Image Segmentation Using Fuzzy C-Means

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*Abstract: This contribution describes using fuzzy c-means clustering method in image segmentation. Segmentation method is based on a basic region growing method and uses membership grades' of pixels to classify pixels into appropriate segments. Images were in RGB color space, as feature space was used L*u*v* color space. Results were obtained on five color test images by experimental simulations in Matlab.*

Keywords: fuzzy c-means, images segmentation, feature space

1 Introduction

Image segmentation was, is and will be a major research topic for many image processing researchers. The reasons are obvious and applications count endless. Most computer vision and image analysis problems require a segmentation stage in order to detect objects or divide the image into regions, which can be considered homogeneous according to a given criterion, such as color, motion, texture, etc [1, 2].

Sometime is necessary to adjust computer vision to human vision. Especially is it necessary, when we are segmenting images, which were segmented by people and we try to replace people with computers or when we want to help people in segmentation of images. Typical application is medicine, e.g. segmentation of MRI images or dermatological images [1, 2].

In this paper is used fuzzy c-means clustering method as pre-processing method for basic region growing segmentation method. Basic difference from other approaches is extension of feature space, which results in better segmentation.

As test images were used five RGB color images. These images were firstly converted into L*u*v* color space [3, 4]. Fuzzy c-means method was applied to these converted images with extended feature space. Segmentation method based on region growing was applied at the end of segmentation process. The same method was used in [2, 4, 6]. In [2] was used with simple defuzzification rule, in

[4] was this method enhanced with thresholding parameter T and in [6] was used with another defuzzification rule. Results were obtained by experimental simulations in Matlab.

2 L*u*v* Color Transformation

Based on psycho-visual experiments were suggested by CIE uniform color spaces, e.g. L*a*b* or L*u*v*. In these color spaces is difference between colors computed using Euclidean distance and here exists difference between lightness and chroma. Values of L*, u* and v* are defined by [2, 3, 4, 5]

$$\begin{aligned} L^* &= \begin{cases} 116 \cdot \sqrt[3]{\dfrac{Y}{Y_n}} - 16 & \Leftrightarrow \quad \dfrac{Y}{Y_n} > \gamma \\ \beta \cdot \dfrac{Y}{Y_n} & \Leftrightarrow \quad \dfrac{Y}{Y_n} \le \gamma \end{cases} \\ u^* &= 13 \cdot L^* \cdot \left(u' - u'_n\right) \\ v^* &= 13 \cdot L^* \cdot \left(v' - v'_n\right) \end{aligned} \tag{1}$$

while values of u' and v' are defined by

$$\begin{aligned} u' &= \frac{4X}{X + 15Y + 3Z} \\ v' &= \frac{9Y}{X + 15Y + 3Z} \end{aligned} \tag{2}$$

and constants β and γ have values

$$\begin{aligned} \gamma &= \left(\frac{6}{29}\right)^3 \approx 0.008856 \\ \beta &= \frac{116}{3} \cdot \left(\frac{29}{6}\right)^2 = \frac{29^3}{27} \approx 903.296296 \end{aligned} \tag{3}$$

3 Segmentation Method

Segmentation process consists of several steps. The first of all is input image conversion to chosen feature space, which may depends of used clustering method. In our case is input image converted from RGB color space to L*u*v* color space and L*, u* and v* values are features respectively attributes for fuzzy c-means clustering method.

Next step after input image conversion to feature space is applied clustering. In our case, we have chosen fuzzy c-means clustering method, settings are in experiments section.

After these two steps (input image conversion to feature space of clustering method and accomplishing clustering method) is accomplished next segmentation method.

Method 1 (M1)

BEGIN OF M1

Assumptions: Image transformed into feature space, number of clusters c, stop condition ε, fuzziness parameter m.

Step 1: Cluster image in feature space, with next conditions: number of clusters is c, fuzziness index is m and stop condition is ε.

Step 2: Repeat for each pixel $\mathbf{a}_{ij}$ of image I.

Step 2.1: Find out, into which cluster C_ℓ belongs pixel $\mathbf{a}_{ij}$ at most.

Step 2.2: Find out, whether in the closest surroundings of pixel $\mathbf{a}_{ij}$ exists segment R_k, which points belong to same cluster C_ℓ.

Step 2.3: If such segment R_k exists, than pixel $\mathbf{a}_{ij}$ add to segment R_k, else create new segment R_n and add pixel $\mathbf{a}_{ij}$ to new segment R_n.

Step 3: Merge all segments, which belong to one cluster and are neighbors.

Step 4: Arrange borders of all segments.

END OF M1

Segmentation method used in experiments is based on simple region growing method. Method was used in [2, 4, 6] and in this paper is marked as method M1. In [2] was used with simple defuzzification rule, in [4] was this method enhanced with thresholding parameter T and in [6] was used with another defuzzification rule.

Method M2 is segmentation method based on method M1, but method M2 uses extended feature space, which will be described in next section. Difference between method M1 and M2 will be only feature space.

4 Extension of Feature Space of Fuzzy C-Means

The most important part of this segmentation method is extension of feature space. Extension of feature space is based on simple idea, that neighboring pixels have approximately same values of lightness and chroma. But in real images, noise is corrupting the image data or image usually consists of textured segments. Basic segmentation methods based on fuzzy c-means clustering are working as follows:

1 Convert image into feature space of clustering method (usually is used RGB color space, but IHS, HLS, L*u*v* or L*a*b* color spaces are used too).

2 Run fuzzy c-means method on converted image.

3 Use some defuzzification rule or rules to classify each pixel to segment. Simple defuzzification rule is based on maximal membership grade of pixel to cluster [1, 4].

Basic feature space is only color space, e.g. RGB, HIS, HLS or L*u*v* color spaces as shown on Fig. 1.

This feature spaces in combination with clustering methods have one big disadvantage. In clustering process is not involved information about pixels in neighborhood, which results in bad segmentation results, because of noise or texture.

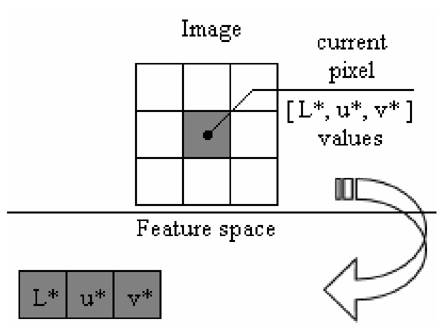

Figure 1
Standard feature space

Extension of feature space is based on involving of neighboring pixels' information. One pixel has 15 instead of 3 features. In simple case [2, 4, 6] has pixel only 3 features (L*u*v* values, Figure 1). In our modification has pixel 15 features, its own L*u*v* values and L*u*v* values of its neighbors. In practical implementation of this extension was used next sequence of pixels: current pixel, up, right, down and left neighbor pixel as shown on Figure 2.

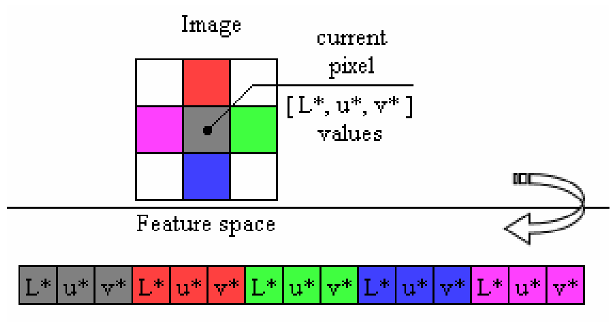

Figure 2
Extended feature space

5 Experiments and Results

In experiments were used five test color images. Experiments were done in Matlab. Conditions for clustering method were: fuzziness index $m = 2$, stop condition $\varepsilon = 0.01$, number of clusters $c = 3$.

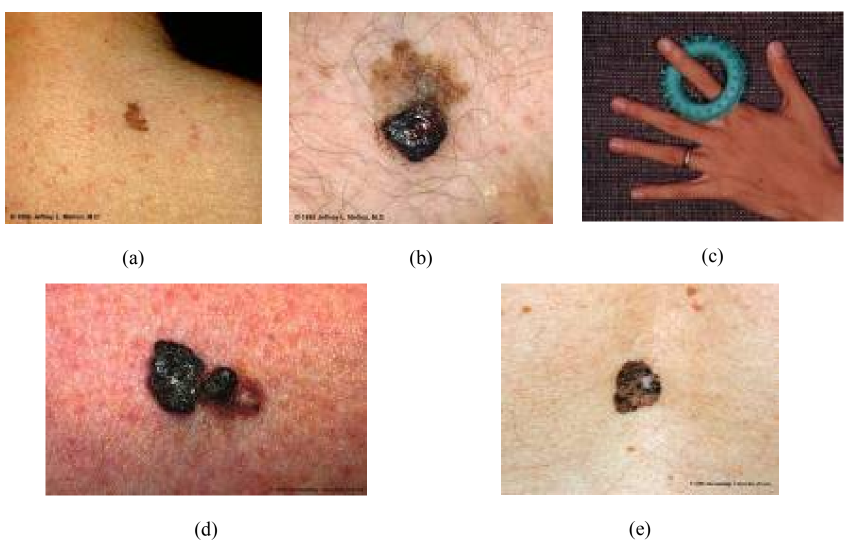

Figure 3
Test color images

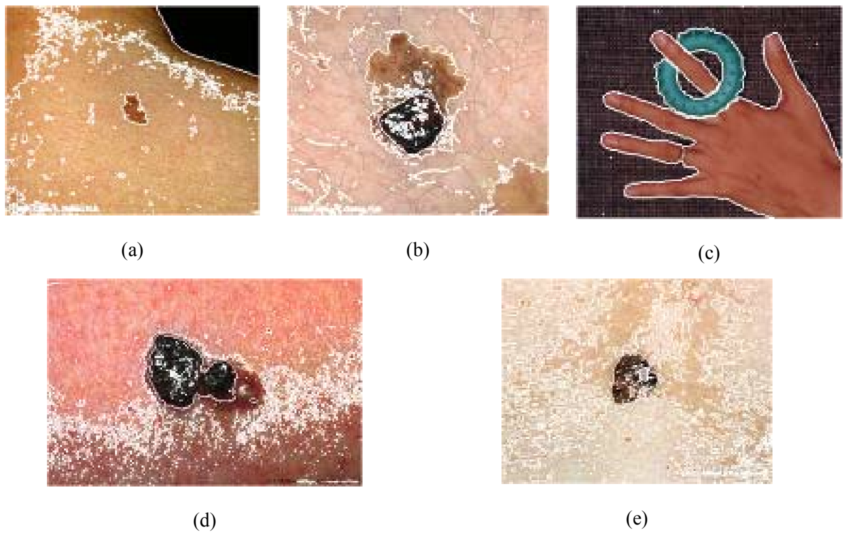

Figure 4
Segmentation results – M1

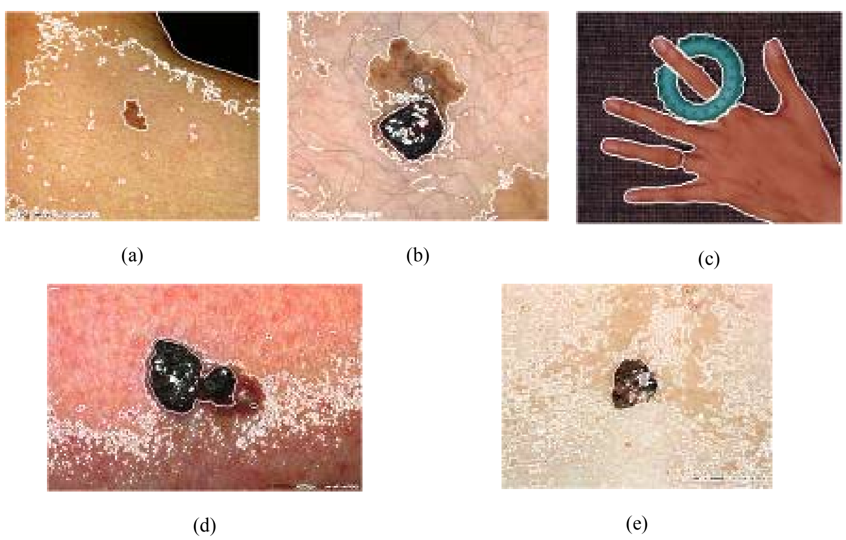

Figure 5
Segmentation results – M2

	(a)	(b)	(c)	(d)	(e)
M1	476	511	22	1944	1405
M2	183	204	10	851	855

Table 1
Segments' count of each method

Conclusions

Method M1 creates big number of segments, which is apparent from results. Method M2 creates much less number of segments. Extension of feature space of fuzzy c-means clustering method brings better segmentation results. This extension filters noise of one pixel's size. Cluster center in our case is typical pixel of segment with its typical neighbors (up, right, down and left neighbor). Method M2 has good segmentation results in case of images with large homogeneous segments, images can be corrupted with one pixel's noise.

But one of demands wasn't reached in experiments. It concerns demand on borders of segment. Border of segment may be simple and may not be rugged. For simplifying, respectively smoothing of segments' borders, may be used another methods, e.g. active contours. However simplifying borders wasn't objective of this work, but it grants impulses for next research.

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