Comparison of Various Edge Detection Techniques

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Abstract* – *Edge detection is used to extract the important features (e.g.-line, curves and corners) which can be used for very handy purposes (e.g.-face recognition, computer vision algorithms). But extraction of Edges from images is an onerous job without effecting the structural properties of image what so ever. Edges in an image signify the abrupt changes in intensity values. So it becomes even more strenuous to extract edges when there is a noise in an image. The reason behind is that the noise also signify the swift changes in the intensity values of an image. In this paper the various edge detection techniques to extract out the edges efficiently and the comparison between them is explained. The comparison is drawn on the parameters- MSE, RMS, and PSNR. The techniques constitute –Robert's, prewitt, sobel and canny edge detection. The output of images is shown using the software Matlab.

Keywords- comparison, edge, edge detection, operators

I. INTRODUCTION

What are Edges and Edge Detection?

Edges in an image are abrupt 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 we can conclude which type of edge is present. These are

Step edge: In step edge the image intensity changes swiftly from one value to another. Meaning the intensity changes like in the digital 0 or 1(high or low).

Roof edge: A Roof edge where the intensity change is not instantaneous but occurs over a finite distance (i.e., usually generated by the intersection of two surfaces).

Ridge edge: In ridge edge the image intensity abruptly changes value but then returns to the starting value within some short distance (i.e., usually generated by lines).

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.

Main steps in Edge Detection.

(1)Smoothing: It suppress noise, without destroying true edges.

(2) Enhancement: apply differentiation to enhance the quality of edges (i.e., sharpening).

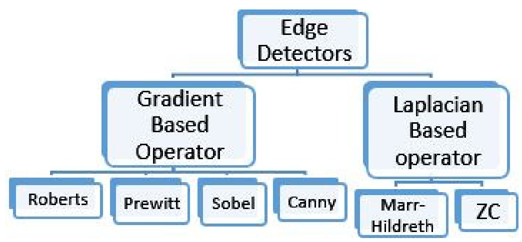
(3) Thresholding: determine which edge pixels should be discarded as noise and which should be retained (i.e., threshold edge magnitude).

(4) Localization: Its objective is to find from all the candidate's edge points the true member of edge.

Edge detection can be broadly divided into two categories which comprises all the techniques:

1. Gradient based operators
2. Laplacian operator

This figure will explain all the techniques which come under these categories-



1. **Gradient based operators**- These are also called the first order operators because by looking the local maxima and minima edges are detected.

If I (x, y) be the input image, then image gradient is given by following formula:

$$\nabla I = \hat{x}\frac{\partial I(x,y)}{\partial x} + \hat{y}\frac{\partial I(x,y)}{\partial y}$$

Where

$$\frac{\partial I(x,y)}{\partial x} is the gradient in x direction$$

Gradient x direction

And

$$\frac{\partial I(x,y)}{\partial y} is the gradient in y direction$$

Gradient y direction

Gradient vector is given by:

$$\nabla f = grad(f) = \begin{bmatrix} Gx \\ Gy \end{bmatrix}$$

The gradient magnitude is given by:

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

The direction of the gradient vector is:

$$\theta = tan^{-1} \begin{bmatrix} \frac{Gy}{Gx} \end{bmatrix}$$

- **Roberts Operator**-It is the first operator which is used for the edge detection. It is given by Robert cross in 1963. The basic idea behind this operator is to approximate the gradient of an image by discrete differentiation. One of simplest and quick method of edge detection. The mask of Roberts operator is :

$$\begin{matrix} -1 & 0 \\ 0 & 1 \end{matrix} \qquad \begin{matrix} -1 & 0 \\ 0 & 1 \end{matrix}$$

Gx Gy

The Gx mask is simply rotated at 45°and Gy is obtained. These two masks can be applied to the image for detecting edges.

- **Prewitt Operator**-It consists of two 3x3 convolution kernels named Gx and Gy. Gx is simply Gy rotated by 90°.Its mask is given by:

  $$Gx = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \quad Gy = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$$

- **Sobel Operator**-The mask of sobel is given as:

  $$Gx = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \quad Gy = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

- **Canny Edge Detector**-All the previous operator had one demerit of noise. When the noise occur these operators have a tendency to assume it as a part of the edge and also sometimes it misses the true edges due to corruption of noise. All gradient based techniques are very sensitive to noise.

  But canny overcomes this demerit by using the Gaussian filter before applying the mask. Gaussian filter reduces the noise as much as possible.

  Canny approach is based on three objectives:

  1. **Low error rate**-All edges should be found in an image none should be left behind. No spurious responses should be there. The edges detected should be as close as to the true edges.
  2. Edge points should be well localized-means the distance between the edge which is marked by the detector should be as near to the Centre of the true edge
  3. **Single point response**-Only one point should be return by the detector for each true edge meaning the number of local maxima around the edge should be minimum.

2. Laplacian Based Operators-These operators use the second order partial differential for edge detection. That's why it is also called the second order operators.This approach is basically defines a discrete formulation of the second order derivative and the filter is constructed on the basis of that formulation. In Laplacian operator we are basically interested in the construction of an isotropic filters.

An isotropic filter is that filter which is rotation invariant meaning that applying the filter as it is then again applying the filter with 90° gives the same result.

The simplest isotropic derivative is the Laplacian which can be shown as for a function of two variables (image) is:

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

- **Marr-Hildreth**- It is also called Laplacian of Gaussian. This is made by scientists named Marr and Hildreth. They have suggested that an operator used for edge detection should have two salient features:
  1. It should be a differential operator that can calculate the first or second derivative at any point.
  2. It should be capable of acting at any desired scale.

     They argued that the most efficient operator that can fulfill these two above conditions is the filter ∇^2G where ∇^2 is the Laplacian operator and G is a 2-D Gaussian function.

$$G(x, y) = e^{-\frac{x^2+y^2}{2\sigma^2}}$$

$$where\sigma isthestandarddeviation$$

Now the ∇^2G expression is given by:

$$\nabla^2 G = \left[\frac{x^2+y^2-2\sigma^2}{\sigma^4}\right|$$

- **Zero Cross**- it is a simple filter which works on the second derivative. It is intersection between the zero intensity axis and a line between the extrema of the second derivative. It is directly used as a function in Matlab software.

II. COMPARISON BETWEEN ALL OPERATORS AND CONCLUSION-

As shown in the images below all the all the operators are applied on the original image where A is the original image with resolution of 512 × 512.

There are different parameters which can be used to show the differences and similarity between these all different edge detection operators. Some of the parameters used is discussed below:

1. **Mean Square Error (MSE)**-In statics, MSE is the most important criteria used to evaluate the performance of predictor and estimate. In this context we will use it to calculate the difference between two operators

$$MSE = \frac{\sum_{M,N}[I1(M,N) - I2(M,N)]^2}{M \times N}$$

2. **Root Mean Square Error (RMSE)**-it is used to measure the magnitude in varying quantity.

$$RMS = \sqrt{MSE}$$

3. **Peek signal to noise ratio (PSNR)**-It is 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.

$$PSNR = \frac{10 \times LOG(\frac{M \times N}{MSE})}{LOG(10)}$$

Now comparison between all the techniques is undertaken. Bitmap image of Lena of resolution 512*512 is used in the Matlab software.

A B

C D

E F

G

Fig 1-Comparsion of all different edge detection operators (A) Original (B) Sobel (C) Canny (D) Prewitt (E) Log(Laplacian of Gaussian) (F) Roberts (G) Zero Cross

MSE-The comparison is made on the MSE and all the corresponding values are taken as shown below:

TABLE I. MSE COMPARISON VALUES

	Sobel	Canny	Prewitt	LOG	Roberts	ZC
Sobel	0	0.0543	2.4033e^-04	0.0221	0.0019	0.0221
Canny	0.0543	0	0.0545	0.0322	0.0563	0.0322
Prewitt	2.4033e^-04	0.0545	0	0.0223	0.0017	0.0223
LOG	0.0221	0.0322	0.0223	0	0.024	0
Roberts	0.0019	0.0563	0.0017	0.024	0	0.024
ZC	0.0221	0.0322	0.0223	0	0.024	0

RMSE- The root mean square error values are also taken. These values are given below:

TABLE II. RMSE COMPARISON VALUES

	Sobel	Canny	Prewitt	LOG	Roberts	ZC
Sobel	0	0.233	0.0155	0.1486	0.0441	0.1486
Canny	0.233	0	0.2336	0.1795	0.2372	0.1795
Prewitt	0.0155	0.2336	0	0.1494	0.0413	0.1494
LOG	0.1486	0.1795	0.1494	0	0.155	0
Roberts	0.0441	0.2372	0.0413	0.155	0	0.155
ZC	0.1486	0.1795	0.1494	0	0.155	0

PSNR-Peek signal to noise ratio values are shown below:

TABLE III. PSNR COMPARISON VALUES

	Sobel	Canny	Prewitt	LOG	Roberts	ZC
Sobel	0	66.8369	90.3774	70.7455	81.2951	70.7455
Canny	66.8369	0	66.8177	69.1033	66.6814	69.1033
Prewitt	90.3774	66.8177	0	70.6985	81.86777	70.6985
LOG	70.7455	69.1033	70.6985	0	70.3768	∞
Roberts	81.2951	66.6814	81.8677	70.3788	0	70.3788
ZC	70.7455	69.1033	70.6985	∞	70.3788	0

III. GRAPH OF COMPARISON ON DIFFERENT PARAMETERS

Now we have shown our comparison on the graphs.

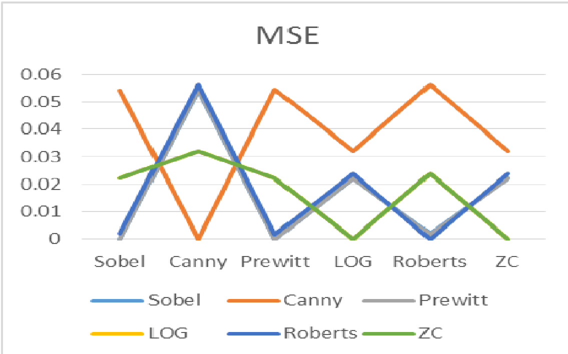


Fig 2. Comparison of all operators on the basis MSE

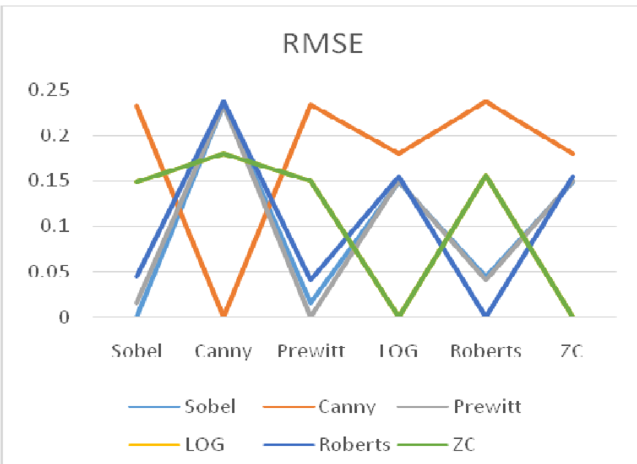


Fig 3. Comparison of all operators on the basis RMSE

The graph shows the different PSNR values in comparison with all the other edge detection operators.

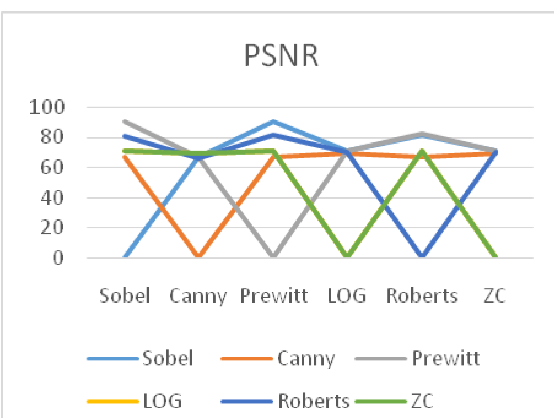


Fig 4. Comparison of all operators on the basis PSNR

IV. CONCLUSION

In this paper all the edge detection techniques are compared on different parameters. If we closely analyze the graphs, the below results can be drawn:-

On the basis on MSE and RMSE

The SOBEL operator shows the most similarity with the prewitt and shows most dissimilarity with CANNY.The CANNY operator shows the most similarity with the LOG/ZERO CROSS and shows most dissimilarity with ROBERTS.The PREWITT operator shows the most similarity with the SOBEL and shows most dissimilarity with CANNY.The LOG operator shows the most similarity with the ZEROCROSS and shows most dissimilarity with CANNY.The ZEROCROSS operator shows the most similarity with the LOG and shows most dissimilarity with CANNY.

The ROBERTS operator shows the most similarity with the PREWITT and shows most dissimilarity with CANNY.
It can be shown as:

TABLE IV. RESULTS DRAWN FROM THE GRAPHS

	Similarity	Dissimilarity
SOBEL	PREWITT	CANNY
CANNY	LOG/ZC	ROBERTS
PREWITT	SOBEL	CANNY
LOG	ZEROCROSS	CANNY
ZEROCROSS	LOG	CANNY
ROBERTS	PREWITT	CANNY

On the basis of PSNR

PSNR shows the quality of an image. The high the value the high the quality. So the from the values it can be drawn that the SOBEL operator gives the most quality image and the ROBERTS operator gives the least quality image.

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