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Detection of end members in agricultural and mineral ore hyperspectral images

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ABSTRACT

Hyperspectral image is the combination of various spectral bands of the electromagnetic spectrum. As a preprocessing step, speckle in hyperspectral images is removed using log color filter and hybrid median filter. Segmentation is required to extract the variety of crops and mineral ores in filtered hyperspectral images of agricultural lands and mines. The reflectance and wavelength of the different forms of mineral ores present in mineral images are determined to find the extent of distribution of ores in mines. This is determined by identifying the end members and their abundance which is spectral un-mixing.

Keywords: Endmembers, Segmentation, Vertex Component Analysis (VCA), Log Color Filter (LCF), Hybrid Median Filter (HMF), Spectral Un-Mixing, Hyperspectral Image (HS)

1. INTRODUCTION

In hyperspectral imaging, the spectrum for each pixel in the image is obtained, with the purpose of finding objects, identifying materials or detecting processes. In the field of agriculture, hyperspectral image processing techniques are used for monitoring the development and health of crops. In oil industries, it is used to identify oil sources in the earth. Speckle noise is a multiplicative noise having a granular pattern and is an inherent property of an image. Speckle noise is generated by waves that constructively or destructively produce light and dark pixels in an image (Bala Prakash K, Venubabu R, Venugopal B, 2011). Speckle removal is performed as it results in reduction of contrast in images and it gives difficulty in performing image processing operation.

Preprocessing of Hyperspectral Images: As a preprocessing step, filtering of images is done to reduce speckle. Filtering may be a technique to remove the unwanted data from the image. Various kinds of filters are used to take away speckle noise from the image. The filters utilized in preprocessing are hybrid median filter and log color filter. Hybrid Median Filter (HMF) comes from a median filter. It preserves edges higher than a median filter. Three median values for the pixels are calculated, specifically 'MR' the Median of horizontal and vertical 'R' pixels, 'MD' the median of diagonal 'D' pixels and also the central row pixels. The filtered value is that the median of the two median values '+', 'X' and also the central pixel 'C' (Rakesh MR, Ajeya B, Mohan AR, 2013).The pixels are taken within the '+' direction and 'X' direction. The pixels are taken within the '+' direction and 'X' direction each horizontally and vertically. By taking the median values the filtering is completed within the hybrid median filter.

Segmentation of Hyperspectral Images: Image Segmentation is a technique for extracting information from an image. It subdivides an image into its constituent objects. The segmentation algorithm uses cluster based system by means of Fuzzy C- means clustering, PSO based FCM. Clustering is that the task of clustering a group of objects within the same group that are additional similar to one another, than those in different groups. Fuzzy C- means that works by assigning membership every information equivalent to each cluster on the basis of distance between cluster center and information points.

PSO algorithm is associate optimization technique that utilizes Darwinian criterion of population evolution for finding optimization issues based on selection. The method of selection is employed to lift the effectiveness of the cluster to fulfill environment optimum.PSO will increase the area of search and these permits to achieve the globally optimized solution. Spectral un-mixing is that the procedure by which the measured spectrum of a mixed pixel is decomposed into a set of constituent spectra and a collection of corresponding fractions or abundances that indicate the proportion of every end member present within the element (Senjia, Yunta Qian, 2009). When the location measurements aren't possible, spectral end members can be derived from its pure features such as wavelength, reflectance and bandwidth. End member extraction is one amongst the tasks in hyperspectral image process. The requirement for end member observation is to detect a material present in a specific region. In the field of mineral extraction it is used to determine the ore present in a particular area. The following section deals about filtering of the hyperspectral images of minerals and agriculture.

2. METHODOLOGY

Speckle noise is outlined as a multiplicative noise having a granular pattern and is an inherent property of images. Hyperspectral images are corrupted by speckle noise. Preprocessing uses filters to scale back the speckle noise within the image.

A. Filtering: The noise will be modeled by random price multiplications with pixel values of the image. The image will be expressed as

$$J = I + n \times I \tag{1}$$

Where

J – Speckle noise distribution

I - Input Pixel

n -uniform noise having zero mean

Hybrid Median Filter: Hybrid median filter is an improved type of median filter that removes the noise and preserves edges higher than median filter. within the Hybrid median filter three median values for the pixels are calculated, specifically 'MR', the meodian of horizontal and vertical 'R' pixels, 'MD' the median of diagonal 'D' pixels and also the central row pixels. The filtered value is that the median of two median values and also the central pixel 'C'. The noisy pixels present within the image are analyzed by the filtered image and also the original image. The steps in filtering the hyperspectral images are as follows

i. Image is Read and Cross is Placed Over Window Element
ii. Calculate the Maximum Rows and Maximum Columns
iii. Find the Median
iv. Place the Masks '+' and 'X' Over the Window Element
v. After Calculating the Mask Filtering is Done
vi. The Steps (2) to (4) are Repeated to Obtain the Filtered Element

The flow diagram of the above algorithm is shown in figure 1.

Log Color Filter: The log color filter is best in obtaining the localized frequency information. The filter provides better result in removing speckle present in the image (Vishal garg, Nisha Raheja, 2002). The algorithm of log color filter is as follows

i. Convert the RGB (Red Green Blue) image into CIE(Color space)
ii. Precompute the Gaussian weights
iii. Now apply Log Function
iv. Extract the Local Region
v. Calculate the Filter Response
vi. Now Convert the Filtered Image into RGB

Five agricultural and five mineral hyperspectral images are now subjected to filtering using Hybrid Median Filter (HMF) and Log Color Filter (LCF). There are several parameters available for analyzing the output of the image namely Peak Signal to Noise Ratio, Mean Square Error, Signal to Noise Ratio, Cross Correlation Coefficient and Standard deviation (Nobi MN and Yusuf MA, 2011). In the present work, the parameters MSE and PSNR are considered.

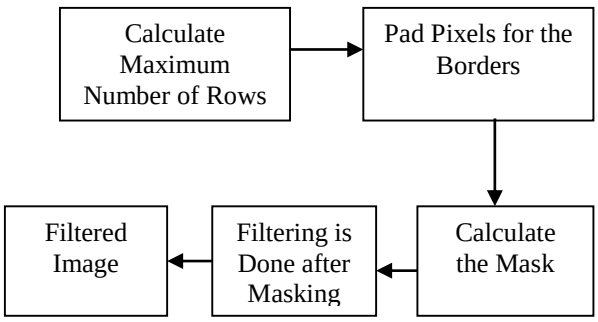

Fig. 1. Flow Diagram of Hybrid Median Filter

Estimation of MSE

Mean square error is employed to find the distinction between two images. It indicates average variations of the pixels throughout the image.

$$MSE = \frac{1}{MN} \sum I(x, y) - DI(x, y) \tag{2}$$

Where

M- Number of Rows within the Image

N- Number of Columns within the Image

I(x, y) - Original Image

DI(x, y) - Denoised Image

A lower MSE indicates a smaller distinction between the initial image with speckle and denoised image.

Estimation of Peak Signal to Noise Ratio (PSNR): PSNR provides the ratio between possible power of the signal and also the power of corrupting noise present within the image. It is a parameter to measure the performance of the speckle noise removal technique. A high PSNR indicates low noise level within the image (i.e.) quality of the image is high (Milind Kumar V Saode, Prashant R Deshmukh, 2011).

$$PSNR = 20\log 10\frac{n^2}{MSE} \tag{3}$$

Where

n- Maximum intensity of the image

MSE- Mean square Error

The maximum pixel intensity in an image is 255. The subsequent section deals with segmenting hyperspectral images of minerals and agriculture using Fuzzy C- means clustering and PSO based Segmentation.

Segmentation of hyperspectral images: The segmentation algorithms used in the present work are Fuzzy C-means clustering and PSO based FCM

Fuzzy C- Means Clustering (FCM): Fuzzy C- means clustering works by assignment membership to every information corresponding to a cluster center on the basis of distance between the center of the cluster and therefore the information. The membership value of every information should be equal to one. Fuzzy C- means offers higher result than K- means during which, the information point exclusively belongs to at least one cluster; whereas in FCM, the information purpose is assigned the membership value of every cluster centre, as a results of which the information purpose might belong to more than one cluster (Harveen Anand, 2012) The algorithm is an iterative clustering technique that produces best partition by minimizing the weighted cluster of sums.

FCM first chooses the amount of clusters then assigns random points to the coefficients after which clusters are formed within the image.

The FCM clustering is as follows:

Let xi be a vector of values for information g_i

Initialize membership U (0) = $[U_{jj}]$ for information g_j of cluster c_j by random

At the k-th step, compute the fuzzy centroid C (k) = $[c_j]$ for j = 1... n_c, wherever n_c is that the range of clusters, using

$$c_j = \frac{\sum_{i=1}^{n}(U_{ij})^m X_i}{\sum_{i=11}^{n}(u_{ij})^m}$$

Where

'm' is the fuzzy parameter

'n' is the range of information points.

Update the membership U (k) = $[U_{jj}]$, using

$$U_{ij} = \frac{\left(\frac{1}{\| x_i - c_j \|}\right)^{\frac{1}{(m-1)}}}{\sum_{j=1}^{n_c}\left(\frac{1}{\| x_i - c_j \|}\right)^{\frac{1}{(m-1)}}}$$

If ||U (k) – U (k-1)||<ε then stop ,else return to Step 2 Verify the membership cutoff for each information assign 'g_i' to cluster 'c_j' if 'u_{ij}' of U (k)>α.

The flow chart of FCM algorithm is as shown in Fig. 2.

The disadvantage of FCM is that clusters are assigned and it involves additional range of iterations.

PSO based Segmentation: PSO algorithm is an optimization technique that utilizes Darwinian criterion of population evolution for solving improvement issues based on natural process. The PSO will increase the space of search and these permits to achieve the globally optimum solution and hence best solution (HesamIzakian, Ajith Abraham, Vaclav Snasel, 2009). The steps concerned in PSO based FCM are as follows

1) Initialize the particle swarm and parameters like population size, initial positions of particles, initial speed, sample size, range of clusters.
2) For every particle, calculate the corresponding cluster center, then the value of the target perform and store the every position as best position and every particle fitness.
3) Select the particle that has the simplest fitness
4) Update the speed and position of every particle

5) Using constraint create the worth of particle meet the constraints of Fuzzy clustering
6) Calculate the corresponding clustering center consistent with the worth of every particle
7) Calculate the fitness of every particle consistent with the particle and its corresponding cluster
8) Compare the fitness of every particle with its best previous fitness
9) Compare the fitness of every particle with the cluster best previous fitness, if higher then set this position
10) If preconditions don't seem to be met then attend step 3. If preconditions are met then stop the iteration and therefore the output is that the best solution.

Five agricultural and five mineral hyperspectral images are segmented using Fuzzy C-Means clustering and PSO based FCM.

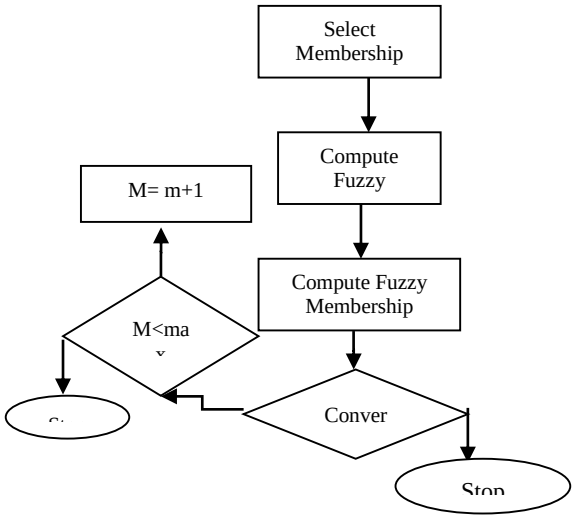

Fig. 2: Flow Chart of FCM

Endmember detection: Endmember extraction is one among the tasks in hyperspectral image process. The necessity for endmember detection is to detect a material present in a particular region (Bin Luo, Jocelyn chanussot, Sylvain doute and Liangpei Zhang, 2013). In the field of mineral extraction it is used to determine the ore present in the particular area. Spectral unmixing is that the procedure by which the measured spectrum of a mixed pixel is decomposed into a group of constituent spectra and a collection of corresponding fractions or abundances that indicate the proportion of every endmember present within the pixel (Lian Miao, Hairong Qi). The measure of endmembers Xi ε Rp for every pixel i , $1 \leq i \leq P$ where $P \geq 1$ is that the range of spectral bands.

The endmember estimation is given by

$$x_i = \sum_{j=1}^{k} a_{ij} V_j + n_i \tag{4}$$

Where

a_{ij} - Proportion of the endmember V_j in the mixed pixel Xi.

n_i- Noise function

k– Number of endmember

For the detection of endmembers we tend to use vertex element analysis. Vertex element analysis is one of the advanced methods for detection of endmembers with the pure pixel assumptions (Abderrahim Halimi, Yoann Altmann, Nicholas Dobigeon, Jean-Yves Tourneret, 2011).The vertex component analysis projects all the image pixels to a random direction and it uses the pixel with the most important projection because the first endmember. The other endmembers that are present are identified by iteratively projecting information onto a direction orthogonal to the subspace of the endmembers that are present. The new endmembers are chosen by the pixel similar to the intense projection. The steps involved in vertex component analysis are as follows:

i. Intialise the Data
ii. Set the threshold SNR Value
iii. Test the Data to be Projected onto the Subspace Dimension
iv. Reduce the Dimension of Endmembers
v. The Auxillary Matrix Stores the Estimated Signatures
vi. Assume One Pure Pixel Present in Input Data
vii. The Estimated Mixing Matrix, Column Constrains the Estimated Endmember Signature
viii. The End Member Identified for the Mineral Ore by Using VCA

3. RESULTS AND DISCUSSION

The results of filtering, segmentation and endmember identification of hyperspectral images of agricultural areas and mineral ores are shown in Figs. 3- 7. Fig. 3 show the image filtered using Hybrid Median Filter (HMF) and Log Color Filter (LCF).

Fig. 3a: HS Image of an Agricultural Area

Fig. 3b: IMAGE Filtered Using HMF

Fig. 3c: Image Filtered Using LCF

Figure.3.Results of Filtering of Agricultural Image

Figure 4 show the image segmented using Fuzzy C- Means Clustering (FCM) and Particle Swarm Optimization Based Fuzzy C- Means Clustering (FCM).

Fig. 4a: Image Segmented Using FCM

Fig. 4b: Image Segmented Using PSO Based FCM

Fig. 4. Results of Segmenting an Agricultural Image

The hyperspectral agricultural images are filtered using HMF and the performance metrics namely Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE) are tabulated in Table 1.

Table.1.Performance Analysis of Hybrid Median Filter for HS Images of Agricultural Region

Hyperspectral Images	**Hybrid Median Filter**	
	PSNR in dB	**MSE**
Vineyards	30.6393	0.0561
Palm oil Area	20.1035	0.6349
Agricultural Area 1	34.9836	0.0206
Agricultural Area 2	25.2954	0.1921
Finland Tree Cover	34.7917	0.0216
Mean	**29.1627**	**0.1850**

The Mean PSNR and MSE obtained for HMF are 29.16 dB and 0.19 respectively. The hyperspectral agricultural images are filtered using Log color filter and the performance metrics namely PSNR and MSE are tabulated in Table 2.

Table.2.Performance Analysis of Log Color Filter for HS Images of Agricultural Region

Hyper Spectral Image	**Log Color Filter**	
	PSNR in dB	***MSE***
Vineyards	28.9412	0.0830
Palm Oil Area	28.3156	0.0958
Agricultural $A = \pi r^2$ 1	31.6562	0.0440
Agricultural Area 2	28.3584	0.0949
Finland Tree cover	30.5167	0.0577
Mean	**29.55762**	**0.07508**

The Mean PSNR and MSE obtained for Log Color filter are 29.56 dB and 0.075 respectively. To find the filter suitable for filtering hyperspectral images, the mean PSNR and mean MSE of both filters are compared in Table 3.

Table.3.Comparison of Performance of Filters for HS Images of Agricultural Region

Hyperspectral Image	Hybrid Median Filter		Log Color filter	
	PSNR in dB	MSE	PSNR in dB	MSE
Vineyard	30.6393	0.0561	28.9412	0.0830
Palm Oil Area	20.1035	0.6349	28.3156	0.0958
Agricultural Area 1	34.9836	0.0206	31.6562	0.0440
Agricultural Area 2	25.2954	0.1921	28.3584	0.0949
Mean	**29.1627**	**0.1850**	**29.55762**	**0.07508**

The Mean PSNR of Log Color filter is slightly greater when compared to that of Hybrid median Filter. Also, the MSE of LCF is lesser when compared to that of HMF. Hence, it is decided to use LCF to remove speckle from hyperspectral images in the present work. Fig. 5 shows the images of mineral ore distribution filtered using Hybrid Median Filter and Log Color Filter.

Fig. 5a: HS Image of Mineral Distribution

Fig. 5b: Image Filtered Using HMF

Fig. 5c: Image Filtered Using LCF

Fig. 5: Result of Filtering Mineral Ore

The above figure shows the result of the hybrid median and log color filtered image. Fig. 6 shows the images of mineral ore distribution segmented using FCM and PSO Based FCM.

Fig. 6a: Image Segmented Using FCM Algorithm

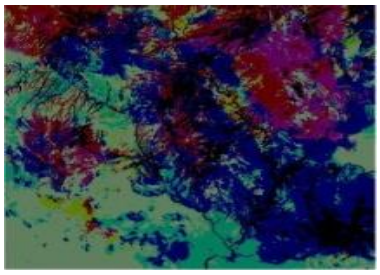

Fig. 6b: Image Segmented Using PSO Based FCM

Fig. 6: Result of Segmenting Mineral Ore

The above Fig. 6 shows the segmented result of Fuzzy C means and PSO based FCM. After the process of segmented the next step that is done is endmember extraction. The Endmembers Present in the image is extracted by using Vertex Component Analysis (VCA) method.

The distribution of mineral ores in a particular region is shown in different colors using Vertex Component Analysis (VCA). In figure 7b, the region marked in blue indicates the samples present and the region marked by red indicates the end members that are analyzed by VCA algorithm.

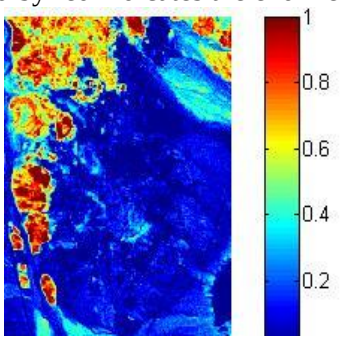

Fig.7a: Input Image Showing Mineral Distribution

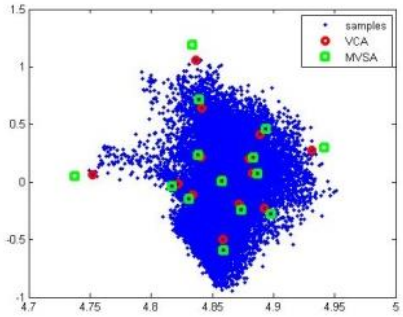

Fig.7b: Endmember Analysis by Using VCA

Figure.7.Results of Endmember Identification in a Mineral Ore

Figure 8 shows the results of the mineral distributed and their spectral signatures that are analyzed by VCA.

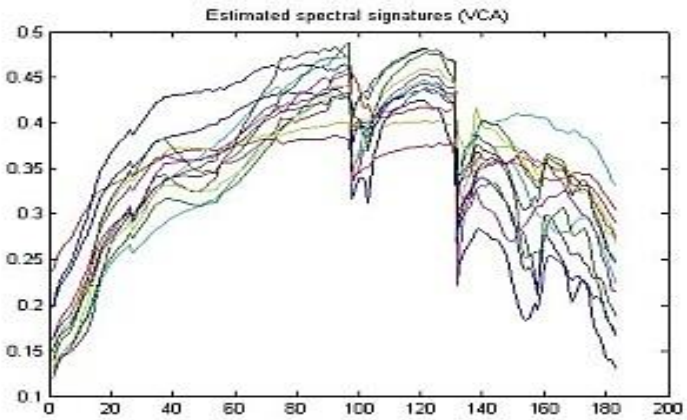

Fig. 8: Spectral Signature by Using VCA

Table.4.Performance Analysis of Hybrid Median Filter for HS Images of Mineral Ores

Hyperspectral Images	**Hybrid Median Filter**	
	PSNR in dB	**MSE**
Coal	26.9820	0.1303
Mineral Exploration	25.6789	0.1759
Geographical hazard	27.4725	0.1164
Emerald Distribution	23.8674	0.2669
Barium	23.1476	0.1350
Mean	**25.4296**	**0.1649**

Table 4. shows the result of filtering hyperspectral images of mineral ore distribution using hybrid median filter. The Mean PSNR of Hybrid Median Filter is 25.42 dB and MSE is 0.16.

Table.5.Performance Analysis of Log Color Filter for hs Images of Mineral Ores

Hyper Spectral Image	**Log Color Filter**	
	PSNR in dB	**MSE**
Coal	28.8529	0.0847
Mineral Exploration	28.7240	0.0872
Geographical Hazard	29.0002	0.0819
Emerald Distribution	28.1873	0.0987
Barium	26.9503	0.1312
Mean	**28.3429**	**0.09674**

The Table 6 shows the result of filtering hyperspectral images of mineral ore distribution using Log Color filter. The Mean PSNR of Log Color Filter is 28.34dB and MSE is 0.096. To find the filter suitable for filtering hyperspectral images, the mean PSNR and mean MSE of both filters are compared in table VI.

Table.6.Comparison of Performance of Filters for HS Images of Mineral Ores

Hyperspectral Image	**Hybrid Median Filter**		**Log Color Filter**	
	PSNR in dB	**MSE**	**PSNR in dB**	**MSE**
Coal	26.9820	0.1303	28.8529	0.0847
Mineral exploration	25.6789	0.1759	28.7240	0.0872
Geographical hazard	27.4725	0.1164	29.0002	0.0819
Emerald Distribution	23.8674	0.2669	28.1873	0.0987
Barium	23.1476	0.1350	26.9503	0.1312
Mean	**25.4296**	**0.1649**	**28.3429**	**0.09674**

The PSNR and MSE for various mineral ore images are tabulated. The Mean PSNR of Hybrid Median Filter is 25.4296dB and MSE is 0.1649.The Mean PSNR of Log Color Filter is 28.3429 dB and MSE is 0.09674. The Mean PSNR of Log Color filter is high when compared to that of Hybrid median Filter also the MSE of LCF is lesser when compared to that of HMF .Hence it is decided to use LCF to remove speckle from hyperspectral images in the present work.

4. CONCLUSION

The Hyperspectral images are affected by speckle, hence preprocessing is done to remove speckle using log color filter and hybrid median filter. From the performance metrics it is analyzed that Log color filter removes speckle efficiently than Hybrid Median Filter. The image is segmented using FCM and PSO Based FCM. After segmentation, the end members and the spectral signatures are analyzed for spectral un-mixing. The next work is to estimate the abundances present in the region and to classify the regions present in the image Using Support Vector Machine and Neural Network Classifier

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