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Robust Skin Area Detection Method in Color Distorted Images

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색 왜곡 영상에서의 강건한 피부영역 탐지 방법

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Abstract With increasing attention to real-time body detection, active research is being conducted on human body detection based on skin color. Despite this, most existing skin detection methods utilize static skin color models andhave detection rates in images, in which colors are distorted. This study proposed a method of detecting the skin region using a fuzzy classification of the gradient map, saturation, and Cb and Cr in the YCbCr space. The proposed method, first, creates a gradient map, followed by a saturation map, CbCR map, fuzzy classification, and skin region binarization in thatorder. The focus of this method is to rigorously detect human skin regardless of the lighting, race, age, and individual differences, using features other than color. On the other hand,the borders between these features and non-skin regions are unclear. To solve this problem, the membership functions were defined by analyzing the relationship between the gradient, saturation, and color features and generate 108 fuzzy rules. The detection accuracy of the proposed method was86.35%, which is 2~5% better than the conventional method.

요 약 실시간 인체 검출에 대한 관심이 높아짐에 따라 피부색을 통한 인체 검출에 대한 연구가 활발히 진행되고 있다. 하지만 대다수 기존 피부 탐지 방법은 정적인 피부색 모델을 이용하기 때문에 색 왜곡이 발생한 영상에서 낮은 탐지율을 보인다. 이러한 문제를 해결하기 위해 본 논문에서는 경사도 맵과 채도, YCbCr 공간의 Cb, Cr 요소를 퍼지로 분류하는 방법을 사용하여 피부영역을 탐지하는 기법을 제시한다. 제안하는 방법의 기본적인 절차는 경사도 맵 생성, 채도 맵 생성, CbCr 맵 생성, 퍼지 분류, 피부영역 이진화 순이다. 이 방법은 색상 이외의 특징을 이용하여 조명, 인종, 나이, 개인차 등에 상관없이 강건하게 피부를 탐지하는 것에 중점을 두고 있다. 색상 이외의 피부 특징은 비피부영역과의 경계가 모호하여 구분이 명확하지 않다. 이를 해결하기 위해 경사도, 채도와 색상 특징간의 관계를 소속함수로 정의하고 이를 이용하여 108가지의 퍼지 규칙을 생성하여 피부영역을 탐지한다. 제안한 방법의 검출 정확도는 86.35%로 기존 방법보다 2~5 % 우수함을 확인하였다.

Keywords : fuzzy, image processing, skin detection

1. Introduction

The techniques for detecting and recognizing human bodies in images are widely used in various fields including security, statistics, military affairs, and marketing. Development of various imaging equipment and distribution of high-speed network in particular has led to growing demand for such techniques. However,

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there are difficulties with normalizing feature of human bodies due to vast diversity in the colors and shapes of clothes and individual differences in movements and physical attributes. Skin region detection is one of the methods developed to overcome those issues. Skin colors are similar between individuals regardless of gender and age, and even across the body of an individual. Therefore, skin color detection can be a useful method of detecting human bodies in images. The methods include: detecting skin color in RGB color space [3], in HSV color space [4][10][x], and in YCbCr color space [1][6][7][9][11]. These methods compute empirical data that are determined as skin color by using various learning images and use the data to define pixels in images that are within a certain color range as skin region. This method produces good results if the skin colored regions are correctly sampled. However, if other areas than skin are included in the color sample range, it determines all of them as skin colors and, also, fails to detect the skin region if the pixel values go beyond the sample range due to lighting, image correction, performance of optical equipment, lens filter, etc. Therefore, to resolve these problems, it is necessary to use other feature than color. Recent research proposed a method that extracts facial components such as eyes and lips and determine the adjacent pixel values as skin[9][11]. This method detects physical elements like eyes and lips in images and assume the surrounding regions as skin, before it extracts pixels that have similar color feature to these regions in order to detect skin regions. However, it can be only used if the face or other body parts are included in the images and, therefore, is not suitable for detecting skin regions in images where it is difficult to detect body parts or where only a part of body is seen Finally, Hwang proposed method to detect the skin region using a cluster of YCbCr color as well as saturation and gradient[1]. This is useful for removing non-skin noise such as wood, clothes, etc. However, we need more research because saturation and gradient have ambiguous histogram values.

This study proposed a method of skin region detection based on fuzzy classification of gradient, saturation, and CbCr color feature. Although color is the strongest feature of skin regions, using only color to detect skin regions can be problematic as it can extract non-human elements that have similar colors, such as wood, leather furniture, external wall of buildings, and soil. Therefore, this study used gradient and saturation, which are also feature of skin regions, in order to minimize detection errors. However, as gradient and saturation are less prominent feature than color and their ranges can be ambiguous, they were classified based on fuzzy classification. The proposed method, first, creates a gradient map, followed by saturation map, CbCR map, fuzzy classification, and skin region binarization in the order. [Fig. 1] is a flow chart of this method.

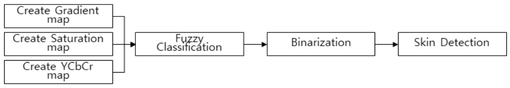

Fig. 1. Flow chart.

2. Extraction of Skin Region Feature

Because skin colors are similar between different races, genders, and age groups, even across the entire body, and permanent, existing techniques of skin region detection only rely on color feature. However, in natural images there are numerous objects and elements that have similar colors to skin regions, such as tree bark, leather, and wall paper, noises which are picked up along with the skin regions. In order to effectively remove these noises, methods to extract skin regions based on fuzzy classification have been researched [2][8][xxx,x] and have shown better performance than the traditional method of extracting skin regions simply by using thresholds. However, all of these methods rely on color information only, such as R, G, B in RGB color space, Cb and Cr in YCbCr color space, and hue in HSV. As a result, they are bound to recognize all colors that are similar to skin regions as skin. In order to resolve this problem, this study used not only colors but also gradient and saturation feature. However, because saturation and gradient have ambiguous ranges, compared to color, as features of human skin, fuzzy classifier was applied to them in order to propose a new method of skin region detection that is robust against noises. In order to extract skin regions, first, the images from which skin regions are to be extracted are received. Subsequently, the gradient values, saturation values, and Cb and Cr extracted from converted YCbCr color space are extracted. Then, the extracted values are classified by using fuzzy and then binarized to detect skin regions.

2.1 Creating a gradient map

In this study, gradient was extracted and used as one of the feature for detecting skin regions in images. The gradient map created by using the extracted gradient values present difference of brightness between pixels in the image and the surrounding images. When the brightness difference from surrounding pixels is greater, the value is closer to 1, and when the difference is smaller, the value is closer to 0. Brightness difference can be calculated by using first derivation edge operator proposed by Sobel, Prewitt, and Robert et al.[5]In this study, Sobel's operator was used. The gradient map in [Fig. 2-(b)]is the result of applying first derivation edge operator to a image. When a gradient map is created, the values are expressed as negative and positive numbers according to the direction of the axis, and only the absolute values, i.e. size, of these numbers were used regardless of the direction of the gradient.

(a) (b) (c) (d) (e) (f)

Fig. 2. example of the feature maps.
(a)Original image, (b)Gradient map extraction result, (c)Saturation map extraction result, (d)Y components, (e)Cr Components, (f) Cb Components.

2.2 Extracting saturation

In this study, saturation was extracted and used as one of the feature for detecting skin regions in images. Saturation is one of the main property of color, along with brightness and hue, and refers to similarity among R, G, B values. When R, G, B values are close to one another, the color is closer to being achromatic, and when the difference among the values is greater, it becomes more colorful. Saturation is extracted by applying R, G, and B to Expression (1) in a image based on RGB color space.

$$S=\begin{cases} 0 & , C_{\max}=0 \\ \dfrac{C_{\max}-C_{\min}}{C_{\max}} & , C_{\max}\neq 0 \end{cases} \tag{1}$$

$$C_{\min}=\min(R,G,B),\quad C_{\max}=\max(R,G,B)$$

C_{min} and C_{max} refer to the minimum and maximum values among R, G, and B in RGB color space. The difference between the maximum value and the minimum value of R, G, and B is normalized as the maximum value, and set between 0 and 1. Then, the extracted saturation values are used for creating a saturation map, as shown in [Fig. 2-(c)] and, then, for operation.

2.3 Extracting CbCr

YCbCr color space was developed for the digital standard television system in the past. As its components, Y denotes brightness, and Cb and Cr color difference of blue and red, respectively. Cb and Cr in YCbCr space are widely used for detecing skin regions in images[1][6][7][9][11]. YCbCr color space is created by encoding RGB information, as Expression (2). [Fig. 2-(d), (e), (f)] shows each component of YCbCr.

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix}=\begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix}+\begin{bmatrix} 65.481 & 128.533 & 24.966 \\ -37.797 & -74.203 & 112 \\ 122 & -93.786 & -84.214 \end{bmatrix}\begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{2}$$

2.4 Fuzzy feature of skin regions

Gradient, saturation, and Cr and Cb values extracted from images are used as fuzzy variables and five membership functions are defined in order to extract skin regions. In this study, to create membership functions, a image editing program was used to separate skin regions in 200 images that include skin regions, and gradient, saturation, and Cr and Cb values were extracted to collect data. [Fig. 3] shows the one-dimensional histogram of gradient, saturation, and Cr and Cb components.

The one-dimensional histogram shows the concentration of components found in skin regions. Gradient is concentrated mostly between 0 and 0.15, whereas saturation is distributed over a relatively large area, however, mostly between 0.2 and 0.4 and 0.5 and 0.6. Cb and Cr are distributed between 0.4 and 0.5 and 0.5 and 0.7, respectively.

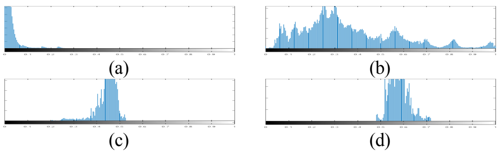

Fig. 3. 1-D histogram of skin components.
(A) gradient histogram, (b) saturation histogram, (c) Cb histogram (d) Cr histogram

While gradient and Cb and Cr are relatively concentrated in certain positions, saturation has a wide range of distribution. Therefore, it is unsuitable to be directly used for detecting skin regions and it is necessary to analyze when the saturation value of skin regions increase or decrease. [Fig. 4] shows the saturation and gradient histograms of two different skin regions of the same person.

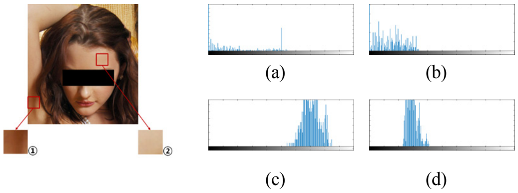

Fig. 4. Difference of gradient, saturation feature value histogram in the same person skin area.
(A) gradient histogram of region ①, (b) gradient histogram of region ②, (c) saturation histogram of region ①, (d) saturation histogram of region ②.

As seen in [Fig. 4], the areas with shadow, especially along the borders, have relatively low contrast and great difference in contrast with the surrounding pixels, thus, resulting in a steep gradient. By contrast, for areas without shadow, the gradient is shallower. Also, regarding saturation, areas with shadow show a high level of saturation and areas without shadow a low level of saturation. In the 50 images of the same person extracted from the same image, also, high saturation in skin regions led to a steep gradient, and low saturation to a shallow gradient. Based on the relationship between saturation and gradient, membership function forms of Expression (3) to (7) and membership function of [Fig. 5]w e r e created. The membership functions were created in a trapezoid based on the distribution pattern in the histogram.

$$\mu_G = \{a_1, a_2, a_3\} \quad (3)$$

$$\mu_S = \{b_1, b_2, b_3, b_4\} \quad (4)$$

$$\mu_{Cb} = \{c_1, c_2, c_3\} \quad (5)$$

$$\mu_{Cr} = \{d_1, d_2, d_3\} \quad (6)$$

$$\mu_{SR} = \{e_1, e_2, e_3, e_4, e_5\} \quad (7)$$

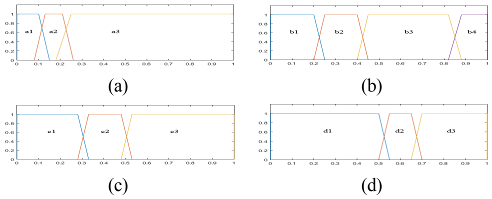

Fig. 5. Graph of membership function.
(A) gradient function graph, (b) saturation function graph, (c) Cb function graph, (d) Cr function graph.

Expression (3) is a membership function of gradient, and Expression (4) of saturation. Expression (5) and (6) represent membership functions of Cb and Cr components, respectively. Expression (7) is a consequent for obtaining the result, with e1, e2, e3, e4, and e5 having 0%, 30%, 50%, 70%, and 100% weight, respectively.

2.5 Creating a fuzzy rule for skin region extraction

Fuzzy variables of skin region feature can be expressed as ‘IF μ_G=a1 and μ_S=b2 and μ_{Cb}=c2 and μ_{Cr}=d2 THEN μ_{SR}= e1.’ Such definition of relationship between different feature is referred to as fuzzy rule. In this study, based on analysis of 200 skin region image, 108 fuzzy rules for extracting skin regions.[Fig. 6] is example of the fuzzy rules.

```
IF µG=a1 & µS=b2 & µCb=c3 & µCr=d3 THEN µSR=e2
IF µG=a1 & µS=b3 & µCb=c1 & µCr=d1 THEN µSR=e2
IF µG=a1 & µS=b3 & µCb=c1 & µCr=d2 THEN µSR=e3
IF µG=a1 & µS=b3 & µCb=c1 & µCr=d3 THEN µSR=e2
IF µG=a1 & µS=b3 & µCb=c2 & µCr=d1 THEN µSR=e3
IF µG=a1 & µS=b3 & µCb=c2 & µCr=d2 THEN µSR=e5
IF µG=a1 & µS=b3 & µCb=c2 & µCr=d3 THEN µSR=e3
IF µG=a1 & µS=b3 & µCb=c3 & µCr=d1 THEN µSR=e2
IF µG=a1 & µS=b3 & µCb=c3 & µCr=d2 THEN µSR=e3
IF µG=a1 & µS=b3 & µCb=c3 & µCr=d3 THEN µSR=e2
IF µG=a1 & µS=b4 & µCb=c1 & µCr=d3 THEN µSR=e1
IF µG=a1 & µS=b4 & µCb=c2 & µCr=d1 THEN µSR=e2
```

Fig. 6. Fuzzy rules for skin area extraction

2.6 Extracting skin regions

To extract skin regions, defuzzification was performed. Defuzzification is a process of producing a quantifiable result by using entered fuzzy variables and membership functions. In this study, it was performed by using a center of gravity method, which is a method that simplified the min-max method and uses only the values of the segment relevant to each rule. It is especially suitable for optimization and adaptive methods, as well as for control problem and dynamic nonlinear systems. Defuzzification produces values between 0 and 1 by pixel, which are binarized to determine skin regions. In this study, after repeated tests using data of 200 images, the threshold value between the skin region and non-skin region was 0.63, which was used for finally distinguishing skin regions from non-skin regions.

3. Experiment and Result

3.1 Experiment method

This experiment was performed by using MATLAB. The image used in the experiment was created by using 300, consisting of 150 images of celebrities collected on the internet and 150 images recorded for the experiment, which were resized into 320x240 (or 240x320) pixels. All experiment images except natural images were compared with skin images extracted by using the 'magic wand tool' in a image editing program, and then, Expressions (8) and (9) were applied to calculate the detection rate and false detection rate regarding the skin regions. TP denotes detection rate and FP false detection rate, and N refers to the number of pixels of the entire image, N_{skin} that of the actual skin regions, M that of the extracted skin regions, and M_{skin} the number of pixels in the extracted skin regions that correspond to the actual skin regions. In order to compare the performance with that of existing methods, the methods proposed by Hwang [1], Hsu [6] and Park [11]were implemented under the same conditions and the results were compared.

$$R_{TN}=\sum_{i=0}^{n_O}(R(i)-S_{TN}(i))/\sum_{i=0}^{n}S_{TN}(i) \qquad (8)$$

$$R_{FP}=\sum_{i=0}^{n_N}(R(i)-S_{FP}(i))/\sum_{i=0}^{n}S_{FP}(i) \qquad (9)$$

3.2 Result

By using the method described in 3.2, skin regions were detected and, based on the detection result, the accuracy of skin region extraction was measured. To do so, skin regions found in all of the images used in the experiment were manually separated and prepared for the comparative analysis. Table 1 shows the accuracy of skin region extraction.

Table 1. Result

Image Type	Hwang Method	Hue Method	Park Method	Proposed
celebrities	88.45%	87.72%	86.66%	92.18%
Ordinary people	80.64%	75.40%	83.15%	80.52%
Total	84.55%	81.56%	84.90%	86.35%

Hsu's method extracts skin regions by using color borders, while Park's and Hwang's method, which is an adaptive extraction method, extracts skin regions to create a sample and use it for extracting skin regions. The result in this shows that the proposed method has improved the accuracy of skin region extraction by one to five percent, compared to the existing methods. Park's method can produce better results than any other method, provided that it correctly extracts skin regions around the eyes. This adaptive method performed especially well in images in which the skin colors were distorted by color correction or lighting or were similar to the background color. However, when the eyes were not correctly detected or other noises were determined as eyes, completely wrong areas were extracted as skin regions. However, the proposed method uses both skin color and other feature and fuzzy classification to adaptively extract skin regions, improving the accuracy by 5% compared to existing methods that use only skin color feature. And Hwang's method is using Euclidean distance in clustered skin color candidates to find skin regions. Because of the clustering algorithm, this method is slow. And sometimes the noise is extracted because the Euclidean distance is short, even though it is not skin area. However this suggests that the method of using fuzzy classification by combining gradient and saturation feature performs as well as the adaptive method of extracting skin regions by sampling actual skin regions.

(a) (b) (c) (d) (e)

Fig. 7. Skin Area Extraction Results. (a) original image, (b) Hwang method, (c) Hsu method, (d) Park method, (e) proposed method

4. Conclusion and further research

Existing methods of skin region extraction that rely only on skin color models cannot correctly detect skin regions in images in which colors were distorted or the background has a similar color to the skin regions. To resolve these issues and detect skin regions in a more rigorous manner, this study proposed a method of creating a skin gradient map to determine saturation and candidate skin regions from which color feature were extracted and, thereby, detect skin regions. Although, sometimes, the results were not accurate because the gradient maps were inconsistent due to the image size, resolution, texture, etc., mostly, the proposed method showed better performance than existing methods in detecting skin regions, especially in images in which the colors were distorted or the background contained colors that were similar to the skin regions. While, in images of people who are wearing clothes that have similar colors to the skin, existing methods extracted the clothes as a skin region, the proposed method distinguished skin from clothes at over 70% rate. Further research will need to be conducted in order to reduce the false detection rate, by discovering other skin feature than color, saturation, and gradient, and improving the fuzzy rule.

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