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A Survey on Image Segmentation Techniques in Digital Image Processing

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Abstract: *Image segmentation is an approach to partition an image into useful parts that are in our interest and these parts are known as segments. Mathematically, this image is known as set while the segments are called subsets of this set. Therefore, image segmentation follows all the rules of set theory. These subsets or segments give us an idea to understand the image in more understandable form. For higher-level feature extraction, the image segmentation process is fundamental and this process depends upon the features of an image such as point, line, edge and region. Image segmentation is a very important process, but difficult process because the accuracy of image segmentation defines success or failure of the computerized analysis procedure of an image. Some of the approaches to divide an image into corresponding partitions are edge detection, threshold and region based methods.*

Keywords: *Image, Intensity, Gray level, Segmentation, Pixels*

1. INTRODUCTION

Image segmentation is an important technique that is used in digital image processing to observe an object in a digital image. Images are an important medium for conveying an information. We can analysis these images and retrieve the information that can be used for many operations. A digital image is composed of a finite number of elements or pixels and the acquisition these pixels to form the digital images is called as imaging. These images are divided into partitions with the purpose of accessing the important segment into it.

Image segmentation is a technique that can determine the parts of images, these parts are called subsets were the whole image is a set. These subsets provide us information about the image that is, which subset is to operate and which isn't? From these subsets, we can take the specific subset under which our object falls and operate on that. Image segmentation is also defined as a process that divides the image into a number of homogenous parts, that are adjacent to each other, in other words we can say that their neighbors of each other. If R represents the entire spatial region occupied by image and R_1, R_2, R_3, …, R_n are n number of sub regions of the image called as partitions.

Then, (a) $\bigcup_{i=1}^{n} R\,i = R$ (b) R_i is connected set, i=1,2,3,…,n (c) $R_i \cap R_j = \emptyset$ for all i and j, i ≠ j.

2. DIFFERENT TECHNIQUES OF SEGMENTATION

Images are the source to provide information visually and this information can be easily understood and remembered by a person for a long time, may for lifetime. However, when we analysis an images we work on its specific area. This area should be highlighted from the rest. The process called as image segmentation does this. Therefore, image segmentation is a technique that divides an image into useful subsets called segments. The image segments are formed on the base of pixel properties like pixel intensity, color, sharpness or brightness of an image. There are a number of techniques that can govern this rule of segmentation. Image segmentation approach is mainly obeyed in the field of medical science. They use this form of technique into an analysis of diseases like detection of brain tumor, liver cancer, bone fracture and in bone marrow diseases.

We can divide an image into two parts, namely: background and foreground. The foreground of an image is an object that we can take in our experimental use and the background as the rest remain of an image. The basis two categories of image segmentation are:

2.1 Discontinuity based segmentation and
2.2 Similarities based segmentation.

These segmentation techniques can further subdivide into various categories. So these sub categories can be shown in Fig.1 as follows:

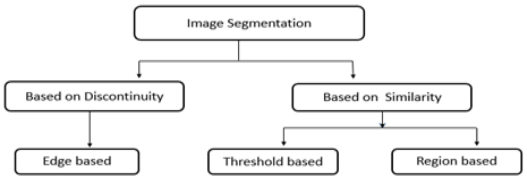


Fig.1 Classification of segmentation

2.1 Discontinuity based segmentation

The discontinuity based segmentation technique is a process in which an operation is taken on the basis of intensity change in grey level of an image. The discontinuity based algorithms work on first and second order derivatives. Usually we use first order derivative, as second order

derivatives are noise sensitive. The change in the first order derivative shows edge detection in an image. While the constant value shows no change, meaning no edge detection. This technique is further subdivided into a method called as edge detection. The edge detection is done on intensity change in grey level, that is, its use first order derivative to detect an edge.

Before discussing edge detection let us first clear what is point and line detection in discontinuities based segmentation

2.1.1 Point detection

Point detection is based on discontinuities in image that approach is based on abrupt changes in intensity of an image. Therefore, these isolate points, whose intensity are changing abruptly, may be detected by following mask.

W1	W2	W3
W4	W5	W6
W7	W8	w9

General Mask

-1	-1	-1
-1	8	-1
-1	-1	-1

Point Detection Mask

The general expression in response of filter/mask is $R = \sum_{i=1}^{n} wizi$ where, z_i is grey level pixel associated with the coefficient of mask w_i. The response of mask is defined with the respect to its center location. If at the location, the response of mask is greater than particular predefined threshold $|R| \geq T$ where, T is non-negative predefined threshold value

2.1.2 Line detection

Line detection is also based on abrupt changes in intensity of grey level of an image. It also reflects a discontinuity in an image. For the line detection, we use the following four types of masks:

-1	-1	-1
2	2	2
-1	-1	-1

Horizontal Mask

-1	-1	2
-1	2	-1
2	-1	-1

+45° Mask

-1	2	-1
-1	2	-1
-1	2	-1

Vertical Mask

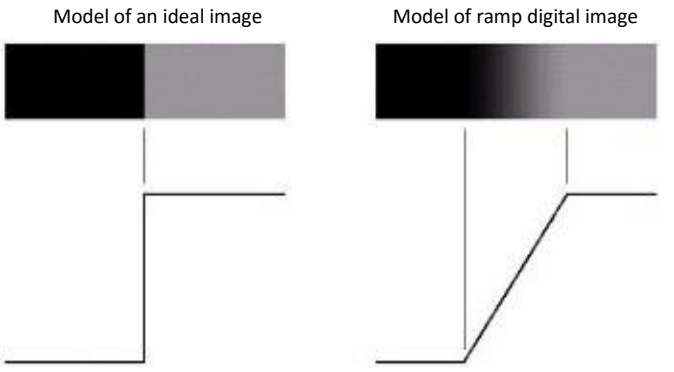
2	-1	-1
-1	2	-1
-1	-1	-1

-45° Mask

By moving first mask on an image, we can detect the one pixel thick line in horizontal direction. The direction of the line is simply decided by the coefficients of the mask. On the basis of the above discussion, second, third and fourth masks are for +45°, Vertical and -45° lines respectively. Now, suppose that we have run all the masks on an image and there are four responses R_1, R_2, R_3 and R_4. Suppose at a particular point $|R_1| > |R_j|$ where, j = 2,3,4 and $j \neq 1$. Then that point is associated with a horizontal line. Therefore, line detection is called low-level feature extraction.

2.1.3 Edge detection based Segmentation

The edge detection based segmentation is an important method of discontinuity-based segmentation in which edges are detected on the bases of value of derivative that is, intensity change in grey level of an image. It is based on discontinuity based segmentation that is, why it also shows abrupt changes in the intensity of grey levels. In mathematics, edges are set of connected line segments that forms a boundary for specific area. An ideal edge has been shown in fig2. Here we see that an immediate transition of grey level has been shown. Edges practically are blurred and degree of blurring depends upon many factors such as the quality of an image. The key points are: (i) ramp slope depends on blurring at edges, if blur is more ramp slope is less and vice versa, (ii) Blurred edges are always thick and sharp edges are always thin, that is shown in figure 2.



(a) Gray level of ideal image (b) Gray level profile of practical image

Fig.2 Intensity change in (a) sharp and (b) blurred edge

The above discussion is only theoretical basics of first order derivative operators of an edge. Practically these can't be implemented on image as that way. For that purpose, we different types of masks.

2.1.3.1 Roberts Edge Detection Mask

This edge detection mask was first introduced by a person called Lawerence Roberts in 1963 and was named after him. The purpose of this mask detects the edge of intensity change in grey level of an image. The input of this mask is a grayscale image and output is produced in the form of black and white image as a skeleton of an edges. The change in pixel is represented in the output image at the edge of an object. Roberts mask is of an order of 2×2 that is shown as below:

1	0
0	-1

G_x Mask

0	1
-1	0

G_y Mask

When we use Roberts masks to general mask of size 3×3 where Z_5 is middle element, the derivative along x-direction is $G_x = (Z_5-Z_9)$ and along the y-direction is $G_y = (Z_6-Z_8)$. The gradient magnitude is given by $|G| = \sqrt{(Gx)^2 + (Gy)^2}$. The gradient direction $\Theta = \tan^{-1}\left(\frac{Gy}{Gx}\right)$.

2.1.3.2 Prewitt Edge Detection Mask

Prewitt edge detection mask was the advanced mask in edge detection technique in segmentation on the base of Discontinuity in gray levels of an image. The other name of this mask is the Discrete Differentiation Operator. This mask is used to detect the edges in two ways horizontal and vertical. However, when these both filters are applied to general mask. The edge detection becomes easy and clear to the user. These two horizontal and vertical masks given by Prewitt are given below:

-1	-1	-1
0	0	0
-1	-1	-1

Horizontal Mask

-1	0	-1
-1	0	-1
-1	0	-1

Vertical Mask

When we use Prewitt masks to general mask of size 3×3 where Z_5 is middle element, the derivative along x-direction is $G_x = (Z_7+Z_8+Z9) -(Z_1+Z_2+Z_3)$ and along the y-direction is $G_y = (Z_3+Z_6+Z_9) -(Z_1+Z_4+Z_7)$. The gradient magnitude is given by $|G| = \sqrt{(Gx)^2 + (Gy)^2}$. The gradient direction $\Theta = \tan^{-1}\left(\frac{Gy}{Gx}\right)$.

2.1.3.3 Sobel Edge Detection Mask

The Sobel edge detection mask was named after Irwin Sobel, who has introduced it. This mask also works on mechanism to detect an edge on the base of first order derivative that is a change in intensity of gray level of an image. It is slightly modified version of Prewitt mask. Here, we have doubled center coefficient of mask for giving more importance to center point. The doubled center point produce slightly more efficient result than Prewitt result. Sobel mask is also two types as of Prewitt horizontal and vertical. These masks are by default of an order of 3×3 and are shown below

-1	-2	-1
0	0	0
1	2	1

Horizontal Mask

-1	0	1
-2	0	2
-1	0	1

Vertical Mask

When we use Sobel masks to general mask of size 3×3 where Z_5 is middle element, the derivatives of along x-direction is $G_x = (Z_7+2*Z_8+Z_9) -(Z_1+2*Z_2+Z_3)$ and along the y-direction is $G_y = (Z_3+2*Z_6+Z_9) -(Z_1+2*Z_4+Z_7)$. The gradient magnitude is given by $|G| = \sqrt{(Gx)^2 + (Gy)^2}$. The gradient direction $\Theta = \tan^{-1}\left(\frac{Gy}{Gx}\right)$.

2.2 Similarities based segmentation

The similarities based segmentation is an approach in which we analysis the pixels of segment on the base of intensity of gray level of an image that is to analysis. In this type of segmentation, the segment is decided on giving predefined condition of the user. These conditions may define on a pixel called as seed pixel and the neighboring pixels are compared with its properties. On the base these properties neighboring is a pixel is included or rejected.

2.2.1 Threshold based segmentation

The threshold-based segmentation is done on the base of predefined value called as threshold value. Each and every pixel in an image is value is compared with this threshold value and hence, this value determines the partition of an image under which it should lie. This value puts pixel in the foreground or background in an output image. There can be multiple threshold values in an image for multiple foregrounds but there will be only one background. The threshold segmentation is of two types, that is Single level Threshold and Multiple Threshold.

2.2.1.1 Single Level Threshold

The single threshold segmentation shows two peaks one for background one for the foreground. This is explained as, when we have an image f (x, y) that has a light object on a dark background. When we draw the histogram of this image, it will have two dominant modes of gray levels. One group near zero point of histogram showing background and one group near maximum points of histogram showing the light object.

So, at point x, y when we one foreground in an image, then

$$g(x) = \begin{cases} a & \text{if } f(x,y) < T \\ b & \text{if } f(x,y) \geq T \end{cases}$$

Here, a ϵ background and b ϵ foreground.

2.2.1.2 Multiple level Threshold segmentation

The multiple threshold segmentation shows more than two peaks in graph to represent multiple objects in an image. The peak of graph at or near minimum is backgrounded and the rest are foregrounded. Suppose, if we consider f (x, y) is an image than histogram of this image have multiple dominant modes, one near to minimum is for background and the rest for our foregrounds.

So, at point x,y when we have two objects of different pixel intensities in an image than,

$$g(x) = \begin{cases} a & \text{if } f(x,y) < T1 \\ b & T1 \leq \text{if } f(x,y) \leq T2 \\ c & \text{if } f(x,y) > T2 \end{cases}$$

Here, a ϵ background, b ϵ foreground one and c ϵ foreground two.

2.2.2 Region based segmentation

The region-based segmentation is based on the rule that to extract information from an image in the form of a group of pixels together into a region that have similar properties like the color intensity of pixels. Therefore, in this way the dissimilar pixels that is, with far intensity than the specified region are separated automatically. This method of segmentation has the capability to partition image into different segments on the criterion of the color intensity of pixels. This relation can be understood by the properties of image segmentation. If R represents the entire spatial region occupied by image and R_1, R_2, R_3,..., R_n are n number of sub regions of the image called as partitions. Then, (a) $\bigcup_{i=1}^{n} R\,i = R$ (b) R_i is connected set, i = 1, 2, 3 ,..., n (c) $R_i \cap R_j = \emptyset$ for all i and j, i ≠ j

The region-based segmentation can be categories into two methods, which are following:

2.2.2.1 Region Splitting and Merging

2.2.2.2 Region Growing Methods

2.2.2.1 Region Splitting and Merging

The region splitting and merging method in image segmentation involves two ideas first to split and perform the operation and then to merge parts to form the original image in the form of segments. The splitting process is performed recursively on an image. The basic idea of image splitting into set of disjoint regions, which are coherent within themselves. The process can be defined as, i) First of all take image as a whole area of interest ii) Look at the area of interest and decide if all pixels contained in that region or not iii) If TRUE, then area of interest corresponds to the region of image iv) If FALSE, then area of interest is splitted into sub areas (usually into four regions) iv) This process is continuously performed until no further splitting is possible. In the worst case, the areas may be of just one pixel.

2.2.2.2 Region Growing Methods

The region growing segmentation method is the opposite of split and merge approach. In this method, a pixel is random chosen, then, on the properties of this pixel the neighboring pixels are compared with the properties of this pixel. If the properties match up given seed pixel than this pixel is included into region to grow that specified region otherwise, it is rejected. The process can be defined as, i) start by choosing an arbitrary seed pixel and compare with its neighbor pixels ii) region will grow if its neighboring pixels are similar iii) the growth of this region stops when no more pixel is similar in properties of this region.

3. CONCLUSION

Image segmentation treats an image as a set and then divides this image into subsets called as segments. These subsets are disjoint subsets such that, intersection between them is a set produced known as null set. Each subset of object represents the meaningful information on the set. Image segmentation is done by mainly two techniques; these are discontinuity based and similarities based. When we divide the image set in itself constitute subsets. This division process is done on the basis of intensity, pixel density, threshold and relation of seed pixel with its neighbors. The various methods under these techniques are edge detection, region splitting and merging, threshold etc. Under these methods we can split an image to extract useful information from them. However, the information extracted by these methods are not 100 percent accurate. Therefore, we need think of extra develop in image segmentation technique that provide us clear and meaningful information in an image to meet the demands of next generation applications.

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