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Feature Extraction Techniques on Facial Images: An Overview

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Abstract: ***This paper provide a general overview on different kinds of feature extraction techniques. These techniques are categorized into four major classes, the first one is feature-based approaches, the second is appearance based approach, and then template-based, and finally part-based approaches. Some techniques are illustrated in details while the others with general explanation. In this research we found that various techniques of feature extraction provide an excellent results for various image processing and pattern recognition applications.***

Keywords: feature extraction, feature-based, part-based, facial recognition, template-based, Appearance-based

1. Introduction

Features are the attributes Features are the attributes which through it the whole image are described. It represents a piece of crucial information which is submitted for solving the computational tasks that relevant to particular applications. Extraction of the useful and important features from the digital images to be subjected to the chosen and classification processes..[1]

This paper aims to provide a general study of the most common classes of feature-extraction techniques which are used for various facial image processing systems without addressing the algorithms used in each technique. The major goal of features extraction is minimizing the originnnal dataset through deriving some characteristics which can be used for classifying and recognizing patterns which represented in the input images. A feature vector is produced from the process of feature extraction, which its dimension is equalized to the extracted features number, is derived. These features must hold the significant information and should be various enough among classes to make the classification performance better. Thus, the process of feature extraction plays a conclusive role in achieving classification process and so, in all processes of segmentation.[2]

2. Related Work

A lot of surveys and reviews are existed in this field, some of these works are listed below to help readers finding them easily:

Rahimeh Rouhi et al (2012) [3] presented their paper about feature extraction in facial recognition, in which four feature extraction techniques are introduced and presented the comparable results of the these techniques with discussion of the pros and cons of each technique.

Vivek Pali et al (2014) [2] wrote a very good paper in this topic, where they explain the most popular techniques of feature extraction with a detailed description of each class of these techniques.

N. Elavarasan, Dr. K.Mani (2015) [4] wrote a survey on feature extraction techniques, where an overview on some feature extraction approaches (PCA, LDA) is achieved.

3. Feature Extraction Techniques' Categories

Various mathematical models can be used to perform feature extraction, image processing methods and tools of computational intelligent like fuzzy logic or neural networks. Generally, feature extraction can be classified into four classes, these are feature based, template-based, appearance-based, and part-based approaches. Figure 1 shows the classification of different feature extraction approaches.

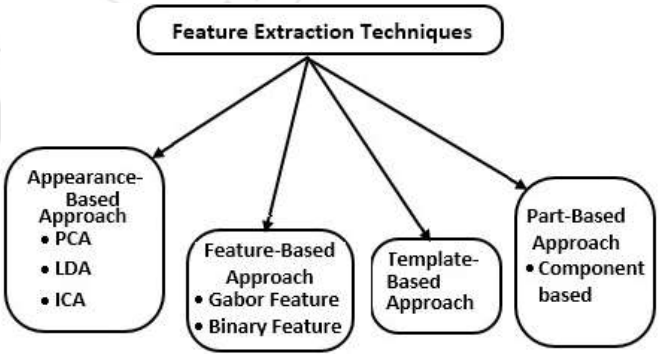

Figure 1: Classification of various techniques for feature extraction. [2]

3.1 Appearance-based Feature Extraction approach

These approaches try to use global representations in identify faces, this means it based on the whole image instead of local features of the facial image. Appearance-based approaches also named holistic-based approaches, where the total information of the entire face patch is used, then some transformation on this patch is performed for deriving a precise representation for recognizing the face. To

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differentiate between appearance-based and feature-based techniques, methods of feature-based derive information directly from some of the detected fiducial points like eyes, lips, and noses, etc. determination of these fiducial points are commonly from the knowledge of domain with discarding the other information, whereas appearance-based approaches accomplish transformations on the entire patch and arrive the feature vector and the base of these transformations usually gained from statistics. There are several techniques in this approach like PCA, LDA, ICA, etc.[2]

Principal Component Analysis (PCA)
This method is the most popular statistical one. It's work based on extracting the lower-dimensional space, where this is achieved by analyzing the structure of covariance for observing the multivariate statistical. PCA is a good tool for reducing the multidimensional data to the lower dimensions and during this process PCA stills retain the most of the information.[5]

Linear Discriminant Analysis (LDA)
This technique work to project the high-dimensional data in the facial image to a lower-dimensional space. Where by using this method the space of dimensionality reduction of the between-class distance is maximized and the within-class distance is minimized and this represent the goal of LDA.[4]

Pros and cons of Appearance-based Techniques
The major benefit of the appearance-based approaches is that the images' contained data is not demolished through focusing on only restricted areas[2].

While the disadvantages are shown below:

- The greatest drawback of Appearance-based is that most these techniques suppose the importance of all image pixels are equal, therefore they don't demolish any information in the images and don't focus on particular regions.
- These techniques are computationally expensive.
- The performance of these techniques under large variations in illuminations, pose, and scale is degraded.

3.2 Feature-based approaches

Unlike appearance-based approaches that depend more on the statistical learning and analysis, feature-based approaches take advantages of image processing, the domain of human knowledge, and computer vision.

Firstly, these approaches process the input images for identifying and extracting (and also measuring) the distinguished facial features like eyes, nose, mouth, etc. and other fiducial marks, then among all those facial points, the geometric relationships are computed, and so the input facial image is reduced to a vector of geometric feature [6].

Elastic bunch graph matching approach is a famous feature-based method, and Dynamic Link Structures represent the base of this technique. For an individual face, generation of a graph by choosing a group of fiducial points from the face. Every one of the fiducial points represents a node of a graph that is fully connected, and also labeled with the response of Gabor filter that applied to a window around the fiducial point. The arches between fiducial points are labeled with a particular distance for each arch. Face bunch graph is generated from combining the representative set of those graphs[7].

Figure 2 shows fiducial points for facial recognition.

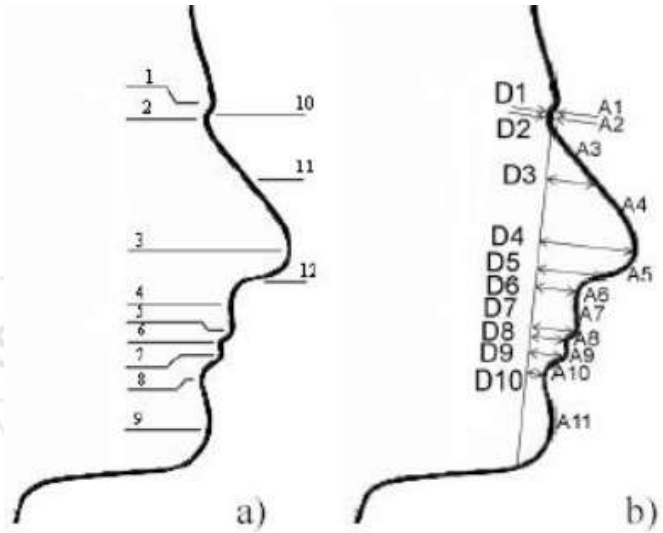

Figure 2: a) fiducial points for facial recognition. b) 21 components of feature vector. [8]

The most famous techniques for feature extraction in face recognition are the local binary pattern and the Gabor wavelet feature.

a) Binary Features
The first proposition of local binary pattern features (LBP) were for texture analysis, but later it used in the analysis of facial images. The simplicity of computation and the tolerance against changes of lighting is the most significant characteristics of LBP features. The features of LBP is derived very rapidly in a single scan from the raw image, and reside in the feature space of low-dimensional, with the keeping a compact representation of distinctive facial data. The image pixels are labeled by LBP operator through thresholding a 3x3 neighborhood for every pixel with the value of a center and the outcomes will be considered as a binary numbers. The binary numbers which is derived called LBP code or Local Binary Patterns that include various kinds of spots, curved edges, flat areas, etc. figure 3 shows LBP operator. The basic LBP operator has a large limitation, which is its small 3x3 neighborhood, where the prevalent features with large scale cannot be captured.[2]

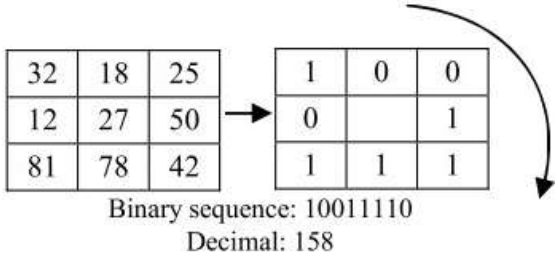

Figure 3: Basic Local Binary Pattern Operator [2]

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b) Gabor Features

Among the huge number of wavelets bases, the function of Gabor provides the optimal solution in both the frequency and spatial domains. In pattern recognition, the causes of making Gabor wavelets are optimal for local feature extraction are listed below:[9]

1) Biological motivation: the similarity between the Gabor wavelets shapes and the receptive fields of cells inthe primary visual cortex is very high.
2) Mathematical motivation: the Gabor wavelets consider an optimal way for measuring the local spatial frequencies.
3) Empirical motivation: the goal of Gabor wavelets is to gain distortion tolerant feature spaces for various tasks of pattern recognition like fingerprint recognition, texture segmentation and handwritten numeral recognition.

Lades et al were the first researchers in using Gabor wavelet in the field of facial recognition by detecting the feature points through using elastic graph matching framework and thus accomplish distance measurement by building the facial model, In contrast, Gabor wavelets which are used for local feature extraction at these feature points. A model graph example is shown in figure 4 while object-adaptive grids for various poses are described in figure 5. [2]

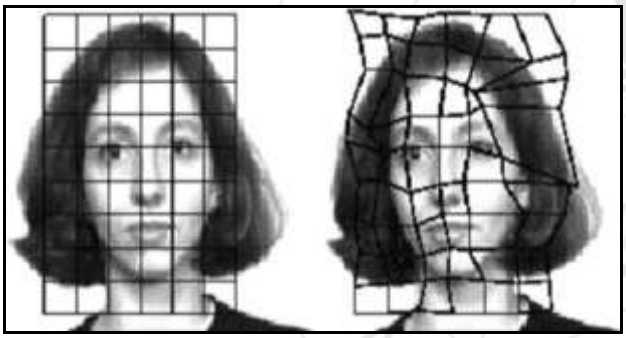

Figure 4: Facial images' graphic models. The model graph. The stored face in the database at left, at the right a deformed graph..[10]

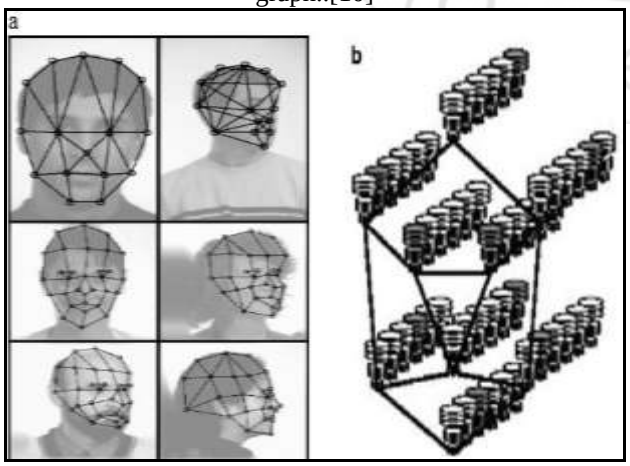

Figure 5: (a) Face adapted graphs for different poses. (b) An example face bunch graph.[11]

The images contain particular angles have features that aligned with it, and for extracting these features Gabor filters can be applied for this mission. The properties of the optimal localization in both frequency domains and spatial domains are acquired by Gabor filter. The frequency and angle represent the most significant parameters of the Gabor filter. Particular features that share similar frequency or angle can be chosen and used for individualizing among various facial expressions depicted in images. [12]

The linear filter that used to detect the edge in the spatial domain is a Gabor filter. Gabor filter has two components to represent the orthogonal directions, these components are real and imaginary. Those two components can be formed into a complex or may be used individually[13].

The Gabor filter bank is exploited to extract the features. The filter bank and other several filters are created and used for extracting multi-scale and multi-orientation features from a given facial image. The filter bank that is commonly used consisting of Gabor filters of 8 orientations and 5 different scales, as shown in figure 6.

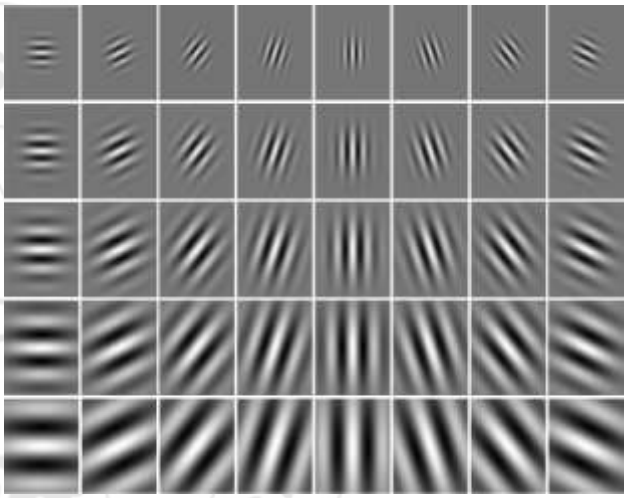

Figure 6: Gabor filter with 8 orientations and 5 different scales. [14]

The representation of Gabor features for the facial image is the result of convolution the image I(x, y) with the Gabor filters bank $g_{u,v}(x,y)$. The result of the convolution process is a complicated value, where the decomposition of it to imaginary and real part is possible as shown in the following equations

The features of Gabor phase are unstable and usually ignored because the responses of computed phase differ significantly even for spatial locations except apart of few pixels. On the other side, the responses of the magnitude differing in a slowly way with the spatial position, thus it considered the preferred choice for extracting the features based on Gabor filter [13].

Pros and cons of feature-based approach

In feature-based techniques, feature point extractions precedes the analysis process that done to match the image to a recognized individual, and such Feature-based techniques have a robustness to the variations of position in the input image, and that considers a great advantage of this techniques. In principle, the schemes of feature-based can be made invariant to lighting, orientation and/or size. High speed matching of the face image is another benefit of these

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schemes. The main disadvantage of these methods is the hardness of detection the features automatically and the truth that the executor of any one of these approaches requires making arbitrary decisions about which features are significant. After all, if the feature set lacks discrimination ability, no amount of subsequent processing can compensate for that intrinsic deficiency.[2]

3.3 Template-based Methods

Template matching is like the use of distance metric to recognize the face, which means picking out a set of symbolic-templates for every class, then computing the similarity measurement between a test image and every class, then select the class that has the higher score of similarity as the correct match.[2] Figure 7 shows the face template.

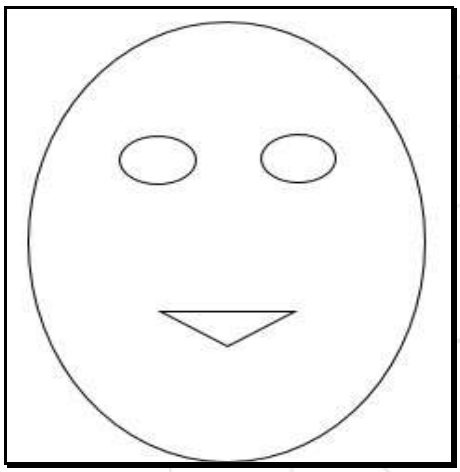

Figure 7: Face Template[15]

3.4 Part-based Approach

The information that results from distinctive facial parts or parts that have robustness against illumination or pose variation can be exploited for face recognition. For the distinction between these methods and the feature-based approaches, part-based approaches detect important parts of the facial image then the part appearances are combined with the tools of machine learning for recognition, whereas at the feature-based approaches, the features are extracted from the facial feature points or from the face as a whole and achieve the recognition by comparing these features.[2]

4. Conclusion

General study of feature extraction techniques that used in the field of face recognition are introduced in this paper and during the reviewing of many researches in this field we found that all these studies concentrate on improvement of extracting the features in high accuracy and speed, and then dimensionality reduction is achieved, thus achieving feature selection accurately. Since facial recognition system should be able to overcome the problems of face recognition like pose, various lighting conditions, face size, etc. so the speed of extraction of features are very important to accomplish this process by incorporating some of these approaches together and this will provide both speed and accuracy.

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