Evaluation of Canny and Otsu Image Segmentation

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Abstract—The paper presents two techniques of image segmentation to facilitate image edge detection, that can be used further by image analysis based on the extracted features of image edges. Canny edge detection and Otsu thresholding are examples of the proposed techniques. The paper evaluates the effectiveness of the two methods with a variety of images, testing their suitability to natural as well as medical images.

Keywords—Image segmentation, Canny edge detection, Otsu thresholding

I. INTRODUCTION

The growing need for automated image analysis and interpretation in a wide range of applications is of particular interest as the segmentation process will reduce the large number of components existing in the initial image into a reduced number of components in the segmented result. Image segmentation is the first step and also one of the most critical tasks of image analysis. It is used either to distinguish objects from their background or to partition an image onto the related regions. Although it is one of the primary steps in object recognition, it is also considered to be one of the most popular problems in computer vision. Image segmentation is the process of dividing an image into regions according to their characteristic e.g., colour and objects present in the image. These regions are sets of pixels and have some meaningful information about objects. In the result of image segmentation we can identify ROI (Region Of Interest) or objects which then will help in interpreting and understanding the content of the considered image. Image segmentation algorithms [1,3,4,8] generally are based on one of the basic properties of intensity values discontinuity and similarity. Methods based on discontinuities are called as boundary based methods and methods based on similarity are called Region based methods. In the first category, the approach is to partition an image based on abrupt changes in intensity, such as edges in an image. On the other hand the second category are based on partitioning an image into regions that are similar according to a set of predefined criteria, thresholding, region growing, and region splitting and merging are examples in this category. In this paper the two categories are considered, in section 2 the description of the used algorithms are provided, in section 3 the experimental results are presented and discussed, conclusion and future work is given in section 4.

II. THE PROPOSED SEGMENTATION ALGORITHMS

The first step in image analysis is to segment an image based on discontinuity (Edge-based) or similarity detection technique (Region-based) that segments an image into regions based on similarity according to a predefined criteria, in this paper the two methods are presented and evaluated, edge based and threshold based segmentation, Canny edge detector is considered to be an example of the first method and Otsu thresholding represent the other method.

II.1 Edge based segmentation

Segmentation Methods based on discontinuity search for abrupt changes in the intensity value. are called edge or boundary based methods [2,4,9]. Edge detection is the problem of fundamental importance in image analysis, and edge detection techniques are generally used for finding discontinuities in grey level images. Edge based segmentation methods detect discontinuities and produce a binary images contained edges and their background as the output of them. Edges are local changes in the image intensity, they typically occur on the boundary between two regions, important features can be extracted from these edges, then The features are used by higher level computer vision algorithms [1,3,10]. Edge detection is used for object detection, recognition and many other applications. It is an active area of research as it facilitates higher level image analysis. A number of edge detectors based on a single derivative have been developed by various researchers. Amongst them most important operators [2,4,5] are the Robert, Sobel, Prewitt, Canny operators. Next Canny edge detection is presented.

II.1.1 Canny Edge Detector

The Canny edge detector is regarded as one of the best edge detectors currently in use, Canny's edge detector ensures good noise immunity and at the same time detects true edge points with minimum error. Canny has optimized the edge detection with regard to the following criteria:

1. Maximizing the signal-to-noise ratio of the gradient.
2. An edge localization factor, which ensures that the detected edge is localized as accurately as possible.
3. Minimizing multiple responses to a single edge.

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The steps of Canny algorithm [1,11,12,13,14] are as follows:

1. Smoothing: Blurring of the image to remove noise by convolving the image with the Gaussian filter.

2. Finding gradients: The edges should be marked where the gradients of the image have large magnitudes, finding the gradient of the image by feeding the smoothed image through a convolution operation with the derivative of the Gaussian in both the vertical and horizontal directions.

3. Non-maximum suppression: Only local maxims should be marked as edges. Finds the local maxima in the direction of the gradient, and suppresses all others, minimizing false edges.

4. Double thresholding: Potential edges are determined by thresholding. Instead of using a single static threshold value for the entire image, the Canny algorithm introduced hysteresis thresholding, which has some adaptivity to the local content of the image. There are two threshold levels, th, high and th, low where th-thl. Pixel values above the th value are immediately classified as edges.

5. Edge tracking by hysteresis: Final edges are determined by suppressing all edges that are not connected to a very strong edge.

II.2. Thresholding segmentation

Thresholding techniques [6,7,8] are image segmentation techniques based on image-space regions. The fundamental principle of thresholding techniques is based on the characteristics of the image. In brightness threshold, all the pixels brighter than a specified brightness level are taken as 1 and unwanted as background 0. Sufficient contrast on objects and background is necessary to do the thresholding. The simplest property that pixels in a region can share is intensity. So, a natural way to separate such regions is through thresholding, to light and dark regions. Thresholding creates binary images from grey level ones by turning all pixels below some threshold to zero and all pixels above that threshold to one. Thresholding is the transformation of an input image to an output binary image g as represented by the next formula, where g(x, y) is a thresholded version of f(x, y) at some global threshold t:

\[ g(i, j) = \begin{cases} 
1 & \text{if } f(i, j) \geq t \\
0 & \text{if } f(i, j) < t 
\end{cases} \]

where t is the threshold, g(i, j) = 1 for image elements as the objects, and g(i, j) = 0 for image elements as the background, in this way the chosen threshold is dependable on the grey level value, this called global thresholding technique. Otsu method thresholding [6,8] is considered to be as an example of this technique.

II.2.1. Otsu thresholding

Because the ease of implementation and the relative complexity, Otsu threshold is used in many applications from medical imaging to low level of computer vision, it is based on the threshold for partioning the pixels of an image into two classes C0 and C1 (e.g., objects and background) at grey level t, where : C0 = \{1, 1, 2, ..., t\} and C1 = \{t + 1, t + 2, ..., l - 1\}, and let q0 and q1 represent the estimate of class probabilities defined as follows:

\[ q_0(t) = \sum_{i=0}^{t} p(i), \quad q_1(t) = \sum_{i=t+1}^{l-1} p(i) \]

and sigmas are the individual class variances defined by:

\[ \sigma_b^2(t) = \sum_{i=0}(i - \mu_0(t))^2 \frac{p(i)}{q_0(t)} \quad \text{and} \quad \sigma_w^2(t) = \sum_{i=t+1}(i - \mu_1(t))^2 \frac{p(i)}{q_1(t)} \]

where the class means are defined by:

\[ \mu_0(t) = \sum_i \frac{p(i)}{q_0(t)}, \quad \text{and} \quad \mu_1(t) = \sum_{i=t+1} \frac{p(i)}{q_1(t)} \]

Here, P represents the image histogram. The problem of minimizing within class variance can be expressed as a maximizing the between class variance. It can be written as a difference of total variance and within class variance:

\[ \sigma_b^2(t) = \sigma^2 - \sigma_w^2(t) = q_0(t)[1 - q_0(t)] \left[ \mu_1(t) - \mu_0(t) \right]^2 \]

Finally, this expression can safely be maximized and the solution is the t that maximizing \( \sigma_b^2(t) \). The steps of the algorithm may be formulated as follows:

- Compute histogram and probabilities of each intensity level.
- Set up initial qi(0) and μi(0).
- Step through all possible thresholds to maximum intensity.
- Update qi and μi.
- Compute \( \sigma_b^2(t) \).
- Desired threshold corresponds to the maximum. \( \sigma_b^2(t) \)

III. EXPERIMENTAL RESULTS

The paper presents two techniques of image segmentation, Canny edge detection and Otsu thresholding, they are tested with a variety of representing medical as well as natural images and their corresponding segmentation using the two methods, as examples of our experiments four images and their segmentation results are shown in Fig. 1 and 2.
Fig. 1. a) original images  b) their Canny segmented images  c) their Otsu segmented images

Fig. 2. original images  b) their Canny segmented images  c) their Otsu segmented images

IV. CONCLUSION

The effectiveness of the proposed algorithms are evaluated for natural and medical images, for natural images as seen in Fig. 1., the two algorithm give good segmented images , where the objects or the edges of the original images are almost fully segmented, and Canny segmentation is more suitable than Otsu for grey scale with a little noise as seen in the right image of Fig. 1.and Otsu gives better results than Canny as seen in the left image, on the other hand for medical images as shown in Fig. 2., generally Otsu gives better results than Canny, especially for endoscopic images, where the objects in these images are considered to be a big challenge to segment. It is recommended for the future work to test the tuning of Canny parameters to give more effective results and to manage with a variety of images, and to smooth image before Otsu segmentation.

REFERENCES