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A combinatorial approach to human face recognition and expression identification

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A new integrated approach to human face recognition and expression identification based on Gray Level Co-occurrence Matrix (GLCM) technique that will be useful for Human Face Recognition and Feature Extraction system based on Local Ternary Pattern (LTP) for expression identification was introduced. It applies GLCM operation to extract the features of facial images to different classes for the purpose of image classification and verification by Kernel Principal Component analysis (KPCA) technique and "expression identification" by extracting the features using LTP method and classifies uses SVM technique. In the proposed method, Gray Level Co-occurrence is used to extract the texture features of an image with different attribute levels, and then the Euclidean distance classifier is used to match the top ten images from all the database images, and finally, KPCA method of the Eigen face is applied only on the ten sorted instead of all the database images which in turn reduces the computational time, and then the LTP features is extracted for the identification of the facial expression with improved recognition rate. The performance Evaluation is done by calculating the False Acceptance Rate (FAR), and the False Rejection Rate (FRR) and compared with the existing methods.

Key words: Face recognition, Gray Level Co-occurrence Matrix, Kernel Principal Component Analysis, false acceptance rate, false rejection rate.

INTRODUCTION

The identity of any person can be recognized only through face. In these aspects, face plays a vital role in carrying information to the human brain and recognizes the identity of the person. An admirable ability of the human brain is the capability to recognize the face of a person individually even though there are a lot number of changes due to their ageing, hair style, and many other texture parameters. Many research works have been carried out in the field of face recognition in the past few decades. In spite all those research works many serious events like terrorist attacks and other disaster incidents have occurred in most sophisticated security systems. Hence many government and private organizations came forward to invest in the development of ideal security systems. Human computer interface using biometric identification like face recognition has a good emerging interest among researchers. A lot of research work on the face and expression recognition has been carried out in the last decades (Fasel and Luettin, 1999; Kailash and Sanjay, 2008; Tolba et al., 2006).

Even though many research works on facial expression have been done, a recognition system with high accuracy still remains a challenging task for the researchers to achieve due to factors like variability, complexity and

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subtlety of facial expressions (Bartlett et al., 2005; Liao et al., 2006; Yu et al., 2007).

The two main methods for the extraction of any facial features are geometry based and appearance-based (Raymond et al., 2010; Ronny Tjahyadi et al., 2004). Among these two methods, the geometry-based methods depends on facial feature detection and tracking with good effectiveness and accuracy. Whereas, in the appearance-based methods, the potential of Gabor wavelets for recognizing expressions from still images have been established (Shan et al., 2008; Feng et al., 2000; Tolba, 2006). The new multi resolution analysis method, also called digital curvelet transform is used recently by excellent face recognition systems (Mohammed et al., 2009; Saha and Jonathan Wu, 2010; Mandal et al., 2007). In general, for any face authentication system, face and facial expression recognition is considered to be the important problems. Face and facial expression recognition are made difficult by a variety of expressions , varying in age, ethnicity, and gender. The digital curvelet co-efficient is applied in this method to form features for representing the complete face (Mohammed et al., 2009; Saha and Jonathan Wu, 2010; Mandal et al., 2007). The local facial information is stored in order to classify the facial expressions. For obtaining the local description of the expressions, selected sub-bands of image that are pre-processed by curvelet transform are used to compute the local binary patterns (LBPs). LBP was proposed for texture classification (Liao et al., 2006) and have been used extensively for expression recognition with a good rate of success in (Tolba et al., 2006).

In communication, our facial expressions play a major role in body language. With the advent innovation in computer science and technology, excellent progress has been carried out in the field of physiology, psychology, artificial intelligence and computer science. The term FER (facial expression recognition) was formed by the combination of computer vision, human-computer natural interaction and image processing. Due to occurring changes in age, gender, and occluding objects, the FER process become very difficult and complex (Fasel and Luettin, 2003). Environmental lighting and gestures are some of the other important factors that affect FER very much. In human communication, emotions can be expressed through face which imparts a large amount of information.

With the advances in information technology, the widespread use of Internet, mobile telephony and other inexpensive computer equipment have made human computer interaction (HCI) a regular activity in everyday life (George et al., 2001). The automatic facial expression recognition (FER) has been studied worldwide in the last twenty years. It has become a hot spot in the computer vision and pattern recognition community. In spite of much effort made on many algorithms, such as PCA and LDA to facilitate a more intelligent and smart human machine interface of multimedia products (George et al., 2001), FER remains a tough problem, due to its relatively low discriminating rate and weak robustness to occlusions and corruptions.

GLCM defines the occurrence of the gray level pixel of an image. It is one of the simplest matrix methods to extract the texture features. This statistical approach provides useful information of the neighboring pixels about the relative position in an image (Robert Haralick et al., 1973). For extracting the feature vectors for face classification from GLCM, two methods have been used. Haralick feature extraction is the first method to form the feature vector, whereas the second method converts the matrix into a vector by directly using GLCM which can be used as a feature vector for the classification process. The output performance of the GLCM based recognition is comparatively higher than the techniques such as PCA and LDA respectively (Eleyan and Demirel, 2009).

GLCM is also applied for fingerprint recognition to extract the statistical properties and further processing is done in recognizing the images from the extracted features. It clearly depicts that GLCM can be used to extract the statistical features in any image for the process of recognition (Ali et al., 2011).

For estimating the similarity between the images, 14 statistical features are extracted from the different GLCM (gray level co-occurrence matrices) (Robert Haralick et al., 1973). But the most widely used properties in the proposed work are energy, entropy, contrast and inverse difference. A face recognition technique that integrates KPCA (kernel principal component analysis) and HRBF (hierarchical radial basis function) network classification model was proposed. A set of image pre-processing techniques like geometrical transformation, edge detection and histogram equalization are used for the purpose of improving image quality. KPCA extracts features and HRBF identify the faces. For acceleration of HRBF network convergence and for improving the solution quality, the PSO (particle swarm optimization) and the ECGP (extended compact genetic programming) is applied to optimize the HRBF network structure and parameters (Jin et al., 2007).

From the above literature it is clearly understood that the GLCM have been considered an efficient algorithm for extracting the statistical features in any recognition process. There are various techniques available for face recognition which outperforms high recognition rate. As a new approach we integrated face recognition along with expression identification using GLCM with KPCA and LTP with SVM.. In this paper, first the GLCM feature vectors for the database images and the query image are extracted and using the Euclidean distance transform the images are matched. Only top ten images that are similar to the feature vectors are sorted in the ascending order while the KPCA is applied only to these images for face recognition, later LTP features are extracted and classified using SVM to identify the facial expression of

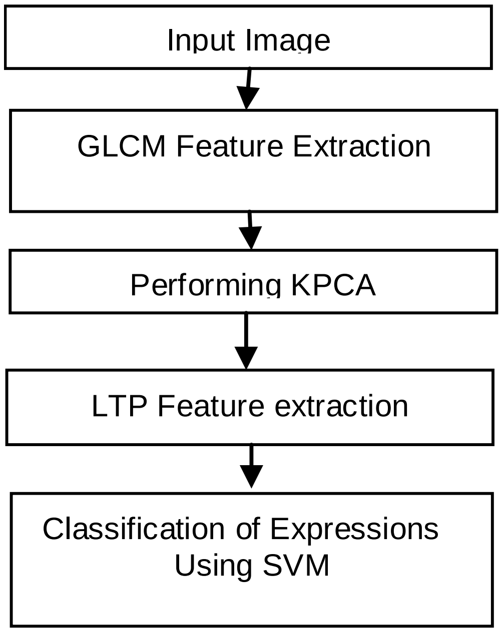

Figure 1. Block diagram of the proposed method.

the given key image.

PROPOSED METHOD

The proposed method uses the combination of Gray Level Co-occurrence Matrix and KPCA for authentication and increases the overall recognition rate of the system with minimum false acceptance rate and false rejection rate (FAR and FRR). Both GLCM and KPCA are integrated to increase the accuracy of the recognition system.GLCM features are extracted from all the images in the database and images are sorted in ascending order, the images having equivalent energy values to that of the input image are sorted. Then storing of the first ten images is done in performing KPCA. LTP features will be extracted from the images after KPCA operation and the expression identification is done.

Though there are 14 statistical properties to be extracted , only four widely used properties such as energy, entropy, contrast and inverse difference moment are used in the proposed algorithm to reduce the computational complexity involved. The flow of the proposed method is shown in Figure 1.

Proposed algorithm

Step 1: Grayscale image is obtained from the color image, and then the image co-occurrence matrix is generated.

Step 2: Then the following equations is used to compute the four texture properties.

$$Energy, E = \sum_x \sum_y P(x,y)^2 \quad (1)$$

$$Entropy, S = \sum_x \sum_y P(x,y) \ \log P(x,y) \quad (2)$$

$$Contrast, I = \sum_x \sum_y (x-y)^2 P(x,y) \quad (3)$$

$$Inversedifference, H = \sum_x \sum_y \frac{1}{1+(x-y)^2} P(x,y) \quad (4)$$

Step 3: GLCM features are extracted for both the database images and the query image.

Step 4: Similarity feature vectors are calculated using the Euclidean distance classifier and accordingly the database images are sorted in the ascending order with reference to the input image and the first ten images are separately stored in a separate database.

Step 5: Now, the snapshot method of the Eigen face is applied only to the sorted ten images of the above process, which highly reduces the computational time, thereby increasing the accuracy of the recognition.

Step 6: For the output image after PCA operation, LTP features will be extracted and classified for the expression identification using SVM.

Thus the proposed method uses GLCM (Gray level co-occurrence matrix) to classify the images according to the four statistical feature values. The classified images are then performed with the snapshot method of the Eigen face for authentication and verification.

Face recognition using KPCA

Kernel principal component analysis (KPCA) tries to overcome the disadvantages by extracting features of face image in high-dimensional spaces. Nonlinear extraction that is closely related to methods applied in support vector machines and so on is done in KPCA. More suitable feature sets for categorization are extracted by KPCA than classical PCA. Good dimensional reduction and better performance are achieved by KPCA than PCA. The block diagram of face recognition by using KPCA is shown in Figure 2.

Pre-processing

Preprocessing is done to make the images suitable for the purpose of recognition. The performance of recognition is improved by preprocessing. The following are the steps in preprocessing:

Noise reduction: All the unwanted noise in the image is removed by performing noise reduction process. Salt and pepper noise which is usually present in all the images is eliminated by this process.

Histogram equalization: The visual appearance of the input image is enhanced by histogram equalization. Firstly the noise is removed and then histogram equalization are applied so that the visual appearance of the input image is enhanced.

Discrete wavelet transforms

After preprocessing, the image is made to undergo the process of discrete wavelet transform. It is a type of signal representation that gives the frequency content of the signal at a particular time or spatial location. A good localization, both in time and frequency domain is obtained by this process. As the processing of image in special domain is more complicated, the image is converted to the

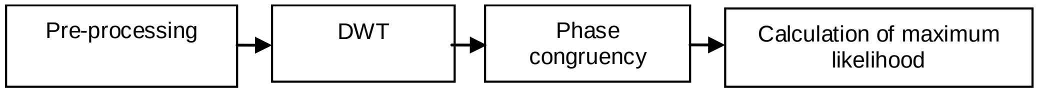

Figure 2. Steps in KPCA method.

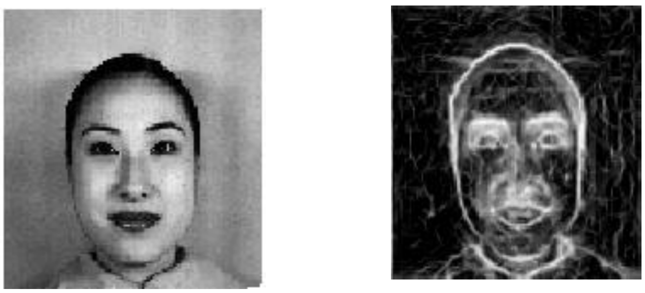

Figure 3. Image before and after phase congruency extraction.

Figure 4. The sample images of the JAFFE database that have been excluded the non-face area.

frequency domain. The image possessing frequency or spectral information has more data to be processed.

Phase congruency

It is a method of edge detection which is immune against illumination and contrast changes. Phase congruency also measures the significance in an image. An absolute measure of feature points is provided by phase congruency because of its dimensionless property and invariant property. It is independent and invariant to changes in image brightness or contrast. The proposed method applies phase congruency to the image obtained after discrete wavelet transform as shown in Figure 3.

After the features are extracted by phase congruency, the background is eliminated and only edges are taken into consideration.

Calculation of Euclidean distance

A covariance matrix is constructed after taking phase congruency in the proposed method. Then Eigen values and Eigen vectors of the matrix are calculated by processing the covariance matrix. The next step is the calculation of the maximum likelihood value from the Eigenvalues. A threshold value is introduced in the calculation of maximum likelihood value and this threshold value is predicted by testing with different values. If the value of maximum likelihood is greater than 1, then the image is authorized and if it is lesser than one, then it is unauthorized.

Figure 5. Image before and after Histogram equalization.

LTP feature extraction

The LTP Feature extraction includes four steps, viz:

Cropping: This is a preliminary step used to remove unwanted portions of the image and to keep only the region of interest. This is required, as the unwanted non ROI parts affect the overall recognition rate of the system. Figure 4 shows the sample of the database used in our approach after cropping. Once the cropping is done, the images undergo the process of histogram equalization.

Histogram equalization: Histogram equalization based on block division is performed on the temporary images where the images are divided into sub-blocks. Each sub-block of the temporary images may have different block sizes from each other. Secondly, the contrast factors of all equalized temporary images are calculated and a global contrast enhancement algorithm is applied by selecting the temporary image possessing the largest contrast factor. The selected equalized temporary image is used to extract the global equalization function which is applied to the original image. It can be seen that a visually comfortable result image is produced by the proposed algorithm as shown in Figure 5.

Feature vector and extraction (LTP): In general, feature extraction is used to reduce the amount of source required to describe any data with accuracy. Analysis with large number of variables will be the major problem because it needs high computation power and large memory which always over fits the training sample and poor generalization of new samples. Textural features of the images using LTP (Local Ternary Patterns) which is the combination of two LBP can be created in the following way.

The examined window is divided into cells.

i) Compare each pixel with its 8 neighboring pixels in the clockwise or anti-clockwise direction.
ii) If the value of the center pixel is greater than its neighbor, "1" is written. On the contrary if it is lesser, then "0" is written. An 8 digit binary value which is then converted to decimal value is obtained.
iii) The histogram is computed over the cell, where the frequency of each "number" occurs.
iv) The histogram is then normalized.
v) The feature vector for the window is obtained by concatenating normalized histograms of all cells.

The LBP code which is a binary code is extended to a 3 level value and is called LTP in which gray levels in a zone are quantized to

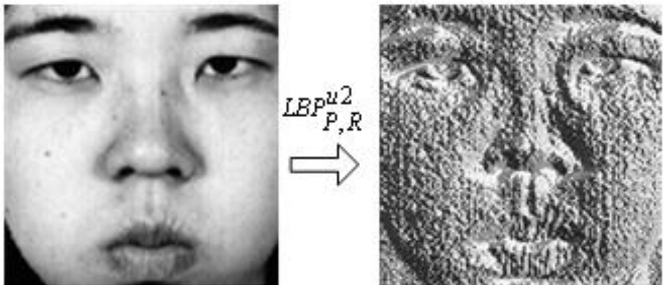

Figure 6. The instance of LBP processing of facial expression image.

Figure 7. JAFFE database.

Figure 8. GUI Performing PCA technique with GLCM feature extraction for face verification with LTP technique for expression identification.

zero (that is, if the values are same it is taken as "0") and gray levels having values above and below compared with the center pixel are quantized to "1". Three level value codes are obtained by user specific threshold and hence it is more resistant to noise. The image after undergoing LTP operation is shown in Figure 6.

Classification (SVM): SVM is a type of the pattern classification method based on the statistical learning theory, and designed to minimize the construction risk. It not only distinguishes the class, but also finds the best separation line between the two classes. For higher dimensional data, SVM find a best classification hyper plane.

As the SVM undergoes a binary classification problem, it is commonly referred to as multiclass problem. This type of problems is solved by creating a new multiple classification mold, however this is complex in calculation, and hard to implement. Hence this problem can be resolved by using many sub-classifiers such as binary classifiers. The two regular strategies to form a multiclass classifier from a series of binary classifiers are OAO (one against one) and OAA (one against all). Looking into the issue of multi-classes classification, the most popular strategy used is "one against- all SVM". In the case of "k classes" data samples, SVM binary model is used by the OAA-SVM classifier for separating the classes and the rest of them.

$$\min_{w,b,\xi} \frac{1}{2}\|w\|^2 + C\sum_i \varepsilon_i \quad (5)$$

or all

$$s.t\left\{ y_{i(w.x_i - b)} \geq 1 - \varepsilon_i \right.$$

$$\varepsilon_i \geq 0 \quad (6)$$

Here w denotes the normal vector that is perpendicular to the hyper plane and separates class y from the others, I ξ are the slack variables. The slack variable is the measure of how much misclassification took place. x and b is an offset scalar. The following rule is applied to obtain the final classification of each instance:

$$y_i = \arg\max_{k(1.....k)} \left(w_i^T y_i \left(x_i \right) + b_i \right) \quad (7)$$

DATABASE USED WITH OUTPUT GUI

The face image database used here is JAFFE having variation in facial expressions. Figure 7 shows the sample face images from the JAFFE database.

JAFEE database

The database consists of total 213 images of 7 facial expressions taken in the frontal view namely angry, happy, sad, surprise, fear, and disgust and neutral, posed by 10 Japanese female models as shown in Figure 7.

The output GUI Performing PCA technique with GLCM feature extraction for face verification with LTP techniques for expressing is shown in Figure 8.

PERFORMANCE ANALYSIS

The proposed method is analyzed with a JAFFE database to evaluate the following performance:

1) Analysis of false acceptance rate, false rejection rate and recognition rate of face and expression identification using different threshold values.
2) Comparison of recognition rate of the proposed method for face recognition with existing methods.

Analysis of false acceptance, false rejection and recognition rate of face and expression identification using different threshold values

The performance of false acceptance and false rejection

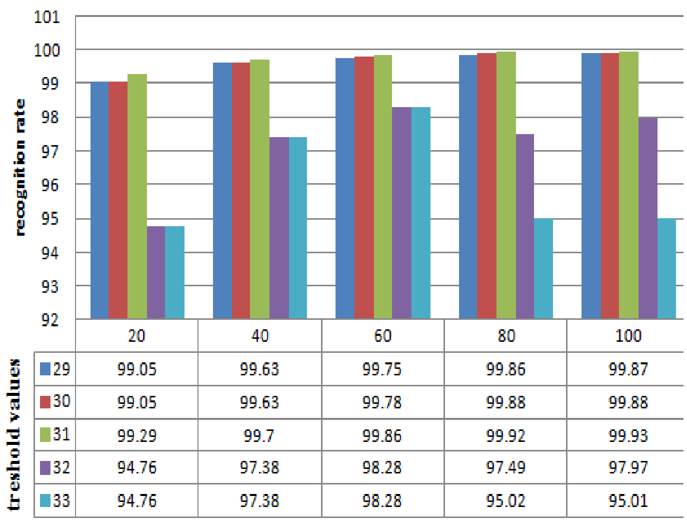

Figure 9. Recognition rate vs no. of images for different threshold values.

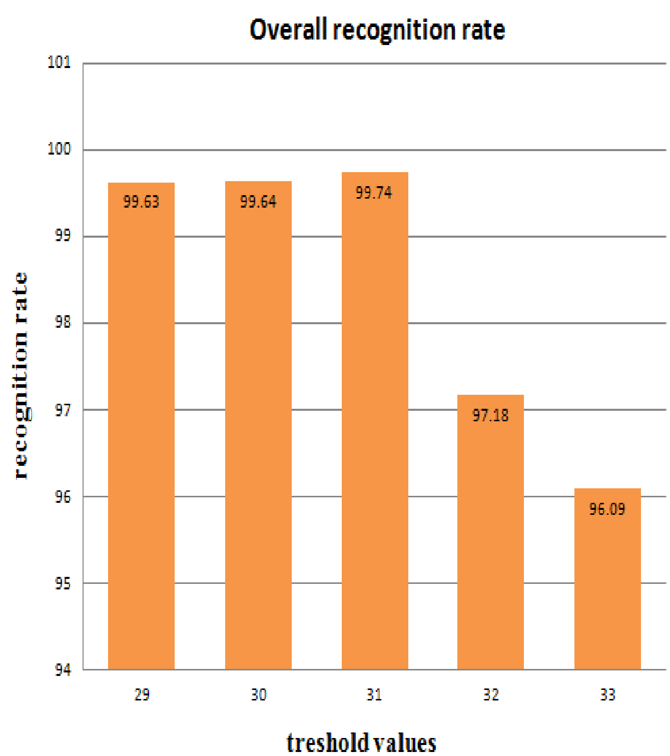

Figure 10. Performance analysis of overall recognition rate for different threshold values.

rate of face and expression identification using different threshold values is analyzed by setting different threshold values for the recognition algorithm.

Table 1 depicts the FAR and FRR values for the different threshold levels. First, looking into the threshold value of 30, it can be seen that the system is not suitable for efficient face recognition and expression identification. Hence a value 31 is tested with the algorithm and the values are analyzed as shown in the above table. The FRR decreases to some extent but still have a non ideal case of greater FRR. Finally the same process is repeated for a threshold value of 32 and the values are plotted. It is clearly evident that, to the threshold value of 32, FRR decreases compared to that of the previous threshold value 31 whereas the FAR increases. The threshold value of 31 or 32 can be adapted to the system but to be specific in choosing the threshold value, analysis of recognition rate is done with all the threshold values and different size of the input image database as shown in Figure 9.

The error rates FRR and FAR are interrelated and together they define the recognition rate or accuracy of a verification system.

$$Accuracy = \frac{(1-FRR)+s(1-FAR)}{1+s}$$

Where, *s* is a scalar skew parameter which is common between authorized and unauthorized users. Here the skew parameter taken is the number of input images given. The FAR and FRR can be adjusted by altering a threshold on the confidence scores. Figure 9 shows the analysis of recognition rate with all the threshold values and different size of the input image database. Also it is noticed that for the threshold value of 31, the recognition rate is comparatively high for all sizes of image databases. Hence the value of 31 is considered to be the appropriate threshold value of the system to perform with high percentage of recognition accuracy. Also the performance analysis of overall recognition rate for different threshold values is shown in Figure 10.

Performance analysis of recognition rate for face recognition using different methods in the literature

Table 2 clearly states that the rate of recognition is 99.7396% for the proposed method which is relatively high when compared to all the other available existing methods in the literature. This proves the efficiency of the proposed method.

Conclusion

Thus the proposed method based on Gray Level Co-occurrence matrix and Snap Shot Method of the Eigen Face using KPCA experimentally proves that it achieves a minimum FAR and FRR for an optimum threshold value of 31 and a higher recognition rate and a lesser computational time for the images with different facial expressions and also with different tilt angles when compared with the other existing methods. Most of the applications like: forensic applications, criminal investigations, secure electronic banking, and mobile

Table 1. Performance analysis of FAR and FRR of different threshold values.

No. of input images from JAFFE database	Analysis of FAR and FRR for different threshold values					
	For threshold value = 30		For threshold value=31		For threshold value =32	
	FAR	FRR	FAR	FRR	FAR	FRR
20	0	20	0	15	5	10
40	0	15	0	12.5	2.5	7.5
60	0	13.34	0	8.34	1.67	5
80	0	10	0	6.25	2.5	3.75
100	0	12	0	7	2	5

Table 2. Recognition rate for the proposed and existing algorithms in the literature.

Recognition method	*PCA [32]*	*LDA [32]*	*GLDA [32]*	*IGLDA [32]*	*Proposed method [GLCM + KPCA & LTP+SVM]*
Recognition rate (%)	88.92	92.50	95.11	97.01	99.7396

phones, video surveillance, credit cards, secure access to buildings. For different expressions and poses, the proposed method works well for JAFFE database with high recognition rate.

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