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Automatic Facial Skin Segmentation Using Possibilistic C-Means Algorithm for Evaluation of Facial Surgeries

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Abstract**—**Human face has a fundamental role in the appearance of individuals. So the importance of facial surgeries is undeniable. Thus, there is a need for the appropriate and accurate facial skin segmentation in order to extract different features. Since Fuzzy C-Means (FCM) clustering algorithm doesn't work appropriately for noisy images and outliers, in this paper we exploit Possibilistic C-Means (PCM) algorithm in order to segment the facial skin. For this purpose, first, we convert facial images from RGB to YCbCr color space. To evaluate performance of the proposed algorithm, the database of Sahand University of Technology, Tabriz, Iran was used. In order to have a better understanding from the proposed algorithm; FCM and Expectation-Maximization (EM) algorithms are also used for facial skin segmentation. The proposed method shows better results than the other segmentation methods. Results include misclassification error (0.032) and the region's area error (0.045) for the proposed algorithm.

Keywords**—**Facial image, segmentation, PCM, FCM, skin error, facial surgery.

I. Introduction

IMAGE segmentation is one of the important steps in image analysis that is proposed as a classification method so that every pixel just belongs to one class. Generally segmentation consists of dividing an image into some homologous regions such that the combination of every two of them creates a congruent region [1].

Different segmentation algorithms have been proposed that can be utilized in different cases with respect to the application and their functionality. For segmenting the medical images of lungs, Fuzzy C-Means (FCM) and Enhanced Possibilistic C-Means (EPCM) have been exploited in [1]. In [2], the combination color and boundary data are used for hand segmentation. Reference [2] has used artificial neural networks for modeling hand's skin. This model is used for hand segmentation in order to obtain probability map.

Different methods of segmentation are those based on region (region growing, region splitting, region merging, split and merge techniques, NNs), those based on boundary (watersheds region, Laplacian of Gaussian, Canny edge detector, Prewitt filtering, Hough Transform, wavelets) and those based on pixels (Bayesian Classifier, Piecewise linear Classifier, Gaussian classifier, histogram based thresholding, fuzzy k-means clustering, NNs, HMMs, GAs) [3].

Segmentation as a preprocessing stage has so many applications in some concepts like computer vision, pattern recognition, medical images analysis and hand and face identification.

As we know, human face plays an important role in a person's appearance. So the importance of facial surgeries is clear. Surgeons, in order to verify and predict the results of surgery and besides prevent of some probable emotional consequences due to face modification and measuring the face features for surgery planning need strongly some automatic software which is able to measure the facial features, before and after the surgery. In the first step, for measuring and extracting the parameters of the face, segmentation and extraction of facial skin is necessary.

In literatures, different methods have been exploited for facial skin segmentation. For example, in [4] improved Otsu method has been used for facial skin segmentation. Reference [5] has used entropy thresholding for face segmentation and its objective function is optimized using bacterial foraging algorithm. In [6] and [7] FCM and EM algorithms have been used, respectively, by using varying illumination correction. Although, FCM has appropriate functionality in segmentation, it's not good for noisy data and outliers. So, in order to handle this problem, in this paper we use PCM algorithm for facial skin segmentation. In order to evaluate this algorithm, we apply it to database of Sahand University of Technology of Tabriz, Iran and the results will be compared with FCM results.

The rest of this paper is organized as follows: In Section II an appropriate color space is introduced and PCM clustering algorithm is explained. PCM and FCM algorithms are compared in Section III and finally we have experimental results and conclusion in Sections IV and V, respectively.

II. Proposed Algorithm

Since the images used in this paper are colored and human face has an enormous range of colors, selecting of an appropriate color space seems to be necessary. So, many color spaces can be used to model facial skin including RGB, HSV, YCbCr and CIELUV. The simplest for modeling the color of facial skin is YCbCr [7].

For converting an RGB image to an YCbCr one, we use the following formula [6]:

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$$faceimage = \frac{1}{3}(c_b^2 + \tilde{c}_r^{\,2} + \frac{c_b}{c_r}) \quad (1)$$

$C_b, \tilde{c}_r, \frac{c_b}{c_r}$ are all normalized in [0,255] interval. $\tilde{c}_r$ and c_r have negative values. c_r are chromaticity values in YCbCr color space. Obtained data from (1) are very suitable for skin segmentation and the practical results are satisfactory.

A. Possibilistic C_means Clustering (PCM)

The main motivation of possibilistic clustering was to overcome the problems and limitations of fuzzy clustering methods. In [8], for the first time, the objective function of FCM was adjusted and a new algorithm named PCM were introduced. The second term of PCM objective function includes a parameter η that its value is estimated by given data. It is worthy to mention that PCM is a general idea of possibilistic approach. The membership of a point to a class represents the typicality or the possibility of the point belonging to the class. By putting some limitation on objective function, the effect of noisy data and outliers gets declined. Noise points or outliers are less typical, so typicality –based memberships automatically reduce the effect of noise points and outliers. In PCM, the clusters are independent, so the objective function of ith cluster is [8]:

$$J(U,V) = \sum_{i=1}^{c}\sum_{k=1}^{n} u_{ik}^m d_{ik}^2 + \sum_{i=1}^{c} \eta_i \sum_{k=1}^{n}(1-u_{ik})^m \quad (2)$$

PCM is based on minimizing above objective function. U is membership function and V is center matrix of clusters. Membership function satisfies following conditions:

$$0 < u_{ik} < 1 \text{ for } 1 \le i \le c \text{ and } 1 \le k \le n$$

$$1 < \sum_{k=1}^{n} u_{ik} < n \text{ for } 1 \le i \le c$$

$$\sum_{k=1}^{n} u_{ik} = 1 \text{ for } 1 \le k \le n$$

$d_{ik}^2 = \|x_k - v_i\|^2$, x_k is the kth data and v_i is the center of ith class and η_i is either “scaling” parameter or “bandwidth” or “resolution”.

Like FCM, if we calculate the first derivation of objective function respect to u_{ik} and v_i, we will have:

$$\frac{\partial J(U,V)}{\partial u_{ik}} = \sum_{i=1}^{c} \frac{\partial}{\partial u_{ik}} \sum_{k=1}^{n} u_{ik}^m d_{ik}^2 + \sum_{i=1}^{c} \eta_i \frac{\partial}{\partial u_{ik}} \sum_{k=1}^{n}(1-u_{ik})^m = 0 \quad (3)$$

$$u_{ik} = \frac{1}{1 + \left(\frac{d_{ik}^2}{\eta_i}\right)^{\frac{1}{(m-1)}}} \quad (4)$$

$$\frac{\partial J(U,V)}{\partial v_i} = \sum_{i=1}^{c} \frac{\partial}{\partial v_i} \sum_{k=1}^{n} u_{ik}^m d_{ik}^2 + \sum_{i=1}^{c} \eta_i \frac{\partial}{\partial v_i} \sum_{k=1}^{n}(1-u_{ik})^m = 0 \quad (5)$$

$$v_i = \frac{\sum_{k=1}^{n} u_{ik}^m x_k}{\sum_{k=1}^{n} u_{ik}^m} \quad (6)$$

Equations (4) and (6) are the result of solving (3) and (5), respectively. Besides, we can estimate η_i as follows:

$$\eta_i = \frac{\sum_{k=1}^{n} u_{ik}^m d_{ik}^2}{\sum_{k=1}^{n} u_{ik}^m} \quad (7)$$

If initial clusters are selected such that adjusted memberships are maximum, then objective function will be maximized. We get this result, when the initial points of clusters lie in dense regions, because adjusted memberships have decreasing relation with the distance from initial point.

So for appropriate functionality of PCM, η, initial values of clusters and m have to be selected carefully. The block diagram of proposed algorithm is shown in Fig. 1. As you see, in the first step by exploiting the designed system in Sahand University of Technology, orthogonal colored images are prepared. In the preprocessing step, RGB images are mapped into an appropriate color space and the image size of original input color images was change to 256*170 pixels. The third step is applying a clustering algorithm to the image which is PCM in this paper, and finally after post processing and noise filtering, facial skin will be segmented.

III. PCM and FCM Comparison

By doing some modifications on FCM objective function, the objective function of PCM is obtained. FCM divides the input data into *n* partitions regardless of the real amount of clusters, so it can be possible to not having the same number for partitions and clusters, while PCM is a mode-seeking algorithm, which means that its clusters are calculated with respect to dense regions of input data. So, the designated regions in PCM are completely matched with clusters of input data.

The objective function of PCM can be defined as a set of *c* independent functions. Even if we don’t have the certain value of *c*, the proposed algorithm works well using a good estimation of, appropriate initialization and initial function. This algorithm is able to find *c* clusters from data that belong to either more or less than *c* clusters. In fact, PCM has this advantage against FCM that you don’t need to know the exact number of clusters.

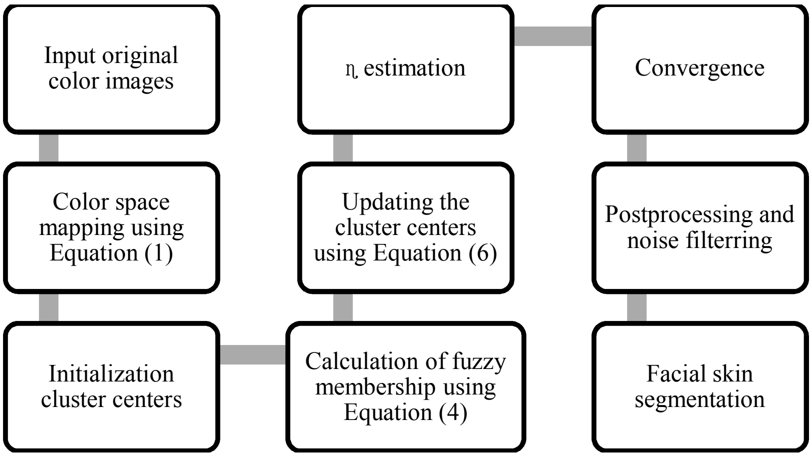

Fig. 1 Block diagram of the proposed algorithm for facial skin segmentation

Another advantage of PCM compared to the FCM is that FCM has problem in noisy environment and outliers as shown in Fig. 2. Fig. 2 (a) shows the classification using FCM algorithm on a data set with two classes. The two classes are indicated by square and cross symbols. Fig. 2 (b) shows the classification when the noise is added. As you see, in second case, FCM cumulate the two clusters into 1 class and noise points into 1 another class.

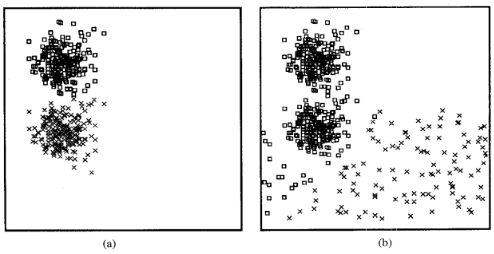

Fig. 2 Result of classification of a data set with two classes using FCM algorithm: a) Without noise, b) Noisy conditions [9]

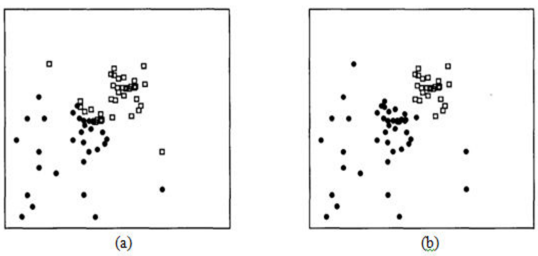

Fig. 3 Comparison of functionality of PCM and FCM algorithms in noisy environment: Result of a) FCM algorithm, b) PCM algorithm [8]

PCM, by putting some limitation on objective function, gets declined the effect of noisy data and outliers. Figs. 3 (a) and (b) show the crisp partition from the FCM and PCM algorithms, when noise is added, respectively. In the next part, we will see the results of PCM and FCM applied to our data.

IV. Experimental Results

To evaluate the functionality of the PCM we have used the database of Sahand University Of technology, Tabriz, Iran. This database contained three orthogonal facial images (for each person) which were taken simultaneously by the designed orthogonal camera system at Sahand University of Technology, Tabriz, Iran. This system is based on orthogonal placement and calibration of three cameras. These cameras are special and with specific technical characteristics for the simultaneous, fast, accurate and high quality imaging. This system contains a head fixer which increases the accuracy of imaging and sets the head in its best position. All input images were resized to 256*170 pixels.

Fig. 4 shows the results of PCM and FCM which are applied on the dataset. The first column is the main input image from frontal view, the second column shows the results of color space mapping Refer to (1) and the third and fourth columns show the results of FCM and PCM algorithms, respectively. As shown in Fig. 4, PCM has extracted the facial skin with a better accuracy compared to FCM. Since the segmentation results of facial skin can have different applications in facial surgeries, extraction of facial skin, exactly, is so important. Meanwhile, in order to extract the different parts of face like mouth, eyes and so forth, the accurate extraction of facial skin is necessary.

Four different metrics are used to evaluate the results of the facial skin segmentation algorithms [6]. Skin Error (SE) is defined as the number of skin pixels determined as non-skin divided by the number of skin pixels which are segmented manually. On the other hand, Non-Skin Error (NSE) is defined as the number of non-skin pixels determined as skin divided by the number of skin pixels which are manually segmented. The combination of these two parameters gives us another parameter, ME, which is defined by the following formula [4]:

$$M_E = (SE^2 + NSE^2)^{\frac{1}{2}} \quad (8)$$

Another parameter is relative foreground area error (RAE) which is defined as following [7]:

$$RAE = \begin{cases} \dfrac{A_O - A_T}{A_O} \; if \; A_T < A_O \\ \dfrac{A_O - A_T}{A_O} \; if \; A_O < A_T \end{cases} \quad (9)$$

where A_o is the area of reference image, and A_T is the area of thresholded image. Obviously, for a perfect match of the segmented regions, RAE is zero [6].

In order to have a quantitative analysis of PCM, as shown in Table I, we exploited four parameters which are SE, NSE, ME and RAE. As you can clearly see, PCM compared to FCM and EM is more efficient.

Fig. 4 PCM and FCM comparison, first column: original images. Second column: result obtained from color mapping. Third column: result of FCM algorithm. Fourth column: result of PCM algorithm

TABLE I
PERFORMANCE OF DIFFERENT METHODS OF SKIN SEGMENTATION IN FACIAL IMAGES OF FRONT VIEW

	RAE		M_E		NSE		SE	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Standard EM Algorithm [6]	0.045	0.037	0.042	0.031	0.110	0.060	0.300	0.074
Standard FCM Algorithm	0.060	0.036	0.033	0.031	0.080	0.036	0.194	0.060
PCM Algorithm	0.054	0.041	0.032	0.036	0.038	0.035	0.119	0.360

V. CONCLUSION

Since nowadays, surgeons need an automatic measurement system for measuring the features of face before and after the surgery and the first and most important step is the extraction of facial skin, in this paper, in order to handle the limitations of FCM, we substituted it by PCM algorithm. After explaining PCM in details, we investigated its advantages against of FCM and finally we compared the experimental results of PCM with FCM and EM algorithms. Quantitative and qualitative analysis of the results showed that the proposed algorithm is more efficient compared to two others.

REFERENCES

[1] M.Gomathi, P.Thanagaraj, "A New Approach to Lung Image Segmentation using Fuzzy Possibilistic C-Means Algorithm", *International Journal of Computer Science and information Security*, vol.7, no. 3, March 2010.

[2] W.Bu, K.Wang, X.Wu, X.Cui, and Q.Zhao, "Hand Segmentation for Hand_based Biometrics in Complex Environments", *Journal of Software*, vol. 8, no. 10, October 2013.

[3] N.A. Ibraheem, R. Z. Khan, and M. M. Hasan, "Comparative Study of skin Color based Segmentation Techniques", *International Journal of Applied Information Systems (IJAIS)*, New York,USA, vol. 5, no. 10, August 2013.

[4] B. Wang, X. Chang, C. Liu, "Skin Detection and Segmentation of Human Face in Color Images", *International Journal of Intelligent Engineering and Systems*, vol. 4, no. 1, 2011.

[5] M. A. Bakhshali and M. Shamsi, "Facial Skin Segmentation Using Bacterial Foraging Optimization Algorithm", *Journal of Medical Signals & Sensors*, vol. 2, issue. 4, October 2012.

[6] M. Shamsi, R. A. zoroofi, C. Lucas, M. S. Hasanabadi, and M.R. Asharif, "Automatic facial skin segmentation based on EM algorithm under varying illumination", *IEICE Transaction on information and systems*, vol. 91, No. 5, May 2008.
[7] M. A. Bakhshali, M. Shamsi, A. Golzarfar, "Facial Skin Segmentation with Varying Illumination Correction for Evaluationof Facial Surgery Systems", *2012 IEEE Symposium on Industrial Electronics and Applications(ISIEA2012)*, Bandung, Indonesia, September 23-26, 2012.
[8] R. Krishnapuram and J. Keller, "A possibilistic approach to clustering", *IEEE Trans. Fuzzy Syst.,*vol. 1, pp. 98-110, May 1993.
[9] R. Krishnapuram, and J. M. Keller, "The Possibilistic C-Means Algorithm: Insights and Recommendations", *IEEE Trans. Fuzzy Syst,* vol. 4, no. 3, August 1996.