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Comparative performance analysis of various digital image edge detection techniques with hybrid edge detection technique which is developed by combining second order derivative techniques log and Canny

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Abstract

Edge detection is a digital image processing technique to find the boundaries or edges of an image or object through 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 hybrid techniques that combine second-order derivative techniques Log and Canny, With Conventional Sobel, Prewitt, Roberts, Canny and Log Operators Edge Detector Techniques With regard to visual inspection, 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.

Keywords: Hybrid technique, 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), Bit error.
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1 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

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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. In this paper, various edge detection techniques learned to identify edges in an image and comparative analysis are also carried out among these techniques.

2 Types of 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

$$N(x, y) = I(x, y) + J(x, y) \tag{2.1}$$

And multiplicative noise model formula is given by

$$\mathrm{N(x, y) = I(x, y)xJ(x, y)} \tag{2.2}$$

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. Various types of sounds are discussed, namely, Gaussian noise, salt and pepper noise and Poisson noise .Gaussian noise is an additive noise and the main source of noise is caused by data acquisition . Gaussian's noise is distributed evenly in the signal. That means each pixel in noisy images is the number of the noise values of Gaussian distributed randomly and the true pixel value. This type of noise has a Gaussian distribution. This noise is independent of each pixel and does not depend on the signal intensity. Speckle Noise is a multiplication noise type and mainly present in ultrasound medical images and SAR (synthetic aperture radar). Speckle noise is mainly due to constructive and destructive disorders of ultrasonic waves that are passed to the human body. The noise of salt and pepper also referred to as a distributed flat-tail or impulse noise. An image that is influenced by salt and pepper noise has dark pixels in bright areas and bright pixels in dark areas. Salt and pepper noise especially Caused by not functioning pixel elements in the camera sensor, the wrong memory location, or time error from the digitization process. The main source of salt and pepper noise is caused by an error in the ADC (analog to the digital converter) and because of bit errors in transmission.

3 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.

4 Traditional and hybrid edge detectors

4.1 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

$$\mathrm{G_X} = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}, \quad \mathrm{G_Y} = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \tag{4.1}$$

4.2 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.

$$\mathrm{G_X} = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}, \quad \mathrm{G_Y} = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \tag{4.2}$$

4.3 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.

$$\mathrm{G_X} = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}, \quad \mathrm{G_Y} = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} \tag{4.3}$$

4.4 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.

$$\log(\mathrm{x}, \mathrm{y}) = \frac{1}{\pi\sigma^4}\left(\frac{2\left(\mathrm{x}^2+\mathrm{y}^2\right)}{\sigma^2} - 1\right)\mathrm{e}^{\frac{\mathrm{x}^2+\mathrm{y}^2}{2\sigma^2}} \tag{4.4}$$

Convolution matrix is as follows

$$\mathrm{G_X} = \begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}, \quad \mathrm{G_Y} = \begin{bmatrix} -1 & -1 & 1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix} \tag{4.5}$$

4.5 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.

$$\mathrm{G_X} = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix}, \mathrm{G_Y} = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{bmatrix} \tag{4.6}$$

Step 3: strength and direction calculated as

$$\mathrm{G} = \sqrt{\mathrm{G_X^2} + \mathrm{G_Y^2}} \quad , \quad \theta = \arctan\left(\frac{\mathrm{G_Y}}{\mathrm{G_X}}\right) \tag{4.7}$$

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

4.6 Hybrid Edge Detection Technique

The hybrid technique provides a relatively complete edge profile and improves the accuracy of an edge. This method focused on the removal of noise and accuracy in edge detection. For the removal of noise, a median filter is used, which helps the efficient removal of salt noise and pepper. The objective of the hybrid edge detection technique is to improve the detection of the edge with the efficient removal of noise.
Step 1: Take a digital test image and add noise.
Step 2: Apply the medium filter to remove noise.
Step 3: Apply Log operator in the image for edge detection and obtain output 1.
Step 4: Now apply the Canny operator similarly in the same image that you enter in step 2 and obtain output 2.
Step 5: For the hybrid method, add both outputs 1 and 2 respectively
Hybrid image = output 1 + output 2

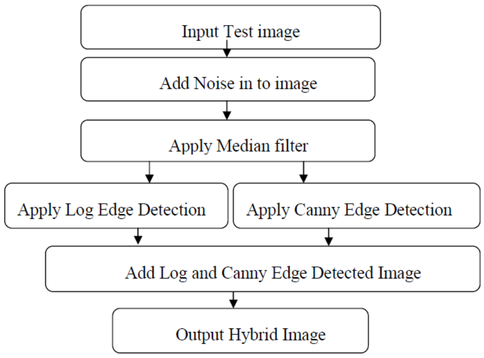

Figure 1: Methodology of Hybrid Technique

5 Performance Parameters

5.1 M.S.E.

The lowest value of MSE represents more under the error.

$$\mathrm{MSE} = \frac{1}{\mathrm{MN}} \sum_{0}^{\mathrm{M}-1} \sum_{0}^{\mathrm{N}-1} [\mathrm{f}(\mathrm{x},\mathrm{y}) - \mathrm{g}(\mathrm{x},\mathrm{y})]^2 \tag{5.1}$$

5.2 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

$$\mathrm{RMSE} = \sqrt{\frac{1}{\mathrm{MN}} \sum_{0}^{\mathrm{M}-1} \sum_{0}^{\mathrm{N}-1} [\mathrm{f}(\mathrm{x},\mathrm{y}) - \mathrm{g}(\mathrm{x},\mathrm{y})]^2} \tag{5.2}$$

5.3 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.

$$\mathrm{SNR} = 10\log_{10}\left(\frac{\sum_{\mathrm{X}=0}^{\mathrm{N}-1}\sum_{j=0}^{\mathrm{M}-1}\mathrm{II}(\mathrm{x},\mathrm{y})^2}{\sum_{\mathrm{x}=0}^{\mathrm{N}-1}\sum_{\mathrm{y}=0}^{\mathrm{M}-1}(\mathrm{II}(\mathrm{x},\mathrm{y}) - \mathrm{RI}(\mathrm{x},\mathrm{y}))}\right) \tag{5.3}$$

5.4 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.

$$\mathrm{PSNR} = 10\log_{10}\left[\frac{\mathrm{M} * \mathrm{N}}{\mathrm{MSE}}\right] \tag{5.4}$$

5.5 BIT ERROR

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

$$\text{Bit error } = \frac{1}{\text{PSNR}} \tag{5.5}$$

5.6 M.A.E.

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

$$\text{MAE} = \frac{1}{\text{NM}} \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} |\, A(i,j) - B(i,j)| \tag{5.6}$$

6 Methodology

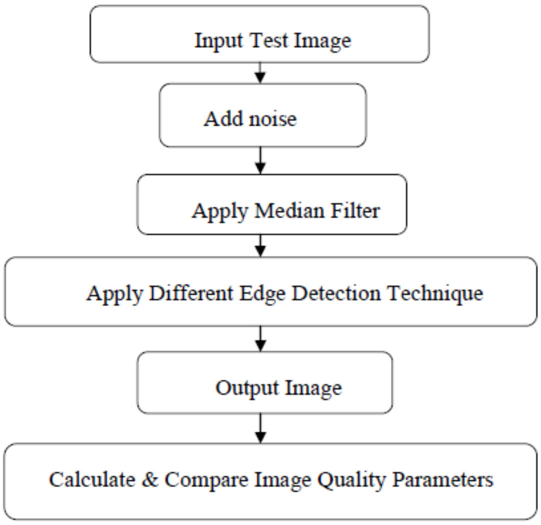

Figure 2: Proposed Methodology

7 Experimental results

The experiment was carried out with the following Standards

Image	Gray scale image of the "cameraman" size of 256x 256
Software used	R2016A MATLAB
Noise	salt and Pepper noise (noise density = 0.05), white Gaussian noise(mean = 0, variance = 0.01), Poisson noise, Speckle noise (mean = 0, variance = 0.04)
Smoothing Filter	Median filters (3x3),
Edge Detector	Sobel.Prewitt.Log.Canny Hybrid by combining second order derivative techniques Log and 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	Salt and pepper noise	17975.2838	134.0719	118.693	5.584	0.0016	0.1791
	Gaussian noise	17975.5016	134.0727	118.6932	5.584	0.0016	0.1791
	Poisson noise	17975.2953	134.072	118.6932	5.584	0.0016	0.1791
	Speckle noise	17975.5114	134.0728	118.6962	5.584	0.0016	0.1791
Prewitt Edge Detector	Salt and pepper noise	17975.3493	134.072	118.693	5.584	0.0016	0.1791
	Gaussian noise	17975.5357	134.0729	118.6937	5.584	0.0015	0.1791
	Poisson noise	17975.297	134.072	118.6934	5.584	0.0016	0.1791
	Speckle noise	17975.2379	134.0718	118.6956	5.5841	0.0016	0.1791
Roberts Edge Detector	Salt and pepper noise	17973.8906	134.0667	118.6873	5.5844	0.0019	0.1791
	Gaussian noise	17974.5354	134.0691	118.6905	5.5842	0.0018	0.1791
	Poisson noise	17974.1262	134.0676	118.6886	5.5843	0.0019	0.1791
	Speckle noise	17975.8232	134.0739	118.6968	5.5839	0.0015	0.1791
Canny Edge Detector	Salt and pepper noise	17964.0723	134.0301	118.6409	5.5868	0.0043	0.179
	Gaussian noise	17952.2251	133.9859	118.5962	5.5896	0.0072	0.1789
	Poisson noise	17960.5588	134.017	118.6291	5.5876	0.0052	0.179
	Speckle noise	17930.588	133.9051	118.5428	5.5949	0.0124	0.1787
Log Edge Detector	Salt and pepper noise	17969.4399	134.0501	118.674	5.5855	0.003	0.179
	Gaussian noise	17968.5483	134.0468	118.6709	5.5857	0.0032	0.179
	Poisson noise	17969.6348	134.0509	118.6753	5.5854	0.003	0.179
	Speckle noise	17955.1382	133.9968	118.6321	5.5889	0.0065	0.1789
Hybrid Edge Detector	Salt and pepper noise	17951.6567	133.9838	118.59	5.5898	0.0073	0.1789
	Gaussian noise	17938.8825	133.9361	118.5449	5.5928	0.0104	0.1788
	Poisson noise	17947.4941	133.9683	118.5764	5.5908	0.0083	0.1789
	Speckle noise	17902.735	133.8011	118.4449	5.6016	0.0192	0.1785

Figure 3: comperitive performance of edge detectors

8 Conclusion

This document discussed the comparison between traditional edge detection techniques and the hybrid approach to the edge detection technique, which is the combination of trunks and border detectors. 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. As we hope, we receive the results accordingly. The value of MSE is lower, RMSE is also low, while PSNR is high, and the bit error is low for the comparative hybrid edge detection techniques to other traditional edge detection techniques.

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