A Probabilistic Approach to Skin Detection

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Abstract

In this paper, we present an approach to skin detection in images, which labels each pixel as skin or non-skin based on a simple probabilistic model acquired from a database of manually labeled images. We tested several variations of this approach (using different color spaces and pre-processing techniques) and the achieved accuracy seemed quite encouraging with, a detection rate of 77,79%.

1. Introduction

Detecting regions of skin in photographs is a very important step to a wide range of applications, such as nudity detection [3], face recognition [6], and surveillance applications [4].

The above has motivated the development of a myriad of techniques to identify skin regions of a given image, such as: the application of statistical color models in a 256^3 bins histogram [5], of minimum and maximum thresholds for each channel of the pixels [6], of the Expectation-maximization algorithm with spatial constraints [2], and a mixture density function [7]. Some of them, such as [6], redundantly apply the same technique for several color spaces and perform a polling algorithm to obtain the final result. In addition, some region growing techniques, based on color similarity, can be applied in order to reduce the false rejection of skin pixels [1, 7].

In this paper we present a novel approach to skin detection in color images which is based in a simple probabilistic model to be applied in each channel of the pixels that compose the image, thus reducing the dimensionality of the histograms ($256c$ bins, where c is the number of channels in the adopted color space).

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2. Proposed Approach

The approach presented in this paper is based on the application of a simple probabilistic model which is obtained by the analysis of a large database of images that had been previously labeled in a manual fashion – made available by Jones and Rehg [5].

The first step is to determine which color space will be used to classify the images, given that the labeled database needs to be preprocessed on the chosen color space.

Once the color space is determined, all images in the database will have their corresponding color channels extracted from both the whole image and from the manually labeled skin map correspondent to that image. Then, the occurrences of all levels of each channel that are present in the images are summed up.

After summing the occurrences of each level, two values are determined, which are the total occurrence of each level of the channel in the whole database ($O_c(l)$), and also the number of times in which that level is correspondent to a skin pixel ($S_c(l)$).

Then, the probability of a given level of a channel appears as skin in the whole database of manually labeled images as the ratio between the total number of appearances as skin and the total occurrence of the level (see Equation 1).

$$P_c(l) = \frac{S_c(l)}{O_c(l)} \tag{1}$$

After obtaining the probability values, the "skiness" of a pixel $p(l_1, l_2..l_n)$ can also be obtained by multiplying the values of probabilities of all levels associated to it in the chosen color space. Equation 2 is used to obtain the "skiness" of a given pixel.

$$s(p) = \prod_{i=1}^{n} P_{c_i}(l_i) \tag{2}$$

The probability values of all the pixels can then be mapped to gray scale levels, in order to compose a complete gray scale skiness map of the original image that will be presented to a threshold filter. This picture generates the final binary skin map of the image, in which each pixel of the gray scale skiness map is thresholded to white (skin pixel) or black (non-skin pixel), according to Equation 3. The threshold t is chosen to achieve equal error rate, *i. e.*, equal false positive and false negative rates.

$$T_f(p) = \begin{cases} white & \text{if } s(p) > t \\ black & \text{if } s(p) \leq t \end{cases} \quad (3)$$

3. Experimental Results

The proposed approach has been tested in several color spaces, using a series of preprocessing techniques. For all tests executed, the training database of manually labeled skin images was composed of the same set of 1000 jpeg files, and the test data set was composed of other also manually labeled 1000 images. In the beginning of the test, the preprocessing function was applied in all images of the data set – eventually, the preprocessing function was the identity function, which does not modify the images.

After that, the computation of the probability occurs, followed by the generation of the gray scale skiness maps of each image of the test database. In some of the tests, a blur filter was applied in the gray scales map, to turn them a little smoother. Finally, the each threshold (from 0 to 255) was tested in order to obtain the equal error rate threshold of the skin detector.

The detection rate – the ratio between the number of detected skin pixels over the total skin pixels presented to the detector – is the value that best characterize the accuracy of the skin detector obtained using the proposed approach. As the skin detector should also have minimum false positive and false negative rates, these are important values to be analyzed.

#	C. S.	P. P.	Blur	D. R.	F. P.
1	RGB	Identity	No	72.75%	22.25%
2	RGB	Identity	Yes	72.98%	26.91%
3	RGB	No Brightness	No	79.44%	20.63%
4	RGB	No Brightness	Yes	79.77%	20.08%
5	HSV	No V Channel	No	78.76%	21.25%
6	HSV	No V Channel	Yes	78.86%	21.00%

Table 1. Experimental Results

As can be observed in Table 1[1], the best skin detector (79.77% of detection rate) was obtained using RGB color space, nullifying the brightness discrepancies among the pixels – preprocessing was executed by converting the images first to HSV color space, modifying V values to 50%, and converting back to RGB color space –, and applying the blur filter in the image. However, as some non-skin regions can have colors which are very similar to skin colors, the false positive and negative rates are still very high.

1 C. S. = color space; P. P. = pre-processing; D. R. = detection rate; F. P. = false positive rate

4. Conclusions and Future Work

The main contribution of this work is the proposal of a simple technique which can effectively detect skin patches in color images. The experimental results show that the presented approach is very promising, once its detection capability is high – comparable to the results obtained applying more complex techniques such as [5, 6], which detected 88% of the skin pixels in equal error rate – and the complexity of the implementation is low.

The false positive and false negative rates, on the other hand, are high as well, indicating that the skin detector fails in when labeling more non-skin pixels as skin than could be acceptable, which leads to the need of further investigation in order to reduce these errors. One possible way is the application of more restrictive thresholds followed by a growing region technique, in order to reduce false positives. Some research will also be done to perform classification of local regions of a previously segmented image as a whole.

References

[1] M. Akbari and M. Nakajima. A novel color region homogenization and its application in improving skin detection accuracy. *Proceedings of the 3rd international conference on Computer graphics and interactive techniques in Australasia and South East Asia*, pages 269–272, 2005.

[2] A. Diplaros, T. Gevers, and N. Vlassis. Skin detection using the em algorithm with spatial constraints. *Systems, Man and Cybernetics, 2004 IEEE International Conference on*, 4, 2004.

[3] P. Fuangkhon and T. Tanprasert. Nipple detection for obscene pictures. In *Proc. of WSEAS Int. Conf. on Signal, Speech and Image Processing*, pages 315–320, August 2005.

[4] R. L. Hsu, M. Abdel-Mottaleb, and A. K. Jain. Face detection in color images. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 24(5):696–706, 2002.

[5] M. Jones and J. Rehg. Statistical color models with application to skin detection. *International Journal of Computer Vision*, 46(1):81–96, 2002.

[6] R. Montufar-Chaveznaza, F. Gallardo, and S. Hernandez. Face detection by polling. pages 292–297, September 2005.

[7] J. Ruiz-del Solar and R. Verschae. Skin detection using neighborhood information. *Proceedings of the Sixth IEEE International Conference on Automatic Face and Gesture Recognition*, 2004.