Segmentation of Skin Color Regions Based on Fuzzy Cluster

Kong Xiao[1], Liu Danghui[1,2] and Shen Lansun[1]

1. Signal and Information Processing Lab, Beijing University of Technology, Beijing 100022, China
2. The Academy of Equipment, Command and Technology, No. 77, Mailbox 3380, Beijing 101416, China

ABSTRACT

Skin color is an important feature for face detection in color images. By building and applying a statistical skin color model, possible face regions in color images can be obtained. However, due to the including of different race of people's skin color points, this general statistical model is not accurate enough to segment each specific image as we expected. Besides, most 2D skin color models, e.g. CbCr, which is 2D projection of 3D color distribution, can't adapt itself to lighting variation. So we present a 3D CrCbCg model to describe skin color distribution more precisely. Meanwhile, considering skin points in a specific image have a relatively stable distribution, we present a fuzzy cluster based skin model to remove background points which are wrongly retained by the general model. Experimental results show that our algorithm can effectively improve segmentation results.

1. INTRODUCTION

Human skin color is an important feature of face region in color images[1-3]. Because of its insensitive to the variations of pose, rotation and facial expression, it can be used to distinguish skin regions from complex background, and effectively reduce the size of searching space. Because skin color points exhibit a convergent cluster in color space, some simple models[4-6] were usually used. However, with the variations of lighting condition and different race of people, simple 2D skin color model cannot describe the distribution as accurate as possible. So, Hsu[4] presented a lighting compensation algorithm by a non-liner color transformation to overcome the variation of skin color with changing lighting conditions. Dios[5] present a new color space YCgCr, which can be derived from YCbCr, and get a little better result compared with YCbCr. The general model is usually obtained by using all kinds of skin color points. Considering color points distribution in a specific image, a further refinement can be applied to get more satisfied results.

In this paper, we present a fuzzy cluster based skin segmentation algorithm. In training phase, a statistical skin color model in 3D CrCbCg space is obtained. In testing phase, first use color model to extract skin region and then a further segmentation is applied to achieve more accurate results. Experiments show that our algorithm can effectively improve segmentation results.

2. SKIN MODEL IN CrCbCg COLOR SPACE

CbCr, which is 2D projection of 3D color distribution, can't adapt itself to lighting variation. Simply discarding luminance information will definitely affect the model's accuracy.

We present a 3D CrCbCg model to describe skin distribution more precisely. The three components, Cr, Cb and Cg, can be calculated by the relation between Y, Cb, and Cr (Equ.1). Skin color distribution in CrCbCg space is shown in Fig.1. By using the complete color information, our model can be roughly independent of luminance change and adapt itself to different lighting condition.

$$\begin{bmatrix} Cg \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 128 \\ 128 \\ 128 \end{bmatrix} + \frac{1}{256} \cdot \begin{bmatrix} -81.085 & 112 & -30.915 \\ -37.945 & -74.494 & 112 \\ 112 & -93.768 & -18.214 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

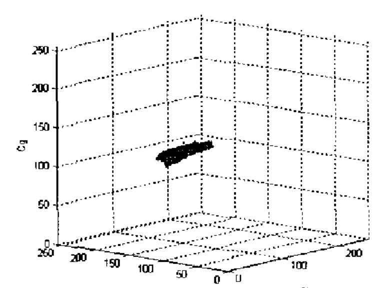

Fig.1 Skin point distribution in CgCbCr space

3. FUZZY CLUSTER BASED SKIN EXTRACTION

Most skin color segmentation algorithms only apply statistical skin color models to extract skin areas, that is, only uses the prior knowledge. Thus, for a specific image there will be lots of background points which are wrongly retained by this general model. Considering skin points in an image have a relatively stable distribution and background points have a more scatter distribution, we present a fuzzy cluster based skin color model to refine the output and increase accuracy of the skin segmentation.

3.1 Skin color region extraction based on statistical model

After skin color regions extraction by the statistical model, there are many background areas such as hair, darker clothes, etc. left together with real skin region. We find that in most images, color distribution of these residual points exhibits an obvious cluster-distributed characteristic, as illustrated in Fig.2. The different colors, red, blue, green, cyan, magenta and yellow, represent possibilities of color points, from big to small.

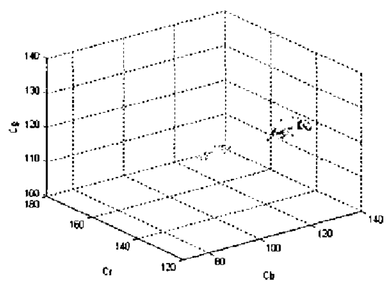

Fig.2 Skin point distribution in a specific image

By analyzing them, we know that cluster in the middle represents white, yellow skin-tone and possibilities of points don't change much, cluster in upper-right represents background and possibilities change greatly.

A fuzzy cluster algorithm can be designed based on this feature to separate points into two clusters, retain real skin and eliminate wrongly judged background points.

3.2 Fuzzy cluster algorithm

We apply improved C-mean cluster algorithm[7] to the residual points. $\{x_i, i = 1,2,\ldots,n\}$ is the set containing n samples, c is the number of cluster, $m_i, i = 1,2,\ldots c$ is the center of cluster, $\mu_j(x_i)$ is membership function which indicate the possibility of sample i belongs to cluster j.

Lost function can be defined by membership function:

$$J_f = \sum_{j=1}^{c}\sum_{i=1}^{n}[\mu_j(x_i)]^b \left\|x_i - m_j\right\|^2 \qquad (2)$$

where b is a constant to control the fuzzy degree.

Limit the membership function to make the sum of membership function of all samples to all clusters as follows:

$$\sum_{j=1}^{c}\sum_{i=1}^{n}\mu_j(x_i) = n \qquad (3)$$

Follow Equ.3's constraint, Equ.2's minimum can be computed:

$$m_j = \frac{\sum_{i=1}^{n}[\mu_j(x_i)]^b x_i}{\sum_{i=1}^{n}[\mu_j(x_i)]^b}, j = 1,2,\ldots,c \qquad (4)$$

$$\mu_j(x_i) = \frac{n(1/\left\|x_i - m_j\right\|^2)^{1/(b-1)}}{\sum_{k=1}^{c}\sum_{l=1}^{n}(1/\left\|x_l - m_k\right\|^2)^{1/(b-1)}}, \qquad (5)$$

$$i = 1,2,\ldots n \quad j = 1,2,\ldots c$$

In practical use, we add a weight parameter to membership function when update m_j:

$$m_j = \frac{\sum_{i=1}^{n}[\mu_j(x_i)]^b w_i x_i}{\sum_{i=1}^{n}[\mu_j(x_i)]^b w_i}, j = 1,2,\ldots,c \qquad (6)$$

where w_i is the possibility of each skin points.

Based on this algorithm, an iterative procedure is applied as follows:

1. Set the number of cluster c=2 (means separate points into two cluster) and parameter b=2 (for the convenience of calculation)
2. Initialize membership function $\mu_i(x_j)$=1/c (means no preference for each cluster) and center of cluster m_i (initially set to be statistical center from large images)
3. Use current cluster center m_i to calculate membership function, by Equ.5
4. Use new membership function $\mu_i(x_j)$ to update cluster center, by Equ.6
5. If algorithm convergent iteration stops, otherwise, back to step 3.

3.3 Judgment of skin color cluster

After applying cluster algorithm, we need to determine which cluster is corresponding to the real skin region. So we design three criteria to ensure robustness of algorithm.

1. Different importance of skin color points in statistical model. When training skin model, we attach a mark to the points whose possibilities in training set are high enough (Fig. 3). If cluster lies mostly in these marked areas, we will retain it regardless of whether following two criteria is satisfied, so that we can avoid skin region wrongly judged as background..
2. Distance between two cluster centers. If residual points in test image have a distribution similar to

Fig.2, we can get two cluster centers between which the distance will be far enough. If points are not obviously clustered, general model's result will be retained with no change.

3. Deviation of possibility in each cluster. In real skin area, possibilities of points don't change much so that deviation will not be so large. On the contrary, in background area, there will be a non-regular distribution, the possibilities change largely, and the deviation is much larger than that of skin region.

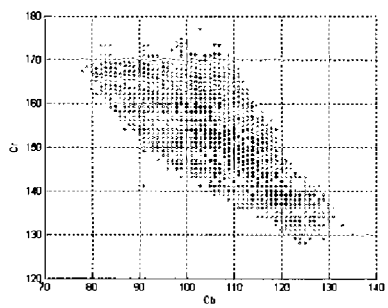

Fig.3 Distribution of high possibility points in skin model

4. EXPERIMENT RESULT

We use two test sets to validate our algorithm.

First is HHI test set[8], containing 206 images. The characteristics of this set are simple background and one image containing one face which takes up much space in image. The difficulty of this set lies in lighting condition changed greatly, background tone very close to the skin. Because of these, most segmentation algorithm can't get satisfied results from it. The goal of using this set is to compare our algorithm to others.

Second is built by ourselves, containing 478 images. The source of s includes digital images, screen shots, Internet, etc. Each image contains one or more faces with complex background, the face size and lighting condition varies greatly. The goal of using this set is to investigate algorithm's ability of adapting to complex images.

We use three criteria to evaluate the performance.

- **Better result:** result images mainly have skin regions, most of background points are discarded, containing two parts of images:
  Obviously improved: much background which retained by general model are effectively eliminated.
  Retain better: the output of general model is good enough, so we just retain it.
- **No significant improve:** result images retain the skin region, but still have much background, containing two parts of images:
  A little improvement: only has a little improvement.
  Approximately same: approximately no change to the general model.
- **Worse result:** much skin region is discarded, containing two parts of images:
  Become worse: the cluster algorithm eliminates many real face points.
  Retain worse: retain the worse result of general model.

Test results are shown in Table.1. Some segmentation results are shown in Fig.4.

Experiment results show that our algorithm is an effectively skin segmentation algorithm and can achieve satisfied results for most of images in the test set.

5. CONCLUSION

In this paper, we analyze the problem existed in most skin segmentation algorithms and present a new algorithm based on 3D color space and fuzzy cluster. Experiment results show our algorithm can achieve better results than other method that only use the general model.

6. ACKNOWLEDGEMENT

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Table.1 Performance of our algorithm

Test set	Image contained	Better result		No significant improve		Worse result	
		Obviously improved	Retain better	A little improvement	Approximately same	Become worse	Retain worse
HHI	206	83	62	4	56	1	0
		40.29%	30.10%	1.94%	27.18%	0.49%	0%
		145, 70.39%		60, 29.12%		1, 0.49%	
		Total: 99.51%				**Total: 0.49%**	
Ours	487	203	190	7	54	16	8
		42.47%	39.75%	1.46%	11.30%	3.35%	1.67%
		393, 82.22%		61, 12.76%		24, 5.02%	
		Total: 94.98%				**Total: 5.02%**	

(a) (b) (c)

Fig.4 The compare of segmentation results
(a) original images, (b) segmentation by the general model, (c) segmentation by our improved algorithm