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Comparative Performance Analysis of various Digital Image Edge Detection Techniques Against Gaussian Noise

[1] Pratima Dubey,[2] Dr. Soni Changlani,
[1]Research Scholar,[2]Professor
[1]Department of Electronics and Communication Engineering
[2]Department of Electronics and Communication Engineering
[1] LNCT University, Bhopal, (M.P.), India
[2] LNCT University, Bhopal, (M.P.), India

Abstract : The edge detection is a digital image processing technique to find the boundaries or edges of an image or object through the brightness discontinuity. There are many operators to get boundaries or edges but we need more effective and accurate methods. This paper will provide a comparison of Conventional Sobel, Prewitt, Roberts, Canny and Log Operators Edge Detector Techniques against Gaussian noise With regard to Mean Square Error (MSE), Root Mean Square Error (RMSE), signal to noise ratio (SNR) , peak signal to noise ratio (PSNR) , mean-absolute error (MAE) and Bit error, etc.

***IndexTerms* - Sobel operator, Prewitt operator, Roberts operator, canny operator, log operator, Edge detection, mean square error (MSE), Root mean square error (RMSE) , mean-absolute error (MAE) ,signal to noise ratio(SNR), Peak signal to noise ratio(PSNR) and Bit error.**

I. Introduction

Image processing is a method of analyzing and manipulating digital images with computers using mathematical operators. In image processing, inputs are images and results can be a characteristic or set of image parameters or images. An image consists of various information such as contour object, orientation, size and colour. So, to find information about objects, edges involving the object must be identified. Edge detection is a method for detecting the occurrence of edges and locality made by sharp and sudden variations in intensity (brightness or colour) of an image.The purpose of the edge detection is to detect information on object form and reflectance in the image. Edge detection is an important step in image analysis and processing, computer vision, human vision, object detection and pattern recognition. There are various edge detection techniques to detect edges. Different edge detectors work differently. Means that some edge detectors need more time and detect more edges with respect to others. This Research paper discussed the comparison of traditional edge detection techniques against the Gaussian noise.

II. Gaussian noise in image

Generally two types of noise models are present in any recovery system. They are additive noise models and multiplication noise models. The mathematical formula of the additive noise model is generally given by,

$$N(x, y) = I(x, y) + J(x, y) \quad (1)$$

And multiplicative noise model formula is given by,

$$N(x, y) = I(x, y) \times J(x, y) \quad (2)$$

Where N(x, y) is an original noisy image, I(x, y) is a noise free image of the original image and J(x, y) is the image which consist of noise that is in I(x, y). All Denoising techniques, aims to remove the noise J(X, Y) and restore the original image I(x, y) thus, preserve all the features of the original image. Generally Gaussian noise and salt and pepper noise are under the additive noise model and the speckle noise are under the noise of multiplication. Additive noise is rather easily removed than multiplication noise.Gaussian noise is also referred to as additive noise, it is called because each and every pixel is modified in such a way that certain distributions are added to each pixel. The most commonly observed distribution is the distribution of Gaussian or a bell curve. This is due to poor illumination during the capture or due to high temperatures. It can also cause noise in the electronic circuit. Gaussian distribution is always symmetrical. Gaussian noise usually occurs in amplifiers and detectors so that it is also known as electronic noise.

III.Noise Removal Median filter

The median filter is a better static filter, non-linear, whose response is based on the classification of pixel values contained in the filter region. The median filter is quite popular to reduce certain types of noise. Here, the central value of the pixel is replaced by the median of pixel values under the filter region. The median filter is good for the salt and pepper noise. These filters are widely used as smoothers for image processing, as well as in the processing of the signal.

IV. Edge detectors

A. Sobel

The Sobel edge detector calculates the gradient using the discrete differences between the rows and columns of a 3x3 neighborhood. The Sobel operator is based on conversing the image with a valuable, small, separable and whole filter.
The array of convolution is the following

$$G_X = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}, \quad G_Y = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \tag{3}$$

B. Prewitt

Prewitt operator edge detection masks are the one of the oldest and best understood methods of detecting edges in images The Prewitt edge detector uses the following mask to approximate digitally the first derivatives Gx and Gy.

$$G_X = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}, \quad G_Y = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \tag{4}$$

C. Roberts

In Robert edge detection, vertical and horizontal edges are removed individually and then come together for the resulting edge detection. The Roberts edge detector uses the following masks to digitally approach the first derivatives as differences between adjacent pixels.

$$G_X = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}, \quad G_Y = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} \tag{5}$$

D. LOG operator

This operators finds edges looking for crosses from zero after filtering F (x, y) with a lackish of the Gaussian filter. In this method, Gaussian filtering is combined with lacacian to decompose the image where the intensity varies to detect the edges effectively. Find the right place of the edges and the widest area test around the pixel.it is based on second order derivatives and discover the edges at the zero crossing. It works in frequency domain. The registration operator is defined as follows.

$$\log(x, y) = \frac{1}{\pi\sigma^4}\left(\frac{2(x^2+y^2)}{\sigma^2} - 1\right) e^{\frac{x^2+y^2}{2\sigma^2}} \tag{6}$$

Convolution matrix is as follows,

$$G_X = \begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}, \quad G_Y = \begin{bmatrix} -1 & -1 & 1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix} \tag{7}$$

E. Canny Operator

The Detection of Canny Borders is a multi-stage algorithm to detect a wide range of edges in the images. This detector finds edges looking for local maximum F (X, Y) gradient. The method uses two thresholds to detect strong and weak edges and includes weak edges at the output only if they are connected to strong edges.
Canny edge detector also known as the optimal detector, the cannoso algorithm follows the following steps
Step 1: The median filter is used for noise removal.
Step 2: Following the Canny mask is used to find the intensity of the gradient.

$$G_X = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix}, \quad G_Y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{bmatrix} \tag{8}$$

Step 3: strength and direction calculated as

$$G = \sqrt{{G_X}^2 + {G_Y}^2}, \quad \theta = \arctan\left(\frac{G_Y}{G_X}\right) \tag{9}$$

Step 4: Apply the magnitude of gradient with non-maximum and suppression.
Step 5: Apply the no maximum threshold in the output suppression image.

V. Performance Parameters

1. M.S.E.

The lowest value of MSE represents more under the error.

$$MSE = \frac{1}{MN}\sum_0^{M-1}\sum_0^{N-1}[f(x, y) - g(x, y)]^2 \tag{10}$$

2. R.M.S.E.

The RMSE is a measure of precision. It is also non-negative, and the lowest value of this is better than superior.

$$RMSE = \sqrt{MSE} \tag{11}$$

$$RMSE = \sqrt{\frac{1}{MN}\sum_0^{M-1}\sum_0^{N-1}[f(x, y) - g(x, y)]^2} \tag{12}$$

3. S.N.R.

The SNR can be defined as the ratio of the signal power to the noise power. It is measured in dB and can be calculated as.

$$\mathrm{SNR} = 10\log_{10}\left(\frac{\sum_{x=0}^{N-1}\sum_{j=0}^{M-1} \mathrm{II}(x,y)^2}{\sum_{x=0}^{N-1}\sum_{y=0}^{M-1} (\mathrm{II}(x,y)-\mathrm{RI}(x,y))}\right) \quad (13)$$

4. P.S.N.R.

The PSNR is defined as the ratio of the maximum intensity of pixels to the mean quadratic error. The PSNR is commonly expressed in terms of the logarithmic decibel scale. The highest PSNR value offers a good image quality.

$$\mathrm{PSNR} = 10\log_{10}\left[\frac{M*N}{\mathrm{MSE}}\right] \quad (14)$$

$$\mathrm{PSNR} = 10\mathrm{Log}_{10}\left(\frac{255*255}{\mathrm{MSE}}\right) \quad (15)$$

5. BIT ERROR

Bit error should be low for good quality image. It is inverse of PSNR.

$$\text{Bit error} = \frac{1}{\mathrm{PSNR}} \quad (16)$$

6. M.A.E.

It means an absolute error between two digital NXM images, measures the absolute proximity of these images together:

$$\mathrm{MAE} = \frac{1}{NM}\sum_{i=0}^{N-1}\sum_{j=0}^{M-1} |A(i,j) - B(i,j)| \quad (17)$$

MAE has to be minimal for the best output of the filter.

VI. Methodology

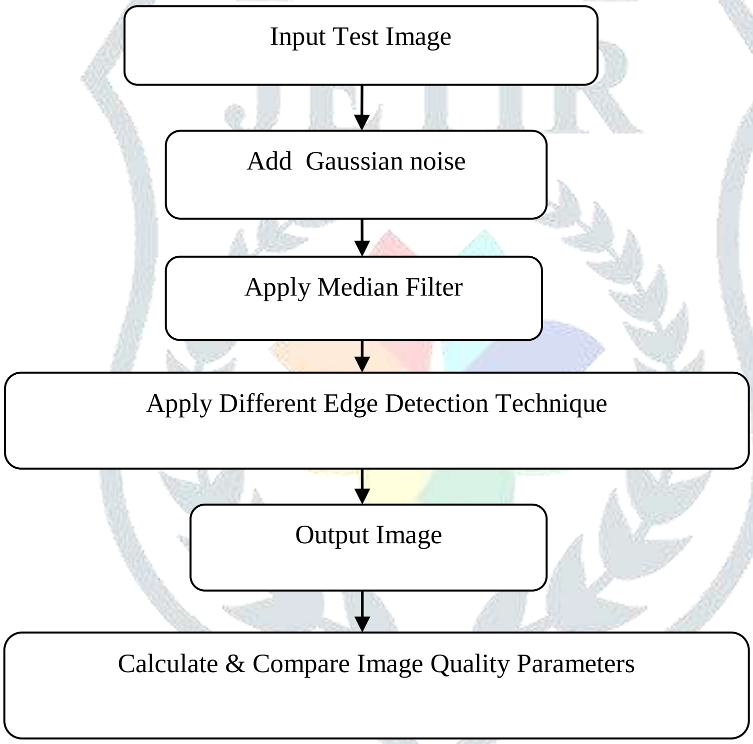

Figure 6.1: Proposed Methodology

VII. Experimental results

The experiment was carried out with the following Standards

Image	Gray scale image of the "cameraman" size of 256 x 256
Software used	R2016A MATLAB
Noise	Gaussian noise(mean = 0, variance = 0.01)

Smoothing Filter	Median filter (3x3),
Edge Detector	Sobel,Prewitt,Roberts,Log,Canny.
Performance Parameters	MSE,RMSE,PSNR,SNR,MAE,Bit Error

FILTER	NOISE	M.S.E.	R.M.S.E	M.A.E.	P.S.N.R.	SNR	BIT ERROR
Sobel Edge Detector	**Gaussian noise**	17975.502	134.0727	118.6932	5.584	0.0016	0.1791
Prewitt Edge Detector	**Gaussian noise**	17975.536	134.0729	118.6937	5.584	0.0015	0.1791
Roberts Edge Detector	**Gaussian noise**	17974.535	134.0691	118.6905	5.5842	0.0018	0.1791
Log Edge Detector	**Gaussian noise**	17968.548	134.0468	118.6709	5.5857	0.0032	0.179
Canny Edge Detector	**Gaussian noise**	17952.225	133.9859	118.5962	5.5896	0.0072	0.1789

Table7.1: comparative performance of edge detectors

VIII. Conclusion

This Research paper discussed the comparison of traditional edge detection techniques against the Gaussian noise. Performance measurement parameters for this comparison are the mean square error (MSE), the average quadratic error of the root (RMSE), the maximum signal to the noise ratio (PSNR) and the bit error. In this comparison we find that Canny Edge Detector performed very well against Gaussian noise . For canny edge detector The value of MSE is lower, RMSE is also low, while PSNR is high, and the bit error is low as compared to other edge detection techniques.

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