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Comparative Analysis of Various Edge Detection Techniques

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Abstract— Edge detection is an important step in digital image processing and is mainly used in the application of feature extraction. One major application of edge detection is in the field of medical image processing. Edge detection is basically the process of detection of those regions in the image where there is an abrupt change in the brightness of the image. In this paper, various edge detection methods are described and compared.

Keywords— Canny edge detection, Morphology, Operators, Gradient, Laplacian

I. INTRODUCTION

Since from the last few decades, application of computer vision is enormously increasing in almost all fields of life. From sorting products in the industry, to surveillance in the security zones, car parking systems to medical image processing. Therefore, automatic visual inspection of the images is very important as it is used in industry for detecting defects in textile design, glass industry and steel rerolling mills, due to the fact that comparison of numbers is more easy than comparison of images. Thus, image analysis is very important and necessary. One main image analysis technique is the edge detection process, in which abrupt change in the image intensity is detected. Different techniques are used for detecting the edges in which the most commonly used and computationally light technique is the Linear Time Invariant filters. In case of first order filters, the aim is to find first order derivative in which its magnitude is high. The other well known techniques for edge detection are grouped mainly in two categories: search based techniques and zero crossing algorithms. In zero crossing detectors, second order derivative is computed for edge detection while in case of search based methods first order derivatives are computed. The most well known conventional methods like Sobel, Canny, Prewitt, and Laplacian belong to one of the above classes. The edge detection aims to identify points in a digital image at which the image brightness changes sharply or abruptly. Image edge detection mainly deals with extracting edges in an image by identifying pixels where the intensity variation is very high. It is a fundamental tool used in most image processing applications which is used to obtain information from the frames as a precursor step to the feature extraction and the object segmentation. The outlines of an object and boundaries between the objects in the image and the background are detected with this process. The edge is the set of the pixel, whose surrounding gray is abruptly or sharply changing. The internal characteristics of the edge which is dividing the same area are the same, where as different areas have the different characteristics. The edge is the basic feature of any digital image. There is a lot of information of the image in the edge of that image. Edge detection refers to the process in which the characteristics of discrete parts are extracted by the difference in the image characteristics of the object, and then the image area is determined according to the closed edge.

II. EDGE DETECTION TECHNIQUES

1) Sobel Operator: Sobel is the well known simple conventional edge detection technique in which 3x3 convolution masks are used for detection of the edges in *x* and *y* directions. These masks are shown in Figure 1. Both masks can be applied to the images independently and the output magnitudes are combined to find the absolute magnitude of the whole image.

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

(a) G_x

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

(b) G_y

Fig 2.1 (a-b): Sobel Masks

2) Prewitt Operator:

Prewitt edge detection method is almost similar to the Sobel operator. In this case, 3x3 masks are used to find the gradients in *x* and *y* directions. This method is suitable for images with high resolution and is computationally more efficient. Masks of Prewitt detector are shown in Figure 2.

-1	**0**	**+1**
-1	**0**	**+1**
-1	**0**	**+1**

(a) G_x

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

(b) G_y

Fig 2.2(a-b): Prewitt Masks

3) Laplacian of Gaussian:

Laplacian operator is a second order derivative operator used for in digital images for edge detection. Laplacian operator is from the zero crossing category of the edge detection techniques. The detector detects the zero crossing in the second derivative to find edges. When compared with first order derivative-based edge detection operators such as the Sobel operator, the Laplacian operator yields better results in the edge localization, But the Laplacian operator is sensitive to the noise.

The Laplacian *L(x,y)* of an digital image with intensity values of the pixels *I(x,y)* is given as :-

$$L(x,y)= \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2} \quad \text{.....(1)}$$

1	1	1
1	-8	1
1	1	1

-1	2	-1
2	-4	2
-1	2	-1

Fig2.3: Approximations to Laplacian Filters

4) Roberts Operator:

Roberts operator performs 2-D spatial measurement of the gradient on an digital image. It results in highlighting of the regions of high spatial frequency which corresponds to the edges. Being the differential operator, the Roberts operator is to approximate the gradient of an image through the discrete differentiation is obtained by calculating the sum of the squares of the differences between diagonally adjacent pixels. The cross convolution mask is shown in figure3.

+1	**0**
0	**-1**

(a) G_x

0	**+1**
-1	**0**

G_y

(b)

Fig 2.4(a-b): Roberts Mask

5) Canny Edge Detector:

Canny is another well known conventional edge detection algorithm which is popular due to its optimum performance. It is basically an optimization problem with constraints. Three different criteria are addressed in this detector i.e. localization, low error rate and single response to the single edge. These parameters were implemented by using the canny operator.

5.1 Steps in Canny Edge Detector:-

5.1.1 Convert to Grayscale :- First convert the image to grayscale using some type of RGB to grayscale conversion.

5.1.2 Noise Reduction :- Noise reduction implies some sort of blurring operations. Gaussian filter is usually used to reduce noise. Commonly used filter is 5×5 filter.

5.1.3 Compute Gradient Magnitude and Angle :- The derivatives (Dx(x, y) and Dy(x, y)) of the image in both x and y directions are calculated. Then the angle of the gradient and the gradient magnitude are also calculated. The angle of gradient is computed as follows :-

$$\theta = \arctan\left[\frac{Dx(x, y)}{Dy(x, y)}\right] \quad \text{.....(2)}$$

5.1.4 Non-Maximum Surpression :- The "non-maximal surpression" keeps only those pixels on a edge which have the maximum gradient magnitude. The maximal magnitudes should always occur right at the edge boundary, and then the gradient magnitude should always fall off with distance from the edge.

So, three pixels in a 3×3 around pixel (x, y) are examined:

• If $\theta(x, y) = 0^\circ$, then the pixels $(x + 1, y)$, (x, y), and $(x - 1, y)$ are to be considered.

• If $\theta(x, y) = 90$, then the pixels $(x, y + 1)$, (x, y), and $(x, y - 1)$ are to be considered.

• If $\theta(x, y) = 45^\circ$, then the pixels $(x + 1, y + 1)$, (x, y), and $(x - 1, y - 1)$ are to be considered.

• If $\theta(x, y) = 135^\circ$, then the pixels $(x + 1, y - 1)$, (x, y), and $(x - 1, y + 1)$ are to be considered.

If pixel (x, y) has the highest gradient magnitude out of all the three pixels which are considered, it is kept as an edge. If one of the other two pixels has a higher gradient magnitude, then pixel (x, y) is not on the "center" of the edge, thus, should not be considered as an edge pixel.

III. ADVANTAGES AND DISADVANTAGES OF VARIOUS EDGE DETECTION TECHNIQUES

The advantages and disadvantages of various edge detection techniques are explained as following :-

Operator	Advantages	Disadvantages
Classical operators like Sobel operator	Simplicity	Inaccurate, sensitive to noise
Laplacian of Gaussian (LoG)	Test wider areas around the pixels, Find the correct places of edges	Does not function properly at the corners and curves where the intensity abruptly changes
Zero Crossing operators like laplacian	Have fixed characteristics in all directions	Sensitive to noise, Respond to some of the already existing edges
Gaussian operators like Canny	Improved signal to noise ratio, Shows better detection in the noise conditions	Complex computations, Takes more time.

IV. LITERATURE STUDY

Nicolaos B. Karayiannis et.al (1999) evaluates a segmentati---on technique for magnetic resonance (MR) images of the bra- in based on fuzzy algorithms for learning vector quantization. The algorithms perform vector quantization by

updating all prototypes of a competitive network with an unsupervised learning process. The segmentation of MR images is formula- -ted as an unsupervised vector quantization process, in which the local values of different relaxation parameters form the feature vectors which are represented by a relatively small set of prototypes. The experiments evaluate a variety of these algorithms in terms of their ability to identify different tissues and helps to distinguish between normal tissues and abnormalities. [1] Mark A. Horsfield et.al (2007) proposed a method for incorporating the prior knowledge into the fuzzy connectedness image segmentation. This prior knowledge is in the form of probabilistic feature distribution and feature size maps in a standard anatomical space and "intensity hints" selected by the user that allow for a skewed distribution of the feature intensity characteristics.[2]

Wenshuo Gao et.al (2010) proposed a method in which Sobel edge detection operator and soft-threshold wavelet de-noising are combined to do edge detection on images which include the White Gaussian noises. Firstly soft-threshold wavelet is used to remove noise and then Sobel edge detection operator is used to do edge detection on the image. This method is mainly used on the images which includes the White Gaussian noises. [3] Er. Manpreet Kaur et.al (2011) proposed modified rule based fuzzy logic technique. Here, first the gradient and the standard deviation are calculated and used as input for fuzzy system and then the traditional algorithms like Sobel, Prewitt, LoG are implemented and the results are compared with modified algorithm and it was found that the proposed technique is to find the more fine edges and reduce the pixels that do not belong to the edge. [4]

C.NagaRaju et.al (2011) proposed a novel edge detection algorithm based on multi-structure elements morphology of eight different directions. Here, the eight different edge detection results are obtained by using morphological gradient algorithm respectively, and then the final edge results are obtained by using synthetic weighted method. The proposed algorithm is more efficient for edge detection than conventional mathematical morphological edge detection algorithms and differential edge detection operators. [5] K. Sai Deepak et.al (2012) proposed a two-stage methodology for the detection and classification of Diabetic macular edema **(**DME) severity from color fundus images. DME detection is carried out via a supervised learning approach using the normal fund- -us images. The feature extraction technique is introduced to capture the global characteristics of the fundus images and discriminate the normal from these images. Dise- -ase severity is assessed using a rotational asymmetry metric by examining the symmetry of macular region. [6]

Hossein Ghayoumi Zadeh et. al(2013) proposed an image analysis approach for automated detection and classification of particular cells, specially the cancer cell from normal cells. In this technique, we can also count the number of defected cells and then also find their position using image processing. The results of this analysis are useable in designing a neural network for more accurate analysis. The particular cells segre- -gation is the most important property of this work. [7] Krishan Kumar et.al proposed (2013) proposed image segme- -entation technique using the edge detection and morphologi- -ical operations and mathematical model is proposed for both the cases. [8]

Pinaki Pratim Acharjya et.al (2013) proposed a method that integrates fuzzy logic and watershed segmentation algorithm using distance transform for digital image segmentation. The proposed method has been applied to a digital image and better performance measure of contour detection has been achieved when compared with conservative watershed method. [9] Somya Saxena et.al (2013) proposed ANFIS edge detector for edge detection on the images. It involves a neuro fuzzy system with the learning capability of neural network and advantages of rule-based fuzzy system. The hybrid algorithm is used to resolve the edge detection issues with the help of least square method and gradient descent method. [10]

V. **CONCLUSION**

Edge detection is the first step in object recognition process. In this paper, we studied various edge detection techniques like Gradient-based and Laplacian-based techniques. Gradient-based techniques like Prewitt operator has a drawback that it is very sensitive to noise. Here, the size of the kernel filter and coefficients are fixed in advance and cannot be changed for a given image. The Sobel operator is also very sensitive to noise but it has advantage of being simple. Laplacian of Gaussian (Log) does not function properly at the corners and curves where the intensity changes abruptly but it helps in finding correct places of the edge. Canny edge detector is more expensive computationally as compared to Sobel's, Prewitt's and Robert's operator. But Canny edge detector also performs better than all these operators in almost all the scenarios.

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