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Efficient Satellite Image Segmentation using Energetic Self Organizing Map

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***Abstract*—Satellite images often require segmentation in the presence of uncertainly which caused due to factors like environmental condition, poor resolution and poor illumination. Image processing applications depends on the quality of segmentation. This paper proposes a novel methodology namely "Satellite Image Segmentation using Energetic Self Organizing Map" (SIS-ESOM) method. This method can be used to improve the accuracy level of the satellite image segmentation. This segmentation method is also tolerable against noises in satellite images. This paper describes the implementation of two novel algorithms, namely Dynamic Adaptive Threshold based Background Optimization (DATBO) method and Energetic SOM (ESOM). The input image is undergone to fuzzy based noise Removal and DATBO image enhancement method. The optimum training samples of Energetic SOM are gathered by reduction of training vectors using Fuzzy C Means (FCM).The computed weight values of SOM are converted into transformed values using Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT). This DWT and DCT transformed weight values are hold much energy. The SOM testing process is applied in an energetic way using DWT & DCT transforms and a new square root($\sqrt{2}$) based similarity measurement method. The new SOM method is called Energetic SOM because it uses the energy transforms such as DWT and DCT. The segmented image obtained from this ESOM is further refined to get fine segmentation. Good segmentation performance can be possible in satellite images with higher PSNR.**

Index Terms: *Satellite image, Segmentation, ESOM, DABTO, FCM, DWT, DCT.*

I. INTRODUCTION

The collections of photographs of planets are called satellite images. A large number of observation satellites has orbited and is orbiting the planet to provide frequent imaginary of its surface. All satellite images are partitions the images into homogeneous regions, each of them correspond to some particular land cover type [1]. The images acquired from the satellite provide huge information. It is very difficult to process and retrieve the necessary hidden treasure without a suitable algorithmic approach. Several methods have been proposed for extracting the necessary information from satellite images [3]. An image processing task on satellite imagery is in incremental state and that each previous step influences to the next. Hence a good segmentation is required to obtain good classification result.The main challenges of Satellite image segmentation are insufficient contrast, luminance issues and noise environment. The partitioning of the digital image into multiple segments is called segmentation. The goal of the image segmentation is to change the representation of an image analysis too easier. Normally image segmentation is used to identifying the objects and boundaries in images. Image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics [1].Keri Woods [9] proposed many adaptive methods have been used for image segmentation, including genetic algorithms [10], neural networks [11], self-organizing map [7] and Fuzzy clustering [13]. In this paper image enhancement techniques [14] is very useful for Satellite Image Segmentation. Image enhancement is basically improving the interpretability or perception of information in images for human viewers and providing better input for other automate image processing techniques [15].

Self-Organizing Map(SOM) [2] is an unsupervised neural network method. The SOM convert patterns of arbitrary dimensionality into the responses of two dimensional arrays of neurons. One important characteristic of SOM is that the feature map preserves neighbourhood relations of the input pattern [4]. SOM consists of input and output layer. Each input is fully connected to all units. The initial weights are random and small, and their contribution for the final state decreases with the number of samples.

The SOM map have been studied in finding fraud user profiles and cellular phones [12]. SOMs are used widely in the segmentation of different types of images [4]. The SOM plays vital role in Satellite image segmentation. The term self-organizing map signifies a class of mappings defined by error-therotic considerations. The first SOM algorithms were conceived around 1981-1982 [8]. Awad et al. in [5] proposed an unsupervised cooperative approach which is a combination of Self Organizing Map(SOM). Marsella and Miranda in [6] proposed a classical neural network with fuzzy logic. This method works on segmenting an image by taking each time a window of fixed dimension. The pixel color values are the input to the neural network (SOM) and the number of input neurons is equal to the number of considered pixels in the window.

The Standard Fuzzy C-Means clustering [7] is one of the most widely used fuzzy clustering algorithms. The FCM algorithm attempts to partition a finite collection of elements into a collection of fuzzy clusters with respect to some given criterion. FCM algorithm is used to measure the amount of fuzziness of spatial criteria.

The proposed methodology is described in section 2.The experimental results are given in section 3. The conclusion session briefs the observation in final section. In the chapter 5 the reference papers which are used in the papers are listed.

II. METHODOLOGY

The concept of the methodology is to achieve the segmented image from the input Satellite image. The input satellite image is handled by fuzzy noise reduction, image enhancement, FCM clustering and Energetic SOM to gain healthier efficiency in satellite image segmentation. The proposed SIS-ESOM method contains 5 modules. They are Fuzzy noise reduction, Satellite image enhancement using DATBO method, Fuzzy – C means segmentation, Energetic SOM training, Energetic SOM testing.
The Fig.1 expresses the principles of the proposed method using block diagram.

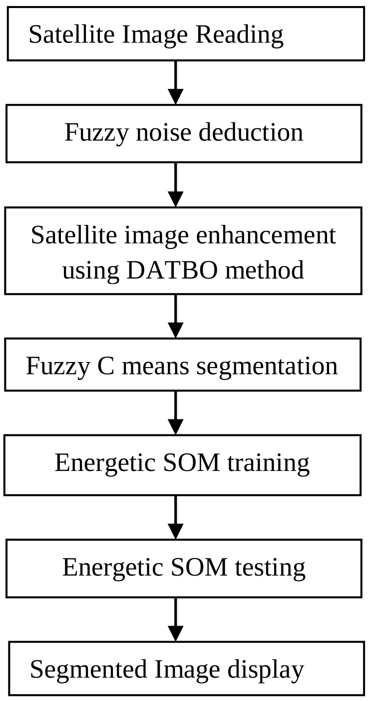

Fig.1. Block diagram of proposed SIS–ESOM segmentation technique.

A. Fuzzy noise Reduction

Satellite image segmentation is much affected by noisy pixels. To increase the segmentation accuracy the noise reduction process is used. The noisy pixels of given satellite image is restored as noise free pixels using a existing noise reduction method namely "Novel two-stage noise adaptive fuzzy switching median" (NAFSM) [16]. This noise reduction algorithm is tolerant with heavy noisy environment. The satellite images are also affected by heavy noisy environment. So the above specified fuzzy noise reduction methodology is used.

The noisy pixels are identified using the histogram of the satellite image and this is known as Stage-1 process. The second stage noise reduction process computes the size of its filtering window depend on the local noise density. This filtering step provides a solution to resolve the high-density salt-and-pepper noise. The correction term for a noisy pixel is computed using the Equation1.

$$\mathrm{Y}(i,j) = [1 - F(i,j)].X(i,j) + F(i,j).M(i,j) \quad (1)$$

where

$\mathrm{Y}(i,j)$ - Restoration term..
$F(i,j)$ - Fuzzy Membership function. $M(i,j)$ - Median computation.
i - Row value of current pixel.
j - Column value of current pixel.

The noisy pixels which are marked by stage 1 process are restored using the restoration term Y(i,j) and the other pixels are leaved without any changes. This noise free image can be referred as $I_{NF.}$ For further detailed study of noise reduction procedure can be obtained by the paper [17].

B. Satellite image enhancement

Image enhancement is the crucial part of image segmentation to hike the true segmentation. This paper proposed a novel method for satellite image enhancement using Dynamic Adaptive Threshold based Background Optimization (DATBO) method. This proposed enhancement methods optimize the background variations so that output of this enhancement supports segmentation process in a fine manner. This is a threshold based enhancement scheme. Normally major existing enhancement schemes support hard threshold type. But this proposed method adaptively found threshold method using the threshold computation by Equation 2.

Algorithm
Input : Noise free satellite imageI_{NF}
Output: Enhanced satellite image I_{ENH}
Step1: Define the Block size as $3X3$
Step 2: Consider a current pixel$I_{NF}(i,j)$ which is located at $(i,j)$and separatea overlapping block
Step 3:Find the minimum and maximum value in the block
Step 4: Find the Background threshold value using Equ. 2.
$THR_{BGND} = (MIN_{Block} + Max_{Block})/2$ (2) Step 5: Find the enhancement term using Equations 2 to 6.

$If\ I_{NF}(i,j) > THR_{Bgnd}$
$C^k = (255 - Min_{Block})/log_{10}(255)$(3)
$I_{Enh(i,j)} = C_k * log10\left(I_{Nf(i,j)}\right) + Min_{Block}$ (4)
$Else$
$C_k = (255 - Max_{Block})/log_{10}(255)$ (5)

$I_{Enh(i,j)} = C_k * log10\left(I_{Nf(i,j)}\right) + Max_{Block}$ (6) End
Step 6: Repeat the steps 2 to 5 until processing all pixels.

The above algorithm supports adaptive enhancement. This method distributes low range values into high range values.

C. Fuzzy C Means Segmentation

The Fuzzy C Means segmentation method is one of the best segmentation methods in image segmentation area. The Fuzzy member ship value computation is the main part of FCM algorithm. The fuzziness of segmentation characteristics are expressed in fuzzy membership matrix. The main steps of FCM are followed:

- Initialization Process
- Distance calculation
- Cluster head computation
- Fuzzy membership function
- Objective function
- Defuzzification

The initialization process contains the cluster head initialization, membership value initialization and parameter initialization. The total number of cluster parameter is also assigned in the initialization process. The distance function computes the difference between the cluster head and data elements. The cluster head computation is performed using membership values. The updated fuzzy membership values are found using fuzzy membership function. The objective function takes the decision about the convergence state of the process. The Defuzzification process reveals the output of the FCM segmentation. The detailed explanation of the FCM method can be known from the paper [17].

The enhanced satellite image can be applied to the Fuzzy C Means algorithm for image segmentation. For segmentation process, the image information is converted into 2x2 size non overlapped blocks. The initialization process is proceed with the number of clusters as 3(more than 3 is also allowed). The cluster head updation and membership updation processes are performed until the convergence state occurred. The defuzziifcation process allocates the data elements to the proper clusters. From this segmentation result, the training samples per cluster is collected and it is known as final training vectors.

D. Energetic SOM Training

A Self-Organizing Map (SOM) [18] or Self-Organizing feature Map (SOFM) is a type of artificial neural network that is trained using unsupervised learning to produce a low-dimensional, discretized representation of the input space of the training samples, called map.

The Energetic SOM Training process is performed using the final training vectors which are obtained from the FCM segmentation. The trained Energetic SOM yields the SOM weight vectors. The weight vector dimensionality is maintained as TotalClusters x VectorLength which can be expressed as 3x4. Here, the number 4 means total elements in the 2x2 size block.

The Discrete Wavelet Transform (DWT) [19] is applied on the 0^{th}weight vector. The Daubechis 4 Wavelet Coefficients (db4) are used for wavelet transform. This DWT energy extraction is performed using the Equations 7 and 8.

$E' = Dwt(WM(0))$ (7)
$E_{Dwt} = [E'(0), E'(1), E'(2)]$ (8)
where

DWT -Discrete wavelet transform
WM -Weight matrix of SOM training
E' - Energy Array
E_{DWT} - Energy vector based on DWT

The Discrete Cosine Transform (DCT) [20] is applied on the 0^{th} weight vector. This DCT energy extraction is performed using the Equations 9 and 10.

$E'' = Dct(WM(0))$ (9)
$E_{Dct} = [E''(0), E''(1), E''(2)]$ (10)
Where

Dct - Discrete cosine transform function
E" - Energy Array
E_{DCT} - Energy vector based on DCT

The fused energy vector is obtained using the concatenation of two transforms. The concatenation of DWT and DCT energy data generates totally 6 elements per cluster. It contains 1 x 6 dimensional fused energy data. In the proposed energetic SOM method the SOM weight information are converted into energetic data format. This process is performed using Equation 11.

$E_F = \{E_{Dwt}, E_{Dct}\}$ (11)
Where

E_F - Fused Energy Vector

The same process is done for the 1^{st} weight vector and a 1x6 energy vector is formed. The same is done for the 2^{nd} weight vector. Finally a 3x6 energy vector is constructed.

E. Fuzzy SOM Testing

In this energetic SOM a new approach is applied for SOM testing process instead of Euclidian distance. A novel neighbour based energetic similarity measurement is introduced. In Euclidian distance method, the distance value is squared but in this new method the distance value is multiplied by the value $\sqrt{2}$. In normal Euclidian distance the subrtraction process is performed in between the corresponding elements of the two participant vectors. But in the new proposed similarity method the usual subtraction process is removed and a new subtraction method with corresponding neighbour elements is introduced.

The energetic similarity measurement is handled by two parameters and they are energy weight vector and block energy vector. The 2x2 size overlapped block is extracted from the noise free image. That block intensity data is converted into energetic data format using DWT and DCT transforms. The matrix shaped block information (2x2) is converted into linear vector shape (1x4). The block DWT energy is computed using equations 12 and 13.

$EB' - Dwt(BV(0))$ (12)
$EB' - [EB'(0), EB'(1), EB'(2)]$ (13) $where$
$BV - Block\ related\ vector$

EB' – Block energy Array

EB'_{Dwt} – *Block Energy vector using Dwt*

The block DCT energy is computed using equations 14 and 15.

$$EB'' - Dct(BV(0)) \quad (14)$$

$$EB'' - [EB''(0), EB''(1), EB''(2)] \quad (15)$$

where

BV – Block related vector

EB'' – *Block energy array*

EB''_{Dct} – *Block Energy vector using Dwt*

The fused block energy data formation is based on the equation 16.

$$EB_F = \{EB_{DWT}, EB_{DCT}\} \quad (16)$$

Where

EB_F = Fused Block Energy Vector

The Energetic similarity measurement is computed using the equations 17, 18 and 19.

$$P = \{0,0,0,1,2,3\} \quad (17)$$

$$q = \{2,3,4,5,5,5\} \quad (18)$$

$$Sim(k) = \sum_0^5 \sum_{j=p(i)}^{q(i)} \left(\mathrm{EB_F}(j) - E_F^k(j)\right) * C \quad (19)$$

$k \in [0, totalcluster - 1]$

Where

p - Starting neighbour location indicator

q - Ending neighbour location indicator

k - Cluster indicator.

sim(k) - Similarity value related with k cluster

C - Multiplication constant (assume as $\sqrt{2}$)

The refinement process is performed by 3 stages. In stage1 process the left, top, right and bottom neighbours are collected and a condition (all the four neighbours are having same value) is evaluated whether it is true or false. If the condition is true and the centre pixel is varied from the four elements then the left neighbour’s value is used to replace the centre location pixels. Here any of the four neighbour values can be used instead of left neighbour because the four neighbours are having same values based on the above described conditions. Next the stage 2 refinement process is performed. In this stage instead of four neighbours, only left and right neighbours are chosen. Then the left and right neighbours are checked for the exact value. If this condition is true and the centre pixels is differ from both the two neighbours then the centre pixel is replaced by either left or right neighbours. Then the stage 3 refinement process is performed. In this stage only top and bottom neighbours are chosen. Then the top and bottom neighbours are checked for the exact value. If this condition is true and the centre pixels is differ from both the two neighbours then the centre pixel is replaced by either top or bottom neighbours. This three stage refinement process enhances the satellite image segmentation output.

The new Energetic similarity measurement is processed to find the best matched k^th clusters. The best matched k^th cluster index is stored as the segmented result in a 2D matrix which is maintained as the same dimensionality with the original image. At the time of storage each and every elements of the query block (2x2) is assigned by the matched cluster index. The same process is performed by each and every block of the segmented image. This is an intermediate level of the segmentation output.

The segmentation result obtained from the energetic SOM is further processed by the refinement work to make the high accuracy segmented result.

III. EXPERIMENTAL RESULTS AND ANALYSIS

The proposed Satellite image segmentation method makes meaningful groups in input satellite images. The proposed Energetic SOM method is applied in this paper for segmentation. The Fuzzy-C means, Fuzzy noise reduction, DATBO image enhancement and Fuzzy C means methods are used to improve the segmentation quality. In this paper, the Aster-GED database is used for satellite image segmentation. This paper uses 150 images from Aster-GED database to test the segmentation performance of the proposed method. In this

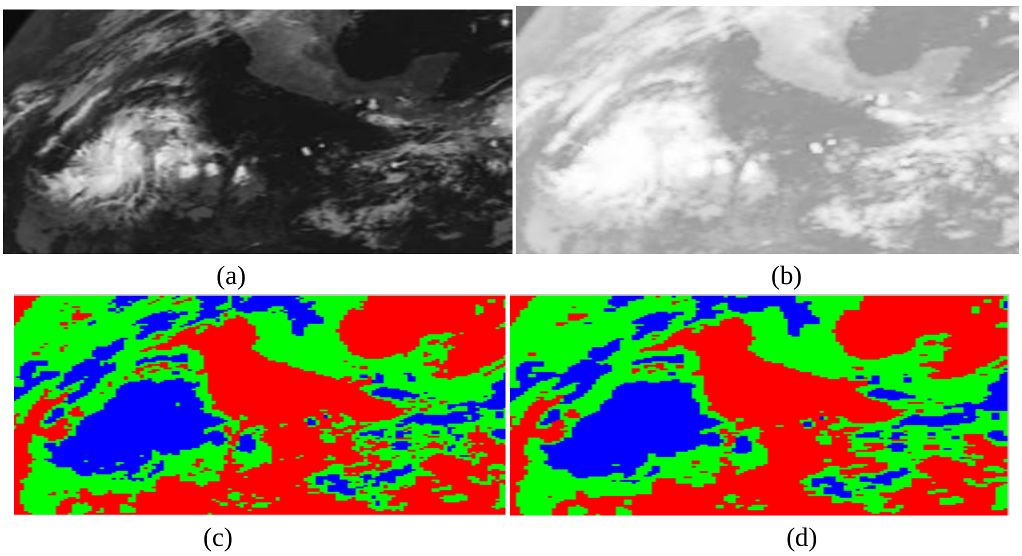

Fig. 2. Proposed Energetic SOM outputs (a) Original Satellite Image (b) Background Optimized image (c) Segmented output image (d) Refined Segmentation output.

analysis the proposed methodology is compared with three existing methods. The names of them are as follows:

1. Multi Layer Level set Approach based Satellite Image Segmentation [MLL-SIS] [21] .
2. Fuzzy Clustering for Satellite Image Segmentation [FC-SIS] [22].
3. Fast Mean shifting algorithm for Remote Sensing Image [FM-SIS] [23].

The figure 2 describes the Energetic-Som method's segmentation output.

Means Square Error (MSE) is a performance measurement parameter used to measure the segmentation quality. The MSE can be calculated using the equation 20. The lower MSE values indicate better segmentation quality in Satellite image segmentation.

$$MSE = \frac{1}{m\,x\,n}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}(I_{Gnd(i,j)} - I_{seg(i,j)}) \quad (20)$$

Where

m - image height
n - image width
$I_{Gnd(i,j)}$ - $(i,j)^{th}$ location of the ground truth image
$I_{seg(i,j)}$ - $(i,j)^{th}$ location of the segmented image

From the table 1 and figure 3 it can be understand that the proposed method holds less MSE when compared with the existing methods. The segmentation method FM-SIS is the second best method in satellite image segmentation in case of MSE.

Table 1: Mean Square Error Analysis

S.No	Satellite image name	Segmentation Method	MSE
1	Satellite image1.Bmp	MLL-SIS FC-SIS FM-SIS Proposed	0.126 0.103 0.058 0.032
2	Satellite image2.Bmp	MLL-SIS FC-SIS FM-SIS Proposed	0.060 0.045 0.025 0.016
3	Satellite image3.Bmp	MLL-SIS FC-SIS FM-SIS Proposed	0.055 0.046 0.040 0.023
4	Satellite image4.Bmp	MLL-SIS FC-SIS FM-SIS Proposed	0.124 0.099 0.072 0.040
5	Satellite image5.Bmp	MLL-SIS FC-SIS FM-SIS Proposed	0.117 0.102 0.070 0.049

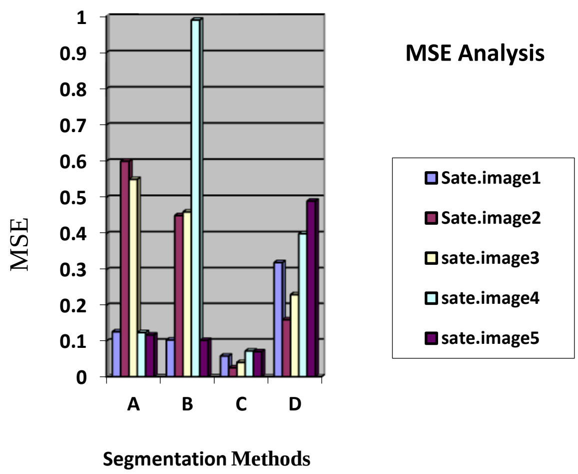

Fig. 3. Mean Square Error Analysis

Table 2. Average MSE Analysis

S.No	Segmentation Method	Average MSE
1	MLL-SIS	0.2044
2	FC-SIS	0.0790
3	FM-SIS	0.0530
4	Proposed	0.0320

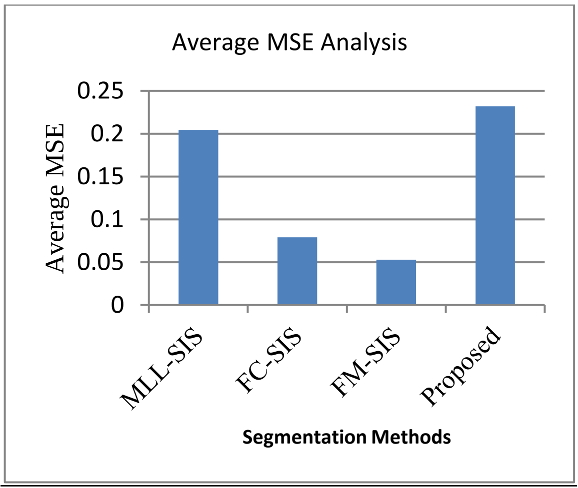

Fig. 4. Average MSE Analysis

From the table 2 and Figure 4 we can be observed the proposed method holds less average MSE compared with the previous methods. To compare second best method FM-SIS with proposed method the difference is 0.021.

The Peak Signal to Noise Ratio (PSNR) is used as a segmentation performance parameter to measure the segmentation quality. It can be computed from the equation 21. The higher PSNR value indicates better segmentation quality in satellite image segmentation.

$$PSNR = 10log_{10}(255^2/MSE) \quad (21)$$

Table 3. Peak Signal to Noise Ratio

S.No	Satellite image name	Segmentation method	PSNR (in db)
1	Satellite image1.Bmp	MLL-SIS FC-SIS FM-SIS Proposed	57.1 58.2 60.5 63.4
2	Satellite image2.Bmp	MLL-SIS FC-SIS FM-SIS Proposed	60.3 61.6 64.2 66.1
3	Satellite image3.Bmp	MLL-SIS FC-SIS FM-SIS Proposed	60.8 61.4 62.1 64.2
4	Satellite image4.Bmp	MLL-SIS FC-SIS FM-SIS Proposed	57.3 58.2 59.4 62.1
5	Satellite image5.Bmp	MLL-SIS FC-SIS FM-SIS Proposed	57.3 58.2 59.6 61.2

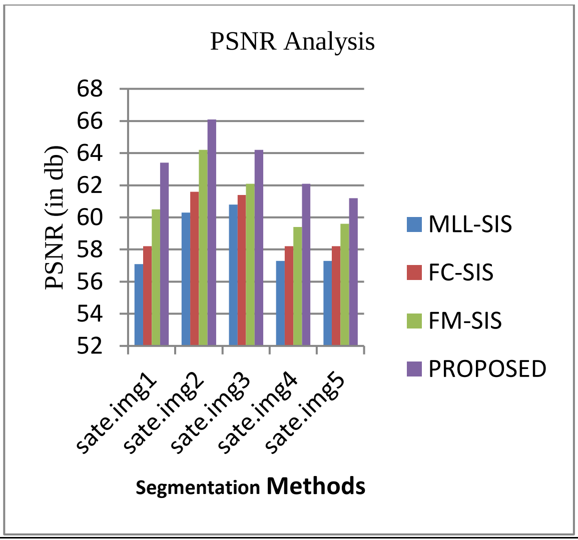

Fig. 5. PSNR Analysis for 4 methods

From the table 3 and figure 5 it can be noticed that the proposed method holds high PSNR compared with the existing methods. The segmentation method FM-SIS is the second best method in satellite image segmentation.

Table 4. Average PSNR analysis

S.No	Segmentation Method	Average PSNR
1	MLL-SIS	58.56
2	FC-SIS	59.52
3	FM-SIS	61.16
4	PROPOSED	63.40

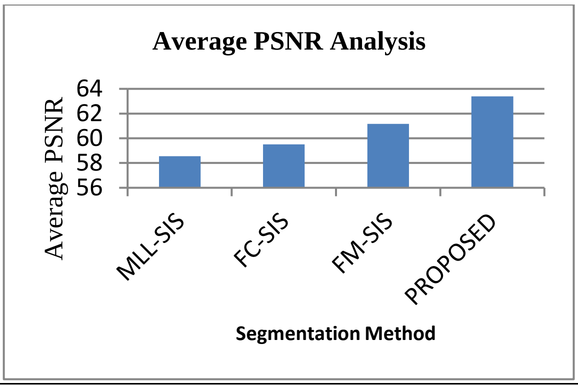

Fig. 6. Average PSNR Analysis

From the table 4 and Figure 6 it can be learnt the proposed method holds high average PSNR compared with the previous methods. When compared with the second best method FM-SIS, the proposed method makes the Average PSNR difference as 2.06.

Table 5. Accuracy Performance Measurement

S.No	Satellite image	Segmentation method	Accuracy In (Percentage)
1	Satellite image	MLL-SIS FC-SIS FM-SIS Proposed	84.17 85.92 88.4 91.47
2	Satellite image2	MLL-SIS FC-SIS FM-SIS Proposed	86.1 87.3 90.42 92.3
3	Satellite image3	MLL-SIS FC-SIS FM-SIS Proposed	85.2 85.9 88.3 91.2
4	Satellite image4	MLL-SIS FC-SIS FM-SIS Proposed	86.7 87.4 89.27 92.20
5	Satellite image5	MLL-SIS FC-SIS FM-SIS Proposed	85.2 86.43 88.56 91.17

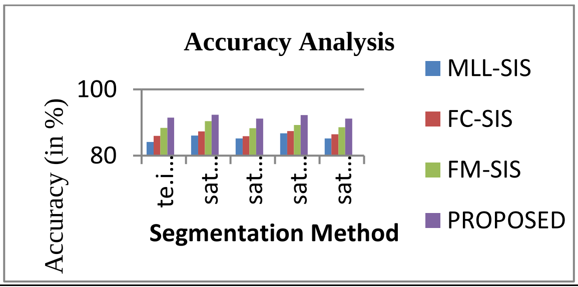

Fig. 7. Segmentation Accuracy Analysis

From the table 5 and figure 7 it understand the proposed method holds high accuracy compared with the existing methods. The segmentation method FM-SIS is the second best method in satellite image segmentation in the case of Image segmentation accuracy.

Table 6. Average Accuracy Analysis

S.No	Segmentation method	Avg. segmentation time taken (in seconds)
1	MLL-SIS	47.72
2	FC-SIS	49.9
3	FM-SIS	54.81
4	PROPOSED	58.43

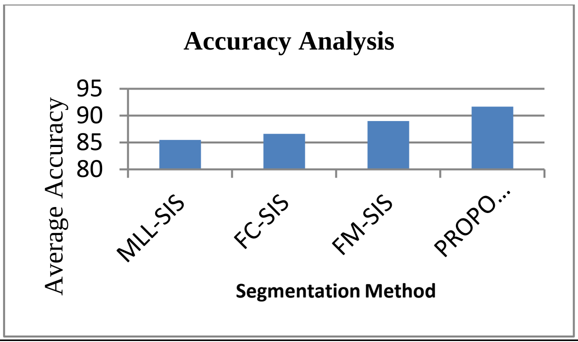

Fig. 8. Average Accuracy Analysis

From the table 6 and figure 8 it can noticed the proposed method holds high average accuracy compared with the previous methods. To compare second best method FM-SIS with proposed method the difference is 4.38.

Table 7. Average time taken

S.No	Segmentation Method	Average Accuracy
1	MLL-SIS	47.72
2	FC-SIS	49.9
3	FM-SIS	54.81
4	PROPOSED	58.43

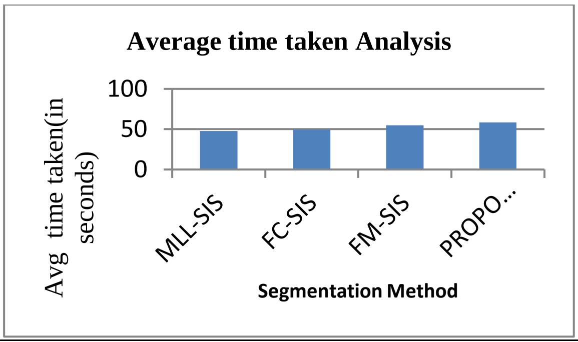

Fig. 9.Average time taken Analysis

From table 7 and Figure 9 it can be understand the proposed method takes some little bit time more than the existing method FM-SIS. But when comparing with the performance of the proposed method this additional time consumption can be neglected because the main aim of this paper is to increase the performance (not about time consumption).

V. CONCLUSION

The proposed satellite image segmentation method segments the input image into multiple meaningful groups to help further valid image processing steps. This paper contributes two novel components for segmentation. They are Dynamic Adaptive Threshold based Background Optimization (DATBO) method and Energetic SOM (ESOM). To get better segmentation the noises from the image are removed. The Dynamic Adaptive Threshold based Background Optimization (DATBO) component helps to improve the performance of Fuzzy C-Means (FCM). The DWT and DCT transforms are used to construct the ESOM algorithm. The refinement process tuned the quality of segmentation in a better mode. The proposed method stays in superior quality in cases of MSE and PSNR and accuracy analysis. By considering the overall gains from the proposed method, this paper concludes that the proposed Energetic-SOM based method is better than existing in case of satellite segmentation. In future more powerful transform based features, such as contourlet can be used to get more accurate segmentation.

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