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3D Face Recognition System- A Review

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Abstract— Biometrics is an upcoming trend in the field of security. The different biometric characteristics are fingerprint, face, iris, retina, signature etc. These characteristics are widely used in different organisations for authentication purposes. For example, in educational fields like schools and colleges, fingerprint recognition is used for attendance system and face recognition is used in mobile phones for identification of an individual user. Similarly, iris recognition is used in the government sector through the use of Aadhar card. 2D Face recognition has been widely accepted by different organisations for authentication and identification purposes. However, there are various issues related to 2D face recognition namely, illumination problem, pose variation and variations in expression. To overcome these issues, 3D face recognition systems could be used. In this paper we discussed and compared the applications of 2D face recognition system with 3D face recognition system. Based on the applicability in all the environments it has been found that 3D face recognition system is more reliable while recognizing any individual. This paper also discusses basic about the Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA) and Local Binary Pattern (LBP). All approaches are being reviewed with respect to the working of the algorithms, significant factor while recognition and applicability to the 3D face recognition.

Keywords—3D Face recognition system, PCA, LDA, LBP.

I. INTRODUCTION

Biometrics is an automated system in which a person's unique physical or other traits are detected and recorded by an electronic device or system as a means of confirming ones identity. These biometric characteristics are divided into 2 parts namely: 1) Physiological and 2) Behavioural. The physiological characteristics are related to a part or organ of the body and it can include fingerprint, iris, face, hand geometry, retina, ear shape, and DNA recognition system. The behavioural characteristics are related to the human behaviour that changes over time and it includes keystroke, signature, and speech recognition system. Biometrics authentication mechanism is an upcoming technology in the field of security. It is more secure than the password mechanisms because unique biometric features cannot be forged easily due to minimal changes being developed over years. The basic block diagram for any biometric system is as under:

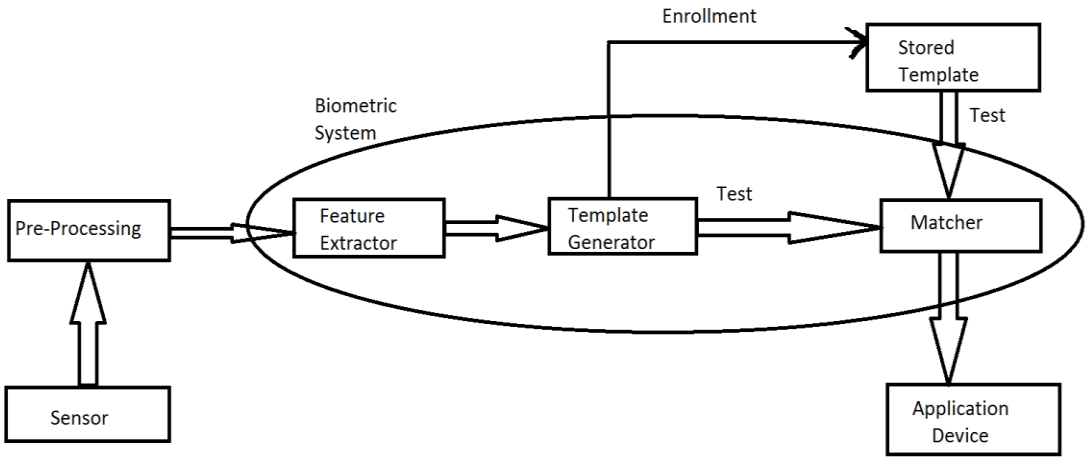

Fig. 1 Block diagram for Biometric System

Face recognition system is one of the important physiological characteristics of the biometric system which is widely used in many fields like IT industries and law enforcement. However, there are certain limitations to 2D face recognition like illumination problem, pose variation and variation in expression. This paper discusses the use of 3D face recognition system to overcome the above problem with the help of algorithms like PCA, LDA and LBP.

The rest of the paper is organized as follows. Section II gives an overview of 3D face recognition. Section III describes the algorithms for 3D face recognition. Section IV gives the comparison between the 2D and 3D face recognition system. It also gives the differences between the PCA, LDA and LBP algorithm discussed in Section IV and finally we conclude the paper in section V.

II. OVERVIEW OF 3D FACE RECOGNITION SYSTEM

Face recognition is the behavioural characteristics of a biometric system which is widely accepted and used for security applications. The 2D face recognition system contains 2D [4] [6] [7] [8] images that have various issues that arise during the collection process. These issues could occur due to illumination problems, pose variation, variations in expression, head orientation and partial occlusion. These issues will degrade the image quality resulting in an inaccurate extraction procedure. Nowadays, 3D face recognition systems are used to overcome these issues. For capturing the sample images, systems use a 3D range camera. 3D face models are generated by using 3D range cameras. It has various advantages over the traditional 2D face images. 3D face models use geometric depth information rather than colour and texture. So when features are extracted they are invariant to the lighting conditions [19]. These 3D face cameras also have the ability to rotate face model in 3D space so that system can detect the images which are taken invariant to head angles as well. Finally the captured 3D models are to scale, so the system can have absolute measurements invariant to camera distance.

III. ALGORITHMS

A. Principal Component Analysis (PCA)

Principal Component Analysis (PCA) [9] is a variable reduction procedure and an efficient method for face recognition. PCA is a linear dimensional reduction technique and is also known as Eigen space projection or Karhunen-Loeve transformation. PCA is appropriate when you have obtained measures on a number of observed variables and wish to develop a smaller number of artificial variables called principal components. It is useful when you have obtained data on a number of variables, and believe that there is some redundancy in those variables. PCA calculates the Eigen vectors of the covariance matrix. PCA is used in face recognition where the Eigen faces are calculated. PCA is used to reduce the dimension of the data. PCA not only reduces the dimensionality of the data it also regains the variations created in the data of the image. PCA is also used in object recognition and gives an accurate result. PCA is a linear transform based on the statistical techniques. PCA is very useful method for data analysis and pattern recognition purpose. The advantage of PCA is that it can be used for compression of data without any loss of data. The steps of PCA [2] [3] [5] are as under:

PCA involves mainly two phases:

- Training Phase
- Testing Phase

The steps involved in the Training Phase are:

- Transform the original images of the training set into a set of Eigen faces E
- Calculate the weights for each image of the training set and store in the set W
- Receive unknown image X, calculate the weights for X and store the weights in the vector WX

The steps involved in the Testing Phase are

Compare the weight WX of the test image X with the weights W of the training image. For this:

1. Calculate the average distance D between the weight vector W and the weight vector WX of the unknown image.
2. Compare D with some threshold value.
   - If D exceeds the threshold, θ, then indicate that the weight vector WX of the unknown image lies too "far apart" from the weights of the faces. Under such case, the unknown image X is not a face.

Otherwise, if X is actually a face, store its weight vector WX for later classification. Note that the optimal threshold value has to be determined empirically.

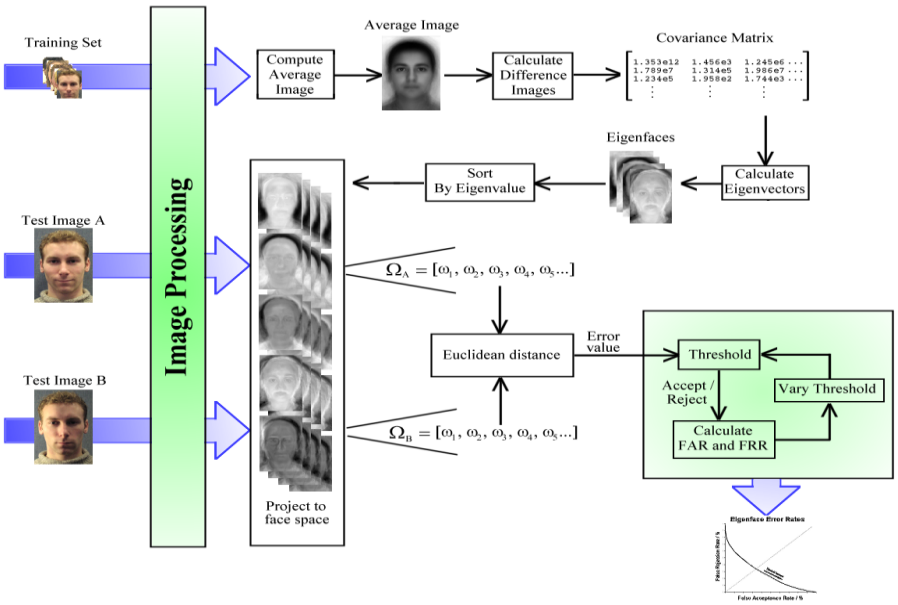

Fig. 2 Block diagram for PCA [19]

B. Linear Discriminant Analysis (LDA)

LDA [15] is a linear transformation process which tries to classify the data in a given image. LDA is basically used for the classification of data into within-class and between-classes. It is a statistical approach which maximises the between class scatter to within class scatter. It is also used for classifying unknown classes based on training samples with known classes. The steps for LDA [4] are as under:

Step1: Samples for class1 and class2
Step2: Calculate mean of class1 and class2 i.e. Mu1 and Mu2
Step3: Covariance Matrix of first class and second class i.e. S1 and S2
Step4: Calculate within-class scatter matrix by using given equation Sw = S1 + S2
Step5: Calculate between-class scatter matrix by using given equation SB = (Mu1-Mu2)*(Mu1-Mu2)
Step6: Calculate mean of all classes
Step7: Compute the LDA projection invSw = inv (Sw) invSw_by_SB = invSw * SB
Step8: The LDA projection is then obtained as the solution of the generalised eigen value problem

$$Sw^{-1}S_B W = \lambda W$$

W=eig(Sw^{-1} sb) Where W is the projection vector

C. Local Binary Pattern (LBP)

LBP [12] is a texture descriptor. It is based on thresholding considering a 3x3 neighbourhood pixels where the centre pixel is the threshold. The values which are lesser than the threshold will be equal to zero while the values equal or greater than the threshold will be 1. For example

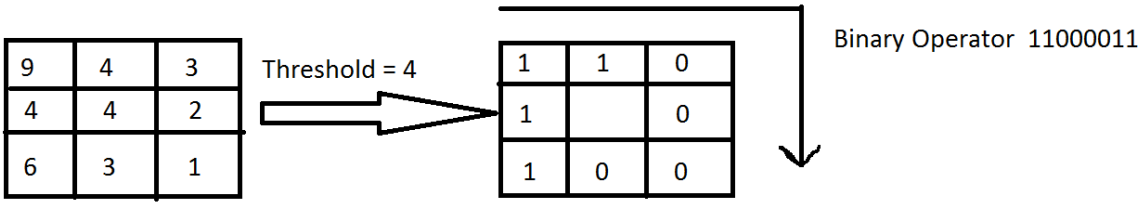

Fig. 3 Preparation of Binary Operator [12]

As shown in fig. 3, consider a 3x3 matrix where the central pixel is the threshold i.e. 4. The values less than 4 are considered as 0 and values greater than 4 is 1. To calculate the LBP operator it moves in circular pattern so the desired output of the binary operator is 11000011.

IV. INFERENCES

The comparison of 2D face recognition and 3D face recognition [1] is given below and is based on the extraction of features, orientation, illumination factor and capturing device.

Table I Difference Between 2d Face Recognition V/S 3d Face Recognition

Sr. No	**2D Face Recognition**	**3D Face Recognition**
1.	Facial features are extracted according to distance between the eyes, width of nose, length of jaw.	Facial features are extracted using the contours of the nose, chin, eyes etc.
2.	The orientation of the face is settled upto 15-20 degrees.	The orientation of the face is settled upto 90 degrees.
3.	The illumination should be proper otherwise poor lighting can affect the performance.	Range camera with infrared light can be used in low illumination too.
4.	Web camera or digital camera is used.	Range camera or Stereoscopic is used.

The comparison of PCA, LDA and LBP is given below and is based on the classification, significant factor while recognition, feature extraction steps and applicability to the 3D face recognition [10] [11] [12] [13]

Table II Difference Between Pca, Lda, Lbp [14]

Sr. No	PCA	LDA	LBP
1.	PCA is used for feature classification	LDA is used for data classification.	LBP is used as a texture descriptor.
2.	It works based on the Eigen vectors	It works on between and within scatter classes.	It works on threshold.

3.	It is used to find the variations of images with respect to mean image.	It minimises between-class to within-class scatter.	As the centre pixel is considered as threshold the LBP pattern is generated in a circular fashion
4.	Compared to LDA and LBP this method is more suitable for 3D face recognition because it is going to find the discrimination with respect to all the images.	This method is suitable for 3D face recognition while developing the system for different set of classes.	It is not suitable for 3D face recognition because it mainly focuses on the local features.

V. CONCLUSIONS

Biometrics is a widely accepted tool for security applications. In this paper we have listed the physiological and behavioural biometric characteristics that are used in different sectors. We have focused on the face recognition system that is one of the physiological characteristics used in a biometric system. Face recognition system is now used for the security purpose in smartphones, laptops, personal computers etc. This paper also focuses on some issues that arise in 2D face recognition system like illumination problem, pose variation and variations in expression. To overcome these issues a proposal to use of 3D face recognition system was mentioned. We have discussed the algorithms used in 3D feature extraction and have shown the comparison of the same. In addition, the comparison between 2D and 3D face recognition system was also summarized.

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