

A Study on Edge Segmentation of Different Types of Datasets with Multiple Algorithms

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Abstract

In this paper, we study edge detection or segmentation, which is recognized as a rudiment innovation as it can evaluate sharpness and analyze object boundaries. That's the reason it has been an influential figure in the image-processing era. Because of this, it has a significant influence in the age of image processing. On the other hand, edge detection is the process of dividing an image into discontinuous regions. It specifies the intensity shift connected to the image's edge. There are several methods for detecting edges. Four edge identification methods on satellite images and satellite images affected by Gaussian noise were examined. Known edge detection technologies such as Canny, Prewitt, Scharr, and Robert operators are included in this study. Additionally, the key feature of an image for evaluating its quality is the Image Quality Assessment (IQA) measure. We primarily take into account SSIM, MSE, PSNR, and RMSE when assessing image quality. Experimental validation has been obtained for the application of the Canny and Prewitt algorithms to the satellite dataset. However, when the Gaussian Noise effect is added to the same dataset, clever edge detection performs better.

Keywords

SSIM, MSE, PSNR, RMSE

1. Introduction

Digital image processing is a necessary tool for processing digital photos using a variety of techniques. Edge detection is one of the most important image-processing algorithms for object recognition [1]. Additional uses include medical

services, satellite imagery, figure printing, and more [2]. Moreover, it is helpful for mechanized motion control schemes, anatomy research, item recognition in blurred images, feature and fingerprint assimilation, functional appliances in radiography, and machine etiology in surgery [3]. Early on in the preprocessing phase, image attributes that are relevant to assessing the form and prospect of items are recognized. Based on these features, the detector must decide if each pixel has to be analyzed as an edge. These criteria result in different gray levels in the image. Edge detection is required to identify the edges of materials in an image. Data extraction, machine vision, image processing, and other applications require it. Usually, edges appear where two distinct regions of an image converge. In many picture data recovery systems, it is the initial stage [4] [5]. Some issues that come up during edge segmentation include the detection of fake edges and the creation of superfluous thick or thin lines. One or two photos are used for edge detection in earlier studies. Examining it with a whole dataset is really difficult. Additionally, noise reduces the effectiveness of several edge detection methods. However, it is a laborious effort to identify the edges of hazy satellite photos. Applications utilizing satellite photos and satellite images with Gaussian effects may employ the specific technique if it performs better in those kinds of images. As technology develops, various methods for edge detection have been created. Quality analysis is also done in this research to compare these methods. In the past, numerous edge detection techniques were widely used. With certain research advancements and applications, L. Zhai *et al.* [6] introduce delegate wavelet transform, obscure, and rephrasing, reflecting the characteristics of edges, conventional detectors, and well-known edge detection approach. An overview of the kernel and soft computing-based approaches was also given by Goel *et al.* [7] offered a summary of the approaches based on soft computing and kernels, along with significant research on edge detection. Soft computing techniques and kernel-based methods are the two categories of methodologies covered in this study. Researchers have proposed surveys of the most recent approaches, including gradient and Laplacian-based edge detection techniques. Neural networks and fuzzy logic have been used by G. M. H. Amer *et al.* [8]. The researchers suggest using adaptive edge detection methods after making adjustments and adjusting for different noise levels. They assert that because Canny Operator is better at filtering out noise, it performs better than conventional algorithms. Edge detection is mentioned by Rashmi *et al.* (2013) [9] as a technique for segmenting image segments according to discontinuity zones. Enhancement of the Canny technique to guarantee RGB image edge detection offers many useful applications without turning to grayscale. The difficulties of choosing an effective segmentation technique as part of image processing are discussed by Muthukrishnan *et al.* [10]. They examined various Gaussian-based and gradient-based edge reveal techniques. They have determined that Canny Edge Detection is the most effective method based on visual examination of their experimental

setup. In the article [11], Joe *et al.* (1997) conducted trials on a variety of segmentation strategies. They contend that the Canny Algorithm is unsuitable for real-time applications because it has the lowest percentage error but the longest execution time. Instead of using “luminosity,” the researchers have developed a new edge detection technique dubbed Log_Sobel, which is based on the “logarithm of luminosity” [12]. They demonstrated that this method is suitable for online detection and performs better and faster than conventional techniques. Another comparison analysis for a number of well-known edge detection techniques is carried out in Paper [13]. The results of their experiment indicate that Canny performs better.

2. This Article Is Meant to Make the Following Contributions

- 1) Conducted experimental research, created features, and used a variety of edge detection algorithms to examine the results.
- 2) For the suggested experiment, quantitative measurement is carried out utilizing SSIM, MSE, RMSE, and PSNR.
- 3) Two datasets are used to assess the experimental results.
- 4) Analysis of the observations and text development.

3. Edge Detection Technique

One important method that is primarily required for feature detection in picture rendition is edge detection. In a digital image where the light changes quickly, extraction aims to identify gaps and pick specific locations [9]. It preserves its constitutional methods for additional image processing while reducing the size of the associated data in the image. An adjacent area is divided into two sections by an edge. Every gray level has different values on both sides and is rather uniform. Small changes in an image’s brightness are called edges. The edges can be used to illustrate the key characteristics. An integral component of image analysis is the edge ascertainment function.

A high spatial frequency sector that is typically associated with edges is highlighted by the Robert operator. The full absolute magnitude of the local gradient of the original data at that location is shown by the pixel rates in the resultant data [10] [13] [14]. Scharr technology, on the other hand, operates on the assumption that the final results filters are numerically consistent. [15]. The Sobel approach and the Prewitt method are nearly identical [4] [16] [17]. It does not compute pixels close to the mid-point of enshrouding and is the reverse of the Sobel operator [16]. In contrast to other well-known edge detection methods, turbulence does not affect the Canny approach. But if it functions well, the Canny operator can be better [10] [18]. Weak edges cannot be detected by other edge detection methods, but canny can them.

The edge portrayal of an image preserves essential information about object configuration while reducing the amount of data that needs to be prepared. Many object assimilation techniques used in vision systems can easily incorporate this visual description [10]. However, there isn’t a single performance directory to

evaluate edge detection techniques. Segmentation systems' efficacy is continuously assessed, both independently and in relation to their functions. Next, compare output photos with colored images using several metrics, including RMSE, PSNR, MSE, and SSIM. Next, Plotting the graph required normalizing the value (see **Figure 1**).

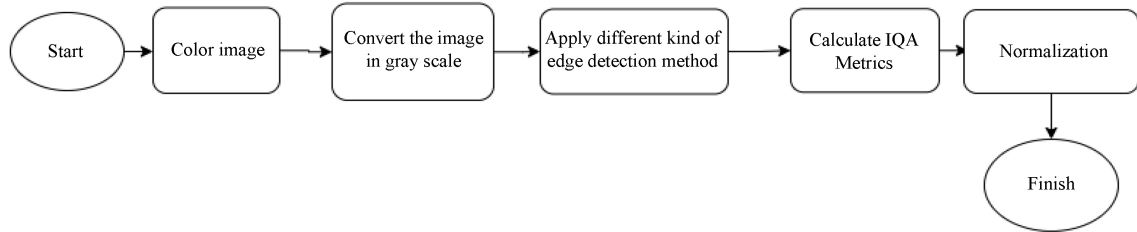


Figure 1. Flow chart for edge detection.

4. Comparative Parameters

Image quality assessments (IQA) are crucial instruments for evaluating how well different software and hardware systems maintain image quality [19]. IQA approaches for measuring quality can be divided into two categories [20]. There are several approaches to image quality assessment (IQA), but the subjective and objective methods are the most widely used. Objective image quality assessment (IQA) has grown rapidly over the past ten years. It's exciting to see the latest developments in autonomous IQA techniques that can forecast the subjective quality of visual signals [21]. Creating mathematical patterns that can reliably and automatically forecast visual perfection is the goal of IQA. Conversely, subjective approaches discuss how a picture is perceived or prediction [22]. The right methodology that can generate photographs of superior quality can be chosen using an objective based on the IQA metric. Which approach produces better and higher-quality photos can be ascertained using the IQA metric's objective [23]. A few mutually agreed-upon objectives Feature similarity measure (FSIM), tone-mapped images quality index (TMQI), dynamic range independent measure (DRIM), visual information fidelity (VIF), multi-scale structural similarity index (MS-SSIM), most obvious distortion (MAD), mean squared error (MSE), and structural similarity index (SSIM) make up IQA. Here, studies are conducted to assess the output quality of each edge detection methodology using SSIM, MSE, RMSE, and PSNR.

5. Mean Square Error

A common technique for evaluating picture efficiency is mean square error. when it offers a zero that exhibits outstanding excellence. The MSE takes into account both its bias and variance. The mean square error (MSE) of an unbiased predictor is its inconsistency. It is also referred to as the standard deviation and is measured in the same units as variance [22]. Better accuracy is indicated by a small MSE score. The following is the formula for calculating MSE.

$$\text{MSE} = \frac{1}{N} \sum |\hat{y}_i - y_i|^2$$

5.1. Structural Similarity Index Method

One popular perception method is the Structural Similarity Index Method. In this method, structural data is considered to prospect image degradation as a switching. It also works in conjunction with other elements like intensity (contrast) masking, light level (luminance) masking, and so on. Structural information is defined as temporally closed or strongly interconnected pixel intensities. Additional useful information about visual things is made possible by these important and advantageous pixels in the picture domain. Luminance masking is the process of making the distorted area of an image less noticeable around the edges of the image. To make texture irregularities in an image less obvious, contrast masking is taken into consideration. It is equivalent to how similar the restored image is to the original. [22], additionally, lower values indicate less similarity.

$$\text{SSIM}(x, y) = \frac{(2v_x v_y + s_1)(2\sigma_{xy} + s_2)}{(v_x^2 + v_y^2 + s_1)(\sigma_x^2 + \sigma_y^2 + s_2)}$$

5.2. PSNR

The peak signal-to-noise ratios for the input and output images are determined by the PSNR metric. But this ratio computes by contrasting the output image's nature with that of the main image. Additionally, better image proficiency is indicated by a higher value [24]. Conversely, PSNR is the ratio of the highest achievable value of a prior signal to the original signal in relation to the square of turbulence that has a direct impact on the outcome. Even while the dynamic province of many motions is quite vast, the PSNR, which is often reported in logarithmic dB, indicates less similarity.

$$\text{PSNR} = 10 \log_{10} (\text{peakval}^2) / \text{MSE}$$

5.3. Root Mean Square Error

The MSE displays the root mean square error. However, because it can assess the faults in predicting datasets, RMSE is becoming more and more popular [25]. A statistical evaluation of the model's perfection for experimental purposes requires RMSE. RMSE is calculated by taking the mean of the residuals, the standard of residuals for each set of data, the square root of the mean, and the residual (difference between estimation and truth) for each item of data. Since RMSE employs and incorporates actual measurements at every anticipated data point, it is frequently utilized in supervised training applications. A smaller value denotes a higher image quality.

$$\text{RMSE} = \sqrt{\frac{1}{N} \sum |\hat{y}_i - y_i|^2}$$

where,

$\hat{y}_1, \hat{y}_2, \dots, \hat{y}_n$ are recognized as predicted values;
 y_1, y_2, \dots, y_n methods identified as observed values;
 n is admitted the amount of perception.

Both satellite and Gaussian-affected photos are employed in the experiment. About 100 photos were utilized in the experiment, and the dataset was gathered from [26]. Each image has a resolution of 1500×1500 pixels, and 1.3178 GB of data are used in the trials.

6. Result and Discussion

Google Colab' is a free cloud-based Jupyter notebook environment used for the experiment, which uses 100 satellite photos to identify the clean edge. After introducing Gaussian noise to the same dataset, the experiment is conducted. Our goal is to gather the edges and put the edges' main function into practice. The results of many edge identification methods evaluated on 100 satellite photos are shown in Figure 2. The outcomes of applying different edge detection techniques to the Gaussian effect on the same dataset are also displayed in Figure 3.

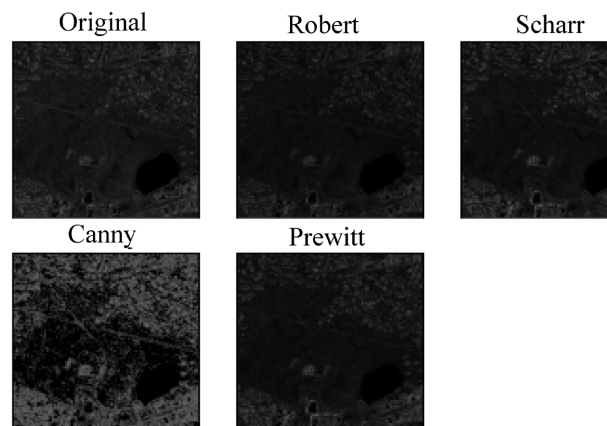


Figure 2. Original satellite image with various edge.

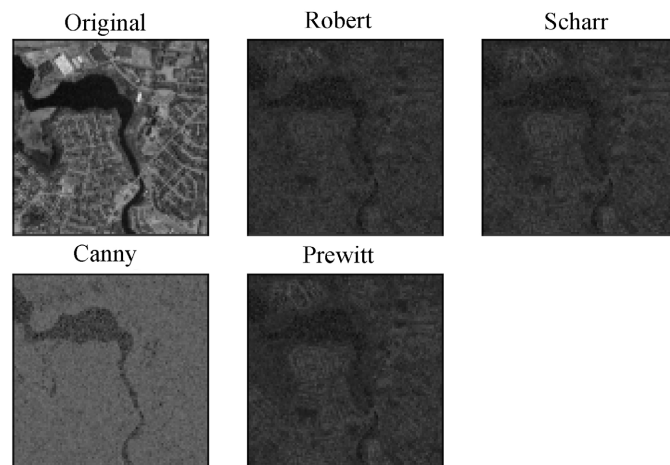


Figure 3. Experimental results of various edge detection methods using Gaussian Noise effected satellite image.

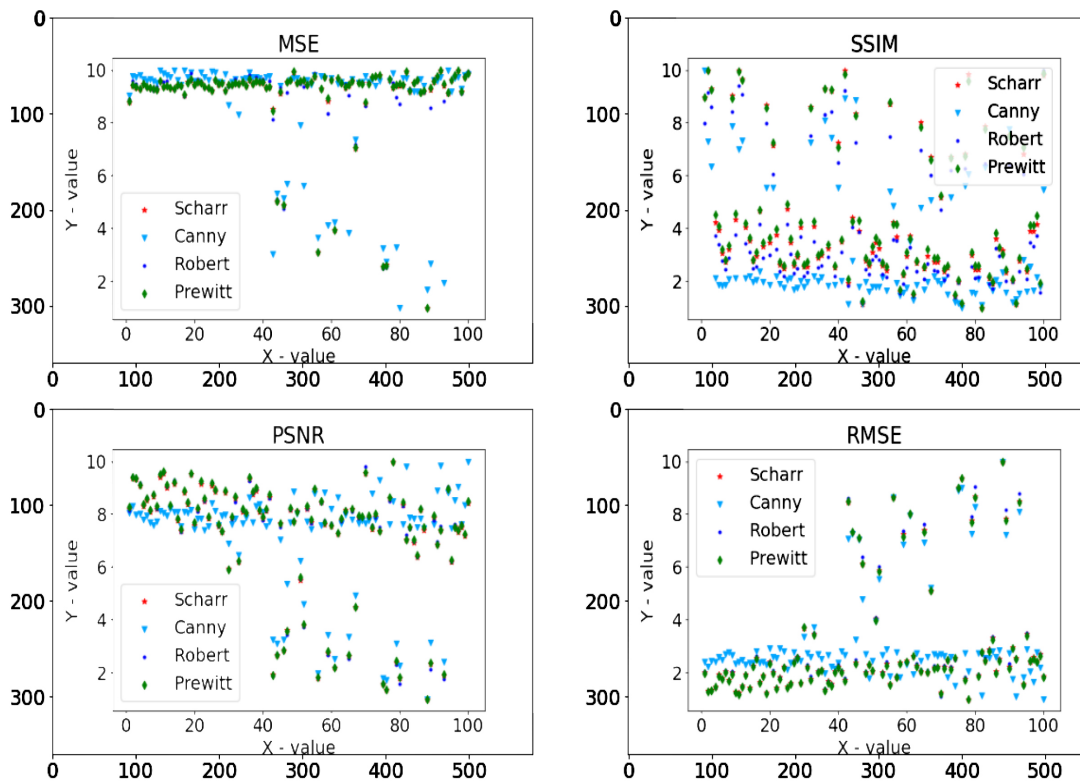


Figure 4. MSE, PSNR, SSIM, and RMSE values for different edge detection techniques using 100 satellite images.

Table 1 presents the mean values for PSNR, SSIM, RMSE, and MSE for numerous edge segmentation methods on satellite image images. **Table 2** describes the same values for Gaussian noise-affected edge segmentation.

Table 1. PSNR, SSIM, RMSE, and MSE values for numerous edge segmentation methods on satellite image Images.

Algorithms	MSE Mean	SSIM Mean	PSNR Mean	RMSE Mean
Scharr	8.999088745424563	4.284074559367789	7.114708499341431	3.0736675
Canny	8.608438309765255	3.006506844809998	7.147585524340723	3.298607
Robert	8.982755495409316	3.8441874369229	7.1327897681155585	3.098182
Prewitt	9.007859249423747	4.36585994609644	7.169926311273446	3.038334

Table 2. PSNR, SSIM, RMSE, and MSE values for numerous edge segmentation methods on Gaussian effected satellite image Images.

Algorithms	MSE Mean	SSIM Mean	PSNR Mean	RMSE Mean
Scharr	8.573418882350534	5.960621107445782	7.952542931234165	2.6705868
Canny	8.362352111747423	3.3931847428226205	7.636413404690499	3.0973427

Continued

Robert	8.98630942464264	3.4511823706130444	7.8790990932185085	2.7408605
Prewitt	8.789043417455723	4.448910122598226	7.808857969536948	2.76669

Using **Table 1**, a graphical representation of performance analysis of edge detection techniques has been depicted in diagram 5. Besides, using **Table 2** data diagram 7 has been delineated

Based on 100 satellite images, MSE, SSIM, PSNR, and RMSE values for different edge detection algorithms are plotted in diagram 4, and the same thing is done for Gaussian-effected satellite images in diagram 6.

7. Conclusion

This research uses performance evaluation to analyze and compare several edge detection techniques with different datasets. Following experimental investigation, it is found that Prewitt and Canny edge detection systems perform better on satellite photos in terms of PSNR, MSE, and RMSE. Prewitt provides results that are more comparable in terms of SSIM. Nonetheless, each term determines Scharr and Robert’s average edge detection performance. Canny outperforms other algorithms in terms of MSE, PSNR, and RMSE when the Gaussian effect is taken into account using satellite photos. But, according to SSIM, Robert produces results that are comparable. Various methods perform better for various photos in the same dataset. Therefore, **Figures 4-7** make it evident that no certain edge detection is more effective for a certain dataset. It can vary in terms of images. An improved filter that reduces noise can be created in the next years to get around the problems and enhance image quality.

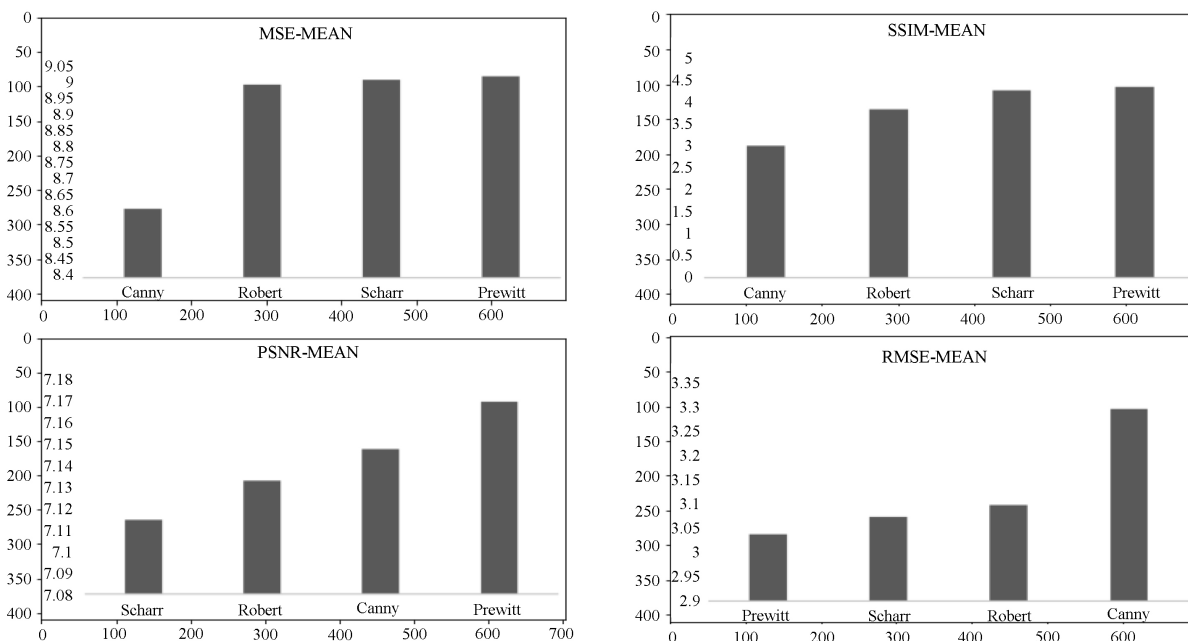


Figure 5. Mean value of MSE, SSIM, PSNR and RMSE for edge detection methods on satellite images.

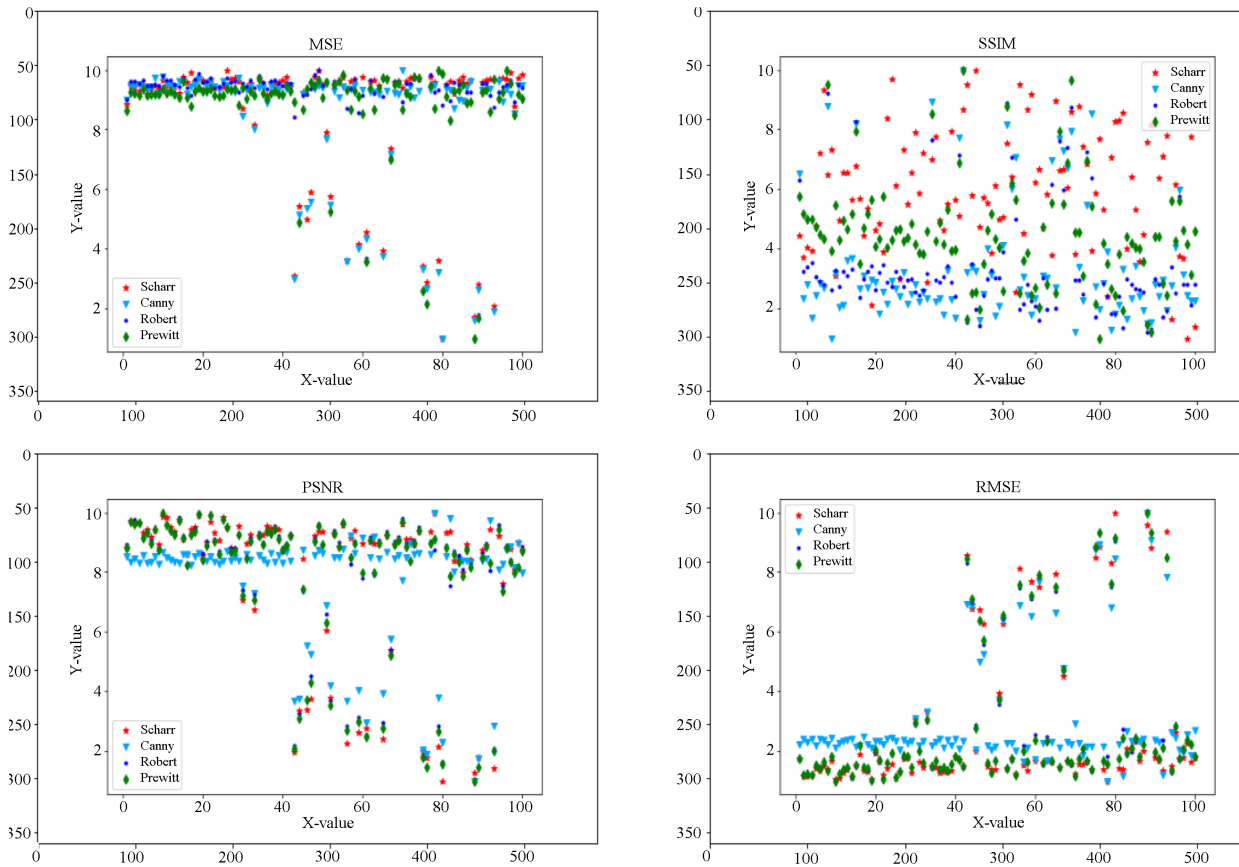


Figure 6. MSE, PSNR, SSIM, and RMSE values for different edge detection techniques on 100 Gaussian effected satellite images.

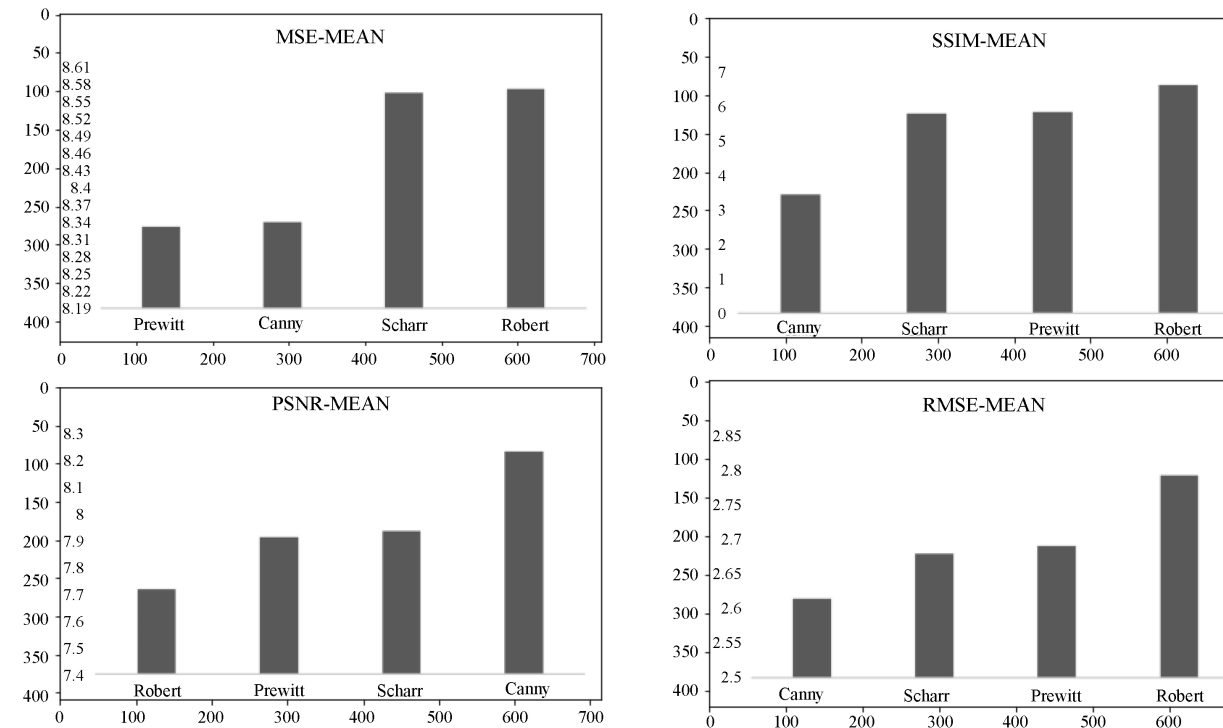


Figure 7. Mean value of MSE, SSIM, PSNR and RMSE for edge detection methods on Gaussian effected satellite images.

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Conflicts of Interest

The authors declare that they have no competing interests.

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