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A Review on Edge Detection Techniques for Image Segmentation

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Abstract*— Image segmentation is the process of subdividing an image into constituent parts or objects in the image. Segmentation is either discontinuity based or region based. Edge detection is the discontinuity based image segmentation technique. In this paper, diverse Edge Detection techniques like Canny Optimal Edge Detection, Sobel Operator, Prewitt Operator and LoG are reviewed, compared and analyzed based on the performance metrics Performance Ratio(PR), Peak signal-to-noise ratio(PSNR), Mean square error(MSE). From the results, Canny Optimal Edge detection (COE) technique provides identifies the edges effectively for noisy and complex images when compared to other techniques

Index Terms— *Image segmentation, edge detection, Sobel Operator, prewitt operator, LoG and Canny operator.*

I. INTRODUCTION

In the current scenario, the digital images play vital role in different applications such as restorations and enhancements, digital cinema, image transmission and coding, color processing, remote sensing, robot vision, hybrid techniques, facsimile, pattern recognition, registration techniques, multi-dimensional image processing, video processing, high resolution display, high quality color representation and super high definition applications. Image segmentation process is important for these digital image processing applications because the raw images are captured by the digital camera or mobile camera with nonessential background scenes or noise. The elimination of background images and noise is quite important to get accurate results. This process is a low level image engineering process which converts the raw images into segments are pixels or objects. These pixels are converted into vectors and analyzed or tested with the any one of the image segmentation process. The removal of noise from the images is performed using de-noising techniques such as filtering, enhancement, detection and localization for identifying the edges. These edges are analyzed with the help of mid and high – level image engineering processing methods. The adequate edges are identified by diverse edge detection techniques in several image processing applications such as object recognition, motion analysis, pattern recognition, computer- guided surgery, finger print recognition, automatic traffic controlling systems, anatomical structure and image processing. Detecting the edges from noisy images or corrupted images is difficult in nature. In the past two decades' several edge detection techniques or algorithms are proposed, based on that the effective edges are evaluated or analyzed. The ultimate reason behind in these methods to restrict the false detection in the edges,edge localization and computational time. In this, canny optimal detection algorithm aims to discover the optimal edge which reduces the probability of detecting false edges, and gives sharp edges.

In this paper is organized as follows: Section II discusses the image segmentation. Section III is for the purpose of providing some information about edge detection techniques and comparison between detection methodologies. Section IV discusses performance analysis.

II. IMAGE SEGMENTATION

Image Segmentation is the process of partitioning a digital image into multiple regions or sets of pixels. Essentially, in image partitions are different objects which have the same texture or color. The image segmentation results are a set of regions that cover the entire image together and a set of contours extracted from the image. All of the pixels in a region are similar with respect to some characteristics such as color, intensity, or texture. Adjacent regions are considerably different with respect to the same individuality. The different approaches are (i) by finding boundaries between regions based on discontinuities in intensity levels, (ii) thresholds based on the distribution of pixel properties, such as intensity values, and (iii) based on finding the regions directly. Thus the choice of image segmentation technique is depends on the problem being considered [1].

An edge in an image is a boundary or contour at which a significant change occurs in some physical aspect of an image, such as the surface reflectance, illumination or the distances of the visible surfaces from the viewer. Changes in physical aspects manifest themselves in a variety of ways, including changes in intensity, color, and texture.

Detecting edges is very useful in a no of contexts. For example in a typical image understanding task such as object identification, an essential step is to segment an image into different regions corresponded to different objects in the scene. Edge detection is the first step in image segmentation.

Another example is in the development of a low bit rate image coding system in which we can code only edges. It is

well known that an image that consists of only edges is highly intelligible. The significance of a physical change in an image depends on the application. An intensity change that would be classified as an edge in some application might not be considered an edge in other application.

In object identification system, an object's boundaries may be sufficient for identify and contours that represent additional details within the object may not be considered edges. An edge cannot be defined outside of the context of an application.

III. EDGE DETECTION TECHNIQUES

A. Edge analysis methods

A high amount of Semantic information about image content is conveyed by shapes of objects. The analysis of object edges which are physical basis to perceive contours and shapes plays an important role in a HVS.

In a simplistic view 'edge' is a discontinuity of amplitude. In natural images it will barely happen that an edge sharply separates two distinct plateaus of amplitude. This type of "step edges" can be found in synthetically generated graphics images. In natural images, due to shadows and reflections, the type of "ramp edges" is a better model characterized by slope width "a" and edge slope 'b' Natural edges are even more smooth as shown in figure 1. The slope is not constant over the edge such that a point of maximum slope edge can be identified[2].

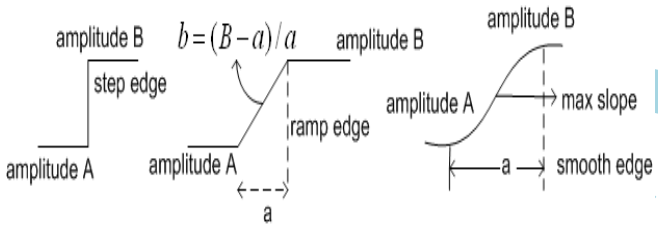

Figure 1:Types of Edges

B. Types of edge detection methods

Edge detection contains three steps namely Filtering, Enhancement and Detection. Most frequently used edge detection methods are used for comparison. These are (1) Canny Edge Detection, (2) Sobel Edge Detection (3) Prewitt edge detection and (4) LOG edge detection. The detail of methods as follows [3].

1. Canny Edge Detection

The Canny edge detection technique is one of the standard edge detection techniques. It was first created by John Canny for his Master's thesis at MIT in 1983, and still outperforms many of the newer algorithms that have been developed. To find edges by separating noise from the image before find edges of image the Canny is a very important method. Canny method is a better method without disturbing the features of the edges in the image afterwards it applying the tendency to find the edges and the serious value for threshold. The algorithmic steps are as follows:

- Convolve image f(r, c) with a Gaussian function to get smooth image f^(r, c). f^(r, c)=f(r,c)*G(r,c,6).
- Apply first difference gradient operator to compute edge strength then edge magnitude and direction are obtain as before.
- Apply non-maximal or critical suppression to the gradient magnitude.
- Apply threshold to the non-maximal suppression image.

2. Sobel Edge Detection

The Sobel edge detection method is introduced by Sobel in 1970 (Rafael C.Gonzalez (2004)). 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. In general it is used to find the estimated absolute gradient magnitude at each point in n input grayscale image. In conjecture at least the operator consists of a pair of 3x3 complication kernels as given away in under table. One kernel is simply the other rotated by 90 degree.

3. Prewitt edge detection

The Prewitt edge detection is proposed by Prewitt in 1970 (Rafael C.Gonzalez [1]. To estimate the magnitude and orientation of an edge Prewitt is a correct way. Even though different gradient edge detection wants a quite time consuming calculation to estimate the direction from the magnitudes in the x and y-directions, the compass edge detection obtains the direction directly from the kernel with the highest response. It is limited to 8 possible directions; however knowledge shows that most direct direction estimates are not much more perfect. This gradient based edge detector is estimated in the 3x3 neighborhood for eight directions. All the eight convolution masks are calculated. One complication mask is then selected, namely with the purpose of the largest module.

4.LOG edge detection

The Laplacian of Gaussian (LoG) was proposed by Marr(1982). The LoG of an image f(x,y) is a second order derivative defined as (1),

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} \quad \text{----------} \quad (1)$$

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. Table 1 illustrates the merits and demerits of these techniques.

IV PERFORMANCE ANALYSIS

The evaluation of detecting edge performance includes

- Find the feasibility of false edges.
- Calculate the Possibility of missing edges.
- Mean and square distance of the edge estimate from the true edge.
- Tolerance to distorted edges and other features such as corners and junctions.

The performance is evaluated using the following parameters such as Performance Ratio (PR), Mean Square Error (MSE) and Peak Signal to Noise Ratio (PNSR). Table

2 compares the effective performance of diverse edge detection methods.

TABLE I: COMPARISON OF VARIOUS EDGE DETECTION TECHNIQUES

S.No	Methods	Operation	Advantage	Disadvantage
1	Sobel Operator	Maximum of edges are identified with respect to perpendicular angle	Simplicity Finding of smooth edges	In accurate Average results with respire to complex images.
2	Prewitt Operator	Provide a better performance on horizontal and vertical edges in the images	Detection of edges and their orientations are high	Inaccurate. Size of the coefficient and kernel filter is fixed and cannot be changed to a given image.
3	LoG	Considers the double edge images. Continuous edges can be detected using raw images	Finding the exact edges. Checks the pixels in wider area.	Few edges cannot be detected.
4	Canny operator	Used to eliminate the noise and to find the effective edges	Finding the error rate is high. Better detection Remove streaking problem. Adaptive in nature. Good localization	False Zero crossing.

The PR is measured by,

$$PR = \frac{\text{True edge pixels identified as Edge(S)}}{\text{False edge pixelsidenified as non} - \text{edge pixels}} \text{---------- (2)}$$

To compare image compression quality MSE and PSNR is used. The PSNR and MSE are measured by the following equations (3) and (4).

$$MSE = \frac{\Sigma[I1(m,n) - I2(m,n)]}{M * N} \text{---------- (3)}$$

Where M and N are rows and column of an image is considered.

$$PSNR = 10\log_{10}\left(\frac{R^2}{MSE}\right) \text{----------}$$

(4)

R is the maximal variation in the input image data.

TABLE II : PERFORMANCE OF EDGE DETECTION METHODS

Technique	PR	MSE	PSNR
Sobel	9.884	3934	17.2154
Prewitt	9.5487	3922	17.2104
LoG	11.6908	3952	17.2118
Canny	17.1933	3969	17.2240

CONCLUSION

In this paper the various edge detection techniques are compared and their performances are analyzed. From the review, the canny edge detection algorithm produces better result when compared to other techniques.

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