Smart Gate: Intelligent Security System Based on Face Recognition

Monika Shah, Deepika Shukla, Dhara Pandya

Abstract*: Features of Human face is one of the unique biometrics used for identifying and recognizing humans. This makes face recognition system an integral component of numerous applications like identity verification of personnel at gates in many organizations, for controlled access of confidential resources, recognizing intruders by nationwide defense institutions, and such many more. Due to this the unavoidable need of face recognition system, practitioners and researchers are putting their continuous efforts to rectify and optimize the face recognition system for different perspectives in terms of accuracy, time, and storage. The techniques are also optimized for face captured at different degree of orientation, change of facial expression with time, lighting condition, with and without eyeglass and other props, but as isolated solutions. The main aim of the paper is to propose a system that can be installed at any door or gate which would operate based on integrated face recognition. The major contribution of this paper is twofold: i) An integrated face recognition solution optimized for recognizing multiple people faces captured at different orientations and even wearing eyeglasses of different shapes, sizes and materials ii) Smart Gate system being activated upon successful recognition of all faces captured simultaneously.

Keywords: Face Detection, Face Recognition, Feature extraction, Eyeglass removal, Smart-Gate.

I. INTRODUCTION

With the advent of new technologies, many organizations are adopting smart solutions for personal identity verification in applications like verified entry at the gate, attendance monitoring of employees, and many other surveillance tasks. The most common methods used in today's scenario are to identify a person are Passwords, PIN (Personal Identification Number), and token systems such as RFID card reader. Since such systems suffer from the problem of falsification, robbery and passes in the user's memory, an impressive enthusiasm for biometric identification systems have arisen in recent years. Fingerprint, iris scan, speech recognition, and face recognition are well-known biometric-based identity verification techniques, but each has its own limitations. For example, the hand should be clean for fingerprint recognition and fails to establish identity successfully if the hands are injured. Other biometric-based identity verification techniques are speech recognition, iris scan, and face recognition. Out of these methods of identity verification, face recognition and an iris scan are considered more stable as the physiological features are rarely changed except in case of severe injury[8]; whereas speech recognition is considered less stable as the speech of a person can easily be mimicked. The iris scan based identification also differs from face recognition from the degree of intrusiveness inherent to the technique. People are less comfortable in placing their eyes before a scanner, than getting their faces scanned while their regular activity. Face recognition possess the benefits of high accuracy and low intrusiveness. It provides high accuracy without being intrusive [8].

Looking at the benefits of face recognition, this work proposes a Smart Gate based on the face recognition technique. That is an employee can get entry with smart verification at the gate without disturbing their normal activities.

One of the critical challenges with both face detection and face recognition is when a person wears an eyeglass. The appearance of a face with the eyeglass frame becomes so diverse as frames come in various materials such as metal or plastic. Due to varied properties of properties of metal or plastic, it becomes a great challenge to recognize a person wearing eyeglasses, especially when the database does not have that person's image with eyeglasses. The reverse case is also critical, where the database contains an image wearing eyeglasses and person comes without glasses. This is mainly due to human's non-uniform practice of wearing eyeglasses. An additional aspect of this criticality is that people may change eyeglasses having different sizes, shapes, and material with time. To resolve this issue smartly, it is required to identify persons wearing eyeglasses in the captured image and remove eyeglasses if found one. Removal will add one more dimension to the criticality. Hence, eyeglass detection and removal algorithm is integrated into the proposed face recognition algorithm in this paper.

The rest of the paper is arranged as follows. Section II introduces briefly the face recognition phases. Section III discusses the literature existing on the field. Section IV proposes a framework of the Smart Gate based on proposed face recognition, which is described in detailed in section V. Section VI describes the experimental setup used to test the

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proposed face recognition algorithm and discusses the results obtained. Finally, we conclude the paper and cite some future enhancement in section VII.

II. FACE RECOGNITION PHASES

Our faces are very complex items with facial components which can vary over time. Humans are blessed with a very good capacity to recognize faces learned throughout their lifetime in fraction of seconds even after years of separation, but the computer system or any machine does not have such a capacity. This creates a need for a face recognition system optimized in such a way that is as intelligent as humans. Face recognition System has fundamentally three phases: face detection, feature extraction and face recognition as shown in in Fig. 1.

Face detection is the process of confirming that a face exists in the image or video and if there is one; return its location and extent. Face detection has its own challenges such as posture variance, the deficiency or existence of physical components, varied facial expressions, occlusion, face orientation and imaging conditions [6].

After face detection from an image, the next step is of feature extraction, which is process of extracting required face features like eyes, nose, lips, etc. The phase also determines the location of these features on the detected face and further uses them for mapping with image database which is the third phase of the typical face recognition system.

The third phase is of recognizing or labeling the detected face in the image with the name of a person. Face recognition methods, in general, can be classified as holistic methods, feature-based methods, model-based methods and hybrid methods [Naeem2015]. In holistic methods, the complete face is considered a single feature for detection and recognition, whereas in featurebased methods, individual features of the face like eye, nose, mouth, ear, etc. are used to recognize the face. In the model-based technique, the 3D facial model is created and further used for recognition and hybrid methods can be any combination of earlier methods.

Fig. 1: Face Recognition System

III. RELATED WORK

The central component of the system proposed herewith is face recognition. Hence, we discuss related work done by various researchers in the area connected with face recognition.

Face detection and localization is an inherent step in any of the face recognition system. Face detection techniques can be categorized into various methodologies like knowledge-base[6], facial component based[29], template based[3], using Eigen faces[18], using neural-network[30], and Harr classifier based [23] [24]. References [3] and [31] describe the work on face detection in detail. Among the techniques mentioned above, Harr-like features [23] is prominently used in various security systems based on face recognition. This method detects faces in varied facial conditions and is also claimed to be 15 times faster as compared to other faces detection methods. Hence, the proposed methodlogy uses Viola-Jones method [23] for face detection.

Feature extraction is the next step in the pipeline of the face recognition system. Feature extraction gives us a reduced representation of an image for further processing. Most of the methods of feature extraction also inherently use feature selection so that the dimensionality of the dataset is reduced. The general flow of feature extraction is depicted in Fig. 2. It is to be well noted that, it is very difficult to draw a crisp boundary between feature extraction and recognition phase in entire face recognition procedure; here we present a general coverage of existing literature without making a distinction between phases. Some of the well-known feature extraction, feature selection and in turn recognition methods available in the literature are Principle Component Analysis(PCA), Linear Discriminant Analysis(LDA), Independent Component Analysis(ICA), and Linear Binary patterns(LBP).

The authors in [18] have integrated PCA for reducing the dimension of the training size while computing the Eigenfaces of training images. The images of the training set are transformed into a set of Eigenfaces. The weights of these Eigenfaces are computed for each image of the training set and stored. When a face in the test image is to be recognized, a set of Eigenfaces and their corresponding weights are computed for test image also. The average of Euclidean distances is computed between weights of the test image and training images. This distance provides the measure of similarity between the test image and training images. If the average distance is greater than a threshold value, then the image is not having a face else closest image's label is the label of the test image. A major limitation of such techniques where PCA is used to reduce number of images needed for training the system such that the transformed dimensions will be less correlated from each other. Also, the only second-order relationship is taken into account among image pixels. A similar technique of extending eigenfaces by combining projection with PCA is presented in [28] also, where a frontal view face recognition technique is reported but only one training image is taken per person to train the model.

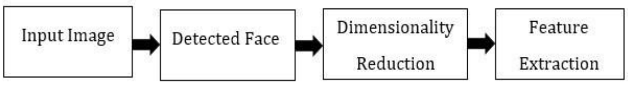

Fig. 2: Flow of Feature Extraction

The technique achieves higher accuracy upto 3-5% as compared to the standard eigenface technique while using 10-15% fewer eigenfaces. In [30], authors have investigated a generalization of PCA as kernel-PCA for learning low dimensional representations in the context of face recognition.

A yet another powerful tool for data reduction and feature extraction in the appearance-based techniques is LDA. A method utilizing the LDA framework has been described in [11] for face recognition. The authors have combined D-LDA (Direct LDA) and F-LDA (Fractional-step LDA) and have proposed DF-LDA (Direct Fractional-Step LDA) to enhance the classification ability of the obtained feature representation. Most of the Face recognition techniques available in literature based on feature extraction are in some form generalization of PCA. The work presented in [1] discusses one such generalization, where higher order statistics is exploited to overcome the shortcoming of PCA. The authors have used ICA using two different architectures. In the first arrangement, images are treated as random variables and pixels as outcomes due to which local basis images are found for faces [1]. In the second arrangement, the pixels are considered as random variables and images as their outcomes which produced factorial face code. They also implemented a classifier that combines the two earlier ICA representations and obtained higher performance than the other arrangements. The work claims that the performance of ICA is better than PCA.

The techniqueses mentioned earlier were not having a clearly defined phase of classification. Several face recognition techniques use various standard classifiers like SVM [22],[7], ANN [12],[14] and [5] in the classification phase of the entire pipeline of the face recognition. These works mainly use some features like Gabor features [12], wavelet[14] and fused them with dimensionality reduction techniques like LDA [12] or PCA[5] and then used classifiers like SVM citea31 or ANN [12],[14],[5]. In addition to this, many techniques reported in the literature have implemented nature-inspired optimization techniques like cuckoo search [13], PSO (Particle Swarm Optimization) [32] for face recognition. Recently, due to the promising success of deep architectures like CNN (Convolutional Neural Network), researchers have started using these architectures for face recognition. Exemplary implementations can be found in [32],[4]. Face recognition based on deep learning being a vast domain and not being the scope of this study, we do not present a detailed study on it. However, the detailed discussion can be found in [25], [33]. As the system proposed here is capable of recognizing faces even when the person comes wearing eyeglasses. So, it would not be out of place to present a small discussion on existing literature of eyeglass detection and removal as needed to explain the concept used in this work. Many researchers have proposed various techniques for eyeglass detection and removal. Saito et al.[20] has used snakes for eyeglass frame extraction. They have taken the assumption that the eyeglass frame is symmetric and exist in the upper part of the facial image. For searching optimum parameters of the snake, genetic algorithm is implemented. One of the limitations of this method is that initially, snakes for all types of eyeglass frames are to be defined which is practically impossible in a real-world scenario. In another work by Saito et al. [19], PCA reconstruction method is used. One problem observed in this method is that even after glass removal traces of glass frame or of the reflection and shade caused by the glasses are noticed. This limitation is removed in [17]. Jiang et al.[9] have proposed a technique using six measures of edge information within several regions near eyes by which it can decide whether the input face wears glasses or not. The issue which is present in this method is that the it fails to detect the position and shape of the glasses. In [10], a common and useful facial feature nose piece is used for checking the presence of eyeglasses. Firstly edge map was produced using the Canny edge detector and then unnecessary edge points are removed by the filtering process. Again the major issue in this method is that if eyeglass frame is large and overlapped with eyebrows then edge detector will not separate eyebrow and eyeglass frame. Wu et al.[27] have presented a method to identify glass frames and separate it from the facial features using stereo facial images. For this purpose, authors have used the obtained 3D features from the trinocular stereo vision system. The shape of various kinds of glasses and identified that the rims lie on the same plane approximately while the other facial features do not. So Hough transform is used to find out a group of 3D features that lie on the same plane and this group is concluded as the rim of an eyeglass. The method requires that the rim of defined eyeglasses should be in the same plane for an image for which we want to check. From this fact, we consider that the rims should be able to be detected by finding out a group of 3D features that lie on the same plane. The Hough transform is a powerful tool to detect the specified geometrical figures among a cluster of data points.

As stated earlier, another important motive of this work is to propose a Smart Gate system having an integrated face recognition setup. Now a day face recognition systems are used extensively for surveillance, security, authentication and access control systems. One such system is presented in [16] where authors have based their system on face recognition. The work does not have any mention of the cases where multiple faces exist in a single image. Also, no explicit discussion is presented that what will happen when the props like eyeglasses are worn by a person in the test image. Here in this work, the Smart Gate will be able to handle both of these cases successfully.

IV. PROPOSED FRAMEWORK OF SMART GATE

Herewith, we illustrate the proposed design of Smart Gate for such organizations, where security person match visitor's face with his/her identity card, verify validity period and allow them to enter the premises. For visitors not having an identity card or having an expired validity period, security person asks the visitor to get an approval letter and after that only new identity card

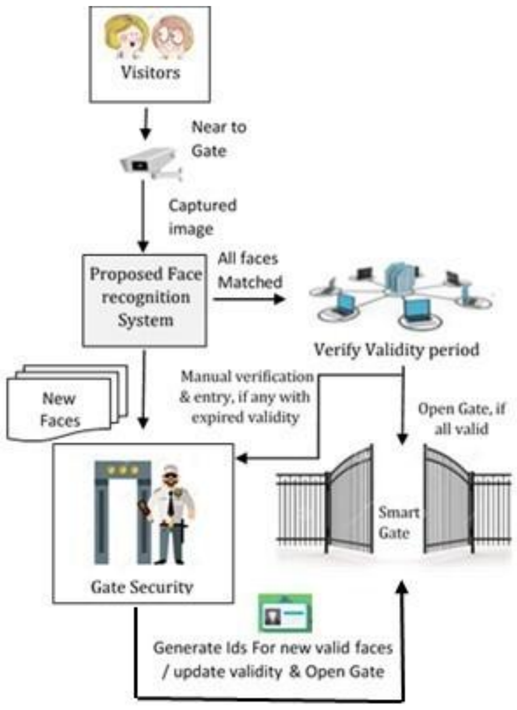

Fig. 3: Proposed Framework of Smart Gate

(describing person photo identity and valid duration) will be issued and then follow the regular process to allow him to enter into the organization's premises. There are a couple of issues with such an existing system.

i) Manual verification is time-consuming ii) Many security resource persons are required for an organization having a large number of employee/visitors visiting organization daily iii) Gate should be small enough to allow only single entry at a time iv) Unnecessary cost of issuing new identity card after every expired duration.

Fig. 3 shows the proposed framework of the Smart Gate. The camera implanted at the entrance gate captures images and sends it to our proposed face recognition system, which is described later in this section. If all faces captured in the image are recognized with our database, then it sends each person's id to the validity period verification system. If all persons entering the gate have a valid validity period, it triggers command to the Smart Gate to open for a few minutes and allow them to enter. If any of the person's id is found with expired validity or any face is found unrecognized, it will be sent to Gate security for manual verification and entry from the Gate. The security person at Gate needs to follow a similar procedure as in the existing system for manual verification. The face is already captured with a new identity by our face recognition system. If required, the security person enters a new validity period for each new person with an expired validity period.

The proposed system has certain advantages: i) It also works for a large sized gate allowing multiple person entry simultaneously. ii) Every visitor does not need to stand in front of the camera one by one for identification. Our system capture faces of all persons coming to the Gate and validates them all simultaneously. iii) It avoids the need of issuing physical identity cards for new faces iv) It also avoids the need of re-issue identity cards on validity extension v) one or two security persons would be sufficient depending on the size of Gate vi) Real time face recognition is an attractive feature of the system.

V. PROPOSED INTEGRATED FACE RECOGNITION SYSTEM

Fig. 4 describes the working of the proposed integrated face recognition system. The Viola-Jones algorithm is used for face detection from the input image. The face so detected will be checked for, whether the person in the image is wearing eyeglasses or not? If eyeglasses are not detected, images are stored in the dataset. If eyeglasses are detected then first of all eyeglasses are removed using eyeglasses removal algorithm, then 50% of the images are stored with eyeglasses worn and another 50% of images with eyeglasses removed. This will facilitate the recognition of the person irrespective of the fact whether he/she is wearing eyeglasses or not at the time of actual usage of the system. Section 5.1 discusses the eyeglass detection and section 5.2 discuss eyeglass removal algorithm in detail. Then face features are extracted using the PCA algorithm and fed to the SVM classifier. SVM classifies face vectors and recognizes the face. The algorithm is capable of recognizing multiple faces at a time.

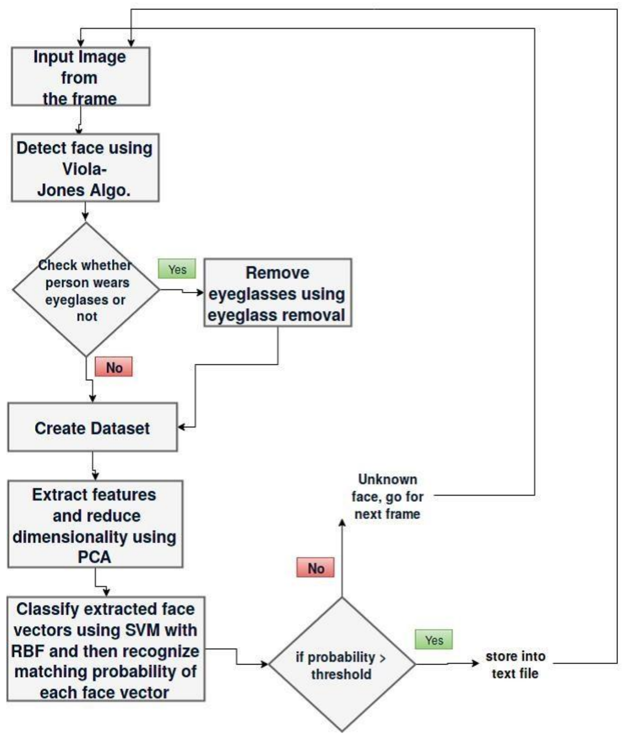

Fig. 4. Proposed Face Recognition algorithm

Eyeglass removal would be a very crucial task for both face detection and face recognition process when people wear eyeglasses. The appearance of the eyeglass frame is varied which adds to the complexity of the problem. The frames

may be made up various material properties such as metal or plastic which gives varied texture to the eyeglass frames. The reflective property of eyeglasses differs significantly from that of human skin.

Faces are always well separated with the background whereas the glasses are stuck to the face & mixed with eyebrows. For this problem, there are two solutions: i) Create a dataset strong as possible i.e. add images of faces which include all types of eyeglass frames as well as consider the minimum to the maximum amount of glass thickness. But, practically it is not feasible. ii) Detect eyeglasses from captured face image, remove the eyeglasses and map it with the dataset.

Removing eyeglasses entirely from the face image without loss of information of the image is not possible as eyeglasses hinder the contour information of the face [20]. So, researchers firstly detect only eyeglass frame and then replace it with skin colour in place of the detected glass frame.

A. Eyeglass frame Detection

Eyeglass Frame Detection and Removal algorithm used in our face recognition system is described in Fig 5. Each face detected from the input image is converted into a gray scale image. Using eyeglass detection presented in [17], the algorithm verifies that the person wears eyeglasses or not.

To check whether a person wears an eyeglass frame or not, first identify and extract eye region from the detected face. The next step is to identify the intensity value of each pixel and compute total for all pixels in the eye region. If the intensity of pixels is greater than the threshold value (here, the threshold taken is 160), then the eyeglass frame is detected on the face. This has been demonstrated in Fig. 6 and Fig. 7. The image in Fig 6 has a total intensity of the eye region is 464, while the image in Fig. 7 has a total intensity of the eye region is 145.

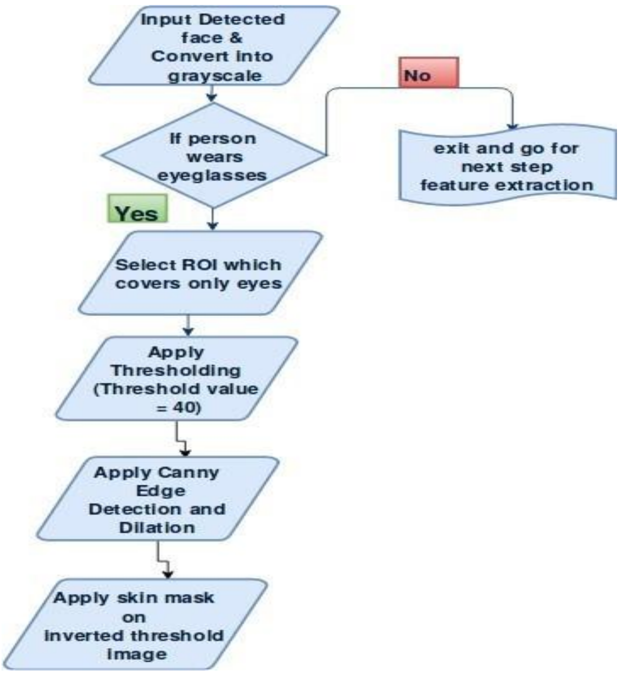

Fig. 5. Eyeglass Frame Detection and Removal

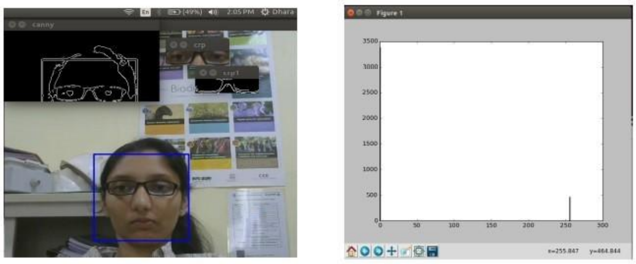

Fig. 6. Eyeglass Detection for an image with eyeglass

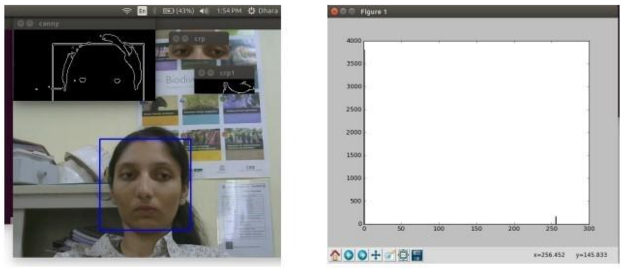

Fig. 7. Eyeglass Detection algorithm for image without eyeglass

If the person wears eyeglass, then ROI(Region of Interest) consisting of eyes only is identified. Then using the Canny edge detector, the region containing only eyeglass frame is identified.

B. Eyeglasses and Reconstruct Glass-Less Image

After extracting the eyeglass region from the detected face, we have to remove eyeglasses from the extracted region.

Saito et al [19] have developed a method using PCA reconstruction. The authors in [17] have used a method developed by Saito et al. which based on example-based learning. In improvised version, firstly, regions occluded by glasses are detected and then learning from a set of example images (glassless images for the person whose glass-less image is to be obtained), glass-less image of the face is generated by recursive error compensation using PCA reconstruction.

The segmented region is dilated and skin colour inpainting is applied to the dilated image. Inpainting is used to reduce the gap between glasses and non-glasses faces for recognition. After extracting eyeglasses from an image, we apply inpainting on the image with the help of mask which will be created as the same size of input image where non-zero pixels corresponds to the area which will be inpainted. In our case, we will use skin colour to inpaint eyeglass area and reconstruct the glass-less image.

C. Feature Extraction using PCA

Faces have many complex features, which may change over time. Complex data cannot be analyzed using a single image of a face, hence large number of images are required for proper analyze. But, it raises other issues. huge memory is needed and over-fitting is caused as a result generalize poorly to new samples. To overcome these problems, we can use dimensionality reduction techniques.

Principal Component Analysis(PCA) is a commonly used technique for dimensionality reduction in various areas like pattern recognition, data representation in computer vision, etc. Kirby and Sirovich have applied PCA for representing faces[15], and Turk and Pentland have applied PCA for recognizing faces [21]. PCA is commonly referred to as the use of eigenfaces [21]. In the PCA technique, each face image would be presented as a weighted sum of the eigenfaces.

A training set consisting of a set of face images(I_1, I_2, I_3, . . . I_M) having each image of sizeN ×N is created. For example, there are 100 images with the same dimension 50 × 50 for the training dataset. So, it would have 50 × 50 i.e. 2500 dimensions for each image. As PCA does not work on images directly but works in vector format. So, N ×N sized image is converted to N2 × 1 format. Normalize the face vectors to remove common features among face datasets. So each face in the dataset will remain with its unique feature.

Average face vector contains facial features, which are common in all images of the dataset. Average face vector is calculated using (1), and it is subtracted from the original face. Equation (2) is used to compute the differences $\boldsymbol{\varphi_j}$ for all I images.

$$\theta = \frac{1}{M}\sum_{n=1}^{M}\tau_n \tag{1}$$

$$\boldsymbol{\varphi_j = \tau_j - \theta} \tag{2}$$

Further, the covariance matrix is computed of a matrix consisting of all normalized face vectors. Covariance matrix of dimension M*M and M eigenvectors will be returned in this work. Thereafter K best eigenfaces having largest eigenvalue are selected that represent the whole training set is selected. Each face is represented as a linear combination of all K eigenvectors, where first eigenface describe major features of the dataset and next eigenface shows next possible features. Here, principle components start from major features to lesser features, which help to reduce time to match features from input image.

D. Classification

Once the features are selected and extracted, the next step is to classify the image. Here, in this work SVM has been used as classifier due to its well-proven accuracy and robustness. During classification, the SVM classifier maps input vectors into high dimensional space using certain linear or non-linear transformations by creating optimal hyper-plane to separate data. Various kernel functions like radial, polynomial, and Gaussian are available in the literature for classifying multiclass data. In our case, we use SVM with Redial basis function (RBF) kernel.

VI. EXPERIMENT SETUP AND RESULT

The face recognition module is a key component for our proposed Smart Gate Framework. Hence, this section discusses the experimental setup for the implementation of our proposed face recognition algorithm over well-known face datasets. Initially, the test platform is described in this section. To compare the robustness of the proposed algorithm, the algorithm was implemented to some well-known datasets, which is summarized later on.

A. Test Platform

We have evaluated our proposed face recognition algorithm using OpenCV 2.4.9 with Python on Ubuntu the operating system deployed to a computer system with i3 Processor, 4GB RAM, and 500 GB hard disk.

B. Dataset Creation

To implement Smart Gate for an organization, it is required to create a dataset of all employees. This subsection describes a method to create a database. For each employee, two sets of images are stored for quick recognition. One set contains face without eyeglasses. If an employee wears an eyeglass, his images will be updated to both sets: i) with eyeglass and ii) without an eyeglass.

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C. Camera

The camera is a prime component for face recognition based Smart Gate activation system. Considering increasing popularity of IP camera for its speed with an internet connection, the performance of proposed face recognition evaluated on both IP camera and a Web camera. HikVision IP camera is used for the experiment. HikVision IP camera has a frame rate of 25 frames per second (fps). With IP camera and good internet connectivity, proposed face recognition system successfully recognize the person in 2 or 3 seconds. if internet connectivity is not good due to any reason, the delay is raised between two frame or loss of frame may be resulted. For applications like Smart Gate seeking real-time results cannot afford such frame delay or incorrect recognition.

Initially, the experiment was conducted on an IP camera, where three types of cases observed: i) During a good internet connectivity period, faces detected successfully in milliseconds. Two scenarios observed when internet connectivity was disturbed. ii) Two persons were entering the Gate with a delay of a fraction of a second. The first person was recognized successfully and the ”Welcome” message was also displayed. But for the second person also, it displayed the name of the first person only, which is an incorrect result. iii) The first person is recognized successfully in real time and Gate was opened to allow him entry. But, the second person needs to wait a little more due to delay transmission.

Looking toward the performance issue of IP camera in the worst case scenario described above, Web camera is preferred here for obtaining real-time performance with a higher accuracy of detection. Finally, for the experiment, Logitech USB camera with frame-rate of 25 frames per second was used. The frame delaying problem with the IP camera will be solved here.

During the experiment, 2 to 4 frames delay with Webcam was observed in rare scenarios.

D. Face Datasets

The performance of the proposed face recognition algorithm was tested on well-known face datasets like Yale [2], Yale B database [2] and AT & T [2]. The main purpose of selecting these face datasets is to test the robustness of the proposed method for recognizing an authorized person. The Yale database consists of 15 person's individual images, where each person will have its own 11 images in different conditions like center light, left light, the right light, with glasses, without glasses, normal face, happy, sad, surprised, etc. So, the Yale face database contains a total of 165 (15 × 11) images. The Yale database B consists of 10 person's individual images where each person will have its own 576 images in different conditions like center light, left light, right light, with glasses, without glasses, normal face, happy, sad, surprised, etc. So, Yale face database B contains a total of 5760 (10 x 576) images. AT & T database contains total 400 images of 40 persons. For reducing the computational complexity, we reduce the size of image samples of each face datasets.

In addition, a new dataset 'face profiles' is also created as per the methodology described in subsection A of this section. 'Face profiles' contains faces with different lighting conditions, and face orientations.

E. Result Discussion

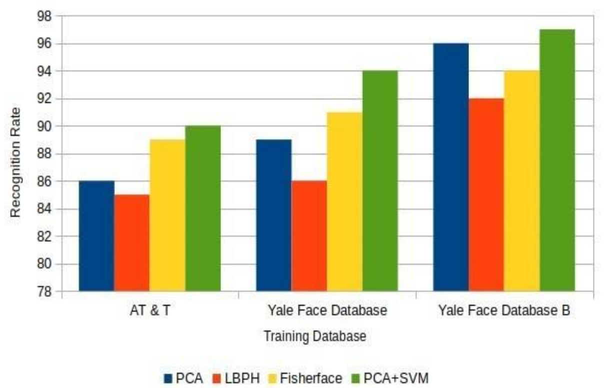

Fig. 8. Face Recognition Using Standard Dataset

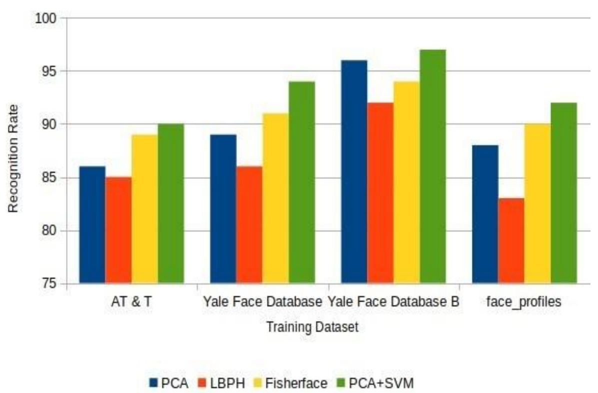

Fig. 9. Face Recognition Using Standard Dataset and our dataset

To get the advantage of both PCA algorithm to detect faces with different orientation and SVM algorithm to detect multiple faces, a hybrid methodology (PCA+SVM) was also evaluated. To test the efficiency of the hybrid methodology, various face recognition algorithms like PCA, LBPH, and Fisherfaces were applied on Yale, Yale B, AT&T, and face profiles datasets. Fig 8 and 9 shows hybrid (PCA+ SVM) works with a higher recognition rate for all datasets.

Fig 10 presents the efficiency comparison of our proposed face recognition algorithm with other face recognition algorithm on well-known face datasets as well as own face datasets. The graph justifies that the proposed algorithm has a higher face recognition rate on all standard and own face datasets.

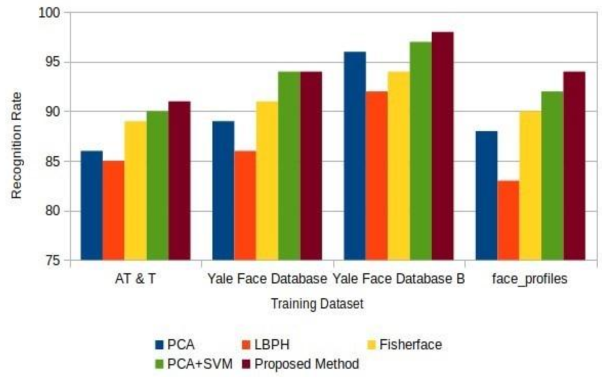

Fig. 10. Comparison of Proposed Face Recognition algorithm with other well-known datasets

VII. CONCLUSION

This paper presents an integrated face recognition algorithm, which is designed to recognize single or multiple faces from an image captured with different imaging conditions, different face orientation, with/without eyeglasses. The proposed integrated face recognition algorithm has been tested on various datasets and achieve up to 97% face recognition rate, which is observed more accurate than other algorithms tested. Examination of failed face recognition system exposed a scenario, where reflection on eyeglasses raise complexity on face features and result inaccurate face recognition. Smart Gate framework with highly accurate face recognition algorithm is proposed here to reduce man hours for identity verification and real time identity verification.

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