

# **Automatic Face Detection Using Color Based Segmentation & Face Recognition Using Eigen Face**

*A Thesis submitted in partial fulfillment of the  
Requirements for the award of degree of*

**Master of Engineering**

**in**

**Electronic Instrumentation and Control**



**Submitted by**

Yogesh

(Roll No. 801051028)

**Under the Guidance**

**Of**

**Mr. Moon Inder Singh**

**Ms. Ruchika Lamba**

Assistant Professor

Lecturer

**Department of Electrical and Instrumentation Engineering**

**Thapar University**

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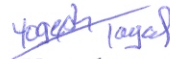
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## DECLARATION

I hereby certify that the work is being presented in the thesis work entitled "Automatic Face Detection Using Color Based Segmentation & Face Recognition Using Eigen Face" in partial fulfillment of award of degree of **Master of Engineering in Electronics Instrumentation and Control** submitted in Electrical and Instrumentation Engineering department, Thapar University, Patiala is an authentic record of my own work carried under the supervision of **Mr. Moon Inder Singh and Ms. Ruchika Lamba**, Assistant Professor, Department of Electrical and Instrumentation Engineering, Thapar University, Patiala, Punjab.

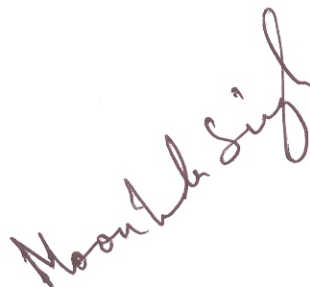
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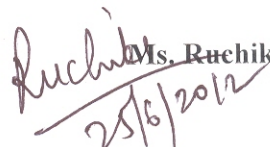
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**Mr. Moon Inder Singh and**

Assistant Professor,

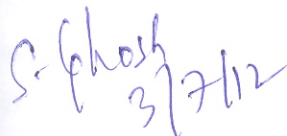
  
**Ms. Ruchika Lamba**

Lecturer

Department of Electrical and Instrumentation Engineering,

Thapar University, Patiala,

Punjab



**Dr. Smarajit Ghosh**

Head of Department,

Department of Electrical and

Instrumentation Engineering,

Thapar University, Patiala,

Punjab

Countersigned by

  
**Dr. Saroj Kumar Mohapatra**

Dean of Academic Affairs,

Thapar University, Patiala,

Punjab

## **ABSTRACT**

One of the most successful applications of image analysis and understanding are face recognition and face detection, which have recently received significant attention, especially during the past several years. At least two reasons account for this trend; the first is the wide range of commercial and law enforcement applications and the second is the availability of feasible technologies due to 30 years of research.

The online services, such as E-Banks, Web-Mails, Social Site in which users are verified by their usernames and passwords, are increasingly exploited by Identity Theft procedures. Identity Theft is a fraud, in which someone pretends to be somebody else to steal money or to get other benefits. To overcome the problem of Identity Theft, an additional security layer is required and here Biometrics present potentially a good solution. In Physiological and Behavioral biometrics, users are verified and identified based on their keyboard and mouse activities.

This thesis proposes a physiological based robust Face Detection and Face Recognition system based on HSV components and Eigen-face technique. Basically the purpose of Face Detection is to determine whether there is any face in an image, while Face Recognition involves confirming or denying the identity claimed by a person. The contributions of this thesis are the following:

The first part of this thesis addresses a multi-views robust, improved segmentation algorithm for Face Detection employing HSV technique on color images with multiple-faces and skin tone. The goal of face detection is to identify all image regions which contain a face regardless of its three-dimensional position, orientation, and lighting conditions. Such a problem is challenging because faces are non-rigid and have a high degree of variability in size, shape, color, and texture.

In the second part, a novel generative approach for Face Recognition, based on an Eigen-face description of the face is discussed. The result of this work is an algorithm that is fast & requires a simple training procedure and is highly efficient in bad lighting condition. After analyzing both algorithms and identifying their limitations, we conclude with several promising directions for future research.

## ACKNOWLEDGEMENT

The real spirit of achieving a goal is through the way of excellence and austere discipline. I would have never succeeded in completing my task without the cooperation, encouragement and help provided to me by various personalities.

With deep sense of gratitude I express my sincere thanks to my esteemed and worthy supervisor, & Co-supervisor **Mr. Moon Inder Singh**, Assistant Professor and **Ms. Ruchika Lamba**, Lecturer Department of Electrical and Instrumentation Engineering, Thapar University, Patiala for their valuable guidance in carrying out this work under their effective supervision, encouragement, enlightenment and cooperation. Most of the novel ideas and solutions found in this thesis are the result of our numerous stimulating discussions. Their feedback and editorial comments were also invaluable for writing of this thesis.

I shall be failing in my duties if I do not express my deep sense of gratitude towards **Dr. Smarajit Ghosh**, Professor and Head of the Department of Electrical & Instrumentation Engineering, Thapar University Patiala who has been a constant source of inspiration for me throughout this work.

I am also thankful to all the staff members of the Department for their full cooperation and help. This acknowledgement would be incomplete if I do not mention the emotional support and blessings provided by my friends. I had a pleasant enjoyable and fruitful company with them.

My greatest thanks are to all who wished me success especially my parents and brother, whose support and care makes me stay on earth.

Place: Thapar University, Patiala

Date:

Yogesh

801051028

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# **LIST OF ABBREVIATIONS**

HSV	Hue, Saturation, Value
PIN	Postal Index Number
FBI	Federal Bureau of Investigation
CBI	Central Bureau of Investigation
ATM	Automatic Teller Machine
PDA	Personal Digital Assistant
ID	Identification
OS	Operating System
PC	Personal Computer
DB	Database
DNA	De-oxyribo Nucleic Acid
RGB	Red, Green, Blue
PCA	Principal Component Analysis
LDA	Linear Discriminant Analysis
SGLD	Space Gray Level Dependence Matrix
PDMs	Point Distribution Models
ASM	Active Shape Model
SVM	Support Vector Machine
HMM	Hidden Markov Model
NRGB	Normalized Red, Green, Blue
HIS	Hue, Saturation, Intensity or brightness
CIE-LUV	International Commission on Illumination
DCT	Discrete Cosine Transform

FERET	Face Recognition Technique
CMY/K	Cyan, Magenta, Yellow/Black
TSL	Tin, Saturation, Light
PAL	Phase Alternate Line
NTSC	National Television System Committee
ICA	Independent Component Analysis
ANN	Artificial Neural Network
EBGM	Elastic Bunch Graph Matching
LBP	Local Binary Pattern
KPCA	Kernel Principal Component Analysis
AAM	Active Appearance Model
MLP	Multi layer Perceptrons
KLT	Karhunen-Loeve Transform
FWT	Fast Wavelet Transform
FFT	Fast Fourier Transform
DWT	Discrete Wavelet Transform
SVD	Singular Value De-composition
HO-SVD	High Order- Singular Value De-composition
FLD	Fisher Linear Discriminant
RT	Radon Transform

## **RELATED PUBLICATION**

- ♦ Published paper titled **“A Comparative analysis of Different Face recognition technique: A review (Eigen face, Neural network, and Local feature analysis)”** at 3<sup>rd</sup> National Conference, Recent Innovations In Engineering & Technology, in Galaxy Global Group of Institutions, Ambala, March 2012.
- ♦ Published paper titled **“Automatic Face Detection Using Color Segmentation”** at International Journal of Scientific and Research Publication (IJSRP), ISSN: 2250-3153, Volume 2, Issue 6, June 2012.

## INTRODUCTION

### 1.1 Overview

Different aspects of human physiology are used to authenticate a person's identity. The science of ascertaining the identity with respect to different characteristics traits of human being is called biometrics. The characteristic traits can be broadly classified into two categories i.e. physiological and behavioral. Measurement of physical features for personal identification is an age old practice which dates back to the Egyptians era. But it was not until 19<sup>th</sup> century that the study of biometrics was extensively used for personal identification and security related issues. With the advancement in technology, biometric authentication has been widely used for access management, law enforcement, security system. A person can be identified on the basis of different physiological and behavioral traits like fingerprints, faces, iris, hand geometry, gait, ear pattern, voice recognition, keystroke pattern and thermal signature.

### 1.2 Motivation

As continual research is being conducted in the area of Biometrics, one of the most practical applications under strong development is in the construction of a face recognition system. A comprehensive description of biometric recognition based on the most popular human biometric traits is provided. A great emphasis was placed on the face characteristics, particularly on the state of the art of the component-based face recognition. While the problem of recognizing faces under gross variations remains largely unsolved, a demonstration system as proof of concept that such systems are now becoming practical have been developed. A system capable of reliable recognition, with reduced constraints in regards to the facial position and expression of the face and the illumination variation and background of the image has been implemented. We have implemented and compare existing face recognition algorithms which are widely used and subject of interest.

### 1.3 Objective of dissertation

- ❖ Study of various face detection techniques and implementing HSV based detection technique.
- ❖ Comparison of proposed algorithms with existing HSV based model.

- ❖ A technique for face recognition named Eigen face technique.
- ❖ Comparison of algorithm with three algorithms, existing in literatures.

## **1.4 Organization of dissertation**

**Chapter 1** This chapter describes the introduction part of the work (face recognition and face detection), with the highlighted view on objective of the work which is to be carried out in the thesis.

**Chapter 2** In this chapter, the background, classification, pros and cons & applications of biometrics are discussed.

**Chapter 3** This chapter forms an objective of thesis. The work is carried out in MATLAB environment. HSV technique used for face detection with results has been discussed.

**Chapter 4** This chapter presents the result of face recognition based Eigen face technique.

**Chapter 5** This section deals with analysis of all the conclusions and discussions which has been done in the presented work so far with a brief overview on the future possibility of the remaining work in the same domain.

# BIOMETRICS

## 2.1 Introduction

Biometric authentication as well as verification has been widely used for access management, law enforcement, security system and entertainment over the past few years. A person can be identified or verified on the basis of different physiological and behavioral traits like fingerprints, live scans, faces, iris, hand geometry, gait, ear pattern, voice recognition, keystroke pattern and thermal signature etc. Behavioral or soft-biometric attributes could be helpful in classifying different persons however they have less discrimination power as compared to biometric attributes from the original traits, for example facial expression recognition, finger print etc. The characteristic of a biometric system based on feature can be made depending on different factors like reliability, universality, uniqueness, non-intrusiveness and its discrimination power depending upon its application [2.1].

“Biometrics” is derived from ‘Greek’ word and where,

- (i) Bio means “life” and
- (ii) Metric means “biological process or measurement”.

i.e. biometric means “life measurement”, or in other words the application of statistical analysis to biological data. But nowadays, this technology is used as an automated method for identifying (one-to-many matching) a person or verifying (one-to-one matching) the identity of a person based on a physiological, chemical or behavioral characteristic or attributes of the person. Because the process is automated, biometric authentication (prove or show authentication) generally requires only a few seconds, and biometric systems are able to compare thousands of records per second [2.2]. In recent years, biometrics authentication has seen considerable improvements in reliability and accuracy, with some of the traits offering good performance.

The number of attacks that can be launched against authentication systems based on passwords and tokens are listed below:

- (a) Client attack (e.g., guessing passwords, stealing tokens)
- (b) Host attack (e.g., accessing plain text file containing passwords).

- (c) Eavesdropping (e.g., “shoulder surfing” for passwords).
- (d) Repudiation (e.g., claiming that token was misplaced)
- (e) Trojan horse attack (e.g., installation of bogus log-in screen to steal passwords)
- (f) Denial of service (e.g., disabling the system by deliberately supplying an incorrect password several times) [2.1].

## 2.2 Classification of Biometrics

Figure 2.1 shows the Classification of Biometrics [2.3].

### 2.2.1 Physiological Biometrics

### 2.2.2 Behavioural Biometrics

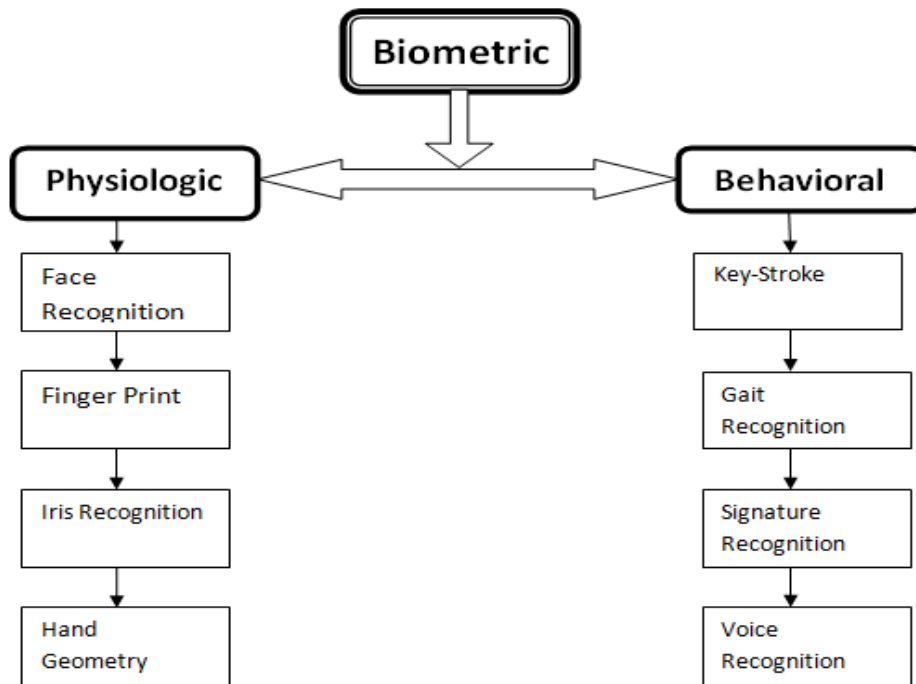


Figure 2.1 Classification of Biometrics

### 2.2.1 Physiological Biometrics

Physiological biometrics depends upon the physical appearance of the human body or shape of the human like nose, chin, eyes, face and lips etc. Face recognition, finger print, iris technology, retina technology, hand geometry, odour or DNA deoxyribonucleic acid etc. are the examples of physiological biometrics as shown in figure 2.2

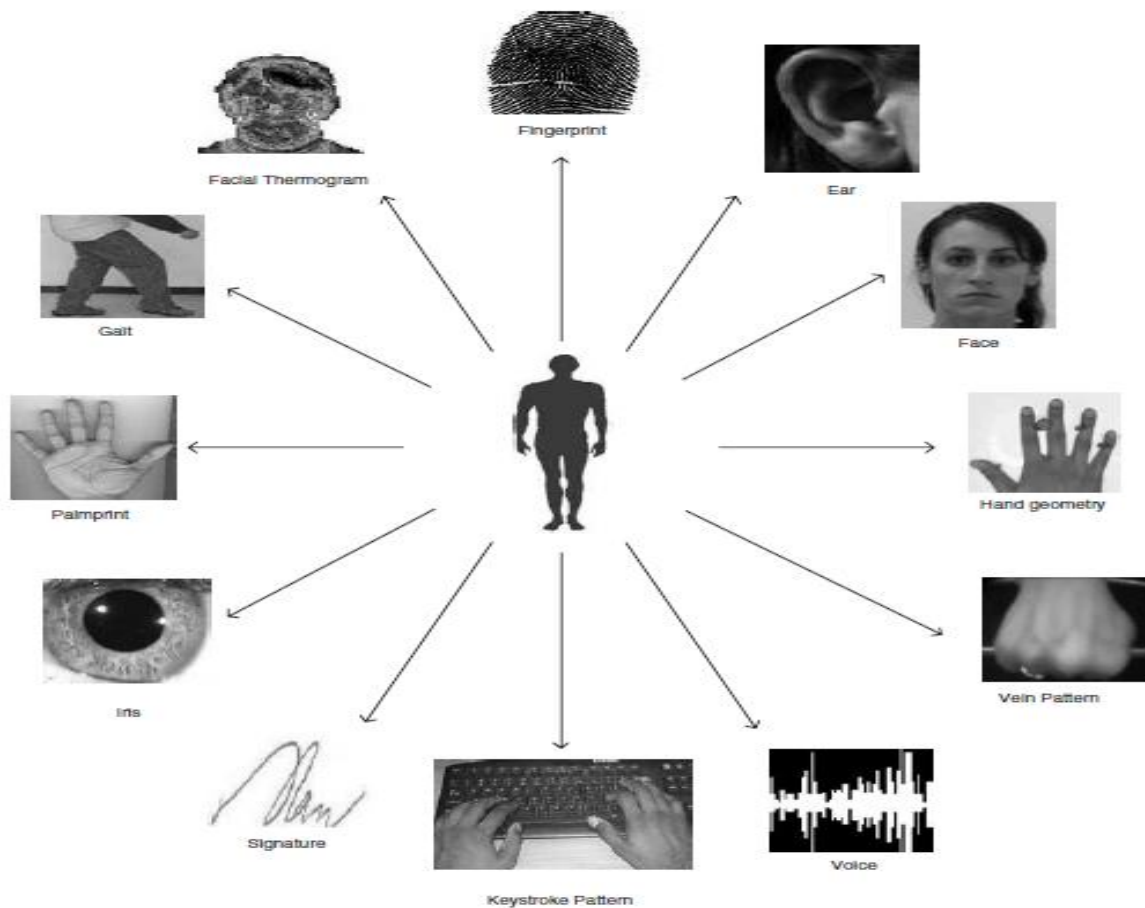


Figure 2.2 Biometric traits

### 2.2.1.1 Finger Print Recognition

Nowadays we have different types of biometrics but among the many biometric features, the fingerprint is considered one of the most practical ones. Fingerprint recognition requires less effort from the user, does not capture other information like hand biometrics, and provides relatively good performance. Also, finger print is most widely used recognition technique, because sensors used are of low cost, (A fingerprint sensor is an electronic device which is used to capture a digital image of the fingerprint pattern), which enables easy integration into PC keyboards, smart cards and wireless hardware. Finger print biometric is shown in figure 2.3.

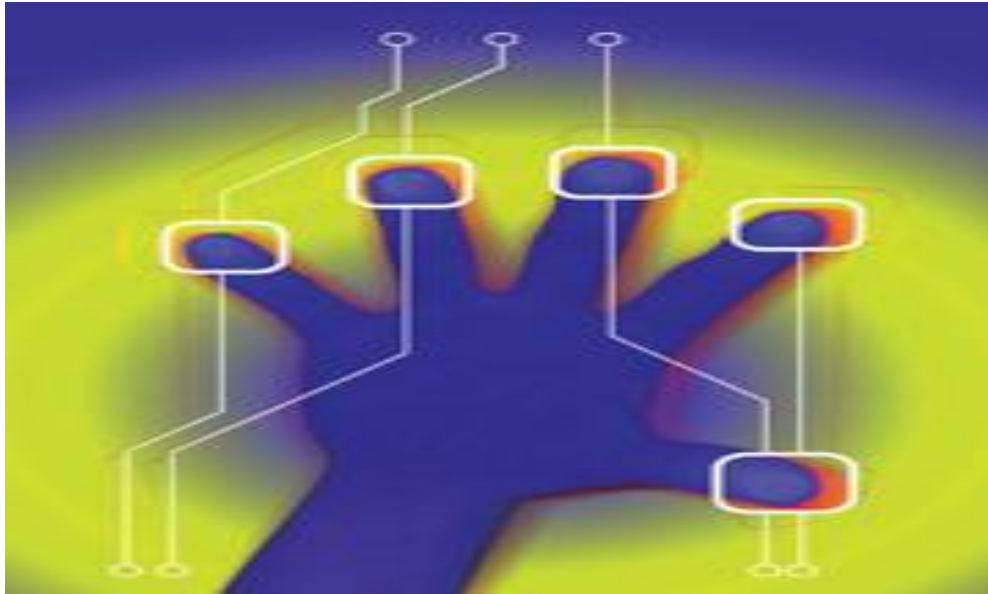
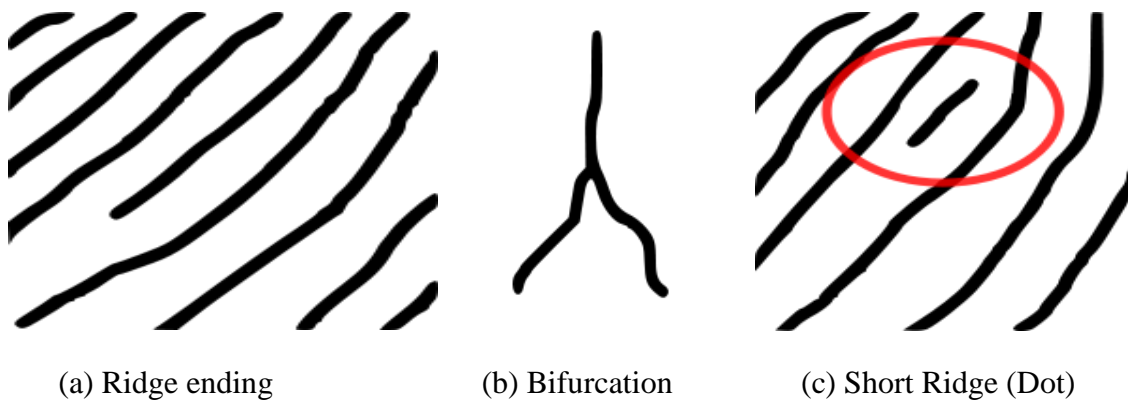


Figure 2.3 Fingerprint Biometric



(a) Ridge ending

(b) Bifurcation

(c) Short Ridge (Dot)

Figure 2.4 Finger print ridge pattern (a) Ridge ending, (b) Bifurcation, and (c) Short Ridge

Basically, Fingerprint recognition is used for identification in which we extract features and match fingerprint minutiae (features) around the core point, such as ridge (arch, loop, whorl etc) termination, ridge ending, short ridge and bifurcation as shown in figure 2.4. Since fingers experience so much wear and tear from cuts and burns, software must be able to do image rebuilding. The drawback of using this system is capability of a biometric device to be reliable in real-life conditions. [2.4, 2.5]

### 2.2.1.2 Iris Recognition

The human iris is an annular part between pupil (black portion) and cornea shown in figure 2.5. Iris is an inner organ part of human body. The structure of human Iris contains five layers of fiber like tissues. These tissues are very complex and reveal in various forms. The

surface of iris also contains a complex structure such as crystals, thin threads, spot con caves, radials, furrows, stripes etc. Iris is a place where our nerve systems are situated and it gives information about human body [2.6].

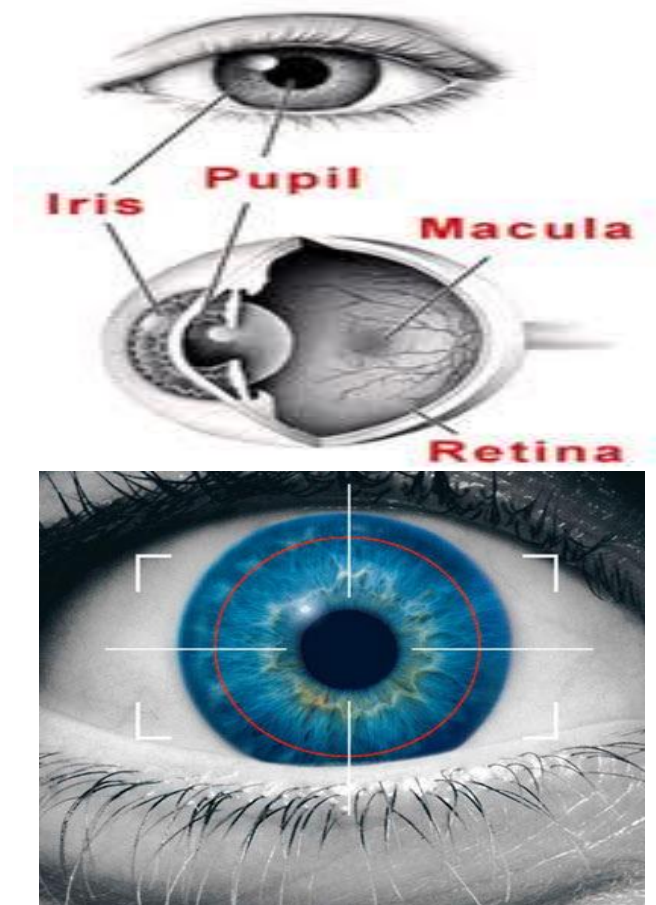


Figure 2.5 Iris Recognition Biometric

Iris-based recognition is the most widely used biometrics among various biometric techniques (face, fingerprint, palm vein, signature, palm print, iris, etc.) because of its unique, stable, and noninvasive characteristics. It is the process of recognizing an individual by analyzing the random pattern of the iris and comparing it with that of reference in the database (DB) [2.7].

### 2.2.1.3 Hand Geometry Recognition

Basically Hand geometry consists of two sides; one is Palm side and Dorsum side or top side or back side of the hand [2.8] as shown in figure 2.6. Hand Geometry recognition is the method of personal authentication and available for over twenty years. To achieve personal authentication, a system may measure either physical characteristics (length, width, thickness and surface area etc) of the fingers or the hands. Hand geometry has gained

acceptance in a wide range of applications. It can frequently be found in physical access control in commercial and residential applications, in time and attendance systems and in general personal authentication applications.

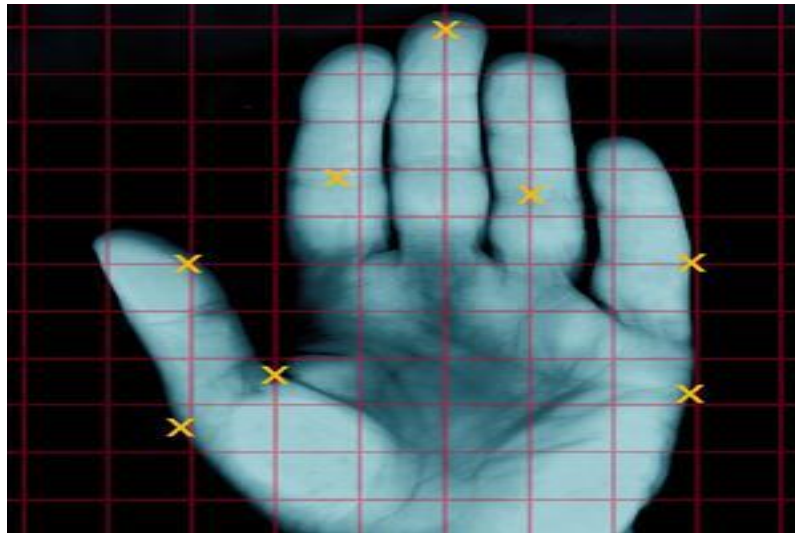


Figure 2.6 Hand geometry recognitions

Hand geometry recognition systems may provide three kinds of services, Verification, Classification and Identification. For verification, the user provides his/her identity along with the hand geometry and the system verifies his/her identity. For classification, the user does not provide any identity information but is known to be legitimate. For identification, the user does not provide any identity information other than the hand geometry and may be an intruder. Without hand geometry we can't identify a person. The system tries to identify the individual or deny access [2.9].

#### **2.2.1.4 Face Recognition**

The face is our primary focus of attention in social intercourse, playing a major role in conveying identity and emotions. We can recognize thousands of faces learned throughout our lifetime and identify familiar faces at a glance even after years of separation. This skill is quite robust, despite large changes in the visual stimulus due to viewing conditions, expression, aging, and distractions such as glasses, beards or changes in hair style.

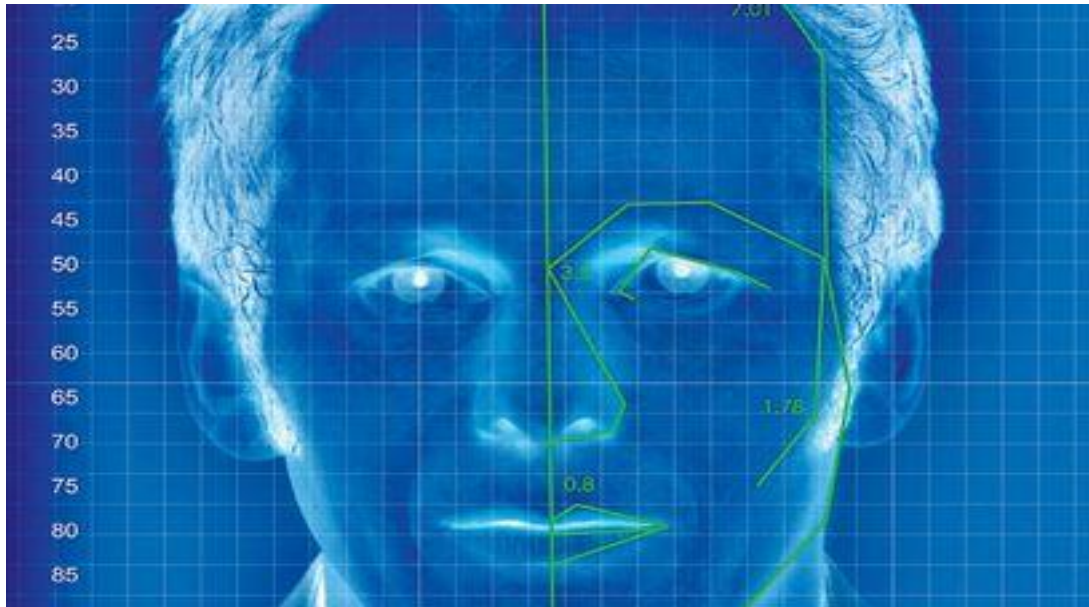


Figure 2.7 Face Biometrics

Face recognition plays an important role in many applications such as security systems, credit card verification and criminal identification. For example as shown in figure 2.7, the ability to model a particular face and distinguish it from a large number of stored face models would make it possible to improve criminal identification. The face is made up of many distinct micro and macro elements. The macro elements include the mouth, nose, eyes, cheekbones, chin, lips, forehead, and ears. The micro features include the distances between the macro features, or a reference feature and the size of the feature itself. Also, unseen to the human eye is the fact that our bodies and faces radiate heat, which can be measured by using infrared cameras. All these features can be used by face biometric systems to help identify and authenticate someone. The use of these traits is described in greater detail in the section regarding algorithms. Although an ability to infer intelligence or character from facial appearance is suspect, the human ability to recognize faces is remarkable.

The first step of human face identification is to extract the relevant features from facial images. Research in the field primarily intends to generate sufficiently reasonable familiarities of human faces so that another human can correctly identify the face. The question naturally arises as to how well facial features can be quantized. If such a quantization is possible, then a computer should be capable of recognizing a face, given a set of features. Investigations by numerous researchers [2.10, 2.11, 2.12] over the past several years have indicated that certain facial characteristics are used by human beings to identify faces.

## 2.2.2 Behavioural Biometrics

Behavioural biometrics is related to behaviour, nature and expression of human or person like heat of the body. Many biometrics techniques like keystroke, signature, voice recognition, ear pattern, gait recognition and palm print recognition come under behavioural biometrics as shown in figure 2.2 in the biometric brochure, these characteristics are referred to as **traits, indicators, modalities** [2.1].

### 2.2.2.1 Voice Recognition

Voice or speech recognition is an ability of a machine or program to receive and interpret dictation, or to understand and carry out spoken commands. Strictly speaking, voice is also a physiological trait because every person has a different pitch, but voice recognition is mainly based on the study of the way a person speaks, commonly classified as behavioral as shown in figure 2.8.



Figure 2.8 Voice recognitions

Speech recognition, which can be classified into identification and verification, is the process of automatically recognizing who is speaking on the basis of individual information included in speech waves. This technique makes it possible to use the speaker's voice to verify their identity and control access to services such as voice dialing, banking by telephone, telephone shopping, database access services, information services, voice mail, security control for confidential information areas, and remote access to computers. On the other hand, speaker verification is the process of accepting or rejecting the identity claim of a

speaker. Most applications in which a voice is used as the key to confirm the identity of a speaker are classified as speaker verification. Speaker recognition methods can also be divided into text-dependent and text-independent methods. The former requires the speaker to say key words or sentences having the same text for both training and recognition trials, whereas the latter do not rely on a specific text being spoken [2.13].

### 2.2.2.2 Keystroke Recognition

Keystroke dynamics utilizes the rhythm and manner in which an individual types characters on a keyboard. The original keystroke data contain the pressing key time and releasing key time shown in figure 2.9, from which two kinds of features are extracted, flight time and dwelling time. The flight time is defined as the time difference between one key release and the following key press. The dwelling time is the time difference between the press and release of one key.



Figure 2.9 Keystroke recognitions

The technology, which measures the time for which keys are held down, as well as the length between strokes, takes advantage of the fact that most computer users evolve a method of typing which is both consistent and idiosyncratic – especially for words used frequently such as a user name and password. When registering, the user types his or her details nine times so that the software can generate a profile. Future login attempts are measured against the profile which, the current claim is that it can recognize the same user's keystrokes with 99 per cent accuracy, using what is known as a “behavioral biometric” [2.14].

### 2.2.2.3 Signature Recognition

Biometric signature recognition systems (shown in figure 2.10) will measure and analyze the physical activity of signing, such as the stroke order, the pressure applied and the speed. Some systems may also compare visual images of signatures, but the core of a signature biometric system is behavioral, i.e. how it is signed rather than visual, i.e. the image of the signature. Handwritten signature is one of the most widely used personal methods for identity verification. As a symbol of consent and authorization, especially in the prevalence of credit cards and bank cheques, handwritten signature has long been the target of fraudulence. Therefore, with the growing demand for processing of individual identification faster and more accurately, the design of an automatic signature verification system faces a real challenge [2.15].



Figure 2.10 Signature Recognition

Handwriting is a skill that is highly personal to individuals and consists of graphical marks on the surface in relation to a particular language. Signatures of the same person can vary with time and state of mind. A method proposed in a signature verification system which extracts certain dynamic features derived from velocity and acceleration of the pen together with other global parameters like total time taken, number of pen-ups. The features are modeled by fitting probability density functions i.e., by estimating the mean and variance, which could probably take care of the variations of the features of the signatures of the same person with respect to time and state of mind. Handwritten signature is a form of identification for a person. Signatures are composed of special characters and flourishes and therefore most of the time they can be unreadable. Also intrapersonal variations and the differences make it necessary to analyze them as complete images and not as letters and words put together [2.16].

#### 2.2.2.4 Gait Recognition

Gait is one of the biometrics that is different from the traditional biometrics (face, iris, finger, hand, keystroke, voice, DNA etc). Gait (shown in figure 2.11) refers to a manner in which a person walks, and is one of the few biometric traits that can be used to recognize people at a distance. Therefore, this trait is very appropriate in surveillance scenarios where the identity of an individual can be surreptitiously established. Some algorithms use the optic flow associated with a set of dynamically extracted moving points on the human body to describe the gait of an individual. Gait-based systems also offer the possibility of tracking an individual over an extended period of time. However, the gait of an individual is affected by several factors including the choice of footwear, nature of clothing, affliction of the legs, walking surface, etc.

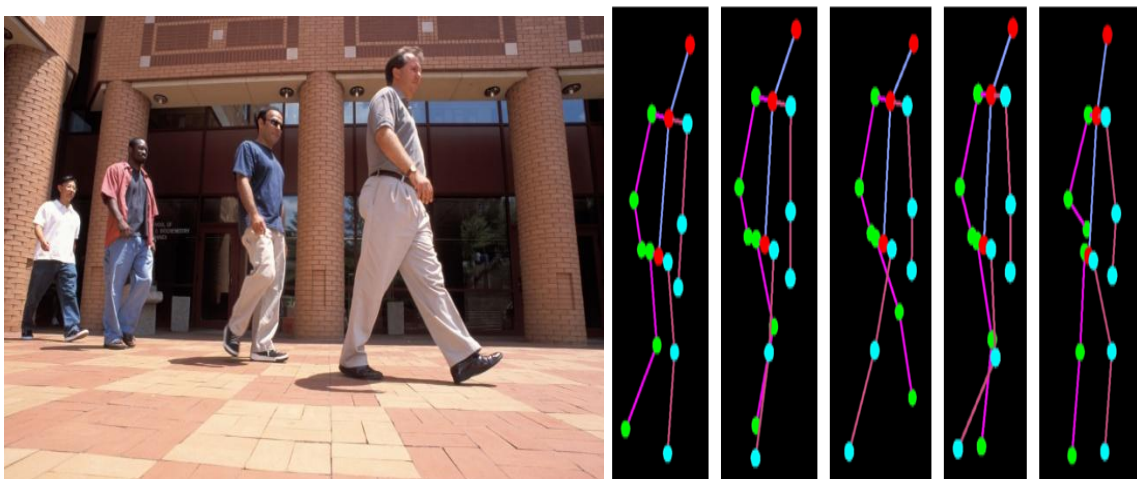


Figure 2.11 Gait recognitions

In addition, it has been shown that gaits are characteristic by which an individual is recognized and that can even reveal an individual's sex. On the other hand, unlike biometrics such as finger-prints and palm-prints, gait recognition requires no contact with a capture device as a gait can be captured in a distance as a low resolution image sequence. Gait recognition is basically divided into two types: (a) Model based and (b) Model-free recognition. In model-based recognition, researchers use information gathered from the human body, especially from the joints, to construct a model for recognition. In general, model-based approach is view and scale invariant. To gather these gait information, a high quality of the gait sequences is required. Thus, some of the model-based recognition systems require multi-camera for collecting the information [2.17].

Traditionally, human beings are identified in several situations in their daily life; either when using a key to open the door of their houses & cars, log in a system via a pass-word, or gain access to automated systems such as cell phone, online banking devices, offices or secure spaces in certain buildings with a PIN code. However, these means of identifying people have shown their limits. In fact, keys to open a door, as password and PIN code can be lost or stolen. Particularly, password and PIN code can be forgotten or neglected by their owners. These weaknesses make the security measures based on such tools less reliable and inefficient nowadays. The direct consequence is that, security mechanisms based on biometric technologies are gaining acceptance by individuals, companies, organizations, and governments, as alternative security means for protecting their systems. The advantage of biometric technologies over the traditional security means based on keys, passwords, and PIN codes is that a biometric signature cannot be borrowed, stolen, or forgotten, and it is practically impossible to forge it. Biometric technologies are being used in security banking systems, mobile phones, immigration, health, authentication systems, and many other applications [2.1].

### 2.3 Applications of Biometrics

After the attack on USA in September 2001 by the terrorist, the implementation of biometrics have increased in public sector and the demand for biometric authentication system has increased in Government as well as Private Areas where they use biometrics applications to authenticate all Federal (FBI) employees and Central (CBI) employees [2.3].

Biometrics is being increasingly incorporated in several different applications. These applications can be categorized into three main groups and some applications are shown in Table 2.1 [2.18].

Table 2.1 Areas and application of Biometrics

<b>Areas</b>	<b>Applications</b>
Information Security	Access Security (OS, Database), Data Privacy (e.g. Medical records), User authentication (Trading, Online, Banking)
Access Management	Secure Access Authentication (Restricted Facilities) Permission based system access log or audit trails.
Biometrics	Personal Identification (National IDs,

	Passport, Driving Licenses, Voter Registration).
Law Enforcement	Video Surveillance Suspect Identification Suspect tracking (Investigation) Simulated aging Forensic reconstruction of face from remaining.
Personal Security	Home video surveillance systems, Expression interpretation (Driver Monitoring System).
Entertainment Leisure	Home video game systems photo camera application.
Commercial	Computer Network Login, Electronic Data Security, e-commerce, internet access, ATM, credit card, Physical access control, mobile phone, medical records management and distance learning etc.
Government	National ID card, managing inmates in a correctional facility, driver's license, social security, welfare disbursement, border control, passport control etc.
Forensic	Corpse Identification, criminal investigation, parenthood.

## 2.4 Advantages of Biometrics

1. Increased securities provide a convenient and low cost additional tier of security.
2. Reduces fraud by employing hard-to-forge technologies and materials. For e.g. minimize the opportunity for ID fraud, buddy punching.
3. Reduces password administration costs, Eliminate problems caused by lost IDs or forgotten passwords by using physiological attributes. For e.g. prevent un-authorized use of lost and found, stolen or "borrowed" ID cards.

4. Integrates wide range of biometrics solution and technologies, customer applications and database into a robust and scalable control solution for facility and network access.
5. It is possible to establish an identity based on who you are, rather than, by what you possess, such as an ID card or what your remember, such as password.
6. It plays a very significant role in area of time and attendance and also helps in saving the cost and time [2.19].

## **2.5 Literature Review**

Debnath Bhattacharyya et.al, gives opinions about the usability of biometric authentication systems, comparison between different techniques and there, pros and cons of biometrics [2.2]. Robert Moskovitch et.al, proposed an Identity Theft, Computers and Behavioral Biometrics. To overcome the problem of identity theft an additional security layer is required, so behavioral biometrics is the solution [2.3]. Amira M. Saleh et.al, discussed a Modified Thinning Algorithm for Finger print Identification Systems in which, a direct gray scale thinning algorithm is proposed for thinning fingerprint images without need to first binarize the image. This is due to the loss of information caused by binarization [2.5]. Zuraini Othman et.al, proposed a preliminary study on Iris Recognition system: Tissues of Body Organs in Iridology, which discussed many factors of Iris like iris structure, measure color of iris, its density, sign on iris image and the location of body organ in iris image as stated in iridology chart the weaknesses on existing iris diagnosis system obtained [2.6]. Amol D. Rahulkar et.al, presented a Half-Iris Feature Extraction and Recognition Using a New Class of Bi-orthogonal Triplet Half-Band Filter Bank and Flexible k-out-of-n: A Post-classifier, which discussed Iris scaling, rotation shifting etc technique for iris features represents [2.7]. B. Mathivanan et.al, focused on An Efficient Hand Image Segmentation Algorithm for Hand Geometry based Biometrics Recognition System, which discussed hand based recognition with significance and dorsum hand image, segmentation of dorsum hand image [2.8]. Yaroslav Bulatov et.al, shows a Hand Recognition using geometric classifier, which discussed classifier and feature extraction from image and use in hand recognition [2.9]. A. Jay Goldstein et.al, proposed an Identification of Human face, which discussed human faces identified by human as well as computer, and extract the features and use for human recognition [2.10]. Patricia Melin et.al, presented a Voice Recognition with Neural Networks, Type-2 Fuzzy Logic and Genetic Algorithms, which discussed intelligent approach for pattern recognition for the case of speaker identification using different techniques of voice recognition [2.13]. Yilin Li et.al,

introduces a new BeiHang (BH) Keystroke Dynamics Database for testing and evaluation of biometric approaches. Different from the existing keystroke dynamics researches which solely rely on laboratory experiments, the developed database is collected from a real commercialized system and thus is more comprehensive and more faithful to human behavior [2.14]. Ismail A. Ismail et.al, presented a new method for off-line signature identification. Fourier Descriptor and Chain Codes features are used in this method to represent Signature image. Signature identification is classified into two different problems: recognition and verification [2.15]. G. Venkata Narasimhulu et.al, proposed a Gate recognition Survey, which discussed over view of gait recognition. Principal Component Analysis (PCA) with Radon Transform (RT), Principal Component Analysis (PCA) without Radon Transform (RT), Linear Discriminant Analysis (LDA) with Radon Transform (RT), Linear Discriminant Analysis (LDA) without Radon Transform (RT), Principal Component Analysis (PCA) with Linear Discriminant Analysis (LDA) and Incremental PCA-LDA algorithms are applied for gait recognition. Gait Energy Image (GEI) has been constructed to apply PCA with and without RT. LDA/PCA algorithm is used for face recognition [2.17]. W. Zhao et.al, discussed face recognition system, different techniques of biometrics, application of biometrics, and pros, cons of biometrics [2.18].

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# FACE DETECTION

### 3.1 Introduction

Because of the increasing instances of identity theft and terrorism incidences in past few years, biometrics based security system has been an area of quality research. Modern day biometrics is a cutting edge technology which enables the automated system to distinguish between a genuine person and an imposter. Automated face recognition is one of the areas of biometrics which is widely used because of the uniqueness of a human face to other human face. Automated face recognition has basically two parts; one is face detection and other one is recognition. To detect a face from an online surveillance system or an offline image, the main component that should be detected is the skin area. This thesis proposes a skin based segmentation algorithm for face detection in color images with detection of multiple faces and skin regions. Skin color has proven to be a useful and robust cue for face detection, localization and tracking. In Face Detection, we check in given input image whether it contains human face or not, if so, then returning the location of the human face. Basically due to lots of research, wide variety of applications (like in computers, communication, image database management, law enforcement, security, smart home application and automatic control systems etc) and difficulties in face detection has become interesting topics of research for the researchers in past decade [3.1]. Face detection is used in many places nowadays especially the websites hosting images like Picasa, photo bucket and Face book. Actually Face Detection is first essential step in Face Recognition system for localizing and extracting the features of given image. Since faces have lot of variation in appearance based approach, face detection is not a simple or straightforward, it consists of a long list of these factors, such as pose variation, occlusion, image orientation, illuminating conditions, facial expression, structural components, facial size found in the image, the scene and complexity of images background and others [3.1, 3.2].

The challenges associated with face detection can be attributed to the following factors [3.3]:

- i. **Pose** Actually face have various position which vary due to the camera positions or lower resolution camera, face pose like (frontal view, 45 degree, profile, upside,

down), and some facial features such as an eye or the nose may become partially or wholly occluded.

- ii. **Presence or absence of structural components** Facial features such as beards, moustaches, growing hair and glasses may or may not be present and there is a great deal of variability among these components including shape, color, and size.
- iii. **Facial expression** Some internal problems of human directly affect the human expression or facial expression.
- iv. **Occlusion** Faces may be partially occluded by other objects. In an image with a group of people, some faces may partially occlude other faces.
- v. **Image orientation** We have different types of camera at different place but the rotation and optical axis of that camera also differ so face images also vary due to rotation and optical axis.
- vi. **Imaging conditions** Some factors should be kept in mind at the time of capturing an image such as lighting (spectra, source distribution and intensity) and camera characteristics (sensor response, lenses) which affect the appearance of a face [3.3].

An algorithm for detecting human faces from RGB image or color images using HSV color models has been presented. The proposed method is applied on various test images and gives satisfactory result. Although, many different algorithms have been implemented for facial detection including the use of color information, principal component analysis (PCA), template matching, Linear Discriminator analysis (LDA), neural network, skin color, edge detection, Hough transforms or Wavelet transforms etc [3.2, 3.4], each algorithm has its own advantages and disadvantages in the form of speed, accuracy, complexity based on the prior information knowledge [3.5].

Many researchers have proposed different methods addressing the problem of face detection. In a recent survey, Ming-Hsuan Yang classifies different techniques used in face detection as Feature-based, Template matching, Knowledge based and Appearance based or Image based [3.3].

## 3.2 Types of Face Detection

Face detection methods have various approaches for detection which are generally classified into four categories [3.6]:

### 3.2.1 Feature based methods

### 3.2.2 Knowledge based methods

### 3.2.3 Machine learning methods or Appearance based methods.

### 3.2.4 Template matching method

Figure 3.1 shows the classification of face detection methods. The first method is based on Feature-based techniques, which use grouping of edge information, integration of skin color, motion, symmetry measures, and space gray level dependence matrix (SGLD), feature analysis, and point distribution models (PDMs).

The second method is Knowledge based which includes multi-resolution based method as shown in figure 3.1. The problem of face detection in still images is more challenging and difficult when compared to the problem of face detection in video or real time applications since motion information can lead to probable regions where a face could be located [3.7].

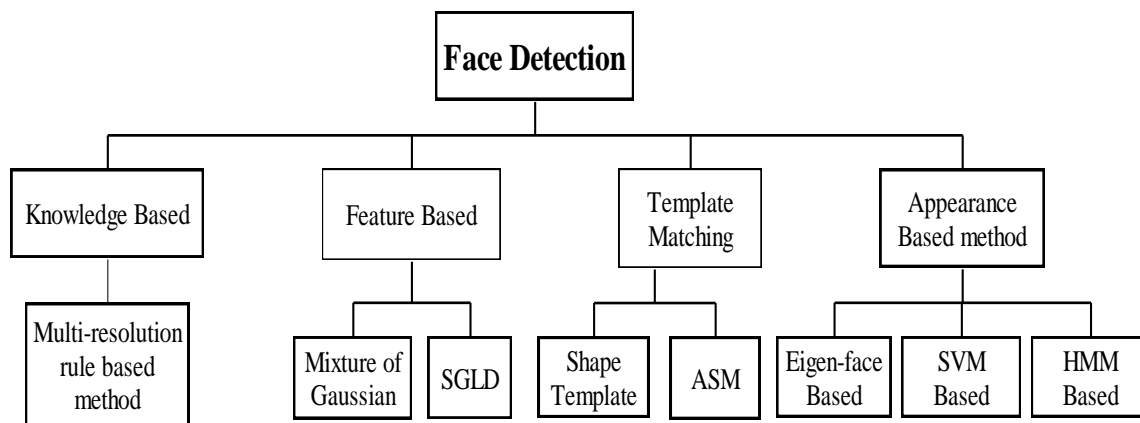


Figure 3.1 Face Detection Methods

The third method is based on Appearance-based Techniques which includes neural networks, linear subspace methods like Eigen faces, fisher faces, Eigen faces with background learning and statistical approaches like support vector machines, higher order statistics, distribution based and information theoretical approaches.

The fourth method is based on Template matching, which use predefined templates such as Shape templates, Deformable template like Active shape model etc [3.7].

### 3.2.1 Feature Based methods

Basically feature based method is most widely used method because it extracts the necessary facial features, and their mutual distances using statistical model are calculated, which is not affected by any type of variation like lighting condition, pose, shape, view and

other factors. These methods are classified according to the extracted features. With the help of Feature based technique, the features of face to gain the required knowledge of face are extracted. Features may be skin color, face shape, and expression or facial features like eyes, nose, eyebrow and lips etc. Feature based methods are used for real time systems. On the other hand, the multi-resolution window scanning used by image based methods is not applicable. Human skin color is an effective feature used to detect faces. As different people have different skin color, several studies have shown that the basic difference is based on their intensity rather than their chrominance. Textures of human faces have a special texture that distinguishes them from different objects. Facial features method depends on detecting features of the face. Some users use the edges to detect the features of the face, and then grouping the edges. Some others use the blobs and the streaks instead of edges. For example, the face model consists of two dark blobs and three light blobs to represent eyes, cheekbones, and nose. The model uses streaks to represent the outlines of the faces like, eyebrows, and lips. Multiple features methods use several combined facial features to locate or detect faces. First, find the face by using features like skin color, size and shape and then verify these candidates using detailed features such as eye brows, nose, and hair. This approach is unable to work under different imaging conditions because the image structure varies too much to be robustly detected. Moreover, if the algorithm fails to detect one of the crucial facial features, it will be unable to find symmetrical relationship among the features and hence fails to detect a face [3.6].

### **3.2.1.1 Low Level Feature Analysis**

#### **3.2.1.1.1 Edges**

As a useful primitive feature in computer vision, edge representation was applied to early face detection system by Sakai et al. [3.7]. Later, this work was upgraded and a hierarchical frame work was proposed by Craw et al. [3.8] to trace the human head line. This approach includes a line follower which is implemented with a curvature constraint. Some more recent examples of edge-based techniques can be found in [3.9, 3.10, 3.11, 3.12]. Edge detection is an important step in edge-based techniques. For detecting edges, various types of edge detector operators have been proposed, the sobel operator is one of them [3.10, 3.13]. Sakai and R. Herpers employed 1<sup>st</sup> and 2<sup>nd</sup> derivative of Gaussian [3.7, 3.14]. While a large scale Laplacian was used to obtain lines [3.7], and steerable and multi-scale-orientation filters are preferred in [3.14]. In a general face detector, which used edge representation, labeled edges are tried to be matched against a face model. Govindaraju [3.9] accomplishes this goal

by labeling edges as the left side, hairline, or right side of a front view face and then tries to match these edges against a face model by using predetermined ratio of an ideal face.

#### **3.2.1.1.2 Skin Color**

Human skin color can be used as an effective feature for face detection, and related applications. Human faces are colored depending upon the region of their habitation, but different studies show that the major difference exists in the intensity rather than the chrominance. Several color spaces have been used to label skin pixels including RGB [3.15, 3.16], NRGB (normalized RGB) [3.17, 3.18 3.19], HSV (or HSI) [3.20, 3.21], YCbCr [3.22], CIE-XYZ [3.22], CIE-LUV [3.23] etc. Color segmentation can basically be performed using appropriate skin color thresholds where skin color is modeled through histograms or charts [3.24, 3.25, 3.26]. More complex methods make use of statistical measures that model face variation within a wide user spectrum [3.17, 3.27, 3.28, 3.29].

#### **3.2.1.1.3 Motion**

Motion information is a convenient way of locating moving objects when a video sequence is provided. Using this information the face searching area can be narrowed. The simplest technique to achieve motion information is frame difference analysis. M. Turk and B. Sankur employed, improved frame difference analysis for face detection [3.30, 3.31]. Besides face region, Luthon et.al, [3.32], also employ frame difference to locate facial features, such as eyes. Another way of measuring visual motion is through the estimation of moving image contours. Compared to frame difference, results generated from moving contours are always more reliable, especially when the motion is insignificant [3.33].

### **3.2.2 Knowledge based**

Knowledge based technique depends on how we are using rules for extracting the features of human face. With the help of simple rules of these extracting features, we can easily make relationships in features of face. Facial features in an input image are extracted and face of the candidates is identified based on the coded rules. A verification process is usually applied to reduce false detections. One problem with this approach is the difficulty in translating human knowledge into well-defined rules. If the rules are detailed (i.e., strict), they may fail to detect faces that do not pass all the rules. If the rules are too general, they may give many false positives. Moreover, it is difficult to extend this approach to detect faces in different poses since it is challenging to enumerate all possible cases. On the other hand, heuristics about faces work well in detecting frontal faces in uncluttered scenes [3.3].

For example, in an image we have different features like eyes that are symmetrical to each other, nose, lips, and mouth. These features of face represent a relative distance, position and relationships respectively. After detecting features from the face image, verification is done to reduce false detection. This approach is good for frontal image; not varying image or lighting condition [3.34].

### **3.2.3 Image or Appearance based Method**

In Image based approach, a predefined standard face pattern or database is used to match with the segments in an image to determine whether it is a face or not. It uses training algorithms to classify regions into face or non-face classes. Image-based techniques depends on multi-resolution window scanning to detect faces, so these techniques have high detection rates but slower than the feature-based techniques. Eigen-faces, Distribution based method, Hidden markov model (HMM) and neural networks etc are examples of image-based techniques. This approach has advantage of being simple to implement, and also good for frontal view but it cannot effectively deal with variation in scale, pose, and shape [3.34].

### **3.2.4 Template matching method**

Template matching methods finds the similarity between the input images and the template images (training images). Template matching method uses the correlation between the input images and stored standard patterns of whole face features to determine the presence of whole face features. Predefined templates as well as deformable templates can be used. This method can be used for both face detection and face locations. In this method, a standard face (such as frontal view) can be used. The advantages of this method are that it is very simple to implement the algorithm, and it is easy to determine the face locations such as nose, eyes, eyebrow and mouth etc based on the correlation values. It can be applied on the various variations of the images such as pose, scale, and shape. Sub-templates, multi-resolutions, and multi-scales have been proposed to achieve the shape and the scale invariance. Smita et.al, presented a localization method based on a shape template of a frontal view face. We can use different methods of edge detection to find out the edges of face like Sobel filter is used to extract the edges [3.35].

## **3.3 Face Detection System**

Face detection is an interdisciplinary field which integrates different techniques such as (i) image processing, (ii) pattern recognition, (iii) computer vision, (iv) computer graphics, (v)

physiology, and (vi) evaluation approaches. In general, the computerized face recognition/face detection includes four steps.

- i. Face image is acquired, enhanced and segmented.
- ii. Face boundary and facial features are detected.
- iii. The extracted facial features are matched against the features stored in the database.
- iv. The classification of the face image into one or more persons is achieved.

Figure 3.2 shows the basic block diagram of face recognition system. The first step of face recognition is to acquire an image either online or offline. After acquisition of image, preprocessing operation is carried out. The unique features of the image are extracted with the help of different image processing algorithms. After the features are extracted, it is matched with the feature database and the final result is obtained.

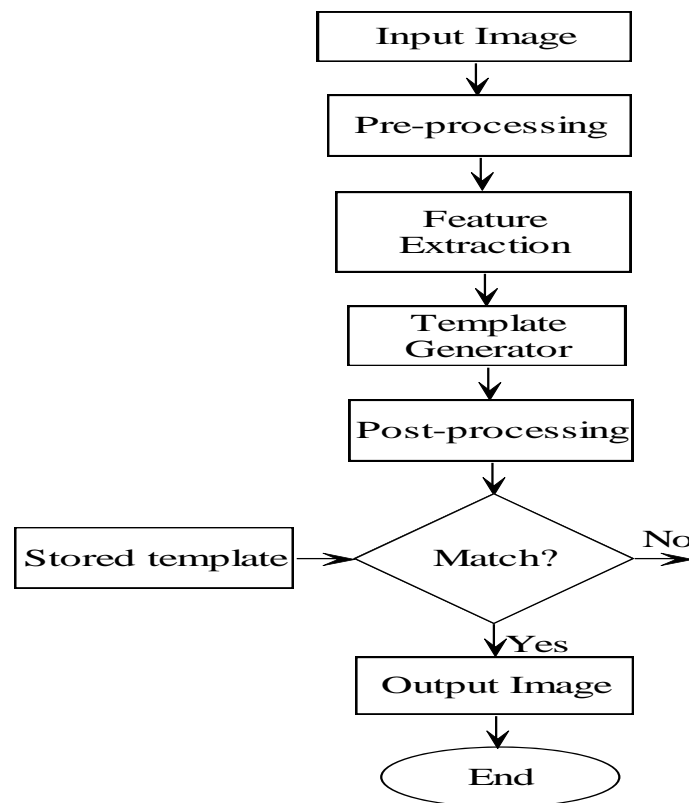


Figure 3.2 Block diagram of face detection/face recognition system

### 3.4 Literature Review

Sung and Poggio [3.36] proposed and successfully implemented Gaussian clusters to model the distribution of facial and non face patterns. Rowley et.al [3.37] used artificial neural network for face detection. Yang et.al [3.3] classified face detection methods in four

categories. (i) Knowledge based (ii) feature invariant (iii) template matching (iv) appearance based. Lu et.al [3.38] used parallel neural network for face recognition. Zhao et.al [3.39] proposed Linear Discriminant Analysis (LDA) for face recognition. H C Vijay Lakshmi et.al, proposed a Segmentation Algorithm for Multiple Face Detection in Color Images with Skin Tone Regions using Color Spaces and Edge Detection Techniques, in which different color space models, specifically, HSI and YCbCr along with Canny and Prewitt edge detection techniques are used for better face detection [3.1]. Iyad Aldasouqi et.al, presented a Smart Human Face Detection System, in which they explained Digital image processing and fast detecting algorithms based on HSV Color model without sacrificing the speed of face detection [3.2]. Ming-Hsuan Yang et.al, conducted a survey of Detecting faces in images and also compared different techniques like Face detection, face recognition, object recognition, view-based recognition, statistical pattern recognition, machine learning etc [3.3].

Diedrick Marius et.al, worked on Face Detection Using Color Thresholding, and Eigen-image Template Matching, compared and used the YCbCr, HSV color model for face detection and segment an image based on Skin color [3.4]. Arti Khaparde et.al, proposed an algorithm based on color segmentation and morphological operation like closing, opening and connecting etc and applied segmentation on HIS and YCbCr color model [3.5]. Amol Dabholkar et.al, worked on Automatic Human Face Detection and Tracking, in which the features using motion based and model-based algorithms were extracted and also used Kalman filter for estimation of the feature motion [3.6]. Aamer S. S. Mohamed et.al, presented a Face Detection based on Skin Color in Image by Neural Networks, in which the approach relies on skin-based color features extracted from two dimensional Discrete Cosine Transfer (DCT) and neural networks, which can be used to detect faces by using skin color from DCT coefficient of Cb and Cr feature vectors [3.34]. Smita Tripathi et.al, proposed a Face Detection using Combined Skin Color Detector and Template Matching Method in which, they discussed Skin Detection with the help of YCbCr color model and edge detection techniques for face detection [3.35]. Jean Paul Niyoyita et.al, described the Face Detection method with Skin Color Information and also implemented Adaptive boost algorithms and six segmented rectangular filters for better performance [3.44]. Sanjay Kr. Singh et.al, compared the different color models like HSV, YCbCr, and HIS, combined these models and developed a new Robust Skin Color Based Face Detection algorithm which gives improved accuracy compared to other techniques [3.45]. Michael Padilla et.al, presented automatic Face Detection Using Color Based Segmentation and Template/Energy Thresholding and

they compared the RGB, HSV and YCbCr Color model techniques for face detection and also applied some morphological operation for better accuracy [3.46]. K. Sandeep et.al, focused on Human Face Detection in Cluttered Color Images Using Skin Color and Edge Information, in which they developed HSV color model based face detection using edge detection technique [3.47]. Chiunhsiun Lin et.al, proposed a an algorithm in which they could detect the multiple faces in color images with various illumination and discussed triangle based segmentation and multilayer neural network using HSV Color space [3.48]. Venu Shah et.al, compared and combined the Traditional Method of HSV Histogram Equalization with Adaptive HSV segmentation and Kekre Transform for Content Based Image Retrieval [3.49]. Hamid Rahimizadeh et.al, presented a Color Image Segmentation based on Bayesian Theorem and Kernel Density Estimation in which they used probability density function based on Bayes theorem for color segmentation and also used HSL color model for face detection [3.51]. Vladimir Vezhnevets et.al conducted a Survey on Pixel-Based Skin Color Detection Techniques, in which they concluded that skin color is very useful and cue for face detection, locating and tracking and also compared the different methods and techniques of face detection [3.52].

### **3.5 Face Databases**

There are different standard face databases available in internet. This section shows some of the standard face databases.

#### **3.5.1 Yale Database**

It consists of a set of standard 165 black and white images of 15 different people (11 Images per Person) taken from Yale university standard database for use in facial algorithm. All the images are properly aligned and taken in same and good lighting and background conditions. Resolution of each image is taken as 320x243 pixels. Figure 3.3 shows some of the faces of Yale database [3.40]. The Extended Yale Database contains 1628 images of 28 human subjects under 9 poses and 64 illumination conditions [3.41].



Figure 3.3 Faces of Yale Database

### 3.5.2 FERET Database, USA

This database contains 1564 sets of images for a total of 14,126 images that includes 1199 individuals. All the images are of size 290x240. This database was cropped in MATLAB environment and segregated into sets of 250 female and 250 male faces manually. Figure 3.4 shows some of the images of the FERET database [3.42].

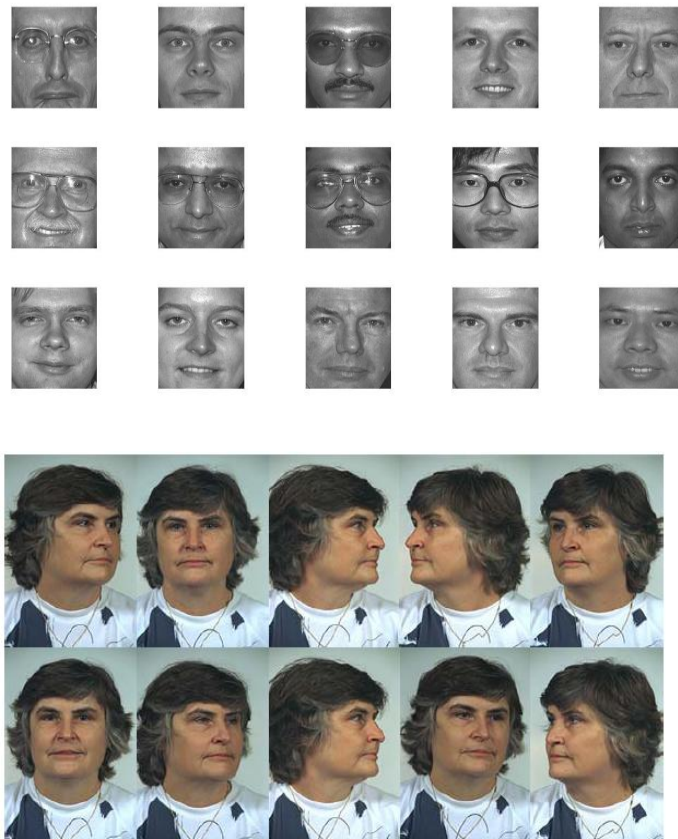


Figure 3.4 Faces of FERET database

### 3.6 Color space model and Color transformation

Basically, color pattern is not easily perceived and interpreted by human brain because it is a physiological phenomenon that is not fully understood by brain. The physical nature of color can be understood on the basis of practical and theoretical results. In 1666, Sir Isaac Newton discovered the color pattern when a beam of sunlight passes through a glass prism, emerging light is not white but it produces a spectrum of colors that may be divided into seven broad regions: violet, indigo, blue, green, yellow, orange, and red respectively. Characterization of light is central to the science of colors. Basically light is of two types chromatic and achromatic where, achromatic indicates intensity or amount of intensity. In Black and white TV, we have intensity range that represent achromatic light. On the other hand, in chromatic light we have electromagnetic spectrum which has range from 400 to 700 nm. We mainly use three quantities to represent quality of chromatic light source; radiance, luminance, and brightness. In our eye, we have cone sensor which is responsible for color division. This is divided into three principle sensing categories red, green, and blue (RGB). Our cone sensors are 65% sensitive to red light, 33% to green light and only 2% for blue respectively. Due to these characteristics of the light for human eye, colors are seen as variable combination of three primary colors red(R), green (G), and blue (B). Main purpose of the RGB color model is for the sensing, representation, and display of images in electronics system such as television, computers and also in photography. If these three standard colors are mixed in various intensity proportions all visible colors can be produced, that are called secondary colors. Now when we are working with color images, we need to describe the information of each pixel of that color image. When human eyes perceive the color, it is seen in 3-D due to those three-color components red (R), green (G), and blue (B). We have three characteristics; Hue (H), Saturation (S), and brightness or value (V) which is used to distinguish one color from another color. Nowadays, a different type of color model is used which is widely classified and have broad applications areas. Digital image processing have different type of color model and most commonly used are RGB (red, green, and blue) for color monitoring and there are more broadly classified models for color printing like color video cameras; the CMY (cyan, magenta, and yellow) and CMYK (cyan, magenta, yellow, and black) respectively. There is a HSI (hue, saturation, and intensity) model also which is used for perceiving and interpreting color by human eyes. We can represent three components of color in several ways like RGB color model, HSV/HSI color model, YUV

color model, TSL color model, CMY color model, YIQ color model and YCbCr model etc [3.43].

### 3.6.1 The RGB Color Model

The primary components of RGB model are red, green, and blue which can be represented on a Cartesian coordinate system as shown in figure 3.5. In RGB color cube, there are three primary colors values red, green, and blue at three corners and other three secondary values cyan, magenta, and yellow at other corners; black at origin; and white is at the corner farthest from the origin. Point between black and white represents a gray scale level which is formed by a line between black and white [3.43].

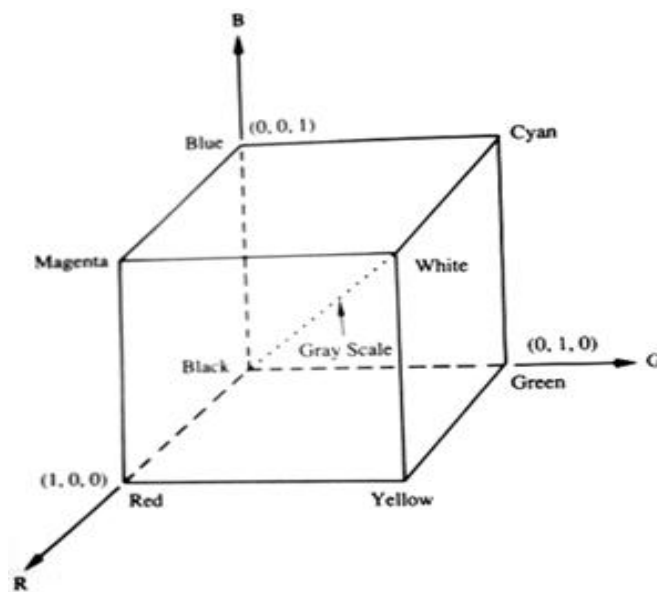


Figure 3.5 Schematic of RGB color cube along with points

The images which are captured with a colored video camera are in RGB format. Actually in RGB format luminance effect may vary with lighting condition on human face, which is not reliable to detect skin and non-skin region. So there is a need to transform image into other format because a point at skin color is changed due to variation in lighting condition. For example, we have more light at face on one point, so due to luminance effect we can't detect that face have skin regions or non-skin region. Luminance can be removed from the color representation in the chromatic color space.

With the help of RGB model, we can develop numerous color spaces or models for various applications and purposes. They are usually obtained via a transform from RGB space or other "basic" color space. Those color spaces can be classified in two categories: (a)

chrominance channels such as normalized RG, HS, CbCr and (b) color vectors that consist of all color channels (RGB, HSV, YCbCr, and CIE-Lab) [3.44].

### 3.6.2 The CMY and CMYK Color Models

The secondary colors which originate with the help of primary colors are cyan (C), magenta (M), and yellow (Y) or primary color pigments. For example, when a surface is coated with cyan substances and then lightened by white light no red light is reflected from the surface due to cyan pigment. That is, cyan subtracts red light from reflected white light, which itself is combination of equal amount of three colors i.e. red (R), green (G), and blue (B) light this is shown in figure 3.6.

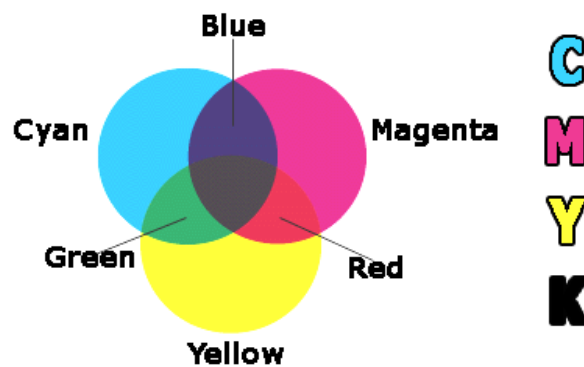


Figure 3.6 CMYK/CMY color model

When we take color print out, then some internal operation occurs during printing which deposits color pigment on paper. So it takes CMY as input and performs RGB to CMY conversion internally then it prints the paper. This conversion is shown by equation 3.1 and 3.2:

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (3.1)$$

Or

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} C \\ M \\ Y \end{bmatrix} \quad (3.2)$$

Let us assume all color values have been normalized to the range [0, 1].

With the help of CMY components we can find out the individual values of RGB. When we combine cyan, (C) magenta (M), and yellow (Y), it produces mudding look black color so that model are called CMYK color model which is shown in equation.

$$\text{CMYK}=\text{C}+\text{M}+\text{Y} \quad (3.3)$$

Let assume all color values have been normalized to the range [0, 1].

### 3.6.3 The YCbCr Color Models

YCbCr color model wedge the digital image into two parts, luma or luminance component and chroma or chrominance component. Due to luminance and chrominance effect, it becomes most important in digital video camera to handle video information. In YCbCr color model, Y stands for luminance effect, Cb and Cr stands for chrominance effect or blue-difference and red-difference respectively. Although Y luma represent black and white color, while Cb, and Cr represents RGB colors as shown in figure 3.7.

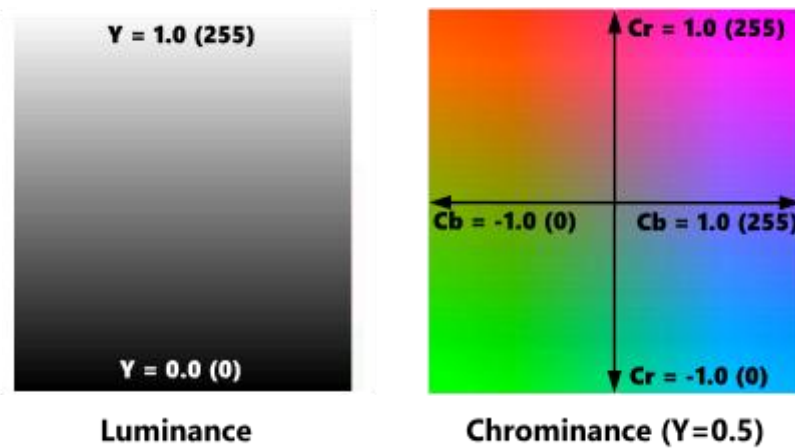


Figure 3.7 YCbCr color model with luminance and chrominance effect

YCbCr is also represented by  $Y'CbCr$ , where  $Y'$  show prime of Y component or gamma compressed component. YCbCr color model is family of television transmission color space. YUV and YIQ color model also belongs to analog space for PAL and NTSC systems. Basically, YCbCr is also secondary color model because it is formed with the help of primary colors RGB which is shown in equation (3.4).

$$Y = .299R + .587G + .114B \quad (3.4)$$

Equation (3.5) & (3.6) is used to calculate luma component

$$Cb = -0.169R - 0.332G + .500B \quad (3.5)$$

$$Cr = 0.500R - 0.419G - 0.081B \quad (3.6)$$

Let us assume all color values have been normalized to the range [0, 1] [3.45].

### 3.6.4 The HSV Color Model

Color model is used to specify the colors in some standard of the color models used are RGB color model for color monitors, CMY and CMYK model for color printing. HSV color model is the cylindrical representation of RGB color model. HSV stands for hue, saturation and value. "Hue" describes the combination of primary colors red (R), green (G), blue (B) and secondary colors cyan (C), magenta (M), yellow (Y), which form the basic pure color of the image. In each cylinder, the angle around the central vertical axis corresponds to "hue" or it form the basic pure color of the image, the distance from the axis corresponds to "saturation" or when white color and black color is mixed with pure color it forms the two different form "tint" and "shade" respectively, and the distance along the axis corresponds to "lightness", "value" or "brightness" or it provides an achromatic notion of the intensity of the color or brightness of the color as shown in below figure 3.8.

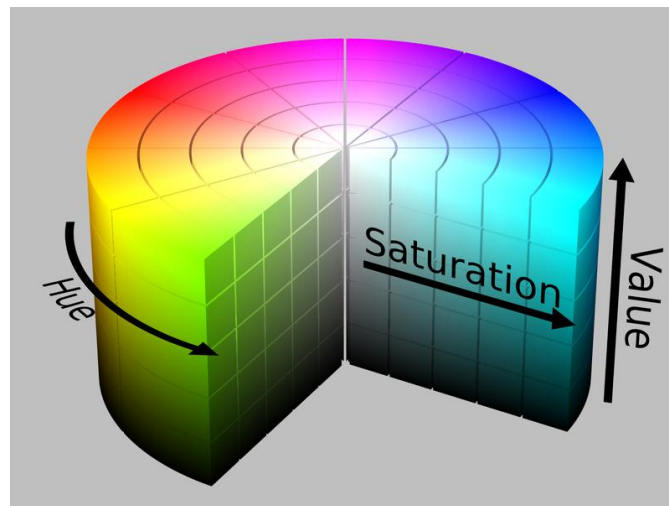


Figure 3.8 HSV color space

RGB is primary color which may be the most commonly used to describe the color information. It has the negative aspect that each of the coordinates (red, green, and blue) is subjected to luminance effects from the lighting intensity of the environment. The HSV color space, however, is much more natural and provides color information in a manner more in line how humans think of colors and how artists typically mix colors. HSV have cylindrical coordinate to represent a RGB color model at a point. Basically when we adjust a hue component then we can get desired color, if we want dark red color to pink then we adjust saturation value, and if we want darker or brighter component then we adjust intensity component, and get desired result. In HSV model, hue coordinate start from primary color

red at 0°, passing through green primary at 120°, and the blue primary at 240° and enclosing to red with 360° which is shown in below figure 3.9 [3.46].

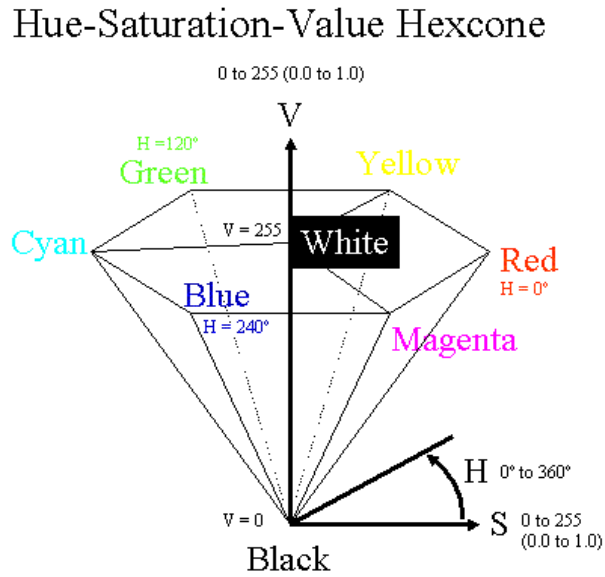


Figure 3.9 HSV model Cylindrical Coordinates

Basically, HSV color space is nonlinear transformation of RGB color space, and has cylindrical coordinate while RGB has Cartesian coordinate systems. With the help of Cartesian coordinates of RGB, we can transform cylindrical coordinates of HSV color space into Cartesian coordinate and make a nonlinear to linear transform [3.46]. As we know RGB coordinate lies between from 0 to 1, where 0 being the least amount and 1 being the greatest amount, HSV model can be presented by a Hex-cone. In Hex-cone representation, the hue (H) is interpreted as a three-dimensional conical formation of the color wheel. The saturation (S) is represented by a distance from the center of a circular cross-section of the cone, and the value (V) is the distance from the pointed end of the cone. Figure 3.10, show a value of H varies from 0° to 360° or 0 to 1 on circular scale i.e. color represented by H=0 and H=1 are the same, value of S varies from 0 to 255 or [0 1] i.e. 1 representing 100 percent purity of the color and similarly for V [3.46, 3.47].

Since the RGB values generally lie in the range of 0 to 255, we need to use the formulae given by equation (3.7), (3.8) and (3.9) below, which will convert the Hue values (H) between 0° and 360°, Saturation values (S) between 0 and 1 and Values (V) between 0 and 1 [3.49].

$$H = \left[ \left( \frac{H}{255} \right) * 360 \right] | 360 | \quad (3.7)$$

$$S = \frac{S}{255} \quad (3.8)$$

$$V = \frac{V}{255} \quad (3.9)$$

After the conversion from RGB color space to HSV color space of the entire image, the image is divided into different regions depending on the values of hue and saturation. RGB color space is very sensitive to lighting conditions or intensity difference; we have many methods for color segmentation to get better color constancy (Human has high sensitivity in identifying object colors in a wide range of illuminations, this is called color constancy). We will use HSV color space instead of the RGB color space. The HSV color space has been chosen because of the following reasons:

- i. In the HSV color space, the brightness component or “value” (V) is independent factor, so we can use this characteristic to overcome the problem of brightness variation.
- ii. The HSV color model over alternative models such as RGB or CMYK, because of its similarities to the way humans tend to perceive color. The HSV (Hue, Saturation, and Value) model is also called HSB (Hue, Saturation, and Brightness) [3.46].

### **3.7 Skin Color Segmentation**

Basically, segmentation means dividing an image into regions that are homogeneous with respect to one characteristic or more features. Image segmentation is initial step in pattern recognition and image analysis, because with the help of image segmentation we try to segment that part which is not necessary for analysis. Typically, segmentation of an object is achieved by identifying all pixels that belong to the object or by locating those that form its boundary. The former is based primarily on the intensity of pixels, but other attributes, such as texture, that can be associated with each pixel, can also be used for segmentation [3.43].

According to Hamid Rahimizadeh et.al [3.51] “the image segmentation problem is basically one of the psychophysical perception, and therefore not susceptible to a purely analytical solution”. Color image segmentation attracts more and more attention because color images can provide more information than gray level images. If we have a good format of image, then we can perform better image analysis and pattern recognition, so we should transform an image into another better represented form for getting good results.

A new algorithm based on skin color segmentation in RGB models has been presented. This algorithm tries to find the skin region and then from the skin region, facial features have been extracted to get the face from the skin region. Our results show that we can segment the face more effectively by using the proposed algorithm. The study on skin color segmentation classification has gained increasing attention in recent years due to the active research in content-based image representation. For instance, the ability to locate or detect image object as a face can be exploited for image coding, editing, indexing or other user interactivity purposes. Moreover, face localization also provides a good stepping stone in facial expression studies. It would be fair to say that the most popular algorithm to face detection is the use of color information, whereby estimating areas with skin color is often the first vital step of such strategy. Hence, skin color segmentation has become an important task. Much of the research in skin color based face detection is based on RGB, YCbCr and HSV color spaces. In the section 3.6 the color spaces have been described.

### **3.7.1 Skin Color Based Face Detection in RGB Color Space**

Sanjay Kr. Singh et al. [3.45] proposed one of the simplest algorithms for detecting skin pixels which to use skin color algorithm. The perceived human color varies as a function of the relative direction to the illumination. The pixels for skin region can be detected using a normalized color histogram, and can be further normalized for changes in intensity on dividing by luminance. And thus, an  $[R, G, B]$  vector is converted into an  $[r, g]$  vector of normalized color which provides a fast means of skin detection. This gives the skin color region which localizes face. The output is a face detected image which is from the skin region. This algorithm fails when there are some more skin regions like legs, arms, etc.

### **3.7.2 Skin Color Based Face Detection in YCbCr Color Space**

Sanjay Kr. Singh et al. [3.45] proposed a skin color classification algorithm with color statistics gathered from YCbCr color space. Studies have found that pixels belonging to skin region exhibit similar Cb and Cr values. Furthermore, it has been shown that skin color model based on the Cb and Cr values can provide good coverage of different human races. The thresholds have been chosen as  $[Cr1, Cr2]$  and  $[Cb1, Cb2]$ , a pixel is classified to have skin tone if the values  $[Cr, Cb]$  fall within the thresholds. The skin color distribution gives the face portion in the color image. The constraint of this algorithm is that the image should contain only face as the skin region.

### 3.7.3 Skin Color based Face Detection in HSV Color Space

According to K. Sandeep et al, [3.47] HSV gives the best performance for skin pixel detection. We conducted our own experiments independently and converged to the same fact. Our experiments also showed the superiority of HSV color space over RGB and YCbCr color spaces. Skin color can be modeled using a histogram, of H component and demonstrated that the histogram model is superior to other models. Also, the histogram is easy to implement and is computationally efficient. The removal of V component takes care of varying lighting conditions. H varies from 0 to 1 on a circular scale i.e. the colors represented by H=0 and H=1 are the same. S varies from 0 to 1, 1 representing 100 percent purity of the color. H is partitioned into 100 levels and the color histogram is formed using H. In order to train for skin color, we downloaded color images containing human faces from the Internet and extracted the skin regions in these images manually. Therefore, we took samples (by random) from huge pixels of human faces and obtained the human skin distribution in HSV color space. We collected the human skin colors with different illumination circumstances from 100 faces with background of images. We collected 4900 (70\*70) pixels from each face and each light color of the background. Therefore, more than 490,000 pixels of the human skin colors were used to acquire the cluster or array of skin color. Our training set contained more than 490,000 skin pixels to form the color histogram in H. For each pixel, H value is found and the bin corresponding to these H value in the histogram is incremented by 1. After the training is completed, the histogram is normalized. Though it appears that there are two different regions very much apart with high skin probability, they both belong to the same region, since H is cyclic in nature. Also, we can see that the skin color falls into a very small region in the entire H space. The height of a bin in the histogram is proportional to the probability that the color represented by the bin is a skin color. So we use a threshold between 0 and 1 to classify any pixel as a skin pixel or a non-skin pixel. If the threshold value is high, all the skin pixels will be classified correctly but some of the non-skin pixels will be classified as skin pixels. If the threshold value is low, all the non-skin pixels will be classified correctly whereas some of the skin pixels will be classified as non-skin pixels. This represents a trade-off between percentage of skin pixels detected as skin and percentage of non-skin pixels falsely detected as skin. There is an optimum threshold value with which one can detect most of the skin pixels and reject most of the non-skin pixels. This threshold is found by experimentation.

Given an image, each pixel in the image is classified as skin or non-skin using color information. The histogram is normalized and if the height of the bin corresponding to the H value of a pixel exceeds a threshold called skin threshold (obtained empirically), then that pixel is considered a skin pixel. Otherwise the pixel is considered a non-skin pixel. A skin detected image is one in which only the skin pixels are shown. A general image and its skin detected image as shown in Figure 3.10.

**RGB Image**



(a)

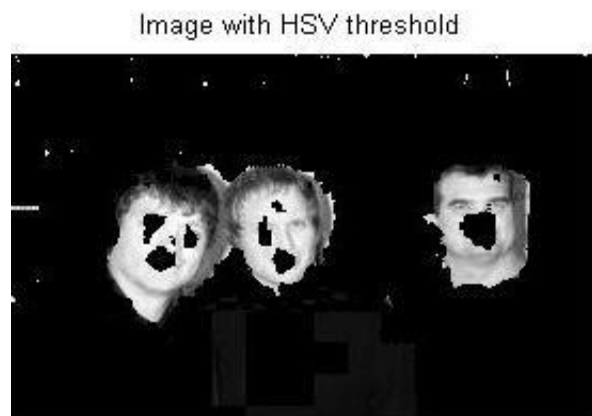
**HSV Threshold Image**



(b)



(c)



(d)

Figure 3.10 (a) (c) RGB image, and (b) (d) Skin detected image

### 3.8 Face Detection using H component or Skin and Non-skin regions for different color spaces

In situations where color description plays an integral role, the HSV color model is often preferred over the RGB model. The HSV model describes colors similar, to how the human eye tends to perceive color. RGB defines color in terms of a combination of primary colors, whereas, HSV describes color using more familiar comparisons such as color, vibrancy and brightness. The color camera, on the robot, uses the RGB model to determine color. Once the camera has read these values, they are converted to HSV values. The HSV values are then used in the code to determine the location of a specific object/color for which the robot is searching. The pixels are individually checked to determine if they match a predetermined color threshold.

The image retrieval process using segmentation of HSV is carried out by converting its RGB color space to HSV color space using the formulae given by equation (3.10) (3.11) and (3.12) [3.49].

$$H = \cos^{-1} \left( \frac{\frac{1}{2}((R-G)+(R-B))}{\sqrt{(R-G)^2 + (R-B)(G-B)}} \right) \quad (3.10)$$

$$S = 1 - 3 \frac{\min(R, G, B)}{R + G + B} \quad (3.11)$$

$$V = \frac{1}{3}(R + G + B) \quad (3.12)$$

This thesis presents an improved color based segmentation technique to segment the skin regions in a group picture and use of skin based segmentation in face detection. Skin based segmentation has several advantages over other face detection techniques like this method is almost invariant against the changes of size of face, orientation of face. The primary aim of skin based segmentation is to detect the pixels representing the skin regions and non-skin regions. After detection of pixels which represents the skin region, the next task is to classify the pixels which represent the faces and non-faces.

Color is a prominent feature of human faces. Using skin color as a primitive feature for detecting face regions has several advantages. In particular, processing color is much faster than processing other facial features. Furthermore, color information is invariant to face orientations. However, even under a fixed ambient lighting, people have different skin color

appearance. In order to effectively exploit skin color for face detection, a feature space has to be found, in which human skin colors cluster; tightly together and reside remotely to background colors.

The first step of face detection is to segment the color image into skin and non-skin region. Different color space has different ranges of pixels which represents skin region and non-skin region.

Skin region in B color space lies in the following range

$$0.79G - 67 < B < 0.78G + 42 \quad (3.13)$$

Non skin region in B color space lies in the following range

$$0.836G - 14 < B < 0.836G + 44 \quad (3.14)$$

Non skin region in H color space lies in the following range  $19 < H < 240$

Skin region in Cb color space lies in the following range  $102 < Cb < 128$

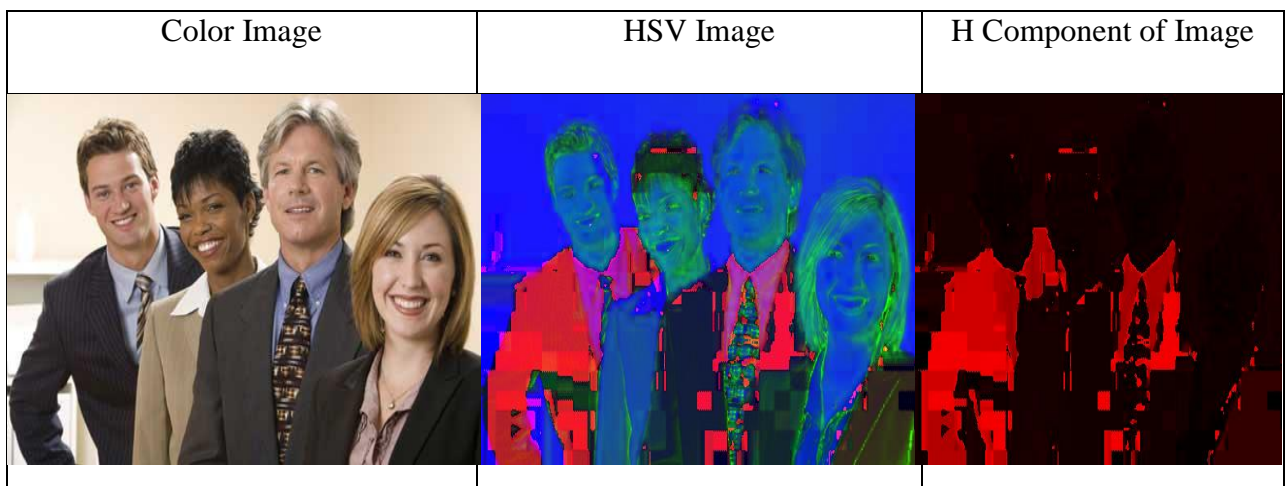


Figure 3.11 (a) (b) (c): RGB image, HSV image and H component of image

From the above ranges, the skin and non-skin segmentation is performed. So now the output image only shows the skin regions and non skin regions are blackened. We have some results based on HSV component as shown in figure 3.11 (a) (b) (c).

After segmentation, morphological operators are implemented with a structuring element. After application of morphological operators, the standard deviation of the area is calculated and rectangles are drawn in the skin regions. If any unwanted rectangles are created, they are removed.

### 3.8.1 Morphological Operators

In recent years image-processing techniques have been developed tremendously and mathematical morphology in particular has been continuously developing because it is receiving a great deal of attention because it provides a quantitative description of geometric structure and shape, connectivity, convexity and also a mathematical description of algebra, topology, lattice theory, probability, and integral geometry. We can use Mathematical morphology in image processing and analysis applications.

Basically morphology word is originated from Greek word “morphe”. In biology terms, morphology denotes a branch of biology that deals with the forms and structures of animals and plants. Morphology means “study of shape” or in other words the morphological transforms were initially applied to binary images as an ad hoc post-processing method helping to remove spurious image elements and to provide elementary analysis of size, shape, and count of objects. Nowadays, the modern generalized morphological methods form a wide class of nonlinear methods applicable not only to binary images, but also to multidimensional gray-scale data; they enable novel interesting approaches to image processing and analysis [3.43, 3.50].

In computer vision, in terms of mathematics, it is used as a tool to extract image components that are useful in the representation and description of object shape analysis, like boundaries, skeleton and convex hull etc. It is mathematical in the sense that the analysis is based on set theory (in set theory with the help of local operator) topology, lattice algebra, functions, and so on. We have many approaches of Morphology like pre-processing, post-processing, feature extraction and segmentation. But here we are using few approaches like segmentation, pre-processing etc [3.43].

Few morphological operations are discussed in following section.

#### 3.8.1.1 Dilation

Dilation is a process that translates the origin of the structuring element throughout the domain of the image and checks to see whether it overlaps with 1-valued pixels. The output image is 1 at each location of the origin of the structuring element if the structuring element overlaps at least one 1-valued pixel in the input image.

Mathematically, dilation is defined in terms of set operations.

The dilation of A by B, denoted by  $A \oplus B$ , is defined as

$$A \oplus B = \{z | (\widehat{B})_z \cap A \neq \Phi\} \quad (3.15)$$

Where  $\Phi$  is the empty set and  $B$  is the structuring element. In words, the dilation of  $A$  by  $B$  is the set consisting of all the structuring element origin locations where the reflected  $B$  overlaps at least some portion of  $A$ . Dilation is commutative, i.e.,  $A \oplus B = B \oplus A$  [3.44].

### 3.8.2.2 Erosion

The Erosion process is similar to dilation process. Erosion shrinks or thins a binary image or object. As in dilation, the manner and extent of shrinking is controlled by the structuring element. The output of erosion has a value 1 at each location of the origin of the structuring element, such that the structuring element overlaps only 1-valued pixels of the input image. The mathematical definition of erosion is similar to that of dilation.

The erosion of  $A$  by  $B$ , denoted by  $A \ominus B$ , is defined as

$$A \ominus B = \{z | (B)_z \cap A^c = \Phi\} \quad (3.16)$$

In other words, erosion of  $A$  by  $B$  is the set of structuring element origin locations where the translated  $B$  has no overlap with the background of  $A$  [3.43].

### 3.8.2.3 Opening

Opening operation with the help of structuring element, smooth the object contour, break thin connections, removes the protrusions and also removes that region of an object which can't have kernel. The morphological opening of  $A$  by  $B$ , denoted by  $A \circ B$ , is simply erosion of  $A$  by  $B$  followed by the dilation of the result by  $B$ .

Mathematically opening formula is given as:

$$A \circ B = (A \ominus B) \oplus B \quad (3.17)$$

An alternative mathematical formulation of opening is

$$A \circ B = \cup (B)_z | (B)_z \subseteq A \quad (3.18)$$

Where  $\cup \{.\}$  denotes the union of all sets inside braces, and the notation  $(C \subseteq D)$  means that  $C$  is a subset of  $D$ . This formulation has a simple geometric interpretation.  $A \circ B$  is the union of all translations of  $B$  that fit entirely within  $A$  [3.43].

### 3.8.2.4 Closing

The morphological closing of A by B, denoted by  $A \square B$ , is a dilation followed by erosion:

Mathematically equation is given by,

$$A \bullet B = (A \oplus B) \ominus B \quad (3.19)$$

Geometrically,  $A \bullet B$  is the complement of the union of all translations of B they do not overlap A. Like opening, morphological closing smoothes the contours of the objects. Unlike opening, however, it generally joins narrow breaks, filling long thin gulfs, and fills holes smaller than the structuring element [3.43].

### 3.8.2.5 Hole filling/Region filling algorithm

A hole may be defined as a background region surrounded by a connected border of foreground pixels. With the help of set of dilation, intersection and complementation, we develop an algorithm which is used in filling holes in an image i.e. called region filling or hole filling algorithm.

Beginning with a point p inside the boundary, the objective is to fill the entire region with 'black'. If we adopt the convention that all non-boundary (background) points are labeled 'white', then we assign a value of 'black' to p to begin.

$$X_k = (X_{k-1} \oplus B) \cap A^c, \quad k=1,2,3, \quad (3.20)$$

Where  $X_0 = p$ ,

$B$  is the symmetric structuring element

The algorithm terminates at iteration step  $k$  if  $X_k = X_{k-1}$ . The set union of  $X_k$  and A contains the filled set and its boundary [3.43].

The various stages in the algorithm are explained using the boy's image (Fig. 3.12). First of all the algorithm classifies skin pixels and non-skin pixels using H components (fig. 3.12 (b)) of the HSV color space. Figure 3.12(c) classifies between the skin pixels and non skin pixels. Figure 3.12(d) shows the image after applying morphological operators. The remaining part of the algorithm uses the skin detected image and the hue image, finds the skin regions and checks the percentage of skin in that region. For regions classified as faces, it uses the height and width of the region to draw a rectangular box with the region's centroid

as its centre. The final result of the algorithm is shown in Fig. 2.12(e). It is to be noted that the face has been correctly located and almost at the right scale.






Original Image	H Component Image	Skin Detected Image	After Morphology Image	Resulted Image
				

Figure 3.12 (a) (b) (c) (d) (e): A test image with boy sitting, H Component image, Skin detected image, image after morphology, result of the proposed algorithm.

### 3.9 The Proposed Algorithm & Results

The automatic face detection algorithm is applied on a wide variety of images taken under different lighting conditions and with different backgrounds. The images also have areas containing skin from other parts of the body such as hands, necks and areas with color very similar to that of skin. These areas get classified as skin.

The complete flow chart of face detection is shown in figure 3.13 and figure 3.14 shows the original images & the image after the algorithm is applied on them.

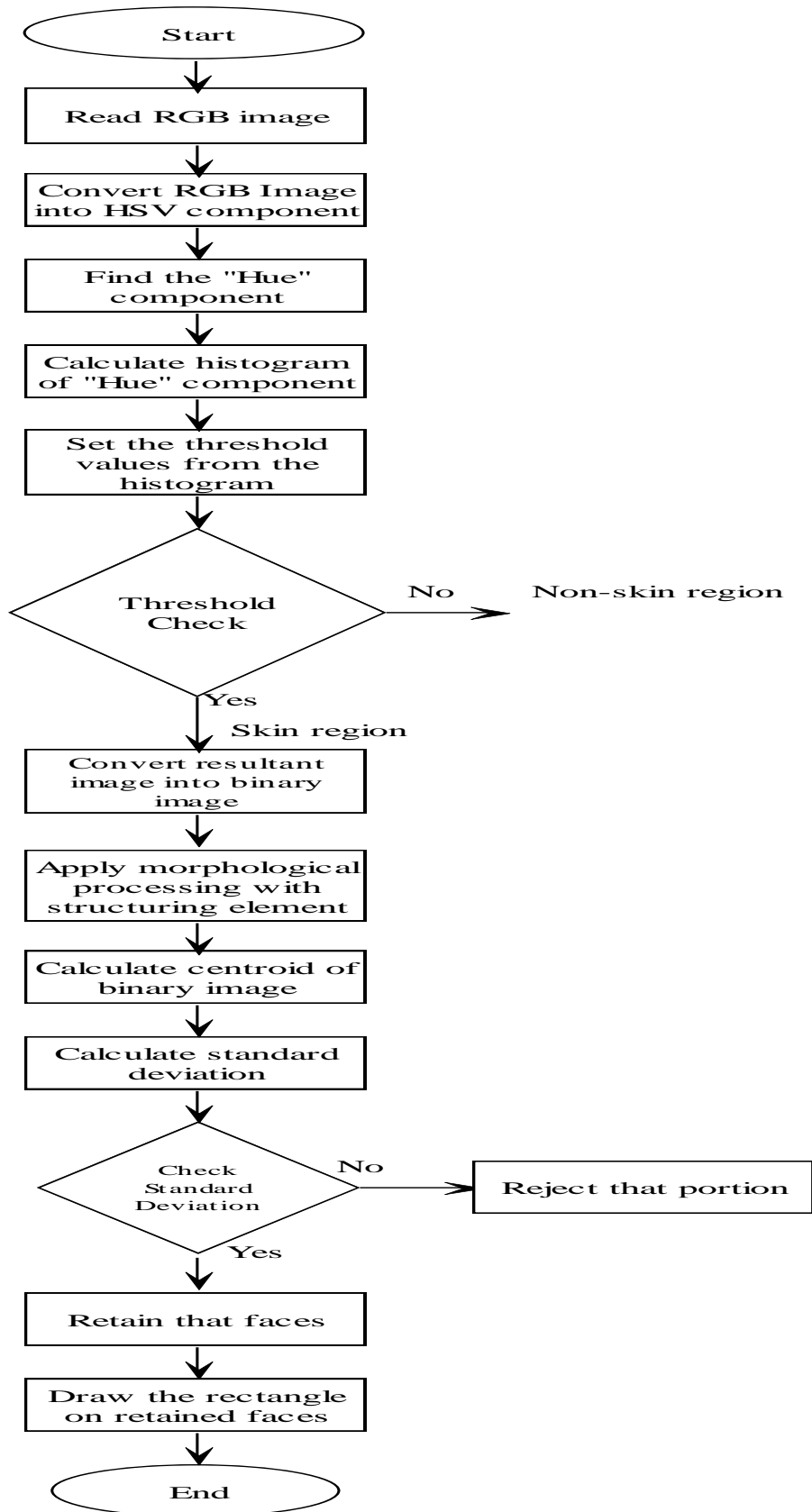

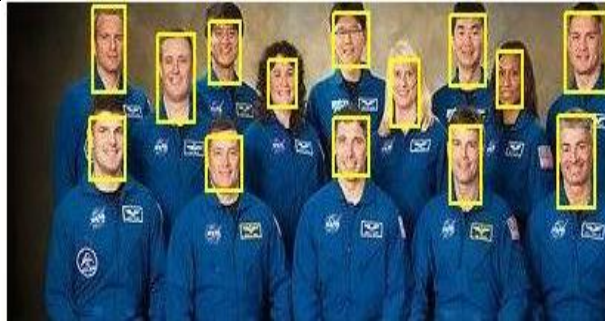



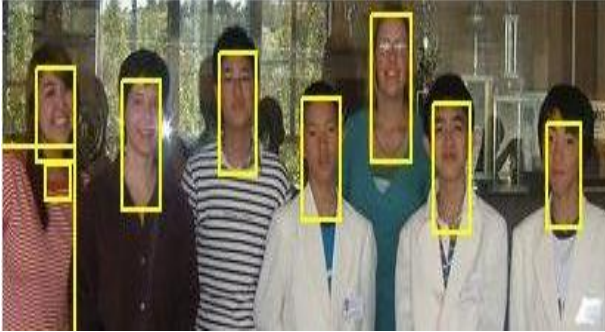
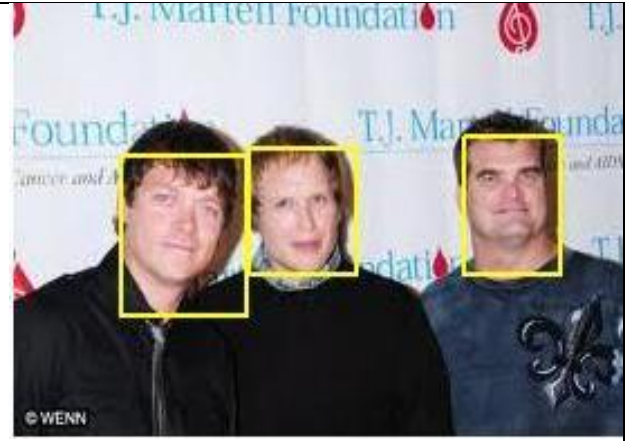


Figure 3.13 Flow chart of Face Detection

Original Image	Resultant Image with face detected
	
(a)	(b)
	
(c)	(d)
	
(e)	(f)



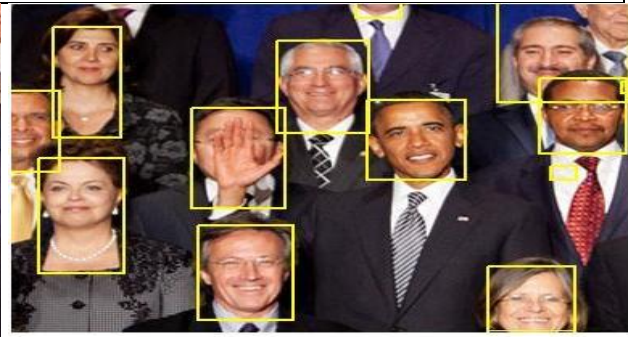
(g)



(h)



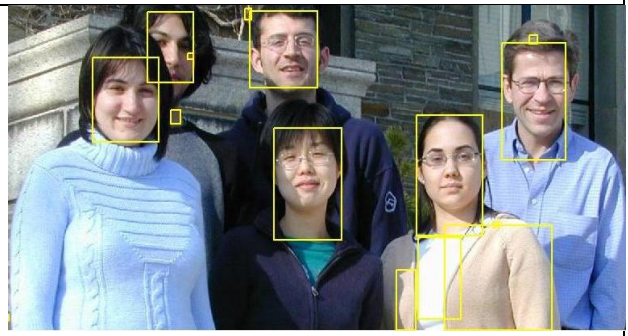
(i)



(j)



(k)



(l)

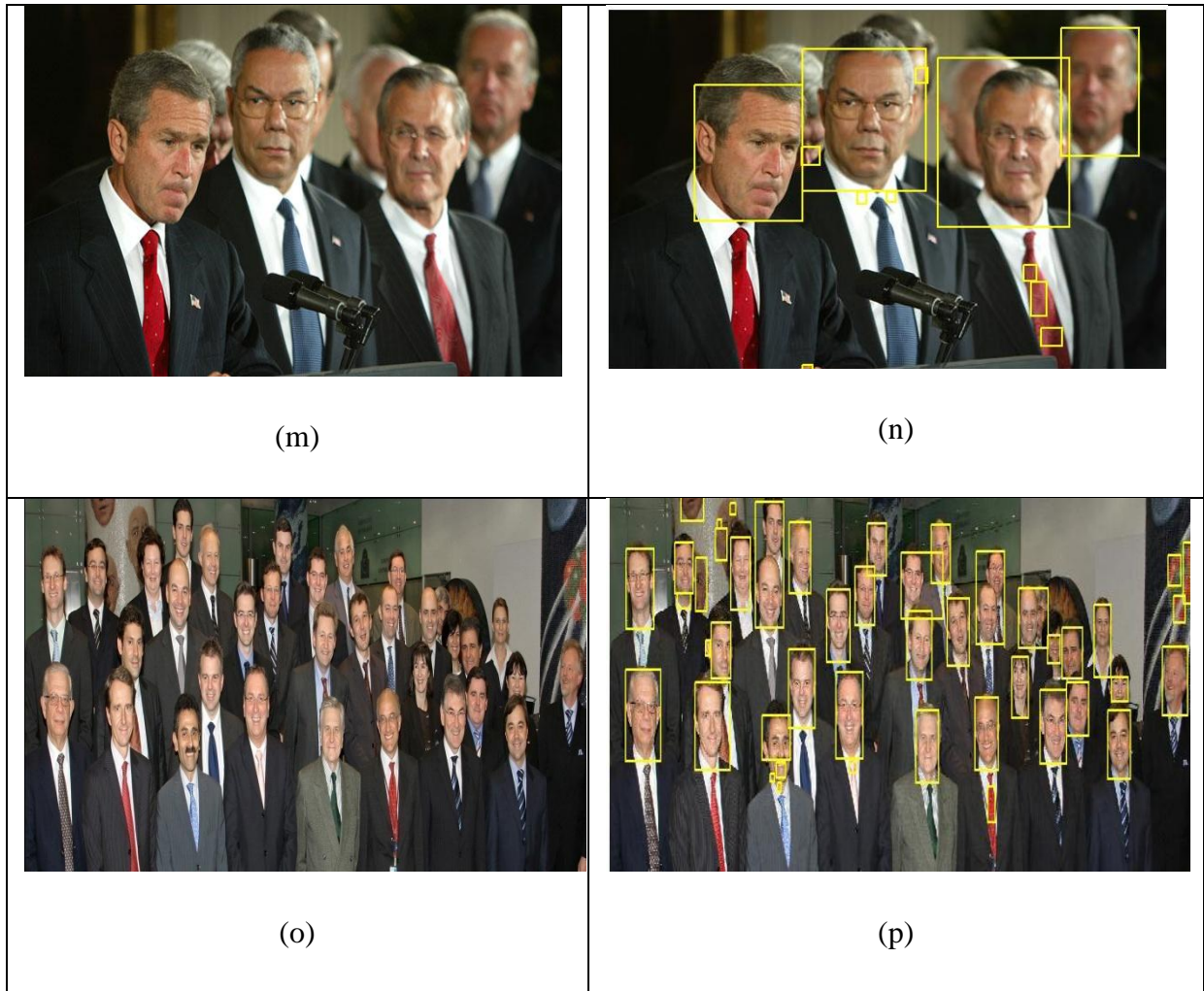


Figure 3.14 (a) (c) (e) (g) (i) (k) (m) (o) RGB image, and (b) (d) (f) (h) (j) (l) (n) (p) Resultant image, Result of face detection algorithm on different images.

To evaluate the performance of the proposed algorithm, following parameters are taken in to consideration. The parameters under consideration are number of faces, detected faces, number of repeat faces, false positive, and time to execute the algorithm and accuracy of face detection.

Table 3.1 Performance evaluation of proposed algorithm

Figure 3.14 (a)	Number of faces	14
	Detected faces	14
	Number of repeat faces	0
	False positive (Wrong detections)	0
	Time to execute	1.684 sec.

	Accuracy	100%
Figure 3.14 (b)	Number of faces	8
	Detected faces	8
	Number of repeat faces	0
	False positive (Wrong detections)	2
	Time to execute	1.760 sec.
	Accuracy	75%
Figure 3.14 (c)	Number of faces	7
	Detected faces	7
	Number of repeat faces	0
	False positive (Wrong detections)	2
	Time to execute	1.559 sec.
	Accuracy	71.5%
Figure 3.14 (d)	Number of faces	3
	Detected faces	3
	Number of repeat faces	0
	False positive (Wrong detections)	0
	Time to execute	1.560 sec.
	Accuracy	100%
Figure 3.14 (e)	Number of faces	10
	Detected faces	9
	Number of repeat faces	0
	False positive (Wrong detections)	3
	Time to execute	1.671 sec.
	Accuracy	70%

Figure 3.14 (f)	Number of faces	6
	Detected faces	6
	Number of repeat faces	0
	False positive (Wrong detections)	5
	Time to execute	2.526 sec.
	Accuracy	60%
Figure 3.14 (g)	Number of faces	4
	Detected faces	4
	Number of repeat faces	0
	False positive (Wrong detections)	7
	Time to execute	1.868 sec.
	Accuracy	42%
Figure 3.15 (i)	Number of faces	34
	Detected faces	32
	Number of repeat faces	0
	False positive (Wrong detections)	10
	Time to execute	2.518 sec.
	Accuracy	70.5%

Table 3.1 shows the performance evaluation of the proposed algorithm and the overall accuracy of the algorithm is found out to be 73.68%.

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# FACE RECOGNITION

### 4.1 Introduction

Face biometrics is used by everyone every day. The face is the first defining characteristic that we use to identify someone. It is the face that is recalled when trying to remember what someone looks like. We use it, and eventually come to depend on it, for recognition. We carry photo IDs that we show as proofs of identity. On the cards are pictures of our face. Our trust in our ability to judge if we know someone by his/her face can also fool us as well. We have all at one time or another thought we recognized someone's face, only to have it not be the person we thought. For many people, including parents, twins present a unique problem. Some twins can be so similar that even the parents may need to identify them by some other means. The human brain is complex and, some would argue, the most powerful computer in the world. It has specialized functions for senses, but even it can be fooled. Not surprisingly, the use of face biometrics for identification is often questioned. Face recognition is a non-intrusive method, and facial attributes are probably the most common biometric features used by humans to recognize one another. Even the ability to merely detect faces, as opposed to recognizing them, can be important. Detecting faces in photographs for automating color film development can be very useful, since the effect of many enhancement and noise reduction techniques depends on the image content. Although it is clear that people are good at face recognition, it is not at all obvious how faces are encoded or decoded by the human brain. Human face recognition has been studied for more than twenty years. Unfortunately developing a computational model of face recognition is quite difficult, because faces are complex, multi-dimensional visual stimuli. Therefore, face recognition is a very high level computer vision task, in which many early vision techniques can be involved [4.1, 4.2].

The image of a face changes with facial expression, age, viewpoint, illumination conditions, noise etc. The task of a face recognition system is to recognize a face in a manner that is as independent as possible of these image variations. Furthermore, the human face is not a unique, rigid object. Indeed, there are numerous factors (shown in section 4.2) that cause the appearance of the face to vary. Variation in the facial appearance can be categorized into two

groups: intrinsic factors and extrinsic. (1) Intrinsic factors are due purely to the physical nature of the face and are independent of the observer. These factors can be further divided into two classes: intrapersonal and interpersonal. (a) Intrapersonal factors are responsible for varying the facial appearance of the same person, some examples being age, facial expression and facial paraphernalia (facial hair, glasses, cosmetics, etc.). (b) Interpersonal factors, however, are responsible for the differences in the facial appearance of different people, some examples being ethnicity and gender. (2) Extrinsic factors cause the appearance of the face to alter via the interaction of light with the face and the observer. These factors include illumination, pose, scale and imaging parameters (e.g., resolution, focus, imaging, noise, etc.) [4.3]. With the help of facial expression we can read the emotion, intention etc these are the most powerful, natural, and immediate means for human beings to communicate. Facial expression carries crucial information about the mental, emotional and even physical states of the conversation. Next generation of human can implement the computer interfaces. So with the help of computers, we can recognize facial expressions and respond to the emotions of humans accordingly enable better human-machine communication development of information technology. Recognition of facial expression in the input image needs two functions: locating a face in the image and recognizing its expression. We believe recognition of human facial expression by computer is a key to develop such technology. In recent years, much research has been done on machine recognition of human [4.4].

## **4.2 Face Recognition System**

Generalized face recognition system is shown in figure 4.1, which have different modules; Sensor, pre-processing, feature extraction, template generator, post-processing etc. A biometric system is essentially a pattern recognition system that acquires raw biometric data from a person using single or multi sensor, and do some pre-processing on that data, and extracts features using feature extraction then generate the template, and match the output image (which is got after post-processing) to store template in the database, and executes an action based on the result of a comparison.

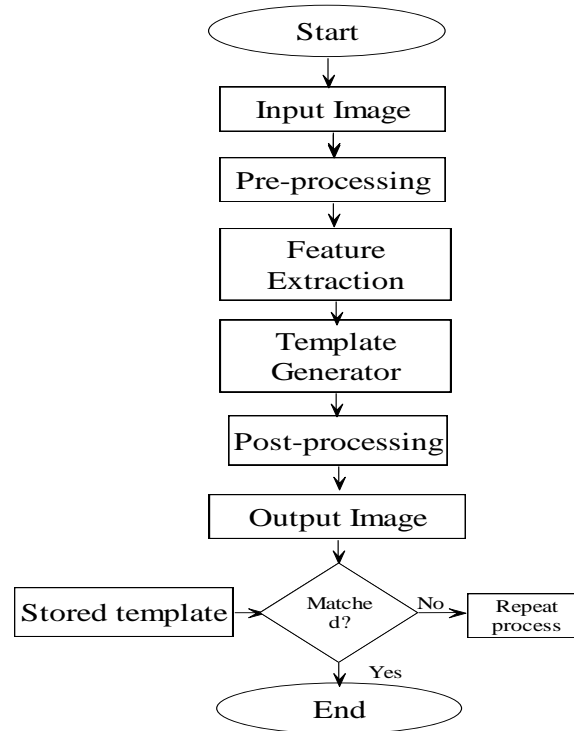


Figure 4.1 Generalized Flow Chart of Face Recognition Technique [4.5]

#### 4.2.1 Sensor

In Face recognition system a single or multi sensor system is used to capture an image or acquire all necessary data, like facial features, expressions etc. It is the module where the face image under consideration is presented to the system. An acquisition module can take an image in several different environments.

#### 4.2.2 Pre-processing

In pre-processing module, following steps are carried out to pre-process the captured image. It gets the samples ready for the forthcoming blocks, reducing the noise and even transforming the original signal to a more readable one. An important property of this block is that it tries to reduce lightning variations among pictures. In this case, samples are first resized to standard dimensions according to a requirement of  $N*N$  pixels.

The pre-processing process may involve number of steps is given below.

- i. Image size Normalization
- ii. Histogram Equalization

- iii. Enhancement
- iv. Median Filtering
- v. High pass filtering
- vi. Background removal
- vii. Translational and rotational normalization
- viii. Illumination normalization

### **4.2.3 Feature Extraction Module**

After pre-processing, we get enhanced face image, which is presented to extract the important features in order to find the key features that are going to be used for classification. In other words, vector feature or key feature which is sufficient for representing a face image is extracted [4.5].

### **4.2.4 Template Matching**

Various methods are employed to match templates against enrollment templates assigning confidence levels to the strength of each match attempt. If the score surpasses a predefined level, the comparison is deemed a match. In many cases, a series of images is acquired and scored against the enrollment, so that a user attempting 1:1 verification within a facial scan system may have 10 to 20 match attempts taking place within 1 to 2 seconds. This sets facial – scan apart from most other biometrics.

### **4.2.5 Post-processing**

After completing the above steps, post-processing of the image is carried out. In post-processing, elements that are not used in comparison algorithms are discarded in template to reduce the file size [4.5].

## **4.3 Challenges involved in Face recognition**

At the time of face recognition, a face recognition system encounters various problems during the recognition process due to complexity of face. It is possible to classify a face recognition system as either ‘robust’ or ‘weak’ based on its recognition performances under these circumstances. The objectives of a robust face recognition system are given below:

### **4.3.1 Scale invariance**

This may happen due to focal distance between the face and the camera. As this distance becomes lesser, the face image gets bigger.

### **4.3.2 Shift invariance**

The same face can be presented to the system at different perspectives and orientations.

### **4.3.3 Illumination invariance**

Face images of same person can be taken under different illumination conditions such as, the position and the strength of the light source can be modified.

### **4.3.4 Noise invariance**

A robust face recognition system should be insensitive to noise generated by cameras. Also, it should function under partially occluded images.

## **4.4 Characteristics of Face Recognition**

Basically, a human physiological or behavioral trait is used as a biometric characteristic as long as it satisfies the following requirements [4.6]:

4.4.1 Universality (Everyone should have it),

4.4.2 Distinctiveness (No two should be the same),

4.4.3 Permanence (It should be invariant over a given period of time)

4.4.4 Collectability (Could be collected easily).

4.4.5 In the real life applications, three additional factors should also be considered

4.4.5.1 Performance (accuracy, speed, resource requirements),

4.4.5.2 Acceptability (it must be harmless to users) and

4.4.5.3 Circumvention (it should be robust against various fraudulent methods)

Although many researches in biometric recognition have demonstrated that the best biometric solutions nowadays are those combining at least two biometric traits, also called multimodal biometric systems, human face have been a subject of interest to a growing number of researches in biometric recognition over the recent years. The reasons being that, not only does the human face meet the above criteria of a good human biometric trait, but also face recognition systems are useful in many applications including public security, law

enforcement and commerce, such as mug-shot database matching, identity authentication for credit card , passport and driver license, access control, information security, and intelligent surveillance. In fact, face images can be captured at a distance without any cooperation from the user. Therefore, face recognition technologies need an ongoing improvement in order to fit the needs of their broad application domains [4.7].

A number of approaches for face recognition and classification have been proposed in the literature. These can be classified as Principal Components Analysis (PCA) [4.8, 4.9, 4.10, 4.11, 4.12], Linear Discriminant Analysis (LDA) [4.5, 4.11, 4.12, 4.13, 4.15], Independent Components Analysis (ICA) [4.12, 4.13, 4.14, 4.16, 4.17], Discrete Cosine Transform (DCT) [4.19, 4.20, 4.21, 4.22, 4.23], Neural Network (NN) [4.11, 4.12, 4.24, 4.25, 4.26, 4.5, 4.27], Wavelet based [4.27, 4.28, 4.29], Hidden Markov Model (HMM) [4.30, 4.28, 4.29, 4.31], Elastic Branch Graph Method (EBGM) [4.18, 4.31], and Local Binary Pattern (LBP) [4.32]. Techniques like PCA and LDA treat the face image as a vector in a high-dimensional space and derive a lower dimensional representation (in the case of PCA) or a discriminatory representation (in the case of LDA). LDA provides a better performance but is computationally more intensive compared to feature-based approaches. Also, the performance of data analysis techniques depends on the training data. Most of the recognition research is performed on gray-scale datasets. Color is not taken into consideration in the majority of these studies. We have compared recognition rates between different traditional and new face recognition methods, and attempts to identify the role of color in face recognition. We also argue that color could have a significant impact on face recognition performance and should be a factor in face recognition technologies [4.33]. Face recognition is one of the few biometric methods that possess the merits of both high accuracy and low intrusiveness. It has the accuracy of a physiological approach without being intrusive. While network security and access control are it most widely discussed applications, face recognition has also proven useful in other multimedia information processing areas [4.24].

## **4.5 Face recognition Techniques**

Figure 4.2 shows various Face recognition techniques which can be classified into four categories based on the way of representation of a face [4.32].

### **4.5.1 Appearance based**

#### 4.5.2 Image based approach

#### 4.5.3 Feature based

#### 4.5.4 Model based

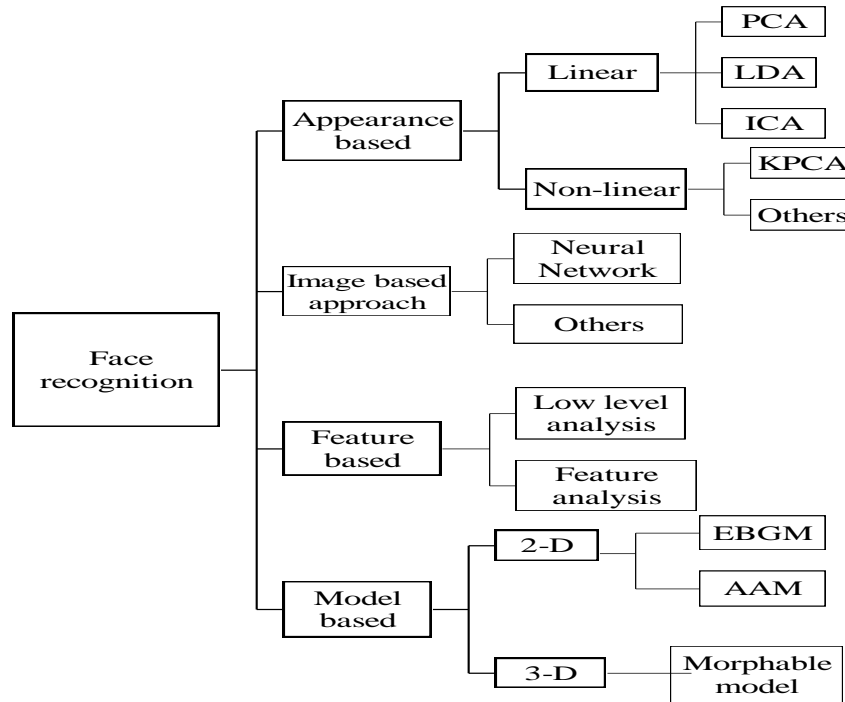


Figure 4.2 Face Recognition Techniques

Face Recognition have four major research groups which propose four different approaches to the face recognition technique, in which largest group [4.33, 4.34, 4.35] is dealt with facial characteristics which are used by human beings in recognizing individual faces. The second group [4.38, 4.39, 4.40, 4.41, 4.42] performs human face identification based on feature vectors extracted from profile silhouettes. The third group [4.37, 4.38] uses feature vectors extracted from a frontal view of the face. The fourth group depends upon model in 3-D and 2-D. These four different approaches to the face recognition are discussed in following section.

#### 4.5.1 Appearance Based

The first method is Appearance based or based on information theory concepts, in other words, on the principle component analysis (PCA) method. In this approach, the most relevant information that best describes a face is derived from the entire face image. Based on the Karhunen-Loeve expansion in pattern recognition, M. Kirby and L. Sirovich have shown

that any particular face could be economically represented in terms of a best coordinate system that they termed "Eigen-faces"[4.35, 4.36]. These are the Eigen functions of the averaged covariance of the ensemble of faces. Later M. Turk A. Pentland proposed a face recognition method based on the Eigen-faces approach [4.43].

#### **4.5.2 Feature Based**

The second method is Feature based, from which we extract feature vectors from the basic parts of a face such as eyes, nose, mouth, and chin. In this method, with the help of deformable templates and extensive mathematics, key information from the basic parts of a face is gathered and then converted into a feature vector. L.Yullie and S. Cohen [4.41] played a great role in adapting deformable templates to contour extraction of face images.

#### **4.5.3 Image based**

The third method is based on Image based method, in which we trained the database using learning method i.e. called Neural Network. The Self organizing map is the best known and widely used learning algorithm in training multilayer Perceptrons (MLP). Alaa Eleyan [4.11] et.al, plays great role in developing PCA and LDA algorithms using neural networks.

#### **4.5.4 Model Based**

The fourth method is Model based, in which we have 2-D, 3-D based method. In model based method the 2-dimension or 3-dimension of EBGM, Active appearance model (AAM) etc are discussed.

Now that we know what constitutes a facial image and how a face can be imaged, we need to know what types of algorithms are used. The algorithms used to match and enroll a face fall into the following categories:

4.5.1.1 Independent Component Analysis (ICA)

4.5.1.2 Linear Discriminant Analysis (LDA)

4.5.1.3 Eigen Face or Principle Component Analysis (PCA)

4.5.2.1 Artificial Neural Network (ANN)

4.5.3.1 Discrete Cosine Transform (DCT)

4.5.3.2 Wavelet based

4.5.4.1 Hidden Markov Model (HMM)

4.5.4.2 Elastic Bunch Graph Matching (EBGM)

#### **4.5.1.1 Independent Component Analysis (ICA)**

ICA is well known technique that is useful to extract statistically independent signals from mixed signals and also extract image features for face recognition. An ICA based face recognition method assumes that a facial image can be represented by a linear combination of statistically independent sources. It is well known that ICA better represents a variety of data distributions than PCA. Thus, ICA techniques have been popularly applied lately to the problem of face recognition, especially for face recognition under variations of illumination, pose and facial expression. ICA is a general framework of PCA to maximize a degree of independence for source signals using higher order statistics. Till now, ICA is applied to blind source separation, but it can be also used for feature extraction. Bartlett and Sejnowski regarded the source signal of a set of image data as an efficient code for image description. They investigated the utility of independent component encoding in comparison with PCA based encoding. As a result, ICA has better performance than PCA for face recognition. This result is not always useful for pattern recognition due to some characteristic properties of image data. However, ICA based methods do not consider class information. Hence an ICA based method is appropriate only for data representation, and is not tuned for classification of data [4.14].

#### **4.5.1.2 Linear Discriminant Analysis (LDA)**

Linear Discriminant Analysis is also a well-known scheme for feature extraction and dimension reduction. It has been used widely in many applications such as face recognition, image retrieval, microarray data classification, etc. Classical LDA projects the data onto a lower-dimensional vector space such that the ratio of the between-class distance to the within-class distance is maximized, thus achieving maximum discrimination. The optimal projection (transformation) can be readily computed by applying the Eigen decomposition on the scatter matrices. An intrinsic limitation of classical LDA is that its objective function requires the non-singularity of one of the scatter matrices. For many applications, such as

face recognition, all scatter matrices in question can be singular since the data is from a very high-dimensional space, and in general, the dimension exceeds the number of data points. This is known as the under sampled or singularity problem [4.16].

#### **4.5.1.3 Principle Component Analysis (PCA)**

Principal component analysis (PCA), which is also known as Karhunen-Loeve (KL) transform, is a classical statistic technique that has been applied to many fields, such as knowledge representation, face recognition and image compression. The objectives of PCA are to reduce the dimensionality of the dataset and identify new meaningful underlying variables. The key idea is to project the objects to an orthogonal subspace for their compact representations. It usually involves a mathematical procedure that transforms a number of correlated variables into a smaller number of uncorrelated variables, which are called principal components. The first principal component accounts for as much of the variability in the dataset as possible, and each succeeding component accounts for as much of the remaining variability as possible. Till now, there has been an extensive literature that addresses both the theoretical aspect of the PCA method and its application aspects [4.44].

#### **4.5.2.1 Artificial Neural Network (ANN)**

Artificial neural network is a branch of artificial intelligence which has fast emerged with wide range of applications in pattern recognition and data processing. It is popular because of its adaptive learning, self organizing, real time operations and fault tolerance via redundant information coding. There are many efficient algorithms using which we can implement ANN [4.26]. ANN is a very well-known, powerful, and robust classification technique that has been used to approximate real-valued, discrete-valued, and vector-valued functions. ANN has been used in many areas such as interpreting visual scene, speech recognition, learning robot control strategies, etc [4.5, 4.25].

The ANN is made up of the following parts which are shown in figure 4.3 [4.1].

- i. Face detection and framing
- ii. ANN input level
- iii. Receptive fields
- iv. Hidden units

v. Output

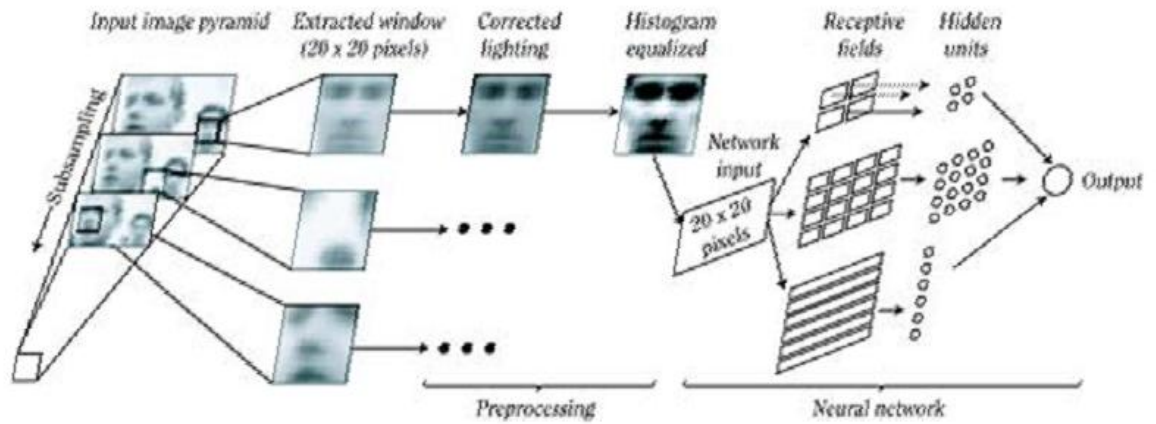


Figure 4.3 Generalized ANN for face processing

#### 4.5.3.1 Discrete Cosine Transform (DCT)

The mathematical theory of linear transforms plays a very important role in the signal and image processing area. They generate a set of coefficients from which it is possible to restore the original samples of the signal. In many situations, a mathematical operation generally known as a transform is applied to a signal that is being processed, converting it to the frequency domain. With the signal in the frequency domain, it is processed and, finally, converted back to the original domain. A mathematical transform has an important property, when applied to a signal; they generate de-correlated coefficients, concentrating most of the signal's energy in a reduced number of coefficients. The Discrete Cosine Transform (DCT) is an invertible linear transform that can express a finite sequence of data points in terms of a sum of cosine functions oscillating at different frequencies. The original signal is converted to the frequency domain by applying the direct DCT transform and it is possible to convert back the transformed signal to the original domain by applying the inverse DCT transform. After the original signal has been transformed, its DCT coefficients reflect the importance of the frequencies that are present in it. The very first coefficient refers to the signal's lowest frequency, known as the DC-coefficient, and usually carries the majority of the relevant (the most representative) information from the original signal. The last coefficient refers to the signal's higher frequencies. These higher frequencies

generally represent more detailed or fine information of signal and probably have been caused by noise. The rest of the coefficients (those between the first and the last coefficients) carry different information levels of the original signal [4.45].

#### **4.5.3.2 Wavelet based**

In numerical analysis and functional analysis, a discrete wavelet transform (DWT) is any wavelet transform for which the wavelets are discretely sampled. As with other wavelet transforms, a key advantage it has over Fourier transforms is temporal resolution i.e. it captures both frequency and location information. The first DWT was invented by the Hungarian mathematician Alfred Haar. For an input represented by a list of  $2n$  numbers, the Haar wavelet transform may be considered to simply pair up input values, storing the difference and passing the sum. This process is repeated recursively, pairing up the sums to provide the next scale, finally resulting in  $(2n - 1)$  differences and one final sum. The Haar DWT illustrates the desirable properties of wavelets in general. First, it can be performed in  $O(n)$  operations; second, it captures not only a notion of the frequency content of the input, by examining it at different scales, but also temporal content, i.e. the times at which these frequencies occur. Combined, these two properties make the Fast wavelet transform (FWT) an alternative to the conventional Fast Fourier Transform (FFT). The discrete wavelet transform has a huge number of applications in science, engineering, and mathematics and computer science. Most notably, it is used for signal coding, to represent a discrete signal in a more redundant form, often as a preconditioning for data compression [4.27].

#### **4.5.4.1 Hidden Markov Model (HMM)**

HMM are a set of statistical models used to characterize the statistical properties of a signal. HMM consist of two interrelated processes: (1) an underlying, unobservable Markov chain with a finite number of states, a state transition probability matrix and an initial state probability and (2) a set of probability density functions associated with each state [4.30]. HMM is a finite set of states, each of which is associated with a multidimensional probability distribution. Transitions among the states are governed by a set of probabilities called transition probabilities. In a particular state an outcome or observation can be generated according to the associated probability distribution. HMM views a face image as a sequence of states produced when the face is scanned from top to bottom. The embedded HMM

proposed by Nefian consists of a set of super states and each super state is associated with a set of embedded states. Super states represent primary facial regions whilst embedded states within each super state describe in more detail the facial regions. Nefian [4.30] defined five super states: forehead, eyes, nose, mouth and chin. Transitions between embedded states in different super states are not allowed. The observation sequence extracted from a test image is input to all of the trained HMMs associated with each person and the conditional probability given by each HMM is calculated. The identity of the input face is determined by the HMM which gives the highest probability. In implementation of HMM based face recognition, a face image is divided into a series of overlapping image blocks. While an observation vector is extracted from each image block, the observation sequence for the HMM can be generated by concatenating the observation vectors. A simple candidate for observation vector could be the concatenation of the grey values of pixels in the image block. However, gray values are very sensitive to image variation due to illumination, translation and rotation. Moreover, since the dimension of the observation vectors is high, much computation is required. Image transform techniques will be helpful to make the model more robust and perform feature dimension reduction at the same time [4.28].

#### **4.5.4.2 Elastic Bunch Graph Matching (EBGM)**

Elastic Bunch Graph Matching is an algorithm developed in which all human faces share a similar topological structure. EBGM represents faces as graphs, with the nodes positioned at fiducial points. Labeled graph is a basic object representation form for EBGM algorithm. It is composed of nodes and edges, nodes are labeled with wavelet response coefficients bundled in feature vectors and edges are labeled with distance vectors between adjacent nodes. The node labels describe the image information locally, and the edge labels encode the topological relationship of local facial feature positions. Nodes of the labeled graph are usually defined at the points which are useful for recognition; these points are called feature points. A structure vector is a concatenation of all the edge labels of a face; it describes the shape of the face. Stored model graphs can be matched to new images to generate image graphs, which can then be incorporated into a gallery and become model graphs. The assembly of some labeled graphs which are taken from different face images is called face graph bunch and it covers a wide range of possible variations of facial features, expressions, illuminations [4.18].

## 4.6 Literature Review

Rabia Jafri et.al, discussed different survey of face recognition techniques that operate on intensity images, deal with video sequences, and those which require other sensory data such as 3D information or infra-red imagery [4.3]. Rajkiran Gottumukkal et.al, presented an improved face recognition technique based on modular PCA approach and compared with conventional PCA method under varying conditions and got better results compared to conventional PCA [4.8]. Mandeep Kaur et.al, proposed a Recognition of Facial Expressions with Principal Component Analysis and Singular Value Decomposition, in which Principal Component Analysis (PCA) is implemented with Singular value decomposition (SVD) for Feature Extraction to determine principal emotions for Face Recognition [4.9]. Srinivasulu Asadi et.al, made a comparative study of face Recognition with Principal Component Analysis and Cross-Correlation Technique. They applied a different technique of face recognition on different test samples and got better results if samples are increased, then accuracy is decreased [4.10]. Alaa Eleyan et.al, compared PCA and LDA based Neural Networks for Human Face Recognition in which the PCA based system consists of PCA preprocessing followed by a FFNN based classifier (PCA-NN) and the LDA based system performs pre-processing followed by another FFNN (LDA-NN) based classifier[4.11]. Kresimir Delac et.al, presented an Independent Comparative Study of PCA, ICA, and LDA on the FERET Data Set in which they compared the three most popular appearance-based face recognition projection methods (PCA, ICA, and LDA) in completely equal working conditions regarding preprocessing and algorithm implementation [4.13]. Jieping Ye et.al, presented a Two-Dimensional Linear Discriminant Analysis, which is most widely used for dimension reduction and feature extraction using PCA, and did a comparative study of conventional LDA and 2-D LDA [4.14]. Petra Koruga et.al, reviewed Face Recognition Algorithms and their application in age estimation. This paper describes the principal component analysis (PCA), independent component analysis (ICA), elastic bunch graph method (EBGM), and linear discriminant analysis (LDA), methods used their comparison & how are they used in age estimation [4.18]. Shang-Hung Lin et.al, introduced a face recognition technology, in which they explained new information processing technology, it also shows the readers the generic framework for the face recognition system, and the variants that are frequently encountered by the face recognizer [4.24]. K.Rama Linga

Reddy et.al, implemented a face recognition system using neural network on multi-scale feature of face, in which multi-scale features are input to neural network classifier, which uses back propagation algorithm and radial function network to recognize familiar faces [4.26]. Ara V. Nefian et.al, presented a Hidden markov model (HMM) for face recognition in which 2-D coefficient of DCT as features for face recognition using HMM were used [4.30]. Hongchuan Yu et.al, compared 1D-PCA, 2D-PCA to nD-PCA, in which nD-PCA algorithm exploited a newly proposed Higher Order-Singular Value Decomposition (HO-SVD) to evaluate the validity and performance of nD-PCA [4.44].

Derzu Omaia et.al, proposed a 2D-DCT Distance Based Face Recognition using a reduced number of coefficients, and without any pre-processing step, the proposed method achieves high recognition accuracy [4.45]. Parvinder S. Sandhu et.al, introduced PCA features for Feature extraction and matching was done for the face under consideration with the test image using Eigen face coefficients [4.46]. H. B. Kekre et.al, proposed Eigenvectors of Covariance Matrix using Row Mean and Column Mean Sequences for Face Recognition, which can be used in real time application like crowded public place etc and gives a better result comparison to normal PCA techniques [4.47]. Ross Cutler proposed a Face Recognition Using Infrared Images and Eigen-faces and compared favorably with visible light techniques and gave better results [4.48]. Juneho Yi et.al, showed Face Recognition based on ICA combined with FLD, in which independent component analysis +linear discriminant analysis (ICA+LDA) were compared and ICA+FLD, and ICA+FLD (Fisher linear discriminant) gave better output in comparison to ICA+LDA [4.49].

## **4.7 The Proposed Algorithm of Face Recognition**

We developed an algorithm with the idea of M. Turk and A. Pentland [4.43] in order to develop a face recognition system based on the Eigen-faces approach. They argued that, if a multitude of face images can be reconstructed by weighted sum of a small collection of characteristic features or Eigen pictures, perhaps an efficient way to learn and recognize faces would be to build up the characteristic features by experience over time and recognize particular faces by comparing the feature weights needed to approximately reconstruct them with the weights associated with known individuals. Therefore, each individual is characterized by a small set of feature or Eigen picture weights needed to describe and

reconstruct them. This is an extremely compact representation when compared with the images themselves.

The Eigen-face based algorithm is applied on a wide variety of images taken under different lighting conditions and with different backgrounds. The images of face also changes with facial expression, age, viewpoint, illumination conditions, noise, pose variation, hair, growing beards, glasses and cosmetics etc. The task of a face recognition system is to recognize a face in a manner that is as independent as possible of these image variations. Furthermore, the human face is not a unique, rigid object. Indeed, there are numerous factors that cause the appearance of the face to vary [4.3]. With the help of Facial expression, the emotion, intention etc can be read. These are the most powerful, natural, and immediate means for human beings to communicate. Facial expression carries crucial information about the mental, emotional and even physical states of the conversation. The complete flow chart of proposed face recognition is shown in figure 4.4.

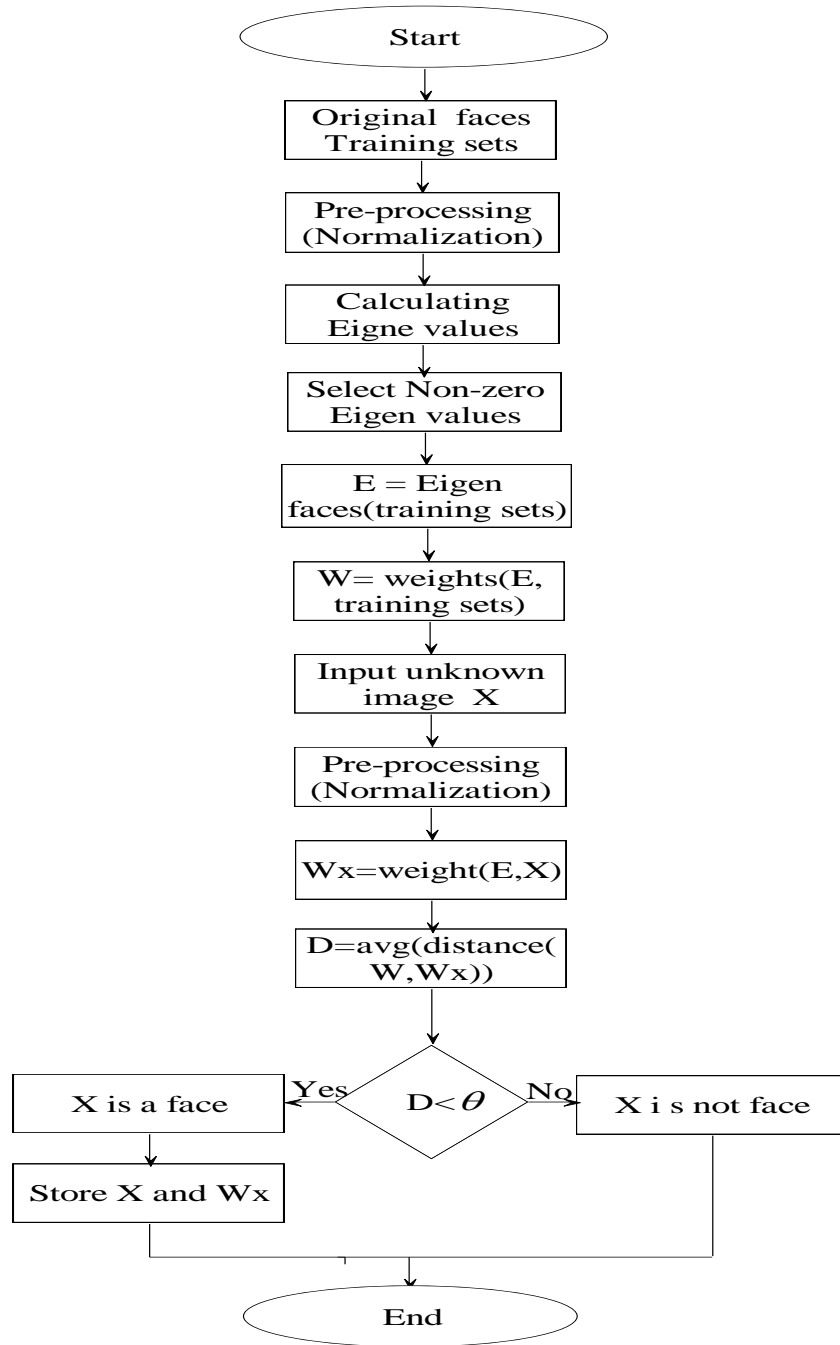


Figure 4.4 Flow-chart of Eigen based proposed algorithm

#### 4.7.1 The Eigen face approach

Eigen face method for human face recognition is remarkably clean and simple. The basic concept behind the Eigen face method is information reduction. When one evaluates even a small image, there is an incredible amount of information present. From all the

possible things that could be represented in a given image, pictures of things that look like faces clearly represent a small portion of this image space. Because of this, we seek a method to break down pictures that will be better equipped to represent face images rather than images in general. To do this, ‘base-faces’ are generated and then image being analyzed by the system is represented as a linear combination of these base faces. Once the base faces have been chosen, we have essentially reduced the complexity of the problem from one of image analysis to a standard classification problem. Each face that we wish to classify can be projected into face-space and then analyzed as a vector. A k-nearest-neighbor approach, a neural network or even a simply Euclidian distance measure can be used for classification. The technique discussed in can be broken down into the following steps:

- a. Computing the Eigen-faces.
- b. Project training data into face-space to be used with a predetermined classification method.
- c. Evaluate a projected test element by projecting it into face space and comparing to training data [4.46].

#### 4.7.1.1 Computing Eigen-face

Consider face images (X, Y), in 2-dimesional (2-D) of size  $N \times N$  array with 8-bit intensity values. These images can be thought of as a vector of dimension  $N^2$  or a point in  $N^2$ -dimensional space. A set of images therefore corresponds to a set of points in this high dimensional space. Since facial images are similar in structure, these points will not be randomly distributed, and therefore can be described by a lower dimensional subspace. Principal component analysis gives the basis vectors for this subspace (which is called the “face space”). Each basis vector is of length  $N^2$ , and is the eigenvector of the covariance matrix corresponding to the original face images.

An  $N \times N$  matrix A is said to have an eigenvector X, and corresponding Eigen-value  $\lambda$ , if

$$AX = \lambda X \quad (4.1)$$

Evidently, Eq. (4.1) can hold only if

$$\text{Det}[A - \lambda I] = 0 \quad (4.2)$$

This, if expanded out, is  $N_{th}$  degree polynomial in  $\lambda$  whose roots are the eigenvalues. This

proves that there are always N (not necessarily distinct) Eigen values. Equal Eigen values coming from multiple roots are called "degenerate".

Let the training set of face images are  $I_1 I_2 \dots I_M$  then, the average of the set is defined by

$$\Psi = \frac{1}{M} \sum_{n=1}^M I_n \quad (4.3)$$

Each face differs from the average by the vector  $\Phi_i = I_i - \Psi$ . The Co-variance matrix

$$C = \frac{1}{M} \sum_{n=1}^M \Phi_n \Phi_n^T \quad (4.4)$$

has a dimension of  $N^2 \times N^2$ . Determining the eigenvectors of C for typical sizes of N is intractable. Fortunately, we determine the eigenvectors by solving a  $N \times N$  matrix.

A set of original, gray level, training, normalized and average image is shown in Figure 4.5 (a) (b) (c) (d) & (e) respectively.

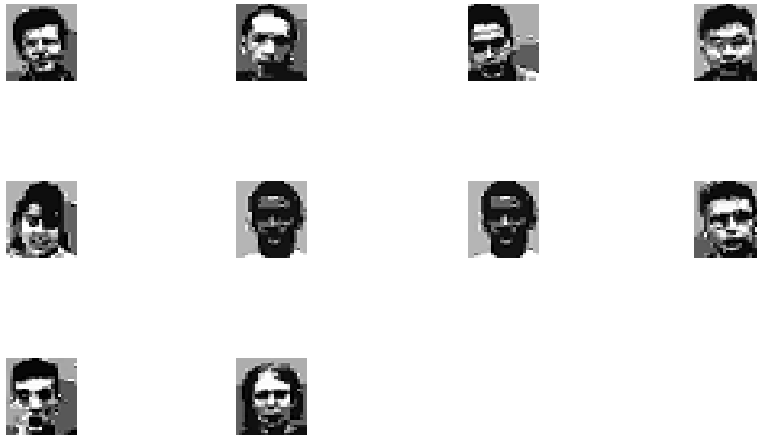


(a)

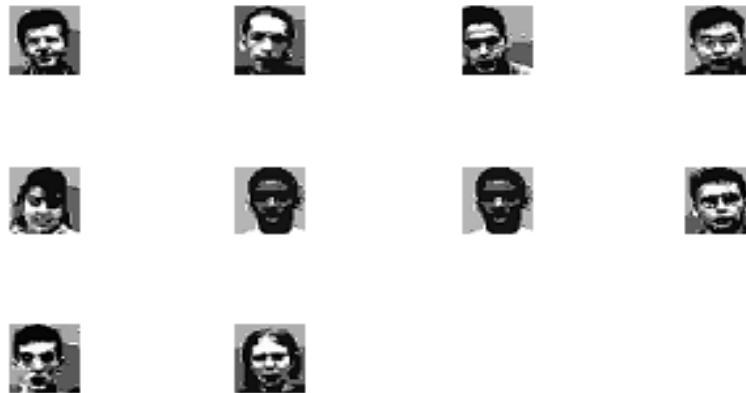


(b)

### Training set



### Normalized Training Set



(d)

Mean Image



(e)

Figure 4.5 (a) RGB Image database with different condition and illumination, (b) Gray size database of Original Image, (c) Training Set of original Image, (d) Normalized Training Set (e) Mean Image of normalized Training Set.

We need a computationally feasible method to find these eigenvectors. If the number of data points in the image space is less than the dimension of the space ( $N < N^2$ ), there will be only  $N-1$ , rather than,  $N^2$  meaningful eigenvectors. The remaining eigenvectors will have associated Eigen values of zero [4.43, 4.48].



Figure 4.6 Eigen-faces of Training Sets

#### 4.7.2 The Mathematical approach

In mathematical terms, distribution of faces, or the eigenvectors of the covariance matrix of the set of face images, treating an image as point (or vector) in a very high

dimensional space is follow. The eigenvectors are ordered, each one accounting for a different amount of the variation among the face images. These eigenvectors can be thought of as a set of features that together characterize the variation between face images. Each image location contributes more or less to each eigenvector, so that it is possible to display these eigenvectors as a sort of ghostly face image which is called an "Eigen-face". Sample face images and the corresponding Eigen-faces are shown in Figure 4.5(c) and Figure 4.6 respectively. Each Eigen-face deviates from uniform gray where some facial feature differs among the set of training faces. Eigen-faces can be viewed as a sort of map of the variations between faces.

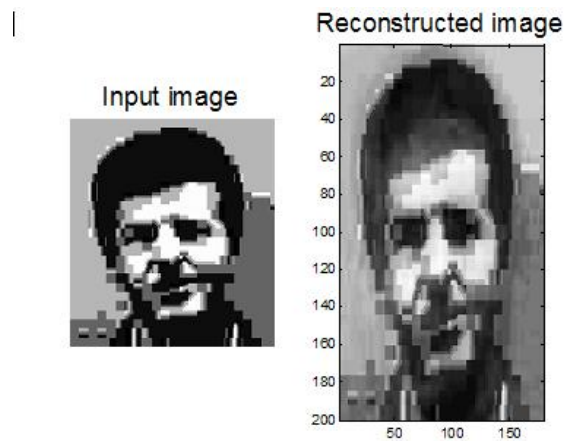


Figure 4.7 Input image and reconstructed Image

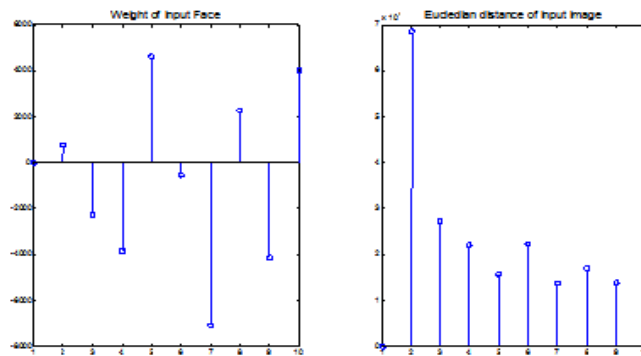


Figure 4.8 Weight and Euclidean Distance of Input image

Each individual face can be represented exactly in terms of a linear combination of the Eigen-faces. Each face can also be approximated using only the "best" Eigen-faces, those that have the largest Eigen values, and which therefore account for the most variance within the

set of face images. The best M Eigen faces span an M-dimensional subspace which we call the "face space" of all possible images.

A new face image ( $\mathbf{r}$ ) is transformed into its Eigen-face components (projected onto "face space") by a simple operation as shown in figure 4.7.

$$W_k = u_k^T (\Gamma - \Psi) \quad (4.5)$$

for  $k = 1, \dots, M$ . This describes a set of point by point image multiplications and summations, operations performed at approximately frame rate on current image processing hardware. The weights form a feature vector,

$$\Omega^T = [W_1 \ W_2 \dots \dots \dots \ W_M] \quad (4.6)$$

describes the contribution of each Eigen-face in representing the input face image, treating the Eigen-faces as a basis set for face images. The feature vector is then used in a standard pattern recognition algorithm to find which of a number of predefined face classes, if any, best describes the face. The face classes  $Q_j$  can be calculated by averaging the results of the Eigen-face representation over a small number of face images (as few as one) of each individual. In the proposed face recognition system, face classes contain only one representation of each individual.

Classification is performed by comparing the feature vectors of the face library members (as shown in figure 4.8) with the feature vector of the input face image. This comparison is based on the Euclidean distance between the two members to be smaller than a user defined threshold  $\epsilon_k$ . This is given in Eq. (4.7).

$$\frac{\|\Omega - \Omega_k\|}{\|\Omega_k\|} \leq \epsilon_k \quad (4.7)$$

If the comparison falls within the user defined threshold, then face image is classified as "known", otherwise it is classified as "unknown" and can be added to face library with its feature vector for later use, thus making the system learning to recognize new face images [4.11, 4.43].

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## CHAPTER 5

### Result and Discussion

The existing algorithm and proposed algorithm based on HSV are compared based on various parameters. Table 5.1 and Table 5.2 show the results of existing and proposed algorithm, respectively. It is observed that the proposed algorithm is giving better results than the existing one in terms of accuracy.

Table 5.1 Parameters of Existing algorithm based on HSV

Training Images	Faces	Correct	False Positive	False Negative	Accuracy (in %)
Training Image1	21	21	1	0	100
Training Image2	23	21	3	2	91
Training Image3	23	22	0	1	96
Training Image4	24	22	0	2	92
Training Image5	24	23	0	1	96
Training Image6	24	23	0	1	96
Training Image7	22	19	1	3	86
<b>Total</b>	<b>161</b>	<b>151</b>	<b>7</b>	<b>10</b>	<b>95</b>

Table 5.2 Parameters of Implemented algorithm based on HSV

Training Images	Faces	Correct	False Positive	False Negative	Accuracy (in %)
Training Image1	14	14	0	0	100
Training Image2	8	8	2	0	100
Training Image3	7	7	2	0	100
Training Image4	3	3	0	0	100
Training Image5	10	9	1	1	90
Training Image6	6	6	7	0	100
Training Image7	4	4	7	0	100
Training Image8	34	32	4	2	94
Training Image9	13	12	5	1	93

Training Image10	7	7	5	0	100
Training Image11	7	7	5	0	100
Training Image12	9	8	6	1	90
Training Image13	6	6	4	0	100
Training Image14	28	26	6	2	93
Training Image15	9	9	4	0	100
Training Image16	3	3	1	0	100
<b>Total</b>	<b>168</b>	<b>161</b>	<b>59</b>	<b>7</b>	<b>97.5</b>

The Comparative analysis of proposed Eigen-face based algorithm with respect to various algorithms like (2D-PCA) 2-dimensional principle component analysis, (DTM) Deformable Template Matching and (ACRT) Adaptive Concentric Ring Template is done and Table 5.3 shows that better results are achieved.

Table 5.3 Comparison of various existing algorithms and proposed Eigen-face algorithm

<b>Methods</b>	<b>Rotation angle (in degree)</b>	<b>Matching Rate</b>	<b>Matching Time (in sec.)</b>
2DPCA	0	88	2.35
DTM	0	91	1.98
ACRT	0	86	3.48
<b>Eigen-face</b>	<b>0</b>	<b>100</b>	<b>2.01</b>

## Conclusion

This dissertation proposes an algorithm with good accuracy and running time for face detection based on HSV skin color segmentation. Though there are some cases of false positives, the overall performance of the proposed algorithm is quite satisfactory. The training images on which the algorithm is tested are natural images taken under uncontrolled conditions. The efficiency of the face detection was found to be 97.5%. In addition, HSV color model is chosen because it is fast and compatible with human color perception. Hence it can be concluded that the present algorithm demonstrates better performance with respect to speed, low false positive rate and high accuracy.

In case of Face recognition, we compared the parameters of face recognition with existing one like 2D-PCA, DTM, and ACRT techniques and the matching rate as well as matching time of our proposed algorithm is good with respect to existing one and achieved better results.

We compared the few techniques used in face recognition and some pros and cons of those techniques are achieved. In thesis, we proposed an Eigen face based recognition and based on this recognition, we also proposed a detection technique using HSV component, and these techniques are successful in detection as well as recognition.

## **Future Scope**

- With the help of DSP processor we can speed up the process of face detection and face recognition techniques.
- We can implement this technique in real time application.
- We can also implement this technique with hardware.