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EDGE DETECTION USING MULTISPECTRAL THRESHOLDING

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Abstract
Edge detection is a fundamental tool in image processing and computer vision, particularly in the areas of feature detection and extraction. Among various edge detection methods, Otsu method is one of the best optimal thresholding methods for general real world images with regard to uniformity and shape measures. In this paper, a multispectral thresholding algorithm using Otsu method is proposed to detect the edges in multispectral images. Natural, art and simulated images are considered for testing. Since the edges are well known in the simulated images, they are considered for performance evaluation. The results of proposed method, Edge Detection using MultiSpectral Thresholding (EDMST), are compared against the results of Canny Otsu, Improved Otsu, Median based Otsu and Improved Gray Image Otsu edge detection algorithms based on the human visual system, the number of edges and the number of pixels. The experimental results show that the proposed method achieves better performance and hence applied on Satellite images.

Keywords:
Edge Detection, Multispectral Thresholding, Otsu Method, Satellite Images, EDMST

1. INTRODUCTION

Edge pixels are pixels at which the intensity of an image function changes abruptly, and the edges are sets of connected edge pixels. Edge detectors are local image processing methods designed to detect edge pixels [1]. Edge detection is one of the most commonly used operations, and there are probably more algorithms in the literature for enhancing and detecting edges due to the fact that the edges form the outline of an object, which is subject of interest in image analysis and vision systems. An edge is the boundary between an object and the background, and also between overlapping objects. Hence if the edges in an image can be identified accurately, all the objects can be located and basic properties such as area, perimeter, and shape can also be measured. Since computer vision involves the identification and classification of objects in an image, edge detection is an essential tool [2].

From an information theory perspective, even though as edge pixels typically constitute less than 5% of the total pixels, they are very rich in information. In this context, edge detection can be viewed as an information filter that greatly reduces the number of pixels that have to be considered with little impact on the information content [3].

Many of researchers have keenly studied the performance of different edge detection techniques and analysed them. Thresholding is one of the simplest and most commonly used techniques to separate the foreground from its background. Among many threshold selection methods, Otsu 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 method has the important property that it is based entirely on computations performed on the histogram of an image, an easily obtainable 1-D array [1]. Several successful thresholding methods based on histogram techniques have been proposed. In all the cases, the input image must be in gray scale. The satellite images have multiple bands and each one have specific information. When the multi spectral images are converted into gray scale, some information may be lost. To avoid the loss of information, a novel algorithm EDMST is proposed based on the concept of multispectral thresholding using Otsu method. This algorithm is tested with natural, art and simulated images. For performance evaluation, the simulated images are used due to the fact that the edges are well-known in advance. Experimental results show that the proposed algorithm is efficient and generate more number of edges.

The rest of the paper is organized as follows: section 2 deals with the related work on edge detection. Section 3 describes the methodology. Results and the experimental analysis are presented in section 4. Finally, section 5 concludes the paper.

2. RELATED WORK

Contours of images or, edges provide valuable information towards human image understanding. Edge detection process is the most important image processing step in human visual system. Naturally, it has become a serious challenge to the image processing scientists, and since the last two decades, in particular, numerous methodologies have been proposed for edge detection [4].

It is universally acknowledged that the Otsu method, proposed in 1979, is the best method of choosing threshold value automatically. Its basic principle is to split the pixels of the gray image into two classes, and confirms the best threshold value through the maximum variance between the two classes [5].

In Otsu based segmentation for Thermal image, the RGB image has been converted into gray scale by using the Eq.(1),

$$R' = G' = B' = \frac{R+G+B}{3} = 0.333R + 0.333G + 0.333B \quad (1)$$

and it has been converted into thresholding image by Otsu method [6].

The Canny detector (Canny [1986]) is the most powerful edge detector, in which the local gradient and edge direction are computed at each point in the smooth Gaussian filtered image.

Locally maximum strengthen point in the direction of the gradient is considered as edge point and are linked by double thresholding and connectivity analysis, set by the user. Otsu method has been applied to choose the threshold value, k^*, automatically by considering the standard deviation, $\sigma = 2$, $Th_2 = k^*$, and $Th_1 = 0.5 * Th_2$ as three parameters to obtain the contour [5]. Otsu method has been applied on the basic global thresholding image in an improved medical image segmentation algorithm. The computational time and separability factors were calculated on medical MRI and CT-Scan images [7].

In the original Otsu algorithm, n_i denote the number of pixels with intensity i in L distinct intensity level {0, 1, 2,...,L-1} of $M\times N$ pixel size digital image. The normalized histogram components p_i has been calculated as,

$$p_i = \frac{n_i}{MN} \tag{2}$$

where, $MN = n_0 + n_1 + n_2 + \ldots + n_{L-1}$, $p_i \geq 0$

$$\sum_{i=0}^{L-1} p_i = 1$$

Select the threshold value, $T(k) = k$, $0 < k < L-1$, and use it to split the image into two classes, C_1 and C_2, with intensity values in the range [0,k] and [k+1, L-1]. The between-class variance σ_B^2 of C_1 and C_2 has been calculated based on the cumulative sums, the mean intensity values and the global mean. But in improved median based Otsu image thresholding, median gray level values are used instead of mean values to calculate the between-class variance [8].

Shannon entropy and Tsallis entropy has been used as global and local threshold values to segment the image and apply the 3×3 mask to detect the edges [9].

Fuzzy relative pixel value algorithm has also been used to detect an edge from the satellite image, in which a set of fuzzy conditions were used to highlight all the edges that are associated with an image and tested the relative values of pixels which is present on an edge [10].

The ultrasound image edges have been detected in [11] by using the combination of Bilateral Filter, Otsu Threshold and Gabor Filter. In general, the quality of ultrasound images has been corrupted due to the existence of speckle noise. After this noise has been suppressed by applying bilateral filter, Otsu threshold is used to segment the image and the edges have been detected by Gabor filter. Conventional edge detection methods have also been used to detect the edges on the image before and after segmentation and the results were compared.

Using the concept of Genetic algorithm, the edge detection method with optimal threshold value, over the gray scale image, has been proposed in [12]. The input image has been divided into m segments based on Otsu multilevel threshold. The fitness function, which is the ratio between the class variance and total class variance of gray levels for the whole image, has been calculated. The Genetic algorithm has been introduced to maximize the fitness function for optimal threshold value.

Based on between class variance the Synthetic Aperture Radar (SAR) images have been segmented in [13]. Otsu method and the techniques that related to it, such as valley emphasis technique, neighborhood valley emphasis technique, variance and intensity contrast technique and variance discrepancy technique have been compared and identified that for smallest region uniformity, Otsu is the best method.

In [14], the optimal number of level for different thresholds has been automatically identified. The author has constrained the searching space in the valleys of the histogram instead of entire histogram of the image. The valleys are selected by removing monotonically increasing area, monotonically decreasing area, local peaks and invariant area, from the histogram. For each valley, the neighborhood gray value, cumulative sums, cumulative means, global means and the corresponding between-class variances have been calculated and from those values, the optimal number of levels and their corresponding thresholds has been obtained. Based on these results the gray images have been segmented and the edges are identified.

The characters in the number plate, present in any image have been recognized in [15]. An adaptive threshold based global binarization and locally applied Otsu binarization was combined to extract the number plate from the gray scale image. Then the characters have been segmented by projection profile technique and were recognized using Support Vector Machine.

From the study, it has been observed that most of the edge detection algorithms convert the color image into gray scale image before processing, which may lead to information loss. Moreover, remote sensing or meteorological satellite images may have more spectral band, which cannot be converted into gray scale. Hence the EDMST method has been proposed to overcome this problem.

3. METHODOLOGY

A multispectral image is a collection of several monochrome images of the same scene, each of them taken with a different sensor. Each monochrome image is referred as a band. In image processing, multispectral images are most commonly used in Remote Sensing applications. Satellites usually take several images from frequency bands in the visual and non-visual range. All the standard single band edge detection operators can also be applied to multispectral images by processing each band separately. The simplest way to find the edges in a multispectral image is to obtain a threshold independently in each band, detect the edges and combine them to form a single contour image.

3.1. EDMST ALGORITHM

Step 1: For each spectral band,

a. Smooth the image with a Gaussian filter.
b. Compute the normalized histogram of the image using Eq.(2).
c. The cumulative sums, $P_1(k)$, $P_2(k)$, the cumulative means, $m_1(k)$, $m_2(k)$, the global mean, m_G and the between-class variance, $\sigma_B^2(k)$, has been calculated as follows, for $k = 0,1, \ldots, L-1$.

$$p_1(k) = \sum_{i=0}^{k} p_i \tag{3}$$

$$p_2(k) = \sum_{i=k+1}^{L-1} p_i \tag{4}$$

$$m_1(k) = \frac{1}{P_1(k)} \sum_{i=0}^{k} ip_i \qquad (5)$$

$$m_2(k) = \frac{1}{P_2(k)} \sum_{i=k+1}^{L-1} ip_i \qquad (6)$$

$$m_G = \sum_{i=0}^{L-1} ip_i \qquad (7)$$

and

$$\sigma_B^2(k) = P_1(k)\left(m_1(k) - m_G\right)^2 + P_2(k)\left(m_2(k) - m_G\right)^2 \qquad (8)$$

d. Obtain the Otsu threshold, k^* by averaging the values of k corresponding to the various maxima detected in $\sigma_B^2(k)$.

Step 2: Using the thresholds obtained in step 1, segment the region in each spectral band and detect the edges.

Step 3: The detected edges are combined by image addition.

Step 4: The edges are made thin by applying the morphological operation.

4. RESULTS AND DISCUSSION

The EDMST algorithm for color image has been implemented and tested with numerous natural, art and simulated images. A simulated image is useful because the number of edges is well known in advance and can therefore be used to evaluate quantitative performance. Thus to validate the performance of the proposed algorithm, a sample of twenty simulated images of size 900×900 are considered. The original images and their corresponding edges of proposed EDMST and other methods are shown in Fig.1, Fig.2 and Fig.3.

4.1. THE PERFORMANCE EVALUATION

To evaluate the performance of the proposed edge detector, three approaches has been used. One is the human visual system because this is the most general purpose vision system. From Fig.1, Fig.2 and Fig.3, it can be easily seen that the proposed method detect more edges than the other methods.

Other performance measures are based on number of edges and number of pixels. The samples used in this work are simulated one. Since the edges are well known in advance, total number of edges present in each image has been calculated manually. The results of contours which has been detected using the proposed EDMST method, Canny Otsu [5], Improved Gray with Otsu [6], Improved Otsu [7] and Median based Otsu [8] are compared with the actual edges computed. The original edges and the edges detected in the proposed and other methods are listed in the Table.1.


(a) Original


(b) EDMST


(c) Canny Otsu


(d) Improved Gray


(e) Improved Otsu

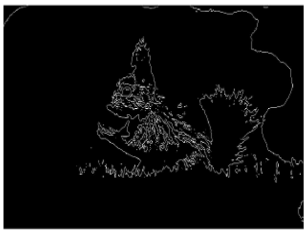
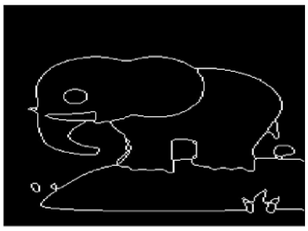
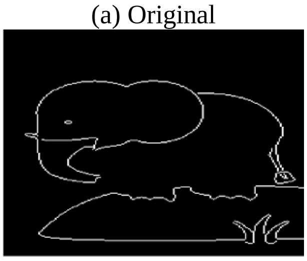
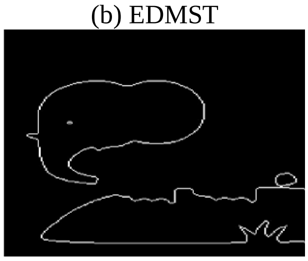

(f) Median Otsu

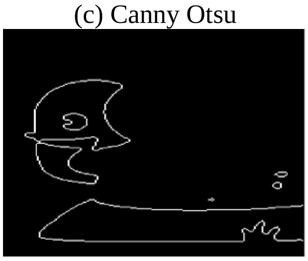
Fig.1. Output of Natural Image


(a) Original


(b) EDMST


(c) Canny Otsu


(d) Improved Gray


(e) Improved Otsu

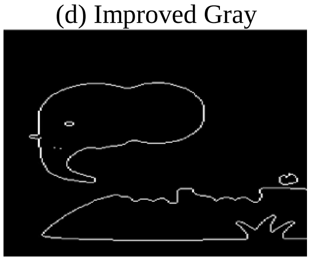
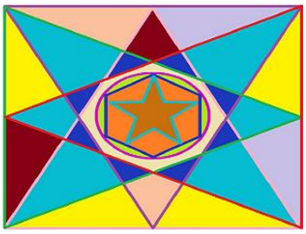
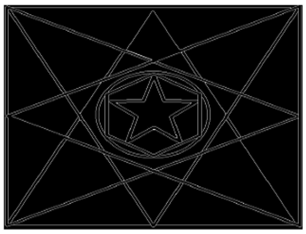
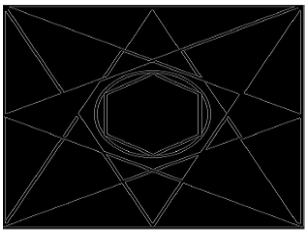

(f) Median Otsu

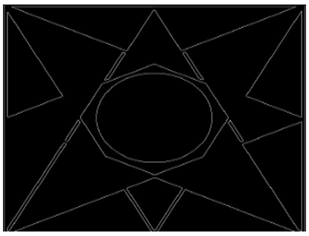
Fig.2. Output of Art Image


(a) Original

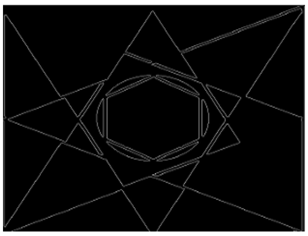

(b) EDMST



(c) Canny Otsu



(d) Improved Gray



(e) Improved Otsu

(f) Median Otsu

Fig.3. Output of Simulated Image

From the Table.1, it is observed that out of twenty images the proposed method detect maximum edges in sixteen images (80 %). In the samples, all the edges are detected in Image5 (95 edges), Image9 (40 edges) and Image14 (62 edges), and in total 85.5% edges are detected in the proposed method.

Table.1. Number of Edges Detected

Input	Original	EDMST	Canny Otsu	Improved Gray with Otsu	Improved Otsu	Median based Otsu
Image 1	32	26	19	13	13	3
Image 2	32	24	32	16	8	8
Image 3	11	10	7	3	5	1
Image 4	95	87	73	95	95	95
Image 5	95	95	95	95	37	29
Image 6	68	53	22	26	35	34
Image 7	68	41	47	36	20	27
Image 8	68	51	33	40	24	32
Image 9	40	40	28	32	16	16
Image 10	48	43	45	8	9	8
Image 11	66	53	35	30	31	10
Image 12	48	42	33	26	12	4
Image 13	61	32	30	27	16	0
image 14	62	62	62	55	40	40
Image 15	135	128	91	48	71	0
Image 16	135	117	111	99	71	6
Image 17	15	12	8	7	3	2
Image 18	62	56	48	24	14	6
Image 19	62	54	48	33	31	3
Image 20	110	97	81	55	46	16
Total	1313	1123	948	768	597	340

Table.2 shows that out of twenty sample images the proposed algorithm detect more number of pixels which are true positive in fifteen images. There is only less than 0.05% difference in the number of pixels obtained in the remaining five images.

Table.2. Number of Pixels Detected

Input	EDMST	Canny Otsu	Improved Gray with Otsu	Improved Otsu	Median based Otsu
Image1	5473	4033	2770	2651	664
Image2	8462	10108	3628	2930	2926
Image3	10831	5245	3164	3962	2114
Image4	6112	5541	6516	6581	6697
Image5	6678	6551	6534	2900	1363
Image6	7803	3361	3961	4939	5248
Image7	6082	6593	5465	2565	3236
Image8	8329	4982	5718	3043	4997
Image9	7920	5743	6065	2558	2558
image10	9273	9301	3052	3136	3060
Image11	9923	8030	7479	7160	2970
Image12	10356	7162	6301	4317	2968
Image13	5640	4864	3845	1549	0
Image14	10850	11432	9312	7967	7994
Image15	20220	15982	11001	12384	0
Image16	19089	17806	16548	13834	2376
Image17	9584	6384	5586	2394	1596
Image18	11136	9037	5234	3364	1636
Image19	12051	10423	7471	8403	1420
Image20	12529	9463	8414	5379	2975
Total	198341	162041	128064	102016	56798

The total number of edges and the total number of pixels present in the samples and their percentage (%) have been tabulated in Table.3 and the corresponding graphical representations are given in Fig 4 and in Fig 5.

Table.3. Detected Edges and Pixels in Percentage

Methods	No. of Edges out of 1313 edges		No. of Pixels out of 16,200,000 pixels	
	Edges obtained	No. of Edges in %	Pixels obtained	No. of Pixels in %
EDMST	1123	85.53	198341	1.22
Canny Otsu	948	72.2	162041	1.0
Improved Gray with Otsu	768	58.49	128064	0.79
Improved Otsu	597	45.47	102016	0.63
Median based Otsu	340	25.89	56798	0.35

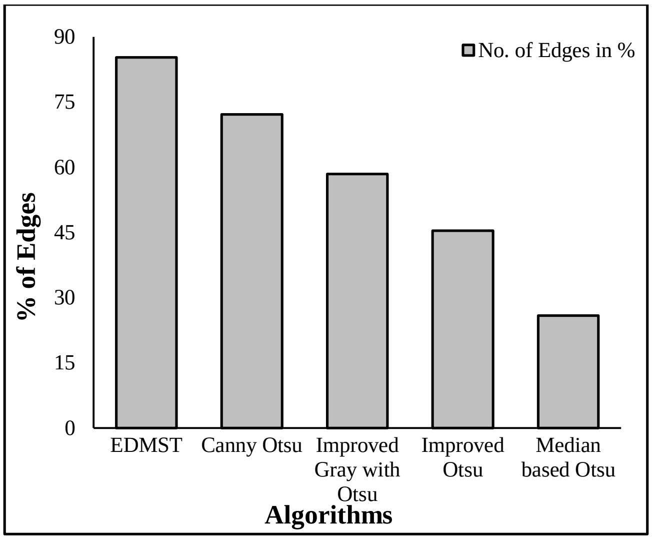


Fig.4. Graphical representation of detected edges in %

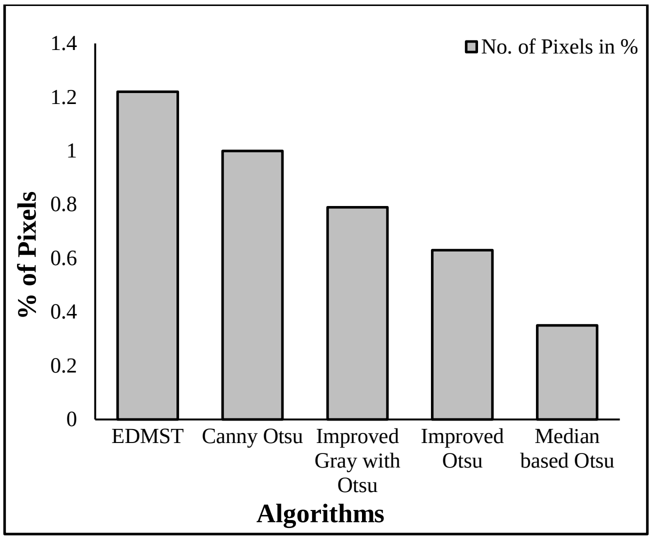


Fig.5. Graphical representation of detected pixels in %

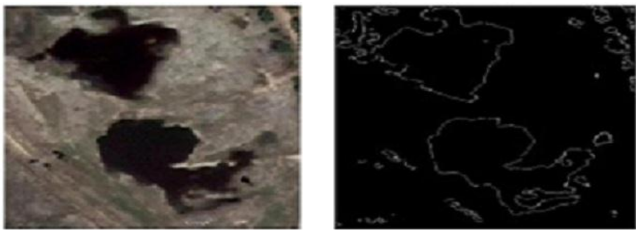
The edges detected by an edge detector can be grouped as correct edges (true edges), which correspond to edges in the scene, false edges (false positive), which do not correspond to edges in the scene, and missing edges (false negative), that should have been detected in the scene. False edges and the missing edges are of misclassification errors in edge detection [16]. Performance of the proposed method has been presented in Table.4. In simulated images, the proposed algorithm detects nearly 85% of true edges and remaining as missing edges. The false edges have not been identified.

Table.4. Performance of EDMST

Total no. of edges	True edges	False negative edges	False positive edges
1313	1123 (85.5 %)	190 (14.5 %)	0

4.2. SATELLITE IMAGES

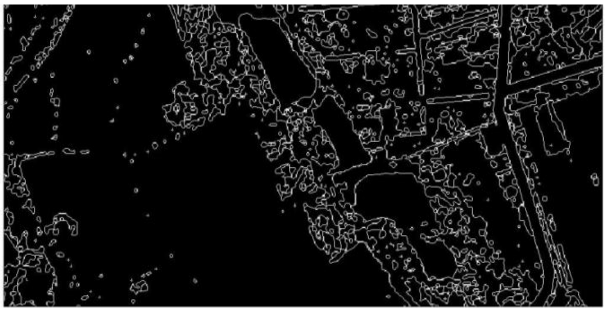
From the results, it can be easily seen that the proposed EDMST has stronger edge detection capability and identify more complete edges. Hence the proposed EDMST is applied for Google Map images. The Fig.6 and Fig.7 shows the result obtained.



(a) (b)

Fig.6. Google Map Image captured on 26, June 2014
(a) Original Image (b) Image Obtained using EDMST Algorithm

(a) Original Image



(b) Image Obtained using EDMST Algorithm

Fig.7. Google Map Image captured on 24, December 2015

5. CONCLUSION

In this paper an efficient algorithm is proposed to detect the edges for multispectral images. The Otsu method is used to calculate the threshold value. The proposed algorithm is tested with natural, art and simulated images, compared with existing algorithms and applied on satellite images. Experimental results prove that the proposed algorithm is efficient and improve the effect of edge extraction. All the methods are purely based on intensity values. Due to noise and interference, the discontinuity in intensity leads to false edges. From the study it is identified that if the variation in the intensity is less, then there is a chance for false edges. In future, the proposed algorithm can be modified to consider this intensity variation also.

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