Detection of Satellite Image Edges using B^2MST

K. P. Sivagami
Department of Computer Science
J K K Nataraja College of Arts & Science
Komarapalayam, TN, India
kpsivaravi@gmail.com

S. K. Jayanthi
Department of Computer Science
Vellalar College for Women
Erode, TN, India
jayanthiskp@gmail.com

S. Aranganayagi
Department of Computer Science
J K K Nataraja College of Arts & Science
Komarapalayam, TN, India
arangbas@gmail.com

***Abstract*- In image processing and pattern recognition, edge detection is used to preserve the structural properties in an image which significantly reduces the amount of data and also filters out the useless information. Edge detection is an important area in processing the satellite images which are of high resolution with lot of information. Bi-level Bi-stage concept has been used to detect the edges based on global and local threshold values in Shannon entropy Multi thresholding (SMT) method for gray scale images. To extend this concept for multispectral images, a Shannon entropy Multispectral Multi Thresholding (SM^2T) algorithm has been proposed. Even though this method detects more edges than SMT, Edge Detection using Multispectral thresholding (EDMST) method, based on Otsu thresholding values for multispectral images, detects more edges than SM^2T method. Bi-level Bi-stage Multispectral thresholding (B^2MST) algorithm has also been proposed based on global and local Otsu thresholding values to improve the EDMST method. Even though all the methods are applied on natural, art and simulated images, the performance is evaluated on simulated images, due to the existence of well known edges. The result of SMT, SM^2T, EDMST and B^2MST methods have been compared based on human visual system, number of edges detected and F-measure. Finally it has been observed that the B^2MST shows better results and hence applied on satellite images.**

Keywords - Edge Detection, Multispectral Images, Otsu thresholding, Bi-level, Bi-stage, B^2MST, EDMST, Shannon Multi Thresholding (SMT), Shannon Multispectral Multi Thresholding (SM^2T)

I. INTRODUCTION

Vision is our most dominant sense, hence the images observed by us in pictorial form plays an important role in human perception [1]. The goal of image processing is not only to obtain the image that is more suitable for human observation and understanding but also to recognize the image automatically by computer. The decomposition of a large and complex image into small images with independent feature is the main step of image processing [2].

The edge, basic characteristic of an image, is a collection of pixels based on a measure of intensity-level discontinuity at a point. The discontinuities are abrupt changes in pixel intensity which characterize boundaries of objects in a scene. The image intensity abruptly changes from one value on one side of the discontinuity to a different value on the opposite side occurs in Step edges. But in Line edges the intensity abruptly changes value but then returns to the starting value within some short distance. However, in real images the step and line edges are rare due to the low frequency components or smoothing introduce by most sensing devices. Instead of instantaneous changes in the intensity values, the changes occur over a finite distance leads Step edges into Ramp edges and Line edges into Roof edges [3].

Edge detection plays an important role in image processing and analyzing system. Successful edge detection has a great impact on the result of subsequent image processing, e.g. region segmentation, object detection, and in a wide range of applications, from image and video processing to multi/hyper-spectral remote sensing image analysis. In case of multispectral satellite image processing, each channel may provide different or even conflicting information. Here, edge detection becomes more important and essential to detect different areas of interest for different applications.

From the information theory perspective, only less than 5% of total pixels constitute the edges but they are very rich in information. Since the satellite images are of high resolutions with a lot of information, the edge

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detection algorithm significantly reduces the amount of data to be processed by filtering out the less relevant data, while preserving the important structural properties of an image through edges. With effective edge detection, the subsequent task of interpreting the information contents in the image can become substantially simplified [4].

For gray-scale images, the edge detection has been thoroughly studied and is well established. However, for color images, especially multispectral images, the area is still in its infancy and even defining an edge itself is pretty challenging. Since most of the existing color image edge detection algorithms depend on gray scale only, by converting RGB (Red, Green and Blue, 3 bands) color image into gray, the edge detection in multispectral images with multiple bands are still challenging.

To overcome the above problem, two algorithms have been proposed to detect the edges in multispectral images, Shannon Multispectral Multi Thresholding (SM^2T) and Bi-level Bi-stage Multispectral Thresholding (B^2MST). SM^2T, the improved version of Shannon Multi Thresholding (SMT) method [5], is based on multi-channel concepts. Even though SM^2T improves the detection of edges, Edge Detection using Multispectral Thresholding (EDMST) method [4] based on multi-channel concepts, produces better result. Moreover another algorithm, B^2MST has been proposed using the concept of 'bi-level by-stage' based on SMT and the concept of multi-channel based on EDMST and it detects more number of edges than EDMST method. These algorithms are tested with simulated, art and natural images. For performance evaluation, the simulated images are used due to the fact that their edges are well known in advance. Experimental results show that the B^2MST algorithm is more efficient and generates more number of edges than other algorithms.

The rest of the paper is organized as follows. Section II deals with the related work on edge detection and Section III describes the methodology. Results and the experimental analysis are presented in Section IV and the final Section concludes this paper.

II. RELATED WORK

Edge detection in images has been extensively analysed in computer vision and image processing field for last three decades but it is not entirely solved. There is no universal detection algorithm present in literature which can detect all scales of edges, irrespective of their shape, image type etc. Edge detection methods are image dependent. A large number of studies have been published in the field of image edge detection, which shows its importance in the field of image processing.

In the past, many authors have been using different edge detection methods for color images with three bands, red, green and blue. In most of the cases, the color image has been converted into gray scale and then detected the edges. Thresholding is one of the simplest and most commonly used technique to separate the foreground from its background. For the gray-scale image, bi-level thresholding can be used to create binary images, while multilevel thresholding determines multiple thresholds which divide the pixels into multiple groups. Selection of multiple thresholds can be carried out by either dividing the histogram into multiple groups and finding the threshold for each group [6-10], or dividing the histogram in two stages, one is based on global threshold and the other on local threshold [5][11][12].

In [6], commonly used edge detection techniques like Sobel, Canny, Prewitt, Roberts, Laplacian and Zero crossing have been compared and band wise analysis of these algorithms in the context of object extraction with regard to remote sensing satellite images, from Indian Remote Sensing Satellite as well as Google Earth has also been presented.

An automatic multi-threshold approach has been proposed in [7] for image segmentation. The threshold has been selected based on the heuristic Artificial Bee Colony (ABC) algorithm, which is motivated by the intelligent behavior of honey-bees. In this approach, the parameters of Gaussian mixture model have been calculated by ABC algorithm, which approximate the 1-D histogram of the image. Each Gaussian function represents a pixel class and a threshold for the approximation. Mixture of several Gaussian functions has been grouped by parametric model which holds the probability density function of gray levels.

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When dealing with digital images, most of them are having continuous intensity variation and many important regions will be lost while using single threshold level segmentation. From the histogram of the image, the multiple optimal threshold levels have been calculated in [8] by computing the number of significant peaks which represents the number of distinct regions the image can be divided into. The optimal multi-level thresholds have been calculated by maximizing the class separation while minimizing the areas of the classes by Otsu method of adaptive thresholding.

Edges have been detected in [9] by morphological operators and their combination with the use of various structuring elements. It has been identified that, the circle and square structuring elements produce better result for satellite remote sensing images, which have more details on the edges.

Automatic image segmentation of brain magnetic resonance images has been carried out in [10], to classify the images into variable brain tissue classes based on adaptive multi-level thresholding. The thresholds were chosen using the valleys in the histogram.

The bi-level bi-stage concept has been used in [5] [11] [12] to calculate the multi threshold values. The hybrid entropy, Shannon entropy for global threshold value and Tsallis entropy for local threshold value has been introduced in [11]. In SMT [5], only Shannon entropy has been used to calculate both global and local threshold values. In the current work, this method has been implemented and tested with simulated images. As in [12], the approximated road regions were identified using adaptive global thresholding from high resolution satellite images. The histogram of the gray scale satellite image has been divided into four sections based on mean value of all the pixel intensity values.

From the study, it has been observed that all the above methods convert the color image into gray scale before processing, which may lead to information loss. In case of satellite image processing, edge detection is of high importance due to the fact that it detects different areas of interest for different applications. Moreover the satellite images have more spectral band and certain bands are preferable for analysis of specific features (e.g. water body groups). So, to avoid the information loss in the multispectral images, all the bands are to be considered for processing.

At present color image edge detection methods are mainly extended from monochrome edge detection approaches and are being implemented in different color space. The two main approaches available to detect edges in multi-channel images are monochromatic technique and vector technique. In monochromatic approach, the gray scale edge detection has been applied to each band of the color image and the results are combined using the summation rule, the maximum rule or the OR operation. In the case of vector based approach, each pixel in a multispectral image has been considered as a vector in the spectral domain and then the edge detection has been performed [13]. The simplest way is to detect the edges in each band independently based on the threshold values and combine them to form a single contour image. This technique is proposed in SM^{2}T, a refinement of SMT, which detects the edges for multispectral images by obtaining global and local Shannon entropy threshold values in each spectral band.

Several methods have been proposed to binarize the image. To choose the optimal threshold, for general real world images, Otsu (1979) is one of the best threshold selection methods with regard to uniformity and shape measures [14]. In EDMST [4], the preliminary work done by the same author(s), the edges have been detected for each spectral band by obtaining Otsu threshold value. It has been identified that it detects more number of edges than SM^{2}T. Hencethe novel algorithm B^{2}MST has also been proposed based on bi-level bi-stage method to improve the performance of EDMST.

III. METHODOLOGY

Detecting edges in multispectral satellite images are difficult because different spectral bands may contain different edges. Existing approaches are applied on gray scale images to calculate the edge strength of a

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pixel locally, based on variation in the intensity between the pixel and its neighbors. Thus, they often fail to detect the edges of objects embedded in background clutter or objects which appear only in some of the bands.

It should be noted that the clustering methods often require prior knowledge about the data, such as, the number of clusters and cluster shapes. But for edge detection, however, such a prior knowledge is typically unavailable. To overcome this obstacle, thresholding, the well known method for its stability and robustness without any prior knowledge, has been used. In SMT, the threshold value has been calculated using Shannon entropy and in EDMST, Otsu method has been used. Since SMT and EDMST methods are purely based on the intensity values, there is a chance for missing the edges if the variation in the intensity is less. To overcome this problem, SM^2T and B^2MST have been proposed, which are the combination of bi-level bi-stage and multi-channel concepts.

A. Shannon Entropy

Entropy is a measure of randomness in information theory. Entropy-based thresholding based on information theory has been proposed in [5]. For the gray scale image, whose probability distribution is p_i, $i = 1,2,\ldots,k$ with k gray levels, the probability distributions for object,p_A, and background, p_B, and the corresponding Shannon entropies $S^A(t)$ and $S^B(t)$ have been derived using,

$$p_A : \frac{p_1}{P_A}, \frac{p_2}{P_A}, \ldots, \frac{p_t}{P_A} \tag{1}$$

$$p_B : \frac{p_{t+1}}{P_B}, \frac{p_{t+2}}{P_B}, \ldots, \frac{p_k}{P_B} \tag{2}$$

$$S^A(t) = -\sum_{i=1}^{t} p_i \, log_2(p_i) \tag{3}$$

$$S^B(t) = -\sum_{i=t+1}^{k} p_i \, log_2(p_i) \tag{4}$$

$$where \qquad P_A = \sum_{i=1}^{t} p_i \tag{5}$$

$$P_B = \sum_{i=t+1}^{k} p_i \tag{6}$$

The optimum threshold value has been calculated by maximizing the information measure between the two classes, the object and the background, as in the equation 6.

SMT Algorithm:

Step 1. Find the threshold value (t_1) of the gray scale image, f, of size m x n with histogram$H$ using (1) to (6)
Step 2. In the second stage, based on t_1, split H into two parts, H_1 with intensity values (0, 1, …, t_1) and H_2 with (t+1, t+2, … 255).
Step 3. Using (1) to (6), calculate the threshold values t_2 and t_3 for H_1 and H_2.
Step 4. Create the binary image A, using the condition
$A(i,j) = 1$ if $((f(i,j)>=t_2)$ and $(f(i,j)<t_1))$ or $(f(i,j)>=t_3)$ (7)
$A(i,j) = 0$ Otherwise
Step 5. Obtain the edge detection image, g, from A by applying 4-neighbor connectivity.

B. Shannon Multispectral Multi Thresholding (SM^2T) Method

Since SMT detects edges by converting color scale image into gray scale image, SM^2T algorithm has been proposed based on monochromatic technique. The edges have been identified in each spectral band using SMT and summation rule is applied to obtain a single contour image.

SM^2T algorithm:

Step 1. Obtain the threshold value and detect the edges for each band using SMT algorithm.
Step 2. Apply summation rule to combine the detected edges
Step 3. The detected edges are made thin by applying morphological thinning operation.

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C. EDMST Method

All standard single band edge detection operators can be applied only on the gray scale version of multispectral images, which may lead to information loss. Moreover the satellite images may have more spectral band (greater than 3), which cannot be converted into gray scale. Hence in EDMST [4], for each band, after preprocessing using Gaussian filter, the edges have been detected based on segmentation using Otsu threshold, and added to form a single contour image.

Among many threshold selection methods, Otsu's method is optimum, in the sense that, it maximizes the between-class variance, a well-known measure used in statistical discriminant analysis. The basic idea is that well-threshold classes should be distinct with respect to the intensity values of their pixels and, conversely, that a threshold giving the best separation between classes in terms of their intensity values would be the best (optimum) threshold. In addition to its optimality, Otsu's method has the important property that it is based entirely on computations performed on the histogram of an image [15].

EDMST algorithm:

Step 1. For each spectral band,

1.1 Smooth the image with Gaussian filter.

1.2 Compute the normalized histogram for the image. Denote the components of the histogram by p_i, $i = 0, 1, 2,\ldots,L–1$, where L is the maximum intensity in the image.

1.3 Compute the cumulative sums, $P_1(k)$, cumulative means, $m(k)$, global intensity mean, m_G, and the between-class variance, $\sigma^2_B(\kappa)$, for $k = 0, 1, 2,\ldots, L – 1$, as follows.

$$P_1(k) = \sum_{i=0}^{k} p_i \tag{8}$$

$$m(k) = \sum_{i=0}^{k} ip_i \tag{9}$$

$$m_G = \sum_{i=0}^{L-1} ip_i \tag{10}$$

$$and \qquad \sigma_B^2(k) = \frac{[m_G P_1(k) - m(k)]^2}{P_1(k)[1 - P_1(k)]} \tag{11}$$

1.4 Obtain the Otsu threshold, k^*, as the value of k for which $\sigma_B^2(k)$ is maximum. If the maximum is not unique, k^* can be obtained by averaging the values of k corresponding to the various maxima detected.

Step 2. Segment the image in each spectral band using the threshold value identified in Step 1 and detect the edges.

Step 3. The detected edges are combined by image addition and the morphological thinningoperation has been applied to make the edges thin.

D. B^2MST Method

This method is also proposed to improve the performance of EDMST based on bi-level bi-stage concept using Otsu threshold instead of Shannon entropy threshold. After preprocessing the image using Gaussian filter to remove the noise present in the image, the edges have been identified in two stages for each band independently. First, obtain the Otsu threshold value, k, and split the image into two clusters based on k. Next, find the threshold values t_1 and t_2 for the two clusters using the same method. Detect the edges using k, t_1 and t_2 and combine the detected edges in all bands using summation rule.

B^2MST Algorithm:

Step 1. For each spectral band, a gray level image,

1.1 Smooth the image with Gaussian filter.

1.2 Compute the normalized histogram of the image. For each gray level ***i***, the probability distribution, $p_i = f_i / N$, where N is the total number of pixels and f_i is the frequency of i^{th}gray level.

1.3 The cumulative sums, $P_1(\kappa)$, the cumulative means, $m(\kappa)$, the global mean, m_G and the between-class variance, $\sigma^2_B(\kappa)$, for $\kappa = 0, 1, ..., L$-1, where L is the maximum intensity in the image has been calculated using (1), (2), (3) and (4).

1.4 Obtain the Otsu threshold, κ^* by averaging the values of κ corresponding to the various maxima detected in $\sigma^2_B(\kappa)$.

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1.5 Using the threshold κ, the input image has been divided into two classes C_1 and C_2 with intensity values in the range $[0, k]$ and $[k + 1, L - 1]$ respectively.

1.6 In the second stage, repeat the steps 1.3 and 1.4 to calculate new threshold values t_1 and t_2 for the two classes C_1 and C_2.

Step 2. Using the thresholds κ, t_1, and t_2, obtained in step 1, segment the image into regions in each spectral band and detect the edges.

Step 3. The detected edges are combined using summation rule.

Step 4. By applying morphological thinning operation, the edges are made thin.

IV. Result and Discussion

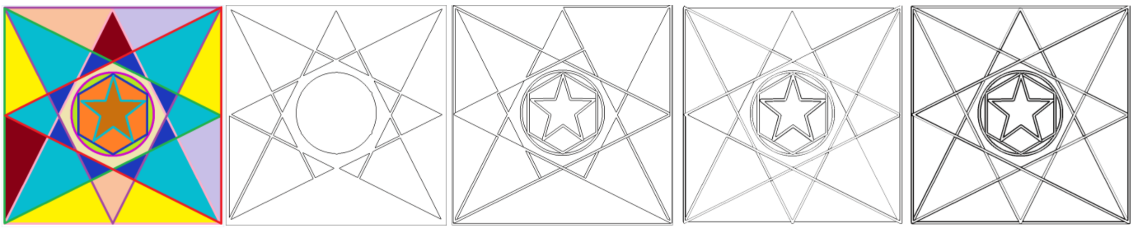
The SM^{2}T and B^{2}MST algorithms have been implemented on numerous simulated, art and natural images and tested with satellite images. Since the edges are well known in advance in the simulated images, they have been used for quantitative performance evaluation. The performance has been observed by using human visual system and by calculating the number of edges and F-measure. The proposed algorithms are compared with EDMST and SMT.

A. Data Sets

In this work, for a test case, own database with 20 simulated images of size 900 x 900 has been created where the true edges are known to lie along a contour. Since the proposed algorithm is mainly based on intensity values, the simulated images have been designed in such a way that it includes all possible color shades. In addition to this, 64 art images from World Wide Web, 200 natural images from Berkeley Segmentation Data set (BSD) and remote sensing satellite images from Google maps have also been considered for this study.

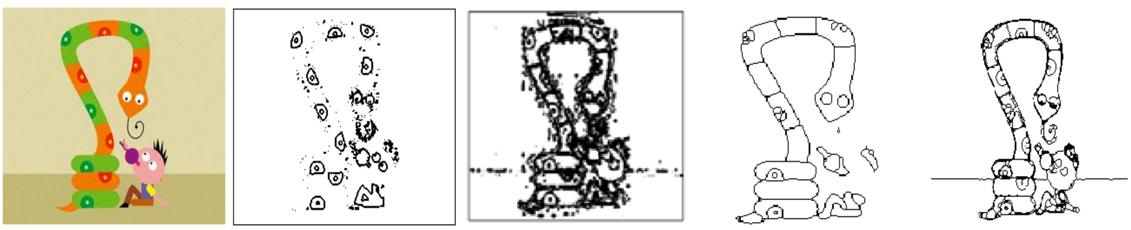
B. Human visual system

This is the most general purpose vision system. The original images and their corresponding edges detected by SMT, SM^{2}T, EDMST and B^{2}MST methods are shown in Fig.1 to Fig.4and also it can be easily seen that the B^{2}MST detects more edges compared to other methods.



a) Original b) SMT c) SM^{2}T d) EDMST e) B^{2}MST

Figure 1: Edge detected in Simulated Image



a) Original b) SMT c) SM^{2}T d) EDMST e) B^{2}MST

Figure 2: Edge detected in Art Image

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C. Number of Edges

The samples used in this work are simulated images since they have well known edges in advance. Manually, the number of edges present in each image has been calculated. The edges detected by an edge detector can be grouped as correct edges (trueedges, TP), false edges (false positive, FP), and missing edges (false negative, FN). In Table I, the results of true edges, false edges and missing edges detected using B^2MST and other methods have been compared with the actual edges computed.

a) Original b) SMT c) SM^2T d) EDMST e) B^2MST

Figure 3: Edge detected in Lenna Image

a) Original b) SMT c) SM^2T d) EDMST e) B^2MST

Figure 4: Edge detected in BSD Image

Table 1. Number of Edges Detected

Input	Original	B^2MST			EDMST			SM^2T			SMT		
		TP	***FN***	***FP***	***TP***	***FN***	***FP***	***TP***	***FN***	***FP***	***TP***	***FN***	***FP***
Image 1	32	31	1	0	26	6	0	31	1	4	18	14	0
Image 2	32	32	0	0	24	8	0	32	0	0	24	8	0
Image 3	11	11	0	0	10	1	0	10	1	0	7	4	0
Image 4	95	95	0	0	87	8	0	94	1	0	59	36	0
Image 5	95	95	0	0	95	0	0	55	40	0	26	69	0
Image 6	68	68	0	0	53	15	0	64	4	0	40	28	0
Image 7	68	64	4	0	41	27	0	48	20	0	26	42	0
Image 8	68	65	3	0	51	17	0	57	11	0	44	24	0
Image 9	40	40	0	4	40	0	0	36	4	0	32	8	0
Image 10	48	48	0	0	43	5	0	47	1	0	40	8	0
Image 11	66	66	0	0	53	13	0	65	1	0	28	38	0
Image 12	48	48	0	0	42	6	0	48	0	0	17	31	0
Image 13	37	32	5	15	32	5	0	29	8	21	9	28	13
image 14	62	62	0	0	62	0	0	62	0	0	24	38	0
Image 15	135	135	0	0	128	7	0	90	45	0	61	74	0
Image 16	135	135	0	0	117	18	0	105	30	0	95	40	0
Image 17	15	13	2	0	12	3	0	12	3	0	12	3	0
Image 18	62	59	3	0	56	6	0	55	7	0	40	22	0
Image 19	62	61	1	0	54	8	0	46	16	0	34	28	0
Image 20	110	110	0	0	97	13	0	97	13	0	62	48	0
Total	1289	1270	19	19	1123	166	0	1083	206	25	698	591	13

TP → True Edges FN → missing edges FT → False edges

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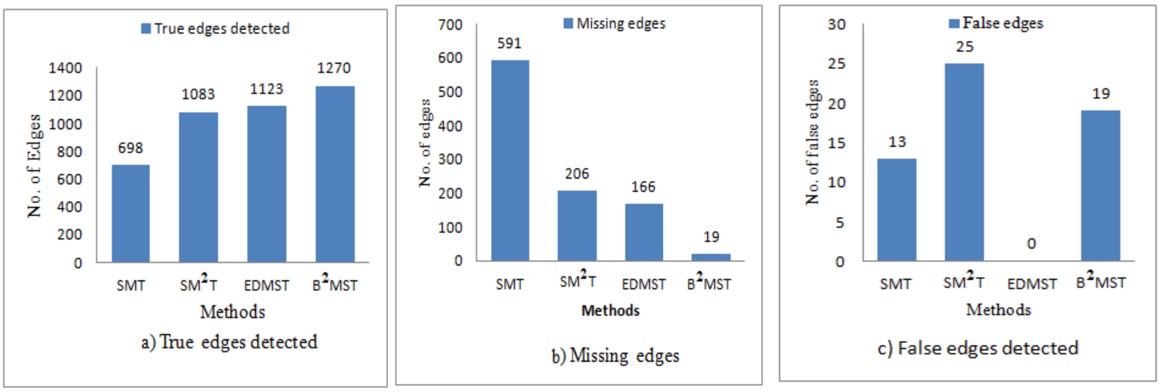
Table 1 shows that, the true edges detected by the proposed approaches, B^2MST and SM^2T are composed of increased number of pixels as compared with the existing methods, EDMST and SMT. It also observed that out of twenty images, even though the proposed method SM^2T detects more edges than SMT, which is less compared with EDMST. But B^2MST detects all the edges in most of the images and maximum edges in the remaining images. So, the missing edges are also less in B^2MST compared to other methods. While considering the false edges B^2MST detects less number of false edges than SM^2T method. This means that, in case of images with lot of details (such as satellite images) the B^2MST delivers a good result, even more detailed result than other edge detection methods.

Table 2 presents the total number of true edges detected in the samples and their percentage. From Table 2, it can be identified that SM^2T gives better result than SMT that means it detects 29.87% of more edges than SMT. The difference between EDMST and SM^2T is only 3.1% and between B^2MST and EDMST is about 11.41%.

Table 2. Detected True Edges in Percentage

Methods	No. of Edges detected out of 1289 edges	No. of Edges in %
B^2MST	1270	98.53
EDMST	1123	87.12
SM^2T	1083	84.02
SMT	698	54.15

The graphical representation of true edges, missing edges and false edges detected are shown in Figure 5. From the Figure5.a and 5.b, it is easily observed that SM^2T is an improved version of SMT and B^2MST is an improved version of EDMST. Out of 1289 edges, B^2MST detects highest number of true edges and minimum number of missing edges than any other methods. Except EDMST, all the methods produce false edges. Compared with SM^2T, B^2MST detect less number of false edges. This has to be reduced in future.



a) True edges detected

b) Missing edges

c) False edges detected

Figure 5: Graphical representation of True edges, Missing edges and False edges.

D. F-measure

The edges detected by an edge detector include the true edges, false edges, and missing edges and the misclassification errors in edge detection are false and missing edges. In a classification task, the **precision** for a class is the number of true edges divided by the total number of edges detected (that is sum of true edges and false edges) and **recall** is the number of true edges divided by the total number of edges present (that is sum of true edges and missing edges). The *F*-measure is the harmonic mean of precision and recall.

$$F = 2 * \frac{Precision * Recall}{Precision + Recall} \tag{12}$$

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Table 3. Overall Comparison between Different Edge Detectors

Method	True edges detected	Missing edges	False edges	Precision	Recall	F-measure (in %)
B^2MST	1270	19	19	0.9853	0.9853	98.53
EDMST	1123	166	0	1	0.8712	93.12
SM^2T	1083	206	25	0.9774	0.8402	90.36
SMT	698	591	13	0.9817	0.5415	69.8

The overall comparison between different edge detection techniques are shown in the Table 3 and its comparison chart is given in Figure. 6. From the figure, it has been concluded that B^2MST gives better performance than other methods.

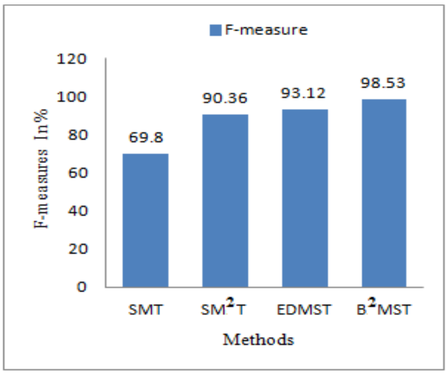
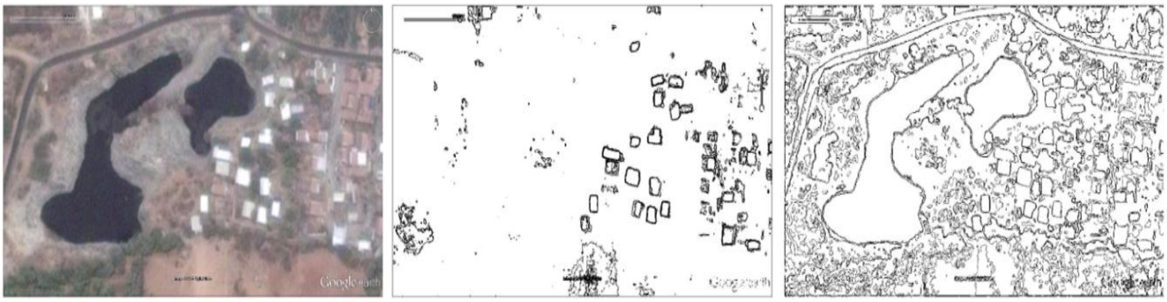


Figure 6: Over all comparison chart

E. Satellite Images

Different types of objects identification on the earth surface is an important feature in remote sensing application. Satellite imagery has been offered by Google Maps, a desktop as well as mobile and smartphone web mapping service, developed by Google. Most of the high-resolution imagery of cities is aerial photography taken from aircraft, while other from satellites. Satellite images are of high resolution and contain a lot of information with multiple bands. Edge detection is the initial step in edge enhancement which is a simple and effective means for increasing geometric details in a satellite image [16].

Since the proposed B^2MST method has stronger edge detection capability and identifies more complete edges than the other methods, it is applied for Google Map images. The sample images, covers the area in and around Erode District, and their edges detected by B^2MST and SM^2T are given in Figure. 7. This shows the B^2MST produces better result; moreover, it detects the edges of natural objects (water body) as well as man-made objects(building). The detected edges are composed of an increased number of pixels, preserving salient information in a better way than the existing image processing techniques.



a) Image 1 b) SM^2T c) B^2MST

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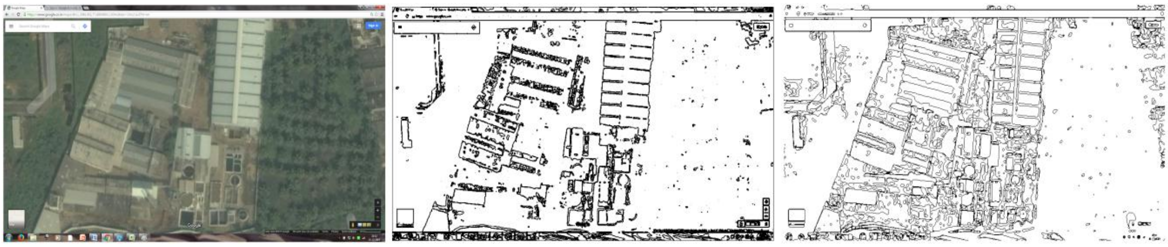
d) Image 2 e) SM^2T f) B^2MST

g) Image 3 h) SM^2T i) B^2MST



j) Image 4 k) SM^2T l) B^2MST

m) Image 5 n) SM^2T o) B^2MST

p) Image 6 q) SM^2T r) B^2MST

Figure 7: Google Map Images

V. CONCLUSION

In this paper, two efficient algorithms, SM^2T and B^2MST, the improved version of SMT and EDMST, are proposed to detect the edges for multispectral images. For each band, the Bi-level Bi-stage concept has been used to detect the edges based on Shannon entropy threshold valueand the outcomes are summed up to get the final result in SM^2T algorithm. This gives better result than SMT but less compared to EDMST. But in B^2MST, the same concept has been applied with Otsu technique, instead of Shannon entropy, to calculate the threshold value, which gives better result than all other methods. The proposed algorithms are tested with simulated, art, and natural imagesand also applied on the Satellite images. Experimental results prove that the proposed B^2MST algorithm is efficient in extracting 98.53% of actual edges. In satellite images, due to the existence of many objects with different shapes and sizes, the proposed algorithm can be extended in future to identify the objects using texture features and also to reduce the false edges.

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