mutual information normalized by the minimum entropy of both features as given below:

$$NI(f_i, f_s) = \frac{I(f_i, f_s)}{min(H(f_i), H(f_s))}$$

2) Principal Component Analysis

Principal Component Analysis (PCA) is a fast and efficient technique that is widely used for appearance based face recognition. The eigenfaces approach is chosen for this study considering its capability of recognizing real time images where orientation, illumination and distortion are continuously changing. PCA allows to compute a linear transformation that maps data from a high dimensional space to a lower dimensional sub-space. PCA uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of uncorrelated variables called principal components.

F. Classification

SVM classifier is being used for the classification of facial expressions. Support Vector Machines are a maximal margin hyperplane classification method that relies on results from statistical learning theory to guarantee high generalization performance. Kernel functions are employed to efficiently map input data which may not be linearly separable to a high dimensional feature space where linear methods can then be applied.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

Efficient facial expression recognition system for tilted face images was implemented in MATLAB 2014 prototype. This system was trained and tested using the Jaffe database consisting of 7 facial expressions given by of 10 Japanese females. Along with dis, a local database consisting of 6 facial expressions given by 6 students is also taken. Both the image and video processing were performed on a desktop PC with the following characteristics: Intel Core i3 CPU, 3.4 GHz, 4 GB RAM. The Zernike moments were computed with couple values (m=10, n=5). A DCT feature vector of 50 coefficients was computed for each faces component, and for LBP, an LBP histogram in (8,1) neighborhood was used. An SVM classifier was used for the classification purpose.

Fig. 9: Images taken for training from Jaffe database

Fig. 10: Images taken for training from Indian Student database.

During training, each image is given its corresponding expression name and an identifier of the person. After this training of all the images in both the dataset, we can test the images by giving input, which is any random set of images from the datasets. Initially the test is done on an input image from which all the facial features are extracted from the eyes, nose and mouth. The image is in frontal pose and all the features are well clear. The input image and the viola jones face is given in the figure below.

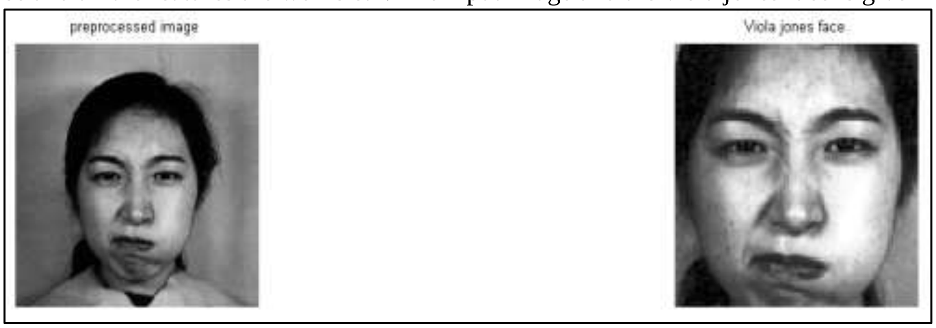

Fig. 11: Input image and its Viola jones face

The following figure shows the extraction of features like eyes, nose and mouth from the viola jones face.

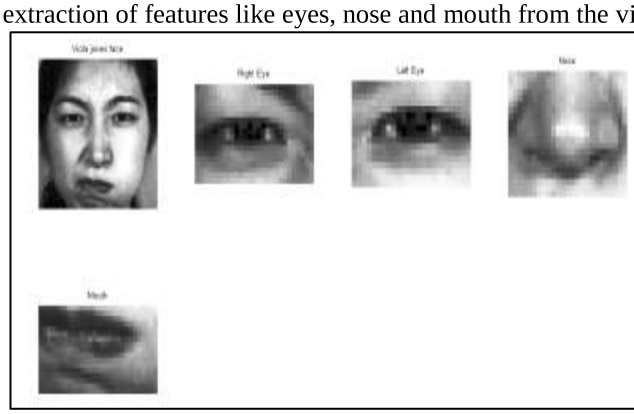

Fig. 12: Detected facial parts

Once the features are extracted, all the features are represented using zernike moments, DCT features and LBP features.

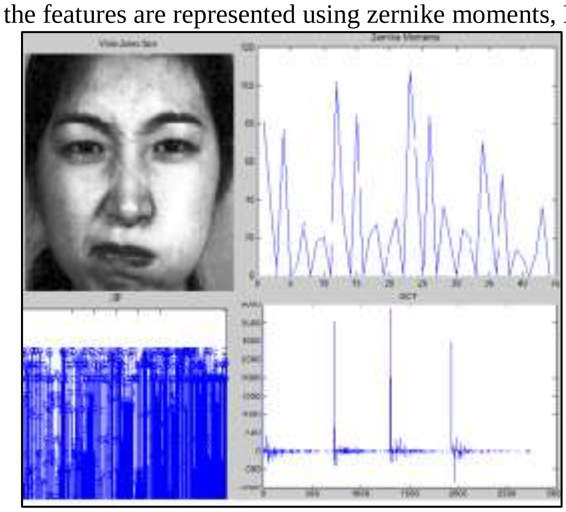

Fig. 13: The zernike moments, LBP features and DCT features of the input image

Next the feature extraction is to be done. Two methods are used. PCA based method and NMIFS method is used for data reduction.

Then train the reduced feature set using SVM classifier.

To measure the performance of the proposed method two metrics were used: precision and accuracy. Precision is related to the detection exactness and accuracy refers to the average correctness of the process.

Table – 1
Comparison of feature extraction using both methods on Jaffee Database

	Jaffe DB+specific feature extraction		Jaffe DB+whole face features	
	Accuracy	**Precision**	**Accuracy**	**Precision**
Anger	88.88	80	90	90
Disgust	87.5	70	90	90
Fear	70	70	80	80
Happiness	80	80	80	80
Sad	83.33	50	100	100
Surprise	55.55	50	90	90
Neutral	90	90	100	100
Overall	**79.03**	**70**	**90**	**90**
	Total images:70		**Total images:70**	
	Image features extracted:62		**Image features extracted:70**	

The result shows that the accuracy and precision for the Jaffee database when the extracting the features from the whole face is better compared to the case when only specific features are being selected from the face.

Table – 2
Comparison of feature extraction using both methods on Indian student Database

	Indian DB+specific features extraction		Indian DB+whole face features	
	Accuracy	**Precision**	**Accuracy**	**Precision**
Anger	100	10	100	30
Disgust	100	10	100	20
Fear	100	10	100	40
Happiness	Nan	0	100	40
Sad	100	10	100	50
Surprise	100	20	100	60
Neutral	Nan	Nan	Nan	Nan
Overall	**100**	**8.57**	**100**	**34.28**
	Total images:26		**Total images:26**	
	Image features extracted:6		**Image features extracted:24**	

The result shows that the accuracy and precision for the Indian Student database when the extracting the features from the whole face is better compared to the case when only specific features are being selected from the face.

A comparison between the dimensionality reduction methods such as NMIFS and PCA was also done. The test was done on the Jaffe database and when the features are extracted from the whole face. Various dimensions were tested for the feature vectors. The table below shows the comparison. It is found that PCA outperforms NMIFS in all dimensions of feature extraction.

Table – 3
Comparison between the prediction accuracy of NMIFS and PCA on various dimensions

	NMIFS	**PCA**
Dimension		
32	57.14	87.14
200	68.57	90.00
2000	90.00	90.00

V. CONCLUSION

This work presented an efficient facial expression recognition system for tilted images. Inorder to improve the facial expression recognition, a comparison between the extraction of features from specific facial parts and from whole face was shown. It was observed that all the images were captured in case of whole face feature extraction compared to others. The extracted features where then represented using the feature vectors Zernike moments, LBP and DCT. Inorder to reduce the feature set, two different feature reduction techniques, namley NMIFS and PCA was used. From experiments it was seen that PCA showed better results compared to NMIFS. SVM classification was done. Results indicate that the method proves to be efficient in recognizing facial expressions when the faces are even titled slightly.

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