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Facial Expression Recognition Using Machine Learning Techniques

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Abstract— Facial Expression Recognition has got much attention in now a days. More and more research is done in this area. Facial Expression Recognition has very vast applications in recent enhancements like Human Computer Interaction (HCI), anti-terrorist activity, robotics, behavioral study, driver safety, health care system. Facial Expression Recognition (FER) system can be divided into two steps. First the facial features are extracted from the preprocessed images or raw image then the second step is to classify that expressions. In proposed work we have used PCA on Gabor images. Those extracted features are given as an input to two different classifiers, Neural Network and Support Vector Machine for recognition. The comparison of results achieved using both classifier is discussed.

Index Terms—Facial Expression Recognition, Gabor Filter, JAFFE, PCA, NN, SVM

I. INTRODUCTION

The community of computer vision has attracted the attention of facial emotion recognition over the last decade A vast amount of work has been done and is in progress to make life easy for the disabled (e.g. blind, dumb) and aged people by the help of improving all aspects of interaction between computers and human beings. In the area of HCI, there is practical usage based emphasis for automating recognition of a particular facial expression out of a pre-defined list. Facial expressions have been extensively studied in psychology [1] [2].

A Mehrabian [3] shows that 55% of human communication done through expressions of face. So, recognition of Facial Expression is very crucial in human computer interaction (HCI).

Fig. 1 Basic Six Facial Expressions [4]

The basic six types of expressions are happiness, sadness, fear, disgust, surprise and anger. Facial Expression Recognition is basically two step process which is shown in below figure.

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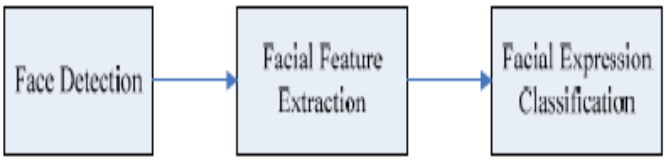

Fig. 2 Facial Expression Recognition System

The first step is to extract the features from the images is divided into two methods 1) Image (Feature) based approach and 2) Model (Template) based approach. The following step is to recognize the expression using one of the known classifier. System is trained in such a way that when any unknown image is given as an input it automatically tells that the image is corresponding to which facial expression. Some known classifiers are 1) Neural Network 2) Support Vector Machine (SVM) 3) Hidden Markov Model (HMM).
In this paper Gabor Filter and PCA (Principal Component Analysis) are used for feature extraction and then the extracted features are given as an input to the well known classifier NN and SVM. The recognition rate is calculated from their outcomes.

II. FACIAL FEATURE EXTRACTION

A.GABOR FILTER

Gabor filter have been extensively used in image processing for feature extraction. The characteristics of certain cells in the visual cortex of some mammals can be approximated by the Gabor filters [5]. Gabor filters are well suited for facial expression recognition because these filters have been shown to possess optimal localization properties in both spatial and frequency domain. Multi resolution analysis is possible with Gabor filter by giving a coefficient matrices and Gabor filter are also found to be unaffected by illumination changes and noise. In this work 2D Gabor filter is used for the purpose of feature extraction.

Gabor filter is a modulation of a Gaussian function means whose impulse response is defined as a harmonic function multiplied by the Gaussian function.

$$G(x,y) = \left(\frac{k^2}{\sigma^2}\right)\left[exp\left(-\frac{k^2}{2\sigma^2}(x^2+y^2)\right)\right]\exp\left(i2\pi f(x\cos\theta + y\sin\theta)\right)$$

Where k is a parameter which determines the orientation and scale (frequency) of the Gabor filter

$$(k_x, k_y) = (k_v\, cos\theta_w, k_v\, sin\theta_w)$$

Where f is frequency and w=(0,1,2,3,4,5,6,7) is for the different orientation.
Features are extracted by simple convolution of the window with the image.

B. PCA (Principal Component Analysis)

PCA (Principal component Analysis) is a way of identifying patterns in data, and expressing the data in such a way as to highlight their similarities and differences. Since patterns in data can be hard to find in data of high dimension, where the luxury of graphical representation is not available, PCA is a powerful tool for analyzing data.
The other main advantage of PCA is that once you have found these patterns in the data, and you can compress the data, i.e. by reducing the number of dimensions, without much loss of information.

C.STEPS TO PERFORM PCA

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Step 1-SELECT THE DATA
In this step the data or image (two dimensional data) is selected on which we are interested to perform the operation.

Step 2- SUBTRACT THE MEAN
We need to subtract the mean from each of the data dimensions. The mean subtracted is the average across each dimension. This will generate a data set whose mean is zero.

Step 3- CALCULATE THE COVARIANCE MATRIX
Suppose if we have two data sets like ages of people and diseases of people. So by statistical study we can measure the relation between the age and disease of people. So here co-variance matrix is useful.

$$var(X) = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(X_i - \bar{X})}{(n-1)}$$

$$cov(X,Y) = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{(n-1)}$$

By two above two equations we can clearly see that in variance they considered only one direction and in co-variance 2 dimensions are considered.
If the value of co-variance matrix is positive then both dimensions can increase together and if it is negative then as one dimension increase then other decrease. If it is zero then the dimensions are independent from each other.

Step 4- CALCULATE EIGENVECTORS AND EIGENVALUES OF THE CO-VARIANCE MATRIX

Eigen vectors can be found for square matrix only and not all the square matrix have eigenvectors. Scaling also doesn't affect the result of multiplication of matrix for Eigen vectors.

Step 5- CHOOSING COMPONENTS AND CREATING FEATURE VECTORS
Eigen vector with highest Eigen value is considered as a principal component. The no of principal components are selected in descending order.

$$FeatureVector = (eig_1\ eig_2\ eig_3\ ....\ eig_n)$$

Step 6- DERIVING FINAL DATASET
It is the last and very much simple step. Here we take transpose of feature vector and multiply it with the transpose of original data vector.

III. CLASSIFICATION

A. CLASSIFICATION USING NEURAL NETWORK
Neural networks are composed of simple elements operating in parallel. These elements are inspired by biological nervous system. As in nature, the network function is determined largely by the connections between elements. We can train a neural network to perform a particular function by adjusting the values of the connections (weights) between elements [6].
Commonly neural networks are adjusted, or trained, so that a particular input leads to a specific

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target output which is shown in figure below. The network is adjusted, based on a comparison of the output and the target, until the network output matches the target [6]. Many target pairs are used in this supervised learning to train the network.

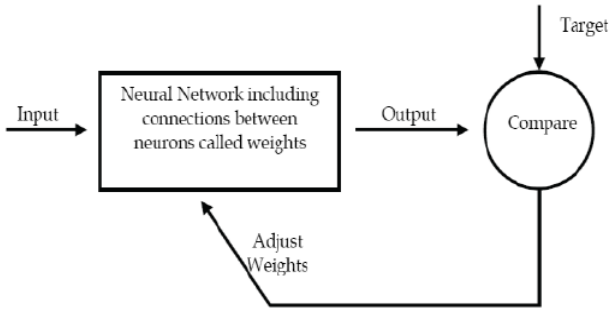

Fig. 3 Neural Network Structure [7]

An ANN is made up of a number of interconnected nodes in layers to form a network which is shown below.

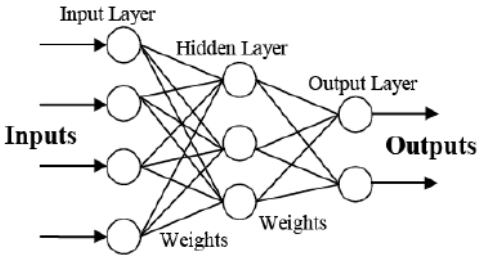

Fig. 4 Artificial Neural Network [7]

In supervised learning a set of inputs are applied to the network and after that the resultant outcomes are compared with the desired ones. There are various flavors of Neural Network are available like: Bidirectional Neural Network (BNN), Probabilistic Neural Network (PNN), Feed Forward Neural Network.

B.CLASSIFICATION USING SVM

SVM is powerful tool used for classification and regression. SVMs are a set of related supervised learning methods used for classification. SVM training algorithms builds a model which is a representation of the examples as points in space, mapped so that the examples of the separate categories are divided by a clear gap that is as wide as possible [8]. New examples are then mapped into that same space and predicted to belong to a category based on which side of the gap they fall on. There are two basic approaches

1) Maximum margin classification (linear)
2) Non linear classification

Maximum margin classification (linear)

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SVM construct a hyper plane that classifies the data. The best hyper plane is the one that represents the largest separation, or margin, between the two classes [9]. So we choose the hyper plane so that the distance from it to the nearest data point on each side is maximized. If such a hyper plane exists, it is known as the maximum margin hyper plane and the linear classifier it defines is known as a maximum margin classifier.

Suppose some given data points each belong to one of two classes, and the goal is to decide which class a new data point will be in. In the case of support vector machines, a data point is viewed as a p-dimensional vector (a list of p numbers), and we want to know whether we can separate such points with a p – 1 dimensional hyper plane [6].

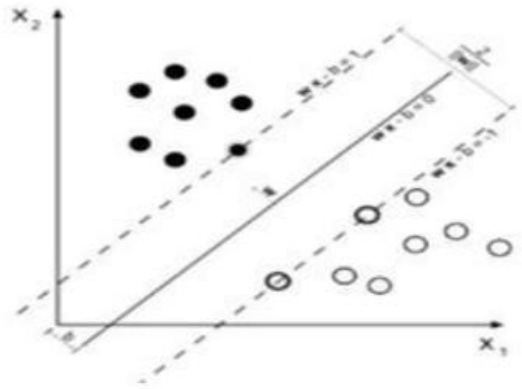

Fig. 5 Maximum margin hyper plane [8]

Non Linear Classification

Data which is not linearly separable can be classified using nonlinear classifier by applying kernel trick to maximum margin hyper plane. The maximum margin hyper plane is transformed into the feature space. The non linear kernel function is used to transform it into the high dimensional feature space. Some common kernels are shown below [8].

Polynomial: $K(xi, xj) = (xi \cdot xj)\, d$
Radial Basis: $K(xi, xj) = \exp(-\gamma \|xi - xj\|^2)$ for $\gamma > 0$
Sigmoid: $K(xi, xj) = \tanh(kxi \cdot xj + c)$ for $k > 0, c < 0$

Multiclass SVM

The task of multiclass SVM is to assign labels to instances by using support vector machines, where the labels are drawn from a finite set of several elements. The solution is to reduce the single multiclass problem into multiple binary problems [10]. Each of the problems yields a binary classifier, which is assumed to produce an output function that gives relatively large values for examples from the positive class and relatively small values for examples belonging to the negative class.

Two common methods to build such binary classifiers are
(1) One-verses-one where each classifier distinguishes between one of the labels to the rest.
(2) One-verses-all where each classifier distinguishes between every pair of classes.

Classification of new instances for one-versus-all case is done by a winner-takes-all strategy, in which the classifier with the highest output function assigns the class. For the one-versus-one approach, classification is done by a max-wins voting strategy, in which every classifier assigns the

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instance to one of the two classes, then the vote for the assigned class is increased by one vote, and finally the class with most votes determines the instance classification [8].

IV. IMPLEMENTATION AND RESULTS

JAFFE (Japanese Female Facial Expression Database) standard database is used for training and testing the proposed method. It contains total 10 different females images having all seven expressions. All images are taken in very good background and all images are in grayscale. For our experiment we have chosen four females.

Gabor filter is applied on each and every image which is used for training or testing purpose. Here we select the filter of size 5 and sigma as 1.3 and angle is $6\pi/8$.

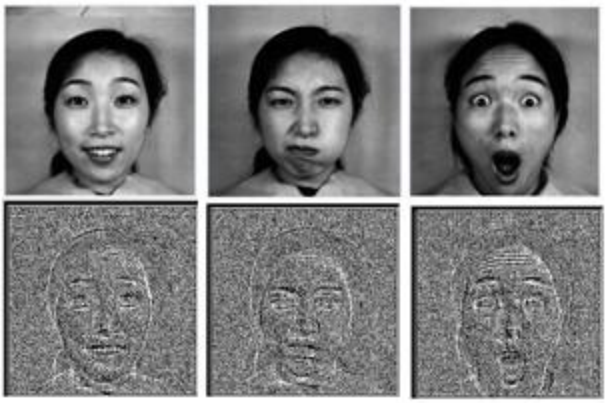

Fig. 6 Facial images with their Gabor output

In proposed algorithm we have done hybrid of two facial feature extraction techniques. In general the Gabor images or PCA images are given to Machine Learning Techniques as a feature but here we apply PCA on Gabor image and then give it to Machine Learning Techniques as a feature.

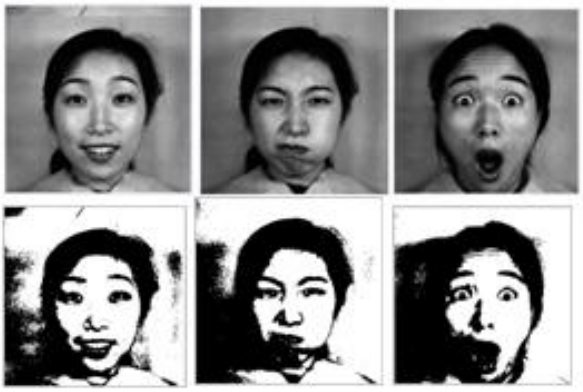

Fig. 6 Facial images with their PCA output

For classification with Neural Network it is created using newff function. Target vector is generated for seven different classes. Network is trained using train function.

For SVM the open source SVM-Light tool is used. SVM builds a model using example file which is the representation of the feature as a point in a space. For the test examples prediction is done using this models and stored in the output file.

Table 1 Expression Recognition Result using NN

	HAPP	SA	SURP	DISGU	FEAR	ANGR	NEUTRA

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	Y	D	RISE	ST		Y	L
HAPPY	**100**	-	-	-	-	-	-
SAD	-	**100**	-	-	-	-	-
SURPRISE	-	-	**57.14**	-	-	14.28	28.57
DISGUST	-	28.57	-	**71.14**	-	-	-
FEAR	-	-	-	-	**42.85**	42.85	14.28
ANGRY	-	10	-	-	-	**90**	-
NEUTRAL	14.29	-	-	-	14.29	-	**71.43**

Table 2 Expression Recognition Result using SVM

	HAPPY	SAD	SURPRISE	DISGUST	FEAR	ANGRY	NEUTRAL
HAPPY	**100**	-	-	-	-	-	-
SAD	-	**90**	-	-	-	-	10
SURPRISE	-	-	**100**	-	-	-	-
DISGUST	-	14.29	-	**85.71**	-	-	-
FEAR	-	-	-	-	**100**	-	-
ANGRY	-	10	-	-	-	**90**	-
NEUTRAL	14.29	-	-	-	-	-	**100**

From above results we can see that the SVM and NN can correctly classify approximate 95% can 77% of testing images.

V. CONCLUSION AND FUTURE WORK

The developed method is tested and cross validated and the detailed results are presented. It is observed that using SVM the recognition is done very efficiently for all seven expressions while

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Neural Network also provides good result except fear and surprise expressions.

SVM is a powerful tool used for classification which does not depend in heuristics. It is superior to neural networks. Also SVM has a high generalization capability. In neural network something should be done to enhance the recognition of fear and surprise. The whole experiment is done using JAFFE database so in future it should be done using various databases.

In future the experiment should be combined with other technologies to provide more realistic results and applicable in various fields. It should also be developed to work on various age groups of person.

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