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Comparison of Edge Detection Technique in Image Processing Techniques

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ABSTRACT

Edge detection refers to the process of identifying and locating sharp discontinuities in an image. The discontinuities are abrupt changes in pixel intensity scene. Traditional method of edge detection involves convolving the image with an operator (2-D filter) which is constructed to be sensitive to large gradients. Edge detectors form a collection of very important local image processing method to locate sharp changes in the intensity function. Edge detection is an important technique in many image processing applications such as object recognition, motion analysis, pattern recognition, medical image processing etc. This paper shows the comparison of edge detection techniques under different conditions showing advantages and disadvantages of the selected algorithms. This was done under Matlab. Further work would be to develop a novel algorithm using the working on the disadvantages and advantages of the existing one to create a novel edge detector..

Keywords: *Edge detectors, Image Processing, Pattern recognition, Object Recognition***.**

1. INTRODUCTION

Edge detection is the process of identifying and locating sharp discontinuities in an image. The discontinuities are abrupt changes in pixel intensity which characterizes boundaries of objects in a scene [8].Edge detection is one of the most frequently used techniques in digital image processing [9]. The boundaries of object surfaces in a scene often lead to oriented localized changes in intensity of an image called edges [10].Classical methods of edge detection involves convolving the image with an operator (2-D filter) which is constructed to be sensitive to large gradients in the image while returning values of zero in uniform regions. Edge detection technique also transforms images benefiting from changes in grey tones in the image. Edges are signs of lack of continuity and ending as a result of this formation the edge is obtained without encountering any changes in physical qualities of image [1], [2]. There are extremely large numbers of edge detection operators available each designed to be sensitive to certain edges [8].Edge detection is difficult to implement in noisy images, since both noise and edges contains high frequency content [8]. Edge detection operator needs to be chosen to be responsive to gradual change which results from refraction or poor focus of the object with boundaries. This prevents problems of false edge detection, missing true edges, edge localization, and high computational time. Hence the objective for comparison of the various edge detection techniques and analysis of the performance of the various techniques under different conditions.

The rest of this paper is organized as; Section 2 presents the Variables involved in selection of Edge detection, this is followed by Edge detection background in Section 3 and Section 4 presents the Edge detection Techniques. Section 5 presents the comparison of the various Edge detection techniques and Finally Section 6 Concludes the paper.

2. THE VARIABLES INVOLVED IN EDGE DETECTOR SELECTION

There are certain types of edge variables involved in choosing a sensitive edge detector they include:

a) Edge Orientation: - the geometry of the operator determines a characteristic direction in which it is most sensitive to edges. Operator can be optimized to look for horizontal, vertical or diagonal edges.

b) Noise Environment:-edge detection is different in noisy images. Since both noise and edges contain high frequency content, attempt to reduce the noise result in blurred and distorted edges. Operators used on noisy images are typically larger in scope so they can average enough data to discount localized noisy pixels. This result in less accurate localization of the detached edges.

c) Edge Structure: - not all edges involve step change in intensity effects such as refraction or poor focus can result in objects with boundaries defined by gradual change in intensity. The operator needs to be responsive to such gradual change, so we do not have problems of false edge detection, missing true edges, edge localization, and high computational time.

Edge detection is one of the most frequently used techniques in digital image processing [9]. The boundaries of object surfaces in a scene often lead to oriented localized changes in intensity of an image called edges [10]. Edge detection is a difficult task, hence the objection for the comparison of various edge detection techniques and analysis of the performance of the various techniques under different conditions.

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3. EDGE DETECTOR BACKGROUND

Edge detection is a tool used in most image processing application. Edge detection is an important technique in applications like object recognition, motion analysis, and pattern recognition. There are many ways to perform edge detection however majority of the different method can be grouped into two major categories:-

(a) *Gradient*-the gradient method detects the edges by looking for the maximum and minimum in the first derivative of the image.

(b) *Laplacian*- the Laplacian method searches for zero crossing in the second derivative of the image to find edges.

Various detection method have been developed over the years, these techniques can be classified into pixel-level and sub pixel level edge detection. Early detection method employed local operators to approximately compute the first derivative of grey level gradient of an image in spatial domain. The location of local maximum of the first derivative and considered to be edge points Prewitt and Sobel operators are examples of gradient based edge detections [3],[4] Marr and Hildreth [5] proposed the Laplacian of Gaussian (LOG) for edge detection which uses Gaussian function for image smoothing, then calculates second derivative. The zero crossing point is considered to be edge points. Canny operator gives the information of both intensity and direction [6]. All method mentioned above are pixel-level edge detection capable of detecting edge fast but low precision. One of the earliest techniques for sub-pixel edge detection was proposed by Hueckel. He determined edge parameters by fitting image data to a Hilbert space of nine points and then the point is declared as an edge point, if the computed edge parameter values for that point are sufficient close to the ideal edge model [7]. In this paper emphasis was not placed on sub pixel level and the techniques compared are pixel level based edge.

3.1. Steps Involved in Edge Detection

Edge detection consist of three major step which are filtering, enhancement and detection

(a) Filtering:-images are often corrupted by noise which is a variation on intensity values, common types of noise are salt and pepper, impulse and Gaussian noise. Salt and pepper noise contains random variation of both black and white intensity values. However the more filtering done to reduce noise result in loss of edge strength [11].

(b) Enhancement: - to facilitate the detection of edges, it is important to determine changes in intensity in the neighborhood of a point. Enhancement emphasizes pixels where there is significant change in local intensity values and it's performed by computing the gradient magnitude [12].

Detection:-points in image have a non-zero value for the gradient and not all of these points are edges for a particular application. So a method is created to determine which points are edge points. Frequently, Thresholding provides the criteria used for detection [13].

4. EDGE DETECTION TECHNIQUES

There are different edge detection techniques available the compared ones are as follow:-

(a) Sobel Operator

Sobel operator is one if the pixel based edge detection algorithm. It can detect edge by calculating partial derivatives in 3 x 3 neighborhoods. The reason for using Sobel operator is that it is insensitive to noise and it has relatively small mask in images. Figure one shows the convolution kernel, one kernel is simply the other rotated by 90^{0}. These kernels are designed to respond 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 input image to produce separate measurement of gradient component in each orientation which can be combined to find the absolute magnitude of gradient at each point.

The partial derivatives in **x** and **y** direction is given as follows:-

$$S_x = \{f(x+1, y-1) + 2f(x+1, y) + f(x+1, y+1)\} - \{f(x-1, y-1) + 2f(x-1, y) + f(x-1, y+1)\} \quad (1)$$

$$S_y = \{f(x-1, y+1) + 2f(x, y) + f(x+1, y+1)\} - \{f(x-1, y-1) + 2f(x, y) + f(x+1, y-1)\} \quad (2)$$

The gradient of each pixel is calculated using:-

$$g(x, y) = \sqrt{(s_x^2 + s_y^2)} \quad (3)$$

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

Gx

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

Gy

Figure 1. Mask of Sobel

(b) Robert Cross operator

The Robert Cross operator performs a simple and quick 2-D spatial gradient measurement on an image. The operator consists of a pair of 2 x2 convolution kernel as shown in figure two. These kernels are designed to respond maximally to edges running at 45^{o} 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 measurement of the gradient component in each orientation these can then be combined together to find

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the absolute magnitude of the gradient at each point and orientation of the gradient is represented by:

$$localization = \frac{1}{\sqrt{E\left[x_o^2\right]}} = \frac{\left|\int_{-w}^{w} G'(-x)\, f'(x)dx\right|}{n_0\sqrt{\int_{-w}^{w} f'^2(x)dx}} \qquad (4)$$

+1	0
0	-1

Gx

0	+1
-1	0

Gy

Figure 2. Robert Cross kernel

(c) Prewitt Detection

The Prewitt Operator is similar to the Sobel operator and it is used for detecting vertical and horizontal edges in images [14]. The Prewitt edge detector is an appropriate way to estimate the magnitude and orientation of an edge. The Prewitt operator is limited to eight possible orientations [10] although most direct orientation estimates are not exactly accurate. The Prewitt operator is estimated in the 3 x 3 neighborhood for eight directions. The entire eight masks are calculated then the one with the largest module is selected.

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

0°

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

45°

Figure 3.Prewitt Mask.

(d) Canny Operator

Among the edge detection already discussed, the (4) Canny edge detector is the most rigorously defined operator and is widely used. In 1986, John Canny defined a set of goal for edge detection and described an optimal method for achieving them; canny specified three issues that an edge detector must address [6], they include:-

- *Good detection (low error rate):* The edge detector should respond only to edges and should find all of them, no edges should be missed. This is explained with the equation below:-

$$SNR = \frac{\left|\int_{-w}^{w} G(-x)\, f(x)dx\right|}{n_0\sqrt{\int_{-w}^{w} f^2(x)dx}} \qquad (6)$$

Where ***f*** is the filter, **G** is the edge signal; denominator is the root-mean-squared (RMS) response to noise n(x) only.

- *Good spatial localization:* - the distance between the edge pixel as found by the edge detector should be possible. It measures the increase as localization improves using the reciprocal of the root-mean-squared distance of the marked edge from the Centre of the true edge; it is expressed with the equation below.

$$localization = \frac{1}{\sqrt{E\left[x_o^2\right]}} = \frac{\left|\int_{-w}^{w} G'(-x)\, f'(x)dx\right|}{n_0\sqrt{\int_{-w}^{w} f'^2(x)dx}} \qquad (7)$$

- *Good Response Rate*: - the edge detector should identify multiple edge pixels where only a single edge exists. Only one response to a single edge, this is implicit in the first criterion, but made explicit to eliminate multiple response. The first two criteria can be trivially maximized by setting f(x) =G (-x).

A typical implementation of the canny edge detector follows the step below.

- Smooth the image with appropriate Gaussian filter to reduce desired image details.
- Determine gradient magnitude and gradient direction at each pixel
- If the gradient magnitude of a pixel is larger than those of its two neighbors in the gradient direction, mark the pixel as an edge otherwise; mark the pixel as the background.
- Remove the weak edges by hysteresis Thresholding

To ensure that closed edge contours are obtained one may use the zero crossings of the Laplacian of Gaussian (LOG) of the image.

5. COMPARISON OF DIFFERENT DETECTION TECHNIQUES.

Edge detection was performed on the image shown in figure 4, this was done using Matlab and the four algorithms discussed above were all implemented on the image shown in figure 4.

Figure 4. Image use for edge detection analysis

The image is a Matlab image (wheel.gif). Figure 5 shows the result of the four algorithms analyzed. From edge detection performed in figure 5, Canny yielded the best result. This was expected as Canny uses probability for finding error rate and localization. Also Canny yields the thin lines for its edges by using non-maximal suppression. It also utilizes hysteresis with Thresholding hence it produces better detection.

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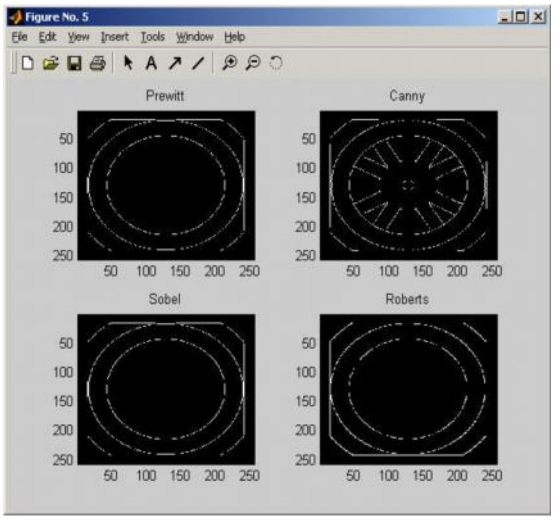

Figure 5. Result of Edge detection

5.1 Advantages and Disadvantages of Edge detectors

An edge detector has its advantages and disadvantages. The classical operators such as Sobel and Robert Cross which uses first derivative has very simple calculations to detect edges but its limitations are inaccurate detection. Since edge detection is a fundamental step in computer vision and image processing it is necessary to point out true edges. Hence it is important to choose an edge detector that best fits the application. A summary of advantages and disadvantages is given in the table below [5], [7] and [15-21].

Table 1. Summary of the Advantages and Disadvantages of the various Edge detectors.

Operator	Advantages	Disadvantages
Classical operators such as Sobel, Prewitt, Robert Cross	Simplicity, detection of edges and their orientations	Sensitivity to noise, Inaccurate.
Canny	Using probability for finding error rate, localization and response, improving signal to noise ratio, better detection, insensitive to noise	Expensive computation, false zero crossing, time consuming. Complex.

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