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An Algorithm and Implementation for Image Segmentation

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Abstract

In this paper we present an image segmentation algorithm based on the gradient histogram threshold image improvement. And the MATLAB simulation result shows that: each kind of image segmentation algorithm has its own advantages, disadvantages and scope. Therefore, it is necessary to judge and analysis the image first before we do image segmentation, then we can choose an appropriate segmentation algorithm and it makes the result of the image segmentation satisfactory.

Keywords*: image segmentation; threshold segmentation; region growing; splitting and merging; boundary detection; MATLAB*

1. Introduction

As the degree of informationization deepens, the image as a kind of carrier which contains large amounts of information reflects its powerful ability of containing information more and more with each passing day. Image segmentation is the key step of image analysis, and is the also the basis of understanding the image further. Image segmentation lies between image processing and image analysis in image engineering. Image segmentation refers to the technology and process which decomposes images into a series of meaningful and characteristic regions and extracts the interested targets. It is an important and fundamental problem in the field of computer vision. The quality of the segmentation results will directly affect the performance of the vision system. Therefore, further research on the evaluation of principle, application and the application effect of image segmentation technology is of great significance. With the development of the disciplines such as mathematics, biology, computer science, image segmentation technology also updates and perfects constantly. However, though there are many kinds of image segmentation algorithm which are put forward already, they are mostly aimed at specific problems, not a universal segmentation algorithm suitable for all images. Therefore, research on image segmentation algorithm and the implementation of it needs further enhancement and improvement.

This paper summarizes the image segmentation algorithms of threshold segmentation, region segmentation (region growing, split and merge) and edge detection. First, this paper introduces the related basic knowledge, research significance and research status quo and development trend of image segmentation. Secondly, this paper introduces the basic principle and MATLAB simulation results of image segmentation algorithm such as threshold segmentation, region growing, split and merge and edge detection. Finally, this paper puts forward the possible future research direction of image segmentation and a kind of improved image segmentation algorithm based on the gradient histogram threshold. The MATLAB simulation results show that: various kinds of image segmentation algorithms have their advantages and disadvantages and applicable scope.

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Therefore, before segmenting an image, one should first make a judgment and analysis of it, and then chooses the appropriate segmentation algorithm, eventually making the image segmentation results satisfying.

2. Image Segmentation

Image segmentation is an important image processing technique which has gotten widely attention in the theoretical research and practical application. However, there are many methods and kinds of image segmentation, some of which can be directly applied to any image, while some of which can only apply to special categories of images. Some algorithms need coarse image segmentation first, because they need to extract the useful information from the image. For example, one can adapt the method of setting the image grayscale threshold to segment the image. It is worth mentioning that there is not only and standard segmentation method. Many different kinds of images or objects can be the image data to be segmented. There are corresponding segmentation methods for different types of images. At the same time, some segmentation methods are only suitable for some special types of image. The quality of segmentation results need to be measured according to specific situations and requirements. Image segmentation is the key step from image processing to image analysis, as it were; the quality of image segmentation results influences the understanding of the images directly.

2.1. Threshold Segmentation

Thresholding is one of the most commonly used image segmentation technology. Its characteristic is simple operation, and the segmentation results are a series of continuous regions. The threshold segmentation of grayscale images is generally based on the following assumption: the gray values of target image and that of the adjacent pixel within the background are highly relevant, while the pixel gray values of target image and that of both border sides of the background are of great difference, and the gray distribution of target image and background is unimodal. If the corresponding unimodal of target image and background are close in size, and the variance is relatively small and the mean values are of relatively big difference, then the histogram of image is of bimodality. The thresholding can effectively segment images with bimodal characteristics.

The process of threshold segmentation is as follows: first, determine a threshold T, for each pixel in the image, if the gray value is greater than T, then set it as the target point (the value is 1), otherwise set it as the background point (the value is 0), or vice versa, so the image is divided into target region and background region. Similarly, in programming, the target pixel can also be set as 255, background pixel 0, or vice versa, so the image is divided into the target region and background region. The formula can be represented as follows:

$$B(x, y) = \begin{cases} 1 & F(x,y)>T \\ 0 & F(x,y)<T \end{cases} \quad (1)$$

When the image contains multiple targets and gray level difference is big, multiple thresholds can be set to realize multi-threshold segmentation.

In the formulation above: T_k is a series of segmentation thresholds: k is the label of each target area; m equals to the number of segmented target areas minus 1. The key point of threshold segmentation is how to determine the proper threshold; the processing results of different thresholds are of great difference, which can affect the follow-up process such as the measurement and analysis of characteristics. If the threshold is too big, it will segment the background pixels into too many targets; while if the threshold is too small, it will segment too much target pixels into backgrounds. There are many kinds of methods to determine the threshold which can be divided into different types. If the

selected threshold value is only associated with the gray level of each pixel, it is called local threshold; If the selected threshold value is not only associated with the gray level, but also related to the location of the pixel, then it is called dynamic threshold or adaptive threshold. The threshold can be generally represented as follows:

$$T = T[x, y, f(x, y), p(x, y)] \quad (2)$$

In the formulation above: f(x,y) is the pixel gray value of point (x,y); p(x,y) is some kind of local property of the neighborhood of the pixel.

As the grayscale contrast between target image and background is relatively strong, the threshold selection is relatively easy. In fact, due to poor lighting or too much image noise, the contrast between the target and background is often not obvious enough, at this time, the threshold selection is not easy. Image preprocessing such as image noise smoothing is generally needed, and then the threshold segmentation can be determined.

2.2. Threshold Segmentation of Gray Histogram

The principle of confirming the method of segmenting threshold by using the characteristics of image gray histogram is: if the size of image's including background region and the size of target region is comparable and that those two have obvious difference on gray level, then this kind image's gray histogram has obvious bimodal. One of the bimodal represents background region's gray level, and the other represents the target gray level. For the ideal image gray histogram, its background gray and target gray corresponding to two different gray peak value, so choose the valley value between two peaks as threshold, it is very quickly to separate an image's background and target. As shown in Figure 1-3.

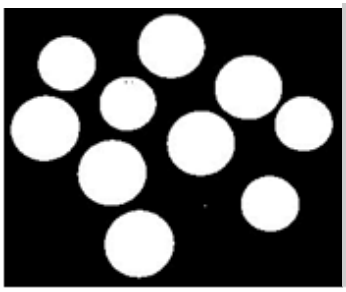

Figure 1. Original Gray Image

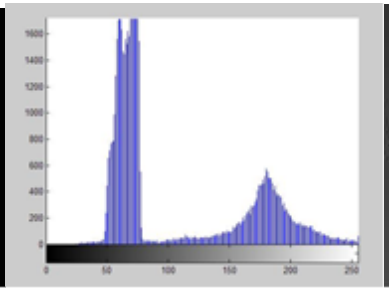

Figure 2. Gray Histogram

Figure 3. Image after Segmentation

3. Deficiency of the Classic Segmentation Algorithm

The merit of the classic histogram threshold segmentation algorithm is it can easily achieve, But it can effective segment only for a few different categories of objects when each of the gray vary widely. When the original image's gray histogram has inconspicuous bimodal, it cannot get ideal image after the segmentation.

Figure 4 is the original Lena image; Figure 5 is the result of classic gray histogram threshold segmentation; Figure 6 shows that it has better segment effect on partial region (such as the face, right background) but in some detail of partial region(such as hat, hair) it failed on separating the image's boundary completely.

Therefore, deficiency of classic histogram threshold segmentation is obviously:

First of all, when the image has inconspicuous gray difference or gray value has large overlap, it can hardly get accurate result;

Secondly, it considers only the gray of the image but not considers the image's spatial information, so it is sensitive to the image's noise gray. In practical application, it is used by combining with other algorithm.

Figure 4. Original Gray Image

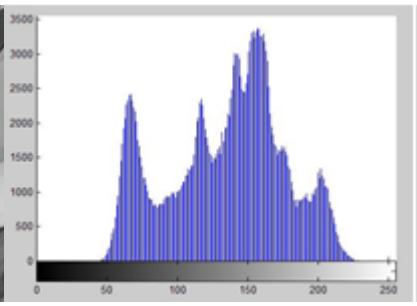

Figure 5. Image Gray Histogram

Figure 6. Image after Segmentation

4. Segmentation Algorithm based on Image Enhancement

Image enhancement is according to the subjective requirements of people to the ideal image, to duel with the original image's sharpening and smoothing process, and make it improve the image quality and achieve the actual application requirements. To improve the image's detail it has to make the original image sharpening, and the image's edge detail is related to the gradient intensity of the image, and the stronger the image edge, the more obvious the image's detail effect.

Gradient image can adapt to the change of the image edge better, edge detection is used to use all kinds of differential operator to extract the image boundary. Most of the image edge information is high frequency signal, which have more relationship with gradient, so that it is more reasonable to have the image that saved complete image edge information gradient sharpened before split.

Assume the definition of the gradient of the image at:

$$grad(\mathrm{x},\mathrm{y}) = \begin{pmatrix} f_x' \\ f_y' \end{pmatrix} = \begin{pmatrix} \frac{\partial f(\mathrm{x},\mathrm{y})}{\partial x} \\ \frac{\partial f(\mathrm{x},\mathrm{y})}{\partial y} \end{pmatrix} \tag{3}$$

Because the gradient is a vector, so it has direction and magnitude:

$$\theta = \arctan(\frac{f_x'}{f_y'}) = \arctan(\frac{\partial f(\mathrm{x},\mathrm{y})}{\partial y} / \frac{\partial f(\mathrm{x},\mathrm{y})}{\partial x}) \tag{4}$$

$$grad(\mathrm{x},\mathrm{y}) = \sqrt{(\frac{\partial f(\mathrm{x},\mathrm{y})}{\partial x})^2 + (\frac{\partial f(\mathrm{x},\mathrm{y})}{\partial y})^2} \tag{5}$$

For an image which the edge area is prominent and quickly changed, the gradient value is bigger; and the gradient is smaller to the edge with the signal value.

So that we can strengthen the detail part of an image with the gradient operator, low-frequency signal need to be saved and make it superposition with the original image information, add a sharpening coefficient as follow:

$$g(\mathrm{x},\mathrm{y}) = \mathrm{f}(\mathrm{x},\mathrm{y}) + \mathrm{k} \times \mathrm{grad}(\mathrm{x},\mathrm{y}) \tag{6}$$

$g(x,y)$ as the image after enhancement; $f(x,y)$ as the original image and it saves the image original background information.

$\mathrm{grad}(x,y)$ as the gradient of the original image and the image's sharpening detail information;

k as the sharpening coefficient, adjusts sharpen intensity. By adjusting K's value, it makes the original image's detail part more outstanding.

5. Experimental Results and Analysis

Figure 7 when k=2, the result of superposition on original image and its gradient, figure 8 the result of new segmentation on original threshold:

Figure 7. $k=2$ **enhance detail image**

Figure 8. $k=2$ **original Threshold segmentation image after enhance**

Figure 9 When $k=5$, the result of superposition on original image and its gradient, figure 10 the result of new segmentation on original threshold:

Figure 9. $k=5$ **Enhance Detail Image**

Figure 10. $k=5$ **Original Threshold Segmentation Image after Enhance**

We can tell from the above that with the increase of K's value, the image's sharpness is increasing, and after the segmentation, the people's hair, eyes are totally segmented. By comparing with picture 2.3's segment effect, improvement is obvious after the enhancement processing.

Gradient is not only an important mathematic operation, but also an important way to highlight detail information in image enhancement. Image gradient can reduce input image's zero-frequency and low-frequency effectively, extract or highlight gray image's edge and detail, and increase the resolution and recognition rate of image. This method has better segmentation effect for the details of the complex gray image, and the calculating increase is not much, and it can be applied to both gray images and color images, and it can overcome the shortcomings of the traditional threshold segmentation method. But in the process of image sharpening enhancing we found that with the increase of k value and the intensity of the gradient sharpening, it enhanced the original

information as well as enlarges the high-frequency noise, shows that the image appears obvious burr noise after segmentation.

Through research and analysis, following conclusions can be reached:

(1) Threshold segmentation method focuses on the selection of threshold value, so the key of this method is how to select the best threshold value. If the threshold selection is not appropriate, it will affect the effect of image segmentation and the effect of following edge segmentation.

(2) It can be seen from the experiment phenomenon that if the gray difference between object and background of the image is not obvious or the integral effect of gray value range overlap is not obvious, then there is no clear distinguishing between background and target, while the other areas of greater gray level difference get better segmentation effect. As a result, the global threshold method is applicable to images of greater gray level differences, if the gray level of the image change is not obvious, then ideal effect can hardly be reached.

(3) The segmentation effect of different edge detection operators on the same image is different, because the convolution form of each edge operator is different, and their sensitivity degree of the light and shade degree of the image, resolution ratio and gray level change are also different. It can be seen from the above experiment phenomenon that no edge operator is absolutely appropriate, for example, although the overall effect of the operator Canny is best, its segmentation result is obviously not as meticulous as operator Prewitt, this is its defect. Each kind of edge detection operator has its corresponding advantages and disadvantages in image segmentation; we can only chooseone with better effect among them. However, we cannot judge the chosen operator is the best, it can only be said that the operator can achieve the best effect for certain images.

(4) Local threshold segmentation method is dividing the original image into smaller images, and selecting the corresponding threshold value for each subimages. Although local threshold segmentation method can improve the segmentation results, but it has several disadvantages:

① The size of each subimagecan not be too small, otherwise the statistics results will be meaningless;

② The segmentation of every image is arbitrary. If there is a subimage lies squarely in the target area or background area, then the segmentation according to the statistical results may produce even worse results;

③ Since local threshold value method must carry on the statistics of each subimage, it is slow, which is difficult to meet the real-time requirement.

(5) Usually, it is not enough to use only one image segmentation method for an image. Mastering the image segmentation theory which has improved induction and classification in accordance with the segmentation algorithm itself is not enough; each method has its shortage. Therefore, using only one method usually cannot achieve very good effect; other methods can also be used in combinationin order to compensate each other. For there is no segmentation method can achieve ideal segmentation results for all images, so according to the different characteristics of image segmentation and combining with the known prior knowledge to study the image segmentation model in accordance with specific image characteristics is an important means to improve the image segmentation.

Although there is a lot of research in image segmentation, there is no method that is suitable for all images so far. The methods put forward in this paper have its using preconditions, therefore, for particular image segmentation, the most important way is to analyze the features of the image and then determine the suitable solution according to the characteristics of the image in order to achieve the best segmentation effect.

6. Conclusions

Image segmentation is recognized as one of the most difficult problem that will exist over a long period of time by the international academia of image understanding and computer vision field. So far, there is neither a universal image segmentation method, nor an objective judgment criteria whether the segmentation is successful or not. In general sense, the thorough understanding of image content is the premise of perfect segmentation. In recent years, with the putting forward of many new theory and methods of each discipline, people puts forward many segmentation technologies which are combined with certain theories, methods and tools. For example, segmentation technology which is based on mathematical morphology, image segmentation method which is based on fuzzy technique, image segmentation method which is based on artificial neural network technology, the application of genetic algorithm in image segmentation, and the segmentation technology based on wavelet analysis and transformation. Although there are more and more research results in recent years, no big breakthrough has been made because of the difficulty of image segmentation. From the perspective of the history of image segmentation study, we can see that there are several obvious trends of the image segmentation study: one is the continuous improvement of the original algorithm; the other is the introduction of new methods and new concepts and effective integrated use of a variety of methods. People gradually realize that the single existing image segmentation algorithm is difficult to obtain a satisfactory segmentation effect for general image; so many people pay more attention to the application of various methods while introducing new methods and concepts. We believe that with the deepening of the research, the existing problems will soon get satisfactory solutions.

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