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RESEARCH ARTICLE

A CONVENTIONAL STUDY OF EDGE DETECTION TECHNIQUE IN DIGITAL IMAGE PROCESSING

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ABSTRACT: Edge detection is a process of identifying and detecting sharp discontinuities in an image. The discontinuities are abrupt changes in pixel intensity gray level value. The traditional method of edge detection involves convolving the image with an operator (2- D filter) which is constructed to be sensitive to noise. Edge detector is a collection of very important local image processing method to locate sharp changes in the intensity value. 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 these algorithms. This was done under Matlab. Further work would be to detection of liver tumor with the help of new developed algorithm.

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

I. INTRODUCTION

Edge detection is one of the most important techniques that have been commonly implemented in image processing. It is used in image segmentation, registration and identification of image processing. The concept of the edge in an image is the most fundamental feature of the image because the edge contains valuable information about the internal objects inside image. Hence, edge detection is one of the key research works in image processing. Edge detection of an image is a very important step towards understanding image features. Therefore, other image processing applications such as segmentation, identification, and object recognition can take place whenever edges of an object are detected. There are some techniques developed to achieve this task such as Sobel, Prewitt, Laplacian, Laplacian of Gaussian (LOG), and Canny which is used to be the optimal edge detector.

Edge detection is difficult to implement in noisy images, since both noise and edges contains high frequency content. 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 edge detection preliminaries, 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 as implementation and Finally Section 6 Conclude the paper.

II. EDGE DETECTION PRELIMINARIES

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

- *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.
- *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.
- *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. The boundaries of object surfaces in a scene often lead to oriented localized changes in intensity of an image called edges. 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.

III. BACKGROUND

Edges consist of meaningful, significant information and features. Applying an edge detector to an image may reduce the amount of data to be processed and may the filter out information that may be regarded as less relevant, while preserving the structural properties of an image. The essential notion of the majority edge detectors is to determine some boundary information in an image that represents the image's interior objects. According to [5], edge is a set on connected pixels that lie on the boundary between two regions. Also, an edge in an image is a contour across which the brightness of the image changes suddenly in amount [14]. Edge refers to the pixel set whose gray level or gradient direction sudden change and usually evinces linear feature [9]. Generally, an edge is defined as the borderline pixels that connect two mutually exclusive regions which differ in their luminance and tristimulus values [16]. The edge of an object is reflected in the discontinuity of the gray [5]. Hence, the fundamental method of edge detection is the local operator edge detection method. In this method, pixel in a region must be compared with its neighbors for the differences in order to detect the edge [5]. The detection operation starts with the inspection of the local discontinuity at each pixel in the region. Consequently, the determination of an edge is based on some characteristics that are amplitude, location and orientation of a region [3]. Therefore, based on these characteristics, the investigator has to examine each pixel to determine whether it is an edge or not [16].

There are many ways to perform edge detection however majority of the different method can be grouped into two major categories:-

- *Gradient***-** The gradient method detects the edges by looking for the maximum and minimum in the first derivative of the image.
- *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 [1],

[11] 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 [15]. In this paper emphasis was not placed on sub pixel level and the techniques compared are pixel level based edge.

Steps Involved in Edge Detection

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

- *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 [15].
- *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 [20].
- *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 [14].

IV. EDGE DETECTION TECHNIQUES

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

- *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:

  Sx = {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)}--------------------(1)

  Sy = {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)} -----------------------(2)

The gradient of each pixel is calculated using:-

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

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

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

- *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 45o 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 the absolute magnitude of the gradient at each point and orientation of the gradient is represented by:

$$\text{Localization} = \frac{1}{\sqrt{(E[x_0^2])}}$$

$$= \frac{\vdots \int_{-w}^{w} g'(-x) f'(x) dx \vdots}{n\sqrt{\int_{-w}^{w} f''(x) dx}}$$

+1	0
0	-1

0	+1
-1	0

- *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

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

- *Canny Operator:* Among the already discussed edge detection algorithm, the Canny edge detection algorithm is the 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, they include [8] --
  - *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:-

$$SNR = \frac{\vdots \int_{-w}^{w} G(-x) f(x) dx \vdots}{n0\sqrt{\int_{-w}^{w} f^2(x) dx}}$$

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.

$$Localization = \frac{1}{\sqrt{E[x_0^2]}}$$

$$= \frac{\left|\int_{-w}^{w} g'(-x) f'(x)\,dx\right|}{n\sqrt{\int_{-w}^{w} f''(x)\,dx}}$$

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.

V. IMPLEMENTATION

Edge detection was performed on the image shown in figure 1 as original image, this was done using Matlab 8.0 (R2013a) and the three algorithms discussed above were all implemented on that image. The result of these algorithms is shown below figure.

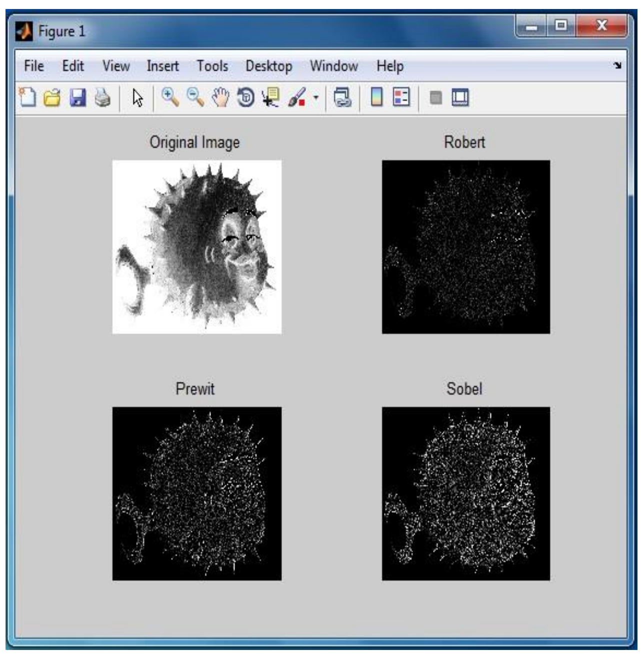

Figure 1: Result of Robert, prewit and Sobel edge detector

Canny edge detector: Canny edge detection was also performed on same image and result was shown in below figure 2. Canny yielded the best results. The result of canny edge detector contains gradient along X-direction and Y-direction then normal of gradient. Canny also utilizes hysteresis with Thresholding and then apply thinning operation.

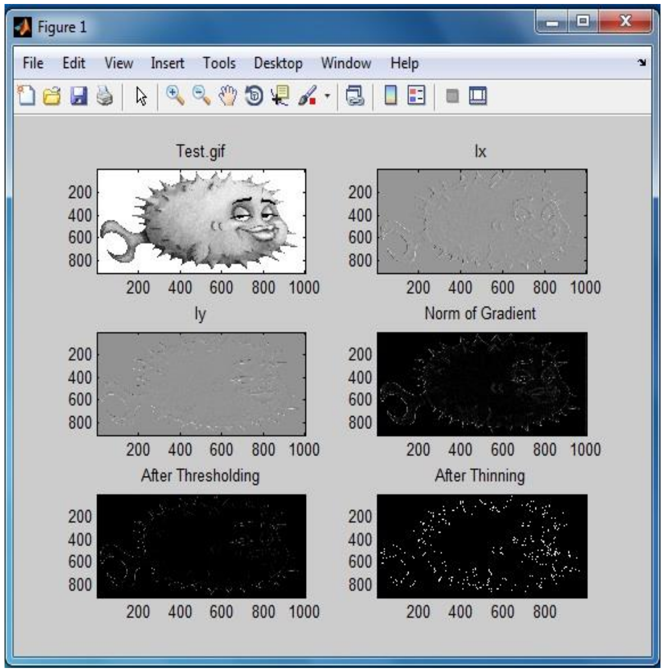

Figure 2: Result of canny edge detector

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 [2], [5], [10], [11], [12], [13], [16], [18] and [21].

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

Operator	**Advantage**	**Disadvantage**
Classical operators such as Sobel, Prewitt, Robert	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.

VI. CONCLUSIONS

Since Edge detection is one of the most important techniques that have been commonly implemented in image processing. It is used in image segmentation, registration and identification of image processing. It is very important to know the differences between edge detection techniques. In this paper we studied the most commonly used edge detection techniques of Gradient-based and Laplacian based Edge Detection. The software is developed using MATLAB 8.0 (R2013a).

Gradient-based algorithms such as the Prewitt filter have a major drawback of being very sensitive to noise. The performance of the Canny edge detection algorithm depends heavily on the adjustable parameter sigma (σ). The bigger the value for σ, the larger the size of the Gaussian filter becomes. This implies more blurring, necessary for noisy images, as well as detecting larger edges. As expected, however, the larger the scale of the Gaussian, the less accurate is the localization of the edge.

Canny's edge detection algorithm is computationally more expensive compared to Sobel, Prewitt and Robert's operator. However, the Canny's edge detection algorithm performs better than all these operators under almost all scenarios. Evaluation of the images showed that under noisy conditions, Canny, LoG, Sobel, Prewitt, Roberts's exhibit better performance, respectively.

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