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Robust and Realistic Classification of Massive Gray Level Thresholding in Remote Sensing Images

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***Abstract* -** Thresholding is an important technique for remote sensing image classification that tries to identify and extract a target from its background on the basis of the distribution of gray levels. Most thresholding techniques are based on the statistics of the one-dimensional histogram of gray levels and the two-dimensional co-occurrence matrix of an image. The remote sensing image classification refers to the process of separating an image into the multi gray level classes or features. The main goal of classification is to simply change the representation of an image into something that is more meaningful and easier to analyze. We present a new algorithm based on robust and realistic classification of massive gray level thresholding representation of remote sensing image. This algorithm allows the distribute the number of gray levels for an image in a fine to grainy fashion, starting with the original gray levels present in the image and all the way down to two gray levels that simply create a binary based version of the original image. This algorithm can also be used to find different gray level threshold image in a natural way without forcing a specific number ahead of time. The accuracy of this algorithm can be most demanding part of a computer vision application. In this work, gray level histogram thresholding is proposed in order to help the classification step to found to be robust way regardless of the classification approach. A proposed method over a remote sensing images have shown that offers very good classification results with a low computation time. Our experimental results show that the thresholding method based on gray level optimization is more efficient than the other classical thresholding methods.

***Keywords* –** RSI, LCS, EBC, RBC, TBT, LTT, GTT and SMGT

I. INTRODUCTION

Remote sensing image classification is a process of partitioning an image into a set of non overlapping regions. Classification is a process of grouping an image into units that are homogeneous with respect to one or more characteristics features. Image classification is the division of an image into regions or categories, which correspond to different objects or parts of objects. The goal of image classification is typically used to locate objects and boundaries (lines, curves, etc.) are more meaningful and easier task in image vision applications. A good classification has the following properties[1]:

- Pixels in the same category have similar gray scale of multivariate values and form a connected region.
- Neighboring pixels are in different categories have dissimilar values.
- The result of image classification is a set of fragments that collectively cover the entire image or a set of contours extracted from the image .
- Each of the pixels in a region are similar with respect to some characteristics property such as color intensity, brightness or texture.

Remote sensing image classification is a low level image processing task that aims at partitioning an image into regions in order that each region groups contiguous pixels are sharing similar attributes (intensity, color, etc.). It is a very important process because it is the first step of the image understanding process and all others steps such as feature extraction, classification and recognition depend heavily on its results. A wide variety of image classification techniques can be categorized into thresholding, edge-based, region growing and clustering techniques. These techniques have been reported in different estimation of results. Image thresholding is an important technique for image processing and pattern recognition that can be classified as bi-level thresholding and multi-level thresholding. The bi-level thresholding classifies the pixels of an image into two classes, one including those pixels with gray-levels above a certain threshold and other including the rest. The gray level thresholding divides the pixels into several classes. The pixels belonging to the same class have gray levels within a specific range defined by several thresholds[2].

II. PRINCIPLES OF REMOTE SENSING

Remote sensing image classification refers to the task of extracting information classes from a multi-level raster image. The resulting raster from image classification can be used to create thematic maps. Depending on the interaction between the analyst and the computer during classification, there are two types of classification: supervised and unsupervised. The objective of remote sensing image classification is to identify and portray as a unique gray level (or color) features occurring in an image in terms of the object or type of land cover these features actually represent on the ground. A broad group of digital image processing techniques of remote sensing application explains the image classification techniques are most generally applied to the spectral data of a satellite image or to the varying spectral data of a series of multidimensional images[3].

Remote sensing research focusing on image classification has long attracted the attention of the remote sensing community because classification results are the basis for many environmental and socioeconomic applications. Image classification is a complex process that may be affected by many factors. The different review methods are suggests that designing a suitable image processing procedure is a prerequisite for a successful classification of remotely sensed data. The effective use of multiple features of remotely sensed data and the selection of a suitable classification method are especially significant for improving the classification accuracy. The continuous and emergence of new classification algorithms and techniques in recent years are highly valuable for guiding or selecting a suitable classification procedure for a specific study. This paper focuses a summarization of massive gray level threshold classification methods and techniques used for improving the classification accuracy. In many remote sensing applications, the gray levels of pixels belonging to the object are quite different from the gray levels of the pixels belonging to the background. The level of thresholding becomes a simple but effective tool to separate objects from the background[4-6].

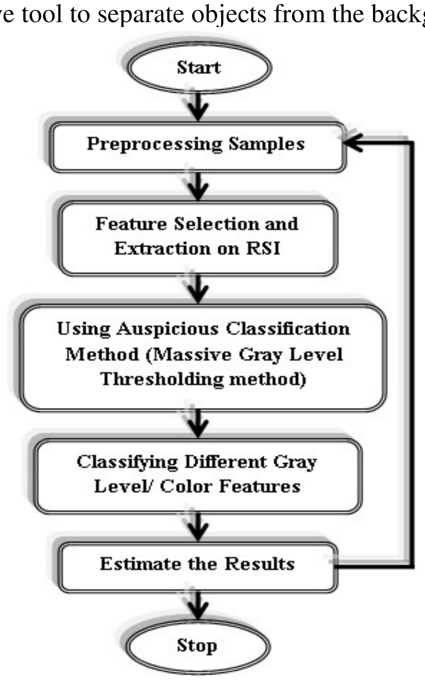


Fig.1. Progression of Remote Sensing Image Classification

III. THRESHOLDING TECHNIQUES IN IMAGE CLASSIFICATION

Thresholding is the operation of converting a gray scale image into a binary image. Thresholding is a widely applied preprocessing step for image classification. In image processing, thresholding is used to split an image into smaller classes or junks using at least one color or gray scale value to define their boundary.

There are three general approaches to classification, termed thresholding, edge-based methods and region-based methods. In the thresholding process, individual pixels in an image are marked as object pixels if their value is greater than some threshold value, otherwise marked as background pixels[7-8].

A. Edge Based Classification (EBC)

In edge based classification, an edge filter is applied to image, pixels are classified as edge or non-edge depending on the filter output, and pixels which are not separated by an edge are allocated to the same category.

B. Region Based Classification (RBC)

In region based classification algorithms operate iteratively by grouping together pixels which are neighbors and have similar values and splitting groups of pixels which are dissimilar in value.

C. Thresholding Based Classification (TBC)

Thresholding based classification techniques are computationally simple and never fails to define disjoints regions with closed boundaries. Threshold technique is one of the important techniques in image classification. This technique can be expressed as:

$$T=T[x, y, p(x, y), f(x, y)] \quad (1)$$

Here, T is the threshold value, x, y are the coordinates of the threshold value point and p(x,y), f(x,y) are points the gray level image pixels. Threshold image g(x,y) can be define:

$$G(x, y) = \begin{cases} 1 & \text{if } f(x, y) > T \\ 0 & \text{if } f(x, y) <= T \end{cases} \quad (2)$$

Threshold classification techniques can be grouped in three different classes[3]:

1) Local Threshold Techniques (LTT): It is based on the local properties of the pixels and their neighborhoods. A threshold value is assigned to each pixel to determine whether it belongs to the foreground or the background pixel using local information around the pixel.

2) Global Threshold Techniques (GTT): Classifying an image on the basis of information obtain globally (e.g. by using image histogram and global texture properties.). In global threshold, a single threshold value is used in the whole image.

3) Split, Merge and Growing Techniques (SMGT): This method use both the notions of homogeneity and geometrical proximity in order to obtain good classification results. Finally image classification is used to group pixels into

regions to determine different level of an image composition[9-10].
However, a wide variety of remote sensing image classification algorithms in thresholding, which is computationally simpler than other existing algorithms. Thus, a computational requirement is an important consideration in thresholding technique is preferred and is widely used tool in image classification. When an image consists of only object and background, the best way to pick up a threshold is to search a histogram in a bimodal and find a gray level which separates the two peaks. However, a practical problem occurs, when the object area is small compared to the background area or when both the object and the background assume some broad range of gray levels. In these cases, the histogram is no longer bimodal of an image.

In spite of the proliferation of thresholding techniques, very little formal evaluation and comparison among the different types of thresholding techniques have been attempted. There are various reasons difficult to selecting a reasonable standard of comparison, difficult evaluation, collection of comprehensive tests and the difficult in interpreting the results in a meaningful and unbiased way. In many industrial applications such as inspection, measurement and some assembly tasks the aim of classification is to separate the object from the background.

IV. PRELIMINARIES

Thresholding is a process of converting a gray scale input image to a bi-level image by using an optimal threshold. Preprocessing is the first phase of classification process. The purpose of preprocessing is to improve the quality of the image being processed. It makes the subsequent phases of image processing like recognition and identification of features are very easier. Thresholding is one of the preprocessing method in remote sensing image classification. In thresholding, the color-image or gray scale image is reduced to a binary image[11].

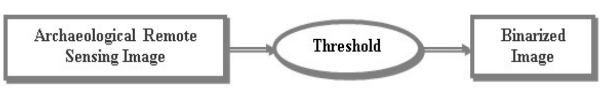


Fig.2. Process of Thresholding along with its Inputs and Outputs.

A. Goals of Thresholding

The purpose of thresholding is to extract those pixels from some image which represent an object and background. Thus the objective of binarization is to mark pixels represents a range of intensities that belong to true foreground regions with a single intensity and background regions with different intensities.

- Set one or more thresholds which split the intensity ranges.
- The intervals defining intensity classes.
- Separate objects from the background.
- Label objects by classifying pixel intensities into two or more classes.
- Improving the histogram for better peak separation.
- Limits the variances of thresholding.

B. Choosing the Threshold

Peaks and valleys of the image histogram can help in choosing the appropriate value for the thresholds. Some factors affects the suitability of the histogram for guiding the choice of the threshold:

- The separation between peaks.
- The noise content in the image.
- The relative size of objects and background.
- The uniformity of the illumination.
- The uniformity of the reflectance.

For a thresholding algorithm to be really effective, it should preserve logical and semantic content. Fig. 3 shows some typical histograms along with suitable choices of threshold.

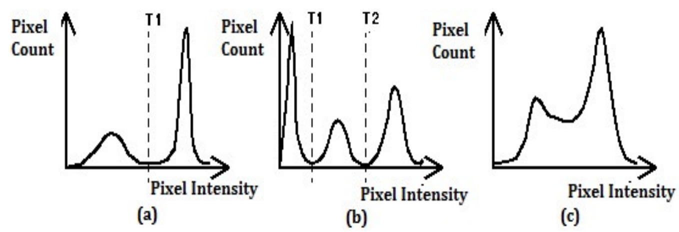


Fig.3. Histograms along with Suitable Choices of Threshold Level

C. Principles of Gray Level Thresholding

Thresholding is a very common because it is simple and effective. Threshold images are usually easier to process, store or compress. The number of thresholds used in the process is given in different names. A single threshold is used in the process is called binarisation and the image produced has only two (bi-level) gray levels and with a multi-level threshold is used the image produced two or more thresholds are used. The gray level thresholding is a simple image classification technique that assumes the following conditions[12]:

- Scene model - Scene contains uniformly illuminated in flat surfaces.
- Image model - Image is a set of approximately uniform regions.

In remote sensing classification, a small number of gray levels typically partition the image into meaningful, distinct regions. With more gray levels, the quantization process is essentially to reduce the number of original gray levels from its initial value of 2^K (typically 256 levels, i.e. K= 8 bits per pixel). Image classification separates distinct or meaningful regions in the image from each other and from their background under the assumption that objects and the background have different grey levels from each other. The quantization is applies further spatial and temporal compression to an image or a set of images to reduce storage and transmission time[13]. We focus our attention on gray level thresholding where a set of thresholds are selected based on the global information of the image represented by the compact form of its histogram. Given the original image I(i, j) and the number of thresholds are N-1, a set of thresholds T_i, where i=0,1,2,3,……., N-2 is computed and used to create a quantized image $QIM_N(i,j)$ with N distinct regions according to the following:

$$QIM_N(i,j) = \begin{cases} q_0 & 0 <= I(i,j) < T_0 \\ q_1 & T_0 <= I(i,j) < T_1 \\ q_2 & T_1 <= I(i,j) < T_2 \\ q_3 & T_2 <= I(i,j) < T_3 \\ q_{N-1} & T_{N-2} <= I(I,j) <= 2^K-1 \end{cases} \quad (3)$$

The quantized levels q_i, where i=0,1,2,3,………N-1 are computed for each threshold region. The number of regions N is defined using N-1 thresholds with 0 (the minimum gray level) and 2^K-1 (the maximum gray level) as the two lower and upper bounds on the thresholds respectively. In the extreme case of binarisation, a single threshold is selected to divide the grey level range 0–2^K into two distinct regions and produces a quantized image as follows:

$$Q_2(I,j) = Q_B(I,j) = \begin{cases} q_0 & 0 <= I(i,j) < T_0 \\ q_1 & T_0 <= I(i,j) <= 2^K-1 \end{cases} \quad (4)$$

Our determination of the threshold levels is based on a remote sensing application of an optimal partitioning algorithm to the histogram of pixel values using a gray level based model of the image. Given a remote sensing image I(i, j), of dimension N_x x N_y, we let I(i, j) represents the intensity at location (i, j) with1<= i <= N_x, 1<= j<=N_y and 0<=I(i, j)<=L-1. The histogram partitioning into N regions is shown in the fig. 4.

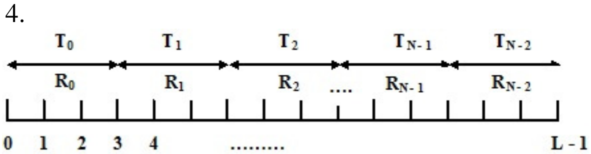


Fig.4. Histograms Partitioning into N Regions using N-1 Thresholds

In this method, our remote sensing image as a probability distribution with each pixels grey level I(i, j) representing an estimate the number of photons reaching that spatial location. Such a model implies that for each image, we have a fixed number of photons G, which equals the sum of all gray level values of all the pixels in the image. That is,

$$G = \sum_{i=1}^{N_x} \sum_{j=1}^{N_y} I(i,j) \quad (5)$$

D. Gray Level Mathematical Morphology

The gray level morphological processing techniques can be used for practical problems such as shading correction. In this paper threshold techniques will be presented in the remote sensing image. A simple estimate of a locally varying threshold surface can be derived from morphological processing, the gray level threshold surface as follows[14]:

$$\theta[m, n] = 1/2(Max(A) + Min(A)) \quad (6)$$

Once again, we suppress the notation for the structuring element B under the maximum and minimum operations to keep the threshold operations is shown in the following fig. 5-6.

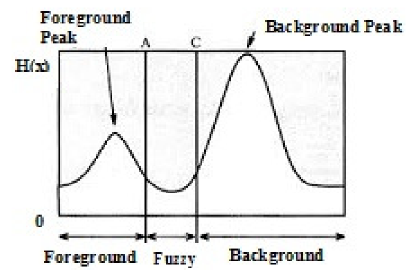


Fig.5. Foreground and Background Peak Levels of Thresholds

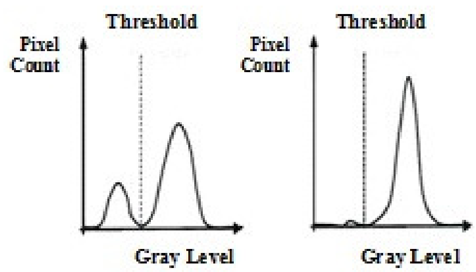


Fig.6. Different Gray Level Thresholds

Using morphological operations we can implement a gray level thresholding technique for Local Contrast Stretching (LCS). The amount of stretching that will be applied in a neighborhood pixels will be controlled by the original contrast in that neighborhood pixels. The morphological gradient defined in equation (7) may also be seen as related to a measure of the local contrast in the window defined by the structuring element B. The local contrast is defined by the following equation:

$$LC(A, B) = Max(A) – Min(A) \quad (7)$$

The procedure for local contrast stretching is given by the equation:

$$C[m, n] = scale * \frac{A – Min(A)}{Max(A) – Min(A)} \quad (8)$$

V. PROPOSED MASSIVE GRAY LEVEL THRSHOLDING OF RSI CLASSIFICATION

A gray level thresholding method has been used as a classification tool in various applications such as document image processing, MRI image analysis, quality inspection, video signal for spatial and temporal classification, remote sensing image classification and color palette design[4]. We created a slightly modified histogram of the remote sensing image based on the basic gray level reduction model. The histogram has two columns, each of size L. The entry (cell) in the first column represents the number of pixels at gray level l_i, which we denote n_i as the second entry, g_i represents the total number of photons in these cells or $l_i * n_i = g_i$. As some of the grey levels can be missing, this can be handled by creating a histogram of only the values present in the image. Following steps describe the proposed algorithm for image classification:

A. Proposed Algorithm

- Test the remote sensing gray scale image taken from any sensor.
- Decide on a prior value based on complexity of the histogram structure and the final number of regions desired in the image. Using log and cost functions.
- Set optimal gray level(-1) = 0 and also set initially N = 0. The optimal gray level algorithm receives the histogram as an interval with the cost function and the prior. Its output is the set of thresholds $\{T_i \mid I = 0, 1, 2, \ldots, M-2\}$, defining each region R_i.
- Create the quantized values of an gray level image $\{Q_i \mid i = 0, 1, 2, \ldots, M-1\}$ based on the thresholds found in the previous step.
- Given optimal gray level (j) for j = 0, 1, . . . , n .
    - Compute optimal gray level (N + 1), for j = 0, 1, . . . , N + 1.
    - Store the value of j where the maximum occurred in last Change (N + 1).
    - Set N = N + 1.
    - If N = L, then stop.
- Extract the set of N–1 thresholds as:
    - T_{N-2} = Last Change (L-1)
    - T_{N-3} = Last Change (T_{N-2})
    - From T_i = Last Change (T_{i+1} - 1) to T_0 = Last Change(T_1)
- Finally, we can get the different thresholded image with various gray levels.

B. Flowchart

The gray level algorithm is a main framework of threshold and with only a different prior input (treated as an adaptable parameter) can produce any desired number of thresholds or gray levels. This algorithm can produce the number of gray levels by selecting a subset of thresholds as boundaries or significant change points in different regions. The gray scale histogram of an image represents the distribution of the pixels in the image over the different gray levels. It can be visualised each pixel is placed in a bin corresponding to the colour intensity or gray scale of that pixel.The flowchart of the massive gray level thresholding algorithm is shown in the fig. 7.

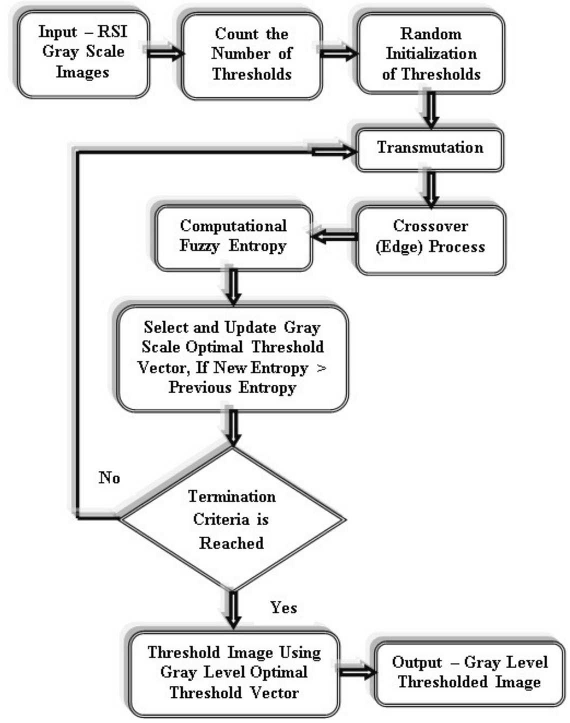


Fig.7. The Flowchart of the Gray Level Thresholding Classification

VI. EXPERIMENTAL RESULTS

The various experiment carried out in the above remote sensing algorithm of gray level threshold classification was performed using Matlab7.6 version and tested the classified techniques on simple remote sensing image and the complete process of different gray level thresholding as illustrated in fig. 8-12.

Fig. 8. Original remote sensing image

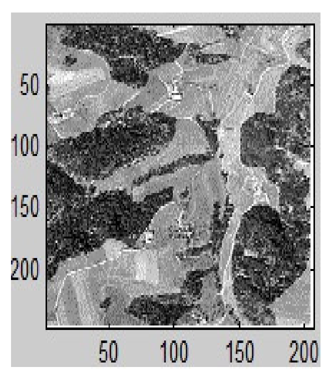


Fig. 9. Gray level dimension image

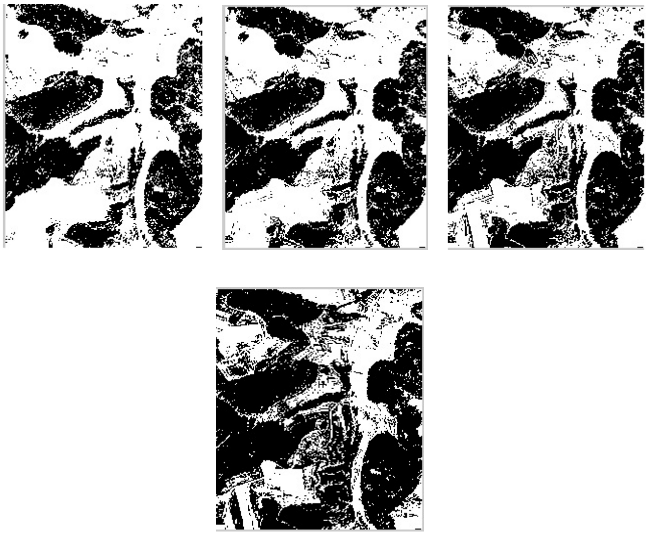


Fig. 10. Minimum gray level images from 0.30 to 0.55.

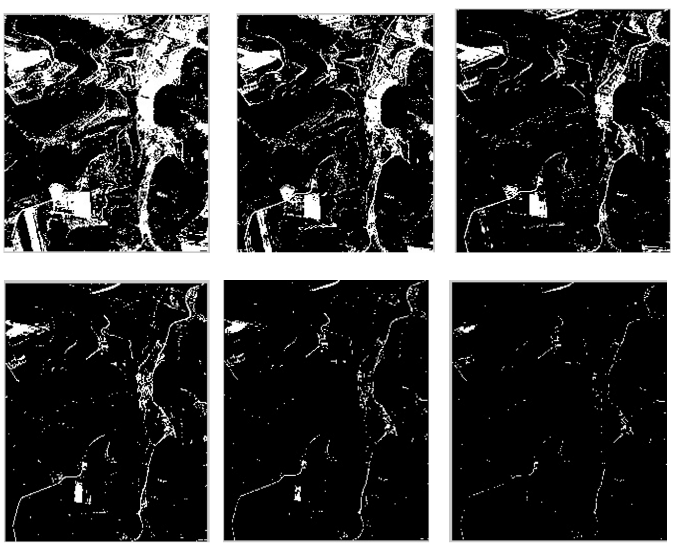
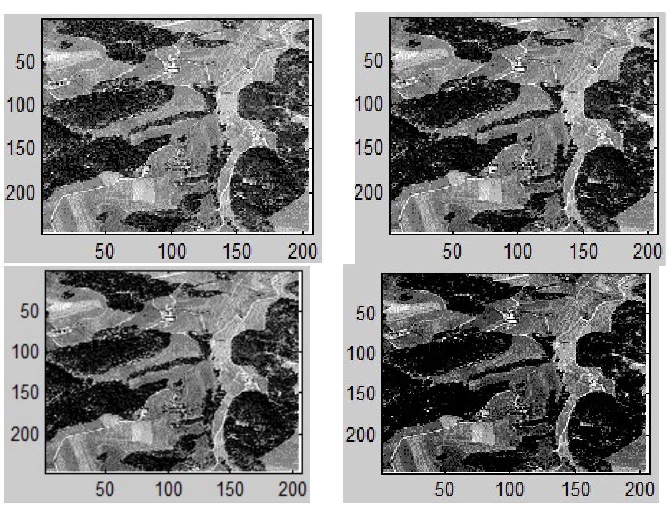


Fig. 11. Maximum gray level images from 0.60 to 0.90



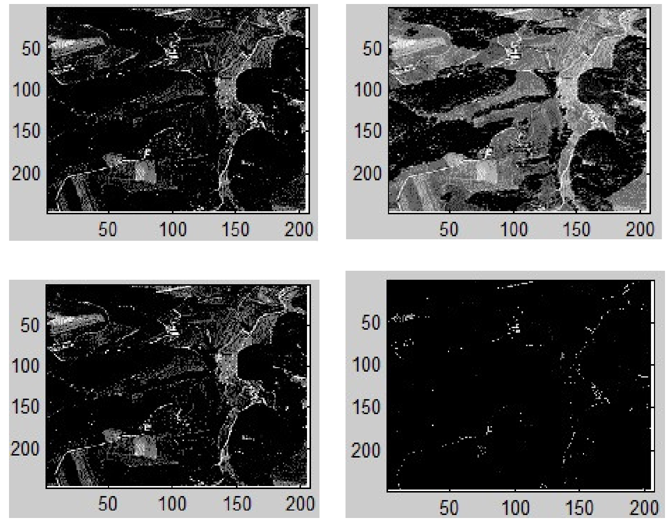


Fig. 12. Classified three level of images with alfa factor from 0.1 to 0.3

VII. PERFORMANCE MATRICS

For evaluating the performance of the proposed massive gray level thresholding algorithm, we have implemented the method on a variety of remote sensing images. The performance metrics for checking the effectiveness of the method are chosen as PSNR and MSE are used to determine the quality of the thresholded image. Thus, for remote sensing image classification using thresholds derived from gray level class variances. Our proposed algorithm is a significant improvement over earlier methods. This paper can accurately classify the different gray levels and the results may be interpreted as due to the comparative powerful energy minimization. The overall execution times of the proposed method were around 15.426071 seconds for the remote sensing image and acceptable times in the usual applications to land cover or remote sensing based classification methods.

In order to measure the performance of the classification, we used the criterion of Peak Signal to Noise Ratio (PSNR), which is used as a quality measurement between the original image and the gray level thresholded image, the value is normally expressed in decibels (dB). If the PSNR value is high then, it achieves the better quality of the thresholded or reconstructed image. The PSNR is defined by the following equation:

$$PSNR = 10 \log_{10}((256 * 256) / MSE) \quad (9)$$

Here, MSE is the mean squared error, which is defined as the following equation:

$$MSE = \frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} [I(i, j) - K(i, j)]^2 \quad (10)$$

Here, I and K are the original and different gray level thresholding images, and M x N are the dimensions of the remote sensing image.

Table 1. Performance Metrics of Proposed Massive Gray Level Thresholding Method

Input Image	Different Perspective	Metrics (dB)		
Remote Sensing Satellite Image	Level of Remote Sensing Image	PSNR S=0	PSNR S=1	MSE
Divergent Observation of Min. and Max. Gray Level Image	Gray level Dim. Image	34.94	34.94	0.61
	Minimum Gray Scale Level 0.30	29.39	29.39	0.85
	Minimum Gray Scale Level 0.35	30.26	30.26	0.82
	Minimum Gray Scale Level 0.40	31.13	31.13	0.79
	Minimum Gray Scale Level 0.45	32.02	32.02	0.77
	Minimum Gray Scale Level 0.50	33.34	33.34	0.74
	Minimum Gray Scale Level 0.55	37.29	37.29	0.69
	Minimum Gray Scale Level 0.60	36.89	36.89	0.61
	Maximum Gray Scale Level 0.65	32.24	32.24	0.53
	Maximum Gray Scale Level 0.70	30.07	30.07	0.42
	Maximum Gray Scale Level 0.75	28.94	28.94	0.32
	Maximum Gray Scale Level 0.80	28.52	28.52	0.27
	Maximum Gray Scale Level 0.85	28.09	28.09	0.19
	Maximum Gray Scale Level 0.90	28.05	28.05	0.17
Dissimilar of Different Gray Level Threshold Image	Threshold Level 1 with Alfa 0.1	37.26	37.26	0.59
	Threshold Level 1 with Alfa 0.2	43.35	43.35	0.56
	Threshold Level 1 with Alfa 0.3	39.20	39.20	0.54
	Threshold Level 2 with Alfa 0.1	48.51	48.51	0.56
	Threshold Level 2 with Alfa 0.2	35.81	35.81	0.52
	Threshold Level 2 with Alfa 0.3	31.42	31.42	0.45
	Threshold Level 3 with Alfa 0.1	38.12	38.12	0.53
	Threshold Level 3 with Alfa 0.2	31.48	31.48	0.46
	Threshold Level 3 with Alfa 0.3	30.57	30.57	0.44
Classification Accuracy of Proposed Gray Level Threshold Method			**92.78 %**	
Overall Computation Efficiency			**15.426071 Sec.**	

VIII. CONCLUSION

Thresholding techniques converts a colored image or gray scale image into binary or bimodal image. The pixels of original image get converted and treated as foreground and background pixels. In case of thresholding techniques, a threshold value may work well in one region of an image, but may perform poorly in another region. This makes it difficult to select thresholds based on global information. The advantage of obtaining binary image through thresholding technique is that it reduces the complexity of the data and simplifies the process of recognition and classification. In this study, robust and realistic classification of massive grey level reduction algorithm was described that allows a natural as well as predetermined different range of the gray levels present in remote sensing image. This algorithm allows the massive gray level threshold based different blocks applied to the histogram of the remote sensing image with an appropriate cost function. The number of desired gray levels is controlled through a prior on the number of classes present in the image and is capable of producing different numbers of gray levels including two gray levels for binary images. The algorithm has a moderate computational efficiency proportional to the square of the number of unique gray levels $O(L^2)$ present in the remote sensing image.

In future, this algorithm can easily be incorporated with other algorithms such as region growing, edge detection, adaptive threshold, vision based application and lossy compression. This algorithm can also be adapted to other features including the speed, the incorporation of spatial information and the quantification to achieve a predetermined number of thresholds in a more systematic way. In this study we develop taxonomy of gray level thresholding algorithms based on the type of information used and we assess their performance comparatively using a set of objective classification quality metrics.

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