Comparative Study of Feature Extraction Techniques for Face Recognition System

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Abstract
Face recognition is one of the most active research areas in computer vision and pattern recognition. This paper compares the different face recognition techniques like visual face recognition, thermal face recognition, eigenface approach and feature extraction techniques like geometry-based feature extraction(Gabor wavelet transform), appearance based techniques, color segmentation based techniques and template based feature extraction. PCA is used in extracting the relevant information in human face. Face images are projected on to the face space which encodes the variation among known face images. This paper discusses feature extraction techniques with pros and cons. Performances of these techniques are different with various factors such as face expression variation, illumination variation, noise and orientation. Visual face recognition systems perform relatively reliably under controlled illumination conditions. Thermal face recognition systems are advantageous for detecting disguised faces or when there is no control over illumination. Thermal images of individuals wearing eyeglasses may be poor performance since eyeglasses block the infrared emissions around the eyes, which are important features for recognition.

Keywords
Face recognition, face feature extraction, PCA, Gabor wavelet transform, template based feature extraction.

1. INTRODUCTION
Face recognition is one of the biometrics methods to identify individuals by the features of the face. Research in this area has been conducted for more than 35 years; as a result, the current status of the face recognition technology is well advanced. Many commercial applications of the face recognition are criminal identification, security system, image and film processing. The face recognition system is able to identify or verify one or more persons. It is usually achieved through three steps: acquisition, normalization and recognition. Acquisition includes the detection and tracking of face-like images in a dynamic scene. Normalization includes the segmentation, alignment and normalization of the face images. Finally, recognition includes the representation and modeling of face images as identities, and the association of novel face images with known models. In order to realize such a system, acquisition, normalization and recognition must be performed in a coherent manner.

Eigenface approach is used for low dimensional representation of faces by applying Principle Component Analysis (PCA). The system functions by projecting face images onto a feature space that span the significant variation among known face images. The significant features are known as "eigenfaces" because they are eigenvectors (principle components). PCA maximizes the variances of the extracted feature and hence minimizes the recognition error and remove noise residing at the discarded dimension. Face recognition technology has numerous commercial and law enforcement applications[3]. PCA is classical technique for applications having linear models [2].

Human facial features play a significant role for face recognition and Neurophysiologic research. It is determined that eyes, mouth, and nose are amongst the most important features for recognition[2]. Recognizing someone from facial features makes human recognition a more automated process. Basically the extraction of facial feature points, (eyes, nose, mouth) plays an important role in many applications, such as face recognition, face detection, model based image coding, expression recognition, facial animation and head pose determination[3]. It is important to note that because the systems use spatial geometry of distinguishing facial features, they do not use hairstyle, facial hair, or other similar factors. Facial recognition can be used generally for police work purposes like public safety, suspected terrorists, and missing children.

The rest of the paper is organized as follows. Section 2, introduces face recognition system. Section 3, discuss existing feature extraction techniques with geometry based methods, appearance based techniques, color segmentation based techniques and template based methods with pros and cons of each. Finally, section 4 concludes the paper and points out the future research aspects.

2. FACE RECOGNITION SYSTEM
Humans are often recognized by faces. The advancement in computing capability over the past few decades enables face recognition automatically. Face recognition is one of the main applications of machine vision that is widely attended in recent years that can be used in ID validity, Identity recognition and so on [1]. Even though face recognition is a very simple process for humans, there is no reliable computerized method for it yet. The difficulties arise due to large variation in facial appearance, head size, orientation and change in environment conditions. A face is a three-dimensional object and can be seen differently according to inside and outside elements. Inside elements are expression, pose, and age that make the face seen differently.

2.1 Visual Face Recognition
Face recognition algorithms can be classified into two broad categories: feature-base and holistic methods [7][8]. The feature-based approaches compute a set of geometrical features from the face such as the eyes, nose, and the mouth. The appearance-based methods consider the global properties of the human face pattern. The face is recognized as a whole without using only certain points obtained from different regions of the face. Feature extraction for face representation is a central issue in face recognition. Feature extraction algorithms aim at finding features from the scenes that distinguish one face from another. Face patterns can have significantly variable image appearances. Therefore it is essential to find techniques that introduce low dimensional feature representation of face objects with enhanced discriminatory power. Data reduction and feature extraction

schemes make the face recognition problem computationally tractable.

A number of earlier face recognition algorithms are based on feature-based methods [9][10][11] that detect a set of geometrical features on the face such as the eyes, eyebrows, nose, and mouth. Properties and relations such as areas, distances, and angles between the feature points are used as descriptors for face recognition. The performance of face recognition based on geometrical features depends on the accuracy of the feature location algorithm. However, there are no universal answers to the problem of how many points give the best performance, what the important features are, and how to extract them automatically.

Appearance-based face recognition algorithms proceed by projecting an image into the subspace and finding the closest point. Linear discriminant analysis (LDA) and principal component analysis (PCA) have been two approaches widely used for dimensionality reduction and feature extraction [12].

2.2 Thermal Face Recognition

Face recognition in the thermal infrared domain has received relatively little attention in the literature in comparison with recognition in visible-spectrum imagery. Identifying faces from different imaging modalities, in particular from infrared imagery becomes an area of growing interest. Despite the success of automatic face recognition techniques in many practical applications, recognition based only on the visual spectrum has difficulties performing consistently under uncontrolled operating environments. Performance of visual face recognition is sensitive to variations in illumination conditions. The performance degrades significantly when the lighting is dim or when it is not uniformly illuminating the face. The differences in the angle of view can affect manual or automatic locating of feature points. Thermal infrared images represent the heat patterns emitted from an object. Since the veins and tissue structure of a face is unique, the infrared images are unique. Thermal Infrared imagery is independent of ambient illumination since the human face and body is an emitter of thermal energy. The passive nature of the thermal infrared systems lowers their complexity and increases their reliability. The human face and body maintain a constant average temperature of about 37 degrees providing a consistent thermal signature. This is in contrast to the difficulties of face segmentation in the visible spectrum due to physical diversity coupled with lighting, color, and shadow effects. At low resolution, IR images give very good results for face recognition.

Thermal face recognition is useful under all lighting conditions including total darkness when the subject is wearing a disguise. Disguised face detection is of particular interest in high-end security applications. Disguises are meant to cheat the human eye. Various disguise materials and methods that have been developed over the years are impossible or very difficult to be detected in the visible spectrum. Visual identification of individuals with disguises or makeup is almost impossible without prior knowledge. The facial appearance of a person changes substantially through use of simplistic disguise such as fake nose or make-up. The individual may alter his or her facial appearance via plastic surgery. Both of these issues are critical for the employment of face recognition systems in high security applications. The thermal infrared spectrum enables us to detect disguises under low contrast lighting. Symptoms such as alertness and anxiety can be used as a biometric that is difficult to conceal as redistribution of blood flow in blood vessels causes abrupt changes in the local skin temperature.

Appearance-based approaches are commonly used for IR face recognition systems [15]. In contrast to visual face recognition algorithms that mostly rely on the eye location, thermal IR face recognition techniques present difficulties in locating the eyes. Initial research approaches to thermal face recognition extracts and matches thermal contours for identification. Such techniques include elemental shape matching and the Eigen face approach.

2.3 The Eigenface Approach

Turk & Pentland were motivated by a technique developed by Sirivich and Kirby. Based on the Karhunen-Loeve expansion (other names such as Hotelling Transform or Principal Component Analysis). Kirby and Sirovich demonstrated that any particular face can be economically represented in terms of a "best coordinate system" and the system was termed "eigenpictures". Eigenpictures are eigen functions of the averaged covariance of the ensemble of faces. In other words, they showed that in principle, a collection of face images can be approximately represented by a small set of standard picture (eigenpictures) with a small set of weights for each of standard pictures.

Following is the procedure of the Eigenface Approach to Face Recognition. In this approach the system was initialized or trained with the following operations.

1. An initial set of face images were acquired. This was the training set.
2. The eigenfaces were calculated from the training set. Only M eigenfaces corresponding to M largest eigenvalues were retained. These eigenfaces spanned the free space which constituted the training set.
3. The M eigenface-weights were calculated for each training image by projecting the image onto space spanned by the eigenfaces. Each face image then will be represented steps were performed to recognize test image.
4. The set of M weight corresponding to the test image were found by projecting the test image onto each of eigenfaces.
5. The test image was determined if it was a face at all be checking whether it was sufficiently closed to face space. This was done by comparing the distance between the test image and the face space to an arbitrary distance threshold.
6. If it sufficiently close to the free space, compute the distance of the M weights of the test image in the training set. A second arbitrary threshold was put in place to check whether the test image corresponded at all any known identity in the training set.
7. If the second threshold was overcome, the test image was assigned with the identity of the face image with which the smaller distance.
8. For the test image with previously unknown identity, the system was restrained by adding this image to the training set.

3. FEATURE EXTRACTION TECHNIQUES

Most facial feature extraction methods are sensitive to various non-idealities such as variations illumination, noise, orientation, time-consuming and color space used[1]. Also a good feature extraction will increase performance of face recognition system. Some image processing techniques extract feature points such as nose, eyes, mouth are extracted and then used as input data to application. For some application it has been the central step. Several Various approaches have been proposed to extract these facial points from images or video sequences of faces. The two basic approaches are as follow:

3.1 Geometry-based Techniques

In this method the features are extracted by using relative positions and sizes of the important components of face. This group method concentrates in two directions. First, detecting edges, directions of important components or region images contain important components, then building feature vectors from these edges and directions. Using filters such as Canny filter to detect eyes or mouth region of face image, or the gradient analysis method which is usually applied in this direction. Second, methods are based on the grayscales difference of important components and unimportant components, by using feature blocks, set of Haar-like feature block in Adaboost method[6] to change the grayscales distribution into the feature. In LBP[7] method, it divides up the face image to regions (blocks) and each region corresponds with each central pixel. Then it examines its pixel neighbors, based on the grayscales value of central pixel to change its neighbor to 0 or 1. Therefore, every pixel will be represented in a binary string. Since then, we build histograms for every region. Then these histograms are combined to a feature vector for the face image. One of the method is Gabor wavelets transform[5][13] feature extraction.

3.1.1 GABOR WAVELETS TRANSFORM

The Gabor wavelet transform uses a set of Gaussian enveloped basis functions that are orthogonal-like basis functions. Gabor wavelets provide analysis of the input image in both spatial and frequency domains simultaneously. Gabor wavelets are widely used in image analysis and computer vision [5]. The advantages of these methods are concentration on important components of face such as eyes, nose, mouth, etc. but the disadvantage is not to represent face global structure and face texture.

3.2 Template Based Techniques

This method group will extract feature of face such as eyes, mouth, nose, etc. based on template function and appropriate energy function[4]. An image region is the best appropriateness with template for eye, mouth or nose, which will minimize the energy. The methods have been proposed such as deformable template and genetic algorithms. In the deformable template method[8], the feature of interest, an eye, is described by a parameterized template. An energy function is defined to links edges, peaks, and valleys in the image intensity with corresponding properties of the template. Then the template matching is done with the image, by altering its parameter values to minimize the energy function, thereby deforming itself to find the best fit. The final parameter values can be used as descriptors for the features.

3.2.1 TEMPLATE BASED EYE AND MOUTH DETECTION

In this method, the correlation of eye template with various overlapping regions of the face image is found out. An eye template is used to detect the eye from face image. The region with maximum correlation with the template refers to eye region.

The method of template matching is given as an algorithm, which is so simple and easy to implement. The algorithm steps are as follows[14].

Step 1: An eye template of size $m \times n$ is taken.

Step 2: The normalized 2-D auto-correlation of eye template is found out.

Step 3: the normalized 2-D cross-correlation of eye template with various overlapping regions of the face image is calculated.

Step 4: The mean squared error (MSE) of auto correlation and cross-correlation of different regions are found out. The minimum MSE is found out and stored.

Step 5: The region of the face corresponding to minimum MSE represents eye region.

Step 6: From eye region eyes points extracted.

Step 7: From eye points mouth point can be detected.

This technique is easily implemented with key face features but it does not represent global face structure. The method does not require any complex mathematical calculation and prior knowledge about the features geometry.

3.3 Color Segmentation Based Techniques

In this approach, the use of skin color to isolate the face. Any non-skin color region within the face is viewed as a candidate for eyes or mouth[13].

3.3.1 COLOR BASED FEATURE EXTRACTION

The use Color models such as RGB with certain range of color pixels, skin region is detected[2][16][18]. After getting the skin region, facial features like eyes and mouth are extracted. The image obtained after applying skin color statistics is subjected to binarization. It is transformed to gray-scale image and then to a binary image by applying suitable threshold. This is done to eliminate the hue and saturation values and consider only the luminance part. This luminance part is then transformed to binary image with some threshold because the features for face are darker than the background colors. After thresholding, opening and closing operations are performed to remove noise. These are the morphological operations, which are used to remove holes. Then eyes, ears, nose can be extracted from the binary image by considering the threshold for areas which are darker in the mouth than a given threshold[18]. The performance of such techniques on facial image databases is rather limited, due to the diversity of ethnical backgrounds.

3.4 Appearance Based Techniques

In these methods is using linear transformation and statistical methods to find the basic vectors to represent the face. In the literature for this aim such as PCA and ICA[17]. In detail, goal of PCA method is to reduce the number of dimensions of feature space, but still to keep principle features to minimize loss of information. PCA method uses second-order statistic in the data. However, PCA method has still disadvantages. High order dependencies still exist in PCA analysis, for example, in tasks as face recognition, much of the important information may be contained in the high-order relationships among the image pixels, not only second-order. While other method ICA uses technique independent component analysis. It is an analysis technique not only use second-order statistic but also use high order statistic. PCA can be derived as a special case of ICA which uses Gaussian source models. PCA is not the good method in cases non Gaussian source models. It has been observed that many natural signals, including speech, natural images, are better described as linear combinations of sources with super-Gaussian distributions. In that case, ICA method better than PCA method because:

I) ICA provides a better probabilistic model of the data.

II) It uniquely identifies the mixing matrix.

III) It finds an unnecessary orthogonal basic which may reconstruct the data better than PCA in the presence of noise such as variations lighting and expressions of face.

IV) It is sensitive to high-order statistics in the data, not just the covariance matrix[13].

The appearance based method group found the best performer in facial feature extraction because it keeps the important information of face image, rejects redundant information and reflect face global structure. It requires that the image matrices must be first transformed into vectors, which are usually of very high dimensionality. This causes expensive computational cost and sometimes the singularity problem.

4. CONCLUSION

The best features for face recognition cannot be simply determined without evaluation of the face recognition algorithms. That is why the best feature sets for face recognition are still not sufficient. Extensive evaluation can help to achieve a more reliable set of face features and help to increase the performance of the overall system. The thermal face recognition achieved higher performance ranks and average confidence rates than visual face recognition under different lighting conditions and expressions in cases where no eyeglasses were worn.

The face feature extraction is important application for various other applications with different techniques considering different parameters. Every method has pros and cons such as template based methods are easy to implement but not represent global face structure. While color segmentation based methods used color model for skin detection with morphology operation to detect features. So different color model and illumination variation factors can affect performance. Appearance based methods represent optimal feature points which can represent global face structure but disadvantage is high computational cost.

The PCA technique performs satisfactory when test image to be recognized. The eigenface approach does provide a practical solution that is well fitted to the problem of face recognition. It is fast, relatively simple. This method was found to be robust enough. Geometry based methods such as Gabor wavelet transform face feature extraction provide stable and scale invariant features. Wavelets enable localization in both spatial and frequency domains with high frequency salient feature detection. And such set of continuous 2D Gabor wavelets will provide a complete representation of any image. Hopefully, the comparisons in this paper do provide a step toward impacting on increasing the performance of feature extraction techniques for face recognition systems.

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