2004년도 정보 및 제어 학술대회(CICS 04) 논문집

퍼지 색상 필터를 이용한 얼굴 영역 추출

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Extraction of Facial Region Using Fuzzy Color Filter

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Abstract - There are no authentic solutions in a face region extraction problem though it is an important part of pattern recognition and has diverse application fields. It is not easy to develop the facial region extraction algorithm because the facial image is very sensitive according to age, sex, and illumination. In this paper, to solve these difficulties, a fuzzy color filer based on the facial region extraction algorithm is proposed. The fuzzy color filter makes the robust facial region extraction enable by modeling the skin color. Especially, it is robust in facial region extraction with various illuminations. In addition, to identify the fuzzy color filter, a linear matrix inequality(LMI) optimization method is used. Finally, the simulation result is given to confirm the superiority of the proposed algorithm.

Key Words : Facial region extraction, skin color, fuzzy model, color filter.

1. Introduction

The facial feature extraction plays an important role in many applications, such as very low bit-rate video coding, and human face recognition. In order to obtain the higher coding gain, the facial feature areas are usually separated from the target image, and then special coding schemes are performed on these areas.

It is still the complex issue to extract the facial region automatically nowadays, although it might not be difficult for people to perceive human faces and facial features from a digital image. The conventional extraction method can be categorized as followings. The template-based facial region extraction method is proposed in [1]. The template-based method extracts the facial region by calculating the similarity between the target image and the template one. There exist a drawback in this method which is not easy to apply to various size images because the size of template is fixed. The feature-based extraction method is used in [2]. This method uses the feature information to detect the facial region. This method can be used easily, but it is hard to get the precise feature information in general situation. The texture-based extraction method is researched in [3]. This method finds the facial region by comparing the matrices containing the illumination information. However, getting the illumination matrices is not easy. The extraction method using neural network is considered in [4]. It used the neural network for the facial region extraction. This method has good confidence, but it takes much time to apply.

In our paper, we propose a new skin color based facial feature extraction method using the fuzzy color filter and the histogram analysis. Two step stages are proposed for the facial region extraction: fuzzy color filtering stage and histogram analysis stage. In fuzzy color filtering stage, the proposed fuzzy color filter is applied to target image to obtain the gray image containing information about the facial region. The fuzzy color filter is constituted with fuzzy model and is identified via LMI optimization method. The specific facial region is determined from the obtained gray image by using histogram analysis. New histogram analysis method is presented to determined the facial region extraction.

The organization of this paper is as follows. After Introduction, the structure and identification method for the proposed fuzzy color filter are presented in Section 2. Section 3 presents the proposed histogram analysis method. Simulation result is given to show the utility of the proposed method in Section 4. Conclusion is given in Section 5.

2. Fuzzy Color Filter for Facial Region Extraction

The skin color of human is very sensitive illumination of environment. Moreover, all people have different skin colors. Thus, it is not easy to recognize the skin color of human in the given image. In order to solve theses difficulties, we propose the fuzzy color filter. The fuzzy color filter recognizes the skin colored region in the target image. In this paper, we use the hue-saturation-illumination(HSI) color space. By using the HSI color space, we can design the color filter which is robust to illumination. The structure of fuzzy color filter can be described as following:

$$R_i: \text{ IF } x_1 \text{ is } M_{i1} \text{ and } x_2 \text{ is } M_{i2} \text{ and } x_3 \text{ is } M_{i3} \text{ THEN } y_i(x) = a_i \quad (1)$$

where, x_1, x_2, x_3 is the ith feature input containing HSI color values, $M_{i1}, \cdots, M_{i3}$ are the antecedent fuzzy sets, $y_i(x)$ is the consequent output of the ith rule, $x=[x_1, x_2, x_3]^T$ is the input feature vector, and a_i

are consequent parameters. In this paper, we suppose that the consequent parameter is determined as 1. The membership function is defined as

$$\mu_{M_{ij}} = e^{-\frac{(c_j^i - x_j)^2}{v_j^i}} \quad (2)$$

where c_j^i is the center and v_j^i is the width of jth feature of the ith rule. Thus, the firing strength $h_i(x)$ can be described as

$$\begin{aligned} h_i(x) &= \prod_{j=1}^{3} \mu_{M_{ij}}(x_j) \\ &= e^{-\frac{(c_1^i - x_1)^2}{v_1^i}} \times e^{-\frac{(c_2^i - x_2)^2}{v_2^i}} \times e^{-\frac{(c_3^i - x_3)^2}{v_3^i}} \\ &= e^{-\sum_{j=1}^{m} \frac{(c_j^i - x_j)^2}{v_j^i}} \end{aligned} \quad (3)$$

where $V_i = diag(1/\sqrt{v_1^i}, 1/\sqrt{v_2^i}, 1/\sqrt{v_3^i})$ is the diagonal matrix containing the widths of the Gaussian membership functions in the antecedent part of the ith rule, and $c_i = [c_1^i\ c_2^i\ c_3^i]$ represents vector that has center values of the membership function of the ith rule. V_i and c_i are determined by using LMI optimization method.

The output of the fuzzy rule is then inferred by following equations:

$$Y(x) = \frac{\sum_{i=1}^{l} h_i(x)\, a_i}{\sum_{i=1}^{l} h_i(x)} \quad (4)$$

where $h_i(x)$ is the firing strength of the ith rule, $\mu_{M_{ij}}(x_C) \in R[0,1]$ is the membership degree of the jth feature of the ith rule. l is the number of fuzzy rule and is determined by manually. In usual, l has the minimum value as soon as possible in order to reduce processing time. The output image after applying the fuzzy color filter can be calculated like as follows:

$$\hat{Y}(x) = \alpha u(Y(x) - Y_{\min}) \quad (5)$$

where $\hat{Y}(x)$ is the filtered output color value of feature x, α is gray color value for skin region, $u(t)$ is the unit step function, and $Y_{\min}$ is the minimum fuzzy color filter output value for skin color. By adjusting $Y_{\min}$, we can modify the robustness of fuzzy color filter.

The fuzzy color filter is trained by using the LMI optimization method. To give robustness property, the skin color sample is acquired from different people under various illuminations. Let $s^k = [s_1^k\ s_2^k\ s_3^k] \in S$ denote the kth input feature of skin color sample and is almost equal to 1. Then V_i and c_i should satisfy following equation:

$$(s^k - c_i)^T V_i^T V_i (s^k - c_i) = 0, \forall s^k \in S \quad (6)$$

To find the V_i and c_i satisfying (6), we formulate the following Theorem.

Theorem 1 (γ-suboptimal Membership Function Identification)

If s is given, V_i and c_i of Gaussian membership function (2) in the antecedent part of the rule i are determined by solving the following general eigenvalue problem (GEVP):

$$\begin{aligned} &\text{minimize}_{\,q_i, V_i}\ \gamma \\ &\text{subject to} \\ &\gamma > v_i > 0 \\ &L_{a(x)} = \begin{bmatrix} \gamma & \bigstar \\ V_i s - q_i & \gamma \end{bmatrix} > 0, \forall s \in S \end{aligned}$$

where $q_i = V_i c_i$, and ★ denotes the transposed element matrix for the symmetric position.

Proof: proof is omitted in this paper.

3. Histogram Analysis for Facia Region Extraction

In the second stage, the specific facial region is determined by using the histogram analysis. After applying the fuzzy color filter, the obtained gray image has two kinds of values: α or 0. The regions marked as α are candidate regions estimated as the facial region. By investigating the candidates region, we can estimate the precise facial region.

Let $I_g \subset R^{m \times n}$ denote the gray image and $x_{ij} \in I_g$ is the one pixel include the facial region information. By adding the gray value of each pixel, we obtain the following two histogram vectors:

$$o_i = \sum_{j=1}^{n} x_{ij} \quad (7)$$

$$p_i = \sum_{i=1}^{m} x_{ij} \quad (8)$$

where $o = [o_1 \cdots o_n]$ is the horizontal histogram vector and $p = [p_1 \cdots p_m]$ is the vertical histogram vector. We segment the facial skin color object by using left and right edge vectors. At first, we investigate the vertical histogram. The segmented vertical histogram $\hat{p}_i$ is calculated by using the following equation:

$$\begin{aligned} \hat{p}_i = &\prod_{k=-l}^{-1} \delta(p_{i+k} - e^1_{i+k+l}) \prod_{k=1}^{l} u(p_{i+k} - e^1_{i+k+l}) \\ &- \prod_{k=-l}^{-1} u(p_{i+k} - e^2_{i+k+l}) \prod_{k=1}^{l} \delta(p_{i+k} - e^2_{i+k+l}) \end{aligned} \quad (9)$$

where l is the length of edge vector and e^1 and e_2 are left edge vector and right edge vector defined as,

$$e^1{}_i = \begin{cases} 0 & , -l, \cdots, -1, \\ d & , 0, \cdots, l \end{cases} \quad (10)$$

$$e^2{}_i = \begin{cases} d & , -l, \cdots, -1, \\ 0 & , 0, \cdots, l \end{cases} \quad (11)$$

where d is the threshold of edge for segmentation. The segmented histogram $\hat{p}_i$ has 1 when segment begin and has -1 when segment end. From these property, we can get the largest segment in vertical histogram. Then we can investigate the horizontal histogram in order to find the horizontal information of the facial region. The segmented horizontal histogram $\hat{o}_i$ is calculated by using following equation:

$$\hat{o}_i = \prod_{k=-l}^{-1} \delta(o_{i+k} - e^{1}_{i+k+l}) \prod_{k=1}^{l} u(o_{i+k} - e^{1}_{i+k+l}) - \prod_{k=-l}^{-1} u(o_{i+k} - e^{2}_{i+k+l}) \prod_{k=1}^{l} \delta(o_{i+k} - e^{2}_{i+k+l}) \quad (12)$$

Similar to vertical histogram, the largest segment is found by investigate segmented horizontal histogram $\hat{o}_i$.

4. Simulation

In this paper, we acquire the 24bit color target images by using CCD camera with 320×240 size. The target image contains the front head and shoulder images. The sample images used to train the fuzzy color filter are obtained from the skin images of three people under 4 different illuminations. In fuzzy color filter, the rule size in (1) is fixed as 2.

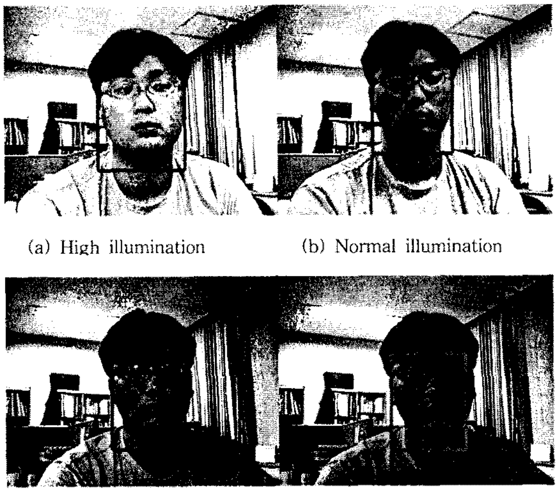
When the target image shown in Figure 1 is given, we can apply the identified fuzzy color filer. Figure 2 shows the filtered image and histogram distribution. The largest segment is then determined by using histogram analysis method. Finally, the extracted facial region is shown as the red box in Figure 1. In order to test the robustness for illumination variation, additional four images with different illumination conditions are used in simulation. Figure 3 shows the target image and the extracted facial region with various illuminations. From simulation results, we can confirm the robustness and superiority of the proposed method.

Figure 1. Target image and extracted facial region.

Figure 2. Fuzzy color filtered image and histogram.

5. Conclusion

In this paper, we present the facial region extraction method via fuzzy color filter. When the target image is given, the gray image is obtained through the proposed fuzzy color filter. LMI optimization method is used to train the fuzzy color filter. The precise facial region is extracted from gray image by using histogram analysis. Finally, utility of the proposed method is checked via simulation results.



(a) High illumination (b) Normal illumination

(c) Low illumination (c) Very low illumination

Figure 3. Facial region extraction with various illumination conditions.

감사의 글: 본 연구는 정보통신부에서 지원하는 URC (Ubiquitous Robotic Companion) 과제의 지원을 받아 수행되었습니다.

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