1. INTRODUCTION

This chapter gives a talk through on face recognition system with a brief explanation on various steps involved in it. This chapter also exchanges observations on approaches used in face recognition system, challenges in face recognition system, effects of varying illumination of face images and applications of face recognition system. It also confers on objective and scope of research and the overall organization of the thesis.

1.1 FACE RECOGNITION SYSTEM

Research in the field of face recognition has seen an upswing due to its potential for application in various fields of interest. Broad areas of applications of face recognition encompass law enforcement systems, information security, access control, e-governance, pervasive computing, gaming, mobile banking, surveillance system and online image search. Internet of Things (IoT) also has a reflective significance on the security and surveillance systems where face recognition could be used for authentication [1]. With the advent of CCTV cameras, the ease of using the face as a biometric measure for identification has also triggered the research in the field of face recognition.

The face is one of the many visual biometric measures, having appealing positives over the other biometric measures for recognizing an individual in day-to-day life. The face is a very natural and human comprehensible way of conveying one’s identity. Other dominating visual biometric measures include Iris recognition, Eye-Retina recognition and Fingerprint recognition [2]. The human iris is a thin circular shaped in the eyes, which controls the diameter and size of the pupils [3]. The iris has its own patterns from eye to eye and person to person contributing to the uniqueness of each individual. Iris recognition security systems are one of the most accurate but still an expensive security system nowadays.

There should be no physical contact between the user and the system during the verification process. Even though no physical contact is
required between the user and system, capturing the iris of an individual is not feasible without the cooperation of the individual. When trying to understand eye-retina recognition, it uses the unique patterns of a person's retina blood vessels. The major advantage of retina recognition is its high accuracy rate with enormous speed. However, the scanning procedure as perceived by some users is protruding and not very user-friendly.

Fingerprint recognition uses the ridges and valleys (minutiae) found on the surface tips of a human finger to identify an individual [4]. If the surface of the finger gets damaged and/or has one or more marks on it, identification becomes increasingly hard [3,4]. Revisiting the face recognition technology after examining the various pros and cons of other biometric measures, the face recognition technology is a non-invasive way to procure a person's identity. Face images can be captured from a distance without the physical involvement of the person. Moreover, face recognition helps in crime identification and prevention purpose because face images that have been recorded and archived can later help to identify the accused.

The primary task in face recognition system is to acquire a real-time face image and compare it with the face images present in the database. The real-time images acquired can be a photograph or a video sequence. The overall block diagram of a face recognition system is given in Figure 1.1.

![Figure 1.1 Overall block diagram of Face Recognition System](image-url)
1.2 FACE DETECTION

Face detection is the initial and essential stage of Face Recognition system. The face detection algorithms detect face images in the captured image. Detection of the face in any scene is a complex task. In real time scenario, face detection can be performed on images acquired with the following backgrounds:

- Face detection on plain background
- Face detection image with unconstrained background,
- Face detection in captured videos

Clutter and complex environment increase the complexity of face detection. When considering a video, it can be divided into frame and each frame is considered an image in which face detection can be done. A noteworthy point is, as the video sequence proceeds the background in the video might keep changing based on the scene. Face detection concentrates on the accurate description of features and conditions that set a human face distinct from other objects in the scene. Face detection with a plain background is a simple task. The background, which is uniform throughout the image can be subtracted from the image and hence the face can be detected. Face Detection by itself can be a separate domain for research. Many algorithms have been developed for the purpose of face detection. Face images with plain background and clustered background is depicted in Figure 1.2.

![Figure 1.2](image1.png)

(a) Face image with a plain background
(b) Face image in an unconstrained background
1.3 CROPPING AND RESIZING

Cropping is the process of subtracting the unwanted portion of an image to improve concentration towards the object of interest. In face recognition system, the face is the object of interest and cropping helps to extract the face from the captured image. The cropped face is further processed for recognition. There are many online image cropping tools readily available for use. They are Fotor-Crop photo online, Cropp.me and ResizelImage.net. These tools are some of the free online tools for cropping and resizing the image.

Resizing is the process of changing the dimension of the cropped image as per the requirements. The necessity behind resizing has two main reasons. Firstly, it is always required to enlarge the portion of interest in the image and secondly, certain face recognition algorithms require the input face images to be of the same size. For example, Principal Component Analysis (PCA) or the Eigenface method takes input face images of the same size for further processing. When resizing there will be change in the quality of the image, hence it is essential to be careful while choosing the appropriate tools for resizing the image.

1.4 ILLUMINATION ENHANCEMENT

Illumination enhancement is also called Illumination pre-processing or Illumination normalization. It is an essential step in face recognition system. Face images acquired in real time scenario are affected by illumination. Hence illumination enhancement becomes imperative in image processing. Illumination enhancement techniques are broadly classified as Gray Level Transformation techniques, Gradient Edge Detection and Reflectance Field Estimation techniques [5]. Gray Level Transformation technique performs illumination enhancement using a nonlinear transformation which performs pixel-wise intensity mapping [5]. Gradient Edge Detection Technique extracts the edges in the image that are insensitive to lighting variation [5]. Edges in the face are less affected by changes in illumination. In Reflectance Field Estimation technique, face reflectance field which is invariant to lighting variation is computed [5].
The first phase of Reflectance Field Estimation is to find the illumination component. Illumination component can be found using Cosine transformations. The second phase is to find the reflectance field using reflectance-illumination model.

These techniques help to improve the contrast and the quality of the image. Face recognition system uses either entire face image or features like eyes, nose, mouth and distance between them for recognition. Illumination enhancement improves the quality of the image and helps to extract the essential features for face recognition.

1.5 FEATURE EXTRACTION

Features are important attributes that help to uniquely identify a face. Extracting such a feature is an important step in face recognition system. Features are broadly classified into the following categories, namely Local (internal) features and Global (external) features [6].

In Local feature extraction technique, information about the eyes, nose, mouth and distance between them are extracted. Local feature extraction is established in two steps. They are feature point detection and feature extraction. Feature point can be detected with the help of Harris corner detector and features can be extracted with 2-D Gabor filters. Local features are more dominant in the recognition of familiar faces [7]. Some examples of local features are eyes, nose, mouth,

In Global (External) feature extraction technique or Holistic technique, whole face image which includes the holistic structural configuration, facial organs and contours are taken as input [8]. Principal Component Analysis is one of the techniques which uses the complete face image as an input and computes Eigenvectors as features that are used in face recognition. Human uses both the local and global features for face recognition [7].

1.6 FACE RECOGNITION

Face recognition approaches are grouped into three main categories. They are, namely Template matching approach, Statistical approach and Neural Network approach.
1.6.1 Template Matching Approach

In Template Matching approach, the input image is compared with a set of stored faces or features in the database [9]. For example, from any given face image the local features such as eyes, nose, mouth is extracted/segmented as sub-images/regions. The sub-regions of the test image can be compared with the sub-regions of the face images stored in the database. Usually either the correlation measure or the distance measure between the extracted and stored features is estimated to recognize the face image. The complexity behind template matching approach lies in extracting the sub-regions from the given face image [10]. The Template matching approach for face recognition struggles to recognize faces with variation in expression, pose and illumination. Hence, Template based approach assumes to have both probe and gallery items to be potentially represented in multiple visual views rather than just one [11].

1.6.2 Statistical Approach

In Statistical approach, the high dimensional data set is reduced to a low dimensional data set. Dimensionality reduction is the key component of statistical approach. Face is a high dimensional data set. Statistical tools help to reduce the dimensions required to represent a face image. Using Statistical approach, redundant or less important features are neglected and the principal features required for recognition are obtained for recognition. Principal Component Analysis is a proven statistical approach used for face recognition.

1.6.3 Neural Network Approach

In Neural network approach, a neural network model is used to recognize faces. At the first stage, the neural network model is trained with a set of extracted features to recognize a known face. The neural network is trained using the training dataset. The training dataset consists of extracted facial features and the corresponding target face (desired output). The neural network is trained using any one of the supervised learning algorithms, which uses the training input and corresponding output data to adjust the network's
weights and thresholds to minimize the error in its predictions on the training set. A properly trained network is capable of mapping the input to a corresponding output. The neural network maps the features of unknown face (test face) to the desired face in the database, which is not used in training face.

Using any one of the above-mentioned approaches or hybrid approach which is the combination of any two approaches, face recognition system correlates the stored image of various personalities in the database to a (newly captured) test image.

The following Figure 1.3 illustrates various steps in face recognition system taking a real-time image as an example. The first step in face recognition process is to first detect the face in the image, then the detected face is cropped. Next step is to resize the cropped image in the required dimensions and is followed by illumination enhancement. After illumination enhancement, the face features are extracted for recognition.

![Figure 1.3 Various stages of face recognition system with a real time example](image)

(a) Captured Image  (b) Face Detection  
(c) Cropped Image  (d) Resized Image  (e) Enhanced Image.
1.7 FACE RECOGNITION BY HUMAN

A human can perform the task of recognition with ease, spontaneity, and the highest level of accuracy. Trying to impart the knowledge of human to a computer is the whole motto behind the computer vision industry. To develop face recognition system, which can be deployed effectively in unconstrained environments demand the necessity of understanding how a human recognizes faces? A human can efficiently recognize faces images with expression, aging, low resolution, illumination variation, under occlusion, changes in personal appearance (wearing spectacles, makeup).

The ability to recognize degraded images increases with the familiarity of the face [12]. The face images are processed holistically [12]. To identify a particular person’s face accurately, facial features and the spatial relationships among features must be studied [13]. Human recognizes face using the “holistic” strategy, which refers to the ability to see the face as a whole, taking into account the spacing between features as well as the shapes of the features themselves [14]. Face-shape appears to be encoded in a slightly caricatured manner [12]. Color cues play a significant role, especially when shape cues are degraded [12]. Among the various facial features, eyebrows, eyes, mouth and then the nose is the order of precedence to convey the identity of a person's face [12].

1.8 CHALLENGES IN FACE RECOGNITION SYSTEM

Face recognition system struggles to recognize face images with expression, illumination variation, aging, makeup, pose, acquisition geometry and so on [15]. One more factor which influences face recognition system is the image characteristics of capture devices (cameras). When trying to recognize faces captured across various devices like digital camera and video footage, the match across these devices are very hard for systems [14]. Example of images, which are subjected to variation in expression, illumination, aging, pose and appearance variation captured in the real-time environment are given in Figure 1.4.
Face recognition algorithms use the facial features, the overall appearance of the face or a combination of local and global features for recognition [13]. But when there is a change in pose, expression, illumination, it affects the features in the face or the overall appearance of the face. Hence, Face Recognition System struggles to recognize face images subjected to variation in pose, expression, or illumination.

![Sample face images of the same person](image)

**Figure 1.4** Sample face images of the same person with (a) no variation (b) variation in expression (c) variation in illumination (d) variation in age (e) pose variation (f) appearance variation

### 1.9 EFFECTS OF VARYING ILLUMINATION

Variation in the illumination occurs due to change in direction of light source and variation in the intensity of light. Face images captured with changes in direction of light source cause shadows to appear in the face images. Face images captured under bright light result in an overexposed image and images captured under dull lighting conditions result in underexposed images [5, 17].

Presence of shadows, overexposed or underexposed face images impair the ability to extract facial features required for recognition. When there is a change in the direction of the light source, then face images tend to
possess shadows and also result in half-lit or dark-lit images. Figure 1.5 gives some examples of face images captured with illumination deficiency.

![Sample face images with effects of illumination](image)

**Figure 1.5** Sample face images with effects of illumination (a) Captured under proper lightening condition, (b) Shadowed image, (c) Captured with a light source to the right of the person, (d) Captured with every less intensity of light.

1.10 APPLICATIONS OF FACE RECOGNITION SYSTEM

Face Recognition Technology (FRT) has numerous applications in various domains. The ultimate purpose of using a Face Recognition system is to identify a person of interest, to verify a person's identity, or to perform open set identification task. It is used in law enforcement where the criminals are tracked under surveillance system, security enforcements like access control and immigration check. It is also used in the gaming industry, authorization check for availing services over the internet and residential security. In the recent years, efficient face recognition algorithms, falling cost of cameras, increased usage of CCTV, availability of high processing power in computers has led to the increase in applications of face recognition systems in various domains.

1.11 PROBLEM STATEMENT

The nucleus of the work is to enhance the illumination affected human face images and proceed with recognition in comparison with the face images stored in the databases. Illumination conditions impair the face recognition accuracy. The difference in the illumination sources (indoor, outdoor) and direction of the light source can present uncontrollable illumination conditions and shadings. As a result, the variation in face images of the same person due to illumination changes is more momentous than the difference in face images of different persons.
1.12 MOTIVATION AND SCOPE OF THE RESEARCH

Societal demands and recent advancements in technology has led to a massive proliferation of use of face recognition technology for identification and authentication. In today's world of automation, face recognition is used for unlocking iPhones, aids in forensic investigations, law enforcements, facilitate secured bank transactions and so on. Although face recognition has reached certain level of perfection, its functionality is limited to problems posed by the real time environment.

Face recognition system encounters many challenges in a unconstrained real time environment. One such challenge presented by the real time environment is open uncontrolled variation in the illumination. So captured face images results as either overexposed or underexposed images. In an underexposed or overexposed face images, important details called feature on the face that are essential for face recognition is hidden or blur. As a result, feature extraction from such illumination affected face images is challenging. Hence, enhancement of illumination affected face images becomes a mandatory/inevitable step before proceeding with recognition.

The prime motive and scope of research is to develop efficient contrast-enhancement methodologies for improving face recognition accuracy. Researchers have proposed and developed many illumination enhancement algorithms. Even though encouraging results have been obtained there is still scope for improvement of existing algorithms. Practically, the existing techniques are unable to perform efficiently in all the possible condition that are commonly encountered by face recognition systems. The proposed algorithms applied on illumination affected face images in Extended Yale Face Database B. Subjective and objective analysis on the illumination enhanced face images is performed to check the efficiency of the proposed techniques. Further Principal Component Analysis is used to check the improvement in the face recognition accuracy.
1.13 RESEARCH OBJECTIVES

The main objective of this research work is to develop methodologies for enhancing the real-time images affected by uncontrolled illumination using modified histogram equalization technique, which improves the accuracy of the face recognition system. The main course of research work concentrates on three aspects, namely Designing a Framework for Localization of the Holistic Methods, Introducing Fuzzy Approach on the Neighbourhood metrics to increase the contrast of the face image and a Hybrid Approach which concentrates on localization and contrast enhancement.

1.13.1 Framework for Localization of Holistic method

The main focus of the research work is on defining a new framework for localizing the holistic technique to adopt local information of an image. Global Histogram Equalization (GHE) is an efficient contrast enhancement technique [18, 19]. Local Histogram Equalization Technique and Partially Overlapped Histogram Equalization Technique are used to localize the global histogram equalization technique [19]. Upon a careful scrutiny of the various frameworks, having their own merits and demerits, Completely Overlapped Uniformly Decrementing Sub-Block Histogram (COUDSHE) equalization has been proposed. The core idea of COUDSHE is to define a unique framework for the localization of global method which adapts to the local brightness of an image.

1.13.2 GHE with Fuzzy Approach on the Neighbourhood Metrics

GHE with Fuzzy Approach on the neighbourhood metric is used to increase the contrast of the image. Contrast enhancement is essential to view the details of the image. GHE is a widely accepted contrast enhancement technique. The contrast of the image improves if GHE transforms the input image into an image, which makes use of the entire range of image intensities equally [18, 19, 20]. The main drawback of GHE is that even after its application on images, the pre-processed image does not make use of an entire range of image intensities. In the histogram representation of the pre-processed image using GHE, there are gaps which
exist as empty bins between filled bins [18, 20]. This indicates that there are many gray level values, which remain unused. Also, after the application of GHE, the frequency of occurrence of gray level value remains unchanged except for that the gray level values only spread out. To overcome this drawback, various neighbourhood metrics like voting metric, distinction metrics had been proposed in literature. These neighbourhood metrics were carefully studied, and Fuzzy approach on the neighbourhood metric has been proposed to increase the spread, which in turn increases the contrast of the face image.

1.13.3 Hybrid Face Image Contrast Enhancement technique

A hybrid approach that results in a completely enhanced image addressing the issues of both localization coupled with high contrast enhancement has been proposed. In this work, Histogram Equalization using Voting Metric, Distinction Metric and Fuzzy approach on the neighbourhood metric, has been applied in the Completely Overlapped Uniformly Decrementing Sub-block framework. This increases the contrast of the face image and adapts to the local brightness of a face image.

1.14 ORGANIZATION OF THE THESIS

The contributions made in this dissertation are presented in eight chapters as follows

Chapter 1 provides an introduction to face recognition systems, procedure involved, various challenges and applications in Face recognition system, and Research Contributions.

Chapter 2 presents a detailed literature survey on various illumination pre-processing techniques, their evolution hierarchy with advancements and contributions towards illumination pre-processing and along with advantages and disadvantages.

Chapter 3 discusses the overall contribution of the dissertation. An overview of the architectural diagram of contrast enhancement
methodologies based on modified histogram equalization technique to enhance the illumination affected images is presented.

Chapter 4 presents a unique framework proposed in Completely Overlapping Uniformly Decrementing Sub-block Histogram Equalization method for localizing the global technique. The experimental results of the proposed technique on illumination affected face images and analysis of the results are also presented in this chapter.

Chapter 5 brings out the performance evaluation of Global Histogram Equalization using Voting Metric and Distinction Metric on facial databases. A new technique, namely Global Histogram Equalization with Fuzzy Approach on neighbourhood metrics is proposed in this chapter. The experimental results of the proposed technique on illumination affected face images and analysis of the results are also furnished in this chapter.

Chapter 6 presents the Hybrid Approach used for both localizing and improving the contrast of the face image acquired in real-time environments. It also presents the implementation results and analysis of the results obtained.

Chapter 7 concludes the dissertation and indicates the future direction for research.