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A Review of Image Thresholding Techniques

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Abstract*— In this study we have conducted an exhaustive survey of image thresholding methods with a view to categorize them, express them under a uniform notation, indicate their differences or similarities, and finally as a basis for performance comparison. Threshold is one of the widely methods used for image segmentation. It is useful in discriminating foreground from the background. By selecting an adequate threshold value T, the gray level image can be converted to binary image.

Keywords*— Segmentation, binary, thresholding, survey, gray.

I. INTRODUCTION

In many applications of image processing, the gray levels of pixels belonging to the object are quite different from the gray levels of the pixels belonging to the background. Thresholding becomes then a simple but effective tool to separate objects from the background. Examples of thresholding applications are document image analysis where the goal is to extract printed characters , logos, graphical content, musical scores, map processing where lines, legends, characters are to be found, scene processing where a target is to detected , quality inspection of materials. Other applications include cell images and knowledge representation, segmentation of various image modalities for non-destructive testing (NDT) applications, such as ultrasonic images in, eddy current images, thermal images; X-ray computed tomography (CAT), laser scanning confocal microscopy, extraction of edge field, image segmentation in general, spatio-temporal segmentation of video images etc.

The output of the thresholding operation is a binary image whose gray level of 0 (black) will indicate a pixel belonging to a print, legend, drawing, or target and a gray level of 1 (white) will indicate the background.

The main difficulties associated with thresholding such as in documents or NDT applications occur when the associated noise process is non-stationary, correlated and non-Gaussian. Other factors complicating thresholding operation are ambient illumination, variance of gray levels within the object and the background, inadequate contrast, object shape and size non-commensurate with the scene. Finally the lack of objective measures to assess the performance of thresholding algorithms is another handicap.

II. THRESHOLDING TECHNIQUES

Threshold technique is one of the important techniques in image segmentation. This technique can be expressed as:

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

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

$$g(x,y)=\begin{cases} 1 & if \quad f(x,y) > T \\ 0 & if \quad f(x,y) \le T \end{cases} \qquad (2)$$

Thresholding techniques are classified as bellow,

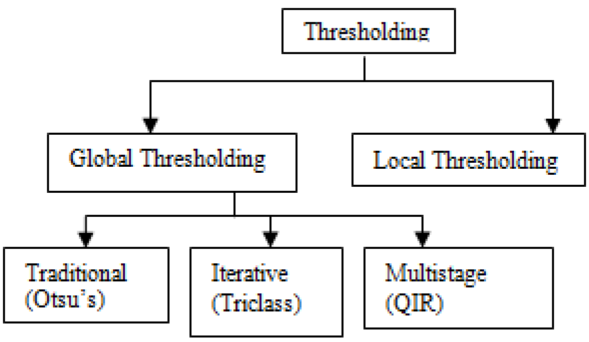

Fig.1 Thresholding Technique

III. GLOBAL THRESHOLDING

Global (single) thresholding method is used when there the intensity distribution between the objects of foreground and background are very distinct. When the differences between foreground and background objects are very distinct, a single value of threshold can simply be used to differentiate both objects apart. Thus, in this type of thresholding, the value of threshold T depends solely on the property of the pixel and the grey level value of the image. Some most common used global thresholding methods are Otsu method, entropy based thresholding, etc

A. Traditional Thresholding(Otsu's Method)

In image processing, segmentation is often the first step to pre-process images to extract objects of interest for further analysis. Segmentation techniques can be generally categorized into two frameworks, edge-based and region based approaches. As a segmentation technique, Otsu's method is widely used in pattern recognition, document binarization, and computer vision. In many cases Otsu's method is used as a pre-processing technique to segment an image for further processing such as feature analysis and quantification. Otsu's method searches for a threshold that minimizes the intra-class variances of the segmented image and can achieve good results when the histogram of the original image has two distinct peaks, one belongs to the background, and the other belongs to the foreground or the signal. The Otsu's threshold is found by searching across the whole range of the pixel values of the image until the intra-class variances reach their minimum. As it is defined, the threshold determined by Otsu's method is more profoundly determined by the class that has the larger variance, be it the background or the foreground. As such, Otsu's method may create suboptimal results when the histogram of the image has more than two peaks or if one of the classes has a large variance.

Fig. 8(a) shows a raw image of a zebra fish embryo. Because zebrafish embryos are transparent we can directly observe many anatomic structures without fixing and staining. For example the spinal cord of the embryo is visible in Fig. 8(a). The segmentation result of Otsu's method is shown in Fig. 8(b). Though the standard Otsu's method can segment the major structure of the embryo it misses detailed anatomic structure such as the spinal cord.

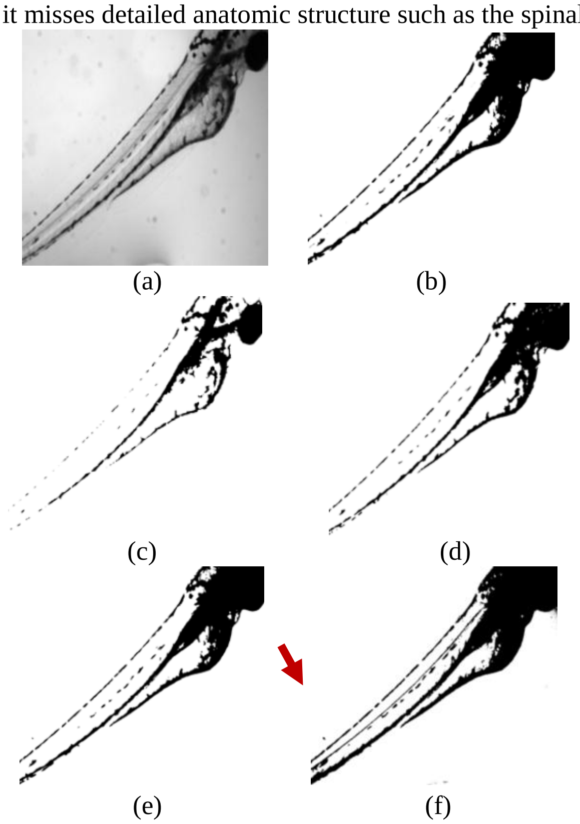

Fig.2: Experiments on a zebra fish microscopic image. (a) A raw zebra fish embryo image acquired by a bright-field microscope. Its spinal cord is pointed by the arrow. (b) The result given by Otsu's method. (c)– (f) The results created by the proposed method on iteration one to four, respectively. In the final result, the spinal cord of the zebra fish embryo, pointed by the red arrow, is fully segmented by our method.

B. Iterative Thresholding(A New Iterative Triclass Thresholding Technique)

A new iterative method that is based on Otsu's method but differs from the standard application of the method in an important way. At the first iteration, we apply Otsu's method on an image to obtain the Otsu's threshold and the means of two classes separated by the threshold as the standard application does. Then, instead of classifying the image into two classes separated by the Otsu's threshold, our method separates the image into three classes based on the two class means derived. The three classes are defined as the foreground with pixel values are greater than the larger mean, the background with pixel values are less than the smaller mean, and more importantly, a third class we call the "to-be-determined" (TBD) region with pixel values fall between the two class means. Then at the next iteration, the method keeps the previous foreground and background regions unchanged and re-applies Otsu's method on the TBD region only to, again, separate it into three classes in the similar manner. When the iteration stops after meeting a preset criterion, the last TBD region is then separated into two classes, foreground and background, instead of three regions. The final foreground is the logical union of all the previously determined foreground regions and the final background is determined similarly. The new method is almost parameter free except for the stopping rule for the iterative process and has minimal added computational load. We tested the new iterative method on synthetic and real images and found that it can achieve superior performance in segmenting images such as zebra fish and nuclei images acquired by microscopes.

Results show that the new method can segment weak objects or fine structures that are typically missed by the standard Otsu's method.

For comparison, Fig. 2(c)–(f) shows the results generated b the new method at iteration one to four, respectively. We can observe that some detailed structures are gradually

segmented. In particularly, the new algorithm is able to accurately segment the spinal cord (pointed by the arrow) at iteration four, as shown in Fig. 2(f).

C. Multistage Thresholding(Quadratic Ratio Technique For Handwritten Character)

The QIR technique was found superior in thresholding handwriting images where the following tight requirements need to be met:

1. all the details of the handwriting are to be retained
2. the papers used may contain strong coloured or patterned background
3. the handwriting may be written by a wide variety of writing media such as a fountain pen, ballpoint pen, or pencil.

QIR is a global two stage thresholding technique. The first stage of the algorithm divides an image into three sub images: foreground, background, and a fuzzy sub image where it is hard to determine whether a pixel actually belongs to the foreground or the background (Figure 5). Two important parameters that separate the sub images are *A*, which separates the foreground and the fuzzy sub image, and *C*, which separate the fuzzy and the background sub image. If a pixel's intensity is less than or equal to *A*, the pixel belongs to the foreground. If a pixel's intensity is greater than or equal to *C*, the pixel belongs to the background. If a pixel has an intensity value between A and C, it belongs to the fuzzy sub image and more information is needed from the image to decide whether it actually belongs to the foreground or the background.

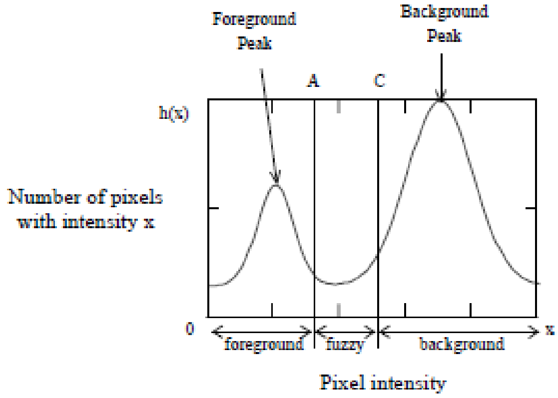

Fig.2:Three subimages of QIR technique

IV. LOCAL THRESHOLDING

A threshold $T(x,y)$ is a value such that

$$b(x,y) = \begin{cases} 0 & \text{if } I(x,y) \leq T(x,y) \\ 1 & \text{otherwise} \end{cases}$$

Where b(x,y) is the binarized image and I(x,y)∈[0,1] be the intensity of a pixel at location (x,y) of the image I. In local adaptive technique, a threshold is calculated for each pixel, based on some local statistics such as range, variance, or surface-fitting parameters of the neighborhood pixels. It can be approached in different ways such as background subtraction, water flow model, means and standard derivation of pixel values, and local image contrast. Some drawbacks of the local thresholding techniques are region size dependant, individual image characteristics, and time consuming. Therefore, some researchers use a hybrid approach that applies both global and local thresholding methods and some use morphological operators. Niblack, and Sauvola and Pietaksinen use the local variance technique while Bernsen uses midrange value within the local block.[1]

V. CONCLUSIONS

We have conducted a thorough survey of thresholding algorithms. To understand parallelisms and complementarities between the various methods we have found it convenient to categorize them into two main classes on the basis of information they are exploiting. This review forms the basis for several studies, as for example their performance assessment in different tasks.

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