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Research Article

COMPARATIVE STUDY OF POSSIBLISTIC FUZZY C-MEANS CLUSTERING BASED IMAGE SEGMENTATION IN RGB AND CIELUV COLOR SPACE

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Abstract

Segmentation is the hot spot in image analysis and computer vision. It is extremely hard to attain the objective of image analysis without the achievement in the segmentation stage. In this work, fuzzy based possibilistic fuzzy c-means (PFCM) clustering had applied for the segmentation of the images. In color image processing, most of the works had performed on device dependent and not perceptually uniform RGB color space. Many color spaces had defined for various applications. In this work, the segmentation of color images had carried out on both device dependent RGB color space and device independent CIELuv color space. The performance analysis of PFCM based segmentation of color images in both RGB and CIELuv color space is evaluated using bivariate image quality parameters. Based on the analysis of the experimental results, PFCM segmentation in CIELuv color space had outperformed the RGB color space

Keywords: Segmentation, Color space, RGB, CIELuv, Clustering, PFCM, Image quality parameters.

1. Introduction

Color based image segmentation provides more meaningful information as compared to gray level and monochrome segmentation [7]. There are only two different variations in monochrome (binary) images and 256 variations in gray scale (intensity) images [8]. It is very difficult to discriminate more than 25 intensity levels for human eye. However, it is very easy to discriminate more number of color shades in color images. This means that color images can provide more information as compared to gray scale images. Moreover, a simple personal computer is enough for the processing of color images. So the color based image segmentation is very popular and widely used.

The segmentation is the most complicated stage in computer vision and image processing. This segmentation process divided an image into a set of different clusters based on color attribute [9]. Each cluster is labeled and characterized to replicate the local structure of the image. So the segmentation can be considered as a clustering problem in which each pixel in a same cluster is similar with respect to color attribute [10].

In this work, a comparative approach of execution of possiblistic fuzzy c-means clustering (PFCM) in RGB and CIELuv color space is proposed. In this work, PFCM clustering had applied for the segmentation of the images. PFCM is based on fuzzy logic and possiblistic theory. This is the combined approach of fuzzy c-means clustering (FCM) and possiblistic c-means clustering (PCM). PFCM has many advantages as compared to FCM and PCM. There is no column sum constraint and repetition of clusters. In image processing, color space is nothing but the representation of colors in a meaningful way in the three or four dimensional Cartesian or polar coordinates. There are various color spaces for different applications.

For example, RGB for displays, CMYK for printing and YCbCr for television broadcasting[11]. Even though RGB color space is not preferred for the segmentation, most of the works had performed on this color space. In this work, the image in RGB color space had transformed into CIELuv color space and then segmentation using PFCM had performed. The experimental result of PFCM had compared with FCM and PCM in both RGB and CIELuv color spaces. The quality of the segmentation process can be evaluated using various image quality parameters [4][5].

This evaluation is based on the comparison of the corresponding pixels of the input and the segmented image. The remaining chapters in this work are organized as follows. Section 2 had explained the proposed method for the segmentation of color images. The brief discussion on experimental result had given in section 3. The summary of conclusions had pointed out in section 4.

2. Proposed Method for Color Image Segmentation

The color image segmentation based on PFCM in CIELuv color space is proposed. The performance of color image segmentation in RGB and CIELuv color spaces had compared and analyzed using image quality measures. Figure 1 illustrates the proposed approach for the segmentation.

A color space is nothing but a method or way of creating and visualizing colors [13]. Human eye describes color as three important attributes of hue, brightness and colorfulness. But a computer monitor define color as the percentage of red (R), green (G), and blue (B) phosphor emissions. Various color spaces had developed for different applications [17].

The input image taken from image sensor is usually in RGB color space. However, this device dependent and non uniform color space is not suitable for objects identification and recognition of colors. Moreover, it is very difficult to find out an exact color in RGB color space. So it is very important to transform RGB color image into other color spaces such as CIELuv[14].

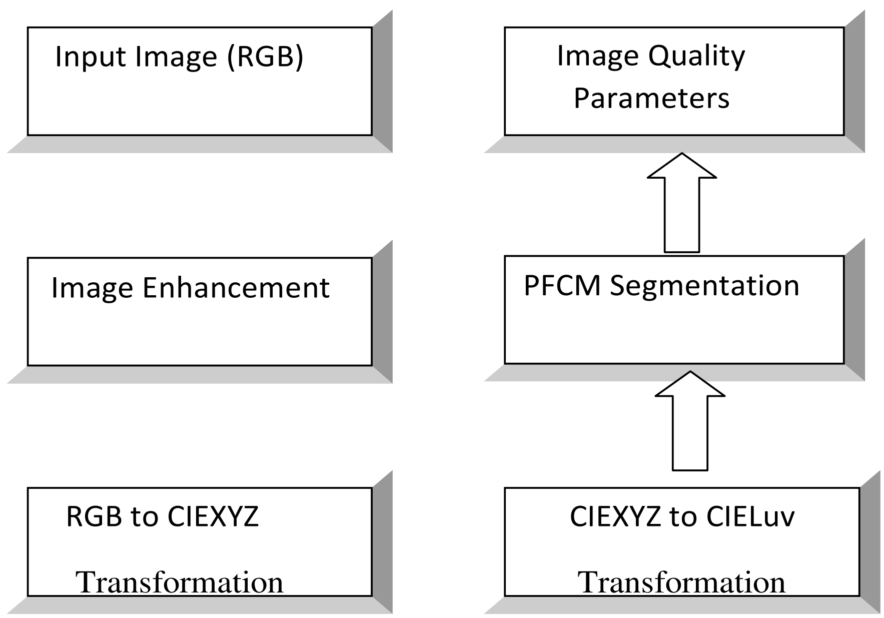

Figure 1: Proposed method for the color image segmentation.

Prior to color space transformation, the quality of the image is improved by the enhancement process. The enhancement process includes the sharpening and smoothening of fine image details. CIEXYZ color space is proposed by the CIE (Commission International de l'Eclairage). This space is developed using three imaginary primary color components X, Y and Z as depicted in fig 2. All the visible colors can easily be described by positive values of X, Y, and Z. The component Y is defined to match closely to luminance and the components X and Z represents the chrominance (color information). The chrominance mainly depends on the dominant wavelength and saturation. The transformation of an image from gamma corrected RGB to CIELUV color space is defined as

$$X = 0.412R' + 0.357G' + 0.180B' \quad (1)$$

$$Y = 0.212R' + 0.715G' + 0.072B' \quad (2)$$

$$Z = 0.019R' + 0.119G' + 0.950B' \quad (3)$$

The main advantage of the CIE XYZ and CIELuv color space is that they are completely device independent. In device independent color space, the same color information is displayed irrespective of equipment (device).However, CIEXYZ color space is not perceptually uniform color space and the shape is very difficult to visualize due to non linear characteristics of the chromaticity diagram. So the image in CIEXYZ color space should be transformed into perceptually uniform color spaces like CIELuv for the extraction of more meaningful information.

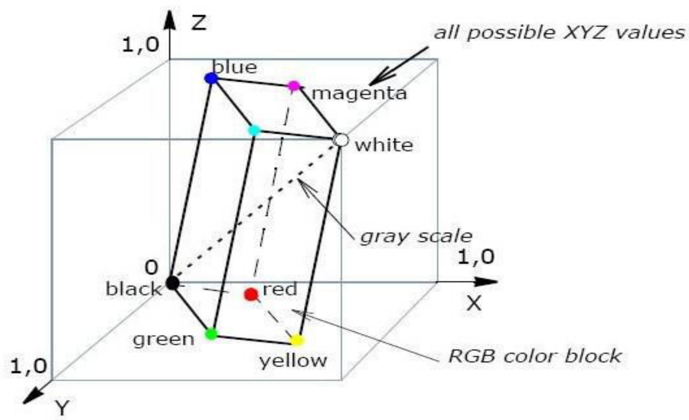

Figure 2: CIEXYZ color space representation

CIELuv color space is uniformly derived from CIEXYZ color space. In perceptual uniform space, such as CIELuv, any two colors those are equally far-away in the color space are equally distant perceptually. In CIELuv color space, the component L indicates the actual visual difference and the color information (red/blue and yellow/blue) are stored in u and v components. The transformation of CIELUV color space is defined as

$$L = 116(Y/Y_n)^{1/3.} - 16 \quad (4)$$

$$u^* = 13L\ (u - u_n) \quad (5)$$

$$v^* = 13L\ (v - v_n) \quad (6)$$

$$u = 4X / (X + 15Y + 3Z) \quad (7)$$

$$v = 9Y / (X + 15Y + 3Z) \quad (8)$$

$$u_n = 4x_n / (-2x_n + 12y_n + 3) \quad (9)$$

$$v_n = 9*y_n / (-2x_n + 12y_n + 3) \quad (10)$$

The representation of CIELuv color space is illustrated in fig 3.

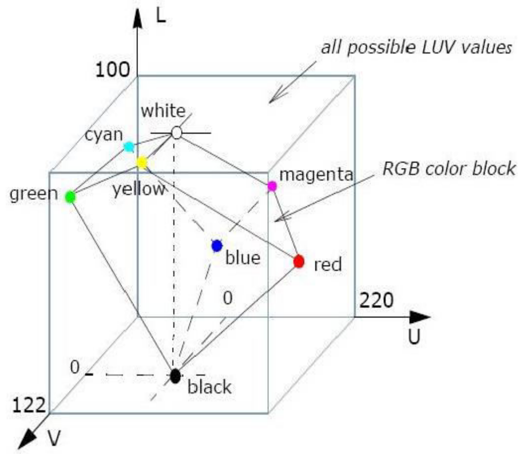

Figure 3: CIELuv color space representation

The next step is the segmentation of color images using a suitable segmentation method. In this work, segmentation is performed using Possibilistic–Fuzzy C-Means (PFCM) clustering. PFCM is a mixture of possiblistic c-means (PCM) clustering and fuzzy c-means (FCM) clustering. PFCM avoids various shortcomings of both FCM and PCM [1].The main disadvantage of FCM is that the less noise sensitivity. PFCM provides solution for this hectic issue. The objective of this clustering algorithm is diminising its objective function as given in (11)

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

Where m, η > 1 and a, b, γ > 0. All are user defined constants.

The quality of the segmentation process can be evaluated using various image quality parameters. In this work, the quality parameters used are Mean Square Error, Root Mean Square Error, and Peak Signal to Noise Ratio, Average Difference, Structural Content, Maximum Difference, Normalized Absolute Error, Laplacian Mean Square Error, ERGAS, Normalized Mean Square Error and Structural Similarity Index Measure For the best quality of image, the value of SSIM and PSNR should be high and the value of other parameters should be low as possible.

3. Experimental Result and Discussion

In this section, experimental results of the proposed approach for the segmentation of color images are presented. The proposed method had investigated using various images to test its efficiency for segmentation.

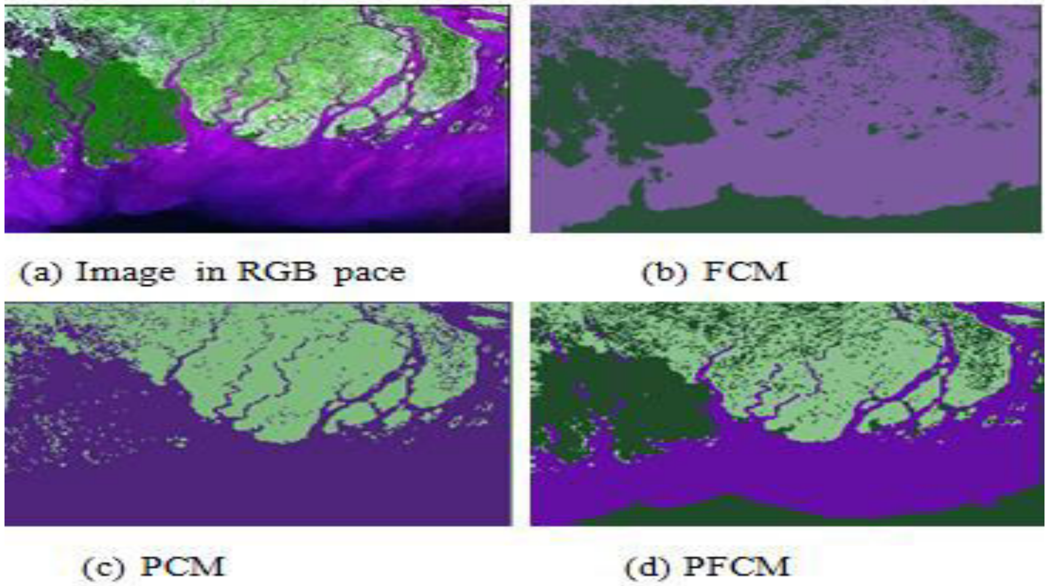

Figure 4: Segmentation result of satellite image of Ganges River Delta of size 200X150.

Fig 4 shows the segmentation of Ganges River Delta using fuzzy based methods FCM, PCM and PFCM. The size of the image is 200* 150. Table 1 illustrates the outcomes of three methods in terms of clusters and computational cost (execution time).

Table 1: Fuzzy Based Segmentation Result for Ganges River Delta Satellite Image in RGB Color Space

Parameters	**FCM**	**PCM**	**PFCM**
No. of clusters	3	3	3
No. of iterations	13	15	13
Execution time	36.233	31.673	0.1837
Cluster centers	78.44 37.52 122.3 78.44 37.52 122.3 127.1 184.4 128.1	42.84 80.67 57.03 42.84 80.67 57.03 122.7 89.83 159.7	76.35 10.12 141.4 76.35 10.12 141.4 124.0 189.3 121.3

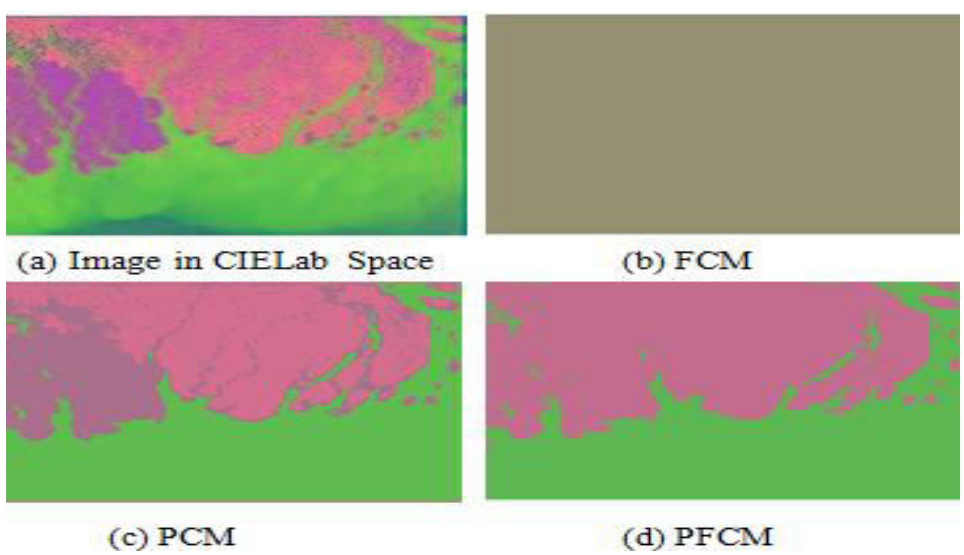

Figure 4: Segmentation result of satellite image of Ganges River Delta in CIELuv color space.

Fig 5 illustrates the segmentation of Ganges River Delta in CIELuv color space using fuzzy based methods FCM, PCM and PFCM. The size of the image is 200*150. Table 2 depicts the result of fuzzy based methods in terms of clusters and computational cost (execution time).

Table-2: Fuzzy Based Segmentation Result for Ganges River Delta Satellite Image In CIELuv Color Space.

Parameter	FCM	PCM	PFCM
No. of clusters	3	3	3
No. of iterations	15	5	15
Execution time	32.57	29.58	0.14971
Cluster centers	213.0 111.5 142.5 168.3 110.6 139.3 95.81 187.3 81.63	242.1 253.8 253.0 209.7 255 244.1 148.5 143.9 113.6	216.0 107.8 142.5 172.5 105.1 142.2 95.27 193.8 77.34

The evaluation of fuzzy based segmentation methods in RGB and CIELuv color spaces using parameters are illustrated in table 3.

Table 3: Performance Evaluation of Fuzzy based Segmentation Result for Ganges River Delta Satellite Image.

Image Quality Parameter	RGB Color Space	CIELuv Color Space
Mean Square Error	6181.7	1891.4
Root Mean Square Error	78.624	43.489
Peak Signal to Noise Ratio	10.219	15.363
Normalized Cross-Correlation	0.9000	1.0476
Average Difference	12.342	10.536
Structural Content	0.7533	0.8429
Maximum Difference	224	51
Normalized Absolute Error	0.5250	0.1554
Laplacian Mean Square Error	18.062	5.7976
ERGAS	3166.6	1537.2
Normalized Mean Square Error	0.8649	0.4492
SSIM	0.6432	0.9120

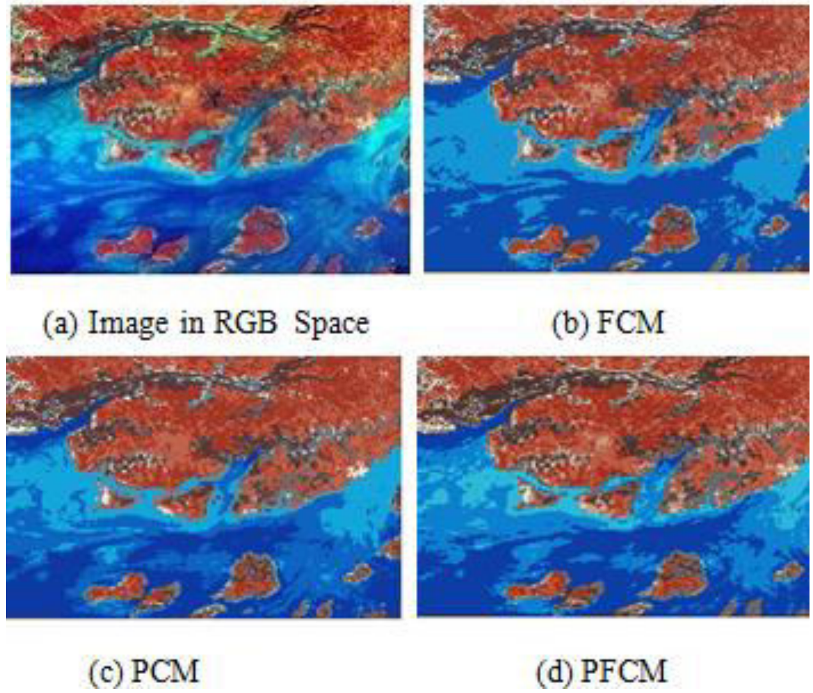

Figure-6: Segmentation result of color image of Guinea-Bissau of size 200X150.

Fig 6 and Fig 7 shows the segmentation of Guinea- Bissau using fuzzy based methods FCM, PCM and PFCM in RGB and CIELuv color spaces respectively. The size of the image is reduced to 200 * 150 in order to lessen the execution time. Table 4 illustrates the outcomes RGB and CIELuv color space based segmentation using fuzzy based methods in terms of clusters and computational cost (execution time in seconds).

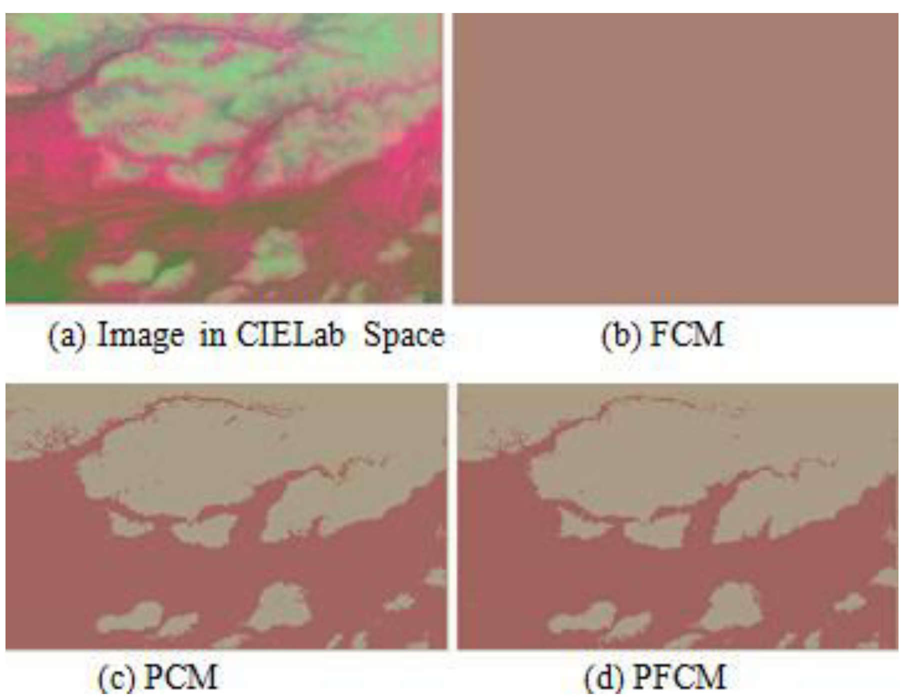

Figure 6: Segmentation result of color image of Guinea-Bissau in CIELuv color space.

Table-4: Fuzzy based Segmentation Result for Guinea-Bissau Satellite Image in RGB and CIELuv Space.

Parameter	FCM		PCM		PFCM	
	RGB	***CIELuv***	***RGB***	***CIELuv***	***RGB***	***CIELuv***
No. of clusters	9	3	9	3	9	3
No. of iterations	15	8	15	6	15	8
Execution time	198	10.6	14.07	21.5	0.384	0.071

The evaluation of fuzzy based segmentation methods in RGB and CIELuv color spaces for Guinea-Bissau satellite image using various image quality parameters are illustrated in table 5.

Table-5: Performance Evaluation of Fuzzy Based Segmentation result for Guinea-Bissau Satellite Image.

Image Quality Parameter	RGB Color Space	CIELuv Color Space
Mean Square Error	3703.4	1620.8
Root Mean Square Error	60.583	40.259
Peak Signal to Noise Ratio	12.483	16.033
Normalized Cross-Correlation	0.7367	0.8817
Average Difference	13.735	11.1684
Structural Content	1.4115	1.2067
Maximum Difference	252	194
Normalized Absolute Error	0.3422	0.1399
Laplacian Mean Square Error	25.960	16.184
ERGAS	2372.1	956.3
Normalized Mean Square Error	0.5781	0.3415
SSIM	6.982	9.0165

4. Conclusion

In this work, a comparative approach of functioning of PFCM method for the segmentation of color images in RGB and CIELuv color space is explained. Based on the analysis of the experimental results, PFCM segmentation in CIELuv color space had outperformed the RGB color space. Most of the image quality parameters had provided the best values for CIELuv color space based segmentation. The segmentation using PFCM is also compared with FCM and PCM to demonstrate the competence of the proposed approach. Even though the results of only two images had shown and analyzed, the proposed approach can be applied and worked equally well for all types of images. The success of the color image segmentation is based on various factors such as the complexity of the image, segmentation technique, color space, image sensor and other environmental issues.

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