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Review of six popular method: Face Recognition

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***Abstract*—Simulation of human ability has always been attractive topic for researchers but had often been limited to hardware part. With the advancement of technology and emerge of deep learning and machine learning, hope to simulate human perception increased. Face recognition is one of the most important capability of human perception that use in routine. Many researches have been done that led to proposing different approach and various methods. This paper is a survey of face recognition methods that proposed in past decades and also categorize them in meaningful approaches**

Keywords— Face recognition, literature review

I. Introduction

Face recognition is one of the most important capability of human perception that use in routine. Literally it refers to the ability of identifying or verifying of subjects. Thanks to advancement of technology, nowadays machines also have this capability. Face recognition is classified under biometric applications [1]. The application maps individual facial features mathematically and compares with stored records of known images. Even though the first attempts in automating face recognition date back to the 1960s, many face recognition analysis and techniques have improved in recent decades. Rapid development in recent years is due to a combination of factors: active development of algorithms, availability of large databases of facial images, and methods for evaluating the performance of face recognition algorithms [1]. As the accuracy of face recognition systems has improved, there is more preferred over other traditional biometric systems such as iris and fingerprint [2].

Face recognition provides a wide variety of applications, ranging from making mug shot albums to video surveillance for law enforcement, static matching on credit cards, ATM cards and access control through face IDs for commercial applications. Camera surveillance and social networks can be highlighted as the main uncontrolled facial image applications [3].

For many years face recognition was the subject of researches that led to proposing different approach and various methods. This paper is a survey of face recognition methods that proposed in past decades and also categorize them in meaningful approaches.

II. Face Recognition Approaches

As mentioned on the introduction; face recognition has been the subject of research for many years, resulting in a variety of algorithms for this purpose. Although all algorithms developed with aims to verify and identify image face, they work with different approach.

Various categorizations are provided for a better understanding of methods. In Paper [4]; divided into three main groups: holistic matching methods that the algorithm is trying to use whole input images and try to find pattern. In general, these approach relay on statistical analysis.

Feature-based methods that try to utilize facial feature such as nose, eye, cheekbone, chin, lips, forehead, ear to distinguish between different faces and as 3rd hybrid approach is a combination of different methods. Paper [5] also classified into three main groups but instead of hybrid methods, introduced soft computing as the third approach that its functionality simulates human mind [6]. Paper [1], used two main groups as global approaches and component-based approach. Paper [3], used ‘traditional’ to categories methods based on statistic models and ‘new’ methods that are generally based on deep learning and NN techniques.

It seems that there is no consensus for a unique classification but with a glimpse into the evolution of methods, it can be understood that all categories refer to three generic groups.

1st: methods based on features of faces.

2nd: methods based on the whole image.

3rd: is the method based on deep learning and soft computing. Alongside these groups, there is also a combination of these approaches known as hybrid approach [7].

Note that scope of this paper's review is limited to 2D face recognition methods.

III. Face Recognition Methods

A. Principal Component Analysis (PCA)

Principal Component Analysis (PCA) is a method based on Karhunen-Loeve expansion in pattern recognition that was invented by Sirovich and Kirby. In the paper [8], they applied PCA to characterize the geometry of faces. Their work demonstrates that any face can be reconstructed by a representative of a coordinate system called "Eigen picture".

Turk and Pentland (1991) proposed the Eigenface method for face detection and face recognition. The idea was motivated by the technique developed by Sirovich and Kirby [9]. Put simply, their method extracts relevant information in a face image, encodes it as efficiently as possible and compares it with the database of a model encoded similarly.

Mathematically, this method tries to find the principal component (PCA) of distributed faces and reduce the data space for the recognition phase [10]. The input faces will convert into feature vectors and then information is obtained from the covariance matrix. These eigenvectors are used to find the variation between multiple faces. Paper [1][11] reports that, "*The M Eigenfaces represent M dimensional face space showed 96%, 85% and 64% correct categorization under varying lighting condition respectively, orientation and size by exploiting 2500 images of 16 each*".

Although many experiments report good results on liner projection such as PCA but in wild situations the performance of the system is far from the ideal. Paper [12] states that failure is due to large illumination conditions, and facial expressions. The paper argues that the main reason is that face pattern lines on a complex nonlinear and non-convex in the high dimension. In order to deal with such cases, Kernel PCA is proposed.

B. Liner Discrimination Analysis (LDA)

Although PCA has proved good performance, poor discrimination within class is a well-known problem in PCA method. Paper [13] proposed Linear Discrimination Analysis (LDA) method to improve face recognition performance under uncontrolled conditions, illumination and facial expression. LDA is based on fisher linear discrimination analysis; it is fundamentally the same as PCA, but the goal is to perform dimensional reduction while retaining class discrimination [14].

LDA was developed with the primary aim of increasing granularity within a class and between classes with hope to improve the recognition rate. However, paper [15] reports that in the same conditions PCA recognition is higher than the LDA method.

As the LDA approach aims at maximizing discrimination within classes, being resistant to illumination change can be an advantage of this method, but finding an optimum way to simultaneously separate multiple face classes is almost impossible. Also, singularity is a disadvantage for LDA. It fails when all scatter metric is singular [16].

C. Independent Component Analysis (ICA)

ICA is a generalized form of PCA, but the aim is to find in-depend underlying factors or components from multivariate (multidimensional) statistical data, rather than uncorrelated, image decomposition and representation.

Theoretically, PCA is trying to find a better set of basis images that have best representation of the face image. In this way the first vector of the PCA basis is the one that can give best explanation of the variability of image (the principal direction) and the second vector is the 2nd best explanation but must be orthogonal to the first one, etc. Nonetheless for a task like face recognition, much information is in high order relation amount the image pixels, hence ICA proposed [17]. ICA is trying to extract independent components of images by maximizing independence. In other word, unlike to PCA that has orthogonal relation between new component, In ICA each basis vector which find is independent from another component.

As ICA is capturing the wide spectrum of images by second-order statistics, it is expected to outperform PCA and paper [17] demonstrate with experiment test on FERET face dataset. Nonetheless paper [18] refutes the claim with a new test on the same data set and justifies that FERET data set was not fully available when the difference appears in result of the test. Moghaddam in [19] claim that there is no statistical difference in the performance of the two methods.

D. Elastic Bunch Graph Matching (EBGM)

Elastic Bunching Graph Model is a feature-based approach. In the context of EBGM, the image represents a graph consisting of nodes and edges. Basically, nodes represent feature points and the edge represent interconnections between nodes to form a graph like data structure [5]. Edges are labeled as distance, and node labels with wavelets that are locally bound into a jet [20]. In this method, facial features are called fiducial points and images are represented by spectral information of regions around these fiducial points. The information is gained by convolving these portions of the image with a set of Gabor wavelet in a variety of sizes and orientation that are call Gabor JETs. By combining these represent graphs into a stack-like structure, we will have a face bunch graph. Face bunch graphs act as representatives of the face in general.

Although EBGM shown good result in with small number of images, by increase the size of gallery, the recognition performance degrades severely. To compensate this degradation, paper [21] recommend to involve PCA method in the process and formed a hybrid method instead.

E. Hidden Markove Model (HMM)

Hidden Markov Models (HMM) is a statistical model used to characterize the statistical properties of a signal [22]. This technique was subsequently applied in practical pattern recognition applications [23]. Although the HMM model was

proposed in 1960 and provided a significant contribution to speech recognition [24], the first effort at face recognition was made by Samaria and Young (1994). It was extended by Nefian and Hayes (1999) and Eickeler et al (1999)[23]. Samaria argues that recognition happened by discrimination of face elements (nose, mouth, eyes, etc.). Based on this logic they converted 2D image to 1D image by observing the sliding window. Each observation is a column-vector containing the intensity level of the pixels inside the window. The sequence is formed by scanning the image in the same order [25]. Overall, the model has two processes. First of all is Markov Chain with a finite number of states. The second process sets the probability density function associated with it [26].

F. Convolutional neural network (CNN)

Nowadays deep learning is very popular topic in computer vision. Deep learning is broader family of machine learning methods based on artificial neural networks. Several architectures proposed that CNN is most usable one in field of computer vision and image processing.

CNN began based on neurobiological experiments conducted by Hubel and Wiesel [27]. In 1989 LeCuN et al. proposed an improved version of ConvNet, known as LeNet-5, and started the use of CNN in classifying characters in a document recognition related application [28]. Due to high computational cost and memory requirements, until early 2000 it was considered a less effective feature extractor, and most preferred to use statistical methods [27]. In 2003, (Simard et al). improved CNN architecture and showed good results compared to Super vector machine (SVM) on a hand digit benchmark dataset; MNIST [29]. SVM is a supervised learning model that mostly use for classification. Since 2015, CNN became a point of interest for researchers and most improvement occurred between 2015-2019 [27].

AlexNet was the first successful architect of this type of neuron network that competed in the ImageNet Large Scale Visual Recognition Challenge on September 30, 2012. The network achieved 15.3% error rate 10.8% is more than second place [30]. Several architectures have been proposed based on CNN, such as VGG, inception block by google, skip connection concept that was proposed in ResNet architecture.

IV. Conclusion

This paper reviewed different approach of face recognition, and introduced (feature-based, holistic approach and soft computing) as three popular approach. Furthermore, discussed about six most popular face recognition methods including Principal Component Analysis (PCA), Liner Discrimination Analysis (LDA), Independent Component Analysis (ICA) methods as holistic approach, Elastic Bunch Graph Matching (EBGM) and Hidden Markov Model (HMM) as feature-based approach and finally Convolutional neural network (CNN) as soft computing approach or deep learning.

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