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An Improved Method for Image Segmentation Based on Mathematical Morphology and Mean Value of K-Mean Clusters

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Abstract
A mathematical morphology based study on image segmentation has been carried out to find the edge maps of two real life images. The study relates with a series of process steps involving gradient image formulation, morphological smoothing operation on the images, marker application, watershed transformation, K-means clustering and merging by taking arithmetic, geometric and harmonic mean values of the pixel intensities of each cluster. The edge map obtained through the geometric mean value of the intensity of the pixel lying in the clusters has been found to yield the most suitable result for human visualization. In the comparative study with respect to the earlier works, it also produces better figure of merits in terms of Pratt figure of merit and edge detection error rate when the same images are acquired in noisy environment.

Keywords: Image segmentation, Mathematical morphology, Edge detection, K-means clustering.

Introduction

Digital image can be segmented broadly in three ways, viz. edge based, region based and mathematical morphology based. Out of these, any combination of these above methods can also be utilized. Watershed transformation has occupied a prominent place in morphology based segmentation [1-4]. In watershed transform any gray level image is considered as a topographic surface which can be either flooded from the upper side or the surface can be filled up from a constant speed of supply of water from the bottom side. In both the cases the topographic space can be differentiated in three zones; regional minima, catchment basins, and upper most ridges (watersheds) [5-6]. The lowermost position of the topographic space where the water drops rest is called the regional minima. The minimum allowable level of rise of water is termed as catchment basin and when the flooding occurs from various subspaces the watershed merges but for certain thin regions (one pixel thick) are called the watershed ridges. The edges technically means the space on the image where the intensity or color level changes drastically and edge map of these edges may take the shape of point, line or straight line or any line of arbitrary shape and direction. The basis of obtaining the edge map is the difference of intensity (DOI) in the image plane. In the image plane some certain portion may have pixel having nearly equal intensity and they may form some clustering around any pixel and K-means clustering method is very popular among these [7-9] due to its well established efficacy.

In the present study watershed transform, regional margining and edge detection are combined. In general, digital images have large number of variations in intensity levels and direct application of watershed transform over raw images may lead to over-segmentation [10-11]. To avoid these some preprocessing is done with the help of morphological smoothing operation on gradient images. In some cases markers are used to limit the over-segmentation [12-14]. The segmented clusters are merged by taking the different types of mean values like, arithmetic mean, geometric mean and harmonic mean and consequently edge intensity, and edge maps are obtained. Out of these three mean values, geometric mean is found to give the most suitable result from the human visual perception as the same can as an edge detector to some extent.

The effectiveness of proposed algorithm in noisy environment was measured in terms of Pratt figure of it (PFOM) and edge detection error rate (EDER) [15]. It has been found that geometric value based calculation has produced the highest PFOM and the least EDER whereas those obtained using arithmetic mean value of the cluster pixels yield the least PFOM and highest EDER. This fact establishes that proposed algorithm can act a good scheme for edge detection.

K- means clustering

For solving the clustering problem, the K-means is one of the most admired and simplest algorithm in recent days. K-means is a simple algorithm that has been adapted to many problem domains like fuzzy feature vectors. Different steps of the algorithm are:

1. Place K points into the space represented by the objects that are being clustered. These points represent initial group centroids.
2. Assign each object to the group that has the closest centroid.
3. When all objects have been assigned, recalculate the positions of the K centroids.

4. Repeat Steps 2 and 3 until the centroids no longer move. This produces a separation of the objects into groups from which the metric to be minimized can be calculated.
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K-means clustering can be defined by the following equation.

$$J = \sum_{j=1}^{k}\sum_{i=1}^{n} ||x_1^j - c_j||^2 \quad (1)$$

Where, $||x_1^j - c_j||^2$ is a chosen distance measure between a data point x_1^j and the cluster centre c_j, is an indicator of the distance of the n data points from their respective cluster centres.

Gradient calculation

Image gradients can be used to extract information from images like size, shape, texture, edge etc. Edges in digital images are areas with strong intensity contrasts and a jump in intensity from one pixel to the next can create major variation in the picture quality. With the help of first- and second- order derivatives such discontinuities are detected. The first- order derivative of choice in image processing is the gradient. The gradient of a 2-D function, $f(x, y)$, is defined as the vector

$$\nabla f = \begin{bmatrix} g_x \\ g_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix} \quad (2)$$

The magnitude of this vector is

$$\nabla f = mag(\nabla f = [g_x^2 + g_y^2]^{\frac{1}{2}} = \left[\left(\partial f/\partial x\right)^2 + \left(\partial f/\partial y\right)^2\right]^{\frac{1}{2}} \quad (3)$$

This quantity is approximated sometimes by omitting the square root operation,

$$\nabla f \approx g_x^2 + g_y^2 \quad (4)$$

Or by using absolute values,

$$\nabla f \approx |g_x^2| + |g_y^2| \quad (5)$$

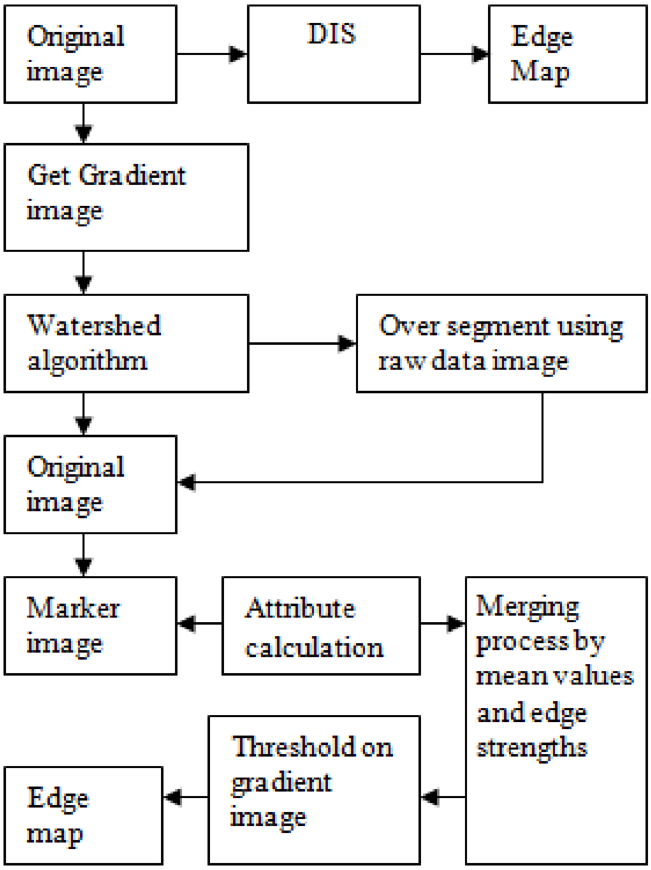

Fig. 1. Flowchart of process steps.

Flowchart and description of process steps

Fig. 2.a. Original image of mountain of 490x415 dimensions.

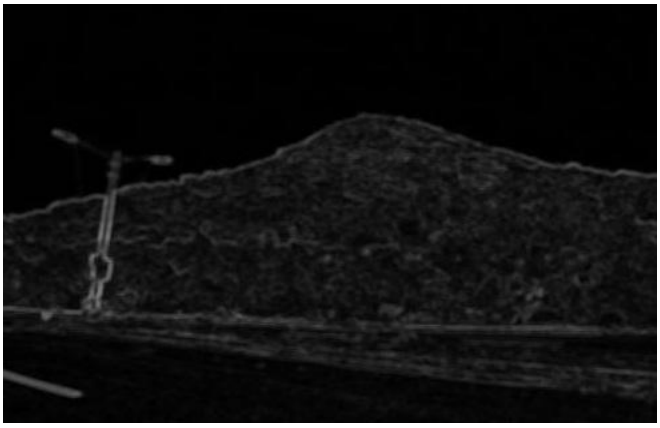

Fig. 2.b. Based on arithmetic mean.

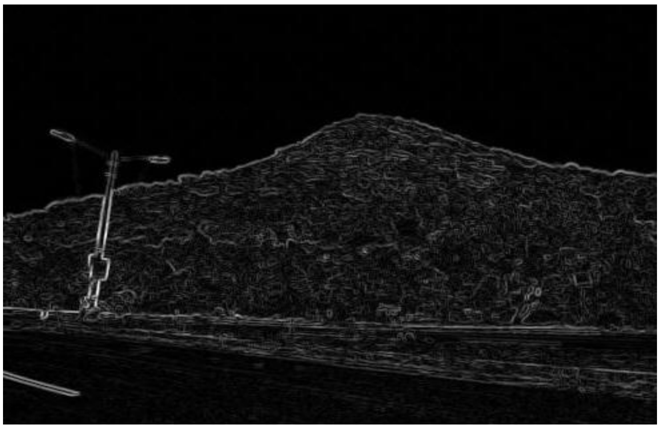

Fig. 2.c. Based on geometric mean.

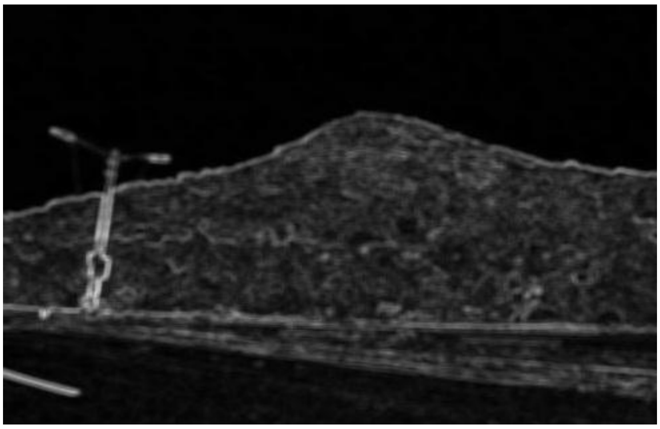

Fig. 2.d. Based on harmonic mean.

Fig. 3.a. Original image beach of 490x450 dimensions.

Fig. 3.b. Based on arithmetic mean.

Fig. 3. c. Based on geometric mean.

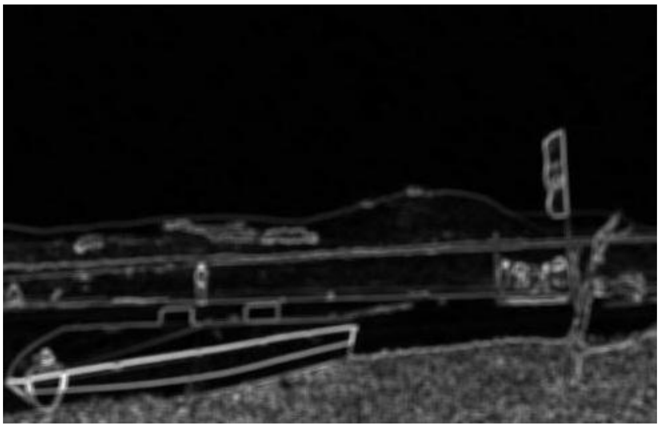

Fig. 3. d. Based on harmonic mean.

Table. 1. Statistical measurements with mean values.

IMAGE	Meanvalues taken	ENTROPY	PSNR	MSE (db)
Mountain	Geometric	4.3422	8.9308	4.4563
	Arithmetic	4.4234	8.7282	4.4322
	Harmonic	.4.4617	8.7014	4.4057
Beach	Geometric	3.4356	10.9306	5.4483
	Arithmetic	3.5185	10.7297	5.4169
	Harmonic	.3.5516	10.7001	5.4059

Two real life images of 490x315 and 490x450 dimensions have been chosen for the experimental purpose. Gradient images are generated from the original images. Watershed algorithm is directly applied on it and over-segmented images are obtained. To reduce the over-segmentation, either morphological smoothing can be done or marker process can be applied on original images. Then the segmented images are obtained with limited number of segmentations. K-means clustering is carried out on segmented portions and merging is done by taking mean value of the pixels. Three types of mean values have been considered namely arithmetic, geometric and harmonic are taken over the intensity of the pixels within each segment. Sobel edge detector is applied on each image to obtain the edge. Gradient images are obtained and threshold operation is carried out on each image and edge maps are obtained. It has been found from the present study that the edge map obtained through arithmetic mean during clustering and merging is found to yield more thin and sharp. It has been found that the edge maps obtained through the arithmetic mean value during clustering and merging operation produces broad edge with less sharp intensity and this holds good for database images as well as real life images. It has been further observed from experiment that the edge maps found through the geometric mean value during the clustering process on the segmented images have thin and sharp edge with prominent intensity. The same type of mean values ware considered and harmonic mean values of the pixel intensities in the sequential regions were calculated during clustering and merging process; it has been found that the edge maps are brooder and blurred compared to those obtained by the mean process. Thus it can be inferred that the geometric value during the clustering and merging process is most suitable to visualize at least by the human visual system.

The proposed algorithm is very much effective in noisy environment and accordingly it has been deliberate in terms of Pratt figure of it (PFOM) and edge detection error rate (EDER). The geometric value based calculation has produced the highest PFOM and the least EDER in respective of those obtained using arithmetic mean value of the cluster pixels which yield the least PFOM and highest EDER. This actuality confirms that the proposed algorithm can produce a good method for edge detection. The two graphs of PFOM and EDER has been shown in below in figures 4.a and 4.b respectively. The green, blue, violate and red color lines represent canny, log, sobel and proposed algorithm respectively.

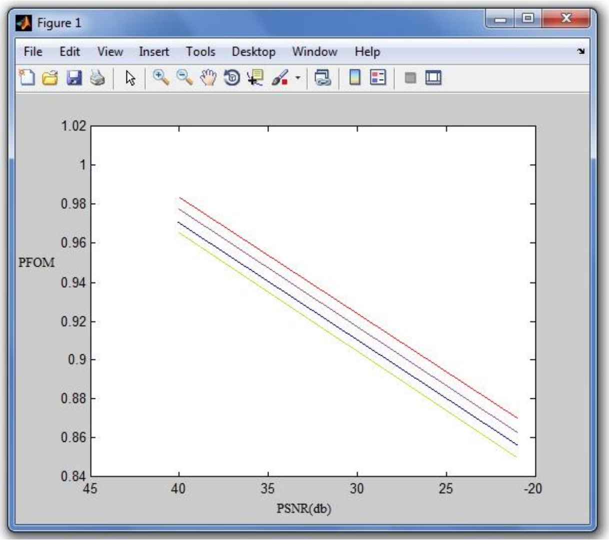

Fig. 4.a. Based on PFOM and PSNR.

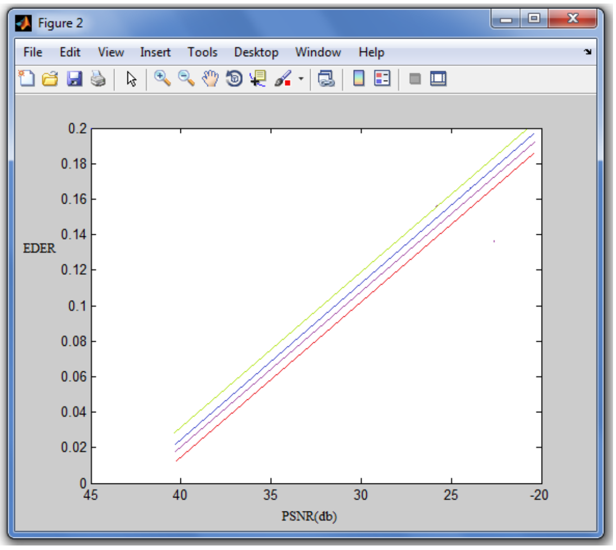

Fig. 4.b. Based on EDER and PSNR.

Conclusion

Two real life images have been considered for having edge map. The process involves gradient image acquisition, use of internal and external markers, watershed transformation followed by clustering and merging process by taking arithmetic, geometric and harmonic mean values of the pixel intensities in each segment. Sobel edge detector mask has been used for getting the gradient of the images at the penultimate stage and finally it was passed through a threshold operation to get the edge map. The final results show that the edge map obtained through geometric mean value yields the most suitable result for human visualization.

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