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Impact of Edge Detection Algorithms on Different Types of Images using PSNR and MSE

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ABSTRACT

Edge detection is the process of detecting sharp changes in image brightness in a digital image. It aids in the recognition of an object and its shape in an image. As a result, edge detection plays a vital role in image processing, especially in domains like segmentation, image registration, and object identification. This paper is an attempt to study the impact of several edge detection algorithms such as Sobel, Prewitt, Robert, Kirsch, Robinson, Laplacian of Gaussian (LOG) and Canny. The three different types of images such as medical, natural and satellite images are considered for experiment. Performance measures used for comparison are Mean Squared Error (MSE) and Peak Signal to Noise Ratio (PSNR).

Keywords: Canny, Edge Detection, Gaussian filter, Image Processing, Sobel, Thresholding.

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INTRODUCTION

Edge detection is one of the most useful image enhancement techniques for boosting the quality of image analysis. In image processing, edge detection minimises the quantity of data (pixel) necessary to represent an image and filters out extraneous data while maintaining the image's structural assets[1]. In recent decades, several edge detection techniques have been presented. There will be a few notable works mentioned. Using a collection of 3x3 filters, Sobel detection calculates the magnitude of a gradient in an image [4][5]. Threshold-based image segmentation techniques are proposed in paper [6], where the segmentation strategies are classed as contextual or non-contextual. Edge detection techniques such as Sobel, Robert, Prewitt, and Canny edge detection operators are compared by the paper [7]. Canny edge detection to identify prawn species is proposed in paper [8]. Comparative study on edge detection algorithms is carried out by work [9]. Comparison of edge detection techniques in food quality inspection is proposed in the work [10].

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The edge detection process has four steps, as shown in fig.1.

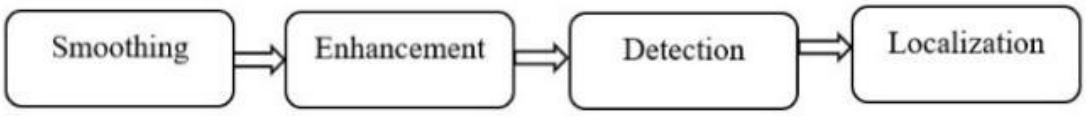

Figure 1: Steps in Edge Detection

Smoothing: In order increase the performance of the edge detector and to reduce noise image filtering is performed in this step.
Enhancement: Image enhancement is done to improve the digital image quality and thereby improving the edges by using high pass filters.
Detection: All edge points will be extracted and then discard edge pixels that has been determined as noise in this step.
Localization: - Confirming the location of an edge is done in this step [2].
In digital image processing, such as object recognition, motion analysis, and pattern recognition, edge detection is one of the broadly adopted techniques. There are a variety of approaches to edge detection, however most of them belong into one of two categories.
In Gradient method, the edges are detected using the image's first derivative.
Laplacian method looks for zero crossing to locate edges using image's second derivative [3].

EDGE DETECTION METHODS

Edge detection techniques commonly used are Sobel, Prewitt, Robert, Kirsch, Robinson, LOG and Canny edge detection algorithms.

Sobel

The algorithm computes gradient of image intensity at each location by analyasing derivatives gives, which gives the direction to increase image intensity from bright to dark at each place using first-order derivative convolution. It plots the edges with the highest gradients [11]. This gradient-based operator has two convolution 3x3 matrices (kernels), one for determining the gradient x axis (rows) and the other for determining the y axis (columns) [15]. Gx and Gy are two matrices depicted in equation 1, where G stands for gradient and x and y represent the horizontal and vertical mask axes, respectively.

$$G_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad Gy = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \qquad (1)$$

To find the gradient at each position, these Gx and Gy are concatenated. Where |G| signifies the gradient G_x^2 and G_y^2 specifies the image's gradient magnitude.

$$|G| = \sqrt{G_x^2 + G_y^2} \qquad (2)$$

Prewitt

Prewitt, the same as Sobel, is a gradient-based operator that calculates the first derivative. For determining the peak gradient magnitude, it uses the 3x3 masks shown in equation 3. It works in that direction after the highest magnitude is discovered.

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Volume-03 | Issue-04 | December-2022

$$G_x = \begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix} \quad Gy = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} \tag{3}$$

Roberts

The Roberts edge detector is a gradient based edge detection operator and provide a 2D spatial gradient measurement of an image and has 2x2 convolution mask. The Roberts edge detection is fast since the filter is small but it is also subject to interference by noise [16].

$$G_x = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \quad Gy = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} \tag{4}$$

Kirsch and Robinson

Kirsch compass kernel detects edge magnitude and direction in all eight directions and it is also a derivative mask. The edge magnitude at a point is considered as the response of the kernel which gives strongest convolution value at that point. The corresponding edge angle at that point is the direction associated with that kernel [18]. The Robinson compass mask is made of Sobel masks, both are similar to Kirsch compass masks, however they are easier to use as the matrix coefficients only contain 0, 1, 2, and are symmetrical, only four mask results must be generated and the other results are the negation of the first four results. An edge, also known as a contour, is a small area with adjacent discrete pixel values [17]. Kirsch and Robinson compass masks are shown in the following equation.

$$\begin{bmatrix} -3 & -3 & 5 \\ -3 & 0 & 5 \\ -3 & -3 & 5 \end{bmatrix} \quad \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \tag{5}$$

Laplacian of Gaussian

LOG combines Gaussian and Laplacian filtering, it's also called the Marr and Hildreth operator. It can detect both edges and noise. It may be used to detect edges at various image scales and degrees of image focus. It finds the correct place of edges and by testing wider area around the pixel [19]. It's a gradient-based operator that subtracts the image's second derivative using the Laplacian. It employs the zero crossing technique of operation. LOG employs both the Gaussian and Laplacian operators, with the former reducing noise and the latter detecting sharp edges in an image [20].

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Volume-03 | Issue-04 | December-2022

Canny

The following are the steps in the Canny Edge Detection Algorithm:

- To smooth out the input image, use a Gaussian filter.
- Calculate the magnitude and angle of the gradient images.
- Suppress the gradient magnitude image with non-maxima suppression.
- Use the double thresholding technique to detect and link edges [18].

PERPOSE WORK / METHODOLOGY

Dataset

The experiment is done by considering test images taken as sets of medical images, natural images, and satellite images. Seven edge detection algorithms such as Sobel, Prewitt, Robert, Kirsch, Robinson, LOG and Canny are applied on the datasets. Medical images are taken from Kaggle Dataset, satellite images are downloaded from Google Earth Pro and natural images from Google Images. All images are in .jpg format and are of same resolution 512x512.

Methodology

The process of proposed work is depicted in the following fig. 2.

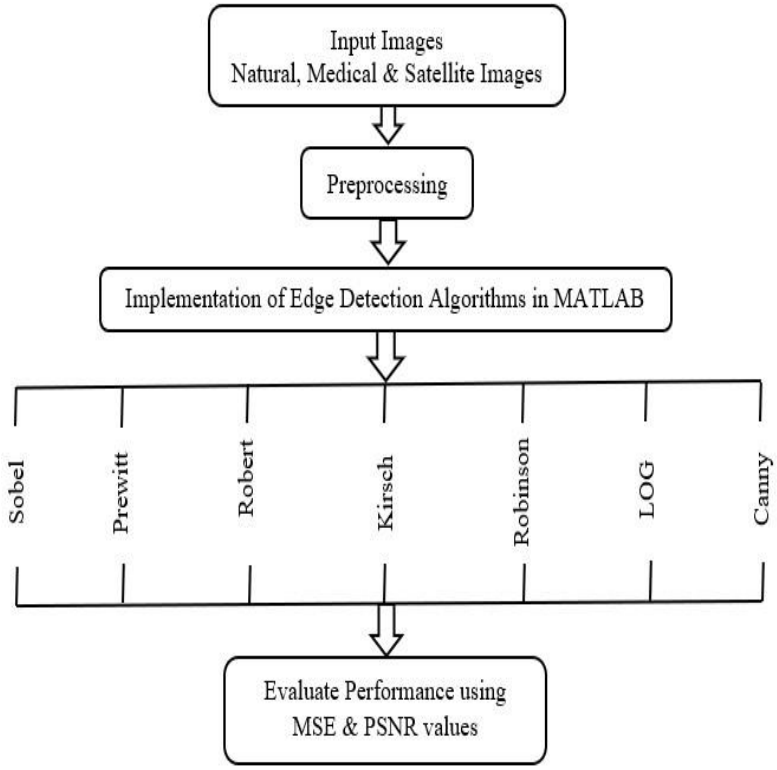

Figure 2: Workflow Diagram.

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Volume-03 | Issue-04 | December-2022

- Read the input images.
- Preprocessing: All input images considered are color images. For edge detection these RGB images are converted to grayscale. Then resize all images to get same resolution i.e., 512x512.
- All seven selected techniques are used to detect edges in test images, and the results are displayed in a frame using subplot.
- Evaluate the performance of all algorithms by calculating MSE and PSNR values and compare the results.

Performance Measures

Edge detection techniques are evaluated based on the identification of actual edges, processing time, error ratio, and noise level, among other factors. In this paper, the quality of the provided edge detectors is compared to a reference image using PSNR and MSE values. The MSE is a measure of the cumulative squared errors between the specified edge detector and the ideal edge. PSNR is used to compare two images [12].

Mean Squared Error

The average pixel difference between the original ground truth image and the edge detected image is referred to as the MSE. The MSE increases as the variance between the original and processed image grows [13].

$$MSE = \frac{\sum_{M,N}[I_1(m,n)-I_2(m,n)]^2}{M,N} \quad (6)$$

Equation 6 is used to determine the MSE.The original image is I1, the edge detected image is I2, and the image's height and width are m and n, respectively.

Peak Signal to Noise Ratio

PSNR is the ratio of a signal's maximum achievable strength to the power of corrupting noise, which affects the representation's quality. The PSNR is typically expressed on a decibel scale.PSNR is an approximate estimate of how good a reconstruction is seen by humans [14]. The higher the PSNR score, the greater the quality of the edge detector discovered.

$$PSNR = 10\log_{10}(\frac{R^2}{MSE}) \quad (7)$$

PSNR is calculated using the equation 7.The maximum variation in the source image data is denoted by R. R is 255 if the data type is an 8-bit unsigned integer.

RESULTS AND DISCUSSION

The experiment is carried out to check the impact of various edge detection algorithms on medical, natural and satellite images. Results are evaluated in terms of PSNR and MSE values. Following Table1, Table2 and Table3 shows the experimental results of medical, natural and satellite images by applying Sobel, Prewitt, Roberts, LOG, Canny, Kirsch and Robinsons algorithms along with the PSNR, MSE values respectively.

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Volume-03 | Issue-04 | December-2022

Table 1: Results of the various Edge detectors for medical images using MSE and PSNR.

Natural Images		1	2	3	4	5
Sobel	**MSE**	7450.12	22206.85	19034.66	23801.8	24128.9
	PSNR	9.443168	4.69993	5.369348	4.398701	4.339424
Prewitt	**MSE**	7450.12	22206.98	19034.79	23801.88	24128.8
	PSNR	9.443164	4.699904	5.36932	4.398687	4.339441
Robert	**MSE**	7450.52	22207.68	19036.42	23802.69	24132.79
	PSNR	9.442935	4.699767	5.368947	4.398539	4.338724
LOG	**MSE**	7447.12	22195.58	19022.17	23795.55	24121.79
	PSNR	9.444918	4.702135	5.372199	4.399841	4.340705
Canny	**MSE**	7452.05	22209.97	19037.91	23803.55	24131.95
	PSNR	9.442042	4.699321	5.368608	4.398382	4.338875
Kirsch	**MSE**	7393.48	22080.15	18836.12	23667.1	23989.75
	PSNR	9.476313	4.724778	5.414886	4.423349	4.364543
Robinson	**MSE**	7433.38	22169.51	18973.23	23762.55	24092.5
	PSNR	9.452935	4.707239	5.383386	4.405869	4.345981

Table 2: Results of the various Edge detectors for natural images using MSE and PSNR.

Edge Detectors\Types of Images		Medical Image	Natural Images	Satellite Image
Sobel	**MSE**	5455.88	7450.12	8952.82
	PSNR	10.796148	9.4431684	8.6452007
Prewitt	**MSE**	5455.91	7450.12	8952.81
	PSNR	10.7961279	9.4431641	8.6452074
Robert	**MSE**	5455.69	7450.52	8954.78
	PSNR	10.7962998	9.4429352	8.6442484
LOG	**MSE**	5452.29	7447.12	8943.86
	PSNR	10.7990072	9.444918	8.6495488
Canny	**MSE**	5456.71	7452.05	8954.62
	PSNR	10.7954935	9.4420421	8.6443292
Kirsch	**MSE**	5386.01	7393.48	8838.08
	PSNR	10.8521309	9.476313	8.7012185
Robinson	**MSE**	5433.8	7433.38	8917.85
	PSNR	10.8137639	9.4529354	8.6621984

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Volume-03 | Issue-04 | December-2022

Table 3: Results of the various Edge detectors for satellite images using MSE and PSNR.

Satellite Images		1	2	3	4	5
Sobel	**MSE**	8952.82	19960.29	5457.66	6661.77	15563.67
	PSNR	8.645201	5.163131	10.79473	9.928906	6.243678
Prewitt	**MSE**	8952.81	19960.41	5457.79	6661.96	15563.69
	PSNR	8.645207	5.163104	10.79463	9.928781	6.243674
Robert	**MSE**	8954.78	19963.54	5458.54	6665.26	15565.35
	PSNR	8.644248	5.162423	10.79403	9.926629	6.24321
LOG	**MSE**	8943.86	19945.53	5452.02	6651.19	15552.83
	PSNR	8.649549	5.166344	10.79923	9.935804	6.246706
Canny	**MSE**	8954.62	19966.62	5458.74	6663.31	15563.71
	PSNR	8.644329	5.161753	10.79387	9.927897	6.243669
Kirsch	**MSE**	8838.08	19772.62	5360.56	6515.73	15377.03
	PSNR	8.701219	5.204156	10.87269	10.02517	6.296074
Robinson	**MSE**	8917.85	19902.7	5428.57	6620.62	15505.51
	PSNR	8.662198	5.175679	10.81795	9.955812	6.259938

Comparative analysis of edge detection algorithms for different types of images is represented in following table 4 and the corresponding graph is shown in fig.3.

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Volume-03 | Issue-04 | December-2022

Table 4: Comparison results of the various Edge detectors for different types of images using MSE and PSNR.

Medical Images		1	2	3	4	5
Sobel	**MSE**	5455.88	9176.12	5608.27	8534.3	8534.3
	PSNR	10.79615	8.538208	10.67651	8.85312	8.85312
Prewitt	**MSE**	5455.91	9176.12	5608.28	8534.33	8534.33
	PSNR	10.79613	8.538207	10.6765	8.853103	8.853103
Roberts	**MSE**	5455.69	9175.76	5607.57	8534.07	8534.07
	PSNR	10.7963	8.538377	10.67705	8.853239	8.853239
LOG	**MSE**	5452.29	9170.73	5602.75	8529.46	8529.46
	PSNR	10.79901	8.540762	10.68079	8.855584	8.855584
Canny	**MSE**	5456.71	9176.4	5608.69	8534.39	8534.39
	PSNR	10.79549	8.538076	10.67618	8.853072	8.853072
Kirsch	**MSE**	5386.01	9072.75	5510.94	8424.92	8424.92
	PSNR	10.85213	8.587412	10.75254	8.909139	8.909139
Robinson	**MSE**	5433.8	9143.27	5577.2	8498.21	8498.21
	PSNR	10.81376	8.553785	10.70064	8.871526	8.871526

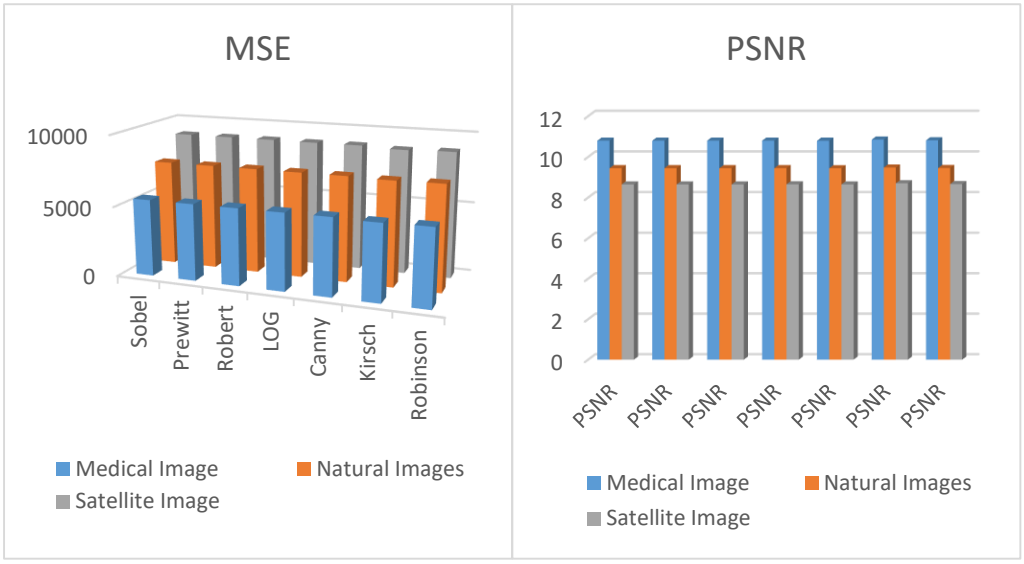

Figure 3: Comparison graph of MSE and PSNR values based on different types of images from different datasets

Following fig.4 shows the sample resultant images after applying various edge detection algorithms. By observing the results, it is noticed that Canny edge detector produces good results in comparison with other edge detection techniques.

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Volume-03 | Issue-04 | December-2022

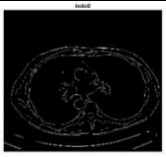
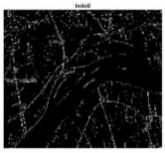
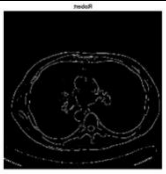
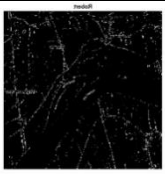
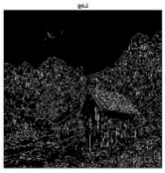
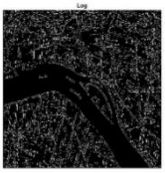
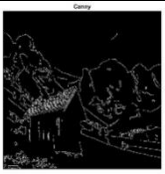
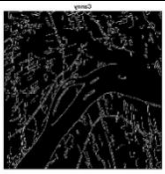
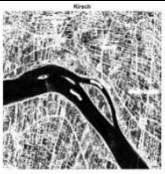
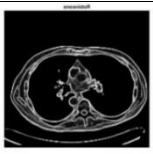
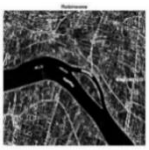
Types of Images	Medical Image	Natural Image	Satellite Image
Original			
Sobel			
Prewitt			
Robert			
LOG			
Canny			
Kirsch			
Robinson			

Figure 4: Results by applying various edge detection techniques on different type of images are displayed.

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Volume-04 | Issue-01 | March-2023

CONCLUSION

The proposed work is implemented by applying edge detection algorithms for three different datasets medical, natural and satellite images. Sobel, Prewitt, Robert, Kirsch and Robinson works on the first order derivatives of image, LOG works on the second order derivatives of an image, Canny edge detection is optimal edge detection technique works by applying non maximal suppression and hysteresis thresh holding to minimize error rate and improve edge localization compared with other algorithms. PSNR and MSE are calculated for each type of the images by applying all the algorithms, the results shows that the canny algorithm is better.

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