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A REVIEW ON FACE RECOGNITION USING DIFFERENT PRE-PROCESSING METHODS IN IMAGES CAPTURED UNDER VARIOUS ILLUMINATION AND POSING CONDITIONS

M. Jasmine Pemeena Priyadarsini, Srinivasa Rao Inbathini and K. Murugesan
School of Electronics Engineering, VIT University, India
E-Mail: jasmin@vit.ac.in

ABSTRACT

The aim of this paper is to implement facial recognition for a dataset that has different illuminated images with variant poses for the purpose of human authentication using an low resolution camera available on the day-to-day electronic gadgets such as mobile phones, tablets and other hand-held devices The basic step in the face recognition from an image is to acquire only the face portion. The acquired image is then taken to the next process called feature extraction. After feature extraction of the image, the face recognition will be performed. The process of face recognition requires many very important aspects to be considered, i.e., the illumination and poses and angle. To accomplish this task, lighting controllers must tactically be employed to ensure that the correct current and timing controls are applied to obtain the probable lighting. A combination of the latest feature extraction and illumination compensation algorithm are used to encode micro-patterns giving an efficient description for face recognition, i.e., Oriented Local Histogram Equalization (OLHE), which has proven to perform exceptionally high under extreme lighting conditions along with the previous state-of-the-art algorithms such as Bit Plane Slicing, Gabor Filter, Local Binary Pattern (LBP) and Local Gradient Oriented Binary Patterns (LGOBP) at the same time as they encode micro-patterns which gives an efficient description for face recognition. The goal is to explore and analyze the performance of the following face Recognition algorithms, namely PCA (Principal Component Analysis), LDA (Linear Discriminate Analysis), CCA (Canonical Correlation Analysis), AAM (Active Appearance Model) and SVM. (Support Vector Machine). It has been proposed that the illumination compensation algorithm OLHE for face recognition is to be utilized. The combination of CCA and OLHE will give the highest recognition rates among the five feature extraction and face recognition algorithms taken into consideration. Upon analysing their performance on the datasets such as FERET, ORL, CMU-PIE, EXTENDED YALE B and newly created VIT DATABASE, this combination is found to be the handpicked illuminated compensation algorithm. These images from the VIT dataset along with the other images from the various open-source databases are subjected to various pre-processing and post-processing methods of feature extraction and the results are tabulated and they are compared.

Keywords: OLHE, LBP, SVM, GABOR FILTER.

INTRODUCTION

Biometrics

Biometrics - 'Bio' means life, while 'metrics' refers to measurement. Biometric method is the method of (Shashidhar and Suresha, 2013; Jonathon Phillips *et al*., 2005) measuring the behavioural and physiological characteristics of a person. These characteristics obtained from the behaviour of a person are unique. i.e., the biometrics measured from one person differs from another person (Anil K. Jain *et al* 2004; Ambika Ramchandra and Ravindra Kumar, 2013). These variations can be used in identifying the person and recognition can be done more accurately in biometrics rather than knowledge based method, password, personal identity number, which are being used for security and recognition. The disadvantage in using these olden techniques is that, if anyone has knowledge of the password or identifying number of others, they can misuse them and there is also a possibility of wrong identification. These problems can be completely solved by biometrics based methods.

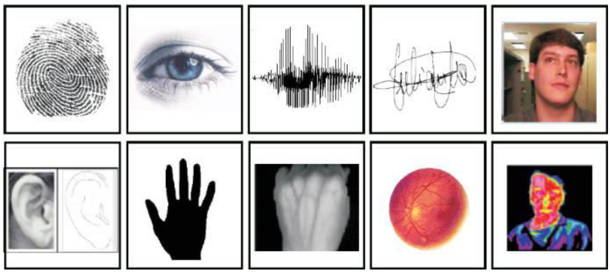

Figure-1. Examples of common biometrics (adopted from Anil K. Jain *et al* 2004).

There are two kinds of biometric characteristics, physiological and behavioural the physiological type deals with the shape of the body, retinal, hand geometry, palm, vein, iris and fingerprint recognition. In behavioural, gait and voice are main metrics as shown in Figure-1. No other methods can replace the security, which is provided by using biometrics, since it is a safer and an easier method. In knowledge based method, people always need to remember the passwords and pin numbers, whereas in biometrics nothing need to be reserved securely and remembered. This unique identity provides the best protection.

MATERIALS AND METHODS

Face recognition

Face recognition is a challenging problem (Ambika Ramchandra and Ravindra Kumar, 2013) in image processing. In recent years, researchers have been very keen about face recognition (Ping-Han Lee et al., 2012), since a high level of security can be achieved by face recognition. In case of iris identification, the user needs to stand in a fixed position in front of the scanning camera. The face recognition method is the one where input face images can easily be captured from the distant camera, which is shown in Figure-2. This seems to be very useful in security and surveillance purposes. Face recognition can be done by various methods such as capturing the face image by visible spectrum or by data extracted from the facial heat emission method. Infrared methods are also used for data acquisition in face recognition. In all other biometrics such as fingerprint recognition, the system needs a key input where the user must place their finger on the recognizing system.

Face region has a number of advantages. Firstly, it is non intrusive. Whereas many techniques require the subject's cooperation and awareness in order to perform identification or verifications, such as looking into eye scanner or placing their hand on fingerprint reader. FRVS (*Finger vein recognition system)* could be used without the subject's notice. A system based on face recognition could be safer, cheap and easy to use.

Figure-2. Sample face images using different illumination and variant poses (adopted by Cha Zhang and Zhengyou Zhang, 2010).

As face detection is the first step of any face processing system, it finds numerous applications in face recognition, face tracking, facial expression recognition, facial feature extraction, gender classification, clustering, attentive user interfaces, digital cosmetics, biometric systems, to name a few. In addition, most of the face detection algorithms can be EXTENDED to recognize other objects such as cars, humans, pedestrians, and signs, etc.

Iris recognition

The measurement of physical characteristic in biometrics is more reliable than passwords. Iris biometric is used for identifying an individual in an intuitive and a natural way. This biometrics based identification is applied in mobile commerce and secure communication areas. For login and transaction purposes in high level security applications, this Iris based biometric authentication is found to be more suitable (Anil K Jain *etal.*, 2004). The input acquisition process has thriven by infrared or video cameras. In the identification process algorithm, speed and accuracy are the important factors. Iris is the annular ring between the pupil and the sclera of the eye. The structure of iris does not vary even after a certain number of years like other parts of human body such as body shape, face, etc. It gives long-term stability and does not need frequent re-enrolment process.

Two individuals can be distinguished by the variations in intensity of its gray level values. Two identical twins, left and right eye of the same person must be distinguished and the existence of minute variation is also taken into account in iris based method, which reserves iris for high security applications. This iris based technology is iris pattern-dependent and does not depend on sight. So it can be used for blind people too. The iris biometrics is highly protected and non-invasive. The iris recognition techniques can effectively prevent unauthorized access to ATMs (Mohammed Nasir Uddin *et al.*, 2011), desktop PCs, cellular phones, workstations, buildings and computer networks. The accuracy attained by these iris recognition systems has proven to be a much more efficient method than other types of biometric systems like voice, print, handprint and fingerprint.

Iris patterns of individuals have been captured in this method and these patterns are matched against the recorded patterns in available databases. Even though iris recognition is found to be more secure, handling degraded and noisy iris images require further amendment. Research issues are based on iris segmentation, localization, nonlinear normalization, occlusion and aliveness detection and large scale identification. It needs to obtain fastest composite time and lowest false rejection rate for template creation and matching (Khattab M. Ali Alheeti, 2011).

Iris recognition modules

The Iris recognition system consists of four main modules as shown in Figure-3. i) The first module is an image acquisition module, which deals with capturing iris images by using cameras and sensors. An image acquisition is a matter of position illumination, and physical capture. The lighting, occlusion and number of pixels on the iris are factors that affect the quality of the image. Many iris recognition systems expect stern cooperation from the user for image acquisition.

ii) Data or Iris image acquisition module is followed by the second module named pre-processing, which involves various steps such as pupil detection, iris boundary detection and iris liveliness detection, eyelid detection and normalization. Iris liveliness detection is used to differentiate living object from a photograph, glass eye, video and other artifacts. It is possible that biometric features can be fraudulently used. Localizing the iris portions and position of the pupil can be achieved by several methods such as integral differential operator, gradient based edge detection and Hough transformation

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methods. The eyelid detection and removal can be done by parabolic arcs to the contours of lower and upper eyelids. It is mandatory to map the extracted iris pattern to the normalized one. These localization methods are based on morphological operators, moments, spring force, probability and gradient. Spring force-driven iteration scheme determines the center and radius of iris and pupil by composition of forces from all points. The inner radius of the pupil and outer boundary can be detected by certain threshold values and image opening and closing operators. The iris localization method is mainly based on intensity gradient and texture difference. The distance between two probability distributions obtained from inner and outer zones can be measured by Kullback-Leibler divergence. Another approach, namely the moment-based texture segmentation algorithm uses second order geometric moments for this prediction. The clustering algorithms like k-means, self-organizing maps and fuzzy k-means are used for segmenting input images to produce the clusters-labeled images. The experiments conducted on UBIRIS database reveal an accuracy level of 98.02% and 97.88% for images captured and segmented.iii) Feature extraction is the third module, which identifies the most prominent features for classification. Some of the features are radius, the shape, the size of the pupil, intensity values, x-y coordinates and orientation of the pupil ellipse and the ratio between the average intensity of two pupils. The features extracted must be encoded to a format suitable for recognition. iv) The fourth module mainly focuses on classification, where recognition has been done by comparison of features with stored patterns. The intra-class and inter class variables are taken as important measures for pattern classification problems.

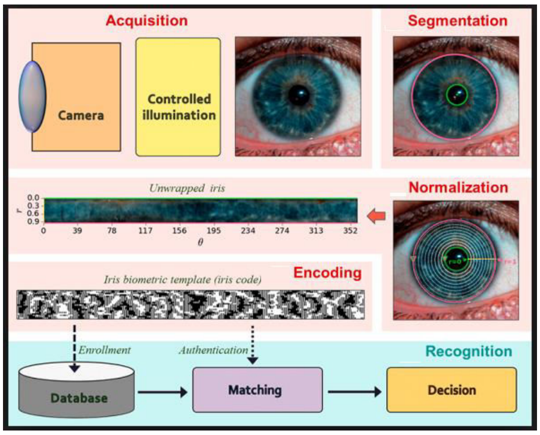

Figure-3. Iris recognition modules (adopted from https://www.google.co.in/ search?biw=1440&bih=758&tbm=isch&imgil=xL75tq)In dranilsin haroy.com/2014/12/05/dissertation_series/.

Fingerprint recognition

Fingerprint recognition is a well known biometric system that is mostly used in various security and authentication applications such as gate access control systems, PC logon, office entry access and so on. The reason behind its popularity is that fingerprint can provide the best balance among authentication performance, size of device, cost and ease of use.

Everyone has unique fingerprints and based on that fingerprint recognition system one can identify a person. Fingerprint recognition is one of the most commonly used methods and actively studied biometric technologies as shown in Figure-4. The reason behind the popularity of the fingerprint recognition based method is that implementation cost is quite low when compared to others like iris and face readers. Fingerprint can be implemented in any environment. This method is less intrusive than face and iris recognition. Most of the people do not like and do not feel comfortable to speak into a microphone and to have their pictures taken by video cameras. Among all other biometrics, finger - based systems are the most convenient and user friendly. Besides, the ability to enroll multiple fingers makes this a very flexible option.

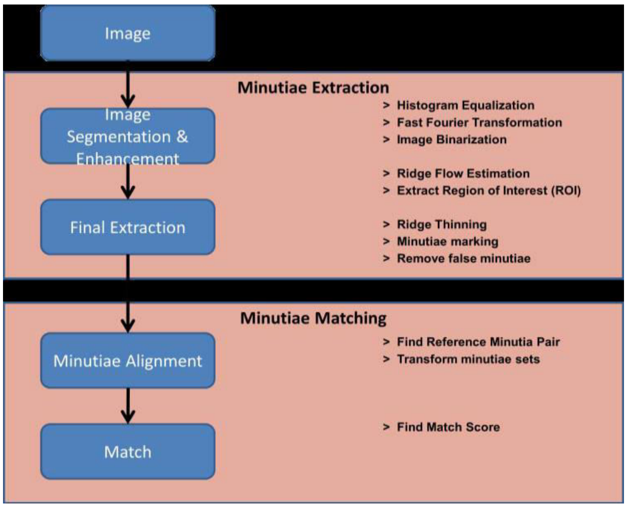

Figure-4. Fingerprint recognition methods.

A fingerprint is identified by the number of valleys and ridges on the surface of the finger (Kekre and Bhadri, 2011). There are two layers available in fingers, the upper skin layer segments identified as ridges and the lower segments identified as valleys. The ridges are further identified as ridge endings and ridge bifurcation. The former is identified by the position where a ridge ends and the latter is identified by the position where a ridge splits into two. Other types of minutiae also exist, including islands, dots, ponds, spurs, bridges and crossovers. Dot is meant for very small ridges, islands meant for ridges slightly longer than dots, which is located in between two temporarily divergent ridges. Lakes or ponds are the empty spaces lying in between two divergent ridges. Spur is a notch protruding from a ridge, bridges and crossovers, where two ridges crosses each other. Every individual's fingerprint pattern is unique, it can be recognized by the flows of furrows and ridges as well as the minutiae points (Sangram Bana and Davinder Kaur 2011). Arch, tented arch, whorl, left loop and right loop are five basic fingerprint patterns. Whorls make up 30% of all fingerprints, Loops account for 60%, and arches

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contribute to 10%. Fingerprints are considered to be unique because any of the two fingers can not have similar ridge characteristics.

The main technologies used for capturing fingerprint image with required detail are silicon, optical and ultrasound. Two main algorithms are available to recognize fingerprints:

a) Patterns: Arch, Whorl and Loop are the three basic elements of fingerprint ridges. An arch is one of the preferred pattern in which the ridges have an entry from one side of the finger, rise in the middle of the finger, forming an arc and then leave from the opposite side of the entry side. In the loop pattern the ridges are used to enter from one side and then form a curve in the middle and leave from the same side. The whorl is another pattern, where ridges form circles surrounding a central point of the finger. Researchers have experimented fingers of the same family members and found that they often share the same general fingerprint patterns, which leads to the belief that these patterns are inherited. During pattern matching, it compares overall characteristics of the fingerprints, and also individual points. Fingerprint characteristics are also dependent on sub-areas of certain interest, including ridge curvature, thickness, and density. On enrollment, each smaller section of the fingerprint and the distance measures are also extracted from the fingerprint. The main part of identification interests in the area around a minutia point are areas with unusual combinations of ridges and areas with low curvature radius.

b) Minutia features: Short ridge (or dot), ridge ending and bifurcation are the main minutia features of the fingerprint. The ridge ending is the place at which a ridge ends. The point at which a single ridge splits into two ridges is referred as bifurcation. The ridges, which are usually shorter than the average ridge length, are referred as dots. These patterns and minutiae are very important measures in the fingerprint based biometrics, since these measures for two fingers are definitely not identical. Minutia matching performs comparison of specific measures. At enrolment (also called registration), the minutia points and their relative distances between each other and their directions are located. In the matching stage, the fingerprint image is subjected to extract these minutia points and patterns and then compared and checked against the registered template.

c) Issues with fingerprint systems: Many of the fingerprint based authentication systems still have some issues left unsolved. One of the major issues is that is that captured images can be easily affected by finger surface which in turn highly degrades the identification performance and overall efficiency. Another major problem is the detection of impersonation of artificial or gummy fingers and finally the loss of security and privacy in fingerprint biometric systems is one of the main area to be focused (Figure-5).

Figure-5. Some illustrations of deployment of biometrics in civilian applications: (a) A fingerprint verification system manufactured by Digital Persona Inc. used for computer and network login (b) An iris-based access control system at the Umea airport in Sweden that verifies the frequent travelers and allows them to access in flights (c) A cell phone manufactured by LG Electronics that recognizes authorized users using fingerprints (sensors manufactured by Authentec Inc.) and allows them to access in the phone's special functionalities such as mobile-banking (d) The US-VISIT immigration system based on fingerprint and face recognition technologies and (e) A hand geometry system at Disney World that verifies seasonal and yearly pass-holders to allow them fast entry (adopted from Karthick Nantha Kumar, 2005).

Merits of fingerprint biometric systems

- They are cheap
- They are easy to use
- They are non-intrusive
- They are small size
- They consume low power
- There is a readily available large database.

Demerits of fingerprint biometric systems.

- Fake fingers or imprints on a glove lead to false detection.
- Some people have wounded or chopped or damaged fingers which gives us poor fingerprints.
- Vulnerable to distortion by twists and dirt.

Multimodal biometric system

In multimodal biometric technology, more than one biometric identifier is used for the identity of the person. The main disadvantage of rejecting valid users due to cuts, bruises and scars are overcome by this system. There are two options available in the multimodal biometric system. Scanning more than one finger and also taking other biometrics like iris, face and voice as input for multimodal biometrics. As another option, we can scan or

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use more than one finger for identification and for achieving high reliability, as the increasing number of input acquisition is directly proportional to the reliability of the biometric system. Increasing input might increase the memory required for database image collection (Anil K. Jain *etal.*, 2004)

Face recognition, fingerprint verification and speaker verification can be integrated into making a personal identification. This multimodal biometrics add the advantages and capabilities of each individual biometric and hence the limitations of a single biometrics can be avoided, which is shown in Figure-6. Experimental results demonstrated that the security level attained by such an integrated system is more reliable than the identity established by a fingerprint verification system, a face recognition system, or a speaker verification system. If one of the systems fails other identity system can perform identification.

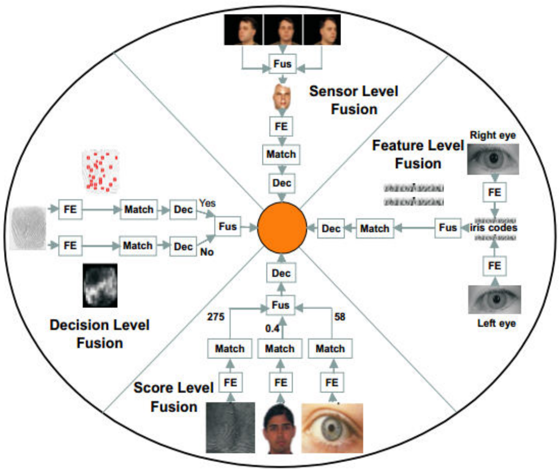

Figure-6. Multimodal Biometric system (adopted from A.K Jain, 2005).

A multibiometric system can be based on one or a combination of the following fusion scenarios:

Multiple sensors: Multiple sensors are tasked to take input of the many biometric identities of the people thus earning the name multi biometric system. *Multiple algorithms:* Different feature extraction algorithms are used to process a single biometric input to create templates with various information content. One such example is the processing of fingerprints or fingerprint images according to minutiae and texture based representation. Although the lack of minute presents a problem and it mainly exists among doctors (who use strong detergents to wash their hands and builders working on a daily wage who handle hard materials on a daily basis). *Multiple instances*: A single biometric modality, but multiple parts of the human body are used. One example is the use of multiple fingers in fingerprint verification. *Repeated instances.* The same biometric modality and instance is acquired with the same sensor multiple times. One example is the sequential use of multiple impressions of the same finger in fingerprint verification. This case is sometimes not considered a motive metric scenario.

FACE RECOGNITION- BACKGROUND THEORY

The initial work in automatic face recognition dates back to the end of the 19th century as reported by Galton (Galton et al., 1879; Galton et al 1888). In his lecture on personal identification at the Royal Institution on 25 May 1888, Sir Francis Galton, an English scientist, explorer and a cousin of Charles Darwin, explained that he had frequently chafed under the sense of inability to verbally explain hereditary resemblance and types of features. In order to relieve himself from this embarrassment, he took considerable trouble and made many experiments. He described how French prisoners were identified using four primary measures (head length, head breadth, foot length and middle digit length of the foot and hand respectively). Each measure could take one of the three possible values (large, medium or small), giving a total of 81 possible primary classes. Galton felt that it would be advantageous to have an automatic method of classification. For this purpose, he devised an apparatus, which he called a mechanical selector that could be used to compare measurements of face profiles. Galton reported that most of the measures he had tried were fairly efficient.

Early face recognition methods were mostly feature based. Galton’s proposed method and a lot of other work to follow focused on detecting important facial features such as eye corners, mouth corners, nose tip, etc. By measuring the relative distances between these facial features, a feature vector can be constructed to describe each face. By comparing the feature vector of an unknown face with the feature vectors of known vectors from a database of known faces, the closest match can be determined. The development and implementation of face recognition systems is totally dependent on the development of computers, since without computers the efficient use of the algorithms is impossible. So the history of facial recognition goes side by side with the history of computers. Research in automatic face recognition dates back at least to the 1960's. Bledsoe, in 1966 was the first to attempt semi-automated face recognition with a hybrid human computer system that classified faces on the basis of fiducial marks entered on photographs by hand. Parameters for the classification were normalized distances and ratios among points such as eye corners, mouth corners, nose tip and chin point. Later work at Bell laboratories) developed a vector of up to 21 features and recognized faces using standard pattern classification techniques.

Martin A. Fischler and Robert A. Elschlager (1973) attempted to measure similar features automatically. They described a linear embedding algorithm that used local feature template matching and a global measure of fit to find and measure facial features. This template matching approach has been continued and improved by the work of Alan L. Yuille and Cohen (Alan L. Yuille, *et al.*, 1992). Their strategy is based on deformable templates, which are parameterized models of the face and its features in which the parameter values are determined by interactions with the facial image.

In Kanade's work (Kanade, T., 1977), series fiducially points were detected using relatively simple image processing tools (edge maps, signatures, etc.) and the Euclidean distances were then used as a feature vector to perform the recognition. The face feature points were located in two stages. The coarse-grain stage simplified the succeeding differential operation and feature finding algorithms. Once the eyes, nose and mouth are approximately located, more accurate information is extracted by confining the processing to four smaller groups, scanning at higher resolution, and using 'best beam intensity' for the region. The four regions are the left and right eye, nose, and mouth. The beam intensity is based on the local area histogram obtained in the coarse-gain stage. A set of 16 facial parameters, which are different distances, areas and angles to compensate for the varying size of the pictures, is extracted. To eliminate scale and dimension differences the components of the resulting vector are normalized. A simple distance measure is used to check the similarity between two face images.

Connectionist approaches to face identification seek to capture the configuration nature of the task. Kohonen (Kononen and Lehtio, 1981) described an associative network with a simple learning algorithm that can recognize facial images and recall a face image from an incomplete or noisy version input to the network. Most connectionist system dealing with faces treat the input image as a general 2-D pattern, and can make no explicit use of the configuration all prosperities of face. Moreover, some of these systems require an in ordinate number of training examples to achieve a reasonable level of performance. Fleming and Cottrell EXTENDED these ideas using nonlinear units and training the system by the back propagation method (Fleming and Cottrell, 1990).

In one of the earliest works reported by Bledsoe (Bledsoe, W.W, 1996), a human operator located the feature points on the face and entered their positions in the computer. Given a set of feature point distances of an unknown person, nearest neighbor or other classification rules were used for identifying the test face. Since feature extraction is manually done, this system could accommodate wide variations in head rotation, tilt, image quality, and contrast. Recent work of Burt uses a smart sensing approach based on multi resolution template matching (Burt, 1888). This course to fine strategy uses a special purpose computer built to calculate multi resolution pyramid images quickly, and has been demonstrated identifying people in near real time.

Kirby and Sirovich were among the first to apply principal component analysis (PCA) to face images and showed that PCA is an optimal compression scheme that minimizes the mean squared error between the original images and their reconstructions for any given level of compression. Turk and Pentland popularized the use of PCA for face recognition. They used PCA to compute a set of subspace basis vectors (which they called Eigen faces) for a database of face images and projected the images in the database into the compressed subspace. New test images were then matched to images in the database by projecting them onto the basis vectors and finding the nearest compressed image in the subspace (Eigen space).The initial success of Eigen faces popularized the idea of matching images in compressed subspaces. Researchers began to search for other subspaces that might improve performance. One alternative is Fisher's Linear Discriminant Analysis (LDA, a.k.a. fisher faces). For any N-class classification problem, the goal of LDA is to find the N-1 basis vectors that maximize the interclass distances while minimizing the intra class distances. From LDA the researches moved to CCA (Canonical Correlation Analysis) which is a multivariate statistical model that facilitates the study of linear interrelationships between two sets of variables. One set of variables is referred to as independent variables and the others are considered dependent variables. A canonical variate is formed for each set. It may be helpful to think of a canonical variate as being like the variate (i.e., linear composite) formed from the set of independent variables in a multiple regression analysis. But in canonical correlation there is also a variate formed from several dependent variables where as multiple regression can accommodate only one dependent AND CCA variable. So they moved to next version called Kernel Canonical Correlation Analysis where same method is followed with minor changes.

FEATURE EXTRACTION AND FACE CLASSIFICATION

The latest pre-processing methods and post processing methods are reviewed in this chapter. The pre-processing algorithms such as Bit Plane Slicing (BPS), Gabor Filter (GF), Local Gradient Oriented Binary Pattern (LGOBP), Contrast-Limited Adaptive Histogram Equalization (CLAHE), Multi-Decomposition Histogram Equalization (MDHE) and Oriented Local Histogram Equalization (OLHE) are among the latest. These algorithms are usually increased the global contrast of the images, which has proven to have an exceptionally high performance under extreme (very poor or very bright) lighting conditions. The post processing methods are Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), Canonical Correlation Analysis (CCA), Kernel Canonical Correlation Analyzing (KCCA), Active Appearance Model (AAM), Hidden Markov Model (HMM), and Support Vector Machine (SVM) are used for face classification.

PRE-PROCESSING

BIT PLANE SLICING

A framework is designed to work for face recognition from video sequence, which is robust to large-scale changes in facial pose and lighting conditions (Yi Dai *et al*., 2009). Two approaches to improve the robustness of the algorithm are presented, a 2D-to-3D face model and Self-PCA (Principal Component Analysis) method based on bit-plane feature fusion. In the training stage, the basic input for recognition systems is a single frontal face image, from which an integrated 3D face model can be constructed. Then the virtual face samples which cover different pose are generated by rotating the resultant 3D face model. After that, a bit planes feature fusion approach is applied to construct a new virtual face to effectively reduce the sensitivity to illumination variances. In the recognition stage, an unknown face video sequence is adopted to find the virtual face and the Self-PCA is performed. The results clearly show the potential of the combination of 2D-to-3D face model and bit planes-based Self-PCA recognition towards pose and illumination variant face recognition in video.

The image system which always has one common difficulty, i.e., finding a capacity of image that varies according to the content of the image and Human Visual System (HVS) (Farzin Yagmaee and Mansour jamzad, 2008). This paper introduced a new method for calculating capacity by using a gray scale image based on bitplane structure. This was achieved by measuring smoothness and connectivity of a specific pixel. The authors paper concluded that bitplane slicing was the best method for calculating the data hiding image capacity of gray scale image.

GABOR FILTER

A novel human face recognition approach is proposed, based on two-dimensional Gabor filtering and supervised classification (Tudor Barbu, 2010). The feature extraction technique proposed in this article uses 2D Gabor filter banks and produces robust 3D face feature vectors. A supervised classifier, which is using minimum average distances, is developed for these vectors. The recognition process, which is completed by a threshold-based face verification method is also provided. A high facial recognition rate is obtained by using our technique. Some experiments, whose satisfactory results prove the effectiveness of this recognition approach, are also described in the paper.

LOCAL BINARY PATTERN

The entire input face image is splitted into multiple numbers of regions ([20]Timo Ahonen *et al.*, 2006). LBP features were extracted from each of the divided region. The combination of these extracted feature distributions formed feature vector. This feature vector was used as facial descriptor and hence for each smaller region, its equivalent descriptor was calculated here. Author stated that the entire face image can be viewed as composition of small patterns like spots, lines, edges and areas. Local Binary Patterns (LBP) were found as an effective approach for facial image representation, while the facial expressions like fear, anger, sadness, disgust, surprise, happiness and neutral were classified by using Linear Programming (LP) (Feng *et al.*, 2005). Experimental results delivered an accuracy of 93.8% in recognizing facial images. A method to combine local and global texture descriptors to describe the texture has been proposed (Oscar García-Olalla *et al.*, 2013). ALBPS (Adaptive Local Binary Pattern with oriented standard deviation) descriptor carried out the local description and representation of the image was further improved by adding standard deviation. The result analyzed with ALBPS showed 85.63% accuracy of recognition rate.

LOCAL GRADIENT ORIENTATION BINARY PATTERN

A new and innovative method derived from LBP (Local Binary Pattern) has been proposed called LGOBP (Local Gradient Orientation Binary Patterns) (Shu Liao and Albert Chung, 2009). In earlier methods, the gradient oriented information was not taken into account. The gradient information is taken as the main factor to provide more discriminate power. Salient measure function was used to find the salient region of an image and the discrimination level. The experiment resulted in 75.09% Face Verification Rate (FVR). In this paper, two methods were analyzed for improving face recognition. The first method was a saliency measure function to detect salient regions and scales corresponding to facial images. The second method introduces a local gradient orientation binary pattern method to capture the information based on neighborhood gradient orientation. This method evaluates Face Recognition Grand Challenge (FRGC) version database and achieves the highest recognition. A novel methodology for gender classification is presented in this paper. It extracts feature from local region of a face using gray color intensity difference. The facial area is divided into sub-regions and GDP histogram extracted from those regions are concatenated into a single vector to represent the face. The classification accuracy obtained by using support vector machine has outperformed all traditional feature descriptors for gender classification. It is evaluated on the images collected from FERET database and obtained very high accuracy (Mohammad Shahidul Islam, 2013).

ORIENTATED LOCAL HISTOGRAM EQUALIZATION

An Orientated Local Histogram Equalization (OLHE) method to overcome captured high frequency edges or compensated low-frequency illumination has been proposed (Ping-Han Lee et al., 2012). It achieves more compactness with good edge-preserving capability, encoded most edge orientations and performed exceptionally well under extreme lighting conditions.

CONTRAST-LIMITED ADAPTIVE HISTOGRAM EQUALIZATION

The difficulty involved in earlier scale space method by Witkin was eliminated by the anisotropic diffusion method, (Pietro Perona And Jitendra Malik, 1990) authors presented a class of algorithms which use diffusion process. The n boundaries of Intra region smoothing were preferred rather than the entire region in this anisotropic diffusion method. As stated by the author, this method achieved high quality edge detection. Some noise estimate and local contrast have to be made in anisotropic diffusion to tackle gradient error.

In order to achieve real-time subject-independent automatic facial feature enhancement and detection, a novel method is presented in this paper combing with Contrast-limited Adaptive Histogram Equalization (CLAHE) and multi-step integral projection (Yisu Zhao et al., 2010). First, after real-time detecting face images, a sigma filter is used to remove the noise in images. Sigma filtering is chosen in this research because of its validity in noise removal. It has the advantages of providing a good noise removal result, not blurring the image and fast performance. Second, since it is important to extract facial features as accurately and clearly as possible, CLAHE is then applied on images for enhancing the facial features. This step is done after the sigma filter in order not to amplify the noise in images. Third, after enhancing these features, multi-step integral projection is proposed to detect the useful facial features regions automatically. Finally, the detected facial feature region is then extracted by Gabor transformation and the final facial expression recognition is classified by SVMs.

MULTI-DECOMPOSITION HISTOGRAM EQUALIZATION

The image enhancement methods where in histogram equalization was used for enhancing an image is being discussed (Sayali Nimkar *et al.*, 2013. But, the obtained image had unpleasant look due to non-preservance of brightness and contrast. To increase a novelty and eliminate unwanted drawbacks of pervious methods, author introduces multi-decomposition histogram equalization (MDHE) technique to decompose by incoming image using unique logic; sub-images were applied into CHE and finally interpolated into the correct order. This gave a better final image showing improvements in brightness preservation and contrast enhancement and calculated important parameter such as SNR, RMSE, PSNR, MSE etc.,

FACE CLASSIFICATION

They analytically solved the probability distribution for image gradient based on reactance and surface's geometry. This distribution, which is clearly showed image gradient does not consider changes in illumination direction. This author analyzed more samples which were constructed for image gradient, based on distribution and concluded that illumination is insensitive for face recognition (Hansen F et al., 2000).

For each image there were 4050 images of 405 posing conditions of 10 individuals (Athinodoros S. Georghiades, 2001). They were given as training poses to the system. A human can appear in many numbers of positions. For all individuals with different posing, it is complex to feed databases. These approaches with very few images were used in training to compose cone space images. A single image of an object was subjected to the database of different objects. The images possessed in the database were taken at various sampled illumination. The class based re-rendering system was designed to find any new objects, which is looking similar to the images in the database (Amnon Shashua, 2001).

The novel three methods were Gamma Intensity Correction (GIC) method determines an illumination level in the image, Region-based strategy combining with GIC and histogram equalization (HE) was proposed to eliminate side-lighting effect and Quotient illumination relighting (QIR) method used to synthesize images to provide a condition of image under abnormal and normal lighting (Shiguang Shan *et al.*, 2003). Facial recognition systems were implemented in many applications (Eric and Stephen J. Elliott, 2004), but it was not studied in the difficult circumstance. This motivated them to continue studying and improves developing new algorithm. The evaluation result of this paper shows that the enrollment illumination level shows good result rather than the verification illumination level.

Author (Kuang-Chih Lee *et al*., 2005) presented a paper "Acquiring Linear Subspaces for Face Recognition under Variable Lighting", which analyzed a low-dimensional linear space, shadows and light variation of images in face recognition, particularly in human faces. He arranged a physical lighting to directly acquire basic vectors of images to process at low-dimensional linear space. A k-point light source configuration exists, ranging from 5 to 9 to take k-images as a single source. As a result, he achieved an effective subspace in various lighting conditions and subspaces were obtained directly from original images. 3D-reconstruction was avoided. This subspace was constructed in a validate manner for analysis of a face recognition and had a great improvement in signal-to noise ratio. The challenges in face recognition and how to solve and reduce the error rate in real time processing. Face Recognition Grand Challenge (FRGC), which achieved performance with data of 50,000 images. In earlier days (Jonathon Phillips et al., 2007) recognition techniques had been developed in many ways, such as computer design, computer vision and sensor design techniques. All these measures add error rate in recognition. The verification has been done more efficiently and reported that the false acceptance rate is 0.1%.

The base image captured under arbitrary light condition, statistical model was built and then by using learned statistics spherical harmonic basis were developed and the harmonic illumination had a key input and built a statistical model in 3D spaces. Those two methods together recovered and identified across both illumination and pose (Yang Wang et al., 2002).

To enhance face recognition, lighting conditions were considered to get reliable recognition (Xiaoyang Tan and Bill Triggs, 2007). The local ternary pattern (LTP) and local binary pattern (LBP) were enhanced local texture feature and sensitive to noise was less. The local spatial histograms improve the performance of LTP/LBP recognition. It achieves 88.1% of variable rate at false accept rate of 0.1%. The result outperforms in lighting, data sets and feature set of several pre-processing methods. The face recognition has an important role in security purpose, but has some complexity in varying phases of face image. To overcome this to apply the 3D model based algorithm, in this paper he stated a method for verification and identification. The Face verification was a 1:1 match that compares a face image and a database face image. Alternative solutions have been proposed to overcome problems such as the slowest and convergence of the ICP-based methods. (John Wright *etal.*, 2009) face recognitions have problem in automatically varying a facial expression. This problem was overcome by this method, providing the solution of two issues 1. Feature extraction 2. Robust to occlusion. In feature extraction, the down sampled images were converted into Eigen face of the theory of sparse representation (Andrea F. Abate *et al.*, 2007).

Initially a single image was decomposed by logarithmic total variation into small and large scale features. In the result, large scale features were normalized and small scale features were smoothened. Finally, the normalized face image was generated by combining smoothened small scale and normalized large scale features (Xiaohua Xie Tan and Bill Triggs, 2008). Inherent structures of images were derived from the gradient faces. In this method, a gradient form of the image has been generated from original 2D image. Illumination insensitive measures were derived from gradient images and used for recognition. This gradient method had found to be effective in face recognition in different poses and lighting condition (Taiping Zhang *et al.,* 2009).

In the general face feature descriptor was the main factor for identifying the face expression of a human. GLTP (gradient local ternary pattern) operator was used to encode the local texture of an image. This method used to quantize the gradient magnitude of local neighborhoods in three discrimination levels. The conclusion stated by the author was that the facial texture can be effectively represented by GLTP operator than local texture patterns (Faisal Ahmed and Emam Hossain, 2013).

Face recognition became a research in image-processing areas, typically information processing on that image used in security systems and access control systems. Illumination conditions were also included in the real time image capture, it causes problems in recognition. To solve the illumination condition, the preprocessing method was applied in face images. It analyzed lighting variations based on various stages like gamma correction, contrast equalization and difference of Gaussian (DOG) filtering. A face recognition challenge (FRGC) and Yale-B data set techniques were used in the preprocessing method (Anila and Devarajan, 2012).

PRINCIPAL COMPONENT ANALYSIS

The face images were split into a smaller image and some part of image did not vary in different face action in order to analyze this image and to get an efficient result (Rajkiran Gottumukkal *et al.*, 2004). Identification of face expression was analyzed by LTP method. In the former one, the result was subjected to KPCA technique for image classification, while later one used SVM technique. KPCA added the feature of reduced computation time and LTP improved recognition rate (Steven Fernandes and Josemin Bala, 2013; Swarup Kumar Dandpat and Sukadev Meher, 2013). Swarup presented a new method in paper "Performance Improvement for Face Recognition using PCA and Two-Dimensional PCA". Author developed an algorithm and tested against conventional PCA and 2DPCA. Initially the author proposed to identify and to separate the nonzero Eigen values and then assigned different weights to all of them. These differently weighted Eigen values were taken as non trivial principal components. Similar principal components were taken at k nearest distance locations on an image and recognized. This method had use Euclidian distance and achieve high recognition rate than conventional methods.

Dimensionality reduction has an important factor in face recognition to analyze a LBP texture. In this paper, the author proposed a PCA technique and 1DLBP algorithm based on LBP texture. Principal component analysis (PCA) technique mainly concentrates on dimensionality reduction and decompose a facial image into several blocks, this block was projected in one dimensional space to differentiate local and global features to separate individuals. 1DLBP algorithm applied in blocks which were extracted from different resolution. For this algorithm, concatenate resulting vectors in global vector (Amir Benzaoui *et al.*, 2012. Finally, algorithm results were applied once again in PCA technique to reduce dimensionalities of global vector and record pertinent information about individual persons. The results were applied to the AR database to show that the combination of PCA and 1DLBP enhance false alarm rate and recognition rate and also shows more effectiveness in noise, rotations and illumination when compared with other face recognition methods.

The genetic algorithms to improve the recognition in MIPCA (Modular Image PCA). MIPCA has found effective in identifying large expression variations. Genetic algorithm was introduced to optimize best set features. The MIPCA-GA has obtained the high correlation. The result obtained from MIPCA has been considerably improved by genetic algorithm (Shree Devi and Munir Ahamed Rabbani, 2014).

LINEAR DISCRIMINANT ANALYSIS

All image processing methods have their unique advantages and the author proposed method to combine Fisher Linear discriminate method and other image processing methods. While FLD had combined with weighting scheme, it was reported the reduced EER of 15.4% and when FLD was applied to entire face key, the preprocessing time was found less (Thomas Heseltine *et al.*, 2003). A boosted skin-color model in RGB space, which improves the color image face detection. This method differentiates skin of the different human. Spatial templates were added here in the local binary pattern. The LBP took both the spatial texture and principal local shapes. Here LBP histogram was used for representing the human face (Ying-Han Pang *et al.*, 2006). The result shows 94% of the face detection rate among their database consists of multi-face color image and single image of total 485.

The entire data was classified by Clustering data analysis into several groups, which considerably reduced the computational time for image matching and identity purpose (Lishi Zhang et al., 2011). PCA used an independent variable to achieve clearest discrimination between groups. So these papers concentrate to improve those by using fisher linear discriminate analysis approach. This was mainly used for increasing the objective function in data clustering. The clustering function was used to separate a data in grouped image and those separated values were compared to the original image and hence high accuracy output is reached.

CANONICAL CORRELATION ANALYSIS

The Generalized Canonical Projective Vectors (GPVC) gave a good classification report by extracting the combined features of the sample image. Here according to Concordia university database CENPARMI handwritten Arabian numeral had proven that GCPV was the best method than the CPV. The problem faced for the facial expression recognition by kernel canonical correlation analyzing vector. They created the label graph vector and the semantic expression vectors were used for each image. By studying the relation between the LG vector and semantic expression vectors, an expression classification used KCCA; here they proposed another effective KCCA algorithm (Wenming Zheng *et al.*, 2006).

The standard CCA are EXTENDED here by seeking the similarity between the two sets of different image, without turning the images into vectors by reshaping it. According to them the 2D-CCA method decreases the complexity of the process, when compared to standard CCA. They showed the uses of the 2D-CCA used by examples like learning correspondence of the face image of different poses (Annan Li *et al.*, 2011) shows that it is difficult to recognize the face image in different poses. Hence here, in this paper they proposed a method for face recognition in different poses. CCA correlation was measured for different poses in media subspace for obtaining the similarity. By selecting the maximum intra-individual correlation, recognition approach was developed. This experiment results show that the proposed method had higher efficiency than other based on the FERET database.

(Dianting Liu *et al.*, 2009) Based on the CCA ideas, Dianting proposed a method called multi spectral feature extraction. The proposed method extracts most similar features. Instead of extracting similar pattern features which form discriminate vectors in an effective manner of recognition. According to their experiment result based on the Notre Dame face database proposed method works well than the previous method. Face Recognition, the LDA method was widely used same as LDA, for bio-metrics and image processing CCA was powerful method. For that reason they go for the CCA method of face recognition. Theory, method of coding and encoding the face image was reported here as their proposed methodology according to the information they gathered on the face recognition. By using their proposed method, they reported the accuracy rate average of 99% (Dominik Jelšovka *et al.*, 2011).

A Heterogeneous and synthesized face recognition using a subspace mapping. Heterogeneous means images taken in various spectral bands. The visual light, 3D range and NIR facial images were represented by the LBP (local binary pattern). Mapping of the LBP face pattern was studied by the CCA. The final decisions were taken according to the calculated matching scores of CCA. With the help of the CCA transformation matrices from the previous section a ridge regression was applied for determining the linear similarity between the images were done in the synthesis part. The experiment shows that, it was a trustable heterogeneous face synthesis (Mengyi Liu *et al.*, 2012).

ACTIVE APPEARANCE MODEL

The image processing effects for three methods of image processing was researched by Thomas Heseltine. The three methods were the direct correlation methods, Eigen method and fisher face method. By using a large facial image set of the test image the effectiveness was calculated by comparing the false rejection rate, false acceptance rates and error rates. Those test images were taken in varied lighting conditions. Their test presented the difficulties in the recognition from that they found some advantage and best method for face image processing (Thomas Heseltine et al., 2003).

HIDDEN MARKOV MODEL

The automated face recognition system was massively infected by interclass variations between enrollment and identification; lighting conditions were a major contributor to these variations. The histogram was widely used in face recognition. Multi-resolution property of wavelet transform was used in face recognition to extract facial features descriptions, i.e. fusion of match scores from low to high frequency based face representation to improve recognition accuracy under varying lighting conditions. Image quality was also used to adaptively select fusion parameter for wavelet based multi-stream face recognition (Xiaoming Liu and Tsuhan Chen, 2003).

SUPPORT VECTOR MACHINE

The method proposed by Ruo was used in videos for analysis of face recognition; the video was recorded and the frames are collected, analyzed and HVFs were automatically obtained from videos with different frame rates and to illumination interference. The different emotions of image frame were taken from human image; those images were saved in database and compared with the original image. This method was proved to get high accuracy result (Ruo Du *et al.*, 2009).

A novel approach called multi class SVM for face recognition had been Author Yew had proposed. The Adaboost training algorithm was used to detect the face regions and then image feature was extracted from a holistic approach. After the generation of feature vector, multi-class SVM were suggested for image classification.

Through various numbers of experiments, the images at 2.6m or lesser could provide better recognition (Yew and Chuu Tian, 2011).

Expressionless facial images are also called as neutral images. Every image database consists of these neutral images. The images which captured from non frontal view can also consist of facial expressions like smile, joy, sorrow, etc. these images often cause the face recognition algorithm to fail. So Petpairote proposed a method which covers the original image with facial expression to develop a neutral expression invariant image. The correctness of the face recognition were improved by covering the facial expression of the probe image using the database of neutral faces. Modified method of thin plate splines covering was used to achieve the neutral images. Two well known databases like AR-Face and MUG_FED databases were used in the proposed system. Principal component analysis (PCA), linear discriminate analysis (LDA) and local binary pattern (LBP) were used to improve the face recognition in his proposed method (Chayanut Petpairote and Suthep Madarasmi, 2013).

Linear Kernel was used to achieve high classification rate of 91.87% (Isra'a Abdul-Ameer and Abdul-Jabbar, 2014). Two different sets of image were taken, one set was a false image with noise and another set was a false image without noise. This image was applied to our proposed method and the face recognition rate was calculated, and they proved that the image, de-noise has most powerful issue for face recognition rate.

FACE RECOGNITION BY ELASTIC BUNCH GRAPH MATCHING

Image graphs of new faces are extracted by an elastic graph matching process and can be compared by a simple similarity function. Phase information is used for accurate node positioning. Object-adopted graphs are used to handle large rotations in depth. In our case, a Jet is a primitive wavelet transform that is a set of 40 complex Gaussian wavelet coefficients obtained for one image point. This leads on to the dilation and rotation of pixels from the wavelets in the jet. All these make up a set of graphs and nodes for Elastic Bunch Graph Matching. Once the system has one manually-defined graph, graphs for new images can be generated automatically. The system presented is very flexible (Laurenz Wiskottlt *et al*., 1999).

MOTIVATION BEHIND RESEARCH PAPER

The major problems in biometrics are to recognize the person and also to avoid spoofing. The most important area where the biometrics have to advance is to bring the biometric technologies (BT) in all electronic devices. The major problems in bringing this BT in all electronic gadgets are the different illumination conditions and poses during the image capturing. These conditions required for facial recognition or person identification should be cost effective and consume less time with a simple design. While comparing with other BT, the facial analysis is \considered as the best way of identifying a person.

STATEMENT OF PROBLEM

Face Recognition (FR) has received significant attention, especially during the last few years. Recently the FR system has gained a special importance because of its necessity in many applications. Face recognition has substantial potential in the future for a wide range of problems, such as:

- Helping the government officials tocatch criminals and suspected terrorists and
- Helping in minimizing cyber crimes

The facial image recognition plays a vital role in biometrics. Though the development of processor and camera system increases the usage of this facial image recognition in all consumer electronics, still it is sluggish (due to poor illumination conditions and variant poses). The reason behind this is due to the biometric authentication software and their algorithms for detection. In the facial image recognition, one of the very basic complications that arise is to solve the recognition of an image in a differently illuminated area and with variant poses. The same face may appear in a different way due to the change in lighting. Illumination can change the appearance of an object drastically. Illumination problems can be solved using various methodologies such as the heuristic approach, the Statistical approach, the light-modeling approach, the pose variation, the multi-image approach, the single-model based approach and the geometric approach.

Also, to solve this problem, a novel method of facial image recognition is implemented based on the objective and quantitative methods. This objective quantitative method serves as a good subjective test and is quite easy to apply.

OBJECTIVE OF THE RESEARCH WORK

The basic objectives of this research work are summarized as following:

- To create a new facial database from various illuminated condition and a variety of poses.
- To apply various feature extraction and classification algorithms to the public databases (FERET, ORL, CMU-PIE and EXTENDED YALE B) and newly created VIT Database.
- To evaluate the best illumination compensation method to be adopted in real time environment.
- To study the merits of the algorithm's performance with differently illuminated images, pose variant images.

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- To produce comparative results on open-source databases and the newly created VIT Database.

PROPOSED METHODOLOGY

An automated method of recognizing a person using any physiological or behavioural characteristics is known as Biometrics (Anil K. Jain *et al*., 2004; Ambika Ramchandra *et al*., 2013). The field of biometrics examines the physical or behavioural traits that can be used to determine a person's identity. Facial recognition is the appropriate one that everyone prefers because there is no physical interaction and it has a high accuracy in authenticating a person. The block diagram of methodology is shown in Figure-7.

The diagram shown below represents the various stages of an image is taken through for facial recognition. When an image is chosen for face recognition, one needs to take into account the various illumination conditions and variant poses of the person in the photograph. The open-source databases mentioned in the figure are obtained from the internet and the VIT database is generated by using an ordinary camera from an electronics store. The images in the database are the photographs of the VIT students captured under various illumination conditions and variant poses so as to pose a challenge for face recognition for us to rectify, by using the proposed methods.

The ideology is to subject all the databases of the facial recognition process as proposed in this research work and to compare the results and find the best method for the most efficient recognition. The face images are collected in two types. The first type is standard open source databases such as FERET, ORL, CMU-PIE and EXTENDED YALE B. The second type is newly created database with normal camera under different illumination and pose under varying distance and environment conditions. Both the type of images are taken to the next step for feature extraction. The various feature extraction techniques are BPS, GABOR filters, LBP, LGOBP and OLHE. These features extracted image from different

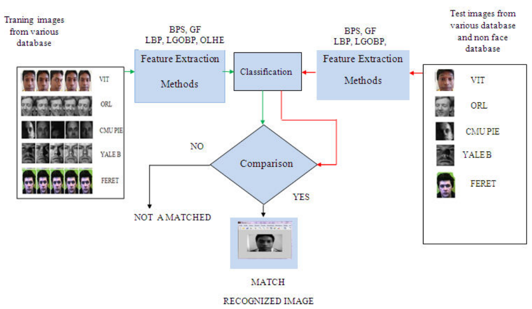


Figure-7. The block diagram of methodology.

algorithms are given as input to the different types of classification algorithms, by taking an image from different feature extraction algorithms and finding for the performance of different classification algorithms. These face recognition techniques are discussed in detail in the following chapters. The disadvantage of open source database and the newly created VIT database are also discussed. A novel formation for the more accurate and quick recognition in all inverted images and for different camera captured images are explained in the results with the discussion.

FEATURE EXTRACTION USING VIT AND OPEN SOURCE DATABASES

Feature extraction (generally known as pre-processing) is often explained as the operation performed on images at the lowest level of abstraction (abstraction, means, presenting the user with only the necessary details disregarding the other details). It eliminates the changes in facial appearance caused by the pose variations and illumination changes. We shall discuss about how the problem posed by the pose and illumination variations can be rectified. Pose variations are caused by changes in the angle at which the image is being captured and the elevation at which a given face is being observed. The test images are shown in Fig.8 (a) and (b). Thus, pose variations occur due to scale changes as well as in-plane and out-of-plane rotation of faces. Out-of-plane changes are difficult to handle. In fact, out-of-plane rotations can be addressed only to a certain extent by the utilization of warping techniques, where the centre positions of the distinctive facial features are utilized as reference points to normalize the test facial images. On the other hand, scale changes can be handled by using a normalization process based on a stretching transform.

Illumination variations can be almost eliminated by filtering the input image with Gabor wavelets. (Zhang *et al* 1997; Jonathan Howell and Hailary Buxton, 1997). Elimination of variation due to a partly lightened face is difficult. Unanticipated reflections in eyes, teeth and wet skin may be corrected by using brightness models.

The pre-processing method applies face normalization (or use of normalized extracted features) that generates scale, illumination, and pose invariant data.

Figure-8(a). Sample images using different lighting conditions and variant poses from the CMU-PIE database.

Figure-8(b). Sample images using different lighting conditions and variant poses from VIT database.

FACE RECOGNITION PROCEDURE

The entire sequence of training and testing is sequential and can be broadly stated as consisting of the following steps:

a) Database preparation
b) Training process
c) Testing process
d) Performance analysis

A. Databases preparation

The VIT database was prepared using an ordinary camera with a low resolution (DSC WISO Sony 10.1 Mega Pixel), the images were taken under variant illumination conditions and different poses. The students appearing in the photos are VIT students from the batch 2009-2012.

In VIT Database, there are about 100 images in each of the two sets. All images displayed and the images extracted from the video sequences are captured using different poses, illumination conditions and variant poses (10 images per person). The differently illuminated and pose variant images are captured with the DSC WISO Sony camera which is about the resolution of 10.1 Mega-Pixels and these images are taken as input images for the face recognition system. The Fig. 9 (a) and (b) shows the images of the students from the VIT database with variant poses and different illumination condition.

Figure-9(a). Sample of VIT databases set -1 using 100 images.

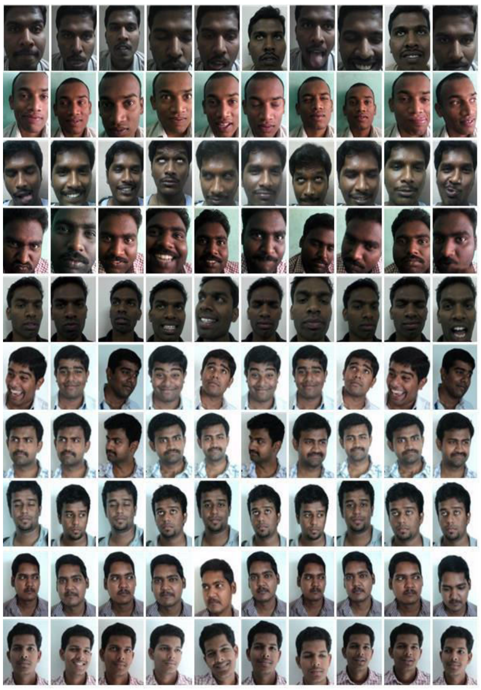


Figure-9(b). Sample of VIT databases set -2 using 100 images.

A typical video-based face recognition system automatically detects face regions, extracts features from the facial regions appearing in the video, and recognizes facial identity if a face is present. In surveillance, information security, and access control applications, face recognition and identification from a video sequence is an important problem. Face recognition based on video is preferable over using still images. It was also demonstrated that humans can recognize animated faces better than randomly rearranged images from the same set (Zhao *et al.*, 2003). Though recognition of faces from video sequence is a direct extension of still-image based recognition, significant challenges for video-based recognition still exist and they are:

a) The quality of the video is low

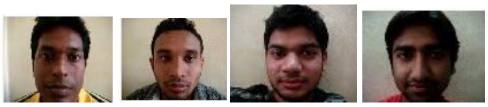
Usually video acquisition occurs outdoors (or indoors but with poor lighting conditions for video capture) and the subjects are not cooperative. There may be large illumination changes and pose variations in the face images.

b) Face images are small

Again, due to the acquisition conditions, the size of faces are smaller (sometimes much smaller) than the assumed sizes in most still-image-based face recognition systems.

c) The characteristics of faces/human body organs

During the past few years, research on human action/behaviour recognition from video has been very active and fruitful. Generic description of human behavior which is not particular to an individual is an interesting and useful concept. The Figure-10(a) shows us the sample of images extracted from the video sequence. The Figure-10(b) shows the images extracted per frame of the video that is of the duration of 180 seconds. The images in the Figure-10(a) are the screen shots of the paused video sequence, whereas the images in the Figure-10(b) are extracted using MATLAB per frame of the video sequence. The frame rate of the video is 30 frames per second.



File Name: MOV03149.MPG MOV03151.MPG
MOV03199.MPGMOV03214.MPG

Figure-10 (a). Sample of facial images extracted from video sequences.

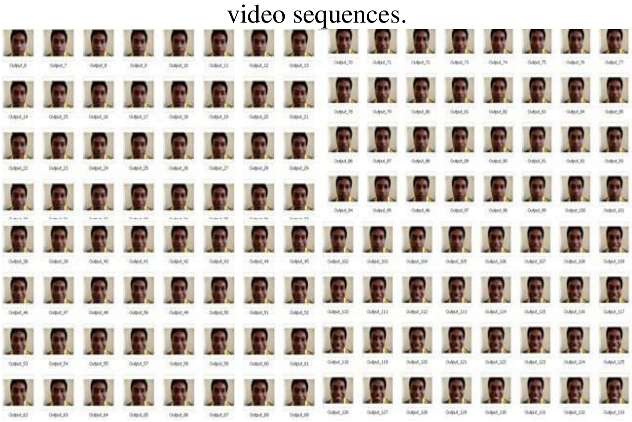


Figure-10(b). Sample of image conversion from video to still images.

The other databases used are the open source databases (www.face-rec.org/databases/) such as

a) The Face Recognition Technology (*FERET*) program *database.*

b) ORL database provided by AT&T Laboratories from Cambridge University.

c) CMU-PIE database provided by Simon Baker.

d) Extended YALE B database provided by UCSD Computer Vision.

B. Training process

After database preparation, we have to train the images. Training the images means that converting them into gray scale images if they are colored, normalizing them if required and extracting the features. Since it is a feature based method, all the important features of face like eyes, nose, and mouth are extracted. Images of the same person are classified under the same group and images of different persons are classified under a different group. After creation of the group, their weight vectors of the images are calculated using co-variance matrix; these weight vectors are called training image weight vectors.

C. Testing process

The recognition of the images in the training process and thereby calculating the weight vectors is the main aim, the same is done for the testing images as well. The Euclidian Distance is then calculated by the difference of the weight vectors of training images and testing images. After that, the minimum Euclidian distance is found out. Recognition of the test images from the database with the help of minimum Euclidian distance is done. Finally, the recognized test image is matched with the particular image in the training database.

FEATURE EXTRACTION METHOD 1: BIT PLANE SLICING

Bit Plane Slicing is a well known technique used in image processing (Ruo Du et al 2009). In image compression, bit plane slicing is widely used. Bit plane slicing is the conversion of images into multilevel binary image. These binary images are then compressed using different algorithms. Each pixel is a the series of digital bits and from these digital bits binary images are to be extracted. The extracted binary image gives us binary information. This information is used for computing image feature in the image retrieval process.

The digital image is constructed by m x n pixels. Each pixel is represented by a value. For 8-bits gray-level image, pixel's value is represented from 0 - 255. Computer manipulates the signals for true and false, so the pixel's value is formed by binary in 8 bits. According to Gonzalez. 2005, higher-order bits contain the majority of visually significant data, and lower-order bits contain more subtle details in the image. So, 8 groups are formed according to bits' order and called bit-plane. Bit-plane 0 is formed by least significant bits, and bit-plane 7 is formed by most significant bits.

Face recognition using bit planes followed by face classification algorithms is used to implement the model for test database of video sequences to distinguish it from a training set of stored faces with some real-time variations as well. The approached method is based on extracting significant bit planes of the image and creating a virtual image by combining the bit planes, giving most of the information of the image multiplied by the weights (Yi Dai *et al*., 2009). Weights are selected such that higher order bit planes carry more weights.

MATHEMATICAL DEFINITION

Let Γ_i denote the m^{th} image of the i^{th} person (m=1, 2,...,M， i=1, 2,...,I), the mean image is given as

$$\Psi = \frac{1}{M}\sum_{i=1}^{M}\Gamma_i \quad (1)$$

The bit-plane extraction is performed on Γ_i to get its five bitplanes and mark them as B_i i is the 1,2,6,7,8). A new virtual face of the m^{th} image of the i^{th} person is thus given by

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Computation of virtual image

$$V = \sum_{i=1,2,6,7,8} B_i \alpha_i \quad (2)$$

In the above equations (2), the parameters α_i is non-negative coefficients determined by a trial procedure (Figure-11).

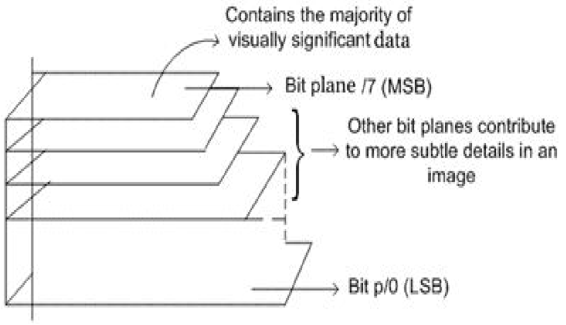

Figure-11. Bit plane slicing.

Among 8 single bit-planes, bit-plane 0 to 3 have a very low information, which are lower than Recognition rate 60%, while bit-planes 4, 5, 6, and 7 achieve over 88% accuracy for face recognition. The higher order bit-planes have better performance because they are considered as visually significant data, which contain enough information for recognition.

SIMULATION RESULT WITH VIT AND OPEN SOURCE DATABASES

The image Figure-12 was chosen to be the test image from VIT database for feature extraction using Bit Plane Slicing (BPS) algorithm and the 8-bit feature extracted output using Bit Plane Slicing histogram equalization.

Similarly the test images were chosen from different public databases such as FERET, ORL, CMU-PIE and EXTENDED YALE B and features were extracted using BPS algorithm. The test image and the outputs of different databases are shown in the Figure-12 The Figure-12 are the various bit planes of the images that are extracted using bit plane slicing with the help of MATLAB software. For analysis purposes, we have compared the standard open source databases with the VIT database whose images were captured using different illumination conditions and variant poses.

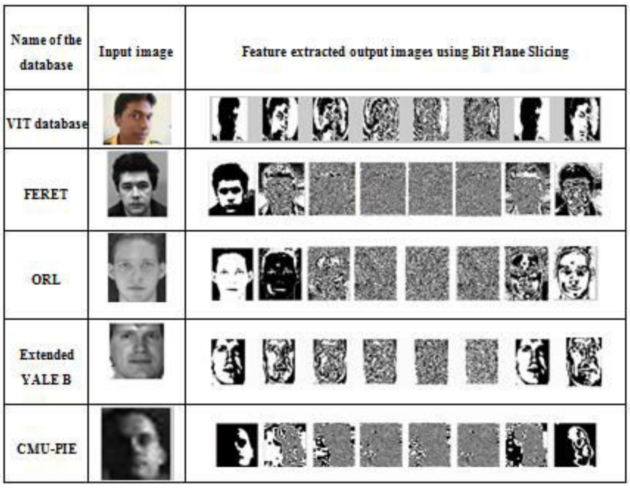

Figure-12. Input test image and Bit Plane Slicing – 8 bit outputs.

These extracted features from the pre-processing stage aid us in overcoming the illumination challenges faced while face recognition and are used as the input for the post-processing stages.

FEATURE EXTRACTION METHOD 2: LOCAL BINARY PATTERNS

The local binary pattern is the best texture descriptor that has been commercially used over the years for many applications. It was introduced by Timo Ahonen *et al*., (2006) and Di Huang *et al*., LBP has computational efficiency and it is invariant to monotonic gray level changes.

LBP Operator: LBP characterizes the local image texture by thresholding the 3x3 neighbourhood for each pixel with centre pixel as reference values. As a result, we will get a binary number. We can assign the neighborhood of the centre pixel by a set of sampling points with any radius. If the sampling point does not fall in the centre of a pixel, bilinear interpolation can be used. Formally, given a pixel at (x_c, y_c), the resulting LBP can be expressed in decimal form as:

$$\mathrm{LBP}(x_c, y_c) = \sum_{n=0}^{7} s(i_n - i_c)2^n \; s(x) = \begin{cases} 1 & \text{if} x \geq 0 \\ 0 & \text{if} x < 0 \end{cases} (3)$$

$$s(x) = \begin{cases} 1 & if x \geq 0 \\ 0 & if x < 0 \end{cases} (4)$$

Where $i_c$is the gray level of the centre pixel and i_n is the gray level of the surrounding pixels (Figure-13).

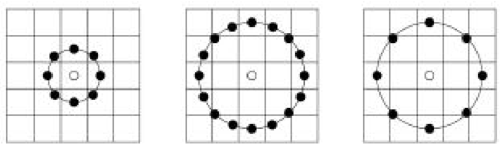

Figure-13. The circular (8,1), (16,2) and (8,1) neighbourhood are illustrated.

Face description: The face image will undergo pixel wise LBP operation based on the number of sampling points and the radius set. (We use $(x_c, y_c) = [8,1]$) as it has proven efficient. Now by using the above, we build a local description of the face and globalize the local descriptors to form a texture description of the whole face, which is shown in Figure-13.

Name of the database	Input image	Feature extracted output images using LBP
VIT database		
FERET		
ORL		
Extended YALE B		
CMU-PIE		

Figure-14. Test image under low light conditions using VIT and open source databases) and LBP processed output image.

SIMULATION RESULT WITH VIT AND OPEN SOURCE DATABASES

The image portrayed below is chosen from the VIT database for the feature extraction using LBP Figure-14 shows the test image under low light conditions and the LBP processed output image using VIT and open source databases such as FERET, ORL, CMU-PIE and EXTENDED YALE B databases.

FEATURE EXTRACTION METHOD 3: LOCAL GRADIENT ORIENTED BINARY PATTERN

LGOBP (Local Gradient Oriented Binary Pattern) is developed from LBP (Local Binary Pattern) and a robust texture descriptor. LGOBP encodes higher order pixel wise information when compare to LBP and the invariant property of monotonic gray level in LBP is preserved (Shu Liao *et al.*, 2009). It captures the neighborhood gradient orientation information which is not implemented in the local binary pattern to give more discriminant power.

LGOBP OPERATOR

For each pixel V_c, $\psi(\nabla_{v_c})$ be the gradient orientation angle. A circularly symmetric neighborhood system with radius R is taken at centre pixel (V_c) with k neighboring pixels uniformly located on the circle. Neighboring pixels that do not fall in the image grid are interpolated using bilinear interpolation. The K neighboring pixels are denoted as V_i where i= 1, 2,3,...,k and $\psi(\nabla_{v_c})$ gives the gradient orientation angle of V_i (Figure-15).

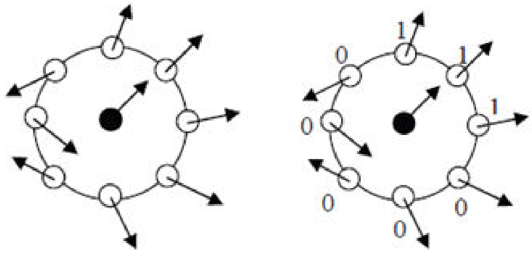

Figure-15. Arrows represent the gradient orientations of different pixels and binary numbers are assigned to each neighbouring pixel.

The gradient orientation space is uniformly divided into 4 subspaces, the pixels with gradient orientations that fall in the same subspace are considered with the same gradient orientations. Each pixel is given a label, which means each pixel is given a label according to its gradient orientation.

$$l(v) = \begin{cases} 1, \ if\,\psi(\nabla_v) \in \left(0, \frac{\pi}{2}\right) \\ 2, \ if\,\psi(\nabla_v) \in \left(\frac{\pi}{2}, \pi\right) \\ 3, \ if\,\psi(\nabla_v) \in \left(\pi, \frac{3\pi}{2}\right) \\ 4, \ if\,\psi(\nabla_v) \in \left(\frac{3\pi}{2}, 2\pi\right) \end{cases} \quad (5)$$

After the labels are allocated using the above equation to analyse the pixel wise information between the center pixel V_c and the neighboring pixel V_i the corresponding labels obtained from the equation. 6 are compared and each neighboring pixel is assigned a binary number by the following equation.

$$B(v_i) = \begin{cases} 1, if\, l(v_i) = l(v_c) \\ 0, if\, l(v_i) \neq l(v_c) \end{cases} \quad (6)$$

LGOBP encodes the 2nd order pixel information because the gradient orientations already contain the 1st order pixel-wise properties, LGOBP is also a monotonic gray level transformation invariant even though the gradient magnitude of each pixel changes their gradient orientations remain the same (Shu Liao *et al.*, 2009). Similar to LBP, LGOBP is uniform as the bit wise transition from 0 to 1 of the neighbouring pixels, which are less than or equal to 2. We concatenate all the LGOBP features to form a global image, which as shown in Figure-16.

SIMULATION RESULT WITH VIT AND OPEN SOURCE DATABASES

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The below test image was chosen from the VIT database for the feature extraction using LGOBP algorithm. The test image was taken under a low lighting condition. Figure-16 shows the test image under low light conditions and the LGOBP processed output image.

Name of the database	Input image	Feature extracted output images using LGOBP
VIT database		
FERET		
ORL		
Extended YALE B		

Figure-16. Test image under low light conditions using VIT and open source databases) and LGOBP processed output image.

Similarly the test images were chosen from various open source databases such as FERET, ORL, CMU-PIE and EXTENDED YALE B and the features of the image were extracted using LGOBP (Linear Gradient Oriented Binary Pattern) algorithm. The test images and the output for each of the different open source databases is shown alongside.
The output images displayed above are the results of one of the pre-processing methods (LGOBP) that are later compared to the other pre-processing methods used here, to find out the most efficient method.

FEATURE EXTRACTION METHOD 4: ORIENTED LOCAL HISTOGRAM EQUALIZATION

The difference between LHE and OLHE is the orientation (direction) of the edges of the image. In LHE, for each pixel, histogram equalization is performed on the width-by-height window centered on a particular pixel using

$$f(x) = round\left[\frac{cdf(x)-cdfmin}{w.h-cdfmin}(L-1)\right] \quad (7)$$

Where *x* is the pixel intensity, *cdf(x)* is the cumulative distribution function of the histogram, $cdf_{min}$is the minimum intensity in the window and L is the number of output gray levels. In a square window, the centre pixel is known as the anchor. Every pixel in the image repeats the above method and uses *f(x)* for its new intensity value, which is shown in Figure-17.

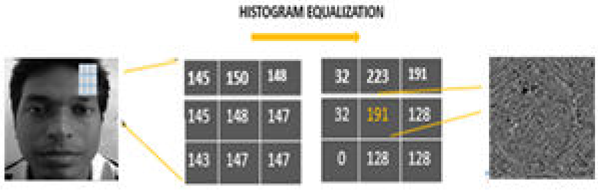


Figure-17. Illustration of LHE using VIT Database.

LHE Operator

The generalized LHE operator The generalized LHE operator $L_k^{\xi,\eta}(I_{W*H}) = I'_{W*H}$, where ξ and ηare the relative positions of the anchor point to the pixel to be processed and $I_{(W*H)}$ is the input image and $I_{(W*H)}$ is the histogram equalized image. W and Hare the width and height of the window respectively. The pixel which has to be processed will have a high intensity value when it is brighter than all the neighboring pixels before local histogram equalization.

OLHE Operator

Operators {ξ, η}other than the center pixel are oriented and hence they are known as OLHE operators.

$$\mathcal{O}_k^{\searrow} \equiv \mathcal{L}_k^{(\frac{(k-1)}{2}, \frac{-(k-1)}{2})}, \mathcal{O}_k^{\downarrow} \equiv \mathcal{L}_k^{0, \frac{-(k-1)}{2}} \quad (8)$$

$$\mathcal{O}_k^{\swarrow} \equiv \mathcal{L}_k^{(\frac{-(k-1)}{2}, \frac{-(k-1)}{2})}, \mathcal{O}_k^{\rightarrow} \equiv \mathcal{L}_k^{(\frac{(k-1)}{2}, 0)} \quad (9)$$

$$\mathcal{O}_k^{\leftarrow} \equiv \mathcal{L}_k^{(\frac{-(k-1)}{2}, 0)}, \mathcal{O}_k^{\nearrow} \equiv \mathcal{L}_k^{(\frac{(k-1)}{2}, \frac{(k-1)}{2})} \quad (10)$$

$$\mathcal{O}_k^{\uparrow} \equiv \mathcal{L}_k^{(o, \frac{(k-1)}{2})}, \mathcal{O}_k^{\nwarrow} \equiv \mathcal{L}_k^{(\frac{-(k-1)}{2}, \frac{(k-1)}{2})} \quad (11)$$

Where k is an odd number. These OLHE operators are applied on basic image elements to give results. LHE and OLHE operators give the same result for ideal edges. For example, if the intensities of the pixels of a local window at its upper left side are smaller than the intensity of the given pixel $\mathcal{O}_3^{\nwarrow}$ is the strongest result (Figure-18).

SIMULATION RESULT WITH VIT AND OPEN SOURE DATABASES

The below test image was chosen from the VIT database for the feature extraction using OLHE algorithm. The test image was taken under a low light condition. Figure-18 shows the test image under low light conditions and Figure-18 shows the OLHE processed output image.

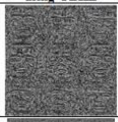
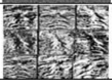
Name of the database	Input image	Feature extracted output images using OLHE
VIT database		
FERET		
ORL		
Extended YALE B		
CMU-PIE		

Figure-18. Test image under low light conditions (VIT Database) and OLHE processed test image.

OLHE C

Where C stands for averaged. When a lower feature dimension is requested, the OLHE images can be combined to form the image that has the same dimensions of the input image. This can be given by

$$\mathcal{O}_k^c(I) \equiv [\mathcal{O}_k^{\searrow}(I)\mathcal{O}_k^{\downarrow}(I)\mathcal{O}_k^{\swarrow}(I)\mathcal{O}_k^{\rightarrow}(\mathrm{I})\ \mathcal{O}_k^{\leftarrow}(\mathrm{I})\ \mathcal{O}_k^{\nearrow}(I)\mathcal{O}_k^{\uparrow}(I)\mathcal{O}_k^{\nwarrow}(I)] \quad (12)$$

Similarly the test images were chosen from different public databases such as FERET, ORL, CMU-PIE and EXTENDED YALE B and feature extracted using OLHE algorithm. The test image and the outputs of Different databases are shown below.

The output images displayed above are the results of one of the pre-processing methods (OLHE) that are later compared to the other pre-processing methods used here, to find out the most efficient method. Thus, upon further comparison of the results we shall find that OLHE method has a greater efficiency compared to the other pre-processing methods utilized to extract the facial features of the test image.

FEATURE EXTRACTION METHOD 5: GABOR FILTER

It is a linear filter used for edge detection. In a two-dimensional case, Local Spectral Energy density can be provided by the absolute square of a correlation between an image and the two-dimensional Gabor function concentrated around a given position and frequency in a certain direction. In the spatial domain, Gaussian kernel function modulated by a sinusoidal plane wave makes a 2D Gabor filter. With different frequencies and orientations, useful features of an image may be extracted by using a set of 2D Gabor filters

A 2-D Gabor function is a plane wave with relative width (σ), restricted by a Gaussian envelope function:

$$\frac{\sigma}{\lambda} = \frac{1}{\pi}\sqrt{\frac{ln2}{2}}\cdot\frac{2^b+1}{2^b-1} \quad (13)$$

$$g\lambda,\sigma,\varphi,\theta,\gamma(x,y) = \exp\left(-\frac{x^2+\gamma^2y^2}{2\sigma^2}\right).\cos\left(2\pi\frac{x}{y}+\varphi\right) \quad (14)$$

$$x' = x\cos\phi + y\sin\phi \quad (15)$$

$$y' = -x\cos\phi + y\sin\phi \quad (16)$$

The value of σ is set to π for the image of resolution 200x180. A set of Gabor kernel comprises of 8 orientations from 0 to 180 degrees that makes altogether 8 different Gabor filters. The 8 different Gabor filter kernels obtained as described above. The outputs of Gabor filter for different feature points are convolved with image for the selected coordinates of feature points.

The Gabor filter provides a different orientation of the Gabor kernel for different postures. It detects the feature points (eyes, nose, and mouth) with edge detection of the faces. By changing the value of spatial frequency, aspect ratio and phase offset, we can get a different Gabor filter kernel changing the posture of the image of a person.

SIMULATION RESULTS WITH VIT AND OPEN SOURCE DATABASES

The below test image was chosen from the VIT database and for the feature extraction using Gabor algorithm. The test image was taken under a low light condition. Figure-19 shows the test image under low light conditions and the Gabor filter processed output image.

Similarly the test images were chosen from different public databases such as FERET, ORL, CMU-PIE and EXTENDED YALE B and feature extracted using a Gabor filter algorithm.

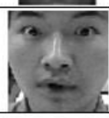
Name of the database	Input image	Feature extracted output images using GF
VITdatabase		
FERET		
ORL		
Extended YALE B		
CMU-PIE		

Figure-19. Image under low light conditions (VIT Database) and Gabor filter processed test image.

The five pre-processing techniques, namely Bit plane slicing, Gabor filter, LBP, LGOBP and OLHE were

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performed on four publicly available database FERET, ORL, EXTENDED YALE B, CMU-PIE and the newly generated VIT database using SVM post-processing technique. Thus, upon further analysis, we found out that the VIT database had a promising recognition.

SUMMARY AND CONCLUSIONS

The introduction to biometrics and the importance of biometrics in day-to-day life and the recent status of the recognition in the form of literature surveys are discussed in detail. The methodology of various feature extraction techniques such as BPS (Bit Plane Slicing), LBP (Local Binary Pattern), LGOBP (Local Gradient Orientated Binary Pattern), OLHE (Oriented Local Histogram Equalization), Gabor Filter and classifications such as PCA(Principal Component Analysis), LDA(Linear Discriminant Analysis), CCA(Canonical Correlation Analysis), AAM(Active Appearance Model) and SVM(Support Vector Machine) are viewed. Moreover, this thesis focuses about open-source databases such as FERET, ORL, CMU-PIE and EXTENDED YALE B database and the newly generated VIT database. It explains image extraction and classification and also describes about the image captured in low illumination point of view for VIT database along with image extraction and classification. In entirety the results achieved from the different databases are analyzed and compared.

The Eigen face approaches provide a practical solution that is well fitted for the problem of face recognition. It is fast, relatively simple, and works well in a different environment. Certain issues of robustness to changes in lighting, head size, and head orientation are done. The tradeoffs between the numbers of Eigen faces necessary for unambiguous classification are matters of concern. The speed of processing is faster than other methods.

Principal Component Analysis (PCA), which is good for low dimensional representation for face images, but is unable to discriminate between variations due to illumination changes. So in order to solve this problem we transitioned to LDA (Linear Discriminant Analysis) method.

LDA (Linear Discriminant Analysis) solves the change in illumination problem to some extent by finding the transformation such that it maximizes the inter-class separation and minimizes the intra-class variations.

AAM (Active Appearance Model) which has the capability of analyzing the variation of different individuals in a training database and mimics this variability in the process of fitting the model. The shape of the face is modeled, where a large database of shape annotation is aligned into a common mean removing location, scale and rotation effects. Shape variation is then analyzed, producing a parameterized linear model. The AAM texture model is an improvement in Eigen faces approach, where affine texture mapping is used to remove texture differences due to shape changes. Similar to the shape models, after texture alignment, a Principal Component Analysis is used to model texture variation.

Shape and texture models, regarding the nature of different parameter units, are combined into single coupled model. Even though AAM is better, further work needs to be done to extend this automatic face recognition system to be used for general purposes.

SVM (Support Vector Machine) is used for classification and regression among other tasks. SVMs deliver a unique solution, since the optimality problem is complex. This is an advantage compared to Neural Networks.

The system utilizing the proposed methodology was successful in handling various illuminated condition and pose variant condition using CCA (Canonical Correlation Analysis) post-processing technique with OLHE (Oriented Local Histogram Equalization) pre-processing technique. CCA is proven that the efficiency of a face recognition system critically relies on compensating the illumination variation of the face images.

The five state of the art algorithms BPS, GF, LBP, LGOBP and OLHE were critically analyzed on the five databases which lead us to the conclusion that OLHE is the best performing illumination compensation algorithm among its peers. Albeit the unavailability of a compact representation of OLHE without data loss, reducing the size of the training and test images led to a faster and accurate representation of OLHE. Thus making it acceptable for practical usage.

Canonical Correlation Analysis (CCA) which combines five feature extractors to improve the performance of the system, by obtaining the advantages of both(PCA&LDA). CCA also finds the transformation for each extractor database and maximizes the correlation between them. But in CCA, canonical function can be interpreted by the sign and the magnitude of the canonical weights assigned to each variable in its respective canonical variant.

A high-performance illumination compensation method is achieved and the results are discussed in the thesis. The analysis and comparisons that have been made in this thesis pave the way to conclude that the efficiency of a facial recognition system critically relies on compensating the illumination variation of the facial images.

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