

The edge detection enhancement on satellite image using bilateral filter

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Abstract.

Satellite imagery is the image taken from satellites from outer space. It captures the appearance of the earth's surface through remote sensing. Usually, satellite image's object is hardly detected because many objects are covered with cloud shadows in the sky. Edge detection has an important role in image analysis. Edge detection aims to extract the boundary of an object contained in the image. Gaussian Filter is usually used on edge detection to smooth the image and reduce noise. However, in satellite image, we can improve it by using another filter. In this research, we compare gaussian filter with bilateral filter and analyze those two methods. We also using several operators to see the optimized process. After the experiment, by using the comparison parameter such as largest PSNR value, and the smallest MSE value, we can conclude that Bilateral Filter with Canny Operator is the most optimized edge detection for Satellite Imagery.

Keywords: Gaussian Filter, Bilateral Filter, Edge Detection, Satellite Imagery, Roberts Operator, Canny Operator, Frei Chen Operator

1. Introduction

Satellite imagery is very useful in various sectors such as geography, mining, and energy, meteorology, weather, forestry, etc. Satellite imagery is difficult to detect because many of the satellite images are covered with cloud shadows in the sky [1]. There are many methods for edge detection. Some methods for edge detection are using Roberts Operator, Canny Operator, and Frei Chen Operator. These methods have different characteristics. Edge detection becomes the main approach in image recognition and analysis can be based on the edge of the image containing useful information [2]. Image enhancement using the Gaussian Filter is commonly used for edge detection to reduce image noise. Gaussian filters are applied to smooth the image and reduce the noise, but will also smooth the edges [3]. Bilateral filter is a technique to smooth images while preserving the edges [4]. This technique is very similar to Gaussian filtering [5]. Bilateral filter is a non-iterative, local and simple nonlinear technique by combining gray degrees based on geometric proximity and photometric similarities [6]. Therefore, this paper proposes an optimized algorithm for satellite image edge detection based on image enhancement using Bilateral Filter by preserving edges. The purpose of this research is to analyze traditional edge detection of Gaussian Filter on satellite images and improve edge detection with Bilateral Filters, then the comparative analysis is conducted in this research to see the optimized edge detection.

In image processing, filtering is one of the bases used in various tasks such as interpolation, re-sampling, and noise removal. The filter used depends on the nature of the task performed by the filter and the type of data to be used for the operation [7]. Filtering is one tool used in many fields for various applications, especially in this section for image enhancement.



2. Gaussian Filter

Gaussian Filter is used in the field of image analysis especially for smoothing process, blurring, eliminating detail, and noise removal [8]. In Gaussian Filter, the intensity value of each pixel is replaced by the average of the weighted value for each of its neighboring pixels and pixels itself. The number of neighbors involved depends on the filter being designed. For digital image processing, the zero mean Gaussian of two variables is expressed by the equation:

$$f(x, y) = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{x^2+y^2}{2\sigma^2}\right) \quad (1)$$

Discrete estimates of this continuous function are determined using two parameters [9]

- (1) the desired size of the kernel (as $N \times N$ filter mask);
- (2) the value of σ , the standard deviation of Gaussian function.

3. Bilateral Filter

Bilateral filters are one of the noise reduction methods that have two kernel filters: spatial kernel and range kernel [5]. The spatial kernel aims to smooth the image based on the Gaussian function [10]. Spatial Kernel is the distance between the pixels of the image (Euclidean distance), and range kernel is the similarity of the intensity between the two pixels in the image. Spatial kernel (W_{σ_s}) is the realization of spatial proximity measurement is by the equation

$$W_{\sigma_s} = \exp\left(\frac{-\|p-q\|^2}{2\sigma_s^2}\right) \quad (2)$$

While range kernel (W_{σ_r}) means the weighting of pixels in accordance with the size of the difference in intensity of the pixel with the intensity at the pixel which is the center of analysis on the image. Calculation of range kernel in each pixel is shown in the equation.

$$W_{\sigma_r} = \exp\left(\frac{-(|I(p)-I(q)|^2)}{2\sigma_r^2}\right) \quad (3)$$

Bilateral Filtering ($W^B(p)$) computation as follows:

$$W^B(p) = \frac{1}{W} \sum_{q \in N(p)} G_{\sigma_s}(\|p-q\|) G_{\sigma_r}(|I_p - I_q|) I_q \quad (4)$$

Where I is a grey level image, $N(p)$ is a neighborhood of p , I_p is the intensity value at pixel location p , W_p is the normalization factor which ensures pixel weights sum to 1

$$W_p = \sum_{q \in N(p)} G_{\sigma_s}(\|p-q\|) G_{\sigma_r}(|I_p - I_q|) \quad (5)$$

4. Edge Detection

Edge is the essential characteristic of an image [4]. The edges of an image contain crucial information from the image Edge detection is a significant step in image processing. Image edges can represent the objects contained in the image, shape, size, and sometimes also information about the texture. Edge detection is used to extract the essential features [14].

4.1 Roberts Operator

The first operator used for edge detection is the Roberts Operator [11]. It was given by Robert Cross in 1963. Roberts operator is a first-order operator, which uses a partial differential operator to find the

edge [2]. Roberts operator is a simple edge detection technique and has a fast computing rate. The image to be detected by the edge is combined with the mask of the operator and the gradient magnitude to be calculated directly. The Roberts operator uses the following 2x2 masks:

$$G_x = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \quad G_y = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix}$$

4.2. Canny Operator

Canny is one of the modern edge detection algorithms. In 1986 John Canny proposed three criteria to be the basis of filter mining to optimize edge detection in noise-sensitive images. The first step in implementing Canny is to smooth the image [2]. Then find the image gradient in both vertical and horizontal directions [12]. Canny uses a Gaussian filter before applying the mask. Gaussian filters can reduce the noise as much as possible [11]. Canny edge detectors are not sensitive to noise causing Canny can detect weak edges [2].

4.3. Frei Chen Operator

Frei Chen is a unique operator [12]. Frei Chen mask contains the base vector. This is implemented in the 3x3 image area represented by the number of nine Frei Chen masks [13]. Here we described the frei chen operator used in this research :

$$G_1 = \frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & \sqrt{2} & 1 \\ 0 & 0 & 0 \\ -1 & -\sqrt{2} & -1 \end{bmatrix} \quad G_2 = \frac{1}{2\sqrt{2}} \begin{bmatrix} 1 & 0 & -1 \\ \sqrt{2} & 0 & -\sqrt{2} \\ 1 & 0 & -1 \end{bmatrix} \quad G_3 = \frac{1}{2\sqrt{2}} \begin{bmatrix} 0 & -1 & \sqrt{2} \\ 1 & 0 & -1 \\ -\sqrt{2} & 1 & 0 \end{bmatrix}$$

$$G_4 = \frac{1}{2\sqrt{2}} \begin{bmatrix} \sqrt{2} & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & -\sqrt{2} \end{bmatrix} \quad G_5 = \frac{1}{2} \begin{bmatrix} 0 & 1 & 0 \\ -1 & 0 & -1 \\ 0 & 1 & 0 \end{bmatrix} \quad G_6 = \frac{1}{2} \begin{bmatrix} -1 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 0 & -1 \end{bmatrix}$$

$$G_7 = \frac{1}{6} \begin{bmatrix} 1 & -2 & 1 \\ -2 & 4 & -2 \\ 1 & -2 & 1 \end{bmatrix} \quad G_8 = \frac{1}{6} \begin{bmatrix} -2 & 1 & -2 \\ 1 & 4 & 1 \\ -2 & 1 & -2 \end{bmatrix} \quad G_9 = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

4.4. Slope Magnitude Method

Slope magnitude can use the following equation where G_x and G_y is the image gradient in the horizontal and vertical direction [12]. Calculation of Gradient Magnitude (significant slope of the line) is denoted by Equation 6 below:

$$G = \sqrt{G_x^2 + G_y^2} \cong |G_x| + |G_y| \quad (6)$$

Where: G = gradient magnitude
 G_x = gradient to point x
 G_y = gradient to point y

5. Mean Square Error (MSE)

MSE is the mean of the square of the error value between the original image and the image of the image processing. The greater the value of MSE, the worse the quality of the resulting image.

Conversely, the smaller the value of MSE, the better the quality of the resulting image. Mean Square Error (MSE) can be formulated as follows [11]:

$$MSE = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} (f(x, y) - g(x, y))^2 \quad (7)$$

Where: M = the length of the image in pixels

N = image width in pixels

$f(x, y)$ = pixel value after edge detection

$g(x, y)$ = pixel value after edge detection

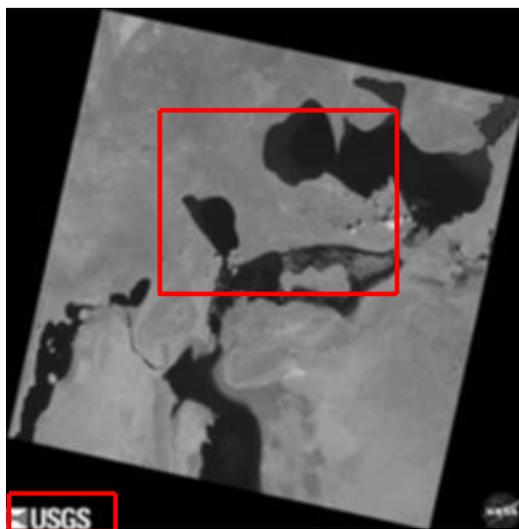
6. Peak Signal to Noise Ratio (PSNR)

Peak Signal to Noise Ratio (PSNR) is a calculation that determines the value of an image produced. The value of PSNR is determined by the size or magnitude of the MSE value that occurs in the image. The greater the value of PSNR, the better the resulting image. Conversely, the smaller the value of PSNR, the resulting image gets worse. PSNR can be calculated by the formula [14]:

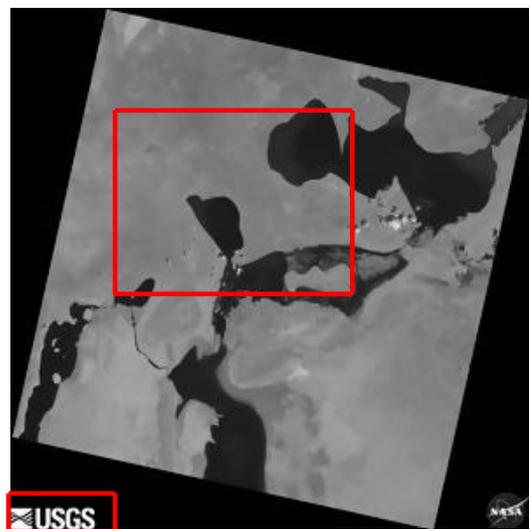
$$PSNR = 10 \text{ Log } 10 \left(\frac{255^2}{MSE} \right) \quad (8)$$

7. Results and Discussion

The dataset used in this research are satellite images which has been resized into 300 x 300 pixels resolution. We retrieve the data from USGS (United States Geological Survey). In this research we use lakes and seas object from the image. Figure 1 shows the comparative result between gaussian filter and bilateral filter



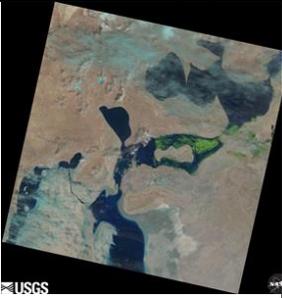
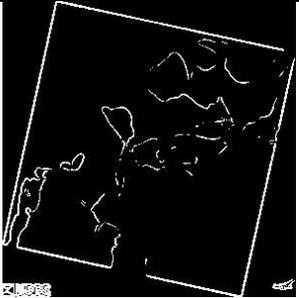
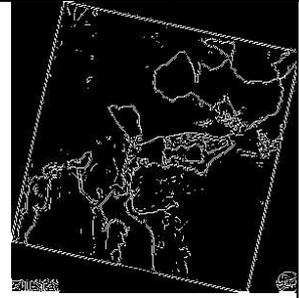
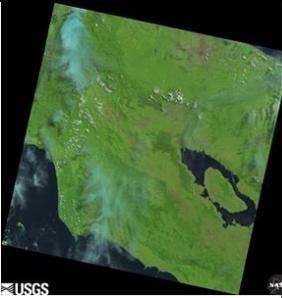
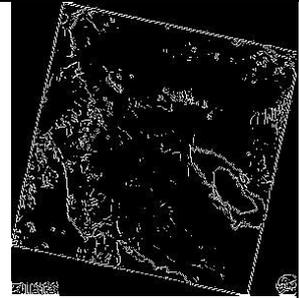
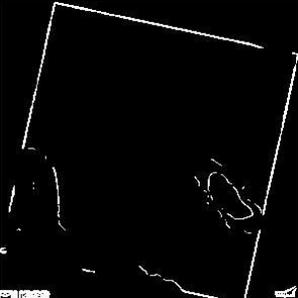
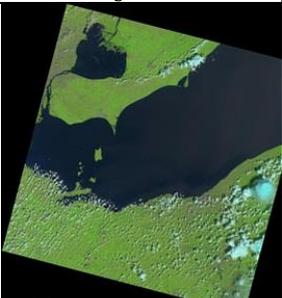
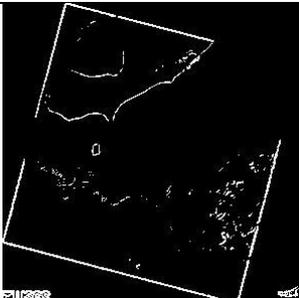
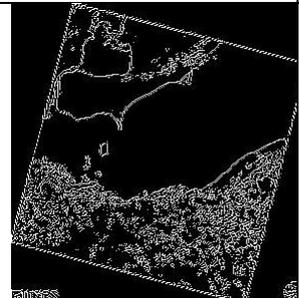
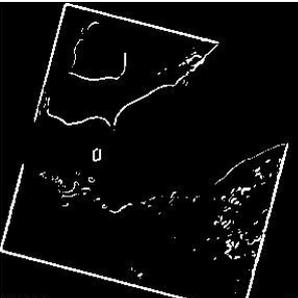
(a) Gaussian Filter, $\sigma = 1.4$
MSE = 10437.2
PSNR = 7.94495



(b). Bilateral Filter, $\sigma_s = 1.4$, $\sigma_r = 0.05$
MSE = 10436.3
PSNR = 7.94543

Fig 1. Experiments for satellite imagery show the results of the image using Gaussian Filter looks more blur than the image of Bilateral Filter which preserves the edge

Table 1. Edge detection results on satellite images with Gaussian Filter

Satellite Imagery	Roberts	Canny	Frei Chen
 Aral Sea.jpg $\sigma_s = 1.5$			
 Toba Lake.jpg $\sigma_s = 2$			
 Erie Lake.jpg $\sigma_s = 2.5$			

In table 1 we use different σ_s values for each image. The result shows edge detection on Roberts, and Frei Chen produces a smooth edge of the line and seen several lines cut off. While Canny produces more edge. Clouds on satellite imagery are also considered as edges. The higher the value of σ_s given to the Gaussian Filter will remove the edge of the image.

In table 2 we only use different σ_s values for each image and keep the σ_R value. The image on the edge detection of Roberts and Frei Chen has increased even the edge of the line on Frei Chen is thicker than using Gaussian Filter. Edge detection with Bilateral Filter can retain the edges although on Canny is not very visible.

We also experiment with increasing value of σ_R on the Bilateral Filter. The result shows that if the value of σ_R higher than before, the noise on the image becomes faded because σ_R controls the power of the noise filter on the image. As a result, the detected image loses many edges. While at σ_s , the higher the value of σ_s , then the object in the image faded. But it can still keep the edge so edge information can still be seen.

Table 2. Edge detection results on satellite images with Bilateral Filter

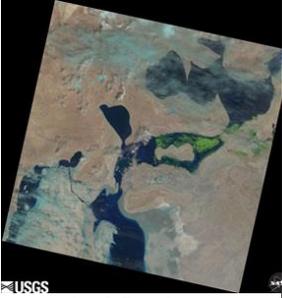
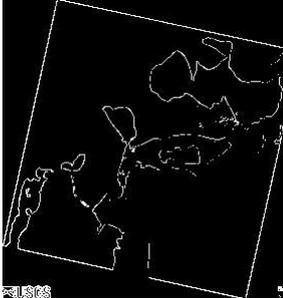
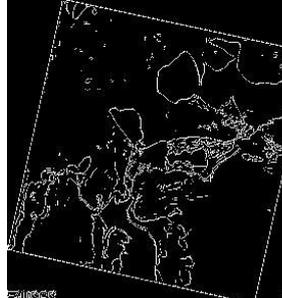
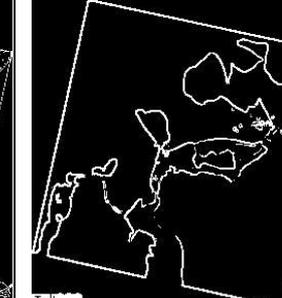
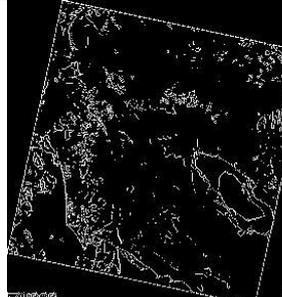
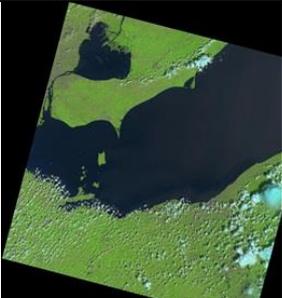
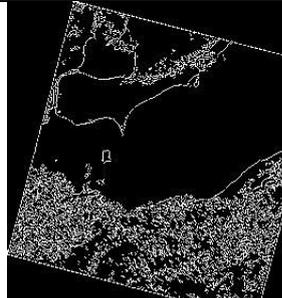
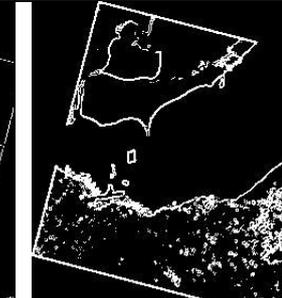
Satellite Imagery	Roberts	Canny	Frei Chen
 Aral Sea.jpg $\sigma_s=1.5$ $\sigma_R=0.05$			
 Toba Lake.jpg $\sigma_s=2$ $\sigma_R=0.05$			
 Erie Lake.jpg $\sigma_s=2.5$ $\sigma_R=0.05$			

Table 3. MSE and PSNR result for 300*300 pixels satellite image with Gaussian Filter

Methods	Aral.jpg $\sigma=1.5$	Toba.jpg $\sigma=2$	Erie.jpg $\sigma=2.5$	Nyasa.jpg $\sigma=3$	Malawi.jpg $\sigma=4.5$	Tanganyika.jpg $\sigma=6$
Roberts	MSE : 10510.5 PSNR: 7.91457	MSE : 8108.37 PSNR: 9.04147	MSE : 6922.77 PSNR: 9.726	MSE : 5902.17 PSNR: 10.4207	MSE : 6406.89 PSNR: 10.0643	MSE : 6716.1 PSNR: 9.85963
Canny	MSE : 10196.8 PSNR: 8.04618	MSE : 7865.46 PSNR: 9.17356	MSE : 6444.9 PSNR: 10.0386	MSE : 5541.44 PSNR: 10.6946	MSE : 6101.34 PSNR: 10.2766	MSE : 6316.61 PSNR: 10.126
Frei Chen	MSE : 10508.3 PSNR: 7.91546	MSE : 8107 PSNR: 9.0422	MSE : 6920.95 PSNR: 9.72915	MSE : 5891.82 PSNR: 10.4283	MSE : 6400.17 PSNR: 10.0689	MSE : 6704.71 PSNR: 9.867

Table 4. MSE and PSNR result for 300*300 pixels satellite image with Bilateral Filter

Methods	Aral.jpg $\sigma_s=1.5$ $\sigma_R=0.05$	Toba.jpg $\sigma_s=2$ $\sigma_R=0.05$	Erie.jpg $\sigma_s=2.5$ $\sigma_R=0.05$	Nyasa.jpg $\sigma_s=3$ $\sigma_R=0.05$	Malawi.jpg $\sigma_s=4.5$ $\sigma_R=0.05$	Tanganyika.jpg $\sigma_s=6$ $\sigma_R=0.05$
Roberts	MSE : 10512.3 PSNR: 7.91384	MSE : 8108.6 PSNR: 9.04135	MSE: 6918.15 PSNR: 9.7309	MSE: 5701.52 PSNR: 10.5709	MSE: 6203.37 PSNR: 10.2045	MSE: 6502.57 PSNR: 9.99995
Canny	MSE : 10255.4 PSNR: 8.02128	MSE: 7850.84 PSNR: 9.18164	MSE: 6146.8 PSNR: 10.2447	MSE: 5462.4 PSNR: 10.757	MSE: 5994.87 PSNR: 10.353	MSE: 6250.33 PSNR: 10.1718
Frei Chen	MSE : 10505.6 PSNR: 7.91658	MSE: 8104.82 PSNR: 9.04337	MSE: 6910.57 PSNR: 9.73566	MSE: 5699.88 PSNR: 10.5721	MSE: 6202.02 PSNR: 10.2055	MSE: 6501.34 PSNR: 10.0008

Bilateral Filter is applied to improve the limitation of Gaussian Filter. The evaluation results of the proposed technique show that the lowest MSE value and the highest PSNR are owned by Canny Detector after using Bilateral Filter. Based on experimental results, Bilateral Filters can efficiently detect the edge of the image.

8. Conclusion and Future Work

In this research, the performance comparison between Gaussian and Bilateral Filters on image edge detection indicates that edge detection using Bilateral Filter is better at retaining the edge information of the image. Improved edge detection on the image can also be seen from the lowest value of MSE and the highest PSNR value with Bilateral Filter.

9. References

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