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Performance Comparison of Recognition Techniques to Recognize a Face under Different Emotions

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ABSTRACT: *A human face is a major identity mark but it is also a good communicator and hence exhibits/reflects various emotions like happy, sad, anger, disgust, and surprise. In situation where we want to find a suspected person, the person may be in any mood depicting any facial expression (happy, sad, anger, disgust, surprise and neutral, but in the dataset there may be only one image depicting any one facial expression. The main objective of this paper is to identify a suspected person (in any mood) against the neutral images stored in the database. Hence the main objective of this paper is to evaluate performance of the Principle Component Analysis (PCA), Coefficient of Correlation (CoC) and Structural Similarity Index Metric (SSIM) individually as well as with DWT to recognize the same face with different Expressions. This paper analysis the performance of different techniques on face recognition under different emotions. For this purpose, the performance of all techniques has been analyzed on the Japanese Female Facial Expression (JAFFE) database. Results demonstrate that SSIM with the combination of Discrete wavelet transform (DWT) at level-4 provides better recognition rate.*

Keywords: *Coefficient of Correlation, Face Recognition Rate, Principle Component Analysis, Structural Similarity Index Metric.*

I. INTRODUCTION

Human are generally recognized by their faces. The emotions and intentions of human beings are mostly communicated through facial expressions. A face recognition technique automatically identifies a person by camparing features of input face image with existing images which are present in database [3]. Facie recognitions systems are very usefull for security purpose and authentication of user etc. Research on this technology started in the mid 1960s.. in 1990, paul Ekman [3] purposed the Facial Action Coding System (FACS) for describing expressions, such as happy ,anger, fear, disgust, neutral, sad, and surprise. James J. Lien and Takeo Kanade[4] have used affine transformation for image normalization and facial feature point tracking method for feature extraction to developed automatic facial expression recognition system . They used Hidden Marko Model for classification. The Maja Pantic and Marian Stewart [5] have presented the machine analysis of facial expressions. Praseeda Lekshmi. V et.al [11] proposed an analysis of face expression using neural network and gabor wavelets. The gabor wavelet is used as a feature extraction method and neural network is used for classification. G. U. Kharat et al.[6] presented Discrete Cosine Transform (DCT), Fast Fourier Transform (FFT), and Singular Value Decomposition (SVD) techniques for feature extraction . Fourier Transform (FFT) and Singular Value Decomposition (SVD) are used to extract the useful features for emotion recognition from facial expressions. Renuka R. Londhe et al. [22] used several properties associated with the face for recognition of facial expression .the statistical parameters has been used to compute results. Expression recognition has been performed with artificial neural network [22].

II. FACE EXPRESSION RECOGNITION TECHNIQUES

A. Principal Component Analysis (PCA)

PCA is very popular technique and used for extraction of features, recognition of pattern, data compression and pre-processing for images. It is also capable for dimension reduction of an image[1]. PCA algorithm extracts orthonormal linear projections, called eigenvectors that maximize the scatter of all projected samples. It enables one to represent an image as linear combination of orthonormal vectors, called eigen pictures [4].The step by step instructions along with the formulas for the recognition of faces using Principal Component Analysis (PCA) are as follows[13]:

STEP 1: Take M face images and make a set S.

$S = \{\Gamma_1, \Gamma_2, ..., \Gamma_M\}$ (1)

STEP 2: calculate the mean

$\Psi = \frac{1}{M}\sum_{n=1}^{M}\Gamma_M$ (2)

STEP 3:obtain Φ by subtracting the mean from Original Image

$\Phi = \Gamma_i - \Psi$ (3)

STEP 4: Calculate the covariance matrix

$$C = \frac{1}{M}\sum_{n=1}^{M}\Phi_n\ \Phi_n^T \quad (4)$$

$A = \{ \Phi_1, \Phi_2, \ldots, \Phi_n\}$ (5)

STEP 5: Calculation of the eigenvectors and eigen values of the covariance matrix and select the principal components.

$\omega_k = \mu_k^T(\Gamma - \Psi)$ (6)

Where ω = weight, μ = eigenvector, r = new input image, Ψ = mean face.
The weight vector $\mathbf{\Omega^T}$ is given by [13]

$\Omega^T = [\omega_1, \omega_2, .. , \omega_M]$ (7)

B. *Coefficient of Correlation (CoC)*

Correlation is a method for establishing the degree of probability that a linear relationship exists between two measured quantities. In 1895, Karl Pearson defined the Pearson product-moment correlation coefficient, r. it is commonly used in statistical analysis, pattern recognition and image processing. For monochrome digital images, the Pearson's CoC is defined as [12]:

$$\mathrm{CoC} = \frac{\sum_i (x_i - x_m)(y_i - y_m)}{\sqrt{\sum_i (x_i - x_m)^2}\sqrt{\sum_i (y_i - y_m)^2}} \quad (8)$$

Where, x_i is the intensity value of ith pixel in first image and y_i are intensity values of i^{th} pixel in second image. x_m and y_m are mean intensity values. The correlation coefficient has the value r =1 if the two images are identical, r= 0 If they are completely uncorrelated and r= -1 if they are completely anti-correlated [12]. The CoC is a pure number and it does not depend upon the units in which the variables are measure. The Pearson product-moment CoC is a dimensionless index, which is invariant to linear transformations of either variable [2].

C. *Structural Similarity Index Metrics (SSIM)*

SSIM is an image quality assessment measure. The quality of a test image is evaluated by comparing it with a reference image [5]. It is also used to measure the similarity between the structure of test image and stored database images for the recognition of images. This task is separated into three comparisons: luminance, contrast and structure. First, the luminance of each signal is compared. The mean intensity of discrete signal is as follow [6]:

$$\mu_x = \bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \quad (9)$$

The luminance comparison function *l*(x; y) is then a function of μ_x and μ_y:

$l(x; y) = l(\mu_x, \mu_y$ (10)

The mean intensity is then removed from the signal. The resulting signal x- μ_x corresponds to the projection of vector x onto the hyper plane of

$\sum_{i=1}^{N} x_i = 0$ (11)

An unbiased estimate in discrete form is given by:

$\sigma_x = \left(\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu_x)^2\right)^{1/2}$ (12)

The contrast comparison *c*(x, y) is then the comparison of σ_x and σ_y :

$c(x,y) = c(\sigma_x, \sigma_y)$ (13)

The two signals are being compared have unit standard deviation. The structure comparison s (x, y) is conducted on these normalized signals:

$$S(x,y) = S(\frac{X-\mu_x}{\sigma_x}, \frac{Y-\pi_y}{\sigma_y}) \quad (14)$$

Finally, the three components are combined to yield an overall similarity measure [6]: Note that the three components are relatively independent. For example, the change of luminance and/or contrast has little impact on the structures of images. Similarity measure should satisfy the following conditions [6]:

1. Symmetry S(x,y)=S(y,x): i.e. by exchanging the order of input signals similarity measurement should not be affected.
2. Boundedness: S(x,y) ≤ 1 as an upper bound can serve as an indication of how close the two signals are to being perfectly identical.
3. Unique maximum: S(x,y) = 1 if and only if x = y .

The luminance comparison function is [6]:

$$l(x,y) = \frac{2\mu_x\mu_y + C_1}{\mu_x^2 + \mu_y^2 + C_1} \quad (16)$$

Where the constant C1 is included to avoid instability when $\mu^2_x + \mu^2_y$ is very close to zero. Its chosen value is:

$$C_1 = (K_1 L)^2 \quad (17)$$

Where L is the dynamic range of the pixel values and is a small constant. The SSIM index in specific form will be [6]:

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + C_1)\,(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2} \quad (18)$$

III. DISCRETE WAVELET TRANSFORM (DWT)

Jean Morlet introduced a new mathematical tool for seismic wave analysis [8]. The wavelet transform concentrates the energy of the image signals into a small number of wavelet coefficients. It has good property of time-frequency localization [11]. The wavelets analyze the signals according to scale. It was developed as an alternative to the short time fourier to overcome problems related to its frequency and time resolution properties [9]. The Wavelet transform decomposes a signal into four sub bands named LL, LH, HL and HH. LL is the low frequency sub-band of the original Image as it corresponds to the low-frequency components in both vertical and horizontal directions of the original image and it contributes to the global description of an image. Because the sub band LL is a most stable sub band, so it is used to represent features of an image [10]. In this work, LL sub band is used in combination with other algorithms for feature extraction. As size of LL sub band is half the size of original image, so computation complexity reduces. Also the most of the energy is concentrated in the LL sub band which may lead to better recognition.

IV. RESEARCH METHODOLOGY

The following methodology has been used to implement techniques.

D. Basic steps of face recognition using PCA method

Step 1: Read the test image and apply DWT to get LL sub band.
Step 2: Read the image from the database and apply DWT to get LL sub band
Step 3: Calculate the eigenvectors of test image and that of stored database image.
Step 4Calculate the Euclidean distance between test image and stored database images.
Step 5: Read the image from stored database with minimum Euclidean distance and check for successful recognition.
(a) If the test image is recognized successfully then read recognized image and STOP.
(b) Go to step 1 to repeat the same procedure for different images until we get satisfied results.

E. Basic steps of face recognition using CoC and SSIM method

Step 1: Read the test image and apply DWT to get LL sub band.
Step 2: Read the image from the database and apply DWT to get LL sub band
Step 3: Calculate the CoC/SSIM value between LL sub band of test image and that of stored database image.

Step 4: Check whether this calculated value is more than the previously stored value.
(a) If it is less than previously stored value i.e. (Calculated Value < Previous Value), then go to step 5(b).
Step 5: Check for successful recognition.
(a) If the test image is recognized successfully then read recognized image and STOP.
(b) Go to step 1 to repeat the same procedure fort different images until we get satisfied results.

V. IMPLEMENTATION

The implementation of all techniques has been performed in MATLAB tool. The Japanese Female Facial Expression (JAFFE) database has been used for testing which contains 213 images of of 7 face expressions including neutral posed by 10 Japanese female models. In this experiment, all images have been resized to a uniform dimension of 180 x 200. There are 213 test images which have been compared with 10 images (neutral expression) present in database. The performance of all the image recognition methods is evaluated in terms of metrics recognition rate.

VI. RESULT AND DISCUSSION

In experimental results it has been found that neutral expression has maximum recognition rate. But when neutral expression is compared with other expressions the result varies in recognition rate with respect to expressions (happy, sad, anger, disgust, surprise) when a happy face is compared with neutral face then values get changed near lips. There are many variations of happy expressions. In some images lips are very less stretched. In some images lips are stretched in large area and even in some images teeth are visible. Similarly there are many variations in sad, disgust, surprise and angry mood also which leads to variation in contrast measurement. Hence it is necessary to provide uniformity to all pixels. The Table-1 shows the performance of all techniques without combining DWT. It has been found that performance of CoC and SSIM has been increased with DWT. The Table-2 Shows the results when DWT has been applied at level 2. Furthermore it has been observed that when DWT has been applied with Level 4, it has performed better than Level 1, 2 and 3 which has been shown in Table-4 because it yields smoother LL subband. SSIM recognize the images based on a) contrast. b) Illumination c) structure. d) and then overall image comparison..DWT at level 4 provides the uniformity to all Features.

Table-1: Recognition of images with JAFFE Database

Methods	Total images	Recognized Images	Recognition Rate
PCA	213	123	57.74%
CoC	213	167	78.40%
SSIM	213	175	83.56%

Table- 2: Recognition of images with DWT Level-2 with JAFFE Database

Methods	Total images	Recognized Images	Recognition Rate
PCA	213	62	29.10%
CoC	213	172	80.75%
SSIM	213	178	83.56%

Table-3: Recognition of images with DWT Level-4 with JAFFE Database

Methods	Total images	Recognized Images	Recognition Rate
PCA	213	62	29.10%
CoC	213	177	83.09%
SSIM	213	185	86.85%

Hence combination of SSIM and DWT (Level-4) yields best recognition rate as compared to other techniques. From Table-4 it has been observed that all of neutral faces have been recognized by SSIM with DWT at level-4, while recognition rate of sad and disgust expression is very low. The overall performance of all techniques has been shown in Fig 1.

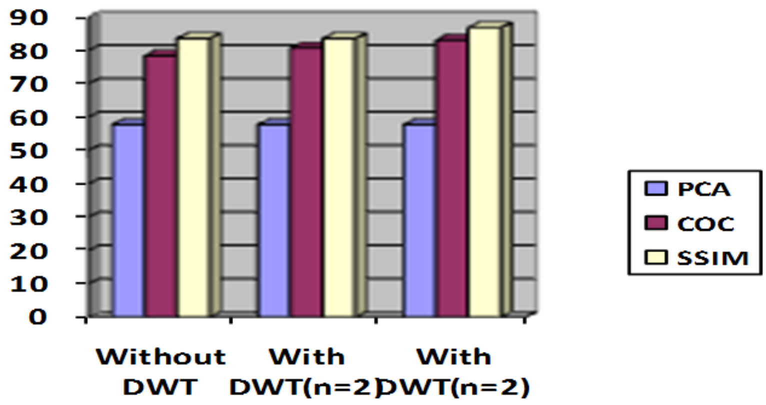

Fig-1 Bar Chart of Image Recognition Rate with JAFFE Database

Table-4: Behavior of SSIM with various Expressions

Expressions	Images not Recognized		
	SSIM	*SSIM + DWT (Level-2)*	*SSIM + DWT (Level-4)*
Neutral	2	1	0
Happy	3	4	3
Sad	10	10	9
Angry	5	5	4
Surprise	8	7	5
Disgust	10	8	7

VII. CONCLUSION

It has been observed that whether PCA is a widely accepted in image recognition systems but it does not work well when different expressions of face are compared with only neutral expression of face. The only neutral expression images are stored in database to reduce the storage space and to enhance the performance of database. The COC and SSIM have performed well on the same dataset and it has been observed that DWT at level-4 has enhanced their performance. The result shows that SSIM with DWT yields better recognition rate. It has been observed that maximum of neutral faces have been recognized by SSIM.

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