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A Comprehensive Study of Major Techniques of Facial Expression Recognition

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***Abstract*— Facial Expression Recognition is one of the challenging and active research topic in the recent years. Facial Expression Recognition System comprises the detection of face, facial feature extraction and classification of facial expression from still images. This paper summarizes the major techniques to recognize the facial expressions from still images. The techniques included in this paper are Principal Component Analysis, Singular Value Decomposition, Neural Network, Cloud Model, Fuzzy Model and K-Means Clustering Algorithm. The performance of these techniques is good enough and almost effective also except fuzzy model. Fuzzy model does not classify the expressions exactly. The main purpose of this research work is to present the major techniques of automatic facial expression recognition in a single view.**

***Index Terms*— Facial expression recognition, K-Means Algorithm, Principal Component Analysis (PCA), Singular Value Decomposition (SVD) etc.**

I. Introduction

Facial expression recognition is a part of image processing. Facial expressions bring information related to human emotion and play an important role in human communication [1]. In 1971, Ekman and Frisen discovered six different facial expressions include happiness, sadness, fear, disgust, surprise and anger along with neutral face. These emotions are universally accepted as basic emotions [2]. Facial expression recognition system organizes in order of processing blocks that consist face detection, facial feature extraction and expression classification. Pre–processing is one of the main steps for facial expression recognition. The purpose to perform pre-processing is to get a clear image [1]. Static images or image sequences are used as a input for recognition of expression. The data base of images that are used only for research purpose are Cohn – Kanade facial expression database, Japanese Female Facial Expression (JAFFE) database, MMI database and CMU-PIE database [12]. The facial feature extraction also plays a vital role in applications of face recognition. Some techniques extract nose, eyes and mouth as a facial feature and used for classification [3]. The application areas related to the face and its expression comprises personal identification, access control, video conferencing, surveillance, human computer application [4].

Many scholars have published a ton of research work on facial expression recognition techniques. Mandeep Kaur, Rajeev Vashisht and Nirvair Neeru presented Recognition of Facial Expression with Principal Component Analysis (PCA) and Singular Value Decomposition (SVD) [5]. Hehua Chi, Lianhua Chi, Meng Fang and Juebo Wu gave a way of Facial Expression Recognition based on Cloud Model [6]. Pushpaja V. Saudagare, D. S. Chaudhari introduced Facial Expression Recognition using Neural Network [7]. Sachin D. More and Sachin Deshpande presented Fuzzy Model for Human Face Expression Recognition [4]. Ahmed M. Zeki, Ruzanna bt. Serda Ali and Patma Appalasamy gave K-Means approach to Facial Expressions Recognition [8].

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II. Methodology Used

A. Principal Component Analysis (PCA)

Principal Component Analysis is a standard statistical technique used for facial expression recognition and broadly used for facial feature extraction [9]. Poor associations of eye locations and mouth locations features is a problem for PCA, thus pre-processing the images can help to improve its effect [10]. By concatenating each row or column of a 2D facial image into a long thin vector, so that image can be presented as 1D vector [9].

Let's assume X vectors of size Y denoting a set of sampled images, a_j's is used to represent the pixel values and v_i represent the image vector.

$$v_i = [a_1, a_Y]^T \quad ; i=1,\ldots,X$$

Let u corresponds to the mean image

$$u = \frac{1}{X}\sum_{i=1}^{X} v_i$$

To get mean centered image, subtract the mean image from each image vector. Let c_i represents the mean centered image

$$c_i = v_i - u$$

The goal is to discover a set of p_i's on every c_i's [9].

B. Singular Value Decomposition (SVD)

Singular Value Decomposition is a technique that is

mostly used for feature extraction. It is a result of linear algebra. SVD plays an important role in different applications such as data compression, pattern recognition and in digital image processing. SVD is used to reduce the storage size of large images by regenerating the original image with nonzero singular value [9][5]. When PCA is used with SVD, it gives better result in terms of its recognition rate and also in other properties [9].

Let M is a matrix of mxn dimension, given as

$$M = XZY^T$$

Where X and Y denote an mxm and nxn orthogonal matrix respectively and Z denotes an mxn matrix that contains the singular values of M along with its diagonal [9].

C. Cloud Model

Suppose Q denotes the quantitative universe of discourse with specific numerical value: $P \subseteq Q$ and R denotes the qualitative concept of space Q. If the certainty of $p(p \in P)$ belonging with R, is a arbitrary number, that is $T_R(p) \in [0,1]$ then the distribution of R from Q to [0,1] in data space is called as cloud.

$$T_R(p): Q \to [0,1] \forall p \in P(P \subseteq Q) p \to T_R(p)$$

In the cloud model, three characteristics are used: Expectation (A_{exp}) denotes the prototype value of concept, Entropy (B_{ent}) denotes the measurement of concept uncertainty and Hyper-entropy (C_{hent}) denotes the measurement of entropy uncertainty. These characteristics are used to classify the expressions [6].

Backward Cloud Generator (BCG) is the main concept of cloud model which gives the characteristics value {A_{exp}, B_{ent}, C_{hent}} that are used to classify the expressions. As shown in fig.1 it observe a group of cloud droplets $Drop(pi, T_R(pi))$ with certain distribution as input and gives three numerical characteristics {A_{exp}, B_{ent}, C_{hent}} as output [6].

Fig.1 Backward Cloud Generator

The calculations of characteristics value are as follows:

Calculate the sample mean: $\overline{P} = \frac{1}{a}\sum_{i=1}^{a} pi$,

Calculate the first order absolute distance: $D = \frac{1}{a}\sum_{i=1}^{a}\left|pi - \overline{P}\right|$

And calculate the variance: $V^2 = \frac{1}{a-1}\sum_{i=1}^{a}(pi - \overline{P})^2$

Now calculate the Expectation: $A_{\exp} = \overline{P}$

Calculate the Entropy: $B_{ent} = \sqrt{\frac{\pi}{2}} \times D$

Calculate the Hyper-entropy: $C_{hent} = \sqrt{V^2 - B_{ent}^2}$

The steps of facial expression recognition based on Cloud Model are shown in fig.2. First, a group of facial images are taken as input. Second, perform the pre-processing steps on the input images to get a set of cloud droplet images. Cloud droplet is one of the units of recognition system, which can form a cloud of group of images that are considered as the standard input images for further processing. Third, by using Backward Cloud Generator (BCG) generate the numerical characteristics {A_{exp}, B_{ent}, C_{hent}} as facial features. At last, based on these features, classify the expressions [6].

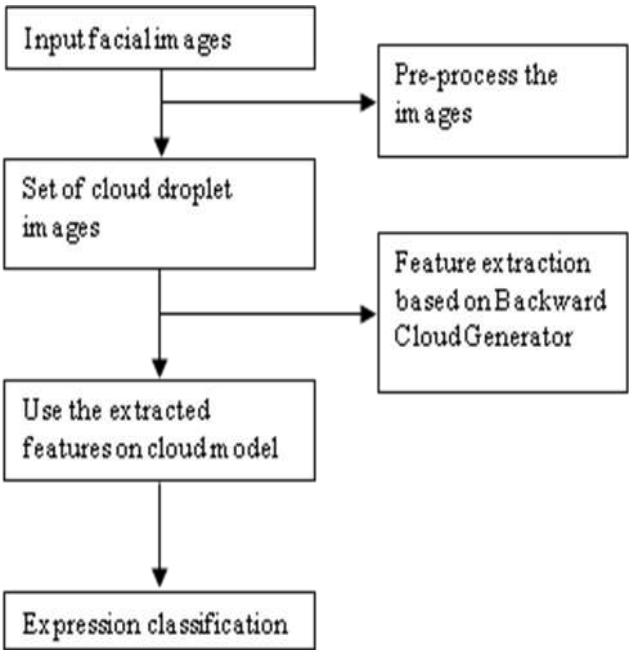

Fig.2 Steps of facial expression recognition based on Cloud Model

D. Neural Network

In neural network, two methods are used: feed forward back propagation method is used to recognize the expressions and principal component analysis is used for facial feature extraction. In feed forward back propagation method, two values are used to show the output in the network, for positive result it shows 1 and for negative result it shows 0 [7].

As shown in fig.3 first layer of the network shows the features {F1, F2, F3,…, Fn} such as forehead, mid forehead, mouth and cheek. These features are used to recognize the expressions. Second layer is the hidden layer, in which the values for features are calculated and the third layer is output layer which consist expressions {E1, E2, E3,…., En} like

happy, sad, angry, fear and surprise, that are realized using the values.

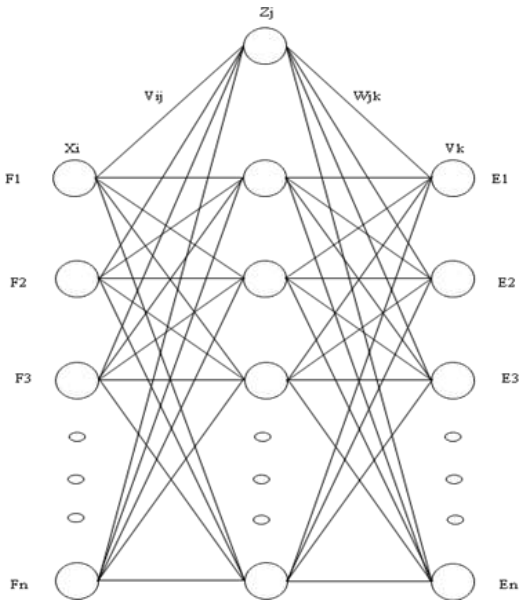

Fig.3 Feed forward back propagation neural network

The facial expression recognition system using neural network includes four stages. As shown in the fig.4 in the first stage, the face is detected from an input image. The input image is taken from the database of images. Next is preprocessing stage, perform to remove the noise from the image. In the third stage, Principal Component Analysis (PCA) method is used to calculate the eigenvalues. In eigen face library, there are two image datasets- training dataset and testing datasets. The training dataset images are matched with the best eignfaces that have the largest eignvalues. At the classification stage, the expression of an input image is classified using neural network [7].

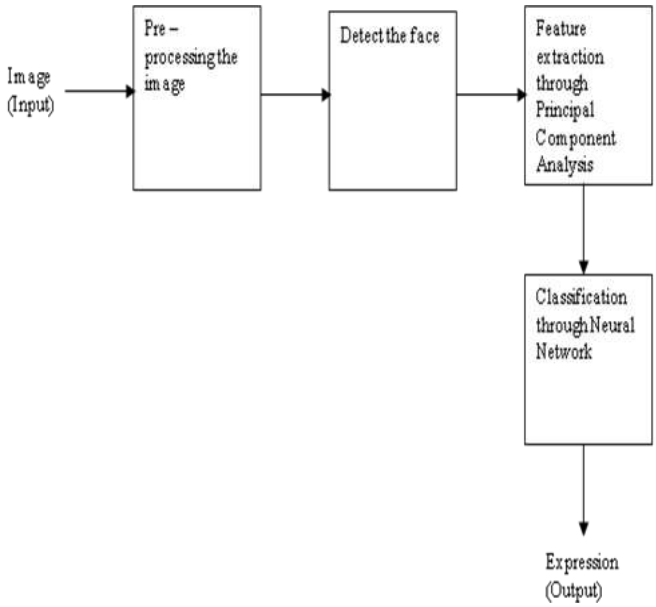

Fig.4 Facial expression recognition system using neural network.

E. Fuzzy Model

Fuzzy model is a new approach in facial expression recognition. In fuzzy model, fuzzy pattern rules are used to recognize the expressions. These fuzzy pattern rules are formed on the basis of extracted features.

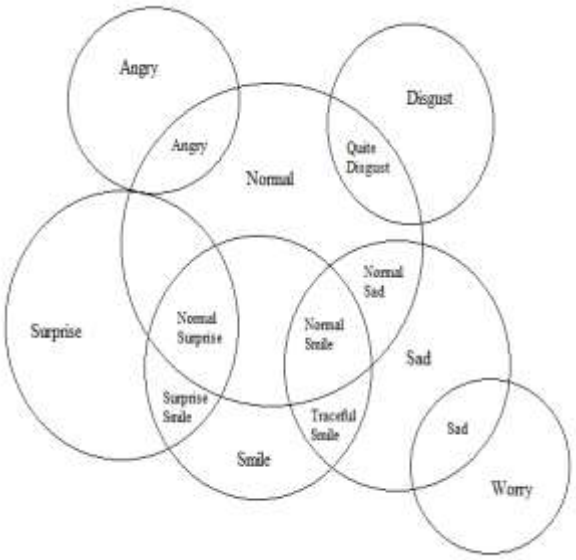

Fig.4 Fuzzy Patterns of expression

Fig.5 shows the facial expression recognition system based on fuzzy model. In the first phase of the system, face is detected from a given image on the basis of skin color. Then in the second phase, face is extracted based on the skin pixels and after enhancement a cropped face region is obtained. Third phase is feature extraction, which provides the features such as eyes, nose and mouth. When the features are extracted, curves are created for these features to obtain the feature points. This is the fourth phase, in which Bezier curve is used for curve formation. At the last phase, fuzzy pattern rules are used and recognize the expression based on the feature points [4].

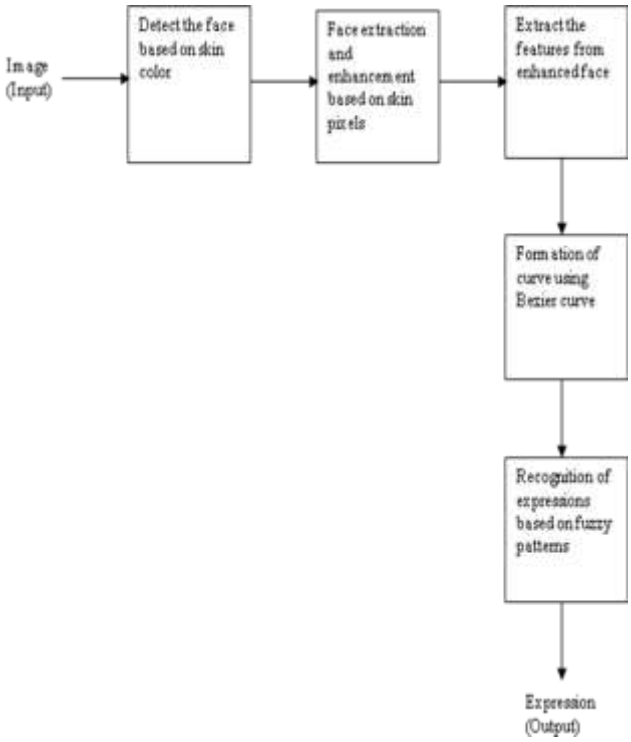

Fig.5 Steps of facial expression reconition based on fuzzy model.

F. K-Means Clustering Algorithm

K-Means algorithm is one of the easiest and most popular algorithms. It is an unsupervised learning and partitioning based clustering algorithm. It creates a number of clusters of a given data objects. But in K – Means algorithm, it is required to specify the number of clusters. Each cluster has a centroid, and based on these centroids the clusters are generated. The data objects are grouped with the centroid that is nearest to it. Once the clusters are generated, centroids are recalculated and based on the new centroids new clusters are made. This process is repeated until the centroids values are not changed [11].

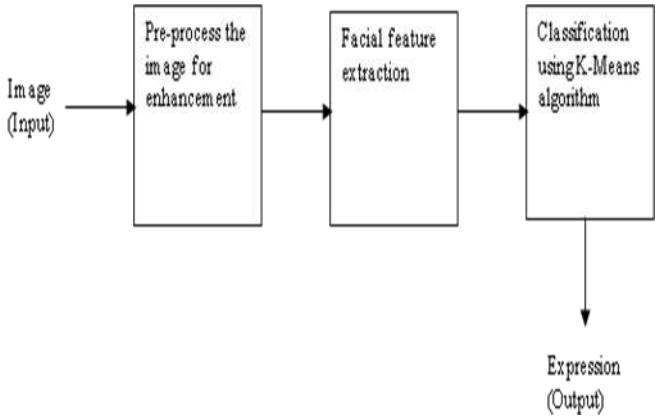

Fig.6 Facial expression recognition using k-means algorithm.

In the facial expression recognition system, there is a series of processes. As shown in fig.6, first a sample image is taken, which go through pre–processing stage to improve the quality. After pre–processing next is facial feature extraction stage. In this stage, the boundary of face and region of interest comprise eyes, mouth & nose are detected to extract the features. This method uses two features: the density of pixels and the ratio of height to width of cropped boundary regions. At the last, based on the features extracted, the expression is recognized using the K–Means algorithm [8].

Table1 Comparison of major techniques of facial expression recognition.

Techniques	Characteristics			
	Pre-processing	Feature extraction	Database	Result
Principal Component Analysis & Singular Value Decomposition [9][5]	To resize the image into uniform dimension	Singular values	JAFFE and real time database	Excellent (100%)
Cloud Model [6]	To get a group of cloud droplets	Three numerical characteristics	JAFFE database	Feasible and effective
Neural Network [7]	To get a normalized image	Eigen values	Collection of images with identical environment	Good
Fuzzy Model [4]	To detect the face based on skin color	Eyes and mouth	Sample facial images	Never gives exact output
K-Means algorithm [8]	To enhance the image quality	Two values- density of pixels and ratio of height to width of cropped boundary of interested region	200 images of faces	Better (76.5%)

III. Comparison

Table1 shows the comparison between the techniques that are discussed in this paper. The characteristics used to distinguish are: pre-processing, feature extraction, database and result. Pre-processing is the main step in facial expression recognition. It is used to get a normalized, enhanced image with less noise. In fuzzy model, pre-processing is based on skin color [4] and in cloud model its outcome is a group of cloud droplets [6]. Second characteristic is feature extraction which gives the extracted features that are used in classification. In PCA and SVD, singular values are extracted using SVD. Cloud model uses three numerical characteristics $\{A_{exp}, B_{ent}, C_{hent}\}$ and K-Means algorithm uses two values- density of pixels and ratio of height to width of cropped boundary region [8]. In fuzzy model, features are limited to eyes and mouth. Neural network uses eigenvalues for classification [7]. Based on the features extracted and the databases used by the techniques, the performances are shown in the table1.

IV. Conclusion

The main objective of this paper is to present the major techniques of facial expression recognition. This paper surveys some of the techniques of past two years in order from 2010 to 2012. The techniques considered in this paper are principal component analysis (PCA), singular value decomposition (SVD), cloud model, neural network, fuzzy model and K-Means algorithm. The experimental results show that PCA with SVD gives excellent result, cloud model and K-Means algorithm are also good in classification of expressions and in fuzzy model it is found that recognition of expressions based on fuzzy pattern rules never provides the output exactly.

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