Towards Integrating Statistical Color Features for Human Skin Detection

Mohd Zamri Osman, Mohd Aizaini Maarof, Mohd Foad Rohani

***Abstract*—**Human skin detection recognized as the primary step in most of the applications such as face detection, illicit image filtering, hand recognition and video surveillance. The performance of any skin detection applications greatly relies on the two components: feature extraction and classification method. Skin color is the most vital information used for skin detection purpose. However, color feature alone sometimes could not handle images with having same color distribution with skin color. A color feature of pixel-based does not eliminate the skin-like color due to the intensity of skin and skin-like color fall under the same distribution. Hence, the statistical color analysis will be exploited such mean and standard deviation as an additional feature to increase the reliability of skin detector. In this paper, we studied the effectiveness of statistical color feature for human skin detection. Furthermore, the paper analyzed the integrated color and texture using eight classifiers with three color spaces of *RGB*, *YCbCr,* and *HSV*. The experimental results show that the integrating statistical feature using Random Forest classifier achieved a significant performance with an F1-score 0.969.

***Keywords*—**Color space, neural network, random forest, skin detection, statistical feature.

I. Introduction

HUMAN skin detection is one of the important approach in image processing and widely adopted in many applications such as face detection [1], face tracking [2], illicit image filtering [3], [4] and others. Skin detection is the process of discriminating skin and non-skin pixels from a color image or video into a group of skin regions [5]. Then, the detected skin regions are processed based on the specific applications [6]. From the literature, several skin detection techniques have been explored extensively over the years. Previously, many skin detection methods have been proposed and successfully applied the color information [7]-[11]. One of the major issue in color-based approach is how to choose the best or suitable color space for skin detection [10]. Numerous researchers have studied skin color features. Their result showed that skin color has a limited range of hues and is not deeply saturated [12]. Also, the skin color falls under a small area in the color space. However, some factors such as illumination, skin-like object, camera characteristics, complex background, and ethnicity make the detection process more difficult [7]. Skin detection categorized into four classes which are explicit skin classifier, parametric, non-parametric and adaptive classifiers. Explicit skin classifier is fast yet the simplest skin color modeling to implement, uses a threshold value to differentiate skin and non-skin pixels. The threshold value of specific color space greatly depends on the training set, and it is difficult to achieve better accuracy in this method. A proper skin boundary is determined to obtain a good result. Although this method is straight forward, they need to adapt to the lighting changes in the color images that might result in poor detection [13]. Parametric classifiers, on the other hand, is based on single Gaussian model (SGM) [14], Gaussian Mixture Model (GMM) [15], multiple Gaussian clusters [16], or an elliptical boundary model [17]. This methods reported to be slow and have low detection accuracy due to dependencies with approximated parameter rather than real appropriate skin color [6], [18]. Furthermore, non-parametric classifiers require an essential set of training data to estimate the skin color distribution. Multi-layer Perceptron (MLP) and Self-Organized Map (SOM) networks are the common architecture used. Thus, neural network has been reviewed that this technique unable to separate skin-like objects and failed to resolve the illumination conditions [12]. More explanation on skin color modeling can be found in [7].

To overcome the generality by the static skin color modeling, dynamic classifiers that are based on artificial neural network (ANN) and or Genetic Algorithm (GA) have been introduced [19]. Most of the skin detection methods consider only color information as the main feature. Conversely, the skin is a group of regions that are homogenously connected pixels. Therefore, texture information can be an additional feature to be exploited. Different texture descriptors such as standard deviation, entropy, skewness, smoothness, kurtosis, and uniformity can be used for skin detection purpose [18], [19]. Taqa and Jalab combine color and texture involving the pixel neighbors using Back Propagation neural network [20]. Three texture descriptors of standard deviation, range, and entropy have been studied. Al-Mohair et al. also proposed hybrid skin detection by integrating color and more textures which Multi-Layer Perceptron (MLP) and k-means are used as the skin classifier [18]. Although color has played important roles in modeling the skin, selecting a suitable color space is vital. Many authors do not provide clear justification for the chosen color space. Selecting the color space for skin detection is more personal interest rather than the evidence [21]. Moreover, [22] proposed a hybrid color space for skin

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detection known as *SKN* color space that exploited from seventeen existing color spaces.

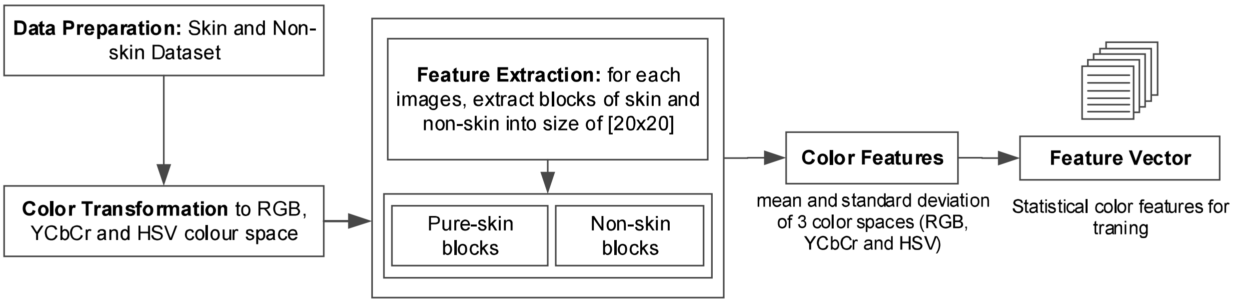

Fig. 1 Data preparation of skin and non-skin statistical color features

This paper studies the effectiveness of integrating statistical color features for skin detection using several classification techniques with three color spaces. This paper presented in four major sections. Firstly, discussion of the related works is done. The next part of the paper introduces the proposed method. Following this, the discussion is undertaken based on the result obtained from the experiment. Finally, the paper is concluded with some future recommendation.

II. Methodology

This work proposes a human skin detection based on an integrated features vector. In this paper, two statistical color features are studied: mean and standard deviation. Sophisticated texture descriptors may be can be used, such as Gabor filters. Unfortunately, Gabor filters slow down the detection process make it unreliable for real-time applications [12]. Fig. 1 shows our method for data preparation of skin and non-skin statistical color features. The proposed method consists of the following phases: data preparation, color transformation, color feature extraction, and vector features representation.

A. Data Preparation: Skin and Non-Skin Dataset

This stage involves collecting samples of pure skin pixels from different people under different illumination variation, as well as the non-skin pixels. The skin images are selected randomly from the Internet. A total number of 550 images are gathered that contains several image variations such as simple background, confusing background, facial image and non-face image. Then, the skin region manually extracted using the photo editor by removing the background and labeled as the ground truth. In labeling the skin, non-skin areas such as eyes, clothes, hair, mouth and lips are filtered out.

In preparing data for the classifiers, two types of data patches are extracted: skin and non-skin blocks. These blocks selected randomly from the head, cheeks, hand, chest and shoulder with 20 x 20 block size as shown in Fig. 2. Selecting the skin blocks even in the same person need to take into consideration due to shadow variation and skin tone.

Each block cannot overlap each other to ensure a variety of the skin block. At the end of this phase, a collection of skin and non-skin blocks of each block with 20 x 20 size are created. The ratio of skin pixels to the total number of pixels in the image varies significantly. This is due to the pixel number of skin, and non-skin pixels does not equal or imbalance data. To resolve this issue, we prepare a balanced dataset with total 5280 blocks of skin (2,112,000 pixels) and non-skin pixels (2,112,200 pixels).

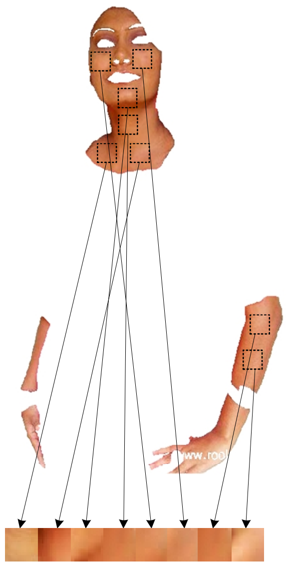

Fig. 2 Skin blocks extraction from the dataset

B. Feature Extraction: Skin Color and Texture Descriptors

In this phase, each block of 20 x 20 size is divided into smaller sub-blocks of 4 x 4 size. The process of color illustrated in Fig. 3. For each sub-blocks, we exploit color and texture features. Twelve features consist of color and texture were used in this study. These features are: mean channel 1, mean channel 2, mean channel 3, standard deviation channel 1, standard deviation channel 2, standard deviation channel 3, mean gray, skewness, smoothness, kurtosis, entropy and uniformity. Channel 1, 2 and 3 refers to the *RGB*, *YCbCr* and *HSV* color space.

III. Experimental Results and Analysis

A set of quantitative analysis was performed to evaluate our proposed method on the skin detection accuracy. We employed eight classifiers including Naïve Bayes, MLP, RBF Network, AdaBoost, Random Forest, Random Tree, Bayes Network and Tree J48. These classifiers are the available and known classifier for classification problems. Finally, we represent the comparison of eight classifiers using three different color space with integrated statistical color features.

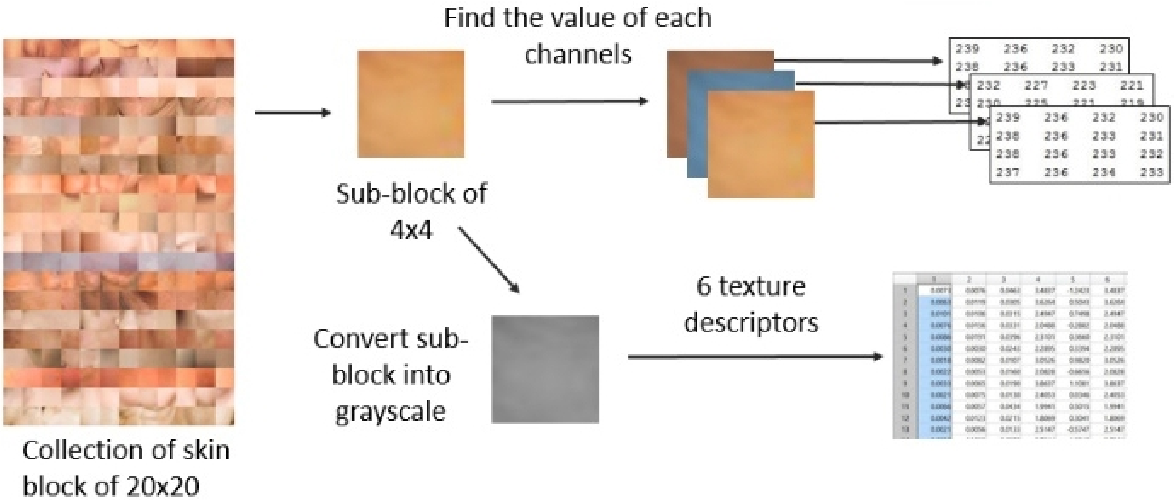

Fig. 3 Skin Color and Texture Extraction Process

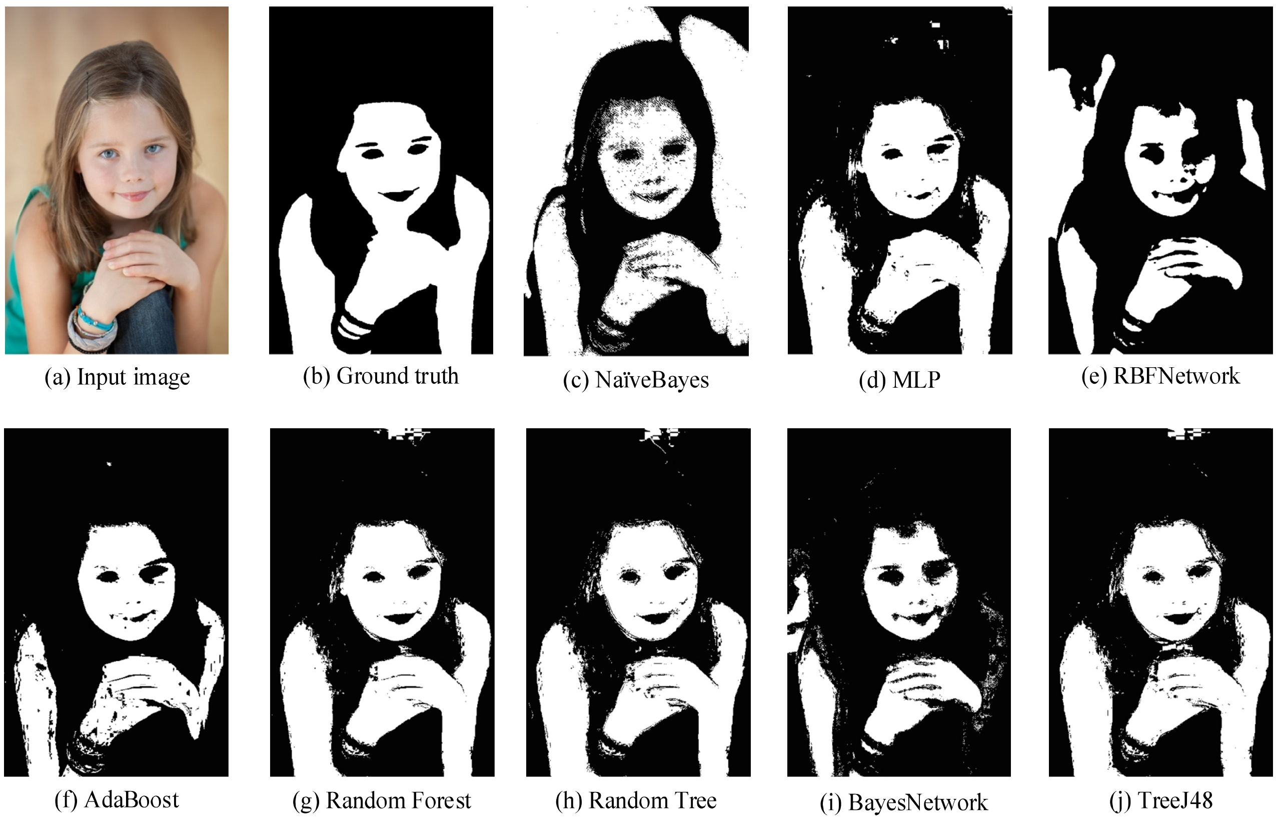

Fig. 4 Qualitative results using seven classifiers with mean only feature

Table I shows the performance of the skin classification using mean color feature only of *RGB* color space. The feature is performed under eight classifiers. Random Forest classifier outperform among all the classifiers. Despite, Random Forest is chosen as our main classifier since a better classification. For the qualitative result, the graphical representation of skin detection is illustrated in Fig. 4. White area indicates the detected skin pixels while black area indicates non-skin pixels.

Thus, we run more features by adding standard deviation which presented in Table II. From the experiment, it indicates that the performance increases as shown in Table III. F-score increases from 0.922 to 0.963. Despite, MLP classifier also shows a great increment from 0.909 to 0.955 based on the F-score.

TABLE I
PERFORMANCE OF SKIN CLASSIFICATION USING MEAN ONLY FEATURE OF *RGB* COLOR SPACE. SIGNIFICANT RESULTS ARE IN BOLD

Classifier	TP rate	FP rate	Precision	Recall	F-Score
NaïveBayes	0.748	0.252	0.758	0.748	0.745
MLP	0.909	0.091	0.91	0.909	0.909
RBFNetwork	0.832	0.168	0.834	0.832	0.832
AdaBoost	0.807	0.193	0.819	0.807	0.805
RandomForest	**0.945**	**0.055**	0.900	**0.945**	**0.922**
RandomTree	0.895	0.105	0.895	0.895	0.895
BayesNetwork	0.771	0.229	0.78	0.771	0.769
TreeJ48	0.921	0.079	**0.922**	0.921	0.921

TABLE II
PERFORMANCE OF SKIN CLASSIFICATION USING MEAN AND STANDARD DEVIATION OF *YCBCR* COLOR SPACE. SIGNIFICANT RESULTS ARE IN BOLD

Classifier	TP rate	FP rate	Precision	Recall	F-Score
NaïveBayes	0.84	0.16	0.853	0.84	0.838
MLP	0.955	0.045	0.956	0.955	0.955
RBFNetwork	0.868	0.132	0.877	0.868	0.867
AdaBoost	0.854	0.146	0.857	0.854	0.854
RandomForest	**0.963**	**0.037**	**0.964**	**0.963**	**0.963**
RandomTree	0.946	0.054	0.946	0.946	0.946
BayesNetwork	0.869	0.131	0.87	0.869	0.869
TreeJ48	0.956	0.042	0.958	0.958	0.958

TABLE III
INTEGRATED FEATURES USING RANDOM FOREST CLASSIFIER UNDER THREE COLOR SPACES. SIGNIFICANT RESULTS ARE IN BOLD

Features	Color Space	Precision	Recall	F-Score
mean (μ)	*RGB*	0.900	0.945	0.922
	YCbCr	0.926	0.925	0.925
	HSV	0.925	0.924	0.924
mean (μ) and standard deviation (σ)	*RGB*	0.964	0.963	0.963
	YCbCr	**0.969**	**0.969**	**0.969**
	HSV	0.950	0.943	0.943

Table III shows the performance of skin classification using *RGB*, *YCbCr,* and *HSV* color space. In this paper, we analyzed two sub-features which are mean, mean and standard deviation. The quantitative result indicates *YCbCr* color space using mean and standard deviation color feature have the highest result with 0.969 F-score. We can conclude that Random Forest classifier shows a consistent performance with three different color space using statistical color features. Hence, it applies to be used for human skin detection purpose.

Random Forest classifier showed a great skin classification in it class compared to other seven classifiers studied in this work. The initial experiment shows more features can increase the classification performance. However, adding too many features will degrade the time processing. Hence, we also analyzed twelve features to selected the best combination both color and texture. By using WEKA tool, we used Info Gain Attribute Evaluation based on the Ranker method.

Table IV shows the ranked twelve features of color and texture descriptor using *YCbCr*. According to the ranking, the first six features can be exploited to be used for skin classification. The last six features are discarded since give the lowest score.

TABLE IV
RANKED FEATURES USING YCBCR COLOR SPACE

Score	Attribute No.	Attribute
0.571	3	mean_*Cb*
0.46	2	mean_Cr
0.336	4	std_*Y*
0.313	12	Smoothness
0.271	10	entropy
0.253	11	uniformity
0.246	5	std_*Cb*
0.223	6	std_*Cr*
0.195	8	Kurtosis
0.18	9	skewness
0.155	1	mean_*Y*
0.114	7	mean_Gray

IV. CONCLUSION

In this paper, we introduced human skin detection using classification techniques based on integrated statistical color features. Eight classifiers including Naïve Bayes, MLP, RBF Network, AdaBoost, Random Forest, Random Tree, Bayes Network and TreeJ48 have been used to compare the performance of skin detection. Furthermore, three color spaces of *RGB*, *YCbCr*, and *HSV* have been studied. Our experiment showed that integrating statistical color features would increase the classification performance. However, not all the features are needed for classification purpose, hence reducing the time speed. The comparing results also indicate Random Forest classifier using *YCbCr* color space improved the detection performance. In the future, we would like to exploit additional features from the texture descriptors and test the skin detection in real-world images using more available color spaces.

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