A STUDY OF REGION- BASED AND CONTOUR-BASED IMAGE SEGMENTATION

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ABSTRACT

In computer vision, segmentation refers to the process of partitioning a digital image into multiple segments (sets of pixels, also known as super-pixels). This paper attempts to undertake a study of two categories of image segmentation which are Contour- Base and Region-Base. In the first category, Contour- Based image segmentation, the study is on some edge detection techniques which include Sobel, Canny and Robert Cross edge detection techniques and for the Region- based image segmentation, the study is on image thresholding. These two categories of image segmentation will be performed using MATLAB Version 7.12.0.635 (R2011a) and the experimental results obtained are discussed.

KEYWORDS

Image segmentation, edge detection, thresholding, MATLAB

1. INTRODUCTION

Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics. The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image. Each of the pixels in a region are similar with respect to some characteristic or computed property, such as color, intensity, or texture [1]. In computer vision, image processing is any form of signal processing for which the input is an image, such as photographs or frames of videos. The output of image processing can be either an image or a set of characteristics or parameters related to image. Also, segmentation refers to the process of partitioning a digital image into multiple segments (sets of pixels, also known as super pixels). Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images [1].

The goal of segmentation is to simplify and change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries in images [2].

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The most studied version of grouping in computer vision is image segmentation. Image segmentation techniques can be classified into two broad families- (1) region-based, and (2) contour-based (edge) approaches. Region-based approaches try to find partitions of image pixels into sets corresponding to coherent image properties such as brightness, color and texture. Contour- based approach usually start with a first stage of edge detection followed by a linking process that seeks to exploit curvilinear continuity. The task of interactive image segmentation has attracted a significant attention in recent years [3]. The process of image segmentation can be seen in two (2) categories. In the first category, the approach is to partition an image based on abrupt changes in intensity, such as edges. In the second category, the approach is to separate an image foreground from its background which is known as Image thresholding. Other examples in this category include region growing, and region splitting and merging.

2. SEGMENTATION BY CONTOUR- BASED APPROACH

2.1. Edge Detection Segmentation

Edge detection is the approach used most frequently for segmenting images based on abrupt (local) changes in intensity [4]. Edge models are classified according to their intensity profiles. A step edge involves a transition between two intensity levels occurring ideally over the distance of 1 pixel. Step edges occur, for example, in images generated by a computer for use in areas such as solid modeling and animation. These clean, ideal edges can occur over the distance of 1 pixel provided that no additional processing (such as smoothing) is used to make them look real. Digital step edges are used frequently as edge models in an algorithm development [4] such as Canny edge detection algorithm.

In practice, digital images have edges that are blurred and noisy, with the degree of blurring determined principally by limitations in the focusing mechanism (e.g. lenses in the case of optical images), and noise level determined principally by the electronic components of the imaging system. In such situations, edges are more closely modeled as having an intensity ramp profile. The slope of the ramp is inversely proportional to the degree of blurring in the edge. Roof edges are models of lines through a region, with base (width) of a roof being determined by the thickness and sharpness of the line. In the limit, when its base is 1 pixel wide, a roof edge is really nothing more than a 1-pixel thick line running through a region in an image [4]. Roof images are usual found in line drawings and satellite images.

(a) (b) (c)

Figure 1(a): Step Edge with intensity profile (b) Ramp Edge with intensity profile (c) Roof Edge with intensity profile

There are many ways to perform edge detection. However, the majority of different methods may be grouped into two categories, gradient and Laplacian [5]. The gradient method detects the edges by looking for the maximum and minimum in the first derivative of the image. The Laplacian method searches for zero crossings in the second derivative of the image to find edges. An edge has the one-dimensional shape of a ramp and calculating the derivative of the image can highlight its location [5].

Edge detection is one of the subjects of basic importance in image processing. The parts on which immediate changes in grey tones occur in the images are called “edges”. Benefiting from the direct relation between physical qualities of the materials and their edges, these qualities can be recognized from edges. Because of these qualities, edge detection techniques gain importance in terms of image processing [6].

Basic Edge detection, which is said to be the detection of changes in intensities for the aim of finding edges, can be achieved using First-Order or Second Order derivatives.

- **First-order derivative**: - The First-order derivative is the Gradient of a 2-D function. The Gradient of a 2-D function f(x,y), is defined as the vector [2].

$$\nabla f = \begin{matrix} g_x \\ g_y \end{matrix} = \begin{matrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{matrix}$$

The Gradient of this vector is

$$\nabla f = mag(\nabla f) = [g_x^2 + g_y^2]^\wedge 1/2$$

To simplify computation, this quantity is approximated sometimes by omitting the square-root operation [2],

$$\nabla f = g_x^2 + g_y^2$$

The angle at which this maximum rate of change occurs is [2]:

$$\propto (x, y) = \tan^{-1} g_x / g_y$$

- **Second-order derivative**:- in image processing generally are computed using the Laplacian of a 2-D function f(x,y) is formed from second-order derivatives [2]:

$$\nabla^2 f(x, y) = \frac{df}{dx} + \frac{df}{dy}$$

In this paper, three (3) edge detection techniques are taken for the study and these techniques include the following;

- Sobel Edge Detection
- Canny Edge Detection
- Roberts Edge Detection

2.2. Sobel Edge Detection

The Sobel edge detection method is introduced by Sobel in 1970 (Rafael C.Gonzalez (2004)) [7]. Sobel calculates not only the magnitude of the edges, but also their direction. The operator uses a 3x3 template horizontally then vertically [8]. One kernel is simply the other rotated by 90o [7].

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

G_x

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

G_y

Figure 2: Sobel convolution masks

2.3. Canny Edge Detection

The Canny edge detector is an edge detection operator which is based on three basic objectives [4];

1. *Low error rate.* All egdes should be found, and there should be no spurious responses. That is, the edges detected must be as close as possible to the true edges.
2. *Edge points should be well localized.* The edges located must be as close as possible to the true edges. That is, the distance between a point marked as an edge by the detector and the center of the true edge should be minimum.
3. *Single edge point response.* The detector should return only one point for each true edge point. That is, the number of local maxima around the true edges should be minimum. This means that the detector should not identify multiple edge pixels where only a single edge point exists.

Canny edge detection algorithm consists of the following [4];

- Smooth the input image with a Gaussian filter.
- Compute the gradient magnitude and angle images.
- Apply non-maxima suppression to the gradient magnitude image.
- Use double thresholding and connectivity analysis to detect and link edges.

2.4. Robert Cross Edge Detection

The Robert's Cross edge detector is a fast and simple convolution-based operator for extracting edges in a digital image. Robert's Cross consists of two 2x2 kernels run over an image separately to find gradient edges [9].

$$\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix}$$

Figure 3: Robert Cross Mask

Convolving the image with the first kernel finds the gradient edges at -45° and the second at 45°. The images below show a test image and the results of the Robert's Cross operator [9].

3. SEGMENTATION BY REGION- BASED APPROACH

3.1. Image Thresholding

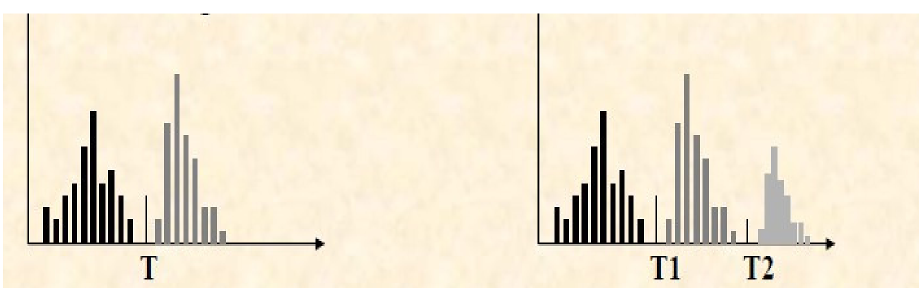
Thresholding is a method in image segmentation which is used in separating the object of an image from its background. Due to its simplicity of implementation, and its computational speed, thresholding enjoys a central position in image segmentation.

Thresholding is the simplest method of image segmentation. From a grayscale image, thresholding can be used to create binary images During the thresholding process, individual pixels in an image are marked as "object" pixels if their value is greater than some threshold value (assuming an object to be brighter than the background) and as "background" pixels otherwise. This convention is known as *threshold above*. Variants include *threshold below,* which is opposite of threshold above; *threshold inside,* where a pixel is labeled "object" if its value is between two thresholds; and *threshold outside*, which is the opposite of threshold inside. Typically, an object pixel is given a value of "1" while a background pixel is given a value of "0." Finally, a binary image is created by coloring each pixel white or black, depending on a pixel's labels [10].

3.2 Definition

Suppose that the intensity histogram in the Figure 1.1 below corresponding to an image, *f(x,y),* composed of light objects on a dark background, in such a way that object and background pixels have intensity values grouped into two dominant modes. One obvious way to extract the objects from the background is to select a threshold, *T,* that separates these modes. Then, any point (x,y) in the image at which f(x,y)> T is called an object point; otherwise, the point is called a background point. In other words, the segmented image *g(x,y),* is given by [4]

$$g(x,y) = f(x) = \begin{cases} 1, & if\ f(x,y) > T \\ 0, & if\ f(x,y) \leq T \end{cases} \qquad \text{Eq. 1}$$



(a) (b)

Figure 3: Showing the intensity histograms that can be partitioned (a) Single Threshold, and (b) Dual Threshold

When T is a constant applicable over an entire image, the process given in this equation is referred to as global thresholding. When the T changes over an image, it is called variable thresholding. The term local or regional thresholding is used sometimes to denote variable thresholding in which the value of T at any point (x,y) in an image depends on properties of a neighborhood of (x,y) (for example, the average intensity of the pixels in the neighborhood). If T depends on the spatial coordinates (x,y) themselves, then the variable thresholding is often referred to as dynamic or adaptive thresholding [4].

Figure 3 (b) shows a more difficult thresholding problem involving a histogram with three dominant nodes corresponding, indicating, to two types of light objects on a dark background. Here a multiple thresholding classifies a point a point (x,y) as belonging to the background if $f(x,y) \leq T_1$ to one object class if $T_1 < f(x,y) \leq T_2$ and to the object class if $f(x,y) \leq T_2$. Therefore the segmented image is given as this

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

where a, b and c are three distinct intensity levels [4].

3.2. Basic Global Thresholding

In an image, when the intensity distributions of objects and background pixels are sufficiently distinct, it is possible to use a single (global) threshold applicable over the entire image. In most applications, there is usually enough variability between images that, even if global thresholding is a suitable approach, an algorithm capable of estimating automatically the threshold value for each image is required. The Global Thresholding uses an iterative algorithm which consist of the following basic steps [4].

1. Selecting an initial estimate for the global threshold, T
2. Segment the image using T in Eq. 1. This will produce two groups of pixels: G_1 consisting of all pixels with intensity values > T, and G_2 consisting of pixels with values $\leq T$.
3. Compute the average (mean) intensity values m_1 and m_2 for pixels in G_1 and G_2.
4. Compute a new threshold value: $T = \frac{1}{2}(m_1 + m_2)$.
5. Repeat steps 2 through 4 until the difference between values of T in successive iterations is smaller than a predefined parameter ΔT.

This algorithm works well in situations where there is a reasonably clear valley between the modes of the histogram related to objects and background [4].

4. EXPERIMENTAL RESULTS

This section presents the results obtained for each of the two categories of image segmentation in the study. These two categories include; (1) Contour-based image segmentation and (2) Region-based image segmentation.

The experiment was performed using MATLAB Version 7.12.0.635 (R2011a) and tested with an image taken in Tianjin, P.R. China with a pixel size of 500x667. The objective is to perform image segmentation using the Contour-based approach by obtaining edges and Region-based approach by separating the objects from the background in the image. The techniques used in the Contour-based approach are Sobel, Canny and Robert Edge Detectors where as thresholding was used for the Region-based approach. The experimental results are shown below.

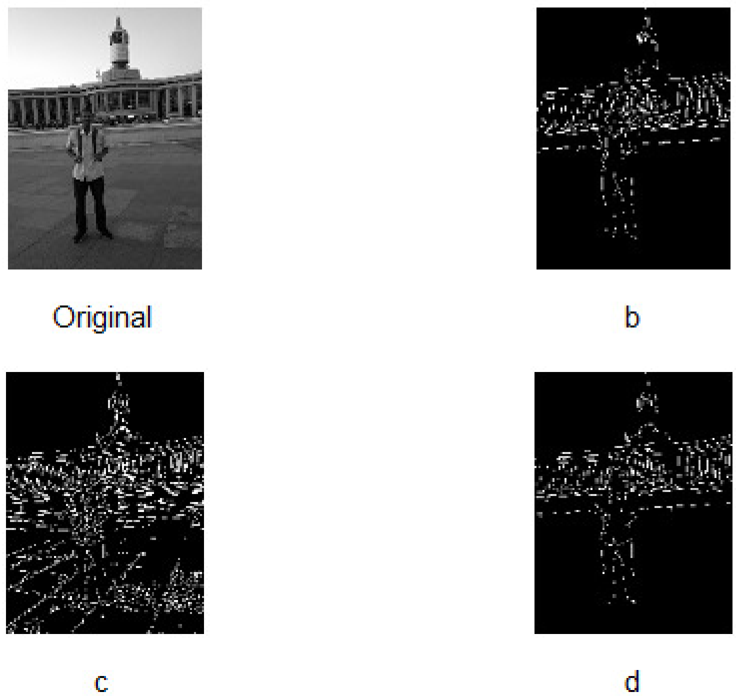


Figure 4: Contour –based: Edge Detection techniques showing the Original Image, (b) Sobel, (c) Canny and (d) Robert Cross

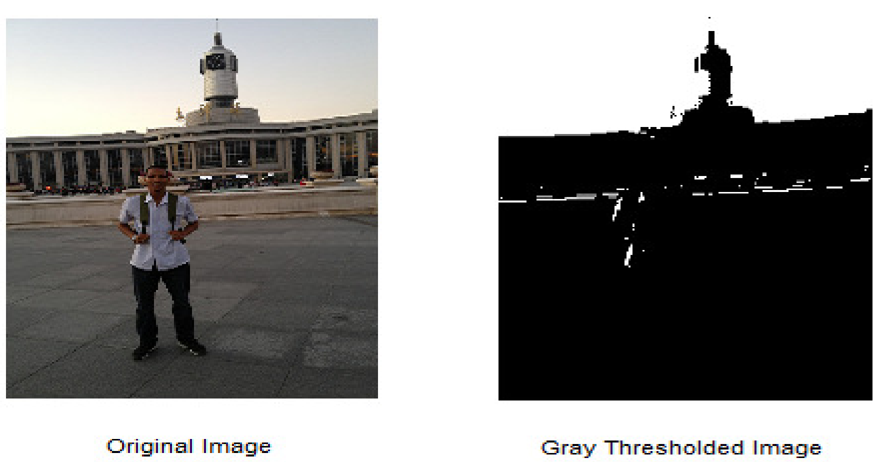


Figure 5: Region- based: Image thresholding showing Original Image and Thresholded image

5. CONCLUSION

In computer vision, segmentation refers to the process of partitioning a digital image into multiple segments (sets of pixels, also known as super-pixels). This paper made an attempt to study two categories of image segmentation. The first category is the Contour- based and the second, Region- based approaches. In the first category, the study was on Sobel, Canny and Robert edge detection techniques which are based on discontinuity intensity level. For the second category, Image Thresholding was the choice of the study.

The experiment was performed using MATLAB Version 7.12.0.635 (R2011a). In the first category of image segmentation, Figure 4. shows Sobel, Canny and Robert Edge Detectors and the results produced edge maps and edges of the image were obtained. It was observed that, Canny Edge detector produce better edge maps making it the superior edge detection technique. For the second category, Figure 5. Image thresholding successfully separated the foreground from the background. The white (1) represents the foreground and black (0) represents the background for the image.

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