COMPARISON OF VARIOUS EDGE DETECTION ALGORITHMS

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Abstract— **Recent advances in network and multimedia technologies have made the storage, access, and editing of digital contents more convenient. The availability of digital contents along with the generality of manipulation technologies have led to serious security concerns and handling needs. Consequently, digital contents are not considered as genuine evidence anymore due to the ease of forgery and manipulation. Such manipulations often corrupt images and sometimes the perfect reconstruction is may not be so easy. The filters are used in the process of characteristic the image by locating the sharp edges that are discontinuous. These discontinuities bring changes in pixels intensities which outline the boundaries of the item. So it is necessary to have some edge detecting tools for reconstructing the manipulated images. Since there are various types of edge detecting algorithms, need of comparison among these based on some parameters is essential. This paper is to compare various edge detection techniques for various images. The main process involved here is to detect edges of various captured images by using Roberts, Priwitt, Sobel and Canny edge detection techniques and evaluate their performance to find better algorithm.**

Index Terms— ***Peak signal to noise ratio (PSNR), Performance ratio (PR).***

I. INTRODUCTION

Digital image processing is a quickly developing field and it has found enormous applications in satellite imaging, medical imaging, camera imaging etc. Edge detection plays a major role in digital image preprocessing for object detection. One of the fundamental parts of image processing is edge detection. Edges are the boundaries between object and background. It is basically the image segmentation process which divides the spatial domain and converts the image into significant parts. With the help of edge detection one can easily detect the features of an image which indicates the end of one region in the image and beginning of another indicating the change in gray level. Edges enclosed much information especially the shape information. Edges in an image are sudden change in intensity values of images. By just seeing at the variation in the intensity values we can reach at the conclusion that this point or pixel is of edge. But now the question is that in which ways the intensity values can be varied.

There are four ways changes in intensity will occur and based on that it can conclude which type of edge is present. These are the following:

a) Step edge, b) Line edge, c) Ramp edge, and d) Roof edge.

Edge detection is the best method to detect the discontinuity in grey level images. The filters are used in the process of identifying the image by locating the keen edges which are intermittent. These discontinuities also make changes in pixels intensities which define the boundaries of the object. So it is required to have some edge detecting tools for recreating the manipulated images [3]. There are various algorithms available for edge detection and these are classified into three main categories:

a) First Order Derivative / Gradient Methods
- Roberts Operator
- Sobel Operator
- Prewitt Operator

b) Optimal Edge Detection
- Canny Edge Detection

c) Second Order Derivative
- Laplacian
- Laplacian of Gaussian
- Difference of Gaussian

The main purpose of studying various edge detection techniques is to overcome the problems such as missing true edges, fake edges, malfunctioning at the corners and curves etc which are encountered throughout the analysis of edges of a picture. This paper familiarize various edge detection techniques to extract out the edges efficiently and comparing these techniques with various parameters like number of edges detected, performance ratio, F-measure and peak signal to noise ratio (PSNR).From this comparison, get some conclusion to find the best edge detection technique.

II. EDGE DETECTION

Edge is defined as the area of significant change in the image intensity/contrast. Locating areas with strong intensity contrasts is called edge Detection. Now it is also possible that a certain pixel can satisfy any variation and we can mistook it for an edge. Various situations can lead to that for instance in poor lighting conditions or a noise can occur which can show all the characteristics of an Edge. So we have to be more cautious about variations showing points (pixels) are edges[4].

STEPS IN EDGE DETECTION

Fig. 1 shows block diagram shows the major steps in edge detection. When input image goes through four processes gives the edges of an image[2].

Filtering – Filter image to enhance the performance of the Edge Detector with respect to noise

Enhancement– Apply differentiation to reinforce the quality of edges (i.e., sharpening).

Detection – Identify edges – thresholding is to determine which edge pixels should be discarded as noise and which should be retained.

Localization – Locate the edge accurately. Its objective is to find from the entire candidate's edge points the true member of edge.

EDGE DETECTORS

Here we discuss about two methods of edge detection.

1. Gradient method
2. Optimal edge detection method

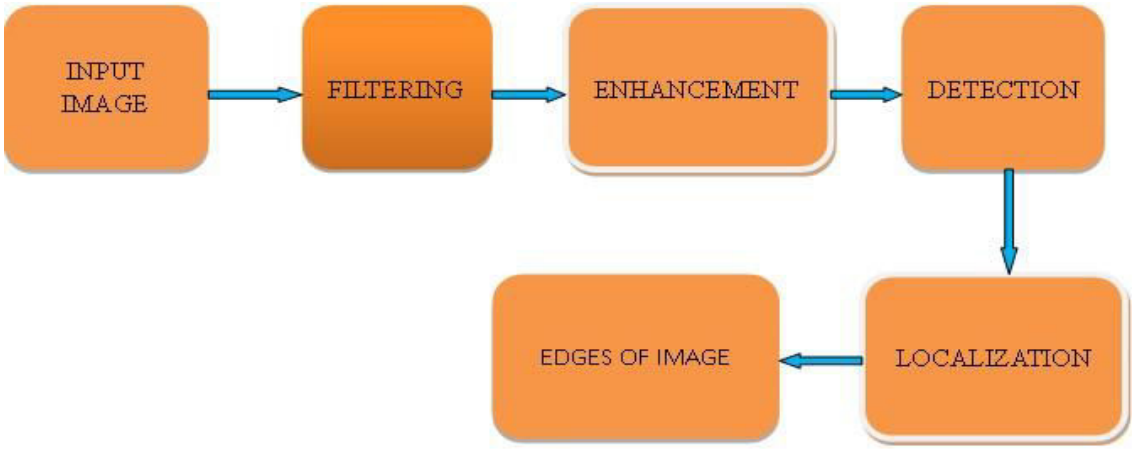


Fig. 1 Block diagram of Edge detection

Gradient method: Gradient based classical operators are used for finding edge strength and direction which are easy to operate but are highly sensitive to noise. Robert, sobel, prewitt can be classified as classical gradient based operators. The gradient based edge detections finds the first derivative of an image where the maxima and minima are occur.The gradient is a vector and so it has magnitude and direction .For a continuous two dimensional function Gradient is explained as,

$$\mathrm{G}[f(x,y)] = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix} \quad (1)$$

Where

$$|G| = \sqrt{Gx^2 + Gy^2} \approx |Gx| + |Gy| \quad (2)$$

It is the magnitude of gradient gives the strength of edge.

$$\Theta = \tan^{-1}\left(\frac{G_y}{G_x}\right) \quad (3)$$

It is the direction that indicates edge direction [2].The various edge detection methods using gradient method is described below:

SOBEL OPERATOR

Sobel operator applies two dimensional spatial gradient measurements on an image and also highlights spatial component that belongs to an edge. The operator holds a two 3×3 convolution mask to find the gradient between two directions (i.e. row and column orientation). For obtaining gradient component in each direction, the mask is used over an image separately i.e. $G_x$andG_y [4]. The Sobel Operator uses the common masks, $G_x$and G_y is shown in fig.2.

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

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

Gx **Gy**

Fig. 2 3×3 Convolution mask for Sobel operator

The edges detected by the sobel operator on matlab are shown in fig.3:

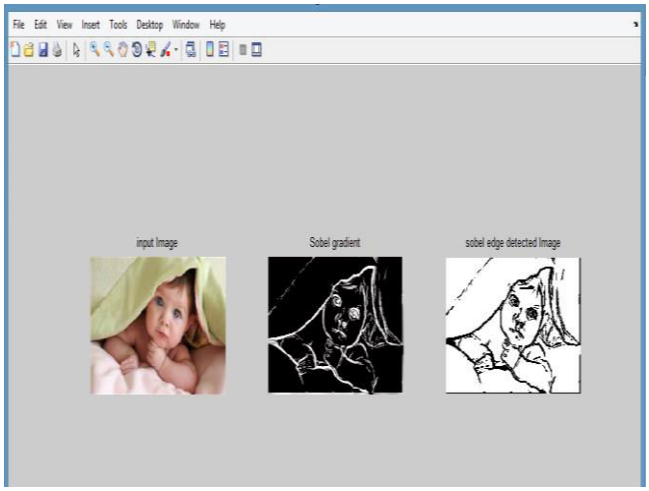


Fig. 3 Edge detection in Sobel operator

PREWITT OPERATOR

The Prewitt operator has importance in image processing, particularly within edge detection algorithms. Basically, it is a discrete differentiation operator, calculating an approximation of the gradient of the image intensity function. At every point in the image, the output of the Prewitt operator is either the corresponding gradient vector or the norm of this vector. The Prewitt operator is based on convolving the image with a small, separable, and integer valued filter in horizontal and vertical directions and is therefore relatively inexpensive in terms of computations. At the same time, the gradient approximation which it produces is relatively crude, in particular for high frequency variations in the image. The Prewitt operator was developed by Judith M. S. Prewitt. The prewitt operator approximate the magnitude and orientation of edges same as sobel operator [4]. The common mask is given by $G_x$and G_y is shown in fig.4.

-1	0	1
-1	0	1
-1	0	1

Gx

1	1	1
0	0	0
-1	-1	-1

Gy

Fig.4 3×3 Convolution mask for Prewitt

The edges of an image detected by the sobel operator on Mat lab are shown in fig.5:

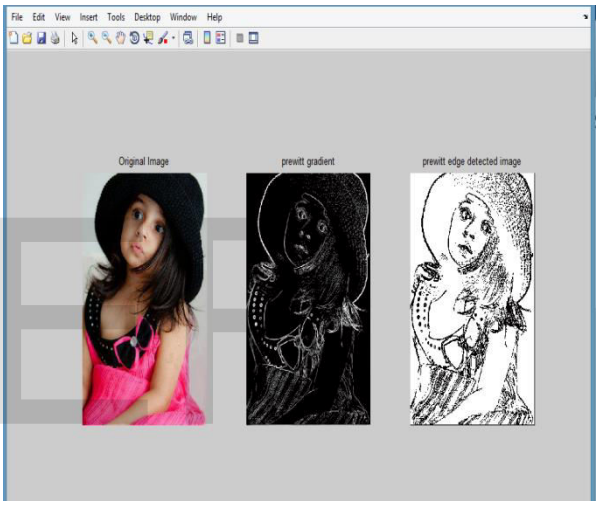


Fig.5 Edge detection in prewitt operator

ROBERT OPERATOR

The Roberts cross operator is an oldest edge detection method used in image processing. It was an earliest edge detection method and was initially presented by Lawrence Roberts in 1963.As a differential operator, the idea behind the Roberts cross operator is to estimate the gradient of a picture through discrete differentiation that is achieved by computing the sum of the squares of the differences between diagonally adjacent pixels [4].

The Robert operator is close to sobel & prewitt and performs two dimensional gradient measurements on an image. It thus projects region which are connected to high spatial frequency of edges. The operator contains pair of 2×2 convolution mask. These masks are prepared in the manner that they give maximally response to the edges which are at 45 degree running to the grid of the pixel. The equation for gradient is given by

$$G[f(i,j)] = |Gx| + |Gy| = |f(i,j) - f(i+1,j+1)| + |f(i+1,j) - f(i,j+1)| \quad (4)$$

The common mask is given by G_x and G_y respectively.

0	-1
1	0

Gx

1	0
0	-1

Gy

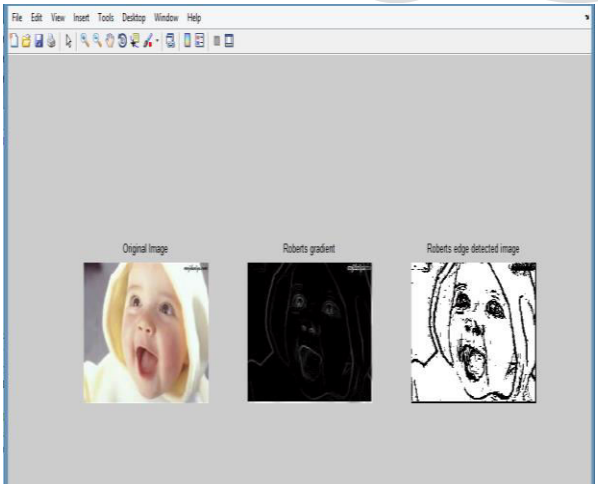


Fig .6 3×3 Convolution mask for Robert

Fig. 7 Edge detection in Robert operator

The edges of an image detected by the robert operator on mat lab is shown in fig.7.

OPTIMAL EDGE DETECTION METHOD

Optimal edge detector supported Low error rate (Edges must not be incomprehensible and there must not be spurious responses), localization (distance between points marked by the detector and the actual center of an edge should be minimum) and response (only one response to a single edge). An example for optimal edge detection is canny edge detection and which is described below.

CANNY OPERATOR

It is very popular and frequently used image processing tool which is used to detect edges in a very robust manner. This methodology is employed to search edges by separating noise from image and extract data from the image while not interrupting its feature. There are some points which are to be kept in mind for upgrading the above said method of edge detection. These points are low error rate, well localization of edge points and one response per edge. The no. of steps should be followed so as to implement canny edge detection algorithm is given below:

Step 1 Smoothing**:** Firstly, Smoothing is done by convolving the image with Gaussian filter to remove noise from the image. The number of steps must be followed in order to implement canny edge detection algorithm. The suitable mask is taken for smoothing with the image. When the width of the mask is larger than the detection, then the sensitivity to noise will be lower.

Step 2 Finding Gradients: After removing the noise from an image by smoothing, the next step is to find the edge strength by taking the gradient of the image. By calculating horizontal and vertical gradient of an image for this purpose, this method applies respective sobel kernel mask in both horizontal and vertical direction.

It uses a pair of 3×3 convolution mask that approximate the x-direction gradient and y-direction gradient.

Step 3 Non Maximum Suppression (NMS): It is applied over the image to search out each maxima in the gradient direction that is preserve as edges and deleting everything else. At last, it will produce thin edges in an output image.

Step 4 Double Thresholding: This kind of thresholding is employed to see the potential edges. The canny edge detector uses the hysteresis to do thresholding. In double thresholding, there are two types of thresholding level i.e. low threshold and high threshold. When the value of edge pixel is stronger than the high threshold then they marked as strong. An edge pixel is said to be a strong if its value is greater than high threshold and weak, if its value is less than low threshold. Weak edge pixel must be suppressed and consider only strong pixel as well as those pixel whose value lies between low and high threshold (if they are connected to strong edge pixel). The edges of an image detected by the canny operator on matlab are shown in fig.8.

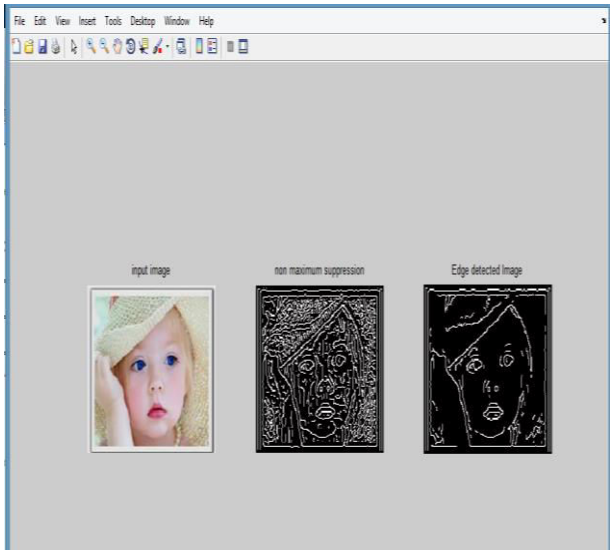


Fig. 8 Edge detection in canny operator

III. COMPARISON AND RESULT

The four edge detection techniques Sobel, Prewitt, Robert and Canny are compared here by using some parameters like Visual comparison with number of edges detected, Performance Ratio (PR), F-measure and Peak signal to noise ratio (PSNR) [1].

VISUAL COMPARISON WITH NUMBER OF EDGES DETECTED

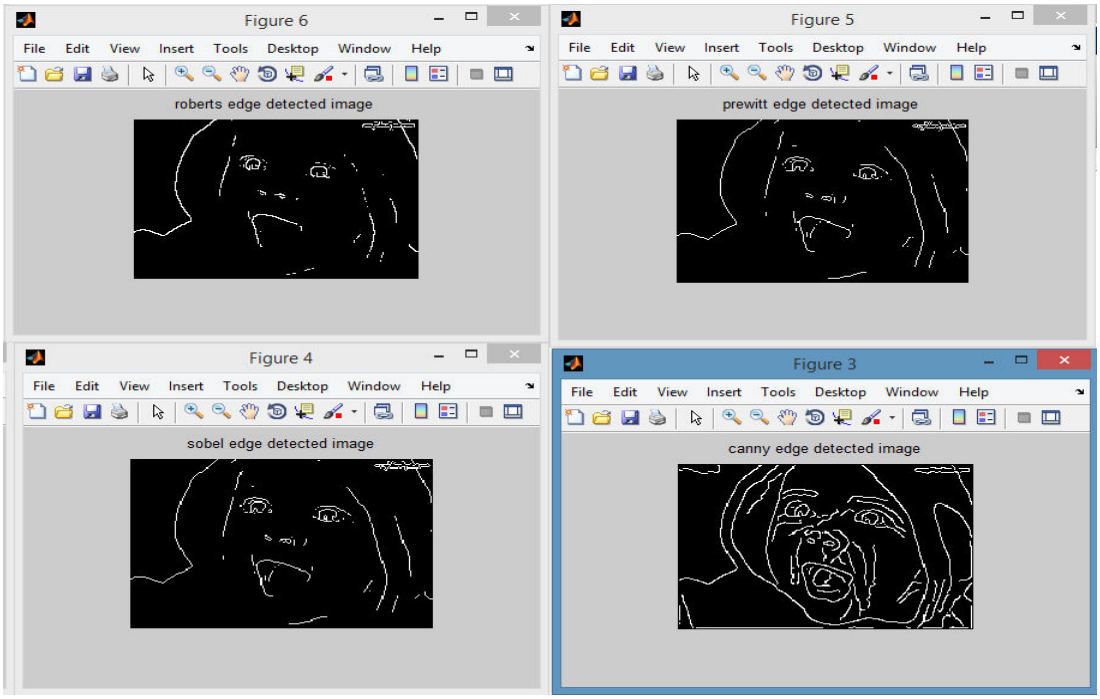
Here we compare four algorithms with respect to visual quality and number of edges detected by each algorithms using Mat lab. According to that we get some conclusion to select a good edge detection method.

VISUAL QUALITY

The four edge detection methods have an edge detected output for a particular image is shown in fig.9. Here from the figure, it is clear that in Roberts operator, spurious dots indicate that the operator is susceptible to noise and it missed a few edges. Sobel operator detects thicker edges and spurious edges are still present but they are relatively less intense compared to genuine lines. Here edge is not localized properly. But it is highly immune to noise. In the case of a Prewitt operator, it is almost similar to sobel operator. But less immune to noise compared to sobel. Canny operator is highly immune to noise and edges are localized properly. It identifies weak edges too.

NUMBER OF EDGES DETECTED

It is the number of white regions which is consider as detected as edges in output. For each operator, calculate the number of detected edges of various images and tabulated in Table I.



Edge detector	Roberts	Prewitt	Sobel	Canny
Image 1	2	5	11	15
Image 2	50	93	155	200
Image 3	2	3	7	19
Image 4	3	12	16	17
Image 5	10	13	22	24

Table 1:No. of edges detected by various Edge

Edge detector	Roberts	Prewitt	Sobel	Canny
Image 1	8.5423	8.9302	8.999	14.05
Image 2	14.6814	15.4654	15.41	21.92
Image 3	8.2621	10.0594	9.979	16.31
Image 4	8.8844	9.5487	9.626	17.56
Image 5	10.2491	11.1083	11.17	16.76

Table II: PR values for various Edge detectors

From the table, number of detected edges is very small for Robert Operator compared to all other operators and very high to Canny operator. For Sobel, no. of edges detected is high compare to roberts operator. No. of detected edges are similar for sobel and Prewitt operator.

PERFORMANCE RATIO (PR)

It is an efficient parameter for measuring the performance of edge detectors. Higher the values of PR, reflects better edge Output .Comparison with ground truth of an image PR is defined as the ratio of number of times both ground truth and edge detected image has non zero output to the number of times both ground truth and edge detected image has opposite output. For ground truth images PR is consider as infinity. The PR values calculated for each operator is shown in Table II:

F-MEASURE

It is the measure of a test's accuracy. Higher the values of F-measure, reflects better Edge Output. Maximum value of F-measure is 1 for ground truth images. Considering both the precision and the recall F-measure is defined as

$$F_1 = 2.\frac{precision\ .recall}{precision\ + recall} \tag{5}$$

Where, precision (also called positive predictive value) is the fraction of retrieved instances that are relevant, while recall (also known as sensitivity) is the fraction of relevant instances that are retrieved. Both precision and recall are therefore based on an understanding and measure of relevance. Suppose a computer program for recognizing dogs in scenes from a video identifies 7 dogs in a scene containing 9 dogs and some cats. If 4 of the identifications are correct, but 3 are actually cats, the program's precision is 4/7 while its recall is 4/9. When a search engine returns 30 pages only 20 of which were relevant while failing to return 40 additional relevant pages, its precision is 20/30 = 2/3 while its recall is 20/60 = 1/3.The F-measure values calculated for each operator is shown in table III. Both performance ratio and F-measures are high for canny edge detector when compared to other three operators, sobel and Prewitt operators have almost same values for two parameters.

PEAK SIGNAL TO NOISE RATIO

It is the ratio between maximum power of the signal and the power of corrupting noise. The more the value of PSNR the better is image reconstruction ability. PSNR comparison values between different edge detectors of a particular image are shown in table IV:

Edge detector	Roberts	Prewitt	Sobel	Canny
Image 1	0.00348	0.00580	0.00608	0.01367
Image 2	0.00176	0.00417	0.00443	0.00758
Image 3	0.00716	0.00986	0.01014	0.01729
Image 4	0.00285	0.00501	0.00517	0.00890
Image 5	0.01142	0.01143	0.01176	0.01393

Table III: F-measures for various Edge detectors

	Roberts	Prewitt	Sobel	Canny
IMAGE 1	49	49.4	49.8	52
IMAGE 2	62.35	63	63.4	72
IMAGE 3	52.3	53.2662	53.3	58.28

Table IV: PSNR comparison values

IV. ADVANTAGES AND APPLICATION

Edge detection is an important technique that reduces unnecessary information in the image while preserving the structure of the image. It is useful to extract important features of an image like corners, lines and curves.These features play important role in higher-level computer vision algorithms (e.g., recognition, Image comparison). It is broadly use to recognize objects, segmentation and boundaries. Main advantages of gradient method are simple, fast and easy to compute. Edges are detected along with their direction.

In the case of optimal edge detection, Signal to noise ratio is improved and better detection in noise condition.When we looks through the application of edge detection techniques, it mainly includes enhancement of noisy images such as satellite images, medical images , x-rays etc. It is also applicable in text detection, mapping of roads and video surveillance. Canny edge detector for remote Sensing Images, because remote sensed images are inherently noisy. Other edge detectors can't use for remote sensing because they are very sensitive to noise.

V. CONCLUSION

Image processing is a fast growing technology and edge detection plays a major role in image preprocessing for object detection. The main aim of this project is to present a review on various edge detection techniques. The sobel, Robert and Prewitt can compute the edges along their orientation easily but the detection of edges are inaccurate and more sensitive to noise. Canny edge detection in comparison to sobel, Robert and Prewitt is complex, its computation is time consuming and detection of edges is immune to noise.

From the comparison of four edge detection techniques canny operator is best and produce better output in terms of PR, F-measure and number of edges detected. Sobel and Prewitt operators are almost similar. Canny operator gives the most quality image and the Roberts operator gives the least quality image in terms of PSNR. Selection of threshold is a practical issue in gradient method.

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