**A survey of skin-color modeling and detection methods**

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**1. Introduction**

Recently, skin detection methodologies based on skin-color information as a cue has gained much attention as skin-color provides computationally effective yet, robust information against rotations, scaling and partial occlusions. Skin detection using color information can be a challenging task as the skin appearance in images is affected by various factors such as illumination, background, camera characteristics, and ethnicity.

The primary steps for skin detection in an image using color information are (1) to represent the image pixels in a suitable color space, (2) to model the skin and non-skin pixels using a suitable distribution and (3) to classify the modeled distributions.

Skin-color distribution is modeled primarily either by histogram models or by single/Gaussian mixture models.

To cope with changes in illumination conditions and viewing environment only *few* skin detection strategies use color constancy and dynamic adaptation techniques. In color constancy approaches, the images are first color corrected based on an estimate the illuminant color.

**2. Skin-color modeling and classification**

1. RGB: o reduce the dependence on lighting, the RGB color components are normalized so that sum of the normalized components is unity (r+g+b=1). The third component does not hold any significant information and is normally dropped so as to obtain a reduction in dimensionality. The differences in skin-color pixels due to lighting conditions and due to ethnicity can be greatly reduced in normalized RGB (rgb) space. Also, the skin-color clusters in rgb space have relatively lower variance than the corresponding clusters in RGB and hence are shown to be good for skin-color modeling and detection.
2. Perceptual color spaces (HSI, HSV): The transformation of RGB to HSV is invariant to high intensity at white lights, ambient light and surface orientations relative to the light source and hence, can form a very good choice for skin detection methods.
3. Orthogonal color spaces (YCbCr): The orthogonal color spaces reduce the redundancy present in RGB color channels and represent the color with statistically independent components. As the luminance and chrominance components are explicitly separated, these spaces are a favorable choice for skin detection. The YCbCr space is one of the most popular choices for skin detection. A variant of YCbCr called YCgCr differs in the usage of Cg color component instead of the Cb component and was reported to be better than YCbCr.
4. Other color spaces: It has been observed that skin contains a significant level of red. Hence, some researchers have used color ratios to detect skin. The combination of color ratios (R/G + R/B + G/B) provided a better response than the individual ratios.

Classifiers:

* Explicit skin-color space thresholding: One of the easiest and often used methods is to define ranges of threshold values for each color space component. Pixel values that fall within these predefined ranges for all the chosen color components are defined as skin pixels. *(See the linked study for the range values)*

It is very difficult to find a range of threshold values that covers all the subjects of different skin color. This technique is less accurate in case of shadows and situations where the skin color is not distinguishable from background. Being not precise it is normally followed by a dynamic adaptation approach.

* Histogram model:

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The performance in the histogram technique is affected by the degree of overlap between the skin and non-skin classes in a given color space and the choice of the detection threshold. Due to its inability to interpolate and generalize the data, the histogram method needs a very large training dataset to get a good classification rate. Also, this method has higher storage requirements.

* Gaussian Classifiers
* Bayesian classifiers

The most important criteria for the performance of any given skin classifier is the degree of overlap between the skin and non-skin clusters in a color space. We can conclude that non-parametric models such as histogram-based Bayes classifier are not affected by the color transformation as the degree of overlap is unaffected by mapping from one color space to another. However, parametric modeling techniques such as Gaussian modeling are affected by choice of color space. It should be noted that the parametric models are also affected by the amount and quality of the training data available.

Many of the existing techniques drop the luminance components to reduce the illumination effects in skin detection without any evidence. As the results suggest, ignoring the luminance component degrades the skin detection performance.

**3. Illumination adaptation approaches**

One of the most important factors for the success of any skin-color model is its ability to be able to adapt to the changes in the lighting and the viewing environment. The skin-color distribution of the same person under different lighting conditions differs. Even under the same lighting conditions, background colors and shadows may influence skin-color appearance. Human visual system can dynamically adapt to the varying lighting conditions and can approximately preserve the actual color of the object. This ability of the humans to reduce the effect of light on the color of the object is referred to as color constancy or chromatic adaptation. However, unlike humans, image capturing devices such as digital cameras are not capable of adapting to the rapidly varying illuminations across scenes. To handle the rapidly changing illumination conditions for skin detection, there are primarily two different classes of approaches: color constancy and dynamic adaptation which are described briefly in the following section.

* Gray World: The Gray World algorithm is one of the simplest and widely used algorithms for estimating the illuminant. It assumes that given an image with sufficiently varied colors, the average reflectance of the surfaces in the image is gray. Hence, any shift from gray of the measured averages on the sensor responses correspond to the color of the illuminant.
* … altri più complicati

**4. Summary and conclusions**

We reviewed the following critical issues regarding skin detection:

* Choice of appropriate color space: The color space representation is often lead by the skin detection methodology and the application. Non-parametric methods such as histogram-based methods are not affected by the color space representation. However, parametric modeling techniques such as Gaussian modeling are affected by the choice of color space. It should be noted that the parametric models are also affected by the amount and the quality of the training data available. The choice of color space should also depend on the available image format and the necessity of a particular color space in post-processing steps. For example, some non-linear color space transformations are too computational expensive to be used in real-time. Dropping the intensity component so as to obtain robust parameters against illumination conditions as approached in many of the works actually reduces the skin detection performance.
* Skin-color modeling and classification techniques: The histogram-based Bayes classifier is feasible for skin detection only with large datasets. Also, this method has very high storage requirements. The performance of mixture and NN (neural network) models is comparable to that of histogram methods even when small datasets are available.
* Color constancy and dynamic adaptation approaches: Obtaining robust color representations against varied illumination conditions is still a major problem. However, the application of color constancy techniques as a preprocessing step to skin-color modeling proved to improve the performance. The NN-based color constancy techniques are very promising as they do not make any explicit assumptions about the scene content. Dynamic adaptation techniques which transform the existing color models so as to adapt to the changing viewing conditions are also available. However, the problem with these approaches is that if we lose track of ground truth, the adaptive model might adapt to non-skin image regions. The problem domain factors such as the characteristics of the data set, the real-time considerations and the skin detection method should lead the choice of one of the illumination adaptation methods.

To improve the accuracy of the classifier, various other features such as shape, spatial and motion information can be used along with skin-color information. However, to build an accurate classifier which can detect all the skin types under different illuminations, shadows, cluttered backgrounds and makeup is still an unsolved problem. Many of the problems encountered in visual spectrum can be overcome by using non-visual spectrum methods such as infrared (IR) and spectral imaging. The non-visual spectrum methods though immune to illumination conditions and makeup are very expensive and bulky, and hence are not suitable to many applications. When these methods are used in real-time, meeting computational and storage requirements is extremely important. Sometimes, accuracy may need to be sacrificed when the skin detection strategy is used only as a preprocessing step to face detection.