A Study on Edge Detection Techniques for Natural Image Segmentation

Saiful Islam, Majidul Ahmed

Abstract*— Natural image segmentation is one of the fundamental problems in image processing. Statistics of 'natural images' provides useful priors for solving under-constrained problems in Computer Vision. Image segmentation is the process of partitioning/subdividing an image into multiple meaningful regions or sets of pixels with respect to a particular application. Image segmentation is a critical and essential component of image analysis system. In literature, there are many image segmentation techniques. One of the most important techniques is Edge detection techniques for natural image segmentation. Edge detection is a fundamental tool for image segmentation. Edge detection methods transform original images into edge images benefits from the changes of grey tones in the image. In literature, there are many Edge detection techniques for image segmentation. In this paper, we used four Edge detection techniques for natural image segmentation and they are Roberts Edge detection, Sobel Edge detection, Prewitt Edge detection, and LoG Edge detection.

Keywords*— Edge Detection Techniques, Image Segmentation, MATLAB.

I. INTRODUCTION

A. Image And Image Segmentation

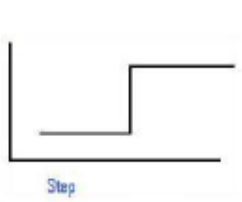
An image is an array, or A matrix, of square pixels (picture elements) arranged in columns and rows. Each pixel represents the color (or gray level for black and white photos) at a single point in the image. An image comes from Latin word 'imago'. Natural images consist of an overwhelming number of visual patterns generated by very diverse stochastic processes in nature. Natural images are particularly noisy due to the environment they were produced. A digital image is a numeric representation (normally binary) of a two-dimensional image. Any image from a scanner, or from a digital camera, or in a computer, is a digital image.

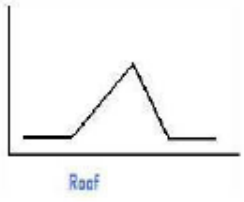
Image segmentation has become a very important task in today's scenario. Image segmentation is a fundamental process in many image, video, and computer vision applications. Natural-image segmentation is one of the classical problems in computer vision. The task of partitioning a natural image into regions with homogeneous texture, commonly referred to as image segmentation, is widely accepted as a crucial function for high-level image understanding, significantly reducing the complexity of content analysis of images. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. It is one of the most difficult tasks in image processing because it determines the quality of the final result of analysis. There are many applications of image segmentation. Some of them practical applications are , Medical imaging, Diagnosis , Treatment planning , Face recognition , Iris recognition ,Fingerprint recognition ,Traffic control systems, Agricultural imaging – crop disease detection etc.

B. Edge And Edge Detection

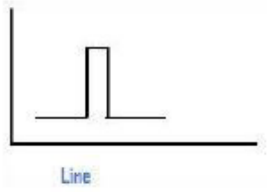
An Edge in an image is a significant local change in the image intensity, usually associated with a discontinuity in either the image intensity or the first derivative of the image intensity. An edge is the boundary between an object and the background. The edge representation of an image significantly reduces the quantity of data to be processed, yet it retains essential information regarding the shapes of objects in the scene. The various types of edge of images are

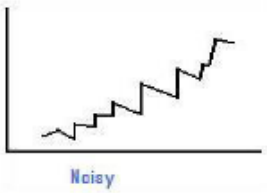
(a). Step Edge (b). Roof Edge





(c). Line Edge (d). Noisy Edge





Edge detection refers to the process of identifying and locating sharp discontinuities in an image. So, edge detection is a vital step in image analysis and it is the key of solving many complex problems.

Edge detection is a fundamental tool used in most image processing applications to obtain information from the frames as a precursor step to feature extraction and object segmentation. The edge detection have been used by object recognition, target tracking, segmentation, data compression ,and also help for well matching, such as image reconstruction and so on. Edge detection is an active area of research as it facilitates higher level image analysis. In image processing especially in computer vision, the edge detection treats the localization of important variations of a gray level image and the detection of the physical and geometrical properties of objects of the scene

The three steps in Edge detection process are

Revised Manuscript Received on February 06, 2013.

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1. **Filtering :** Images are corrupted by noise such as salt and pepper noise, impulse noise and Gaussian noise.
2. **Enhancement:** It emphasizes pixels where there is a significant change in local intensity values and is usually performed by computing the gradient magnitude.
3. **Detection:** Many points in an image have a nonzero value for the gradient, and not all of these points are edges for a particular application.

II. OBJECTIVES OF THIS STUDY

The objectives of this study are as below

1. In this paper, we identify multiple objectives associated with image segmentation problems of natural images.
2. The main aim of this paper is, provide to implement the four most important Edge Detection Techniques like Roberts Edge detection, Sobel Edge Detection, Prewitt Edge detection, and LoG Edge detection for natural image segmentation and their comparisons.

III. METHODOLOGY (EDGE DETECTION TECHNIQUES)

The major property of the Edge Detection Techniques is that its ability to extract the exact edge line with good orientation as well as more literature about edge detection has been available in the past three decades. Edge detection techniques are classified in two categories: parallel and sequential techniques. The parallel edge detection technique implies that the decision of whether a set of points are on an edge or not is dependent on the gray level of the set and some set of its neighbors, which includes high emphasis spatial frequency filtering, gradient operators, adaptive local operator, relaxation, and line and curve fitting, while the sequential edge detection techniques make decision based on the results of the previously examined points.

There are many edge detection techniques in the literature for image segmentation. Among those techniques we have used the most commonly used discontinuity based edge detection techniques for image segmentation are Roberts Edge Detection, Sobel Edge Detection, Prewitt Edge Detection, and LoG Edge Detection.

A. Roberts Edge Detection

The Roberts edge detection is introduced by Lawrence Roberts (1965). The Roberts Cross operator performs a simple, quick to compute, 2-D spatial gradient measurement on an image. The input to the operator is a gray scale image the same as to the output is the most common usage for this technique. Pixel values in every point in the output represent the estimated complete magnitude of the spatial gradient of the input image at that point. The operator consists of a pair of 2×2 convolution kernels as below

Gx		Gy	
1	0	0	1
0	-1	-1	0

Roberts Operator 2x2 Masks

The kernels can be applied separately to the input image, to produce separate measurements of the gradient component in each orientation (*Gx* and *Gy*).

The gradient magnitude is given by:

$|G| = |Gx| + |Gy|$ or by using $|G| = \sqrt{Gx * Gx + Gy * Gy}$.

The angle of orientation of the edge giving rise to the spatial gradient (relative to the pixel grid orientation) is given by:

$\theta = \arctan(Gy / Gx) - 3\pi / 4$.

The Roberts edge detector is a simple operator. The vectorization of this operator allows for a better performance on color images than of the intensity values alone.

Experiment: This technique is implemented using MATLAB and tested with the following image.

Original image

Segmented image using Roberts

B. Sobel Edge Detection

The Sobel edge detection method is introduced by Sobel in 1970. The Sobel method of edge detection for image segmentation finds edges using the Sobel approximation to the derivative. It precedes the edges at those points where the gradient is highest. The Sobel technique performs a 2-D spatial gradient quantity on an image and so highlights regions of high spatial frequency that correspond to edges. This is very similar to the Roberts Cross operator. The Sobel operator consists of a pair of 3×3 convolution kernels as below.

Gx			Gy		
-1	0	1	1	2	1
-2	0	2	0	0	0
-1	0	1	-1	-2	-1

Sobel Operator 3x3 Masks

These kernels are designed to respond maximally to edges running vertically and horizontally relative to the pixel grid, one kernel for each of the two perpendicular orientations. The kernels can be applied separately to the input image, to produce separate measurements of the gradient component in each orientation (call these *Gx* and *Gy*). These can then be combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient.

The gradient magnitude is given by:

$|G| = \sqrt{Gx * Gx + Gy * Gy}$.

Typically, an approximate magnitude is computed using:

$|G| = |Gx| + |Gy|$

The angle of orientation of the edge (relative to the pixel grid) giving rise to the spatial gradient is given by:

$\theta = \arctan(Gy / Gx)$.

Experiment: This technique is implemented using MATLAB and tested with the following image.


Original Image


Segmented Image using by Sobel

C. *Prewitt Edge Detection*

The Prewitt edge detection is proposed by Prewitt in 1970. Prewitt operator edge detection masks are the one of the oldest and best understood methods of detecting edges in images. The Prewitt edge detector is an appropriate way to estimate the magnitude and orientation of an edge. The Prewitt operator uses the same equations as the Sobel operator, except that the constant c = 1.The Prewitt operator consists of a pair of 3×3 convolution kernels as below

Gx

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

Gy

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

Prewitt operator 3×3 Masks

The Prewitt operator measures two components. The vertical edge component is calculated with kernel Gx and the horizontal edge component is calculated with kernel Gy.

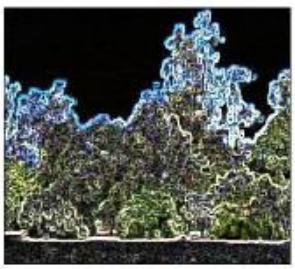
|Gx| + |Gy| give an indication of the intensity of the gradient in the current pixel.

Experiment: This technique is implemented using MATLAB and tested with the following image.

D. *LoG Edge Detection*

Laplacian of a Gaussian function is referred to as LoG. The Laplacian of Gaussian (LoG) was proposed by Marr and Hildreth (1980). The Gaussian filtering is combined with Laplacian to break down the image where the intensity varies to detect the edges effectively. The Laplacian is usually used to establish whether a pixel is on the dark or light side of an edge. The Laplacian is a 2-D isotropic measure of the 2nd spatial derivative of an image.


Original Image


Segmented Image using Prewitt

The Laplacian of an image highlights regions of rapid intensity change and is therefore often used for edge detection. The Laplacian is often applied to an image that has first been smoothed with something approximating a Gaussian Smoothing filter in order to reduce its sensitivity to noise. The operator normally takes a single gray level image as input and produces another gray level image as output. The LoG of an image f(x, y) is a second order derivative defined as,

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

It has two effects, it smoothes the image and it computes the Laplacian, which yields a double edge image. Locating edges then consists of finding the zero crossings between the double edges. The digital implementation of the Laplacian function is usually made through the mask below.

0	-1	0
-1	4	-1
0	-1	0

G_x

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

G_y

Experiment: This technique is implemented using MATLAB and tested with the following image.


Original Image


Segmented Image using LoG

IV. COMPARISONS OF THE VARIOUS EDGE DETECTION TECHNIQUES

We used different natural images to experiment using Robert, Sobel, Prewitt, and LoG Edge Detection techniques. Different edge detection techniques work better under different conditions. There are some differences between various Edge Detection Techniques for natural image segmentation as below

1) The Roberts, Sobel and Prewitt operators use the first derivative, while LoG uses Second derivative.
2) The Roberts, Sobel and Prewitt operators/Edge detections have very simple calculation to detect edges and their orientation but they have inaccurate detection sensitivity in case of noise because the subjective evaluation of edge detection result images show that under noisy condition Roberts, Prewitt and Sobel operator have poor quality.
3) The Roberts operator use 2×2 masks, while Sobel, Prewitt and LoG use 3×3 masks.
4) LOG can finding the correct places of edges and test wider area around the pixel but malfunctioning at corners, curves and where the gray level intensity function varies and it do not find the orientation of edge.
5) Prewitt is very similar to sobel but difference is that Sobel edge detector marks a lot of number of pixels while the Prewitt edge detector marks a few number of pixels.
6) From the above experiment the Sobel has better performance than other edge detection techniques.

V. MATLAB

The name MATLAB stands for matrix laboratory. MATLAB is a software program that allows us to do data manipulation and visualization, image analysis, calculations, maths and programming. It can be used to do very simple as well as very sophisticated tasks. MATLAB is a high-performance language for technical computing. MATLAB is an interactive system whose basic data element is an array that does not require dimensioning.

VI. CONCLUSION

Image segmentation is the key behind image understanding. Image segmentation is one of the most important steps leading to the analysis of processed image data. Natural-image segmentation is one of the classical problems in computer vision. There are many applications of image segmentation like Medical imaging, Treatment planning, Face recognition, Iris recognition, Fingerprint recognition etc. There are many segmentation techniques for natural images. In this paper, we used Edge Detection Techniques. Since edge detection is the initial step in object recognition, it is important to know the differences between edge detection techniques. Here, we studied the most commonly used four Edge detection techniques and they are Robert, Sobel, Prewitt, and LoG Edge Detection. The performance of various edge detection techniques is carried out with different images by using MATLAB software. Different Edge detection techniques work better under different conditions. The Sobel has better performance than other Edge Detection Techniques.

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