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A Study of Impact of the various Averages on the Thresholding of Standard Images

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Abstract: ***For extraction of features and recognition of pattern, one of the most important step is image segmentation. This paper enumerates and reviews the basic image thresholding algorithms and finally discusses the future prospects of these algorithms. The basic algorithm for the thresholding i.e. the global thresholding algorithm is modified by using various first order statistical parameters and result are compared. Some valuable characteristics of the image segmentation comes out after a large number of comparative experiments.***
Keywords: Image segmentation, thresholding techniques, mean, median, geometric mean, harmonic mean, mode, global thresholding.

I. INTRODUCTION

Image segmentation is a fundamental problem in computer vision. Despite many years of research, general purpose image segmentation is still a very challenging task because segmentation is inherently ill- posed. It refers to partitioning an image into several subsets corresponds to a meaningful part of the image.In many applications of image processing, the gray levels of pixels belonging to the object are different from the gray levels of the pixels belonging to the background, thresholding then become a simple but effective tool to separate objects from the background. Image Segmentation algorithms are defined on the basis of one of the two properties intensity values discontinuity and similarity. First, is to partition an image based on abrupt changes in intensity, such as edges in an image. Second category is based on partitioning an image into regions that are similar according to predefined criteria. Separation of objects or image regions is usually required for high level image comprehension in practical applications involving visual inspection. Thresholding based on a feature distribution is widely used to segment the desired image into several image regions because of the simplicity and ability of real time implementations

In general, Image Segmentation algorithm is based upon two basic principles, the trait of pixels and information in the nearby regions. Most of the segmentation algorithms are based upon two characters of pixels gray level: discontinuity around edges and similarity in the same region. Various kinds of thresholding techniques have been proposed over the years, most of which require optimization of a criterion function. Thresholding for image segmentation is usually performed based on the information contained in the gray level histogram of a given image. By finding the valley in the histogram, we can segment a given image into object and background. However, it is really difficult to search for the maximum and minimum gray value, because gray- histogram is uneven for the impact of the noise.[1]. In this paper, firstly, main segmentation algorithms are classified and reviewed: then new algorithm based upon the various statistical measures is developed and evaluation results of proposed segmentation algorithms in MATLAB environment on the various standard images are summarized and compared with the existing algorithms. The threshold value is computed for each of the algorithms on various images. Lastly, the future scope of the segmentation techniques is discussed

II. EXISTING SEGMENTATION TECHNIQUES

Image segmentation is the foundation of object recognition and computer vision. In general, image noise should be eliminated through image preprocessing. And there is some specifically given work to do after the main operation of image segmentation for the sake of getting better visual effect [2]. Image segmentation is the technology and the process that we split the image into various regions of different characteristic and extract interested objects. Although there have been many segmentation algorithms, most of the algorithms have been classified into the segmentation method based on regions and the segmentation and the method based on the border. The segmentation method based on the region, depends on space local features of the image such as gray, texture and the uniformity characteristic of pixels statistics. The segmentation based upon region are thresholding, region growing, region split and merge algorithms and many new algorithms can be developed by combining the given methods. Because these methods depend directly on the gray level images so they are not sensitive to noise. But the flaw with this technique is that it leads to over segmentation of the image and the results depend upon the choice of the segmentation algorithm chosen and the seed point used for segmentation.

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III. THRESHOLDING METHODS

Thresholding techniques are image segmentation based on image-space regions. The simplest property which a pixel in an image shares is intensity. So a natural way to segment such regions is through thresholding, the separation of light and dark regions. Separation of foreground from the background in a document image is commonly referred to as thresholding. Thresholding creates binary image from gray level ones by turning all the pixels below some threshold to zero and all the pixels above that threshold to one.When there is only one single threshold T, any point (x,y) for which f(x,y) >T called an object point; and a point (x,y) is called a background point if f(x,y) < T. According to the aforementioned discussion, thresholding can be viewed as an operation to gain threshold T in the following equation:

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

In this equation, T stands for the threshold ; f(x,y) is the gray value of the point (x,y) and p(x,y) denotes some local property of the point – such as the average gray level value of the neighbor centered at the point (x,y). Based on the equation (1) the thresholding techniques can be classified as automatic, histogram based, hysteresis, P-tile, optimal ,Otsu's, local, global, variable thresholding.

A. Automatic Thresholding

To make the segmentation more robust, the threshold should be automatically selected by the system. This involves knowledge about object, application, size of the object, intensity characteristic of the objects and number of different types of objects appearing in an image .However, this technique can't be used in practical situations.[3]

B. Histogram Based Thresholding

The quality of edge detection depends greatly on the fitness of threshold T. However, it is really difficult to search for the maximum and minimum gray level value, because gray-histogram is uneven for the impact of noise. In this case, we can approximately substitute the curves of object and background with two conic Gaussian curves, whose intersection is the valley of histogram. Threshold T is the gray value of the point at that valley[4].

Parametric and non- parametric approaches have been used to locate the bottom of valley of the histogram. In parametric approach, a model is assumed to have the probability density function of the gray level distribution of each group, which is assumed to be Gaussian. One then attempts to find estimates of the parameters of the distribution using the given histogram.

In non parametric approach, we are interested in separating two grey level distributions in an optimum manner according to a criterion, such as within class variance, between class variance, total variance, or entropy.

C. Hysteresis Thresholding

The output of non local maxima contains noisy local maxima. The contrasts may be different in different points of contour and hence careful thresholding is required in order to remove these weak edges while preserving the connectivity of the contours.[5] Hysteresis is used as a means of eliminating streaking. Streaking is the breaking up of an edge contour caused by the operator output fluctuating above and below the threshold.[6].The algorithm for hysteresis thresholding is as follows. Take into account neighbors

Choose tow thresholds T_{low} and T_{high}

1) If $T > T_{high}$ the pixel is in the body.
2) If $T < T_{low}$ the pixel is in the background.
3) If $T_{low} < T < T_{high}$ the pixel is in the body only if a neighbor is already in the body.
4) Iterate

D. P-tile Method thresholding

The P-tile is a method for choosing the threshold value to input the basic thresholding algorithm. P tile means "Percentile" and the threshold is chosen to be intensity value where the cumulative sum of the pixel intensities is closet to the percentile. The p-tile method uses prior knowledge about the image and require the knowledge about the area or size of the objects in the image. Assuming that we have dark objects against a gray background and objects occupy p% of the image area then an appropriate threshold can be chosen by partioning the histogram.

E. Optimal Thresholding

Optimal thresholding selects a threshold value that is statistically optimal , based on the contents of the image. Given a multimodal histogram, h(x) of an image, where x represents the brightness value then optimal threshold is the value which is used for separating the modes.[7] A standard technique for finding the best threshold for that image is to fit the histogram with the sum of d probability density functions (pdfs). If the pdfs are the Gaussian the model has following form

$$h(x) = \sum_{i=1}^{d} \frac{Pi}{\sqrt{2\pi\sigma_i}} \exp\left(- \frac{\sqrt{(x - \mu i)}^2}{\sigma_i^2} \right) \quad (2)$$

Here, Pi represents a priori probability, μi is the mean and σ_i^2 is the variance of the mode i. For d = 2, the optimal threshold is fount by minimizing the overall probability of error:

$$E(T) = P_2 \int_{-\infty}^{T} p_2(x)dx + P_1 \int_{T}^{\infty} p_1(x)dx \quad (3)$$

With respect to threshold T, where pi(x) is the pdf. A problem that must be solved before finding the optimal threshold is that of fitting a pdf model to the histogram data. A maximum likelihood or mean square error should be used[8].

F. Otsu's Thresholding

Otsu's thresholding technique is based on discriminant analysis which partions the image into two classes Co and C1 at the gray level t such that Co ={1,2,…..,t} and C1 = {t+1,t+2……, L-1} where L is the total number of grey levels in the image. Let the number of grey level pixels in the ith grey level be ni and n be the total number of pixels in a given image[9]. The probability of occurrence of the grey level i is defined as: Pi = ni/n;

Co and C1 are normally corresponding to the objects of interest and the background, the probabilities of two classes' w0 and w1

$$w_0 = \sum_{i=0}^{1} p_i \quad (4)$$

$$w_1 = \sum_{i=t+1}^{L-1} p_i \quad (5)$$

By computing the mean and the between class variance and total variance , an optimal threshold can be computed [10] Otsu's method of thresholding grey level images is efficient for separating an image into two classes where two types of fairly distinct classes exist in the image. Otsu's thresholding method was one of the better threshold selection method for general real world images with regard to uniformity and shape measures. However, Otsu's method uses an exhaustive search to evaluate the criteria for maximizing the between class variances of the image. As the number in classes for an image increases, Otsu's method takes too much time to be practical for the multilevel threshold selection[5].

G. Global Thresholding

In global thresholding the threshold is calculated and applied to all pixels of the image. Most of these methods uses statistical classifiers such as Bayes classifier or maximum likelihood moment preservation, signal processing (maximization of entropy of the image, minimization of variance between the object and the background), Hadamard transform and multi scale histogram separation[11].

H. Local Thresholding

Local thresholding methods uses different thresholds according to the region under consideration. However they often relies on the size parameter which may change for different images or for different locations inside the same image providing in some cases too noisy results[12].

I. Graph Based Segmentation Techniques

In graph based segmentation techniques, the image is represented by graph G(V,E) , where V={v1, v2,……….vn} is the set of vertices corresponding to the image elements , which might represent pixel or regions in the Euclidean space. E is a set of edges connecting certain pairs of neighboring pixels. Each edge has a corresponding weight $w(v_i, v_j)$ which means $(v_i, v_j) \in E$ uses a certain quantity based on the property between the two vertices connected by that edge. For image segmentation , an image is portioned into mutually exclusive components, such that each component A is a connected graph $G'(V', E')$ where $V' \subseteq V$, $E' \subseteq E$ and E' contains only edges built from nodes of V'. This segmentation criterion requires that image elements in each component should have uniform and homogeneous properties in the form of brightness, color or texture and elements in different components be dissimilar.

J. K Means Clustering Algorithm

K mean clustering algorithm is used to cluster pixels into different groups with each group identifying a region. In most cases, an image is first partitioned into blocks of size 4 X 4 pixels. Color or texture feature are extracted for each block. Then, k mean clustering algorithm is applied to cluster the block feature vector into several classes with each class corresponding to one region. Blocks in same class is classified into same region. A so called KMCC (k-mean with connectivity constraint) is used to segment objects from images. It is extended from the k means algorithm. In this algorithm, the spatial proximity of each region is taken into account by defining a new center for the k- means algorithm and by integrating the k means with a component labeling procedure.

IV. VARIANTS OF BASIC GLOBAL THRESHOLDING

In global thresholding we select an initial estimate for threshold and then we segment the image using T which produces two groups of pixels. The average intensity values for the pixels in two regions are computed and the new threshold is computed by finding the average and the above steps are repeated till the difference in T in successive iterations is smaller than predefined parameter. In the step where average intensity for the pixels in two regions are computed, the various other parameters such as mode, mean, median, harmonic mean and geometric mean can be used .Based on these parameters the basic global thresholding produces different values for the threshold. The various parameters used have their own significance in the thresholding algorithm. A mode is elaborated as the average found by determining the most frequent values in a group of values. In context of images, the grey level value which is being repeated maximum number of times will be the mode.[13]. If a 3 X 3 image is given with the values 13,13,13,14,14,16,18,21 then the mode will be 13 as it is the value which is being repeated maximum number of times .Median defines an average found by arranging the given numbers in order and then selecting the one in the middle. In the given image median will be 14 as it is the fifth value in the list.

If we consider f(x,y) as a two dimensional image of size m x n , then the geometric mean of the image denoted by GM is given by

$$GM(f(x,y)) = \left(\prod_{x=0}^{m-1} \prod_{y=0}^{n-1} f(x,y) \right) \exp(1/mn) \qquad (6)$$

Harmonic mean is a number associated with a set of numbers that is equal to the number of numbers divided by the sum of the reciprocals of the numbers. The harmonic mean of a two dimensional image f(x,y) of size m x n is given by

$$H(f(x,y)) = \frac{m\ n}{\sum_{x=0}^{m-1} \sum_{y=0}^{n-1} f(x,y)} \qquad (7)$$

Mean is the most commonly used measure of central tendency. When we talk about an average we usually are referring to the mean, The mean is simply the sum of the values divided by the total number of items in the set. The mean for the image f(x,y) of size m x n is represented mathematically as

$$M_{mean} = \frac{1}{mn} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} f(x,y) \qquad (8)$$

Median is the most powerful order statistic filter in image processing and it represents the 50th percentile of the ranked set of numbers. The median for the image f(x,y) of size m x n is represented mathematically as

$$M_{ed} = \mathrm{mid}\{f(x,y) \mid x = 0,1,2,......m-1, \\ y = 0,1,....n-1\} \qquad (9)$$

From the basic statistics the various variants of the median can be used. For example, the 100th percentile results in the so- called max filter, which is useful for finding the brightest point in the image and similarly the 0th percentile represents the min filter [11]. Mode parameter returns from the sample data set $[a_1, a_2....a_n]$ the value which occurs most frequently. Mode can be represented as

$$M_{mod} = \max\{(\mathrm{freq}(f(x,y)) \mid x = 0,1,2,......m-1, \\ y = 0,1,2,..n-1\} \qquad (10)$$

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V. RESULT AND DISCUSSION

In this paper the various variant of the basic global thresholding algorithm were evaluated. M-files were created in MATLAB 7.0 and the resultant images were evaluated. The results were compared visually and the corresponding threshold values were computed. Harmonic mean is the minimum of all the used first order statistical parameters and when the harmonic mean was used and the threshold corresponding to all the standard images were minimum and the visual details resulted were also not satisfactory. So it is recommended not to use harmonic mean in any image containing any amount of details. Geometric mean is the next parameter which gives the second least value for the threshold after harmonic mean, but the results are better than the harmonic mean. It is recommended not to go for arithmetic mean for any type of images. When mean is used as a parameter in the basic global thresholding it gives the threshold value which is less than the appropriate threshold value and hence it lends to the missing of the various pixels which should have been the part of the segmented image. Mode can be replaced by the mean parameter in the basic thresholding algorithm but it computes a threshold value which is more than the appropriate threshold value which lends to capturing many of the false pixels in the final segmented image. Finally the first order statistic parameter which gives the threshold value i.e. which doesn't leads to the missing of the true edge pixels or capturing of the false edge pixels is the median. Median always select an threshold value which is intermediate between the mode and mean and it gives the best result as compared with the other parameters.

Statistical Parameters	Mathematical Representation	Pepper gray	Lena	Cameraman	House	Walk bridge
Mode	$M_{mod} = max\{(freq(f(x,y)) \mid x = 0,1,2,......m-1, y = 0,1,2,..n-1\}$	0.5549	0.4000	0.3333	0.6020	0.4235
Mean	$M_{mean} = \frac{1}{mn}\sum_{x=0}^{m-1}\sum_{y=0}^{n-1} f(x,y)$	0.4584	0.4803	0.4258	0.5693	0.4978
HM	$\frac{mn}{\sum_{x=0}^{m-1}\sum_{y=0}^{n-1} f(x,y)}$	0.2553	0.4495	0.2854	0.2630	0.2570
GM	$\left(\prod_{x=0}^{m-1}\prod_{y=0}^{n-1} f(x,y)\right)\exp(1/mn)$	0.2675	0.4654	0.2912	0.2934	0.2700
Median	$M_{ed} = mid\{f(x,y) \mid x = 0,1,2,......m-1, y = 0,1,....n-1\}$	0.4784	0.4686	0.3373	0.6000	0.4902

Table I Values Of Various Global Thresholding Variant On Various Standard Images

VI. CONCLUSION AND PROSPECTS

In this paper, we classify and discuss main image segmentation algorithms; introduce the evaluation of image segmentation systemically, evaluate and compare basic, practical segmentation algorithms after a large number of comparative experiments. Although there are myriad of segmentation algorithms designed day in and out , none of them applies to all types of applications. There are many factors such as homogeneity of images, spatial structure character of the image, continuity, texture, image content and so on. An appropriate thresholding algorithm is one which give good results for all types of image applications. Based on these statements, we can foresee the trend of image segmentation as follows:

1) *The Application Of Artificial Intelligence [14]:* Nowadays, although there are many existing image segmentation algorithms, almost each of them aims at a specific single application and only uses a fraction of image information, which limits their use to a great extent. This problem can be solved by using artificial intelligence.
2) *Dynamic Thresholding [15]:* Use of static thresholding in an image can be improved if instead of predefined computed value of threshold we use a dynamic threshold value.

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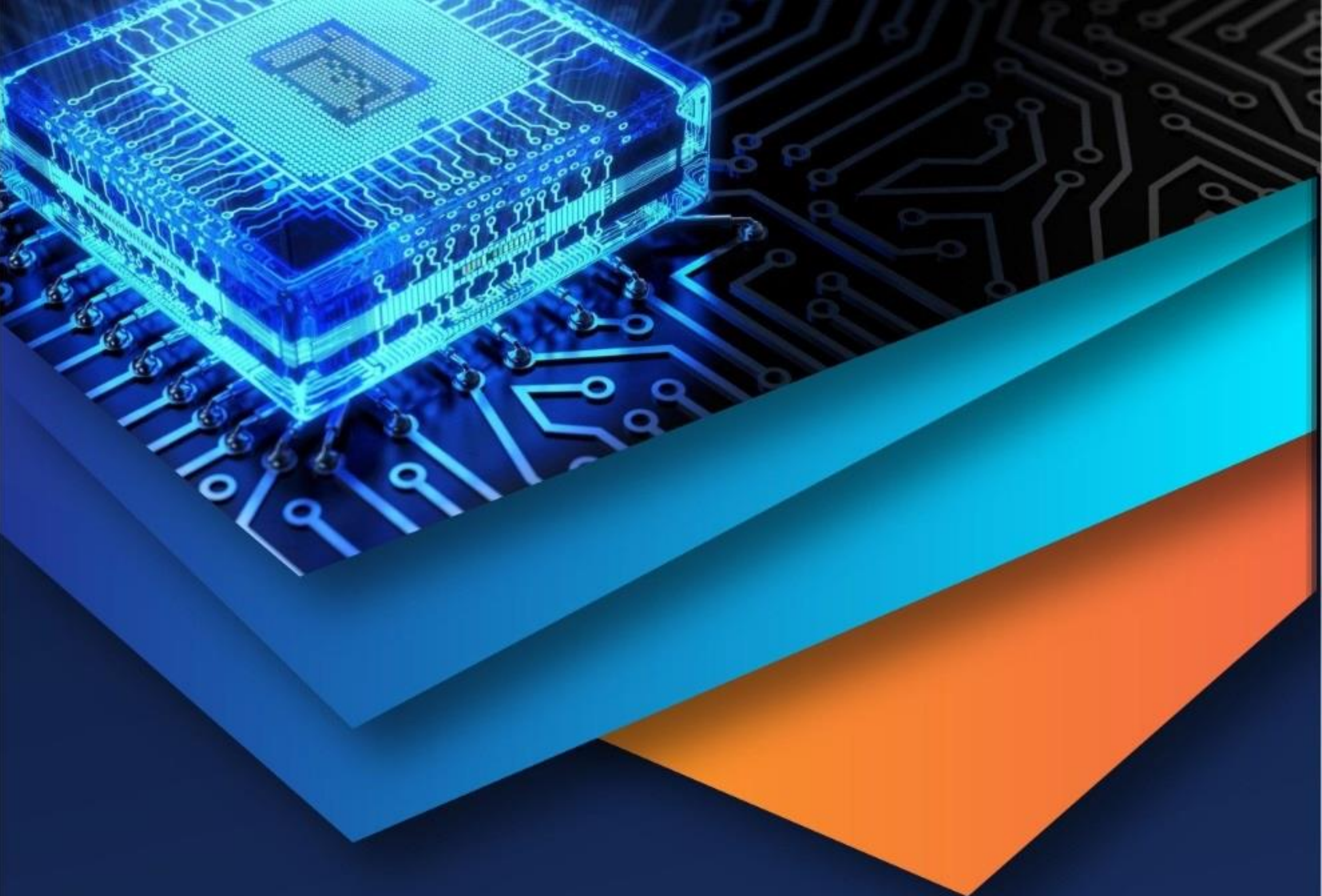

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