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Multispectral Satellite Color Image Segmentation Using Fuzzy Based Innovative Approach

Anil Kumar Gupta[1], Dibya Jyoti Bora[2], Fayaz Ahmad Khan[3]

[1]HOD, Department of Computer Science & Applications, Barkatullah University, Bhopal, Madhya Pradesh, India

[2]Senior IT Faculty, School of Computing Sciences, Kaziranga University, Jorhat , Assam, India

[3]Guest Faculty, Department of Computer Science & Applications, Barkatullah University, Bhopal, Madhya Pradesh, India

ABSTRACT

Multispectral satellite color images need special treatment for object-based classification like segmentation. Traditional algorithms are not efficient enough for performing segmentation of such high-resolution images as they often result in a serious problem: *over-segmentation*. So, an innovative approach for segmentation of multispectral color images is proposed in this paper to tackle the same. The proposed approach consists of two phases. In the first phase, the pre-processing of the selected bands is conducted for noise removal and contrast enhancement of the input multispectral satellite color image on the HSV color space. In the second phase, fuzzy segmentation of the enhanced version of the image obtained in the first phase is carried out by FCM algorithm through optimal parameter passing. Final shifting from HSV to RGB color space presents the segmentation result by separating different regions of interest with proper and distinguished color labeling. The results found are quite promising and comparatively better than the other state of the art algorithms.

Keywords: Color Image Segmentation, CLAHE, Median filter, Multispectral satellite image, RGB, HSV Color Space, FCM Algorithm

I. INTRODUCTION

Image Segmentation is the essential part of an image analysis process [1][2]. It helps us to understand the different regions of interest of the concerned image in a much better way than analysing the whole image at a time. It assists us to perform an object-based analysis of the image where different regions can be treated as different objects or segments. These segments are characterized by means of some homogeneity features like color, texture etc[3]. Color image segmentation offers more advantages than gray image segmentation as human beings are more attracted towards color and can identify thousands of color at a time while only dozens of gray shades can be identified at the same time [4]. Therefore, if both the options are available, then it will be a wise decision to go for color image segmentation than gray image segmentation. However, color-based segmentation is not an easy task to perform. It carries a lot of difficulties and comparatively high complexity. In addition, only a few state of the art algorithms are available for the same. Unsupervised techniques are good for its low complexity and easy to implement characteristics. Also, they are useful for dealing with satellite images [5][6]. In our case, we have multispectral images as the input. They have the characteristics of high resolutions and sensitiveness towards noise [7]. So, special care should be taken to combat noise that may exist in the original image or may appear after the segmentation process. Among unsupervised techniques, FCM is found showing better performance than its hard clustering counterpart K-Means algorithm. Therefore, we have selected FCM algorithm for our task. However, mere applying FCM algorithm does not produce a satisfactory result. Hence, we have developed a novel approach especially for multispectral satellite color image segmentation where we have paid attention in three important issues: (1) Three bands selection and HSV conversion;(2) Input satellite image pre-processing; (2) FCM segmentation. Here, in the first part, selection of three bands and mapping them to R, G and B bands taken place. The formed true color RGB image is transformed into HSV one. In the second stage, pre-processing issues like noise removal and contrast enhancement are carried. In the last stage, final segmentation is done with FCM algorithm. The latter portion of the paper is organized as follows: In section II, a brief review of previous work done in the field is discussed. In section III, the flowchart of the proposed approach is presented. In section III and its subsections, the techniques involved in the proposed approaches are illustrated. Section IV is the experimental and result discussion section. Finally, we have drawn the conclusion in the section V.

II. LITERATURE REVIEW

In [7], the authors presented a multispectral satellite image segmentation technique where they have considered both the spatial and spectral information of the high-resolution images. Multispectral nonlinear edge preserving smoothing is conducted and thereby the multispectral edge is extracted in a local region. This information is used for initial seed selection that is found useful in the later stage of segmentation by modified seeded region growing procedure. The experimental results prove the superiority of the proposed technique in multispectral image segmentation.

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Ganesan et al. [10] proposed an efficient segmentation technique where they used YIQ color space for color information calculations and histogram equalization is applied to the luminance channel. Finally, an improved fuzzy c means is used for segmentation. The results obtained are found efficient for extracting information from satellite images.

In [11], the author Rahman proposed integrated feature distributions based colored texture segmentation algorithm which uses a histogram based color texture extraction method that combines the color texture features and a nonparametric Baysean clustering method is used for final segmentation. This proposed method has an advantage that here we do not need a priori knowledge of the number of regions.

In [12], Kalist et al. proposed a PFCM based satellite color image segmentation in HSL color space. PFCM is a blended version of fuzzy c-means (FCM) clustering and possibilistic means (PCM) clustering. It has a great power of solving the noise sensitivity problem of FCM. Segmentation on HSL color space provides more efficient results than segmentation in RGB color space.

The authors in [13] proposed an FCM based multispectral satellite image segmentation technique which consists of two stages: first RGB and L color transformation are carried out to enhance the color separation of satellite images and FCM is used to group the homogenous regions. Experimental results showed the efficiency of the proposed technique for segmentation of high-resolution multispectral satellite images.

So, from the review of literature following problems are noted down:

1. RGB color space is not suitable to deal with segmentation of high-resolution satellite color images.

2. Satellite images are often found suffering from noises which need to be dealt with before the segmentation process otherwise some miss information may arise as a result of segmentation.
3. FCM is very sensitive to noise, so researchers often deal with this issue by changing the membership function as a result of which time complexity increases.

So, to tackle the above-mentioned problems, we have been motivated to develop a new technique for multispectral satellite color image segmentation. Here, rather than modifying the membership function of FCM (which results in an enormous increase in time complexity), we try to remove the noise in the first stage of our proposed technique. Also, local CLAHE based enhancement is carried out in the beginning stage to perform the needed contrast enhancement. CIELAB is chosen over RGB color space for required color transformation.

III. STEPS INVOLVED IN THE PROPOSED TECHNIQUE

Following are the steps involved in the proposed technique:

Phase 1.

This is the pre-processing stage and most important for an efficient segmentation. This phase consists of following steps:

Step1. Input a 7 band LAN file. Select three bands covering the near infrared (NIR), the visible red, and the visible green parts of the electromagnetic spectrum. Say these bands are band 3,2 and 1.

Step2. Map bands 3, 2 and 1 to R, G and B plane respectively to form an RGB image.

Step3. Color space conversion from RGB to HSV is taken place. Extract V-channel from the HSV converted the image.

Step4. V-channel has been undergone noise detection and removal step using proposed Med_Filt().

Step5. Noise-free V-channel has been undergone local contrast management using BSB_CLAHE()resulting in enhanced V'-channel.

Phase 2.

Step1. Apply FCM algorithm using cluster number=3 and m=2.2 on V'-channel obtained from phase1. It results in V''-channel.

Step2. Replace original V-channel using clustered V''-channel to obtain the segmented LAB image.

Step3. HSV to RGB conversion has been taking place to have the final segmented image.

The following flowchart helps to understand the steps more obviously:

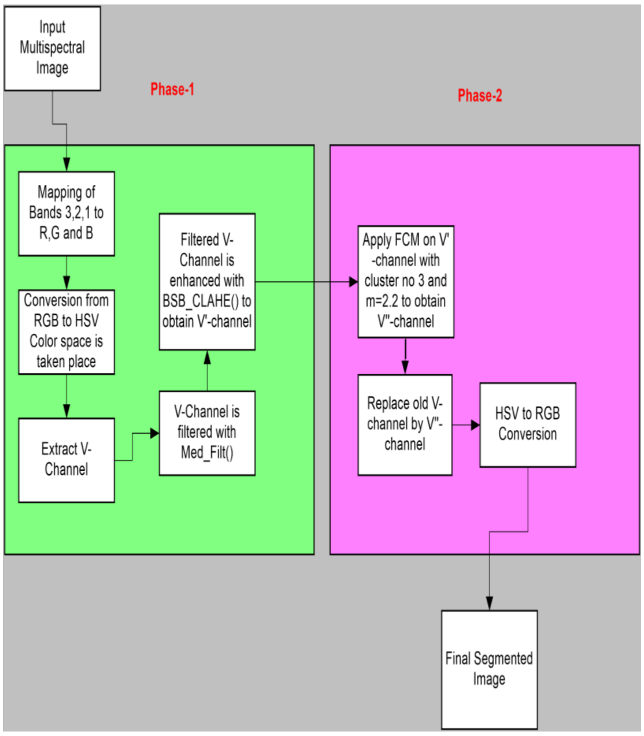


Figure 1. Flowchart of the proposed approach.

Now, in the following subsections, the techniques involved in the proposed approach are discussed thoroughly.

IV. (A) HSV COLOR SPACE

HSV is a frequently adopted color space for color image segmentation [8][9][14]. This color space has the efficiency in organizing any color image in the same way that our human eyes can perceive. Here, the image information is arranged in three channels: Hue (H), Saturation(S) and Value (V). Hue is directly related to color and can be defined as an angle in the range [0,2π]. Saturation channel is used to describe how pure the hue is with respect to a white reference and this is measured as a radial distance from the central axis with values between 0 at the center to 1 at the outer surface. The value channel represents a percentage value goes from 0 to 100, expressing the amount of light illuminating a color [15]. This channel represents the luminance level of a color image. We have used this V-channel in our proposed segmentation approach as this will not affect the hue values and thereby misclassification of colors will not arise. A detail explanation about this color space can be found in [14][15].

HSV color space can be better understood with the following diagram:

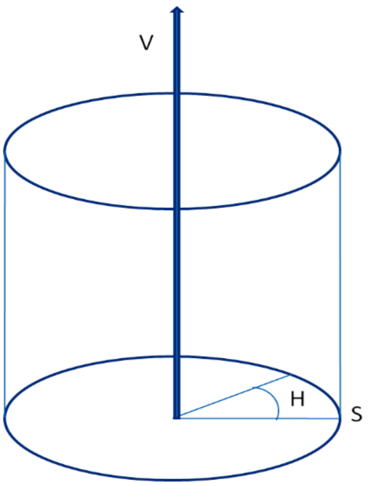
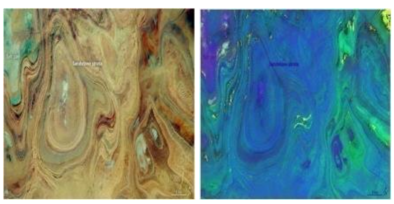
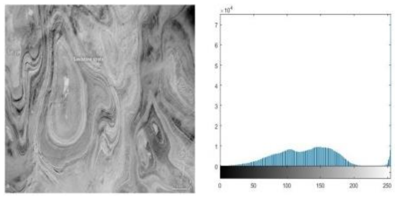


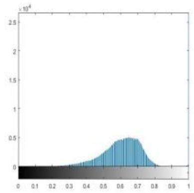
Figure 2. HSV Color Space with the three channels H, S, and V



(a) (b)



(c) (d)



(e)

Figure 2. (a) Original Landsat 8 image [16][17];(b)HSV Converted Image; (c)Extracted V-Channel;(d)Histogram of (a); and (e) Histogram of the V-channel (c).

V. (b) FCM Based Segmentation:

4.3 Fuzzy C-Means Algorithm (FCM):

Fuzzy C-means (FCM) is a famous soft-clustering technique frequently adopted in many unsupervised based data analysis. Here, each data point is allocated to a cluster to some degree that is determined by a membership grade. This technique was originally introduced by Jim Bezdek in 1981 [18] as an improvement on earlier clustering methods [19]. The gradual memberships of data points to clusters measured as degrees in [0, 1] which gives the flexibility to express that data points can belong to more than one cluster.

It is based on minimization of the following objective function:

$$J_m = \sum_{i=1}^{N} \sum_{j=1}^{C} u_{ij}^{m} \, \| x_i - c_j \|^2 \quad 1 \le m < \infty ,$$

where m is the value of the exponent which is any real number greater than 1, uij is the degree of membership of xi in the cluster j, xi is the ith of d-dimensional measured data, cj is the d-dimension center of the cluster, and ||*|| is any norm expressing the similarity between any measured data and the center.

Fuzzy partitioning is carried out through an iterative optimization of the objective function shown above, with the update of membership value uij and the cluster centers cj by:

$$u_{ij} = \frac{1}{\sum_{k=1}^{c} \left(\frac{\| x_i - c_j \|}{\| x_i - c_k \|} \right)^{\frac{2}{m-1}}}$$

,

$$c_j = \frac{\sum_{i=1}^{N} u_{ij}^{m} \bullet x_i}{\sum_{i=1}^{N} u_{ij}^{m}}$$

The iteration will stop if where is a termination criterion between 0 and 1, whereas k is the iteration steps. This procedure converges to a local minimum or a saddle point of Jm. In FCM also, we need to provide the number of clusters beforehand. This procedure converges to a local minimum or a saddle point of Jm.

The formal algorithm is:

1. Initialize U=[uij] matrix, U(0)
2. At k-step: calculate the centers vectors C(k)=[cj] with U(k)

$$c_j = \frac{\sum_{i=1}^{N} u_{ij}^{m} \bullet x_i}{\sum_{i=1}^{N} u_{ij}^{m}}$$

3. Update U(k) , U(k+1)

$$u_{ij} = \frac{1}{\sum_{k=1}^{c} \left(\frac{\| x_i - c_j \|}{\| x_i - c_k \|} \right)^{\frac{2}{m-1}}}$$

4. If || U(k+1) - U(k)||< ε then STOP; otherwise return to step 2.

The time complexity of FCM algorithm is O(ndc2i) [18][19], where n is the number of data points, c is the number of clusters, d is the dimension of the data and i is the number of iterations.

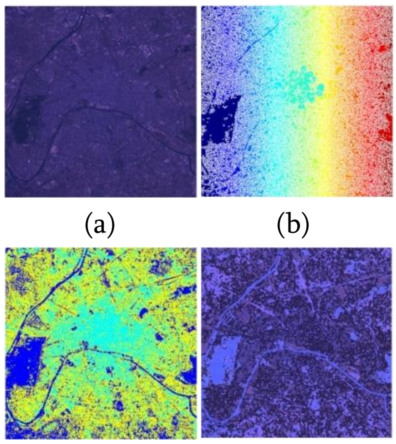
In our case, the contrast-enhanced and median filtered channel V" is undergone fuzzy clustering with fcm algorithm with a number of clusters =3. And, as the value of m also impacts the performance of FCM algorithm[20], so, by trial and error strategy, its optimal value is initially decided and found on average m=2.2 gives an efficient result. So, we keep m=2.2 for the rest of our experiments.

VI. EXPERIMENT AND RESULT DISCUSSION

The proposed approach has been implemented in Matlab in a system with an i5 processor and 64 bit Windows 10 operating system. The multispectral images are collected from [16][17]. The proposed approach has been tested on 30 different images. Here, among them, the results for three different images are presented. The results are evaluated both in the subjective and objective way. For the comparative analysis, we have picked up traditional algorithms like K-Means and Watershed algorithm as because both of these two algorithms are highly adapted for color image segmentation. Here, we are assuming the initial cluster number as 3.

Segmentation results are shown below-

Test Image 1:



(a) (b) (c) (d)

Figure 3. (a)Original Image;(b)Segmented Image by Watershed Algorithm;(c)Segmented Image by K-

Means Algorithm;(d)Segmented Image by Our Proposed Approach.

From the above figure 3(b), it is clearly visible that the segmentation result produced by the watershed algorithm is suffering from over segmentation problem. Here, the regions of interests are not properly identified as a redundant number of segments are generated during the segmentation process. Next, if we observe the figure 3(c), few regions are properly isolated but the local regions inside them are not possible to be identified from the segmentation regions. But, in case of multispectral satellite color image segmentation, it is very important to consider the local regions as they may carry the most important information ignoring which may lead to misleading the analysis process. But from Fig 3(d), the regions of interest are well isolated as well as boundaries are distinct and involve less vagueness. It means our proposed approach succeeds to produce better segmentation.

Test Image 2:

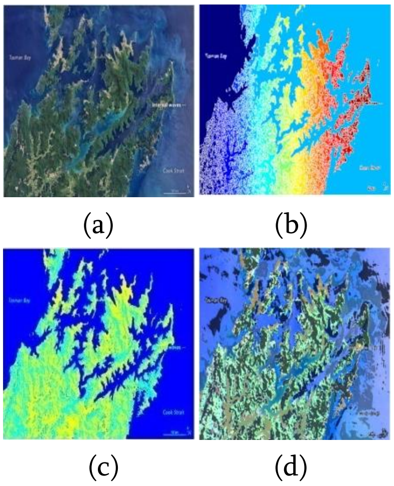


Figure 4. (a)Original Image;(b)Segmented Image by Watershed Algorithm;(c)Segmented Image by K-Means Algorithm;(d)Segmented Image by Our Proposed Approach.

Test Image 3:

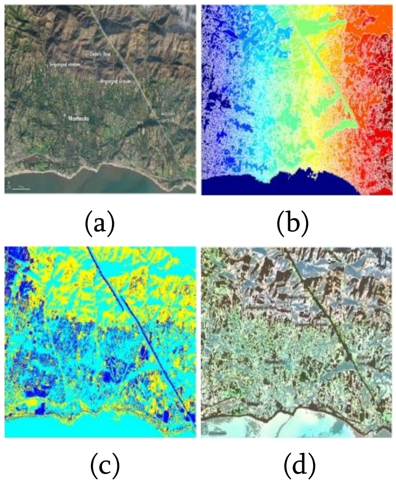


Figure 5. (a)Original Image;(b)Segmented Image by Watershed Algorithm;(c)Segmented Image by K-Means Algorithm;(d)Segmented Image by Our Proposed Approach.

For all the above images, when the **subjective analysis** is done by five different experts, the overall opinion is positive towards our proposed approach. Although, they also state that the segmentation result of K-means algorithm is also good but it may be improved further if some care will be taken on the noise sensitivity issue. Watershed algorithm alone is not found suitable for segmentation of multispectral color images. The over-segmentation is the main problem here.

Objective Analysis:

Objective analysis is required to verify the results mathematically. Mostly researchers select MSE for objective analysis but it is found that in some cases, it does not give an accurate analysis of the results [21]. A better alternative for this purpose is SSIM [22]. SSIM has the ability to automatically predict perceived image quality [8][22]. In our case, mean SSIM (MSSIM) index is used to estimate the overall image quality. MSSIM is calculated using the following equation:

$$mssim(\mathrm{IMG1}, \mathrm{IMG2}) = \frac{1}{N}\sum_{i=1}^{N} ssim(\mathrm{img1}_i, \mathrm{img2}_i)$$

where IMG1 is the original image and IMG2 is its segmented version.; $\mathrm{img1}_i$ and $\mathrm{img2}_i$ are the image contents in the i^{th} local window and N is the total number of the local windows of the image. The MSSIM values are shown in table 1 below:

Table 1.MSSIM values Comparison

Image No.	Image 1	Image 2	Image 3
Watershed Algorithm	0.3402	0.3215	0.3025
K-Means Algorithm	0.4501	0.4018	0.4413
Proposed Approach	***0.4603***	***0.4512***	***0.4823***

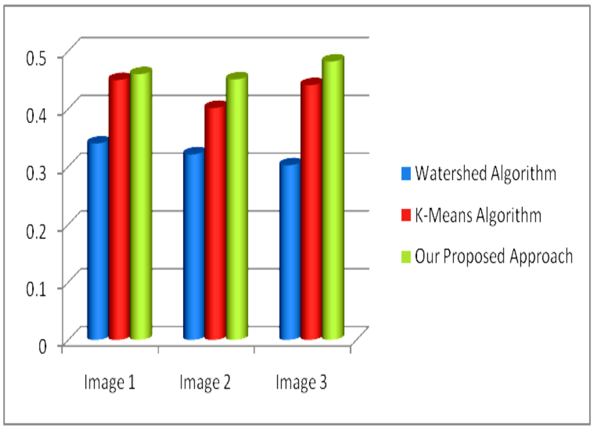


Figure 6. Comparison Chart for MSSIM Values.

So, it is clear from the above table 1(more clearly visible from the chart in figure 6), that MSSIM values for the proposed approach are greater than the same of the Watershed algorithm and K-Means algorithm for all the images. So, it also proves that our proposed approach succeeds to produce better segmentation result for multispectral images than the other traditional algorithms.

VII. CONCLUSION AND FUTURE RESEARCH

A new fuzzy-based Segmentation method for multispectral satellite color images is introduced in this paper. Three important matters are taken into consideration in this proposed approach: consideration of an ideal color space, noise removal and contrast improvement in local regions before going for the final step that is the segmentation step. So, the overall algorithm works in two phases: the first phase is the pre-processing step where all the above mentioned three tasks are incorporated. And phase 2 is the segmentation stage where FCM algorithm is employed to cluster the different regions of interests in the image. The parameters for the FCM algorithm are selected very carefully and tested by trial and error strategy. The proposed algorithm is applied on several multispectral satellite color images and compared the results with the results produced through other traditional algorithms like Watershed algorithm, K-Means algorithm. Both subjective and objective analysis proves the superiority of the proposed technique. The main reason behind this is the consideration of FCM algorithm for region clustering as it has the ability to deal with the segmentation of noisy images in an efficient way than its hard clustering based counterparts. Also, HSV color space contributes very well toward the efficient color computation involved in the whole pre-processing and segmentation process. Median filter Med_Filt() is proved very useful to deal with the impulse noises that commonly exist in the satellite images. Then, Local contrast improvement technique, BSB_CLAHE() adjusted and improved the contrast as a final stage in the pre-processing step.

Although the proposed work is proved an efficient one for multispectral satellite color image segmentation, future work is possible in phase 2 of the proposed technique. Some advanced fuzzy based techniques like Intuitionistic Fuzzy set may be adopted in this phase to bring further optimization to the results. Also, to develop a technique to estimate the initial number of regions beforehand will also be an area for further research.

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