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REVIEW OF EXISTING ALGORITHMS FOR FACE DETECTION AND RECOGNITION

NURULHUDA ISMAIL, MAS IDAYU MD. SABRI
Department of System and Computer Technology (Multimedia), Faculty of Computer Science and Information Technology, University of Malaya, 50603 LembahPantai, Kuala Lumpur, MALAYSIA
nurulhuda.ismail@um.edu.my, masidayu@um.edu.my

Abstract:-In this paper, we present a review on the most successful existing algorithms or methods for face recognition technology to encourage researchers to embark on this topic. A brief on general information of this topic is also included to compose an overall review. This review is written by investigating past and ongoing studies done by other researchers related to the same subject. Five different algorithms have been preferred based on the most widely used criteria. The algorithms are Principle Component Analysis (PCA), Linear Discriminant Analysis (LDA), skin colour, wavelet and Artificial Neural Network (ANN). Certain parameters have been taken into account for the algorithms' review. The parameters are size and types of database, illumination tolerance, facial expressions variations and pose variations. However, no specific justification can be claimed as it is only a review paper based on other researches.

Key-Words: Principle Component Analysis (PCA), Linear Discriminant Analysis (LDA), Skin Colour, Wavelet, Artificial Neural Networks (ANN)

1. INTRODUCTION

Computer vision offers a high demanding applications and outcomes specifically face detection and recognition. This area has always become the researchers' major focus in image analysis because of its nature as human-face primary identification method. It is very interesting and becomes such a challenge to teach a machine to do this task. Face recognition also is one of the most difficult problems in computer vision area. Face detection and recognition also receives a huge attention in medical field and research communities including biometric, pattern recognition and computer vision communities [1][2][3][4].

The field of biometrics technology utilizes detection and recognition method involving human body parts such as fingerprint, palm, retina (eyes) and face. Biometrics ID method of access is not only authenticates but also verifies the identity of a person, which is corresponding to the authorized access. In terms of reliability and security of access, biometrics does offer a better one rather than the conventional access method which using the password. The password access method only authenticates the user but does not actually "know" the user. Other people can easily steal or hack someone else's password. When this happens, the person who stole the password may be able to log into the secured system and access other people's data that is personal and valuable.

Biometrics ID method such as physiological method (face, fingerprint, eyes) is more competent and stable than the behavioural method (keystrokes, voice). Physiological method is more stable because the feature such as face is not easily changed unless severe damage occurred to the face. Instead of behavioural method, such as voiceprint that may change easily due certain reasons like health factor, illness stress. Biometrics characteristics are difficult to imitate and therefore it is very hard to forge. This may be the one the reasons of why face recognition is well known for its functionality. The raising of computer capabilities and the market demand for security has also driven the studies of face detection and recognition into a deeper depth.

Recently, in August 2008, XID Technologies has successfully utilized face recognition technology into their award winning products, Face LogOn Xpress and XS Pro-1000. These products are already in the market for commercialization. XID Technologies is the first company in the world that has developed 3D facial synthesis and recognition solution with the ability to function in outdoor in real world environment [5].

1.1. Face detection and recognition generic framework

The first step for face recognition is face detection or can generally be regarded as face localization. It is to identify and localize the face. Face detection technology is imperative in order to support applications such as automatic lip reading, facial expression recognition and face recognition [6][7]. The framework for both face detection and recognition is almost similar. In this paper, a generic framework is taken as an instance from the research done by Shang-Hung Lin [8].

Basically, this framework consists of two functional segments, which are a face image detector and a face recognizer. The face image detector searches for human faces from the image and localizes the faces from the background. After a face has been detected or localized, the process of recognition will take place to determine who the persons are by the face recognizer. For both face detection and recognition, they have a feature extractor and a pattern recognizer. The feature extractor transforms the pixels of the images into vector representation.

1.2. Challenges in face detection and recognition

Detecting and recognizing faces are challenging as faces have a wide variability in poses, shapes, sizes and texture. The problems or challenges in face detection and recognition are listed as follow [9]:

- Pose
  - A face can vary depends on the position of the camera during the image is captured.
- Presence of structural components
  - There may be another additional components on the face such as spectacles, moustache or beard.
  - These components may have different types, shapes, colours and textures.
- Facial expression
  - The facial expression resembles directly on the person's face.
- Occlusion
  - A face may be partially obstructed by someone else or something when the image is captured among crowds.
- Image orientation
  - It involves with the variation in rotation of the camera's optical axis.
- Imaging condition
  - The condition of an image depends on the lighting and camera characteristics.

There are other challenges (which are not discussed in this paper) in face detection and recognition but these are the most general problems.

2. OBJECTIVE

The objective of this paper is to investigate and identify the crucial elements related to the features of existing algorithms or methods in order to develop facial recognition applications. This paper provides a base-lining study for the analysis of different methods that contribute to its success for each of the method.

3. SIGNIFICANCE OF THIS PAPER

The findings driven from this paper can be benefited as a basic reference and guideline for other researchers in order to develop applications that require face recognition technology. This paper can also be taken as a brief reading to acquire basic idea of algorithms or methods implemented for face recognition application. Numbers of available review papers have done their reviews on only two different algorithms but this paper broaden out review on five different algorithms, which is able to give readers wider information on the existing algorithms.

4. EXISTING ALGORITHMS FOR FACE DETECTION AND RECOGNITION

Numerous robust algorithms have been developed and claimed to have accurate performance to tackle face detection and recognition problems. These algorithms or methods are the most successfully and widely

used for face detection and recognition applications. The algorithms are as follow:

- Principle Component Analysis (PCA)
  a. Eigenface [10][11]
- Linear Discriminant Analysis (LDA)
  a. Fisherface [12]
- Skin colour based algorithm [13][14]
  a. Red-Green-Blue (RGB)
  b. YCbCr (Luminance -Chrominance)
  c. Hue-Saturation Intensity (HSI)
- Wavelet based algorithm [15][16]
  a. Gabor Wavelet
- Artificial neural networks based algorithm [17][18]
  a. Fast Forward
  b. Back Propagation
  c. Radial Basis Function (RBF)

4.1 Principle Component Analysis (PCA)

PCA is a method in which is used to simplify the problem of choosing the representation of eigenvalues and corresponding eigenvectors to get a consistent representation. This can be achieved by diminishing the dimension space of the representation. In order to obtain fast and robust object recognition, the dimension space needs to be reduced. Moreover, PCA also retains the original information of the data. Eigenface based algorithm applies the PCA basis.

- **Eigenface based algorithm**

Eigenface based approach is the most widely used method for face detection. According to Pavan*et al.*, eigenface is well known due to its simplicity, less sensitive in poses and better performance involving small databases or training sets [19]. This approach utilizes the presence of eyes, nose and mouth on a face and relative distances between these objects. This characteristic feature is known as *Eigenfaces* in facial domain [20].

This facial feature can be extracted by using a mathematical tool called Principle Component Analysis (PCA). By using PCA, any original image from the training set can be reconstructed by combining the Eigenfaces. Generally, a face is classified as a face by calculating the relative distance of the Eigenfaces.

4.2 Linear Discriminant Analysis (LDA)

LDA is also known as Fisher's Linear Discriminant (FLD) [8].It reduces the dimension space by using the FLD technique. FLD technique utilizes within-class information, minimizing variation within each class and maximizing class separation.

- **Fisherface based algorithm**

The Fisherface approach is also one of the most widely used methods for feature extraction in face images. This approach tries to find the projection direction in which, images belonging to different classes are separated maximally [19].

According to Shang-Hung Lin, Fisherface algorithm is a refinement of the eigenface algorithm to cater the illumination variation [8]. Bulhumeur reported that Fisherface algorithm performs better than eigenface in a circumstance where the lighting condition is varied [21].This approach requires several training images for each face. Therefore, it cannot be applied to the face recognition applications where only one example image per person is available for training.

4.3 Skin colour based algorithm

Skin colour is the most obvious and important features of human faces. Human skin colours are distinguished from different ethnic through the intensity of the skin colour not the chromatic features [22]. One of facial feature methods is involving skin colour based processing method. According to Crowley and Coutaz [23], one of the simplest algorithms for detecting skin pixels is to use skin colour algorithm. Each pixel is classified as skin colour and non-skin colour. This classification is based on its colourcomponent, which is modelled by Gaussian probability density [24]. For an input image, this method utilizes colour space for the skin region as the classification. Threshold is applied to mask the skin region. Finally, a bounding box is drawn to extract the face from the input image.

According to Sanjay Kr. Singh *et al., s*kin colour processing method offers a faster processing time than other facial feature methods and orientation invariant [13]. However, Yeong Nam Chae*et al.* has a diverse opinion whereby skin colour method is time

consuming as it scans the target image linearly which involves a large space of scanning [25]. Hence, they have proposed a novel method using sub-windows scanning instead of the conventional linear scanning. This proposed method works by scanning the image sparsely based the facial colour density by determining the horizontal and vertical intervals.

From the experiment, the results reveal that this proposed method was successfully detects faces in a shorter period of time compared to the conventional method. The sub-windows scanning method contributes to the less computational time as it skips the sub-windows that do not consist of possible faces.

There are three most popular colour spaces, namely, the RGB [26][27], YCbCr [24] and HSI [28].

- **RGB (Red-Green-Blue)**

In RGB colour space, a normalized colour histogram is used to detect the pixels of skin colour of an image and can be further normalized for changes in intensity on dividing by luminance. This localizes and detects the face. However, this colour space is not preferable for colour based detection methods compared to YCbCr or HIS. A survey that has been conducted Vezhnevets*et al.* reveals that RGB colour space tends to mix the chrominance and the luminance data, high correlation between channels and significant perceptual non-uniformity [29]. These factors contribute to the less favourable of RGB.

- **YCbCr (Luminance-Chrominance)**

This colour space provides a good coverage of different human races. The responsible values are luminance (Y) and chrominance (C). It involves a separation of luminance and chrominance. This algorithm can only be done if chrominance component is used. It will eliminate the luminance as much as possible by choosing the Cb-Cr plane from the YCbCr colour space. A pixel is determined as skin tone if the values [*Cr, Cb*] fall within the thresholds.

- **HSI (Hue-Saturation-Intensity)**

Based on the studies done by Zarit*et al.* HIS deems to be yield the best performance for skin colour approach [28]. According to Kjeldson and Kender [30], a skin region can be separated from the background by using a colour predicate in HSV colour space. Skin colour classification in HSI colour space is similar to YCbCrcolour space but the responsible values are hue (H) and saturation (S).Unfortunately, all of these algorithms fail when there are regions other than face such as arms, legs and other objects in background that have the same colour value.

4.4 Wavelet based algorithm

In wavelet based algorithm, each face image is described by a subset of band filtered images containing wavelet coefficients [31]. Wavelet transform offers a likelihood of providing a robust multi scale way analysis of an image. Wavelets are also very flexible, whereby several bases exist and the most suitable basis can be chosen for an application. The most widely used wavelet method is the Gabor wavelet method especially in image texture analysis [32][33].

- **Gabor Wavelet**

Gabor wavelet transform utilizes spatial frequency structures and orientation relation [34]. This method is a type of Gaussian modulated sinusoidal wave of the Fourier transform. Gabor wavelet approach works by detecting short lines, ending lines and sharp changes in curvature [35]. These curves correspond well with the prominent features of human faces such as mouth, nose, eyebrow, jaw line and cheekbone as depicted in **Fig.1**[35]. Therefore, Gabor wavelet is very well known in feature detecting [36].

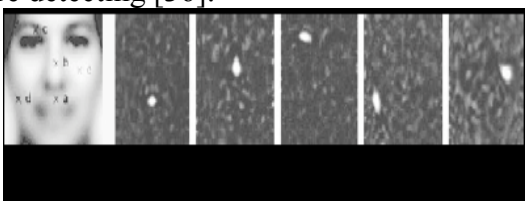

Fig. 1 The prominent facial features are recognized (a) mouth, (b) nose, (c) eyebrow, (d) jaw line and (e)cheekbone

4.5 Artificial neural networks based algorithm

Artificial neural network (ANN) is mostly used as a method for recognition process. ANN will be implemented once a face has been detected to identify and recognize who the person is by calculating the weight of the facial information.

Basically, ANN imitates human brains biological neuron system. A neuron receives a signal from the previous layer then transmits the signal to all neurons on the next layer. Before transmitting the signal to the next layer, the signal has been multiplied by a separate multi weight value and the weighted input is summed. **Fig. 2**illustrates the process [37].

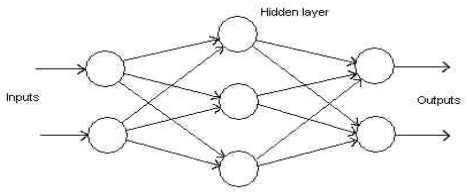

Fig. 2A generalized neural networks

ANN is divided into several types such as feed forward neural network, back propagation neural network and Radial Basis Function (RBF) network. These three networks are considered as the most commonly used in ANN.

- **Fast Forward**

The simplest type of ANN is the feed forward network or also known as multilayer perceptrons. There are no cycles in feed forward network as the information moves forward in only one direction from the input nodes via the hidden nodes and to the output nodes.

- **Back Propagation**

Back propagation deploys the technique of calculating the error made in the output neuron and propagates them back to the inner neuron or this method is also known as "learn by examples". Therefore, a learning set consists of input examples for each case must be included. The output value is compared to the examples in the training set and an error value is calculated. This error value is then propagated back to the neuron and used to adjust the weights. Small changes are made to the weight value to reduce the error value. This process repeats until it reaches a pre-determined value. **Fig. 3**depicts the process of back propagation [37].

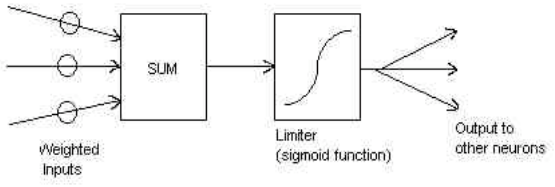

Fig. 3A generalized back propagation neural networks

The back propagation neural network is used to recognize and classify aspects of the image of a human's face such as the expression of the person in the image, the orientation of the face in the image and also the presence of any accessories such as sunglasses and beard [38][39][40].

- **Radial Basis Function (RBF)**

Radial Basis Function (RBF) is used to estimate the functions and identifying patterns. It applies the Gaussian potential functions whereby these functions are employed in the networks [41]. RBF offers advantages in localization, cluster modelling, functional approximation, interpolation and quasi-orthogonality [42].

5. WHY CHOOSE THESE ALGORITHMS OR METHODS?

For this paper, these algorithms were chosen based on the most widely used and most successful [43][19][44]. They also suit the requirement of this paper as well as good instances for reference for further readings and information.

6. WHAT ARE THE REVIEWED FEATURES?

This paper concentrates more on the theoretical part as review of the overall of the highlighted algorithms. Based on these features, the strengths and limitations can be analyzed. The reviewed parameters are explained in the following subsection. Please take note that these parameters are not fixed as every case yields different outcomes. Hence, this review is based on previous researches done by other people. The parameters are such follows:

i. Size and typesof database (dataset)

Based on an experiment conducted by Aleix M. Martinez and Avinash C. Kak [45], they have come out with a conclusion that PCA can outperform LDA when the size of dataset used is small. This experiment was conducted to reinforce their claim that LDA is not always

performs better than PCA. A dataset called the AR-face database from Purdue University is used. The AR-face database is a public dataset, which can be retrieved online. **Fig. 4**supports their claim. They also proved that PCA is coherent when different dataset is used. However, LDA "wins" over PCA when the there is a presence of illumination in the small dataset.

Fig. 4 Example to support their claim that LDA not always outperform PCA.

Haihong Zhang *et al.* [46]have conducted an experiment to evaluate their proposed method, Gabor Wavelet Associative Memory (GWAM) method using three well-known databases, namely, Olivetti-Oracle Research Lab (ORL) database, AR-face database and FERET database.

GWAM is basically using Gabor wavelet method. The experiment reveals an excellent result of the method's consistency and high performance. GWAM performs its best at 100% accuracy in recognizing faces from the ORL database, almost to perfect for FERET database and about 90% recognition accuracy for AR-face database.

PCA method is used as a comparing method for GWAM to be evaluated. PCA however shows a less significant and inconsistent result towards different database. PCA performs its best for ORL database, followed by a significant less accuracy for FERET database and least accurate for AR-face database.

ii. Facial expressions variations

Based on the research done by PraseedaLekshmi V. and Dr. M.Sasikumar [34], Gabor wavelet is used in face detection involving variation of facial expressions. In their experiment, the facial expression that are taken into account are 'Happy', 'Normal, 'Surprise' and 'Anger'. The images are categorized by expression. The 'Anger' expression yields the best result out of all expression that gives result to almost 100% accurate.

Another work related to facial expression using Gabor wavelet has been done by Michael Lyons and Shigeru Akamatsu [47]. Instead of classifying images to facial expression, a difference between similarities and dissimilarities space of the representation is used. It is because facial expressions are not always pure expressions.

iii. Illumination tolerance

An experiment that has been done by K.Y. Tan and A.K.B. See from Monash University (Malaysia) reveals that Eigenface based method outperforms the other methods when dealing with illumination changes [48]. Eigenface yields the best result of the fastest processing time in comparison with others. Three other algorithms have been used in this experiment, namely, Normalized-Cross Correlation, Gradient Image and Relative Gradient Image Feature. However, this result is deemed the best for only when there is a slight variation in illumination.

Another experiment conducted by Yanwei Pang *et al.* yields atypical results from the above experiment [49]. Based on their experiment, LDA performs better than PCA because LDA utilizes within-class information [50] and the most discriminant features while PCA utilizes the most expressive features [11]. This experiment also reveals that a combination of Gabor wavelet and LDA contributes to a better face recognition performance under illumination variation. This method utilizes Gabor wavelet, local features and global features.

iv. Pose variations

A result from an experiment done by Kepenekci*et al.* indicates that Gabor feature performsbetter than Eigenface but less than neural networks [51]. Although it is known that ANN always performs well to cater pose variations but this experiment proves the other way around. Please note that ANN requires more than one facial images for each individual training whereas in this experiment, Gabor wavelet only used one facial image for the training. Therefore, in this case, Gabor wavelet

can be considered to have a better performance that ANN.

Wang *et al.* has come out with their novel Pose Adaptive Linear Discriminant Analysis (PALDA) [52]. PALDA is a proposed method derived from LDA approach. In this experiment, Wang *et al.* indicates that PALDA outperforms other methods.

7. CONCLUSION

Five different methods in face detection and recognition have been reviewed, namely, PCA, LDA, Skin Colour, Wavelet and Artificial Neural Network. There are four parameters that are taken into account in this review, which are size and types of database, illumination tolerance, facial expressions variations and pose variations. From this independent review, please note that the results atypical and variant as they correspond to different experiments or studies done by previous researchers. Thus, no specific justification can be made as a conclusion on which algorithm is the best for specific tasks or challenge such as various databases, various poses, illumination tolerance and facial expressions variations. The performance of the algorithms depends on numerous factors to be taken into account. Instead of using these algorithms solely, they can be improved or enhanced to become a new method or hybrid method that yields a better performance.

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