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A Hybrid Method for Edge Continuity Based on Pixel Neighbors Pattern Analysis (PNPA) for Remote Sensing Satellite Images

Waqas Haider, Muhammad Sharif Malik, Mudassar Raza, Abdul Wahab, Izhar Ahmed Khan, Umar Zia, Jawad Tanveer, Hadia Bashir
Department of Computer Science, COMSATS Institute of Information Technology, Wah Cantt and Vehari Campus, Islamabad, Pakistan
Email: waqasbtn@gmail.com, muhammadsharifmalik@yahoo.com, mudassarr@gmail.com, abdulwahab86@gmail.com, izhar_khan43@yahoo.com, muftiumar@yahoo.com, comsats8@gmail.com, hadia_ciit@yahoo.com

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ABSTRACT

Edge enhancement is derived from lack of accurate result from edge detection techniques. The image which is captured from long distances carries a lot of noise and blur which causes edge discontinuity. Although some novel algorithms which are based on cellular neural network, fuzzy enhancement and binary morphology have shown accuracy in order to obtain refined edge but still the problem of edge discontinuity arises. Eliminating discontinuity of edge a hybrid technique is proposed based on pixel neighbors pattern analysis PNPA. In the technique Canny operator for initial edge detection, PNPA operation for edge enhancement are performed for remote sensing satellite image successively. The visual and subjective evaluation shows that the proposed PNPA operation can effectively eliminate the influence of edge discontinuity which occurred due to noise and blurr in original captured image, as comparing to existing edge segmenting processes.

Keywords: Edge Detection; Edge Enhancement

1. Introduction

Segmenting regions in an image applies frequently the operations for determining edges of regions. In many image processing applications, preserving edges of images is important. Edge is the set of pixels which describes the boundary of any region of the image. As inside an image there may be different regions or multiple structures so edge describes each structure's boundary. The image which is captured from long distance carries noise which causes burred image which ultimately induced discontinuity in edge of that image [1,2] when edge is detected with traditional edge detection operators. Several contributors demonstrated there work in the area of edge detection of remote sensing images which are given in [3-10]. In remote sensing satellite image there are multiple structures in it like roads, fields, rivers, forest buildings and residential areas. Accurate boundary segmentation of such parts in an image totally based on edge detection and edge enhancement. Edge enhancement is a method of image segmentation in which the detected edge should be continuous. But it is an issue which has not been resolved completely so far because in such images which are captured from long distances, the illumination and noise factors are high which causes edge discontinuity.

In this research, discontinuity of edge lines are tried to minimize with proposed hybrid edge enhancement technique PNPA, which is expressed briefly in Section 4 of the paper. The rest of this paper is organized as follows. Section 2 reviews the existing work in the domain of edge enhancement and edge continuity. Section 3 reviews the working and merits/demerits of edge detection operators. Section 4 describes the proposed method (e.g. PNPA) for edge continuity. In Section 5, the comparative evaluation of visual and subjective results are given and finally in Section 6, the discussion and conclusion are given.

2. Existing Work in the Domain of Edge Enhancement

Acquiring edge continuity has been addressed by different new novel techniques which are based on cellular neural network [2] and binary morphology [3] proved better edge quality but the operators which are based on mathematical morphology are not effective for images which have too many ramp edges [11]. In [12] the suitable strategies are expressed for edge thickness and dis-

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continuities inside the detected edges. Enhancing the edge by removing the limitations in different edge detection operators a hybrid approach is presented in [13]. Smoothing edges with integrated functions in [14] an approach is presented which utilizes the bee colony optimization function. Also some novel approaches for addressing edge enhancement are expressed in [15-17]. After analyzing several techniques for edge enhancement there is still discontinuity in edges.

3. Review of Edge Detection Operators Working with Merits and Demerits

In order to obtain edges of any image the traditional approach is shown in **Figure 1**.

When image is captured and during the process of transmission, formation, reception and processing the noise is added with it. The purpose of pre processing is to remove noises from the image. When any edge detection operator is applied, the preprocessing techniques for de-noising are built-in. The most reliable technique for image de-noising is Wavelet analysis [18]. In wavelet analysis during multi scale analysis, image is decomposed (see **Figure 2**) to multi scale frequency components, then for removing noisy data the band passed filter based functions starts working. Finally enhanced image is obtained using wavelet inverse transform. In wavelet analysis the quality of image is improved.

In the process of finding threshold value (see **Figure 1**) by applying derivative operator it got grey change value, then by using threshold, edge pixel set is selected [19]. Suppose an image is $f(x,y)$ after de-noising process, its derivative operator is $\partial f/\partial x$, $\partial f/\partial y$ which represent grey change in two dimensions and it is defined as:

$$\mathrm{d}f = \frac{\partial f}{\partial x}\mathrm{d}x + \frac{\partial f}{\partial y}\mathrm{d}y \tag{1}$$

The Equation (1) gives differential grey change value in the direction $\arctan\left[\frac{\partial f}{\partial y}\middle/\frac{\partial f}{\partial x}\right]$ which actually gives

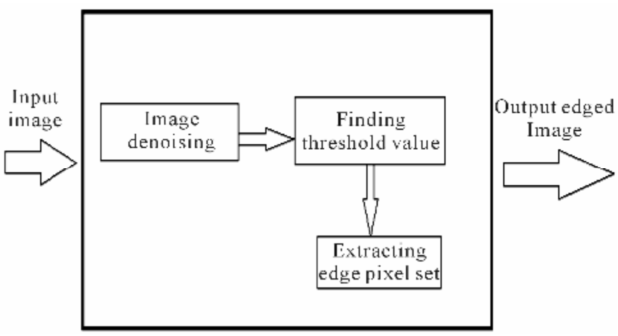

Figure 1. Traditional edge detection operator operation.

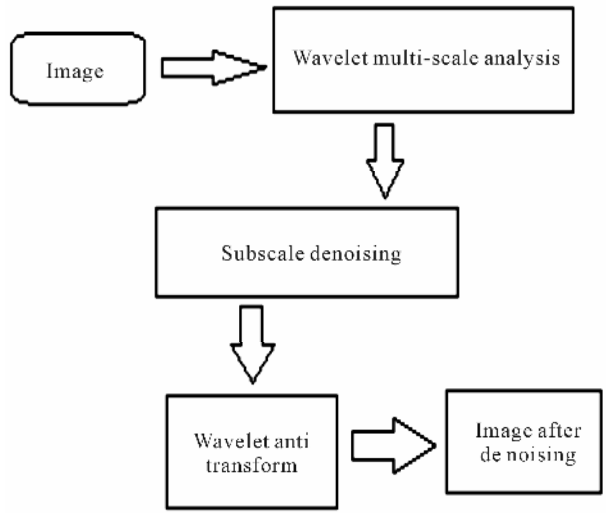

Figure 2. Wavelet analysis for image de-noising sketch.

the threshold value. The distance function G is applied on two dimensional differential intensity components and defined as:

$$G\left[F(x,y)\right] = \sqrt{(\partial f/\partial x)^2 + (\partial f/\partial y)^2} \tag{2}$$

where $\sqrt{(\partial f/\partial x)^2 + (\partial f/\partial y)^2}$ is the maximum directional derivative. In many traditional operators to outstand grey level change gradient operator is used [20] which is defined as:

$$G\left[F(K,L)\right] = \sqrt{\underset{k}{\Delta} F(K,L)^2 + \Delta_L F(K,L)^2} \tag{3}$$

where

$$\underset{k}{\Delta} F(K,L) = F(K,L) - F(K-1,L) \tag{4}$$

$$\Delta_L F(K,L) = F(K,L) - F(K,L-1) \tag{5}$$

In Equations (3) and (4) $K = x$ location point value and $L = y$ location point value. So Equation (3) obtain threshold intensity value in x direction or in k direction by calculating difference between differential grey value at (K,L) and $(K-1,L)$. Similarly Equation (5) gives threshold intensity value in y or L direction by calculating difference. Finally Equation (3) process and obtain gradient G to construct edge pixel set by setting threshold value.

Gradient Operators

Roberts, prewitt, Sobel operators are based on differential operator processing for finding edge pixel set [21]. In Roberts operator for extracting edge pixel set from input image use partial difference operator. So Equation (3) is designed for Robert operator as:

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$$G\left[F\left(K,L\right)\right]=\sqrt{\left[F\left(K+1,L+1\right)-F\left(K,L\right)\right]^{2}+\left[F\left(K+1,Y\right)-F\left(K,L+1\right)\right]^{2}} \quad (6)$$

In Equation (6) Roberts operator consider 2 by 2 template (e.g. 2 neighbor weight) to compute difference operator so the edge extracted is quite thick, not accurate and suitable for steep low noisy images. Also it is not suitable for image having to many segments and blurr.

The Prewitt and Sobel operators are the same in definition and operation as Robert but the difference between both is Prewitt consider 3 by 3 neighbors weight to compute difference operator and Sobel uses 4 neighbor's weight in computing difference operator. Suppose in the process of finding threshold value for edge pixel set , in supposition 3 × 3 matrix given below, the point $f(i,j)$ where *f* grey is grey level change function and (i,j) determines that point pixel which is in process.

$$\begin{matrix} p_0 & p_1 & p_2 \\ p_3 & f(i,j) & p_4 \\ p_6 & p_7 & p_8 \end{matrix}$$

Now the Prewitt and Sobel is defined as:

$$G\left[F\left(i,j\right)\right]=\sqrt{\left(K^{2}+L^{2}\right)} \quad (7)$$

where in case of Prewitt it utilizes less neighbors and the detected edge by the Sobel is wider as it utilizes four neighbors. These classical operators (sobel and prewitt) could detect inaccurate edges incase of noise. Another type is Log operator which is defined as:

$$\Delta^{2} f=\partial^{2} f / \partial k^{2}+\partial^{2} f / \partial L^{2} \quad (8)$$

In log operator the differential coefficient is calculated for the image and the edge detected by the log operator has double pixel boundary. The log operator is very sensitive to noise and also it cannot find the orientation of edge due to Laplacian filter. Log operator is used for judging whether the edge pixel is in dark or bright section. Another type of edge detectors are Canny, Shen-Castan and Boie-Cox which are called Gaussian edge detectors [22,23] because in these detectors Laplacian of Gaussian combined Gaussian filtering along with the Laplacian are included and these are well expressed in [21]. These edge finders remove noise and smooth the detected edge but carries complex computing.

After analyzing the various problems of edge features in which one of them is discontinuity of edge due to noise and blurr in captured image, it is concluded that there is still a challenge to detect continuous edge. So in next section the paper will specifically focus on edge pixel continuity with proposed method.

4. Edge Continuity with Proposed Method

Unlike the traditional approach for edge detection, the proposed edge continuity (PNPA) routine is started from the result of Canny edge detection operator, for simulation the two test images are shown in **Figures 3** and **4**. In **Figure 5** the edge continuity work flow is expressed.

Although Canny has good results but still discontinuity occurs in edge lines so the resulting image of Canny operator is further processed so that to minimize the gaps at edge lines. In PNPA operation (see **Figure 5**) at any point of binary image $p(x,y)$, the 4 connected and 8 connected neighbors are analyzed for achieving the pattern of neighbor pixels and then a value is imposed to that chosen pixel (point) according to achieved pattern. As in binary image zeros shows black (back ground) and ones shows white (edge pixels). The PNPA operation is graphically shown in **Figure 6**. PNPA addresses the point's left, right, top, bottom and diagonal neighbor pixels to check whether these neighbor pixels are zeros or one to get pattern of edge line and then giving value to chosen pixel.

PNPA (Function *P*)

The hybrid function Pixel neighbor pattern analysis got the working and decision making logic of two edge enhancing filters *comparison and selection* (CS) and *weighted majority of samples with minimum range*

Figure 3. Test image A.

Figure 4. Test image B.

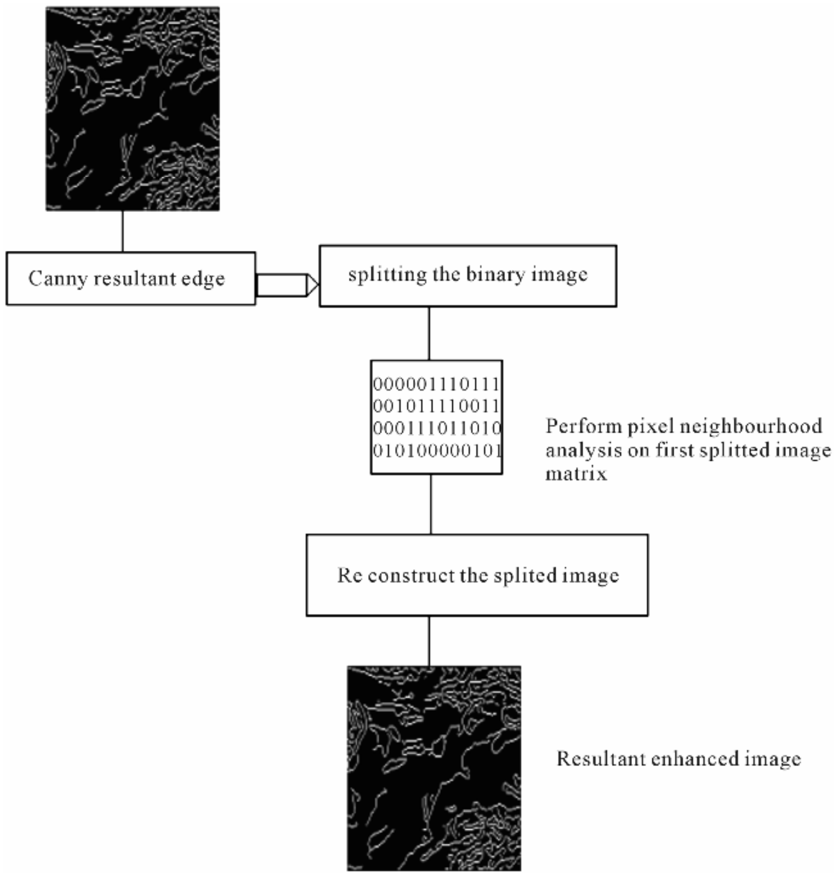

Figure 5. Edge continuity work flow.

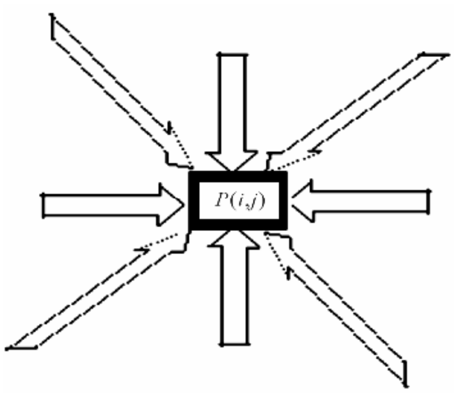

Figure 6. PNPA operation on point.

(WMM) [24-26]. The function $P(\ )$ is defined as:

$$P(\ ) = p_{x,y} = \sum_{i=1}^{n} p_{x_i} + p_{y_i}$$

where n is the size of the upcoming matrix, $p_{x,y}$ is the new point value which is to be determined according to neighbor pattern as p_{x_i} by Equation (10) in case of x-direction. Similarly in case of y-direction the p_{y_i} is calculated by Equation (11). In Equation (9) x direction edge continuity is further given as:

$$P_X = \begin{cases} 0, & \text{if } x+1, x+2, x-1, x-2 = 0 \\ 1, & \text{if } x+1, x+2, x-1, x-2 = 1 \end{cases} \quad (10)$$

Similarly for y direction, the continuity is given as:

$$P_Y = \begin{cases} 0, & \text{if } y+1, y+2, y-1, y-2 = 0 \\ 1, & \text{if } y+1, y+2, y-1, y-2 = 1 \end{cases} \quad (11)$$

Expressing the informal definition of Equation (10) and Equation (11) suppose the upcoming matrix which has to enhance in the problem domain is as follows:

$$\begin{matrix} 1 & 0 & 1 & 1 \\ 1 & 1 & P(i,j) & 1 \\ 0 & 0 & 1 & 0 \\ 1 & 1 & 0 & 1 \end{matrix}$$

At point $P(i,j)$ function P addresses its left, right, top, bottom and diagonal neighbor pixels (see **Figure 6**) whether they are zeros or one to get pattern of edge line and then decide what to give value to chosen pixel, both Equations (10) and (11) works. Also the more accurate analysis for pattern can be achieved by considering neighbors at multiple directions. The neighbor pixels tells PNPA algorithm that what value to be given to chosen pixel whether it remain 0 or converted to 1 to fill up unnecessary edge gaps.

5. Comparative Evaluation of Visual Results

To analyze the comparative continuity of detected edge different traditional edge detecting operators and PNPA are applied on test image A as shown in **Figure 7**.

In **Figure 8** the original image has blur and the arrows shows the specific part of image which are countered with PNPA edge enhancement function. Due to the blur in original image, in **Figure 8** the canny operator missed the desired edges which should be detected. This lack of canny is enhanced with neighbor pixel pattern analysis logic PNPA which is shown in **Figure 8**. Similarly the test image B is analyzed under different edge detection operators as shown in **Figures 9** and **10** expresses the enhancement of edge which is achieved by PNPA operation.

Subjective Evaluation of Edge Detectors and Proposed Method PNPA

In **Table 1** the method of subjective comparative evaluation is taken from [21]. **Table 1** shows that comparing to existing edge detecting operators, the proposed method is capable of serving images in the domain of edge continuity in highly noisy and blurry conditions. Also the method keeps the edge features as well as accuracy and ultimately no un necessary gaps which occurred due to blurr and noise in the original image.

6. Conclusion

Each edge detection technique has its own significance according to the capturing conditions of an image. Some are better for low noisy images and some are better for highly noisy images. So noise in an image effects the

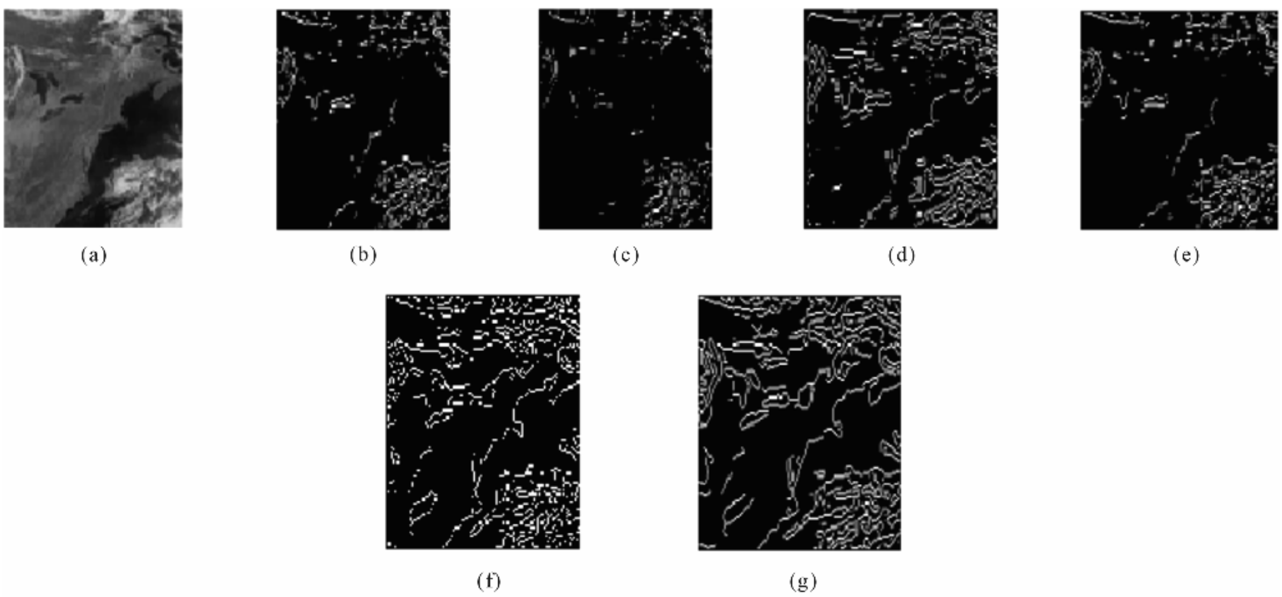

Figure 7. Visual comparative analysis of edge operators result with proposed PNPA operation on image A. (a) Original image; (b) Sobel edge; (c) Robert edge; (d) Log edge; (e) Prewitt edge; (f) Cannv edge; (g) Edge after PNPA.

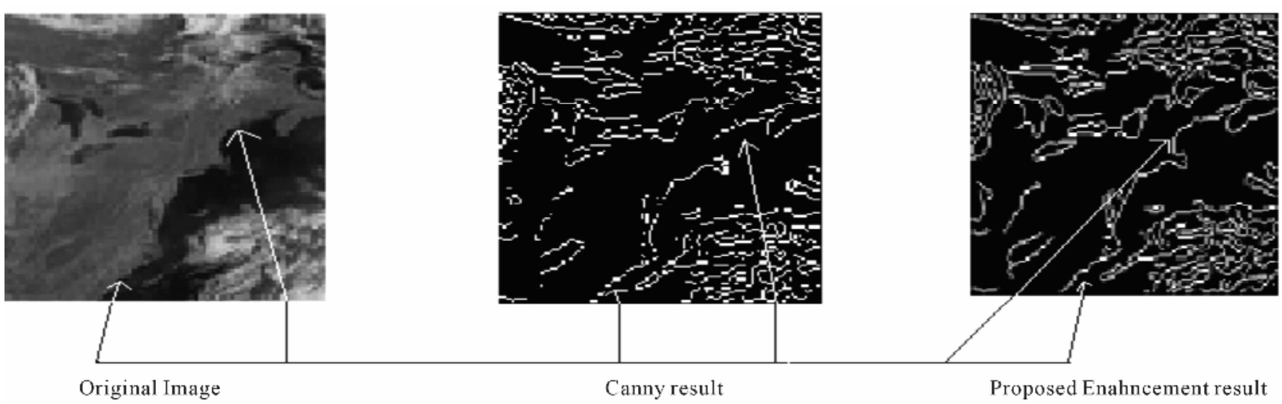

Figure 8. Result elaboration with image A.

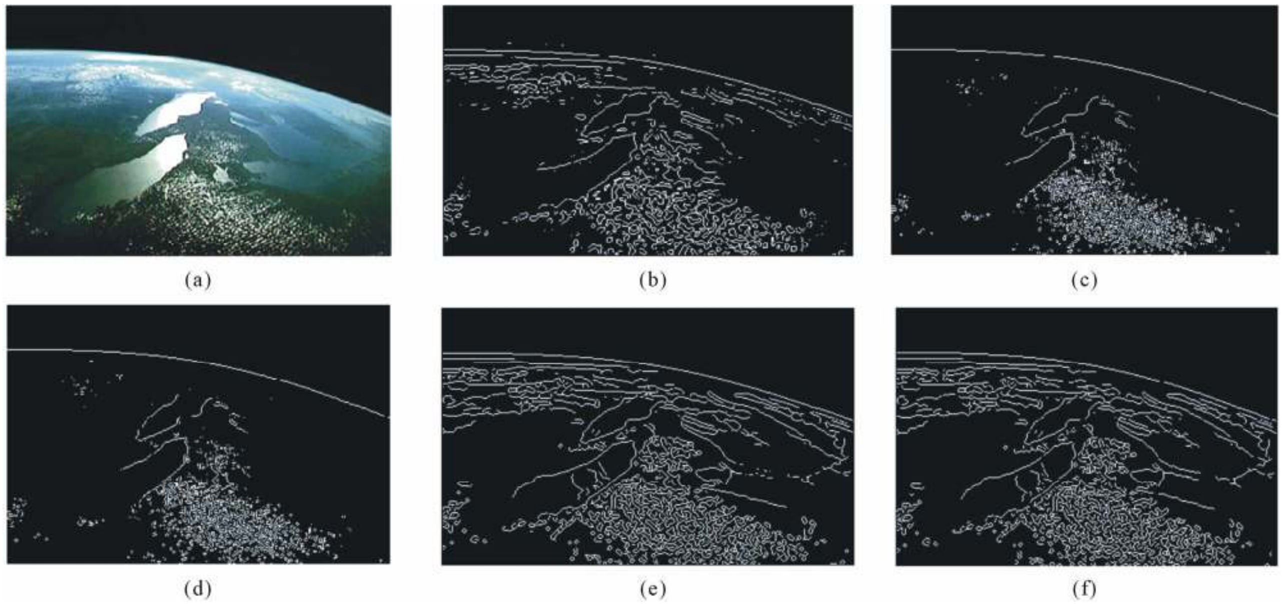

Figure 9. Visual comparative analysis of edge operators result with proposed PNPA operation on image B. (a) Original image B; (b) LOG edge; (c) Prewitt edge; (d) Sobel edge; (e) Canny edge; (f) Edge after PNPA.

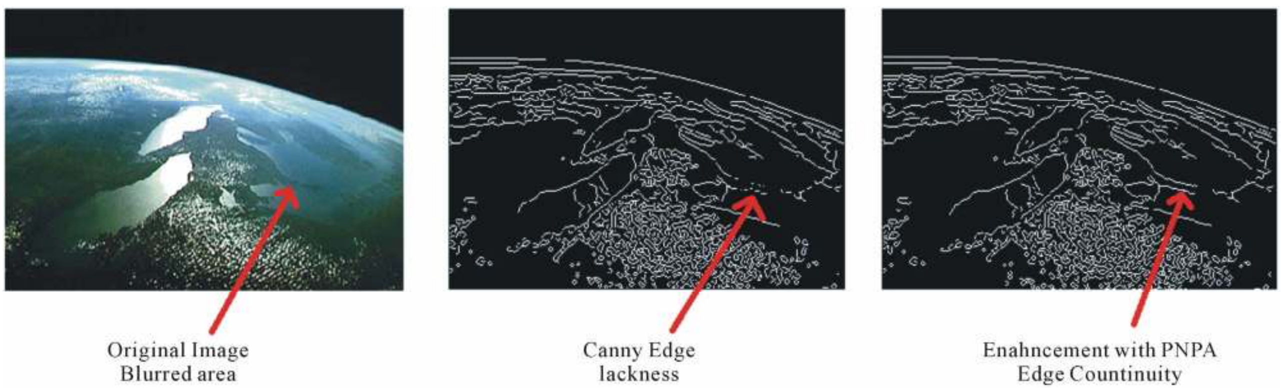

Figure 10. Result elaboration with image B.

Table 1. Subjective comparative evaluation of edge detectors and proposed method PNPA.

Techniques	Best for input image	Suitable noise conditions	Edge feature	Edge accuracy	Edge continuity
Robert operator	Less noisy	Less noisy	Gaps	No	No
Sobel operator	Less noisy	Less noisy	Gaps	No	No
Prewitt operator	Less noisy	Less noisy	Gaps	No	No
Log operator	Noisy	Noisy	Gaps	No	No
Canny operator	High noisy	High noisy	Little gaps at highly noisy area	Better	Better
Canny+ PNPA	Highly noisy	Highly noisy	No gaps	Yes	Yes

results. In order to minimize noise, before detection apply wavelet analysis and then processed for edge extraction. Also the result of any edge detection operator can be further processed for edge enhancement because noise is not completely removed which causes unnecessary edge gaps (discontinuity) and other effects. Hence the satisfactory results can be achieved if suitable edge detection operator and enhancement technique are applied according to the problem as edge discontinuity. Therefore the proposed method could be applied to any image

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where edge continuity is required.

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