Comparison of Facial Recognition Algorithms Based on False Acceptance and False Rejection

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Abstract— This research work on implements a Facial Recognition System using Python programming language and the Open Source Computer Vision (OPenCV) library to identify probe images supplied to the system. The system was implemented using three different algorithms namely; EigenFaces (Principal Component Analysis), FisherFaces and Local Binary Pattern Histogram (LBPH) Algorithms. The comparison is based on the rate of false acceptance (the case when a subject meant to rejected is accepted) and false rejection (the case when a subject meant to accepted is rejected). The face database implemented for the project is the AT&T (formerly Ollivetti Research Laboratory database) which consists of 40 subjects with 10 images per subject all in Portable Gray Map format (pgm) format.

Index Terms— facial recognition system, EigenFaces, FisherFaces, Local Binary Pattern histogram, false acceptance, false rejection.

1.0 Introduction

Technology has evolved in complex and dynamic ways especially when it comes to the manner in which we communicate with one another. At the heart of this, is a rich and growing field called biometrics that is redefining the way in which we identify and recognise each other [13].

The true origins of the simplest Face Recognition technology can be dated back to the early 1800s. Following the invention of the camera, it was almost immediately used as a method for law enforcement to record images of criminals to identify multiple time crime committed by offenders (a popular use of Face recognition till today).The pioneers of automated face recognition include Woody Bledsoe, Helen Chan Wolf, and Charles Bisson [1]

A Face Recognition system is a biometric system. With respect to Face Recognition, the face is considered to be the biometric because it may be used to uniquely identify an individual.

Face Recognition is an active field of research and has increased significantly since the early 1990s. This is mainly due to the fact that government agencies and businesses have realized the vast range of commercial applications that one can provide with Face Recognition. However, the applications of Face Recognition cut across all places including homes and offices. These applications fall in many areas, such as: entertainment, smart cards, information security and law enforcement [2]. Since Face Recognition research is so active, there are a multitude of techniques and algorithms to perform Face Recognition [2][3].

A very important distinction that one should make is between three-dimensional (3D) and two-dimensional (2D) Face Recognition methods. In 3D Face Recognition, a 3D model of a face is used in the recognition process. The 3D model is usually constructed from a set of 2D images or by means of a 3D camera. In 2D Face Recognition a 2D image is used in the recognition process. Within 2D Face Recognition research, one must make further distinctions between still and video based Face Recognition methods. This is mainly due to the fact that still images of faces are captured under controlled conditions such as in a laboratory and are of much higher quality than images captured with a video camera [4].

2.0 Literature Review

[5] provided a comparative study of various Face Recognition systems, to provide researchers an insight into the current scenario of various Face Recognition techniques employed to build distinct Face Recognition systems, which have different accuracy and performance levels, in an unconstrained environment.

[6] proposed system presents a novel method of Face Recognition based on the cloud model, in combination with the traditional facial expression system. The process of predicting emotions from facial expression images contains several stages. The first stage of the system is the preprocessing stage, which is applied by detecting the face in images and then resizing the images. The second stage involves extracting features from facial expression images using Facial Landmarks and Center of Gravity (COG) feature extraction algorithms, which generate the training and testing datasets that contain the expressions of Anger, Disgust, Fear, Happiness, Neutrality, Sadness, and Surprise. Support Vector Machine (SVM) classifiers are then used for the classification stage in order to predict the emotion

[7] discussed serial and parallel implementation of four standard Face Recognition algorithms namely; Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), Independent Component Analysis (ICA) and FISHER Face. The work presented in the paper consists of two sections. In section 1, serial and parallel implementation of the algorithms were discussed and Section 2, presents a comparative performance analysis of the algorithms. All algorithms are implemented using open source OPENCV and OPENMP libraries.

[8] proposed an approach essentially was to implement and verify the algorithm Eigenfaces for Recognition, which solves the recognition problem for two dimensional representations of faces, using the principal component analysis. The snapshots, representing input images for the proposed system, are projected in to a face space (feature space) which best defines the variation for the face images training set. The face space is defined by the 'eigenfaces' which are the eigenvectors of the set of faces. These eigenfaces contribute in face reconstruction of a new face image projected onto face space with a meaningful (named weight).The projection of the new image in this feature space is then compared to the available projections of training set to identify the person using the Euclidian distance. The implemented system is able to perform real-time face detection, face recognition and can give feedback giving a window with the subject's info from database and sending an e-mail notification to interested institutions.

[9] did a review and comparison of techniques such as Principal Component analysis (PCA), Independent Component analysis (ICA), Linear Discriminant Analysis (LDA), and improvements needed in the previous approaches which made Neural Networks based recognition like a boon to the industry. It not only enhanced the recognition but also the efficiency of the process. Choosing Backpropagation as the learning method was clearly out of its efficiency to recognize non- linear faces with an acceptance ratio of more than 90% and execution time of only few seconds.

[10] proposed a face detection algorithm for color images in the presence of varying lighting conditions as well as complex backgrounds based on a novel lighting compensation technique and a nonlinear color transformation. The method detects skin regions over the entire image and then generates face candidates based on the spatial arrangement of these skin patches. The algorithm constructs eye, mouth, and boundary maps for verifying each face candidate. Experimental results for this method demonstrate successful face detection over a wide range of facial variations in color, position, scale, orientation, 3D pose, and expression in images from several photo collections (both indoors and outdoors).

In the work proposed by [11], Face is explained to be a complex multidimensional visual model and developing a computational model for face recognition is said to be difficult. The paper presents a methodology for face recognition based on information theory approach of coding and decoding the face image. Proposed methodology is connection of two stages – Feature extraction using principle component analysis and recognition using the feed forward back propagation Neural Network. The algorithm has been tested on 400 images (40 classes). A recognition score for test lot is calculated by considering almost all the variants of feature extraction. The proposed methods were tested on Olivetti and Oracle Research Laboratory (ORL) face database. The test results are said to give a recognition rate of 97.018%.

[12] proposed a security system that has been developed to prevent robbery in highly secure areas like home environment with lesser power consumption and more reliable standalone security device for both Intruder detection and for door security. The door access control was implemented by using face recognition technology, which grants access to only authorized people to enter that area. The face recognition and detection process is implemented using principal component analysis (PCA) approach and instead of using sensor devices intruder detection is achieved by performing image processing on captured video frames of data, and calculating the difference between the previously captured frame with the running frames in terms of pixels in the captured frames. This is the stand alone security device has been developed by using Raspberry Pi electronic development board and operated on Battery power supply, wireless internet connectivity by using USB modem. Auto Police e-Complaint registration has been achieved by sending security breach alert mails to the nearby police station e-mail id. This proposed is more effective, reliable, and this system consumes very less data and power compared to the other existing systems.

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[14] proposed an algorithm to classify and analyze facial features such as eyebrow, eye, mouth and chin based on the geometric features of the face. As a preprocessing process to classify and analyze the facial features, the algorithm extracts the facial features such as eyebrow, eye, nose, mouth and chin. From the extracted facial features, it detects the shape and form information and the ratio of distance between the features and formulated them to evaluation functions to classify 12 eyebrows types, 3 eyes types, 9 mouth types and 4 chine types. Using these facial features, it analyzes a face. The face analysis algorithm contains the information about pixel distribution and gradient of each feature. In other words, the algorithm analyzes a face by comparing such information about the features.

[15] proposed an algorithm for classifying human face using this machine vision system. This algorithm consists of Convolutional Neural Network and cascade face detector. Using this algorithm, the authors classified the face of subjects. For training the face classification algorithm, 2,000, 3,000, and 4,000 images of each subject were used. Training iteration of Convolutional Neural Network had 10 and 20 and then, Image Classification was performed. About 6,000 images were classified for effectiveness implemented with a system that can classify the face of subjects in real-time using USB camera.

In a work by [19] Fisherface is enhanced in this paper for face recognition from one example image per person. Fisherface requires several training images for each face and can hardly be applied to applications where only one example image per person is available for training. They enhance Fisherface by utilizing morphable model to derive multiple images of a face from one single image. Region filling and hidden-surface removal method are used to generate virtual example images. Experimental results on ORL and UMIST face database show that our method makes impressive performance improvement compared with conventional Eigenface methods.

[16] presented an enhanced approach to improve human face recognition using a back-propagation neural network (BPNN) and features extraction based on the correlation between the training images. A key contribution of this paper is the generation of a new set called the T-Dataset from the original training data set, which is used to train the BPNN. They generated the T-Dataset using the correlation between the training images without using a common technique of image density. The correlated T-Dataset provides a high distinction layer between the training images, which helps the BPNN to converge faster and achieve better accuracy. Data and features reduction are essential in the face recognition process, and researchers have recently focused on the modern neural network. Therefore, a local binary pattern histogram descriptor was used to prove that there is

potential improvement even using traditional methods. Five distance measurement algorithms were applied and then combined to obtain the T-Dataset, which we fed into the BPNN and higher face recognition accuracy was achieved with less computational cost, compared with the current approach by using reduced image features. The proposed framework was tested on two small data sets, the YALE and AT&T data sets, as the ground truth tremendous accuracy was achieved.

[17] presented a novel approach to face recognition which considers both shape and texture information to represent faces images. The face area is first divided into small regions from which Local Binary Pattern (LBP) histograms are extracted and concatenated into a single, spatially enhanced feature histogram efficiently representing the face image. The recognition is performed using a nearest neighbour classifier in the computed feature space with Chi square as a dissimilarity measure.

Extensive experiments clearly show the superiority of the proposed scheme over all considered methods (PCA, Bayesian Intra/extra-personal Classifier and Elastic Bunch Graph Matching) on FERET tests which include testing the robustness of the method against different facial expressions, lighting and aging of the subjects. In addition to its efficiency, the simplicity of the proposed method allows for very fast feature extraction.

3.0 Methodology

A Face Recognition System is implemented using three different Face Recognition algorithms namely; **Eigen Faces**, **Fisher Faces** and **Local Binary Pattern Histogram (LBPH)**. The development is done using the Python programming language and Open Source Computer Vision (OpenCV) library to train images and probe them from the database. The AT&T face (formerly Olivetti Research Laboratory, ORL) database containing 10 images for 40 individuals (subjects) in Portable Gray Map format (pgm) format is used as the training database. Also, the YALE and Face Recognition Technology (FERET) database were used.

3.1 Open Source Computer Vision (OpenCV) Library

OpenCV is an open-source BSD-licensed library that includes several hundreds of computer vision algorithms. The following modules are available:

Core functionality - a compact module defining basic data structures, including the dense multi-dimensional array Mat and basic functions used by all other modules.

Image processing - an image processing module that includes linear and non-linear image filtering, geometrical image transformations (resize, affine and perspective warping, generic table-based remapping), color space conversion, histograms, and so on.

video - a video analysis module that includes motion estimation, background subtraction, and object tracking algorithms.

calib3d - basic multiple-view geometry algorithms, single and stereo camera calibration, object pose estimation, stereo correspondence algorithms, and elements of 3D reconstruction.

features2d - salient feature detectors, descriptors, and descriptor matchers.

objdetect - detection of objects and instances of the predefined classes (for example, faces, eyes, mugs, people, cars, and so on).

highgui - an easy-to-use interface to simple UI capabilities.

Video I/O - an easy-to-use interface to video capturing and video codecs.

gpu - GPU-accelerated algorithms from different OpenCV modules, and some other helper modules, such as FLANN and Google test wrappers, Python bindings, and others (OpenCV, 2014).

3.2 NumPy

NumPy is a library for the Python programming language, adding support for large, multi-dimensional arrays and matrices, along with a large collection of high-level mathematical functions to operate on these arrays. The ancestor of NumPy, Numeric, was originally created by Jim Hugunin with contributions from several other developers. In 2005, Travis Oliphant created NumPy by incorporating features of the competing Numarray into Numeric, with extensive modifications. NumPy is open-source software and has many contributors.

OpenCV-Python makes use of Numpy, which is a highly optimized library for numerical operations with a MATLAB-style syntax. All the OpenCV array structures are converted to and from Numpy arrays. This also makes it easier to integrate with other libraries that use Numpy such as SciPy and Matplotlib.

3.3 An overview of description of the different algorithms

Algorithms to be implemented are given below.

3.3. 1 Eigen Faces (Principal Component Analysis) Algorithm: The approach of using eigenfaces for recognition was developed by Sirovich and Kirby (1987) and used by Matthew Turk and Alex Pentland in face classification Wikipedia contributors (2019). The eigenvectors are derived from the covariance matrix of the probability distribution over the high-dimensional vector space of face images. The eigenfaces themselves form a basis set of all images used to construct the covariance matrix. This produces dimension reduction by allowing the smaller set of basis images to

represent the original training images. Classification can be achieved by comparing how faces are represented by the basis set.

Principal Component Analysis (PCA) is a statistical approach used for reducing the number of variables in face recognition. In PCA, every image in the training set is represented as a linear combination of weighted eigenvectors called **Eigen faces**. These eigenvectors are obtained from covariance matrix of a training image set. The weights are found out after selecting a set of most relevant Eigen faces. Recognition is performed by projecting a test image onto the subspace spanned by the eigenfaces and then classification is done by measuring minimum Euclidean distance.

3.3.2 Fisher Faces (Linear Discriminant Analysis) Algorithm: Image recognition using fisherface method is based on the reduction of face space dimension using Principal Component Analysis (PCA) method, then applies Fisher's Linear Discriminant (FDL) method or also known as Linear Discriminant Analysis (LDA) method to obtain feature of image characteristic.

This algorithm is an improved version of EigenFaces face recognizer. Eigenfaces face recognizer looks at all the training faces of all the persons at once and finds principal components from all of them combined. By capturing principal components from all the of them combined you are not focusing on the features that discriminate one person from the other but the features that represent all the persons in the training data as a whole.

This approach has drawbacks, for example, images with sharp changes (like light changes which is not a useful feature at all) may dominate the rest of the images and you may end up with features that are from external source like light and are not useful for discrimination at all. In the end, your principal components will represent light changes and not the actual face features.

Fisherfaces algorithm, instead of extracting useful features that represent all the faces of all the persons, it extracts useful features that discriminate one person from the others. This way, features of one person do not dominate over the others and you have the features that discriminate one person from the others.

3.3.3 Local Binary Pattern Histogram (LBPH) Algorithm

LBP was introduced by Ojala et al. in 1996, is described as an ordered set of binary comparisons of pixel intensities between the center pixel and its surrounding pixels. It is used for extracting unique and useful features from preprocessed images and is the most efficient and newest approach for face recognition Ojala T., Pietikäinen M. and Harwood D. (1996).

With LBP it is possible to describe the texture and shape of a digital image. Each pixel of an image is labeled with an LBP code which is obtained by converting the binary code into decimal one.

First, it will divide the image to several small blocks from which the features are extracted. Then it will start calculating the LBP histograms for each block from the obtained features. After that it will combine all LBP histograms for that image to obtain one concatenated vector. Images can then be compared by measuring the similarity (distance) between their histograms. Several studies and research work like Ahonen T., A. Hadid and M. Pietikäinen (2004, 2006), Ahonen T., Hadid A., Pietikäinen M. and Mäenpää T. (2004) indicated that face recognition using the LBP method provides very good results with different facial expressions, different lightening conditions, image rotation and aging of persons. Speed and discrimination performance of an LBP system is also magnificent.

4.0 Discussion of Results

There are 400 standard images of the AT&T (ORL) face database in all for the facial detection and recognition processes. Some other standard frontal images of a custom database were also used and the following results were obtained.

4.1 Summary of Precision in Face Recognition Performance

Below is a tabular comparison of results obtained during the analysis of the three implemented algorithms in terms of False Acceptance Rate (FAR) and False Rejection Rates (FRR). A rescaling algorithm was integrated during development to keep all images at (200, 200). All algorithms were implemented using Python (3.6), OpenCV and also the Anaconda environment which contains the NumPy and MatPlot libraries.

The recognition accuracy was calculated by adding the percentage of false acceptance (in which the system identifies a wrong subject) with that of false rejection (in which an ideal subject was rejected through its probe).

Algorithm	False Acceptance Rate	False Rejection Rate	Recognition Rate
EigenFace	4.3%	3.8%	97.8 %
Fisherface	2.8%	1.5%	98.2%
LBPH	1.2%	1.1%	98.9%

Table 1: Showing the recognition accuracy under ORL database.

Algorithm	False Acceptance Rate	False Rejection Rate	Recognition Rate
EigenFace	3.9%	3.4%	97.9 %
Fisherface	2.5%	1.2%	98.4%
LBPH	0.8%	0.9%	99.1%

Table 2: Showing the recognition accuracy under YALE database.

Algorithm	False Acceptance Rate	False Rejection Rate	Recognition Rate
EigenFace	5.3%	4.8%	97.2 %
Fisherface	2.6%	1.7%	98.1%
LBPH	1.3%	1.2%	98.5%

Table 3: Showing the recognition accuracy under FERET database.

5.0 Summary and Conclusion

5.1 Summary

The Comparison of Face Recognition Algorithms studied the flaws and benefits of the implemented algorithms to bring about more accuracy during recognition. It is very important, for a recognition system, especially when implemented for Security and Surveillance purposes to identify the right subjects, in order not to apprehend innocents or deny authorized persons access. The study considered the Eigen Faces, Fisher Faces and Local Binary Pattern Histogram algorithms.

5.2 Conclusion

Based on the results of the recognition tests carried out on the ORL, YALE and FERET databases, the study concludes by identifying the superiority of the Local Binary Pattern Histogram. This is so because, the algorithm extracts unique and useful features from preprocessed images and it is not affected by varying light intensity and other conditions.

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7.0 Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared influence the work reported in this paper.

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