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FEATURE BASED EIGENFACE METHOD FOR FACIAL RECOGNITION

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Abstract— **Digital image processing techniques visually enhances and statistically evaluates some aspect of an image not readily apparent in its original form. Face is the index of the mind, so the recognition of face is an important aspect in various fields. In this paper we discuss about the feature based recognition and eigenface method for facial analysis. In feature based facial recognition method the importance is given to the facial features (eyes, nose, eyebrows, etc.,), whereas the eigenface method gives preference to the face. By combining both the above methods we obtain "Feature Based Eigenface Method" for facial recognition, due to its superiority in its near real time speed and reasonably simple implementation. Using the feature based eigenface method we can develop a better facial recognition systems for Humanoid robots and for crime investigation.**

I. INTRODUCTION

With the advent of sophisticated computers, digital imaging technology has gained increasing importance in every field. Digital image processing stems from two principal application areas: improvement of pictorial information for human interpretation and processing of image data for storage, transmission and representation for autonomous machine perception. The objective of digital image processing techniques is to visually enhance or statistically evaluate some aspect of an image not readily apparent in its original form.

A **digital image** whose amplitudes are finite and discrete quantities, may be defined as a two dimensional function, f(x,y), where x and y are spatial coordinates and amplitude of f at any pair of coordinates (x,y) is called the intensity or gray level of the image at that point. The 2D continuous image f(x,y) is divided into N rows and M columns. The intersection of a row and a column is termed a pixel.

Image processing operations can be roughly divided into four major categories, **Image Acquisition, Image Compression**, **Image Enhancement and Restoration**, and **Image Feature Extraction**.

Image Acquisition is the entry point of the image recognition process. It is the module where the image under consideration is presented to the system. An acquisition module can request a image from several different environments.

The process of image acquisition frequently leads (inadvertently) to image degradation. Due to mechanical problems, out-of-focus blur, motion, inappropriate Illumination and noise the quality of the digitized image can be inferior to the original.

Image enhancement operations are processing techniques that serve to enhance or in some way alter the qualities of an image. Enhancement is basically a heuristic procedure designed to manipulate an image to take advantage of some psychophysical aspect of the human visual system.

Image Restoration is remodeling an image for some degradation by applying inverse processes to undo some known phenomenon in order to recover the original image. Image restoration is a cognitive estimation process in which operations are performed on an observed or measured field to estimate the ideal image that would be observed if no degradations were present in the imaging system. The aim of image restoration is to bring the image towards what it would have been if it had been recorded without degradation.

Image compression is a technique wherein, image containing tremendous amount of redundant information, can be run through algorithms that reduce the number of bits needed to represent them. Image compression is the natural technology for handling the increased spatial resolution of today's imaging sensors and evolving broadcast television standards.

Image feature extraction basically deals with extraction of sub-components (called features) in a given image. This feature extraction provides some quantitative information which is necessary for differentiating one class of objects from another.

II. BACKGROUND STUDY

The **human face** is involved in an impressive variety of different activities. The human face serves as a provider of a number of social signals essential for interpersonal communication in our social life. Personality, gender, attractiveness and age can be seen from someone's face. The face is the mean to identify other members of the species, to regulate the conversation by the means of gazing or nodding, to interpret what has been said by the means of lip-reading, and to understand somebody's emotional state and intentions on the basis of the shown facial expression.

Face recognition is a pattern recognition task performed specifically on faces. It can be described as classifying a face either "known" or "unknown", after comparing it with stored known individuals. It is desirable to have a system that has the ability of learning to recognize unknown faces.

There are two major approaches to face recognition.

A. *Feature Based Face Recognition*

This is based on the extraction of the properties of individual organs located on a face such as eyes, nose and mouth, as well as their relationships with each other. Effective features that can be used in feature based face recognition can be classified as follows:

- First-order features values

  Discrete features such as eyes, eyebrows, mouth, chin, and nose, which have been found to be important in face identification and are specified without reference to other facial features, are called first-order features.
- Second-order features values

  Another configurable set of features which characterize the spatial relationships between the positions of the first-order features and information about the shape of the face are called second-order features.

For different facial contours, different models should be utilized to extract them from the original portrait. Because the shapes of eyes and mouth are similar to some geometric figures, they can be extracted in terms of the deformable template model.

The other facial features such as eyebrows, nose and face are so variable that they have to be extracted by the active contour model. These two models can be illustrated in the following:

- Deformable template model

  The deformable templates are specified by a set of parameters which uses a prior knowledge about the expected shape of the features to guide the contour deformation process. The templates are flexible enough to change their size and other parameter values, so as to match themselves to the data. The final values of these parameters can be used to describe the features. This method works well regardless of variations in scale, tilt, and rotations.
- Active contour model

  It basically relies upon non-deformable features like face, eyebrows and nose. Without these features the face recognition becomes a complex job. These features provide a finalized output when the deformable features are completely specified.

B. *PRINCIPAL COMPONENT ANALYSIS(PCA)*

It is based on information theory concepts, seek a computational model that best describes a face, by extracting the most relevant information contained in that face without dealing with the individual properties of facial organs such as eyes or mouth.

The jobs which PCA can do are prediction, redundancy removal, feature extraction, data compression, etc. PCA utilizes eigenvectors for facial recognition.

III. GENERALIZED MODEL OF A FACIAL ECOGNITION SYSTEM

The various blocks of a generalized model of a facial recognition system is given in Fig.1 and its components are explained.

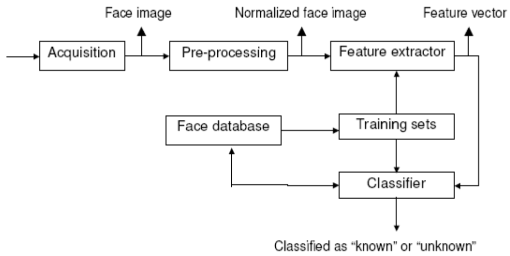

Fig. 1 Generalized model of facial recognition system

C. *Acquisition Module*

This is the entry point of the face recognition process. It is the module where the face image under consideration is presented to the system. An acquisition module can request a face image from several different environments. Image acquisition module consists of an electronic camera equipped with CCD sensors.

A. *Pre-processing Module*

By means of early vision techniques, face images are normalized and if desired, they are enhanced to improve the recognition performance of the system. Some or all of the following pre-processing steps may be implemented in a face recognition system:

- Image size normalization
- Histogram equalization , illumination normalization
- Median filtering
- High-pass filtering
- Background removal
- Translational and rotational normalizations

B. *Feature extraction module*

After performing some pre-processing (if necessary), the normalized face image is presented to the feature extraction module in order to find the key features that are going to be used for classification.

C. *Classification module*

In this module, with the help of a pattern classifier, extracted features of the face image is compared with the ones stored in a face library (or face database). After doing this comparison, face image is classified as either known or unknown.

D. Training set

Training sets are used during the "learning phase" of the face recognition process. The feature extraction and the classification modules adjust their parameters in order to achieve optimum recognition performance by making use of training sets.

E. Face library or face database

After being classified as "unknown", face images can be added to a library (or to a database) with their feature vectors for later comparisons. The classification module makes direct use of the face library.

IV. FEATURE BASED FACE RECOGNITION USING EIGENFACES

Eigenfaces approach is a principal component analysis method, in which a small set of characteristic pictures are used to describe the variation between face images. Goal is to find out the eigenvectors (eigenfaces) of the covariance matrix of the distribution, spanned by a training set of face images. Later, every face image is represented by a linear combination of these eigenvectors. Evaluation of these eigenvectors is quite difficult for typical image sizes but, an approximation can be made. Recognition is performed by projecting a new image into the subspace spanned by the eigenfaces and then classifying the face by comparing its position in face space with the positions of known individuals.

A. Calculating Eigenfaces

Let a face image I(x, y) be a two-dimensional N x N array of 8-bit intensity values. An image may also be considered as a vector of dimension N^2, so that a typical image of size 256 x 256 becomes a vector of dimension 65,536, or equivalently a point in 65,536-dimensional space. An ensemble of images, then, maps to a collection of points in this huge space. Images of faces, being similar in overall configuration, will not be randomly distributed in this huge image space and thus can be described by a relatively low dimensional subspace. The main idea of the principal component analysis is to find the vectors that best account for the distribution of face images within the entire image space. These vectors define the subspace of face images, which we call "face space". Each vector is of length N^2, describes an N x N image, and is a linear combination of the original face images.

Let the training set of face images be $\Gamma_1, \Gamma_2 \ldots \Gamma_m$ then the average of the set is defined by

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

Each face differs from the average by the vector

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

This set of very large vectors is then subject to principal component analysis, which seeks a set of M orthonormal vectors, u_n, which best describes the distribution of the data. The k^{th} vector, u_k, is chosen such that

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

is a maximum, subject to

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

The vectors u_k and scalars λ_k are the eigenvectors and eigenvalues, respectively of the covariance matrix

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

where the matrix $A=[\phi_1,\phi_2,\ldots\phi_m]$ The covariance matrix C, however is $N^2 X N^2$ real symmetric matrix, and determining the N^2 eigenvectors and eigenvalues is an intractable task for typical image sizes. We need a computationally feasible method to find these eigenvectors.

If the number of data points in the image space is less than the dimension of the space ($M<N^2$), there will be only M-1, rather than N^2 , meaningful eigenvectors. The remaining eigenvectors will have associated eigenvalues of zero. We can solve for the N^2 dimensional eigenvectors in this case by first solving the eigenvectors of an M x M matrix such as solving 16 x 16 matrix rather than a 16,384 x 16,384 matrix and then, taking appropriate linear combinations of the face images ϕ_i.
Consider the eigenvectors V_i of A^TA such that

$$A^T A v_i = \mu_i v_i$$

Premultiplying both sides by A, we have

$$AA^T A v_i = \mu_i A v_i$$

from which we see that Av_i are the eigenvectors of $C=AA^T$
Following these analysis, we construct the M x M matrix $L=A^TA$, where $L_{mn}=\phi^T_m \phi_n$, and find the M eigenvectors V_l, of L. These vectors determine linear combinations of the M training set face images to form the eigenfaces U_l.

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

B. Using Eigenfaces to Classify a Face Image

A new face image (Γ) is transformed into its eigenface components (projected onto "face space") by a simple operation,

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

for k = 1,...,M. This describes a set of point by point image multiplications and summations, operations performed at approximately frame rate on current image processing hardware, with a computational complexity of $O(N^4)$.
The weights form a feature vector,

$$\Omega^T = [w_1 w_2 \ldots w_M]$$

that describes the contribution of each eigenface in representing the input face image, treating the eigenfaces as a basis set for face images. The feature vector is then used in a standard pattern recognition algorithm to find which of a number of predefined face classes, if any, best describes the face.

$$\frac{\|\Omega - \Omega_k\|}{\|\Omega_k\|} \leq \varepsilon_k$$

Fig. 2 Person's face

Fig. 3 Eigenfaces obtained by manipulation

C. Rebuilding a Face Image with Eigenfaces

A face image can be approximately reconstructed (rebuilt) by using its feature vector and the eigenfaces as

$$\Gamma' = \Psi + \Phi_f$$

Where,

$$\Phi_f = \sum_{i=1}^{M'} w_i u_i$$

is the projected image.

We see that the face image under consideration is rebuilt just by adding each eigenface with a contribution of w_i to the average of the training set images.

PCA computes the basis of a space which is represented by its training vectors. These basis vectors, actually eigenvectors, computed by PCA are in the direction of the largest variance of the training vectors, we call them eigenfaces. Each eigenface can be viewed a feature. When a particular face is projected onto the face space, its vector into the face space describes the importance of each of those features in the face. The face is expressed in the face space by its eigenface coefficients (or weights). We can handle a large input vector, facial image, only by taking its small weight vector in the face space. This means that we can reconstruct the original face with some error, since the dimensionality of the image space is much larger than that of face space. Each face in the training set is transformed into the face space and its components are stored in memory. The face space has to be populated with these known faces. An input face is given to the system, and then it is projected onto the face space. Since a face is well represented by the face space, its reconstruction is similar to the original; hence the reconstruction error will be small.

ADVANTAGES:

Speed and simplicity: Eigenfaces approach is superior in its near real time speed and reasonably simple implementation, where as feature based face recognition involves complex computations such as deformable templates and active contour models.

Learning capability: Feature based face recognition systems are generally trained to optimize their parameters in a supervised manner. In the eigenfaces approach, training is done in an unsupervised manner. User selects a training set that represents the rest of the face images. Eigenfaces are obtained from the training set members and feature vectors are formed.

Face background: Eigenfaces approach is very sensitive to face background, in case feature vectors are obtained by image additions and multiplications. Feature based face recognition algorithms are less sensitive to face background due to the localization of facial contours by deformable templates.

Presence of small details: Feature based face recognition algorithms can suffer when some details are present on the face image such as dark glasses or beards. For a feature based face recognition system, it is quite impossible to extract the features that are related to the eyes when dark glasses are present on the face. Eigenfaces approach excels in this aspect of face recognition. Small changes in face images such as glasses, beards or mustaches does not cause a decrease in the face recognition performance because the information that is present in the rest of the face image makes it enough to be classified correctly.

The disadvantages of feature based face recognition can be overcome by combining feature based approach (eigeneyes, eigenmouth) and eigenface method, called as Feature Based Eigenface Recognition.

APPLICATIONS:

In Robotics:

Robotics is an applied engineering science that refers to as combination of machine tool technology, electronics and computer science. With the advent of science and technology, robot finds its place in each and every field. Robots called humanoids, having features of that of humans are being created now a day. For robots to recognize face, a facial recognition system is needed. We can implement the face recognition module using the feature based eigenface technique because it is widely implemented and well known for its simplicity and computational efficiency. The simple implementation of robotic facial recognition system is shown in the Fig. 4.

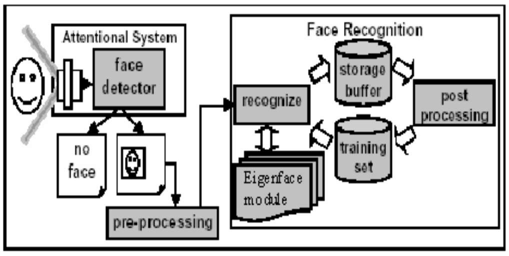

Fig. 4 A Simple Feature based Face Recognition using Eigenface

In crime investigation:

In present situation, the number of crimes committed per year is increasing tremendously. It is necessary to have a check over this crime rates. Most of the crimes are committed by changing one's identity, i.e., by changing facial features (like eyebrows, mustache etc.,). The crime investigation organizations can utilize the advantages of feature based eigenface recognition technique to check the crimes. This can be achieved by maintaining a database of criminals, and by comparing (after eigenface manipulation) the image of the culprit with the existing images in the database.

V. CONCLUSION

The human face serves as a provider of a number of social signals essential for interpersonal communication in our social life. Personality, gender, attractiveness and age can be seen from someone's face. This insists the need for face recognition. Feature based eigenface method provides a better alternative to existing methods. Feature based eigenfaces approach excels in its speed and simplicity and delivers good recognition performances under controlled conditions. Training is done in an unsupervised manner. In this paper we have specified the importance of face recognition using eigenvectors and we have highlighted the applications involving feature based eigenface approach, viz., robotics and crime investigation.

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