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IMAGE EDGE DETECTION: A REVIEW

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ABSTRACT

Edge detection is basically a method an image to identifying and locating sharp discontinuities. Edge detection removes noise and filters out useless information while preserving the essential structural properties in an image. This paper introduces a classification of most commonly used algorithms for edge detection, namely Robert, Prewitt, Sobel, Laplacian of Gaussian and Canny. Upon this assessment, an edge detection method can be characterize boundaries of object and are useful features for object identification, registration and segmentation for further analysis and implementation. It has been shown that the Canny edge detection algorithm performs better compare to all operators under almost all scenarios.

Keywords: Edge Detection, Image Processing, Laplacian of Gaussian, Robert, Prewitt, Sobel, Canny Edge Detection.

I. INTRODUCTION

Digital image is composed of a finite number of elements, in which each element has a special value or position. These elements are cited to as picture elements, and pixels [1]. In Digital Image processing the form of input and output an image or a set of characteristics or parameters related to the image [1] Edge also defined in terms of binary images as the black pixels with one nearest white neighbor [2]. Edges include big amount of important data related to an image. The changes in pixel gray level describe the boundaries of objects in a picture [2]. The main areas in image processing likes Feature detection and Feature extraction in which edge detection is used as a basic tool. Image edge detection trades with drawing out of edges in an image by recognizing high gray level variations in the pixels. This action determines out lines of an object and background of the image [2]. Detection of edge helps in image reconstruction, data compression, and segmentation for an image [2, 3]. Variables convoluted for selection of an edge detection operator include edge coordination, noise environment and edge structure [4, 5]. Edge detection is challenging in noisy images, since both the noise and the edges contain high frequency concentrate.

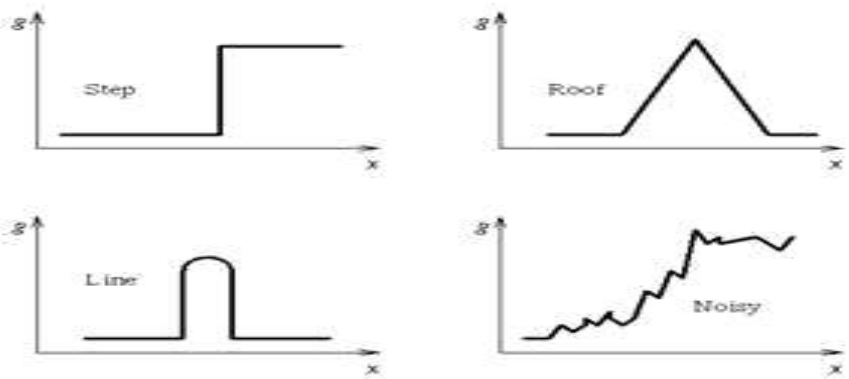

Figure 1 Typical Edge Profiles

Efforts to decrease the noise consequence are blurred and limited edges [6]. Edge detection is used mainly to extract the data about the image e.g. image enhancement and location of object present in the image, and image sharpening and also their shape, size. Depending upon variation of gray level various types of edges are shown in Figure 1.

Traditional methods of edge detection involves the image with an operator, which is made to be subtle to large gradients while returning values of zero in uniform region in an image.

1.1 Different Edge Detection Classification

Edge detection makes use of different operators to detect changes in the gradients of the gray levels. It is divided into two main classes

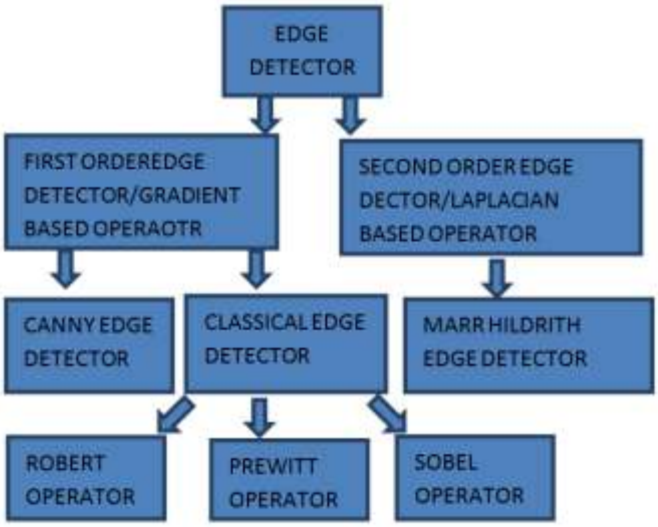

Figure 2 Types of Edge Detector

1.2 Edge Detection Flow Chart

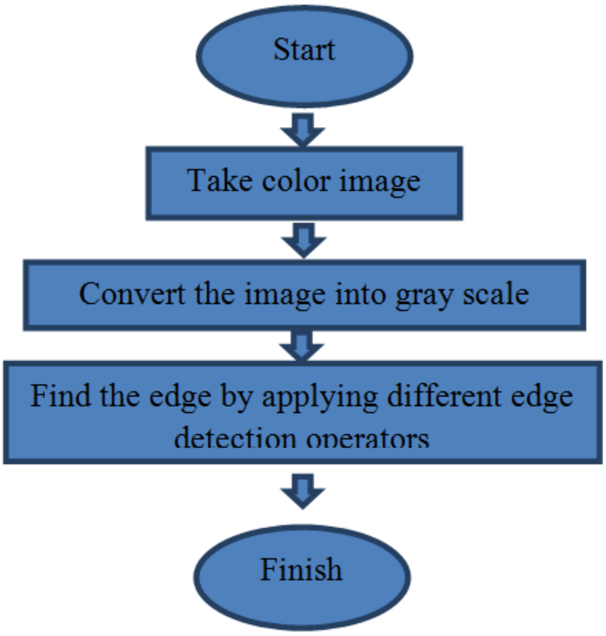

Figure 3 Flow chart for edge detection

1.3 Algorithm for Edge Detection

Step 1-Take a color image.

Step 2-Smoothing: Annihilate as adequate noise as accessible, without wrecking genuine edges.

Step 3- Enhancement: the quality of edges is enhanced by applying differentiation.

Step 4- Threshold: Apply edge magnitude threshold to determine which edge pixels should be retained and which should be discarded as noise.

Step 5- Localization: Ascertain the postulate edge bearings.

Step 6- Evaluation with the algorithms.

Step 7- Get the image after edge disclosure.

II. APPROACHES OF EDGE DETECTION

The course for edge detection is classified into two classes; first approach is gradient based and second approach is Laplacian based [10, 11]. In gradient based edges are detected by taking gradient. It calculates strength of edge by computing the gradient amplitude, and then looking for local directional maxima of the gradient amplitude using a computed estimate of the local orientation of the edge, normally the gradient direction [10, 11]. In laplacian based approaches, edges are found by searching for zero crossings in a second-order derivative expression computed from the image, usually the zero-crossings of the Laplacian or the zero-crossings of a non-linear differential expression.

2.1 Edge Detection Based on Gradient Operator

The gradient operators masks in digital images which calculate finite intensities of either horizontal or vertical directions [2]. The edge is the place where image gray value changes efficiently, so to find out for the maximum and minimum values in the gradient of the image [7, 10] and gradient operator used widely [11]. First-order derivatives in image processing are implemented using the amplitude of the gradient. For a function f(x, y), the differential of ‘f’ at coordinates (x, y) is denoted [12] as the two dimensional column vector

$$\Delta \mathbf{f} = \mathbf{G}[\mathbf{f}(\mathbf{x},\mathbf{y})] = \begin{bmatrix} \mathbf{Gx} \\ \mathbf{Gy} \end{bmatrix} = \begin{bmatrix} \frac{\partial \mathbf{f}}{\partial \mathbf{x}} \\ \frac{\partial \mathbf{f}}{\partial \mathbf{y}} \end{bmatrix} \tag{1}$$

The quantity Δf is known as the gradient of a vector. With the help of vector assessment it can be observed that the gradient vector is directing in the direction of maximum rate of change at (x, y) coordinates. The vector sum of these two gradients is assumed to be taken as the magnitude of the gradient and the angle represents the gradient angle. Magnitude of vector Δf, denoted as M(x, y):

$$\mathrm{M}(x,y) = \mathrm{magnitude}(\nabla f) =$$

$$|\mathbf{G}| = \sqrt{\mathbf{Gx}^2 + \mathbf{Gy}^2} \tag{2}$$

To simplify computation, this quantity is approximated sometimes by omitting the square root operation

$$\mathbf{M}(\mathbf{x},\mathbf{y}) = \mathbf{Gx}^2 + \mathbf{Gy}^2 \tag{3}$$

Or by using absolute values,

$$\mathbf{M}(\mathbf{x},\mathbf{y}) \approx |\mathbf{Gx}| + |\mathbf{Gy}| \tag{4}$$

The direction of the gradient is given as:

$$\theta = \tan^{-1}\left(\frac{Gx}{Gy}\right) \quad (5)$$

Here the angle is measured with reference to x-axis. The direction of the edge at any point is perpendicular to the direction of the gradient at that point.

In a 2D image the [13] gradient is given as:

$$Gx = f(x+1, y) - f(x, y) \quad (6)$$

And

$$Gy = f(x, y+1) - f(x, y) \quad (7)$$

In this edge detection approach the edges are understood high gradient pixels. A derivative of gray level at some direction given by the angle of the gradient vector is beheld at edge pixels. Let Figure 4, denotes the intensities of image points in a 3x3 region. The center point z5 denotes f(x, y) at subjective location (x, y) [1].

Z_1	Z_2	Z_3
Z_4	Z_5	Z_6
Z_7	Z_8	Z_9

Figure 4 Intensities of image points in a 3x3 region [1]

Here intensities Z_1 denotes f(x-1, y-1), Z_2 denotes (x-1, y), Z_3 denotes (x-1, y+1), Z_4 denotes (x, y-1), Z_6 denotes (x, y+1), Z_7 denotes (x+1, y-1), Z_8 denotes (x+1, y), Z_9 denotes (x+1, y+1) [1].

An edge pixel is determined using two crucial features [10, 14].

- In which edge strength is equal to the magnitude of the gradient.
- In which edge direction is equal to the angle of the gradient.

In the process step, we will learn gradient based Roberts edge detector, Prewitt edge detector and Sobel edge detector, Laplacian of Gaussian detector.

2.2 Robert Detector

The Roberts cross operator provides a simple proximity of 2 × 2 mask

G_x=

-1	0
0	1

$G_{y=}$

0	-1
1	0

Figure 5 Convolution masks for Roberts operator [1]

The two masks can be applied separately for the horizontal and vertical edges on the image, results in separate analysis of the two gradient components Gx and Gy in the directions, perpendicular and parallel, is determined respectively [1]:

$$Gx = (Z_9 - Z_5)$$

$$Gy = (Z_8 - Z_6) \quad (8)$$

Masks of even sizes are awkward to implement because they do not have a center of symmetry [1]. Further equation above can be written as given below

$$G[f(x,y)] = [f(x,y) - f(x+1, y+1)] + [f(x+1, y) - f(x, y+1)] \quad (9)$$

The gradient magnitude is given by:

$$G[f(x,y)] = \sqrt{Gx^2 + Gy^2} \tag{10}$$

The approximate magnitude is given by:

$$G[f(x,y)] = |Gx| + |Gy| \tag{11}$$

Here Gx and Gy are calculated using the masks shown in Figure 4. The angle of orientation of the edge (relative to the pixel grid) giving rise to the spatial gradient is given by

$$\theta = \arctan\left(\frac{Gy}{Gx}\right) - \frac{3\pi}{4} \tag{12}$$

The differences are to be intended at the interpolated point [i + 1/2, j + 1/2]. The Roberts operator is a proximity to the ceaseless gradient at this interpolated point and not at the point [i, j] as might be apprehend [14, 15]. The smallest filter mask in which we are interested are of size 3x3.

2.3 Prewitt Detector

The prewitt operator uses the same equations as the Sobel operator, other than the constant c =1. Therefore the convolution masks for the horizontal and vertical edges for the Prewitt operator shown in Figure 6

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

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

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

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

Figure 6 Mask for Prewitt Operators [7]

The Prewitt filter is corresponding to Sobel filter. Note that, contrary the Sobel operator, this operator does not place any prominence on pixels that are closer to the center of the masks [14].Classical operators are simple in which detection of edges & their orientation are possible but classical operators are sensitive to noise, and are in accurate.

2.3 Sobel Detector

The Sobel detector is one of the most frequently used in edge detection [16]. Sobel edge detection can be implemented by filtering an image with left mask or kernel. Filter the image again with the other mask. After this square of the pixels values of each filtered image. Now add the two results and compute their root. The 3 × 3convolution masks for the Sobel based operator for the horizontal and vertical edges as shown in Figure 7 [1]

G_x

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

Gy=

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

Figure 7 Convolution Masks for the Sobel Operator [1, 7]

The difference is taken between the 3rd and 1st rows of 3x3image region is implemented by the left mask of figure 6approximates the partial derivative in x-direction. The difference between the 3rd and 1st columns in the other mask approximates the derivative in y direction [1].

Here the partial derivatives are to be intended by

$$\mathbf{Gx} = (z_7 + cz_8 + z_9) - (z_1 + cz_2 + z_3)\mathbf{Gy} = (z_3 + cz_6 + z_9) - (z_1 + cz_4 + z_7) \qquad (13)$$

With the constant c = 2. Further above equation can be written as given below

$$\mathbf{Gx} = [f(x+1, y-1) + 2f(x+1, y) + f(x+1, y+1)] - [f(x-1, y-1) + 2f(x-1, y) + \quad f(x-1, y+1)](14)$$

and

$$Gy = [f(x-1, y+1) + 2f(x, y+1) + f(x+1, y+1)] - [f(x-1, y-1) + 2f(x, y-1) + \quad f(x+1, y-1)](15)$$

The magnitude of the gradient computed by

$$G[f(x,y)] = \sqrt{Gx^2 + Gy^2} \qquad (16)$$

The angle of orientation of the edge giving boost to the spatial gradient is given by

$$\theta = \arctan\left(\frac{Gy}{Gx}\right) \qquad (17)$$

2.4 Edge Detection Based on Laplacian Detection

To find edges the Laplacian method searches for zero crossings in the second derivative of the image. The gradient operator as presented earlier is anisotropic, i.e., they are rotation invariant [13]. An isotropic operator is one which before and after the resultant image is having no effect on the image. However, calculating 2nd derivative is very sensitive to noise. Before edge detection, this noise should be filtered out. To accomplish this, “Laplacian of Gaussian” is used [14].

III. LAPLACIAN OF GAUSSIAN

Laplacian of gaussian is also known as Marr-Hildreth Edge Detector. Laplacian of Gaussian function is referred to as LoG.

In this approach, firstly noise is condensed by involving the image with a Gaussian filter. After that isolated noise points from the image information and small structures are filtered out with smoothing. Those pixels, that have locally maximum gradient, are contemplated as edges by the edge detector in which zero crossings of the second derivative are used. Only the zero crossings, whose corresponding first derivative is above some threshold, are selected as edge point in order to avoid detection of irrelevant edges. By using the direction in which zero crossing occurs we can obtain the edge direction [14]. The 2-D LoG function centred on zero and with Gaussian standard deviation ó has the form

$$\mathbf{LoG}(x,y) = -\frac{1}{\pi\sigma^4}\left[1 - \frac{x^2+y^2}{2\sigma^2}\right]\epsilon^{-\frac{x^2+y^2}{2\sigma^2}} \quad (18)$$

A three dimensional plot given by the LOG Function is shown in Figure

Figure 8 2-D Laplacian of Gaussian (LoG) function [7]

Unlike the Sobel edge detector, the Laplacian edge detector uses only one mask. It can compute second order derivatives in a one pass. The mask used for it is shown in Figure 9.

0	1	0
1	-4	1
0	1	0

1	1	1
1	-8	1
1	1	1

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

Figure 9 Three Commonly Used Discrete Approximation to the Laplacian Filter [7]

Figure 10

3.1 Detection Using Roberts

The Roberts approach finds edges using the Roberts approximation to the gradient. It returns edges where the gradient of the image is maximum at those points. Results of applying this filter to Figure 10 are displayed in Figure 11.

Figure 11: Roberts edge of Figure 10

3.2 Detection Using Prewitt Filter

The Prewitt approach finds edges using the Prewitt approximation to the derivative. It returns edges where the gradient of the image is maximum at those points. Results of applying this filter to Figure 10 are displayed in Figure 12

Figure 12: Prewitt edge map of Figure 10

3.3 Detection Using Sobel Filter

As mentioned before, the Sobel approach finds edges using the Sobel approximation to the derivative. It returns edges where the gradient of the image is maximum at those points. Figure 13 displays the results of applying the Sobel approach to the image of Figure 10

Figure 13: Sobel edge of Figure 10

3.4 Detection Using Laplacian of Gaussian

The Laplacian of Gaussian approach finds edges after filtering the image with the Laplacian of Gaussian filter by looking for zero crossings. The edge map is shown in Figure 14

Figure 14: Laplacian of Gaussian edge of Figure 10

3.5 Detection Using Canny Approach

The Canny approach finds edges by looking for localmaxima of the gradient of the image. The gradient is calculated using the gradient of the Gaussian filter. The approach uses two thresholds to detect strong and weak edges, and includes the weak edges in the output only if they are associated to strong edges. This approach is therefore less likely than the others to be "fooled" by noise, and more likely to detect true weak edges. In figure 15 illustrates these points where are the result of applying this approach to the image of Figure 10

Figure 15: Canny edge of Figure 10

IV. CONCLUSION

In this paper, we have analyzed the behavior of edge detection capability for images using zero crossing operators and gradient operator. The approaches are useful to the whole image. No specific surface or form is specified. The objective is to investigate the effect of the various approaches applied in finding a representation for the image under various approach studies. On visual perception, it can be shown clearly that the Roberts Prewitt and Sobel, provide low quality edge relative to the others. A representation of the image also be obtained using the Canny and Laplacian of Gaussian approaches. Among the various approaches investigated, the Canny process is capable to detect both weak and strong edges, and seems to be more suitable than the Laplacian of Gaussian. A statistical analysis of the performance gives a robust conclusion of an image.

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