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Implementation of the Watershed Method in the HSI Color Space for the Face Extraction

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Abstract

The color segmentation is an important pre-processing step in the face detection methods. In this paper we present an effective face color segmentation in the HSI (Hue, Saturation and Intensity) space. We propose to modify the merging algorithm of the catchment basins obtained by the watershed segmentation method by adding a criterion based on the relevance of the Hue component. The obtained experimental results are presented to demonstrate the effectiveness of our approach.

1. Introduction

In order to improve the access control to sensitive sites such as airports, banks and research laboratories, the biometric recognition systems are increasingly necessary. Among the various biometric methods currently used (iris, fingerprints, faces) the identification from faces seems to be most promising. However, the effectiveness of this kind of identification systems depends primarily on the used face detection methods.

Several methods dealing with the face detection problem were developed these last years. They demonstrate that the color of the human skin is a reliable feature in such applications and can be used in order to reduce the faces research space. Various color spaces can be used to detect pixels which have the color of the human skin. Peer et al. [1] proposed a skin classification defined explicitly in the RGB space. Hu [2] uses the HSI color space to detect the skin characteristics. A neural network (MLP) is then used to classify the face regions. Saxe et al. [3] use the HSV space. They have developed an iterative method to identify the skin, based on the intersection of histograms. Other interesting methods use the simple Gaussian model [4,5,6], or mixed gaussian models [7] to describe the distribution of the skin colors. Lee et al. [8] propose a new statistical color model for the skin detection, called "Elliptical Boundary Model". This model overcomes the

problems encountered in the simple and mixed gaussian models like as the complexity of their training and their processing time.

Methods which combine various features such as size, shape and the skin color have been proposed. For example, Sobottka et al. [9] propose a face localization and facial features extraction method which use both the elliptic form of the face and the color. This region-based method is more robust to noise and variation of illumination then contour based-method.

However, in the methods presented above, several problems were not solved in a satisfactory way, in particular when the lighting and the orientation of the face are not controlled. In this paper, we present an effective face segmentation algorithm in the HSI space which adapts to the real conditions of scene acquisition such as variable lighting and random orientations of the face. This algorithm uses the watershed segmentation method and takes into account the hue and the saturation during the basins fusion process. The proposed method deals with biometric applications in which scenes contain only one face.

The remainder of this paper is organized as follows. Section 2 is devoted to the definition of the HSI space. The HSI gradient [10] is presented in section 3. Section 4 describes the proposed algorithms for the skin segmentation and the face extraction. Section 5 presents results of our experiments. Finally, section 6 provides conclusions and pointers for future works.

2. HSI Space representation

The HSI system (Hue, Saturation, Intensity) is close to the human perception of colors. The main advantage of this representation is its capacity to ensure a decorrelation of color information. For example, the colors "red" and "pink" are distinguished only based on the saturation component, whereas in the RGB space, there is a high correlation between the three components.

The HSI components are obtained from the RGB ones by using an algebraic transformation [10]: let Y denote the intensity and $(C1, C2)$ the chrominance components, so:

$$\begin{bmatrix} Y \\ C_1 \\ C_2 \end{bmatrix} = \begin{bmatrix} 1/3 & 1/3 & 1/3 \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

The Hue, Saturation and Intensity components are then given by the following equations:

$$I = Y = (R+G+B)/3, \quad S = \sqrt{C_1^2 + C_2^2}$$

$$C_3 = \text{atan2}(C_1, C_2)$$

$$\text{If } (C_3 > \pi/2)$$

$$\text{Hue} = ((\pi/2 - C_3) + 2 * \pi)$$

$$\text{else}$$

$$\text{Hue} = (\pi/2 - C_3);$$

Because Hue component has a cyclic value and so it can be represented by the following figure:

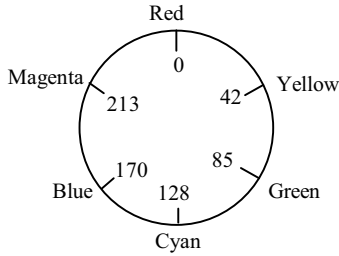


Figure 1. The circular representation of the Hue component

3. HSI gradient

In our segmentation approach, we propose to use the HSI gradient to compute the vectorial gradient of Di Zenzo [11]. The HSI gradient is defined by the three marginal gradients of the Hue (H), Saturation (S) and Intensity (I) components. To compute these marginal gradients we used the CARRON method [10]. The originality of this method lies in the fact that the computation of the gradient is function of the relevance of the Hue component. Indeed, the Hue information has variable relevance: when the color is strongly saturated, Hue is a reliable information and it is not very sensitive to the noise. On the other hand, when the saturation is weak, Hue is very sensitive to noise and thus its relevance is bad. For example, privilege the Hue when it is relevant, allows to surmount the shading phenomena. The coefficient $\alpha(S)$, a function of saturation, is thus built, to measure the relevance of the Hue component. This function is defined algebraically by the following relation (figure 2):

$$\alpha(S) = 1/\pi [\pi/2 + \arctg(\beta(S - S_0))] \quad (2)$$

where S_0 allows to define a mean relevance level of the Hue component related to the saturation level,

and β adjusts the slope of the function around the S_0 level and allows to control the mixing within the situations where the Hue relevance is average (figure 2).

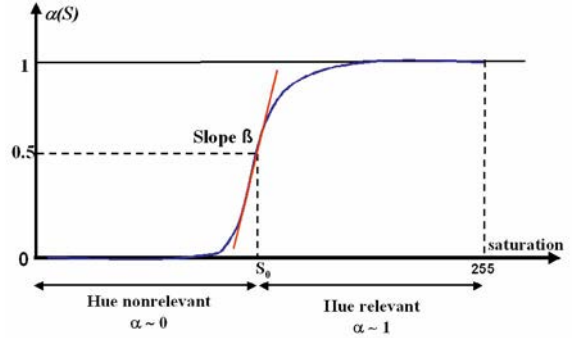


Figure 2. The Hue relevance Measurement

The coefficient $\alpha(S)$ must be a global measurement of the Hue relevance of all the pixels used in the computation of the three components of the gradients (Hue, Saturation and Intensity). An example of the computation of the Hue gradient according to x and y axes is then carried out as follows:

$$G_x^T = \Delta T(T_i, T_j) M_{Sobel}^x, \quad G_y^T = \Delta T(T_i, T_j) M_{Sobel}^y$$

where M_{Sobel} is the Sobel gradient operator, and :

$$\Delta T(T_i, T_j) = \sqrt{\alpha(S_i) \cdot \alpha(S_j)} |T_i - T_j|_{\text{modulo } 255}$$

4. Face Extraction

4.1 Skin segmentation

Our method is based on the watershed algorithm proposed by Andrade [12]. In this method, the catchment basins merging process is guided by two parameters: a depth criterion (the norm of the gradient of the basin local minima) and an area criterion (figure 3). This approach is very efficient to solve the over-segmentation problem of the traditional watershed algorithms [13] enabling the direct segmentation of the original image without the need of an additional post processing step.

We propose to modify the Andrade catchment basins merging rules as follows: we remove the area criterion and replace it by the Hue criterion. Indeed, in our application the region area is not a relevant criterion because faces can have different sizes in the images, on the other hand the Hue information constitutes a discriminating descriptor of the skin color. Thus, the merging rule which we propose combines the Hue relevance (Carron criterion) with the region depth criterion. In the Carron criterion we used the difference in levels between the basin's local minima instead of using the color information related to the pixels.

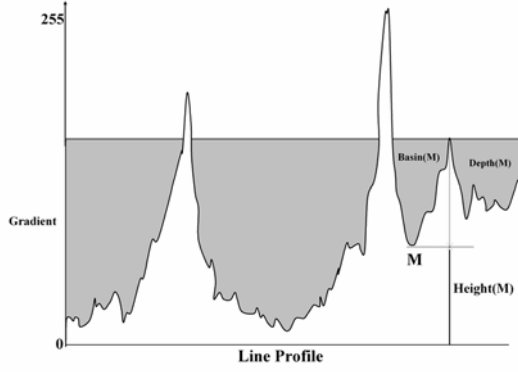


Figure 3 The depth of a catchment basin is the difference of altitude between the flooding level and the height of its minimum M.(from Andrade [12])
Our proposed catchment basins merging algorithm is given below.

Algorithm:

Let S_n , H_n and I_n be the Saturation, Hue and Intensity corresponding to the local minimum of the nth basin. Let B_1 and B_2 be two catchment basins candidate to the merging process. We define the merging criterion as follows :

$$C(B_1, B_2) = p(S_1 - S_2) \left| \left| T_1 - T_2 \right|_{255} \right| - (1 - p(S_1 - S_2)) |L_1 - L_2|$$

where

$p(S_1, S_2) = \sqrt{a(S_1) \cdot a(S_2)}$ is the geometric mean of the weighted coefficients between two local minima of the regions, and $|T_1 - T_2|_{255}$ is the Hue deviation measurement between two local minima of the regions, computed modulo 255.

The merging threshold $Seuil_C$ for the two catchment basins B_1 and B_2 is given by [10]:

$$Seuil_C(B_1, B_2) = p(S_1, S_2) Seuil_T + (1 - \Gamma(S_1, S_2)) Seuil_L$$

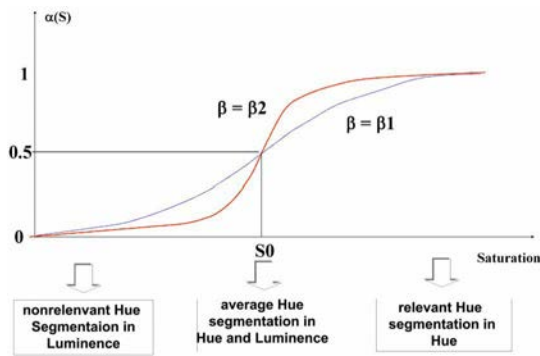


Figure 4. Strategy of use of the HSI components

The threshold of the high saturation ($Seuil_T$) is defined as the first minimum found after the first peak on the saturation histogram. The threshold of weak saturation ($Seuil_L$) is much more difficult to define. It corresponds to the significance threshold of the Hue component in the used transformation

RGB→HSI. Figure 4 summarizes the segmentation strategy according to the choice of the components S_0 and β .

The merging algorithm between two catchment basins B_1 and B_2 is summarized on Figure 5 (S_{prof} is the threshold for the basins depth).

```

haut1 = M - B1 .depth
haut2 = M - B2 .depth

If (C(B1 , B2) <= Seuilc((B1 , B2) &&
( haut1 < Sprof || haut2 < Sprof)
{ if (haut1 >= haut2)
//basin B1 absorb basin B2
// update basin B1
else (haut1 < haut2)
// basin B2 absorb basin B1
// update basin B2
}

```

Figure 5.The catchments basins merging algorithm

4.2 Face Extraction

The watershed algorithm used here allows to obtain large regions which facilitates the later interpretation of the image. In order to extract the face from the segmented image, we combined two regional features : size and colour. Thus, from different Hue histograms of several images, we defined one domain (between 1 and 40) corresponding to the skin color.

Figure 6 shows the Hue histograms obtained for persons with different skin colors and under variable conditions of lighting. For each segmented region, we computed the average of the Hue. Among the regions belonging to the "skin domain " (i.e. whose average Hue belongs to the domain) we retains the region which has the maximum size and we assume that this region correspond to a face.

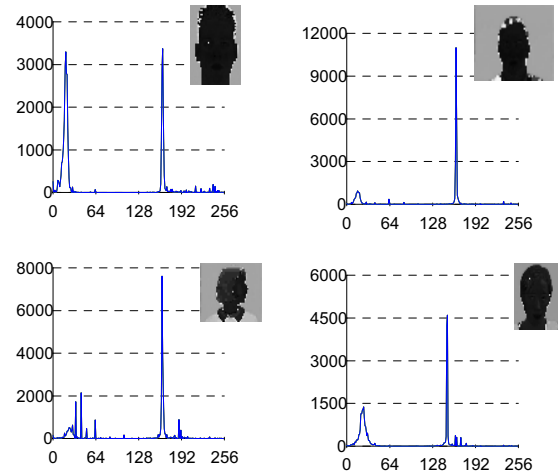


Figure 6. Example of the histograms of Hue images

5. Experimental Results

The algorithm proposed in this paper was tested on several images extracted from the face database XM2VTSDB [14]. These images are taken under variable conditions of lighting and pose. Figure 7 illustrates a result of face segmentation obtained by our method. We notice that the face is well segmented in closed and distinct regions corresponding to the various parts of the face (eyes, nose, mouth and eyebrows).

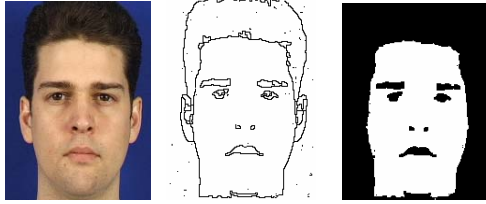


Figure 7. An example of a face segmentation

Figure 8 shows the saturation histogram for the previous image, it allows to determine the segmentation parameters : S_0 and thresholds ST and SL .

The choice of S_0 depends on the characteristics of the scene. Thus, in order to limit the influence of lighting condition on the segmentation, the value of S_0 must be kept low so that the processing is carried out primarily on the Hue component (which is not sensitive to these variations). In our example (image on a blue and dark background) we have set the maximum threshold SL to 68, the minimal threshold ST to 107, and the depth threshold to 25. We also take $S_0 = 83$. This value corresponds to a local minima of the saturation histogram being between the thresholds SL and ST . Finally, to obtain a high slope we chose $\beta = 0.45$

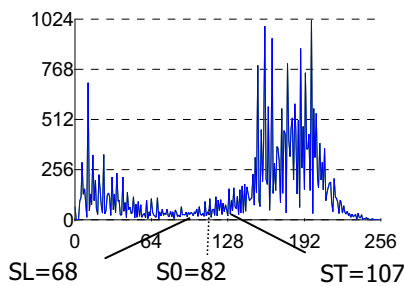


Figure 8. Saturation histogram of figure 6 and the segmentation parameters values

Figure 9 shows some segmentation results obtained on images of persons with different skin colors taken under variable conditions of lighting and pose. Thus, in figure (9-a), (9-b) and (9-c) we consider three people from different ethnic: an African person, an Indian person and a white person, respectively. In images (9-d) and (9-e) the persons are in a profile view and the illumination of their

faces is variable. In figures (9-f) and (9-g) the lighting of the face is heterogeneous (a luminous forehead and shadows on the right profile). We note that in all these cases our algorithm extract the face in a satisfactory way.

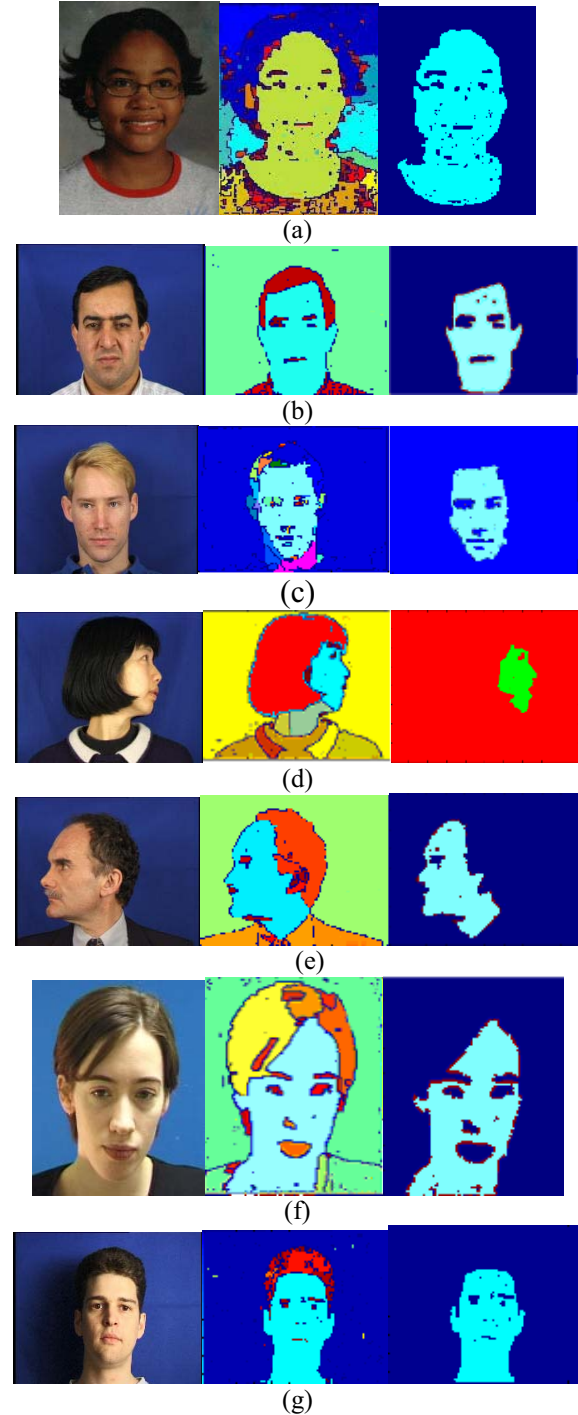


Figure 9. Some experimental results

6. Conclusion

In this paper we proposed a face segmentation and extraction method based on the watershed algorithm and applied to the color images. It is based

on the computation of the HSI gradient and takes into account the Hue relevance during the catchment basins merging process. The obtained results are encouraging and show the robustness of our method against noise and variations of illumination and pose. The advantage of this method consists in using various segmentation strategies according to the saturation value (by brightness, by brightness-hue, and by hue). Our current investigation is how to tune the segmentation parameters in an automatic manner to achieve optimum performance when extracting the face features, in a prospect to develop a semi-constrained face identification system which will allow to control the faces lighting.

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