Next Generation Face Recognition System under Various Illuminations

S. Zeenathunisa
Assistant Professor
Department of Computer Science,
T.S. Narayanaswami College of Arts and Science, Navalur.

ABSTRACT
Identification via face recognition offers enormous advantages to both civilian and criminal detection programs. A next generation system that has the potential to recognize such wanted criminals from a large dataset considered to be used for security of the public safety. It also has the prospective to provide high data rates at low power over various illumination conditions in the, to be identified images. This face recognition technique for next generation acts as a baseline for the development of future solutions for response and recovery. This research is a new state-of-art integrating various techniques to perceive the faces using Illumination Normalization, Feature Extraction and Classification. The Illumination Normalization is useful for removing the dimness and shadow from the facial image which obtained from the large dataset reduces the effect of illumination variations, but, still retains the necessary information of the face. The robust local feature extractor which is the gray-scale invariant texture called Local Binary Pattern (LBP) is helpful for feature extraction. The K-Nearest Neighbor classifier is utilized for the purpose of classification and matching the face images from the dataset. Thus, the next generation system tends to identify and recognize the input face image after preprocessing the image and feature extraction. Various images for the system from Yale-B database are used for testing to achieve the next generation face recognition system which helps in improving the performance in identifying and recognizes the faces in various illuminations.

Keywords: Next Generation Face Recognition System(NGFRS), Illumination Variation, feature extractor, LBP, k-NN classifier

1. INTRODUCTION
Emerging new technologies has created a massive revolutionary over the world. Demand has never been decreased for such changes that deliver fast, inexpensive and accurate information. Such a challenging next generation developing technology is the one which recognizes the face under various illuminations. This technique offers solution which enables to maximize and optimize the recognition processes. Such technology is widely used in identifying the individual automatically. These behavioral or biological characteristics are unique to every individual and they provide some useful information in identifying a person. Here, face recognition plays a vital role in recognizing such an individual. It resolves the problem of identifying or verifying the person by comparing the captured input faces with the face images stored in the dataset [17]. Since face recognition is considered to be the stepping stone to all the facial analysis algorithms, including face recognition, face verification, face authentication, face alignment and face expression tracking [2].

The benefits of face recognition are numerous. It plays an important role in surveillance, security, border crossing, duplication entry, etc., The application areas of face recognition also includes identification for law enforcement, authentication for secure banking and financial transactions, automatic screening at airports, railway stations, shopping malls, hotels, etc., for known terrorists, matching of photographs on passports or on driving licenses and video surveillance usage. Such face recognition application range from static matching of known-controlled frontal images to real-time matching of video image sequences [3]. Such a remarkable next generation face recognition system deserves a higher priority for detecting criminals in the Department of Forensics and Security. Since social acceptability is high for face recognition when compared with other applications like iris, fingerprint recognition which has less acceptability.

Next Generation Face Recognition System analyzes the characteristics of an individual's face images captured through a digital video camera or surveillance camera. The images captured under the surveillance camera may vary with different illuminations. The every image's illuminations depend on the intensity of the gray level. Under those gray level variation images, if any individual suspected to be a criminal, the person has to be identified by the system. It is possible for the human brain to accurately remember and quickly recognizes the person even after several years of separation. Similarly, the next generation system has its capacity to handle large data sets of face images to recognize. This task is relatively easier under a controlled environment for frontal images with background and lighting condition, but, it is highly a challenging task in a less-controlled environment like different illumination variations especially under dark lightings. This situation can be possible by a good integrated approach for face recognition to identify the match under various illuminations.

The research on face recognition has been conducted for more than three decades, but, still the systems are constrained to produce the results to the fullest. Still, more processes and better techniques for facial extraction and face recognition are needed. The future of next generation face recognition system holds great promise for law enforcement applications, as well as for private industry uses to access control to secure computer networks. This paper aims to resolve such a classical problem of human face recognition under various illuminations and develop an efficient method for recognizing human faces. Such different illuminated images are categorized into three type viz., lowest dimness, medium dimness and highest dimness. These are the challenging tasks categories and these less-controlled captured images can be identified by integrating the three efficient techniques such as illumination variation, feature extractor and a recognizer for identifying the equivalent from the existing database. This paper focuses only on the frontal view faces subjecting under the above-mentioned three categories of illumination conditions.

The remaining paper is organized as follows: Section 2 describes some of the related works towards face recognition on changing illumination; various facial feature extraction techniques and the different identification approaches. The Section 3 focuses on recognizing the human face under illuminations using the new integrated approach. In Section 4, the proposed methods experimentation and their results are comprised. Section 5 outlines the summary of the author's conclusion and future work.

2. Review of Literature

This section details the studies reported in the literature on utilizing various lighting variations, which develops a historical and current perspective of activities in the field of Next Generation Face Recognition System. Based upon those ideas from the review of literature, the proposed system has been implemented with a new integrated approach. Moore et al has utilized a concept called de-illumination for estimating intrinsic images. By using little input data and no special equipment like light stage etc., de-illumination is done with a huge number of images of the same object from many possible directions. The underlying idea behind this de-illumination and re-illumination concept is that by breaking down the image into small patches, it is possible to learn machines for specific parts of the face [5].

Aggarwal et al have proposed an algorithm to recognize multiple illuminated faces for just one image. It performs the face recognition under varying illumination without having any prior information about the number of the light sources. It performed much better to make the single light source assumption [12]. Holappa et al [8] highlighted that the optimized illumination condition for 2D face image algorithms along with local binary pattern and using χ^2 distance metric which is the enhanced concept of Tan and Triggs. The use of local binary pattern histograms computed in local image regions was first proposed for face image description by Ahonen et al. This representation has successfully been applied to face recognition, face detection, and also for other tasks such as object recognition.

Wang et al has utilized a technique called Luminance Transient Improvement (LTI) in which the favorable characteristics of Gaussian function, their difference of the outputs with different variances to get the local information of images are obtained. Difference of Gaussian function gives the high performance and also the sharpness of the image can be obtained. Even the computational consumption can be easily cut down [11]. The initial experiments of the proposed system suggested that one of the successful local appearance descriptor called Local Binary Pattern (LBP) is rich in information and computational efficiency. Xiaoyang Tan et al proposed Illumination Normalization preprocessing chain technique which incorporates a series of stages designed to counter the effects of illumination variations, local shadowing, and highlights while preserving the essential elements of visual appearance. The local texture feature sets called the LBP (Local Binary Pattern)/LTP (Local Ternary Pattern) descriptor used for the feature extraction and improved KPCA classifier incorporated for more accurate results in recognizing the human face under different lighting conditions. However, face recognition is a complex task for which it is useful to include multiple types of features and also need to build a final classification stage that can handle residual variability and learn effective models from relatively few training samples [4].

Ahonen et al has prescribed a novel and efficient facial image representation based on Local Binary Pattern texture features in which the face image is divided into several regions and each region is computed using local binary pattern technique. LBP operator has proven to be highly discriminative and its key advantages make it suitable for face image analysis tasks [10]. Maturana et al approach for face recognition highlighted for different pose variations and misaligned faces by using the concept of LBP histogram and Naïve Bayes Nearest Neighbor (NBNN) algorithm. He has utilized a concept called image-to-class distance instead of image-to-image distance. But then, the main drawback of NBNN is its increase in the computational cost relatively when compared with LBP algorithm [7].

Padraig Cunnigham et al highlighted that k-NN process is transparent and so it is easy to implement and it can be very effective if an analysis of the neighbors is useful as explanation of the output of the classifier is useful [10]. The reason behind using k-NN with high dimension data to perform feature selection are for many distance measures, the retrieval time increases directly with the number of features and irrelevant features can have the same influence on retrieval as predictive features so they will impact negatively on accuracy. In situation where an explanation of the output of the classifier is useful, k-NN can be very effective if an analysis of the neighbors is useful as explanations.

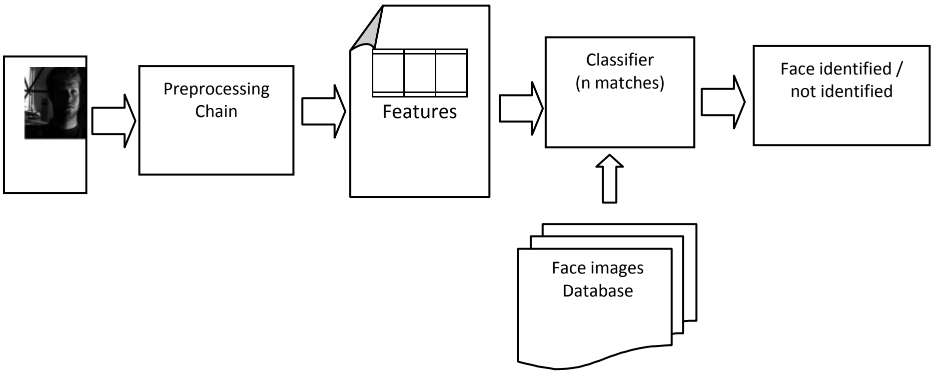

Figure 3.1 Conceptual model of the Next Generation Face Recognition System

3. Next Generation Face Recognition System

The ability of Face recognition system (FRS) is expected to identify faces present in the images using biometric identification and the visual perception. The FRS concentrates only on biometric identification of the face image subjected under various illuminations. Though the familiar systems like fingerprint identification, iris identification, gender, ethnicity, etc., are said to be biometric identifications, facial recognition plays an important role in the field of identifying a person. Such a FRS system undergoes a three step process such as Preprocessing Chain (Illumination Variation), Feature Extractor and Classifier. Figure 3.1 depicts the conceptual model of the Next Generation Face Recognition System.

The face recognition system undergoes some sequential steps to identify a matcher from the existing data set. The procedure for FRS is as follows:

Algorithm:

Step 1 : *Accept the image as an input.*

Step 2 : *The preprocessor follows the following steps 2.1 to 2.4 and repeat it for every given image to remove the darkness and obtain the brighter image.*

Step 2.1: *The gray-scale image is projected under gamma correction which removes the darkness and glows the pixel bright.*

Step 2.2: *The shadiness of the input face can be eliminated by applying the difference of Gaussian filtering.*

Step 2.3: *The face-shaped edge from left lower jaw to right lower jaw can be detected using masking.*

Step 2.4: *The final step of the preprocessor is to apply equalization of normalization which rescales the image intensity, still preserving the required information of the input face image.*

Step 3 : *Apply Local Binary Pattern feature descriptor for the preprocessed image for feature extraction which stores the features in the form of feature vector.*

Step 4 : *These feature vectors are trained with the k–NN recognizer to recognize the given image from the training data set.*

Step 5 : *If the recognized image exists in the training set, then the recognizer identifies the image else does not identified.*

Step 6 : *Repeat the steps from 1 to 5 for each and every input face image to find the matcher.*

3.1 Preprocessor

Facial recognitions are very difficult to compare because their testing must be performed on a large number of samples in different scenarios under different illumination variations, background, different model databases, etc. Here, Yale – B database is used, since, it contains face images with non-homogeneous illumination with changing the position of the illumination source relative to the face. Some of the sample faces are given in Figure 3.2 which are categorized under the three dimness levels. To build a robust and efficient face recognition system, the problem of lighting variations is one of the main technical challenges facing system designers today. Perez et al [14] proposed that face images are significantly change by lighting conditions. The illumination condition is dynamic and varies according to the daylight conditions. Many appearance-based methods have been proposed and reported. Therefore, a developed method is needed to overcome these difficulties and thus in the FRS, an elegant integrated approach has been utilized to eliminate the illumination from the input face image and obtain the necessary information from the same.

Figure 3.2 Sample images of Yale-B Database

The Illumination Variation (IV) step sequentially undergoes four sub steps viz., Gamma Correction, Difference of Gaussian, Masking and Equalization of Normalization. The IV of the FRS removes the noise such as darkness and shadiness from the input image, by preserving the necessary information from the input image for further processing of feature extraction by the feature extractor. Figure 3.3 depicts the sequential steps of the effective IV process. This is an important stage in face recognition system since it helps in getting a sharp-edge image to recognize the input face image.

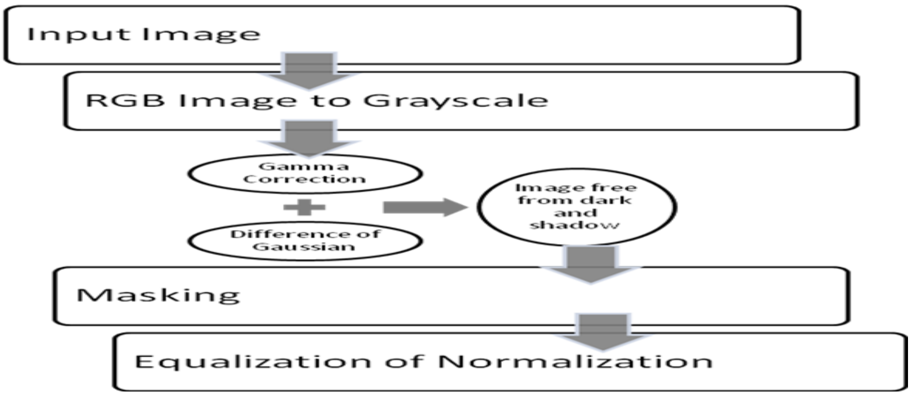

Figure 3.3 Sequential Steps of the Illumination Variation

3.1.1 Input Image

The Input Image for the IV stage has the dimension 150 x 130 which has been taken from the Yale – B database. The images considered are subjected to different dark light variations. One input face image is projected to ten different illumination variations. This input image if obtained as RGB, converted to gray scale and this conversion helps in eliminating the hue and saturation information still retaining the luminance.

3.1.2 Gamma Correction

Gamma Correction is nonlinear gray-level transformation used to correct the power-law transformation phenomena which perform the transformation of an input image to its original appearance. This transformed gamma-corrected image is free from the darkness by compressing all the dark regions into bright regions. It replaces the original gray-level I with I^{Υ} by considering $\Upsilon > 0$, but lies between 0 and 1(i.e., $\Upsilon \in [0, 1]$). Here, the obtained image after gamma correction should be an illumination free image. Hence the value of Υ can be range from [0, 0.5] and by default the value of $\Upsilon = 0.2$ is to be considered.

3.1.3 Difference of Gaussian

Gamma Correction does not remove the complete darkness. Their remains the local shadings such as the shadow below the eye contacts, nose shadow, etc., and those can be removed by applying the high-pass filtering thus by simplifying the recognition problem. The high-pass filter is the one which attenuates low frequencies while passing high frequencies so that the edges of the image become sharper. Hence by implementing the filters using explicit convolution, boundary effects can be minimized. Gaussian filters are the special analysis tools which are easy to manipulate. Utilizing the characteristics of Gaussian function, the gamma-corrected image generates the informative image using the difference between the two Gaussian filters according to the local contrast information of the images [11]. The two Gaussian filters with the variances σ_1 =1.0 and σ_2 = 2.0 by default (always $\sigma_1 < \sigma_2$) can be considered. Though gamma correction produces an informative image, still without DoG filtering, the resulting images suffer from reduced local contrast in shadowed regions [Xiaoyang et al 2010].

3.1.4 Masking

If facial regions such as hair style, beard, etc., that are felt to be irrelevant, then masking can be applied, which simply has a face-shaped region. Also the background change can be minimized by using a mask. Here, the shape of the face from left lower jaw to right lower jaw has been detected and masked.

3.1.5 Equalization of Normalization

The last step of the preprocessing chain is the equalization of normalization which rescales the image intensity, thus highlights the most of the information by preserving the essential elements of visual appearance. This is done using the median of the absolute value of the signal based on

$$I(x,y) \leftarrow \frac{I(x,y)}{(mean(\min(\tau, |I(x',y')|)^{a}))^{1/a}}$$

…...(Formula 3.1)

Here a is a strongly compressive exponent that reduces the influence of large values, τ is a threshold used to truncate the large values after the first phase of normalization, and the *mean* is over the whole unmasked part of the image. By default, the values of a = 0.1 and τ = 10 is used [Xiaoyang et al 2010]. Now, the image is well-scaled, but still has the extreme values. To reduce this, the hyperbolic tangent $I(x,y) \leftarrow \tau \tanh(I(x,y)/\tau)$ can be used and thus limiting I to the range ($-\tau$, τ) [Xiaoyang et al 2010].

Hence the principal objective of preprocessing is to enhance the input image and result in a clearer and sharper image free from darkness and shadiness. Resulting final image obtained from the preprocessor is effectively utilized in the feature descriptor LBP.

3.2 Feature Extractor

The Local Binary Pattern is a highly discriminative function and widely used in ordinary analysis of facial appearances. The proposed approach towards recognizing face under various illuminations is very robust since the local binary operator is subject to invariant against any monotonic transformation of the gray scale. Another additive advantage of this invariant operator is its computational efficiency towards identifying the features exactly. Ojala et al [15] proposed that starting from the joint distribution of gray values of a circularly symmetric neighbor set of pixels in a local neighborhood, an operator called local binary texture is derived which is invariant against any monotonic transformation of the gray scale. These local binary texture patterns are also called as "*uniform*" patterns. The LBP operator takes the local neighborhood which is threshold at the gray level value of the center pixel into a binary pattern. It is defined for 3 x 3 neighborhood giving 8–bit integer codes based on the eight pixels around the center pixel. Figure 3.4 represents the sequence of the LBP to produce the feature vector set.

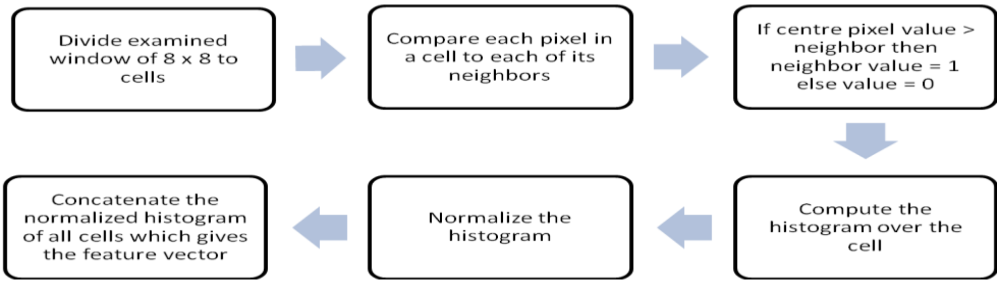

Figure 3.4 Sequence of LBP

The feature vector of the window obtained is carried out for the purpose of recognition of the input face image existing in the training data set using recognizer. This LBP operator produces the highly desirable result for making the recognition simpler. The powerful feature extractor, Local Binary Pattern contributed in this paper is a robust and wide ranging descriptor for extracting features. The result obtained from the implementing of the efficient feature extractor takes to the next stage, classifier, to identify the matcher.

3.3 Classifier

The reason for using classification in face recognition system is that it tries to achieve the exact matcher for the input face image. The idea behind the k–NN classifier used in FRS is to build a classification method using no assumption about the form of the function and also it helps dynamically identify k observations in the training data set that are similar to a new observation that wished to be classify. Because of this reason the classifier k–Nearest Neighbor algorithm is utilized in FRS. k–NN is a non-parametric lazy learning algorithm which is applied to recognition tasks. Classifying for the recognizer can be done by comparing feature vectors of the different points of the images.

Rabbani et al [13] described that the simplest method for determining which face class provides the best description of an input face image is to find the face class k that minimizes the Euclidean distance. The Euclidean distance is the straight line distance between two pixels. The k–NN classifier finds the neighbor set using the Euclidean distance measures. The retrieval image is recognized depending on the minimal distance between the pixels. The most distinguishing nature of this classifier is that it considers the very nearest neighbor pixels for matching and produces a desired output. Whenever the classification is to be made for a new input face image, its distance to each feature in the training set must be determined. Only the k closest entries in the training set are considered for matching.

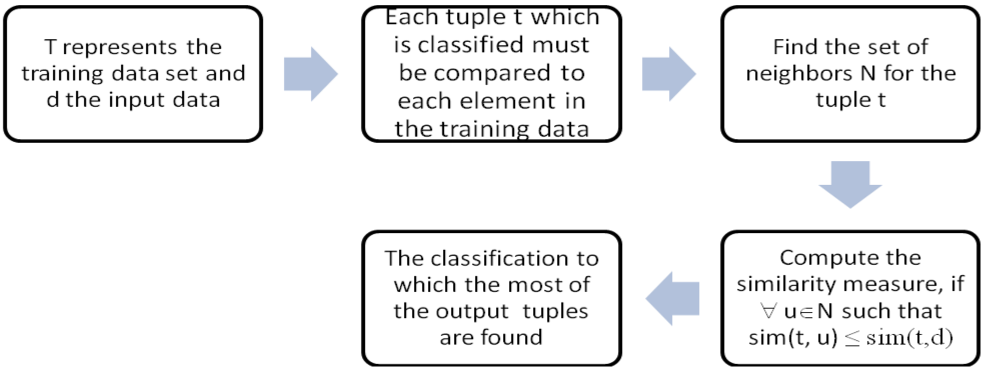

Figure 3.5 Sequence of k-NN Classification

Figure 3.5 gives the steps involved in k-NN classification. k–NN classifier is one of the most successful and beneficial classification techniques in the field of pattern recognition. The main purpose of the classifier is to classify the training set in order to obtain the retrieval image of the query image from the database. Also, the k–NN recognizer has the higher values of the smoothing that reduces the risk of over fitting due to noise in the training data set [17]. This approach has given an intuitive and solid base for experimentation and performs satisfactorily for recognizing the face images under various dark light conditions.

4. Experimental Results

The performance of the integrated approach towards recognizing face under various illuminations for Next Generation FRS specified three stages of face recognition. In the stage (i) the input face image is subjected to illumination variation stage where the dimness and shadiness gets removed to obtain an informative monochromic image. The various steps are involved in this stage which helps to get a bright image. This also facilitates in utilizing the sharpen edge image. In the stage (ii), it then steps into feature extraction. This monochromic image is utilized for extracting features using the significant local feature descriptor called the Local Binary Pattern. In the stage (iii) to recognize the features automatically for the input face image using k–Nearest Neighbor algorithm is utilized. This will classifies the features of the images from the training data set which can easily recognize the input face image. The improvement in the face recognition system is due to the fact that the extensive feature extractor performs faster and takes minimum amount of time in displaying the feature vector for recognizing the face with the help of the classifier.

Figure 4.1 shows the graphical comparison of the three dimness gray level images before and after preprocessing or IV. These three intensified images ranges from 0–255 gray levels. The lowest intensity images of FRS range from 151 to 200 since they are subjected to low dimness where the white domination is more and hence yields less darkness in the face region still the illumination focused is extensible high. The medium intensity images range from 91 to 150 since they are subjected to medium dimness and yields medium darkness in the face region. These medium intensity images produce a good computational efficiency within average amount of time. The highest intensity images range from 0 to 90 since they are subjected to very high dimness where the dark black domination is more and hence yields more darkness in the face region. This high intensity images takes more computational time for classification. Figure 4.2 provides the graph of input image clarity with the time taken for classification.

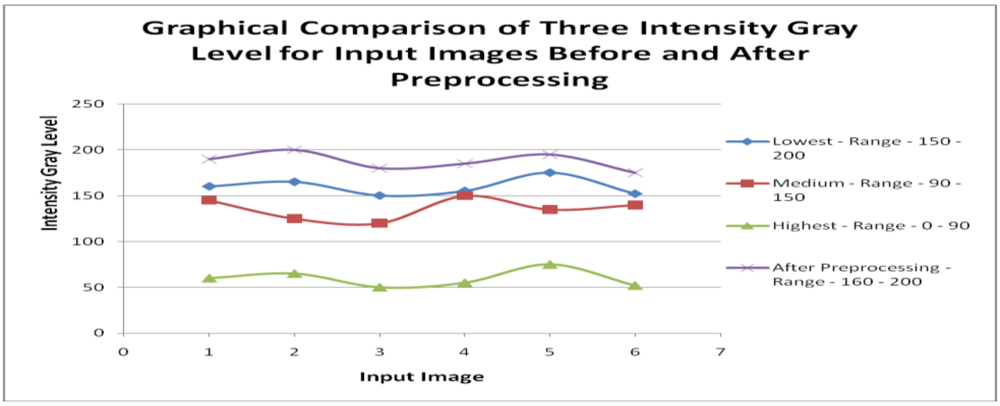

Figure 4.1 Graphical Comparison of Three Intensity Gray Levels

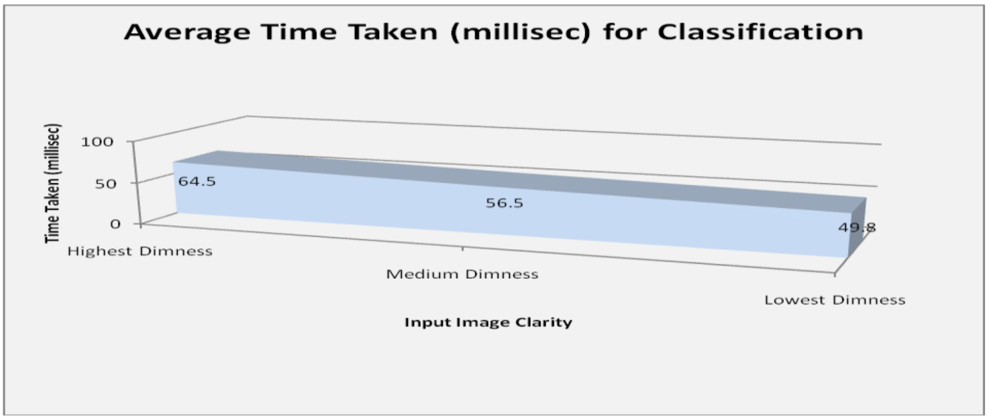

Figure 4.2 Graph of input image clarity Vs. Time taken for Classification

The performance for recognizing the image among the training data set plays a vital role in face recognition system. In FRS, the similarity between the face images has been performed and tested using different number of training and test images. There are 10 images per individual from the Yale – B database considered so that the effect of different number of training and test image combinations are tested. These images are of size 150 x 130 pixels with various dark intensities and they are converted from gray scale to monochromic images by using the illumination variation. The results show that the best performance is achieved since it sharpens the edges of the input face image when the images have medium gray level intensity.

The result obtained under this condition is 91.97% genuine acceptance rate with 8.33% false error rate. When the tested images from other sources comparatively combined with the Yale database, the error result is produced. If there are more tested images per individual, then there is possibility that the success rate can be expected to become closer. Figure 4.3 depicts the result of genuine acceptance rate (GAR) with false error rate (FER) for identification of the input face images. The Medium Dimness images produce 91.97% GAR with 8.33% FER. If the images considered under Highest Dimness which has very high dark domination produces 66.67% GAR with 33.33% FER respectively. The Lowest Dimness images produce 83.33% GAR with 16.67% FER respectively. These GAR and FER of lowest, medium and highest level dimness has been calculated using the formula

$$GAR\ (\%) = \frac{\#\ Correct\ Matches}{\#\ Images\ in\ Training\ Data\ Set} \times 100$$

……….(Formula 3.2)

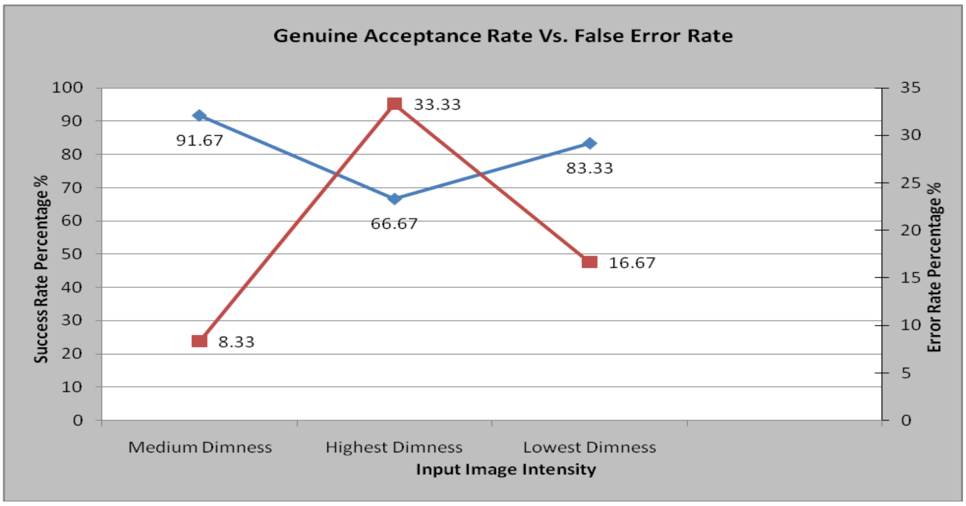

Figure 4.3 GAR Vs. FER

The analysis from genuine acceptance rate produce a good result when the image subjected under moderate or medium dimness is considered. Since the black domination for High Dimness and white domination for Low Dimness are more, the genuine acceptance rate gradually reduces. But still the FRS finds the exact matcher for the every relevant input image with more computational complexity.

5. Conclusion and Future Enhancement

This research mainly focuses on the holistic integrated next generation face recognition approach. This FRS approach is a conglomeration of Illumination Normalization using the sequential steps of illumination variation method, an elegant local feature extractor, the Local Binary Pattern (LBP) and the effective classifier, k–Nearest Neighbor classifier. The results and performances of the integrated approach towards recognizing the face under various illuminations produce a good result. The graphical representations clearly visualize the computational efficiency and intensity levels of the input image under various intensities. Each and every approach in FRS proved its own individuality performances and gives the absolute results. The average time taken is approximately 56secs for medium intensity gray level images comparatively reduced time in recognizing the input face image from the training data set. This approach provides a simple framework for incorporating the various robust techniques in recognizing the human face under dark illuminations. As a future vision, the most elegant LBP technique can be utilized for multi–view faces subjected under various dark illuminations for face recognition and also for various disguised faces.

6. References

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