CHAPTER I
OVERVIEW OF SKIN DETECTION TECHNIQUES

1.1. Overview

This thesis deals mainly with the comparative study of the performance analysis of various human skin detection approaches and design of a new novel class of human skin detection approaches applicable to human face detection in color images. The major contributions of this thesis are that the development of efficient algorithms for detection of human skin regions in color images, classifying each image pixel into skin and non-skin pixels using Piece-wise Linear Decision Boundary (PLDB), Mixed Piece-wise Linear Decision Boundary (MPLDB), Bayesian, Gaussian, Mixed Gaussian (MG) skin classification. These algorithms operates with the help of eighteen different chrominance spaces to improve the performance of human skin detection results in comparison with other conventional human skin detection techniques in general and for human face detection techniques, in particular.

A considerable set of implementations on various research works on Automatic Human Skin Detection Techniques in Color Images in order to perform comparative analysis. Experiments are performed to analyze the performance of the eighteen different color spaces on human skin detection and to compare fifty different human skin classification algorithms. The commonly available techniques such as template matching, facial feature detection and edge detection techniques are used to verify the presence of human facial region in the color images. During the course of this research, an additional set of five algorithms got evolved which are found to be very useful in terms of their comparative performance with the rest of most popular skin detection algorithms.
This Chapter discusses the research issues in the human skin detection arena necessary for detecting human skin regions in images and also to verify the presence of human face regions in the color images given. The human skin detection has many useful applications for biometrics science such as face recognition, video surveillance and security control systems, content-based image retrieval, video conferencing and intelligent human-computer interfaces. Efficient fast automatic techniques are required for detecting skin regions in different type of color images. The focus of the thesis is concentrated on providing the description, comparison and evaluation results of popular methods for skin modeling and developing a new class of human skin detection techniques suitable for face detection in color images based on the requirements identified during the study and analysis of various human skin detection and face detection approaches.

Automatic Human Skin Detection (AHFD) is a standard two-class problem, taking a color image as input and producing a binary image. Pixel-based skin detector works by sequentially and independently analyzing each image pixel’s color and labeling the pixel as skin or non-skin. Some of the human skin detectors are capable of producing not binary, but a continuous output, viz., skin likelihood image, usually normalized to [0, 1]. In this case skin map turns into one-channel skin likelihood image, which can be transformed into skin map by using adaptive threshold [54]. The Automatic Human Skin Detection (AHSD) is also called Automatic Human Skin Segmentation.

Automatic Human Face Detection (AHFD) is a computer technology that determines the presence of human faces in arbitrary (digital) color images. AHFD detected facial features like eyes, nose and mouth and ignores other objects like buildings, trees and bodies. It can be regarded as a specific case of object-class
detection and is a more general case of face localization. In automatic human face localization (AHFL), the task is to find the locations and sizes of a known number of faces. In AHFD, one does not have this additional information. Early face-detection algorithms focused on the detection of frontal human faces, whereas newer algorithms attempt to solve the more general and difficult problem of multi-view face detection. The detection of faces are either rotated along the axis from the face to the observer (in-plane rotation), or rotated along the vertical or left-right axis (out-of-plane rotation), or both.

AHFD is the essential front end of any face recognition system, which locates and segregates facial regions from cluttered images, either obtained from video or still images. Most of the current face detection systems presume that faces are readily available for processing. However, in reality, images used to contain not just faces but also some other objects like background, trees and buildings. Therefore, a system is needed to detect, locate and segment faces in cluttered images, so that these segmented faces can be given as input to human face recognition systems.

The work reported in this thesis concentrates mainly on the automatic human skin detection and to some extent on face detection problem, but it can be extended to face recognition also. The dissertation investigates the features and use of human skin detection to locate facial regions in color images. Specifically, human skin detection techniques based on new novel piece-wise linear decision boundary, mixed piece-wise linear decision boundary and mixed Gaussian skin classification algorithms are developed, analyzed, and applied to a variety of mug-shot color face images. Many of the standard human skin segmentation algorithms like piece-wise linear decision boundary, Gaussian Bayesian skin classifiers etc., produced false
positives (FP) and false negatives (FN). To overcome these problems and to improve the performance of skin detection results, new skin segmentation algorithms are introduced including the features of eighteen color spaces operated on mixed piece-wise linear decision boundary, and mixed Gaussian color models besides the Bayesian color models. Some analysis methods are employed to compare the new algorithms with the standard algorithms and their performance is compared to established skin detection techniques for each of the imaging modalities. The performance measures used to compare the performance of human skin detection algorithms are correct detection rates (CDR) and false detection rates (FDR).

The accomplishments of this work include:

- Discussing the features of human skin detection techniques.
- Discussing various existing human skin segmentation approaches to color face images.
- Developing new skin detection techniques based on explicitly defined skin region, Gaussian and Bayesian skin color models.
- Performing subjective analysis of the new human skin segmentation algorithms to illustrate their behavior when applied to face detection in color images.

1.2. Organization of the Thesis

This dissertation begins with a review of human skin segmentation techniques in Chapter II, followed by the discussion about commonly used human skin and face detection techniques in Chapter III. Chapter IV discussed the literature survey of human skin detection and face detection techniques. In this research work on "A Comparative Analysis of the Automatic Human Skin Detection Techniques in
Color Images and Their Applications to Face Detection”, a considerable set of implementations on various research works on Automatic Human Skin Detection Techniques in Color Images are done in order to perform comparative analysis. Experiments are performed to analyze the performance of the eighteen different color spaces on human skin detection and to compare fifty different human skin classification algorithms. The commonly available techniques such as template matching, facial feature detection and edge detection techniques are used to verify the presence of human facial region in the color images. During the course of this research, an additional set of five algorithms got evolved which are found to be very useful in terms of their comparative performance with the rest of the most popular skin detection algorithms.

The limitations encountered in the behavior of these standard human skin detection techniques are identified that motivated the formulation and development of new class of human skin segmentation techniques recorded in Chapter V of this work. Next, new human skin detection techniques that overcome the weakness of these algorithms applied for color face images are introduced in Chapter V and the potential merits and demerits of these techniques are discussed. The details of the human skin detection approaches identified in this thesis are given below in detail.

Technique 1: **Face Detection using Statistical Models and Explicitly-defined Skin Region Classifiers - FDSE**

A considerable set of experiments are performed to analyze the effects of color space selection on skin segmentation and to compare different skin classification algorithms using Bayesian, Gaussian and piece-wise linear classifier using YCgCr color space. The new derived color space from YCbCr color performs well for skin detection techniques. The commonly used skin color classification
methods are used. The results obtained using the three skin classification algorithms are compared. The Bayesian color model produces better results than Gaussian model. The skin detection method using linear decision boundary classifier in YCgCr color space produces the best results than both Gaussian and Bayesian color models. Lip region detection is done to detect facial features using R/G and R/B color models.

YCgCr color space has a maximum CDR (Correct Detection Rate) of 96.16 when used with Gaussian color model. It has a maximum CDR (Correct Detection Rate) of 98.74 when used with Bayesian color model. The piecewise linear decision boundary classifier applied to YCgCr color space producea still higher classification rates than all other classifiers for images with good illumination conditions with the correct detection rate of 98.76.

[84].

Technique 2: Face Detection in Color Images using Pixel based Skin Color Detection – (FDPS)

A comprehensive study of three important issues of the color pixel classification approach to skin segmentation, namely color representation, color quantization, and classification algorithm is presented. The skin segmentation algorithms use eight different color representations, seven different levels of color quantization, and nine different color pixel classification algorithms. The selection of the best color space for skin detection in color images is important in many computer vision areas and FDPS presents a comparative study on the pixel-based skin color detection techniques using eighteen color spaces, six skin color pixel classification algorithms and one face detection algorithm, namely template
matching technique. The limitations of these methods are that pinpointing the exact face location was more difficult whenever the color characteristics of the background are similar to that of the skin, as there will be more falsely detected background regions with skin-color appearance. Besides these problems skin detection techniques requires face verification techniques. In order to pinpoint the exact face location whenever the color characteristics of the background are similar to that of the skin (which might include falsely detected background regions with skin-color appearance as skin), eighteen chrominance spaces have been used to segment human skin regions using Explicit skin cluster method, Gaussian and Bayesian models [83]. HSV and YCbCr color spaces produce better results even while the color characteristics of the background are similar to that of the skin. The template matching is used to verify the face regions in the color image [12].

Technique 3: Skin Color-based Human Face Detection using Mixed Piece-wise Linear Decision Boundary and Template Matching Classifier - FDMP

Every color space has its own limitations in segmenting the human skin regions. For example, RGB color space is not suitable for characterizing skin-color since in the RGB color space, the triple component (r, g, b) represent not only color but also luminance; the normalized RGB color space cannot differentiate the human skin and the clothes if the human skin color and clothe color are the same and YCbCr and other CRT color spaces used for segmenting human skin are intended for use under strictly defined lighting conditions within closed systems. FDMP proposes a novel method to detect a face from an image using mixed piece-wise linear decision boundary and template matching classifiers. A skin-color map is derived and used on the chrominance component of the input image to detect pixels
with skin-color appearance. **FDMP** uses eighteen different color spaces. The color spaces like HSV, YCbCr and CIE produce better results. **FDMP** is a unique method which combines the skin detected output results obtained from different color spaces using explicit skin cluster methods to get better human skin detection results [127].

**Technique 4: Face Detection in color images using Mixed Gaussian color models – FDMG**

Many existing skin detection methods only work well on simple input images with a complex background and frontal view of the person's face. To cope with more complicated images and conditions, many more assumptions will have to be made. In fact, there is generally little or no constraint on the number, location, size, and orientation of human faces in image and video databases and the background of these images and video scenes is usually complex [86]. The limitation of the most parametric skin color models like Gaussian methods is that they ignore the non-skin color statistics. This, together with dependence on skin cluster shape results in higher false positives rate. **FDMG** proposes a skin segmentation approach and give a comparative analysis of few mixed Gaussian color models using four color spaces. Five combinations of two color space are used in Gaussian model. This new human face detection algorithm involves two stages: applying mixed Gaussian skin color model to segment human skin regions and using template matching technique to detect human face regions in color images. RGB color space will not differentiate the human skin color and the clothes when skin color and clothe color are the same. YIQ color space produces better results than RGB. YCbCr color space produces better results than RGB and YIQ. But YUV color space produces the best results when used to segment skin regions in color images using mixed Gaussian color models. These inferences are derived from the
visual effects and the correct detection rates. In this paper, a novel face detection based on mixed Gaussian color model technique is developed and implemented using face images with different pose, illumination conditions. The Gaussian color model uses YCbCr, YUV, YIQ, YES and other combination of color space, RGB-YUV, RGB-YCbCr, RGB-YIQ, YCbCr-YUV and YCbCr-YIQ. This forms the final nine skin classification algorithms. The Gaussian models used with RGB Color Space produces the maximum skin detection rate of 99.8. The YCbCr color space has the maximum detection rate of 97.4. Similarly, YIQ and YUV have the maximum detection rate of 97.7 and 95.8 respectively. But when two color spaces are combined with Gaussian color models better results are obtained. The combination of RGB and YUV has the maximum skin detection rate of 99.9. Similarly if YCbCr and YUV are combined, it has the maximum detection rate of 99.9. All the other combinations have not produced better results than these two combinations. Experiments with variety of images proves that this technique of detecting face images is more efficient and useful. The method is good because it reduces much of the computational work [85].

Technique 5: Human Face Detection in Color Images using Skin Color and Template Matching Models for Multimedia on the Web (FDTM)

Parametric models can be really slow (like mixture of Gaussians) in both training and work, and their performance depends strongly on the skin distribution shape resulting in false positives rate. The human skin detection technique FDTM is tested on color face database. FDTM proposes four human skin detection strategies using piece-wise linear decision boundary classifier algorithms. The piece-wise linear decision skin classifier algorithms use fixed threshold values which will not be applicable for all kinds of color face databases. In order to obtain good
results, adaptive threshold values are obtained using mean and standard deviation of each image pixels. The first skin detection technique uses the mean and standard deviation of a pixel values to determine the adaptive threshold values. The pixel in any color face image is classified as a skin pixel if the value of Cb and Cr are in the range from minimum and maximum threshold values. With appropriate threshold values of Cb, Cr and α, the color face images are transformed to a binary image showing skin regions and non-skin regions.

The skin detection algorithms detect not only skin regions but also the skin region of a human which are not covered by the clothes wear by the human. Pinpointing the exact face location is more difficult whenever the color characteristics of the background are similar to that of the skin, as there will be more falsely detected background regions with skin-color appearance. Besides these problems skin detection techniques requires face verification techniques.

The second skin detection method uses two color spaces to segment a skin region in the color image given. YCbCr and YIQ are commonly used color spaces in televisions. According to this method, a pixel is classified as a skin pixel if the value of color components is in the range between minimum and maximum threshold values.

The third method uses the three color spaces YCbCr, HSV and YIQ to detect human skin regions in color images. The pixel is classified as a skin pixel if the value of color components is in the range between minimum and maximum threshold values.
The fourth skin detection method uses normalized RGB, HSV, YCbCr, YIQ, RGB to segment human skin regions in color images using piecewise linear decision boundary classifier technique.

In order to detect face region in a given color image in a better way by avoiding the non-face skin region of a human, a combination of two of the best human face detection algorithms, namely, the template matching and golden ratio are used to mark the face regions in the image.

The performance of the proposed skin detection method is good as compared to other conventional skin detection algorithms. The algorithm has the maximum skin detection rate of 99.7. The main advantage of these methods that use explicitly defined skin cluster boundaries is the simplicity and intuitiveness of the classification rules [84].

Chapter VI will present comparative analysis on methods that are not designed to adapt to changing environments. These methods have a lot of assumptions on good illuminations and lighting conditions; such assumptions turn out be real constraints to the objective of a good comparative analysis.

The latter part of this thesis work is focused on certain vital issues of human skin detection techniques namely, color representation, human skin classification and face detection algorithms and propose a new class of five skin classification algorithms. Simulation is carried out to evaluate the performance of the proposed algorithms using number of test images. The algorithms are computationally more efficient than most of the state-of-the-art segmentation techniques. From the visual and objective results, it is very clear that new adaptive class of human skin detection segments face regions in color images efficiently. Simulation results show that the
proposed algorithms are able to produce subjectively and objectively better skin detection results as compared with a number of existing algorithms. The FDSE, FDPS, FDMP, FDMG and FDTM skin classifiers produce much improved performance by reducing false alarms.

Chapter VII concludes the thesis and suggests the ways to improve the method proposed for the future course of the work as well. In this thesis, a novel class of five skin detection techniques is presented for detecting human face regions in color images. Experimental results confirm that the proposed methods outperform the existing state-of-the-art methods both visually and in terms of computational concept.