HSL Color Space Based Skin Lesion Segmentation Using Fuzzy-Based Techniques

P. Ganesan, B. S. Sathish, and L. M. I. Leo Joseph

Abstract Skin lesion is the anomalous intensification contrast to the skin just about it. It is categorized as primary or secondary. The primary lesions are uncharacteristic skin circumstances existence at birth. The secondary lesions are the result of manipulated primary lesions. There are more than 20 types of skin lesions. Segmentation is the process of partition of the test image into number of significant clusters. Every cluster should be unique in terms of any one of the image attributes such as texture, intensity, or color. The accomplishment of image analysis primarily based on the upshot of the segmentation process. The proposed approach performs the skin lesion segmentation using fuzzy c-means clustering (FCM), Possibilistic c-means clustering (PCM). Possibilistic fuzzy c-means clustering (PFCM) and modified fuzzy c-means clustering (PFCM). The experimental result reveals the competency of the MFCM for skin lesion segmentation.

Keywords Segmentation · Color space · Skin lesion · Clustering · Fuzzy c-means clustering

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1 Introduction

In segmentation, the complete image is clustered into number of subimages in a meaningful manner. In a cluster, there should be some uniqueness among all the image elements (pixels) [1–4]. In image processing and computer vision, the role of the segmentation process is inevitable. The outcome of the segmentation process is the basis for image analysis [5]. The segmentation is based on image attributes such as color and texture [6]. Most of the segmentation techniques are application-oriented, i.e., it is very hard to get a meaningful result for more than one application using the same segmentation method [7–9]. This is a major drawback of the segmentation techniques. There are lots of image segmentation techniques based on threshold, edge, region, clustering, and so on. Skin lesion is the anomalous intensification contrast to the skin just about it. It is categorized as primary or secondary. The primary lesions are uncharacteristic skin circumstances existence at birth. The secondary lesions are the result of manipulated primary lesions. There are more than 20 types of skin lesions. In this work, fuzzy cluster-based methods are utilized to segment the skin lesion images. The efficiency of the segmentation methods is measured in terms of PSNR and computational cost. Prior to segmentation, the preprocessing to progress the eminence of the skin lesion image and sharpening is performed on the preprocessed image to enhance fine details. Most importantly, the enhanced image in RGB is transformed into user-oriented, HSL space which fairly accurate the human visual perception.

2 HSL Color Space

This cylindrical color space characterizes the color in more perceptually by three elements as hue [color type varies from 0° to 360° i.e., red (0 or 360), yellow (60), green (120), cyan (180), blue (240) and magenta (300)], the saturation which defines the purity of the color as it varies from 0 to 100% and the lightness in terms of percentage i.e., 100% of lightness is white and 0% is black [10–13]. The renovation of an image form RGB to HSL is as follows:

$$H = \arccos \frac{\frac{1}{2}(2R - G - B)}{\sqrt{(R - G)^2 - (R - B)(G - B)}} \quad (1)$$

$$L = \frac{\max(R, G, B) + \min(R, G, B)}{2} \quad (2)$$

$$S = \left\{ \frac{\max(R, G, B) - \min(R, G, B)}{\max(R, G, B) + \min(R, G, B)} \quad \text{for } L < 0.5 \right. \quad (3)$$

$$S = \left\{ \frac{\max(R, G, B) - \min(R, G, B)}{2 - \max(R, G, B) - \min(R, G, B)} \quad \text{for } L \geq 0.5 \right. \quad (4)$$

3 Fuzzy Clustering for Skin Lesion Segmentation

Fuzzy c-means clustering is the standard algorithm based on cluster centers and membership to partition a complete dataset into number of clusters [14, 15]. This algorithm utilizes the Euclidean distance to compute the space between the pixels (data points) and cluster center [16]. The major function of the algorithm is to lessen its objective function provided in (5).

$$F_m(U, V) = \sum_{i=1}^{c}\sum_{k=1}^{n} \mu_{ik}^{m} \left\| x_k - v_i^2 \right\| \quad (5)$$

where $m =$ the weighting exponent (fuzziness) parameter. Most cases, $m = 2$.
v_i= cluster centers and μ_{ik} = membership.

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

$$\mu_{ik} = \left\{ \sum_{j=1}^{c} \left\{ \frac{\|x_k - v_i\|}{\|x_k - v_j\|} \right\}^{2/m-1} \right\}^{-1} \quad (7)$$

Possibilistic c-means (PCM) clustering provided the solution for the column sum constraint of FCM [8, 17]. The objective function of PCM is illustrated in (8)

$$P_m(T, V; X, \gamma) = \sum_{i=1}^{n}\sum_{k=1}^{c} t_{ik}^{m} d_{ki}^{2} + \sum_{i=1}^{c} \gamma_i \sum_{k=1}^{n} (1 - t_{ki})^m \quad (8)$$

where γ = weighting exponent parameter. When $\gamma = 0$ and $m = 1$, PCM behaves as Hard C-Means (HCM) CLustering. In general, $m = 2$ and $\gamma > 0$ is the preferable choice. The optimum (minimum) can be achieved if it satisfies the following conditions.

$$t_{ki} = 1/\left(1 + \frac{d_{ik}}{\gamma_i}\right)^{1/m-1}, \quad 1 \le i \le c;\ 1 \le k \le n \quad (9)$$

$$v_i = \frac{\sum_{k=1}^{n} x_k t_{ki}^{m}}{\sum_{k=1}^{n} t_{ki}^{m}} \quad (10)$$

The noise sensitivity problem of FCM and coincident clusters issue of PCM is addressed by Possibilistic Fuzzy C-Means (PFCM) clustering [3]. The objective function of PCM is shown in (11)

$$PF_m(T, V, U; X, \gamma) = \sum_{i=1}^{n}\sum_{k=1}^{c} \left(a\mu_{ik}^{m} + bt_{ik}^{\eta}\right) d_{ki}^{2} + \sum_{i=1}^{c} \gamma_i \sum_{k=1}^{n} (1 - t_{ki})^{\eta} \quad (11)$$

where $m, \eta > 1$ and $a, b, \gamma > 0$. The optimum (minimum) can be achieved if it satisfies the following conditions.

$$V_i = \frac{\sum_{k=1}^{n} \left(a\mu_{ik}^{m} + bt_{ik}^{\eta}\right)x_k}{\sum_{k=1}^{n} \left(a\mu_{ik}^{m} + bt_{ik}^{\eta}\right)} \tag{12}$$

$$t_{ik} = \frac{1}{1 + \left(\frac{d_{ik}^2}{\gamma_i}\right)^{1/(m-1)}} \tag{13}$$

$$\mu_{ik} = \frac{1}{\sum_{j=1}^{c} \left(\frac{d_{ik}}{d_{jk}}\right)^{2/m-1}} \tag{14}$$

The major drawback of standard FCM is that doesn't provide any spatial information which is significant for clustering problems. In the modified FCM (MFCM), this is taken into consideration and the spatial information is incorporated as a weighted sum of the membership function [2, 13].

$$S_{ij} = \sum_{k \in W(X_j)} U_{ik}\alpha_{k1} + \frac{\sum_{k \in (X_j)} U_{ik}\alpha_{k2}}{\sum_{t=1}^{c} \sum_{k \in W(X_j)} U_{tk}} \tag{15}$$

The modified membership function is given by (16)

$$U_{ij(\text{new})} = \frac{U_{ij}^{p} * S_{ij}^{q}}{\sum_{k=1}^{c} U_{kj}^{p} * S_{kj}^{q}} \tag{16}$$

It is noted that every pixel has a weight (W_{ji}) corresponding to clusters.

$$W_{ji} = \frac{1}{1 + e^{-\left\{\frac{\|x_j - v_i^2\|}{\sum_{j=1}^{n} \|x_j - v_i^2\| \left(\frac{c}{n}\right)}\right\}}} \tag{17}$$

The objective function of MFCM is illustrated in (18)

$$\text{MF} = \sum_{k=1}^{n} \sum_{i=1}^{c} \left(U_{ik}^{m} W_{ji}^{m}\right) \left\| X_k - V_i^2 \right\| \tag{18}$$

The proposed approach for skin lesion segmentation is illustrated in Fig. 1.

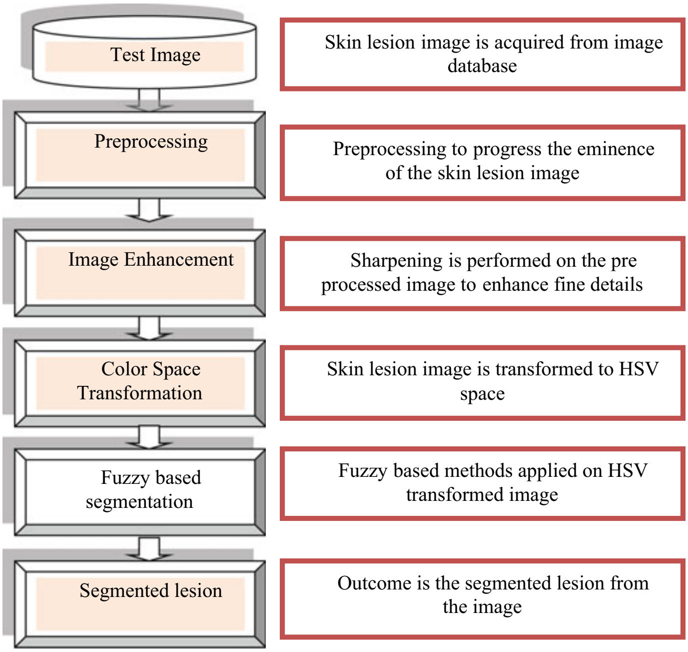


Fig. 1 The proposed approach for skin lesion segmentation

4 Experimental Results and Discussion

Figure 2a illustrates the skin lesion test image to evaluate the efficiency of fuzzy-based techniques for its segmentation. The original size of the input image is 586 * 561 (95.9 KB). The test image is sharpened to enhance its fine details as illustrated in Fig. 2b. The HSL version of the image is depicted in Fig. 2c.

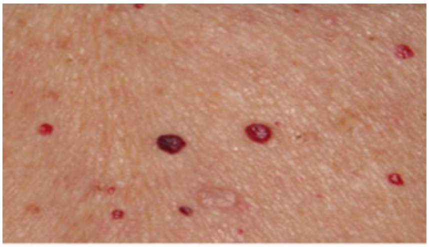
Figure 3a illustrated FCM clustering outcome of the HSL based skin lesion image. This process took 11 iterations to segment the image into three clusters. PSNR is computed as 45.436. The deviation of the segmented image from the input image is error image.

Figure 3b depicts PCM clustering outcome of the HSL based skin lesion image. This process took 15 iterations to segment the image into three clusters. PSNR is computed as 44.960.

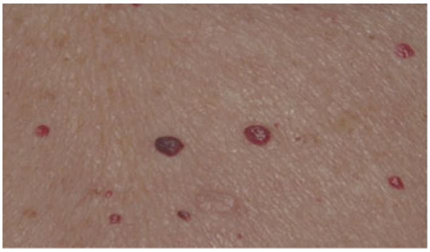
Figure 3c illustrated PFCM clustering outcome of the HSL based skin lesion image. This process took 14 iterations to segment the image into three clusters. PSNR is computed as 45.517.

MFCM clustering outcome of the HSL based skin lesion image is portrayed in Fig. 3d. This process took 15 iterations to segment the image into three clusters. PSNR is computed as 52.463.

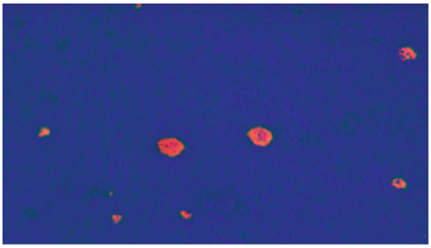
The comparative end result of the proposed approach is demonstrated in Table 1.



(a) test image (RGB)



(b) sharpened image



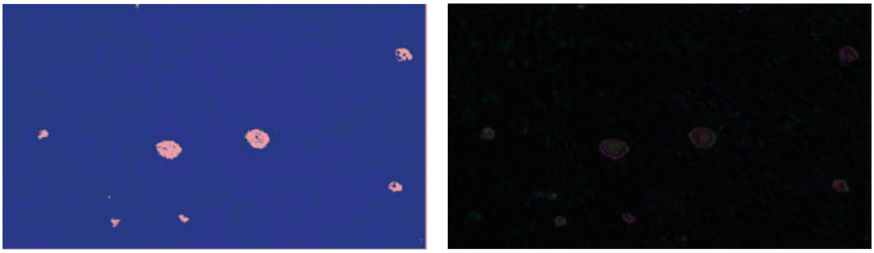
(c) HSL version of the sharpened image

Fig. 2 Test image to test the efficiency of the proposed approach

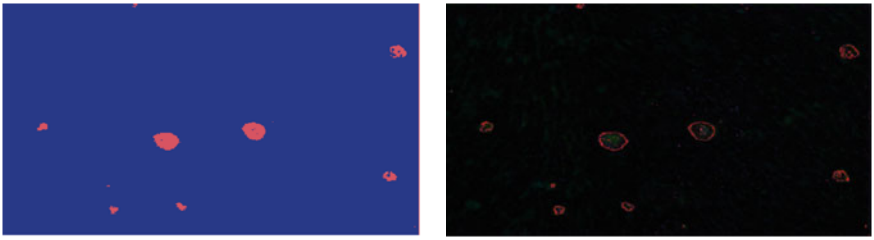
MFCM has very PSNR and PFCM has low computational cost as compared to other methods.

5 Conclusion

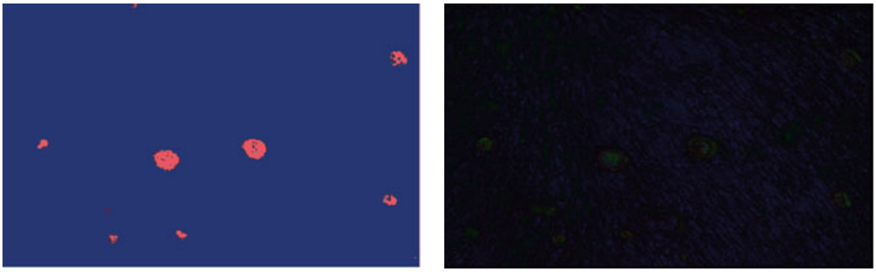
The skin lesion segmentation using fuzzy-based clustering methods is highlighted in the proposed approach. The skin lesion image in RGB is transformed into user-oriented, HSL which fairly accurate the human visual perception. The experimental analysis clearly explained that the competency of the MFCM for skin lesion segmentation. Even though the execution time for PFCM is lesser, MFCM has higher PSNR as compared to other methods.



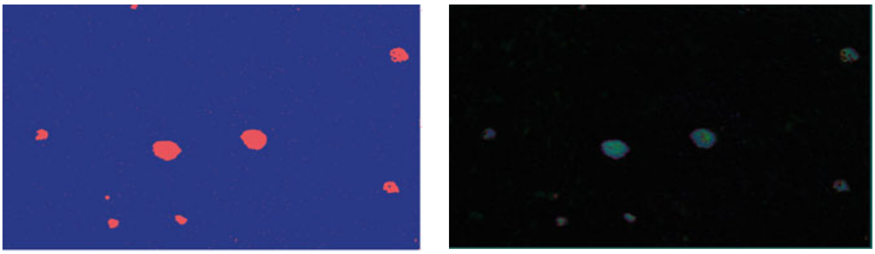
(a) FCM result and its error image



(b) PCM result and its error image



(c) PFCM result and its error image



(d) MFCM result and its error image

Fig. 3 Outcome of HSL color space based segmentation

Table 1 Comparative end result of the proposed approach

Method	No. of cluster	No.of iteration	Computational cost (s)	Cluster centers			PSNR
FCM	3	11	8.6083	232.9 13.44 14.15	155.0 42.84 49.10	164.7 126.1 116.4	45.436
MFCM	3	14	6.8608	245.1 253.1 253.3	222.5 82.34 97.34	13.66 45.77 121.6	**52.463**
PFCM	3	14	**2.30138**	246.8 235.5 13.47	254.5 84.46 45.47	255.6 92.58 121.5	45.517
PCM	3	15	11.7967	230.0 44.78 13.50	137.4 53.57 45.68	149.7 79.07 121.9	44.960

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