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Illumination Invariant Face Recognition System

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Abstract— **A face recognition system is a computer application for automatically identifying or verifying a person from a digital image . Face recognition techniques have always been a very challenging task in real life applications because of the variation in the illumination, occlusion, facial expression and pose of the face images. This paper presents an efficient illumination invariant face recognition system using Discrete Cosine Transform (DCT) and Principal Component Analysis (PCA). A discrete cosine transform is employed to compensate for illumination variations in the logarithm domain. PCA is used for recognition of face images. Cropped Yale Face B Database with 65 illumination variations is used in this approach.**

***Keywords*— Face Recognition, Discrete Cosine Transform (DCT), Principal Component Analysis (PCA), Logarithm transform, Illumination normalization.**

I. INTRODUCTION

With the rapid increase of computational powers and availability of modern sensing, analysis and rendering equipment and technologies, computers are becoming more and more intelligent. Many research projects and commercial products have demonstrated the capability for a computer to interact with human in a natural way by looking at people through cameras, listening to people through microphones, understanding these inputs, and reacting to people in a friendly manner.

The strong need for user-friendly system that can secure out assets and protect our privacy without losing our identity in a sea of numbers is obvious. At present, one needs a PIN to get cash from an ATM, a password for a computer, a dozen others to access the internet, and so on. Although extremely reliable methods of biometric personal identification exist, e.g. fingerprint analysis and retinal or iris scans, these methods rely on the cooperation of the participants, whereas a personal identification system based on analysis of frontal or profile images of the face is often effective without the participant's cooperation or knowledge.

A first step of face recognition system is detecting the locations in images where faces are present. Face detection is a computer technology that determines the locations and sizes of human faces in arbitrary (digital) images. It detects facial features and ignores anything else, such as buildings, trees and bodies. Face detection can be regarded as a specific case of object-class detection. Face detection can be regarded as a more general case of face localization. In face localization, the task is to find the locations and sizes of a known number of faces.

A facial recognition system is a computer application for automatically identifying or verifying a person from a digital image or a video frame from a video source. One of the ways to do this is by comparing selected facial features from the image and a facial database. **Face recognition** is the biometric identification of a human's face and matching the image against a library of known faces. It has become the important area of research in computer vision and one of the most successful applications of image analysis and processing. Recently, the importance of face recognition has been increasingly emphasized in the security since most of the popular areas are covered under cameras in various applications such as bankcard identification, access control, Mug shots searching, security monitoring, and surveillance system, is a fundamental human behaviour that is essential for effective communications and interactions among people [1].

The challenges in face recognition system.

It has already been stated that face recognition techniques have always been a very challenging task for researches because of all difficulties and limitations. Human faces are not an invariant characteristic; in fact, a person's face can change very much during short periods of time and because of long periods of time. One problem of face recognition is the fact that different faces could seem very similar; therefore, a discrimination task is needed. On the other hand, when we analyse the same face, many characteristics may have changed. The challenges associated with face recognition can be attributed to the following factors:

Pose: The images of a face vary due to the relative camera-face pose (frontal, 45 degree, profile, upside down), and some facial features such as an eye or the nose may become partially or wholly occluded.

Presence or absence of structural components: Facial features such as beards, moustaches, and glasses may or may not be present and there is a great deal of variability among these components including shape, colour, and size.

Facial expression: The appearance of faces is directly affected by a person's facial expression such as smiley faces, surprise faces, angry faces etc.

Occlusion: Faces may be partially occluded by other objects. In an image with a group of people, some faces may partially occlude other faces or objects such as mask, cap, spectacles etc. Faces with partially occlusion have less information to recognition process.

Imaging conditions: When the image is formed, factors such as lighting (spectra, source distribution and intensity) and camera characteristics (sensor response, lenses) affect the appearance of a face.

II. Image Pre-processing Methods

Pre-processing images is of vital importance in face recognition. Using a good method of pre-processing can improve the face recognition rate. Pre-processing methods are filtering techniques that can reduce the effect of lighting conditions and improve image quality. Here, Histogram Equalization, Rank Normalization, and Discrete Cosine Transform (DCT) have been used as pre-processing methods.

A. Histogram Equalization

The Histogram Equalization enhances the contrast of images by transforming the values in an intensity image so that the histogram of the output image approximately matches a specified histogram. A processed (output) image is obtained by mapping each pixel with level **r** in the input image into a corresponding pixel with level **s** in the output image.

B. Rank Normalization

The rank normalization function applies rank normalization to the pixel intensity values of an image. This means that all pixels in an image are ordered from the most negative to the most positive. After the ordering the first pixel is assigned a rank of one, the second the rank of two,..., and the last is assigned a rank of N, where N is the number of pixels in the image.

C. Discrete Cosine Transform Normalization

DCT normalization is a three steps process which is combination of Logarithm transform, Discrete cosine transform and Illumination Compensation [3].

Step 1: Logarithm transform.

Logarithm transform is often used in image enhancement to expand the values of dark pixels. The illumination compensation should be implemented in the logarithm domain. The image gray level $f(x, y)$ can be assumed to be proportional to the product of the reflectance $r(x, y)$ and the illumination $e(x, y)$,

$$\text{i.e., } f(x, y) = r(x, y) \cdot e(x, y) \qquad (1)$$

Since the reflectance is a stable characteristic of facial features, the goal is to recover the reflectance of faces under varying illumination conditions. Taking logarithm transform on (1),

$$\log f(x, y) = \log r(x, y) + \log e(x, y). \qquad (2)$$

It follows from (2) that in the logarithm domain, if the incident illumination $e(x, y)$ and the desired uniform illumination e' are given, we have

$$\begin{aligned}\log f'(x, y) &= \log r(x, y) + \log e' \\ &= \log r(x, y) + \log e(x, y) - \square(x, y) \\ &= \log f(x, y) - \square(x, y) \qquad (3)\end{aligned}$$

Where

$$\square(x, y) = \log e(x, y) - \log e'$$

and $f'(x, y)$ is the pixel value under desired uniform illumination. From (3), we can conclude that the normalized face image can be obtained from the original image by using an additive term $\square(x, y)$ called compensation term which is the difference between the normalized illumination and the estimated original illumination in the logarithm domain.

Step 2: Discrete cosine transform

The DCT is performed on the entire face image to obtain all frequency components of the face image. The 2D $M \times N$ DCT is defined as follows:

$$C(u,v) = \propto(u) \propto(v) \sum_{x=1}^{M-1} \sum_{y=1}^{N-1} f(x,y) \times \cos\left[\frac{\pi(2x+1)u}{2M}\right] \cos\left[\frac{\pi(2y+1)v}{2N}\right] \quad (4)$$

and the inverse transform is defined as

$$f(x,y) = \sum_{x=1}^{M-1} \sum_{y=1}^{N-1} \propto(u) \propto(v) C(u,v) \times \cos\left[\frac{\pi(2x+1)u}{2M}\right] \cos\left[\frac{\pi(2y+1)v}{2N}\right] \quad (5)$$

Where

- $\propto(u) = \frac{1}{\sqrt{M}}$ if $u = 0$
- $\propto(u) = \sqrt{\frac{2}{\sqrt{M}}}$ if $u = 1,2,\ldots\ldots,M-1$
- $\propto(v) = \frac{1}{\sqrt{M}}$ if $v = 0$
- $\propto(v) = \sqrt{\frac{2}{\sqrt{N}}}$ if $v = 1,2,\ldots\ldots,N-1$

Step 3: Illumination compensation

Given a face image, illumination variations can be well compensated by adding or subtracting the compensation term $\square(x, y)$ of (3) in the logarithm domain if we know where illumination variations and important facial features are.

The first DCT coefficient (i.e., the DC component) determines the overall illumination of a face image. Therefore, the desired uniform illumination can be obtained by setting the DC coefficient to the same value,

i.e.,

$$Dct(1,1) = \log(mean) \times \sqrt{M \times N}$$

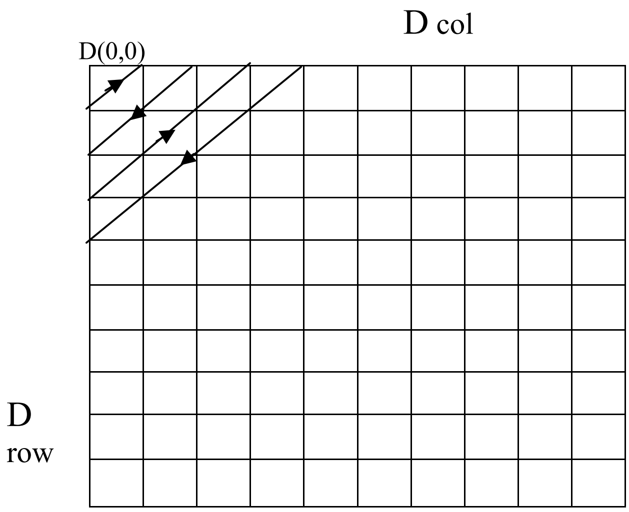

Fig.1. Manner of discarding DCT coefficients

Illumination variations are mainly low frequency components of a face image can be removed simply by setting the low-frequency DCT coefficients to zero. Fig 1 shows that DCT coefficients set to zero in zigzag manner. Finally, we can obtain normalized image by taking inverse DCT.

III. Feature Extraction and Recognition Methods

A. Principle Component Analysis (PCA)

After the completion of pre-processing method, pre-processed image will be given to the PCA for feature extraction and recognition process. Here, result of DCT normalization is better than other pre-processing methods. So, DCT normalized image will be given to the PCA.

Step 1: The first step is to obtain a set S with M face images. Each image is transformed into a vector of size N and placed into the set.

$$S = \{\Gamma_1, \Gamma_2, \Gamma_3, \ldots\ldots\ldots, \Gamma_M\}$$

Step 2: After we have obtained set S, we will obtain the mean image Ψ.

$$\Psi = \frac{1}{M}\sum_{n=1}^{M}\Gamma_n$$

Step 3: Then we will find the difference Φ between the input image and the mean image.

$$\Phi_i = \Gamma_i - \Psi$$

Step 4: We obtain the covariance matrix C in the following manner

$$C = \frac{1}{M}\sum_{n=1}^{M}\Phi_n\Phi_n^T$$
$$= AA^T$$

Step 5: Calculating eigenvectors of the correlation matrix

$$\lambda_k = \frac{1}{M}\sum_{n=0}^{M}(u_k^T\Phi_n)^2$$

$$u_l = \sum_{k=1}^{M} v_{lk}\Phi_k \qquad l = 1, \ldots\ldots, M$$

Where

$$u_l^T u_k = \delta_{lk} = \begin{cases} 1, & if\ l = k \\ 0, & otherwise \end{cases}$$

Step 6: Calculating the signature for each image

$$\omega_k = u_k^T(\Gamma - \Psi)$$

$$\Omega^T = [\omega_1, \omega_2, \ldots\ldots\ldots, \omega_M]$$

B. Recognition Procedure

Step 1: A new face is transformed into its eigenface components. First we compare our input image with our mean image and multiply their difference with each eigenvector. Each value would represent a weight and would be saved on a vector Ω.

Step 2: We now determine which face class provides the best description for the input image. This is done by minimizing the Euclidean distance

$$\varepsilon_k = \|\Omega - \Omega_k\|^2$$

Step 3: The input face is consider to belong to a class if ε_k is minimum. Then the face image is considered to be a known face. Otherwise, the face image is considered as unknown face.

IV. Implementation

First, we have implemented various pre-processing methods (DCT normalization, Histogram Equalization and rank normalization) and their combination to find better pre-processing method. After this, two approaches for face recognition system have been implemented. Results of both approaches have been compared over here.

A. Approach -1

In this approach, input image is directly given to Principal Component Analysis (PCA) for feature extraction and Euclidean distance is used to recognition process

.

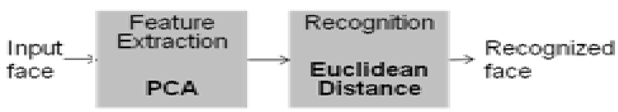

Fig.2. Approach -1

B. Approach-2

This proposed approach presents an efficient illumination invariant face recognition system using DCT Normalization (removing the first *20* coefficients) as a pre-processing method, Principal Component Analysis (PCA) for feature extraction and Euclidean Distance is used to recognition process. The dimensionality of face image will be reduced by the Principal component analysis (PCA) and the recognition will be done by Euclidean Distance.

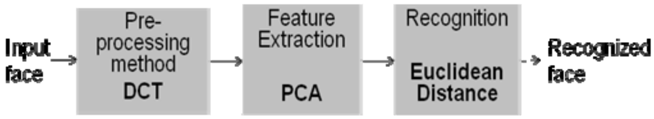

Fig.3. Approach -2

V. EXPERIMENTAL RESULTS

Yale Face Database B

Cropped Yale face Database B is used to evaluate the performance of these approaches [8]. This database contains 65 illumination variation face images for each person. The size of each image is 192 × 168.

A. Result of Pre-processing Methods:

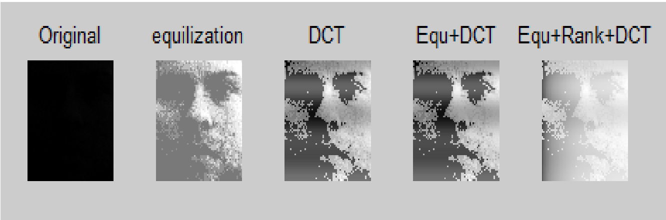

Fig.4. Face with ambient light

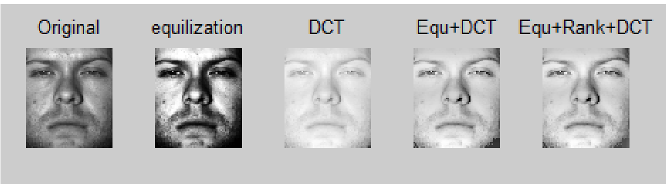

Fig.5. Normal Face

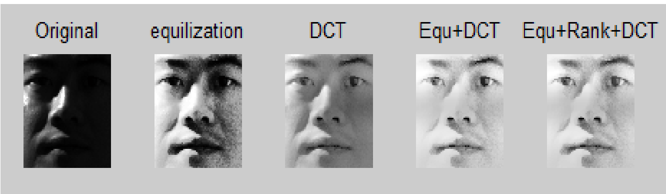

Fig.6. Right side illuminated face

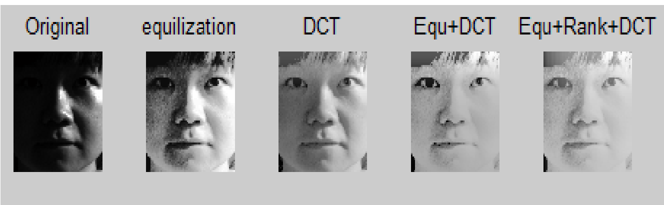

Fig.7. Left side illuminated face

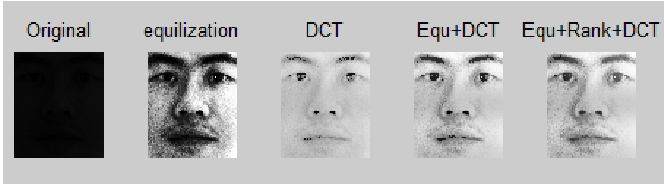

Fig.8. Highly illuminated face

Result shows original image with illumination variation and resulted images which are enhanced by different pre-processing methods for remove illumination. Histogram equalization, rank normalization and DCT normalization pre-processing methods are used. We can analyse from the result that input images with varying illumination have been significantly enhanced using these methods. Here, result of DCT normalization is better than other pre-processing methods. So, DCT normalized image will be given to the PCA for feature extraction and recognition process.

B. Result of Face Recognition System

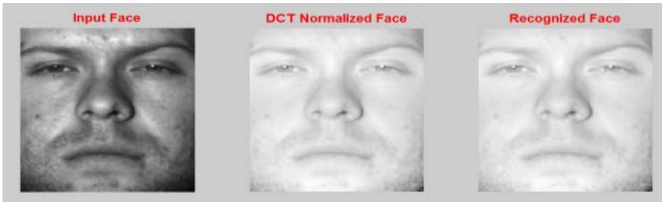

Fig.9. Normal Face Recognition

Fig.10. Left side illuminated face

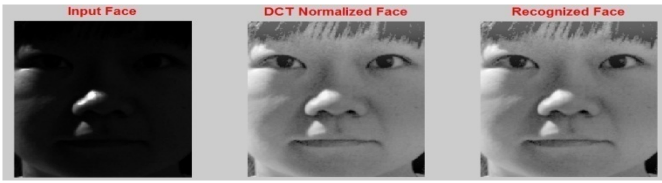

Fig.11. Right side illuminated face.

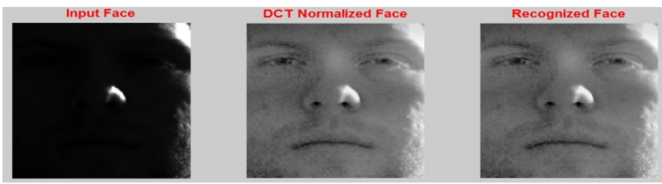

Fig.12. Highly illuminated face.

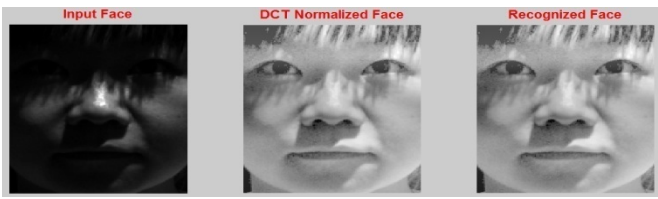

Fig.13. Partially illuminated face.

Fig.14. A case where face recognition system fails.

CHART- I
COMPARISON BETWEEN APPROACH-1 V/S APPROACH-2

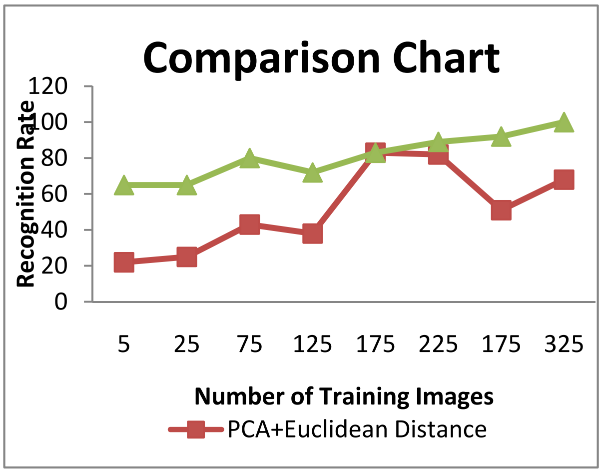

TABLE II
RECOGNITION RATE OF IMPLEMENTED FACE RECOGNITION SYSTEM

Case No.	Number of training images with illumination variation	Number of testing images with illumination variation (for one person)	Number of correctly recognized images (with DCT)	Number of correctly recognized images (without DCT)	Recognition rate in % (with DCT)
1	325	65	65	44	100%
2	275	65	60	33	92%
3	225	65	58	53	89%
4	175	65	54	54	83%
5	125	65	47	25	72%
6	75	65	51	28	80%
7	25	65	42	16	65%
8	5	65	42	14	65%

Table1 shows the result of 8 different cases. Column 2 shows numbers of training images with illumination variation for five people. Here, 65 illumination variations for one person are used in testing which is shown in column 3. Column 4 & 5 describes number of correctly recognized images with DCT and without DCT, respectively. Column 6 shows the recognition rate of the system.

VI. CONCLUSIONS

Conclusion can be done from result of various pre-processing methods that result of DCT normalization is better than all other pre-processing methods used here. An illumination variation under different lighting conditions is significantly reduced by discarding low-frequency DCT coefficients in the logarithm domain. Recognition rate of system using PCA is significantly improved when input image processed with DCT normalization than input image without DCT normalization. This approach is very fast and it can be easily implemented in a real-time face recognition system.

Future work

The dimensionality of face image will be reduced by the Principal component analysis (PCA) and the recognition will be done by the Back propagation Neural Network (BPNN).

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