Comparative Study for Edge Detection of Noisy Image using Sobel and Laplace Operators

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Abstract

Many approaches of different complexity already exist to edge detection in color images. Nevertheless, the question remains of how different are the results when employing computational costly techniques instead of simple ones. This paper presents a comparative study on two approaches to color edge detection to reduce noise in image. The approaches are based on the Sobel operator and the Laplace operator. Furthermore, an efficient algorithm for implementing the two operators is presented. The operators have been applied to real images. The results are presented in this paper. It is shown that the quality of the results increases by using second derivative operator (Laplace operator). And noise reduced in a good range by using mean filter for smoothing before applying Laplace operator. Moreover, thresholding is used for image in both cases to see results in clearer manner.

Key Words: Sobel Operator, Laplace Operator, Noise Reduction, Mean filter, Image Thresholding.

1. Introduction

In human visual systems, edges are more sensitive than other picture elements. Edge detection technique when used alone for image segmentation results in small gaps in edge boundaries. It is sensitive to local variations intensity and the contours obtained are usually not closed. Region growing technique when used alone results in errors in region boundaries and the edge pixels might be joined to any of the neighboring pixels. Edge based region growing corresponds to the optimum image segmentation technique in which the both edge detection approach and region growing approach is integrated. [1]

Edge detection refers to the process of identifying and locating sharp discontinuities in an image. The discontinuities are abrupt changes in pixel intensity which characterize boundaries of objects in a scene. Classical methods of edge detection involve convolving the image with an operator (a 2-D filter), which is constructed to be sensitive to large gradients in the image while returning values of zero in uniform regions. There are an extremely large number of edge detection operators available, each designed to be sensitive to certain types of edges. Variables involved in the selection of an edge detection operator include edge

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orientation, noise environment and edge structure. The geometry of the operator determines a characteristic direction in which it is most sensitive to edges. Operators can be optimized to look for horizontal, vertical, or diagonal edges. Edge detection is difficult in noisy images, since both the noise and the edges contain high-frequency content. Attempts to reduce the noise result in blurred and distorted edges. Operators used on noisy images are typically larger in scope, so they can average enough data to discount localized noisy pixels. [2]

The algorithm described here is for integrating edges and regions. Firstly, the edge map of image is obtained by using Sobel edge operator (first derivative). Then the edge region is grown. Very small regions are removed by merging. The two types of seeds (pixels) hot and cold are obtained in the edge region and according to the type of data being analyzed and application area, the image is segmented into background and foreground objects (thresholding). It offers non-precise segmentation in detecting objects of different sizes and also rigid targets. This approach is not sensitive to the parameters, such as the sizes of different operators and thresholds in the edge detection and edge region detection.

Secondly, edge map is obtained using Laplace operator (second derivative). Mean filter is also used to reduce noise appeared in some regions of resultant edge map of image. After using filtering, then Laplace operator offers very precise and sharpe edges. Thus the effect of noise is completely eliminated. Thresholding also used in order to obtain more clear edges.

The algorithm is implemented in VISUALBASIC and the result demonstrates that the algorithm is robust, satisfying and work well.

2. Related Work

There is a large literature on edge detection. In contrast, the literature on noise estimation and detection is very limited. Related works to this paper are following:

- **Rupinder Singh, Jarnail Singh**; The algorithm described here is for integrating edges and regions. Firstly, the edge map of image is obtained by using canny edge operator. [1]
- **Dr. M. Nagabhushana Rao**; In their paper the comparative analysis of various image edge detection techniques is presented on finger print images. [2]
- **Jagadish H. Pujar**; proposes a novel algorithm for medical image segmentation based on vigorous smoothening by identifying the type of noise and edge detection ideology which seems to be a boom in medical image diagnosis. [3]
- **Andres Solis Montero;** describes a new line segment detection and extraction algorithm for computer vision, image segmentation, and shape recognition applications. [4]

- **Krzysztof Strzecha**; presented computerized system for high temperature measurements of superficial properties. The process of superficial properties determination is based on digital image processing and analysis algorithms. [5]
- **Ce Liu William T. Freeman**; show how to estimate an upper bound on the noise level from a single image based on a piecewise smooth image prior model and measured CCD camera response functions. [6]

3. Edge Detection

Edge detection is by far most common approach for detecting meaningful discontinuities in intensity values. Such discontinuities are detected by first order and second order derivatives. The first order derivative of choice in image processing is the gradient (Sobel). The Laplacian is seldom used by itself for edge detection because as a second derivative, it is unacceptably sensitive to noise. Its magnitude produces double edges and it is unable to detect the edge direction. [1]
Most edge detection schemes are based on finding maxima in the first derivative of the image function or zero crossings in the second derivative of the image function. The difficulty in extending derivative approaches to color images arises from the fact that the image function is vector-valued. Whenever the gradients of the image components are computed, the question remains of how to combine them into one result. Several approaches already exist for color edge detection. Perhaps the simplest one is to apply Sobel masks to the three color channels independently and to combine the results using logical operation. [7]

Edges mainly divide into step shape and roof shape. The water droplet image is step edge where the edge points' first-order derivative has extreme value. The digital image's first-order partial derivatives would approximately be:

$$\begin{cases} f_x' = f(x+1,y) - f(x,y) \\ f_y' = f(x,y+1) - f(x,y) \end{cases} \quad (1)$$

To simplify the calculation of gradient, following approximate formula is used frequently:

$$grad(x,y) = |f_x'| + |f_y'| \quad (2)$$

Generally, the gradient operator is sensitive in level or vertical direction on the edge, while Roberts across operator detects the gradient which cross along with the image coordinate axis 45° and 135°.
The Operator is:

$$grad(x,y) = |f_x'| + |f_y'| = |f(x,y) - f(x+1,y+1)| + |f(x+1,y) - f(x,y+1)| \quad (3)$$

Other common operators include Prewitt operator, Sobel operator, and Laplace operator.[8]

An edge defined in an image as a boundary or contour at which a significant change occurs in some physical aspect of the image. Edge detection is a method as significant as threshold. Four different edge detector operators are examined and it is shown that the Sobel edge detector provides very thick and sometimes very inaccurate edges, especially when applied to noisy images. The LoG operator provides slightly better results. Traditional edge detectors were based on a rather small 3x3 neighborhood, which only examined each pixel's nearest neighbor. This may work well but due to
the size of the neighborhood that is being examined, there are limitations to the accuracy of the final edge. These local neighborhoods will only detect local discontinuities, and it is possible that this may cause 'false' edges to be extracted.

Edges can be detected in many ways such as Laplacian Roberts, Sobel and gradient. In both intensity and color, linear operators can detect edges through the use of masks that represent the 'ideal' edge steps in various directions. They can also detect lines and curves in much the same way. [9]

4. Sobel Operator

At each point in the image, the result of the Sobel operator is either the corresponding gradient vector or the norm of this vector. The Sobel operator is based on convolving the image with a small, separable, and integer valued filter in horizontal and vertical direction and is therefore relatively inexpensive in terms of computations. The elements of the image Im[i,j] are obtained from the Figure. 2(a). The Sobel operator is the sum of the magnitudes of the gradient computed by following the equations given below:

$$G_x = I_m[i+2,j] + 2* I_m[i+2,j+1] + I_m[i+2,j+2] - I_m[i,j] - 2* I_m[i,j+1] - I_m[i,j+2] \quad (4)$$

$$G_y = I_m[i,j+2] + 2* I_m[i+1,j+2] + I_m[i+2,j+2] - I_m[i,j] - 2* I_m[i+1,j] - I_m[i+2,j] \quad (5)$$

Like the other gradient operators, where G_x is gradient in x-direction and G_y is gradient in y-direction are calculated by using the following masks.

$$\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

Figure.1 (a) Gx on 3×3 mask

Figure.1 (a) is the gradient G_x in x-direction using Sobel operator on 3×3 mask and Figure.1 (b) is the gradient G_y on 3×3 masks in y-direction using Sobel operator.

$$\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

Figure.1 (b) Gy on 3×3 mask

This operator places an emphasis on pixels that are closer to the center of the mask. The Sobel operator represents a rather inaccurate approximation of the image gradient, but is still of sufficient quality to be of practical use in many applications. More precisely, it uses intensity values only in a 3×3 region around each image point to approximate the corresponding image gradient, and it uses only integer values for the coefficients which weight the image intensities to produce the gradient approximation.

The Sobel operator follows the procedure similar to the Prewitt operator in calculating the gradients G_x and G_y. The absolute value of the gradients is obtained. By convoluting the 3×3 mask of the Sobel operator on the original image as in Figure.2 (a), the edges can be detected. This operator obtains the edges more effectively than other gradient operators. The result can be obtained as displayed in Figure. 2(b): [2]

Figure. 2(a) Original Image

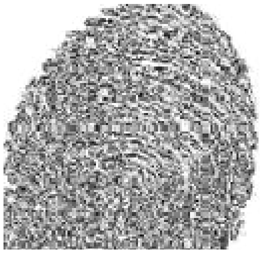


Figure. 2(b) Resultant of Sobel Operator

The incoming image data, in this case, is convolved with four 3 X 3 masks (i.e., Sobel operators) weighted to measure the differences in intensity along the horizontal, vertical left and right directions.

5. Laplace Operator

The edge points of an image can be detected by finding the zero crossings of the second derivative of the image intensity. Calculating second derivative is very sensitive to noise. This noise should be filtered out before edge detection. The Laplacian method searches for zero crossings in the second derivative of the image to find edges. An edge has the one-dimensional shape of a ramp and calculating the derivative of the image can highlight its location. The elements of the image $I_m[i,j]$ are obtained from the Figure.1(a).

The 4-connected Laplacian operator is the magnitude of the gradient computed by using the following:

$$G_x = 4* I_m[i+1,j+1] - I_m[i,j+1] - I_m[i+1,j] - I_m[i+1,j+2] - I_m[i+2,j+1] \quad (6)$$

where G_x is the gradient calculated by using the following mask Figure.3. is the gradient G_x using Laplacian operator on 3×3mask

$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

Figure.3 Connected Neighbors of a pixel

The Laplacian operator follows the procedure similar to the Prewitt operator in calculating the gradients. The absolute value of the gradients is obtained. By convoluting the 3×3 mask of the Laplacian operator on the original image in Figure.4(a), the following result as in Figure.4(b) can be obtained.

Figure.4 (a) Original Image

Figure.4 (b) Resultant of Laplacian Operator.

The 8-connected Laplacian operator is calculated using the following magnitude. The elements of the image Im[i,j] are obtained .

$$G_y = 8*I_m[i+1,j+1]-I_m[i,j]-I_m[i,j+1]-I_m[i,j+2]-I_m[i+1,j]-I_m[i+1,j+2]-I_m[i+2,j]-I_m[i+2,j+1]-I_m[i+2,j+2] \quad (7)$$

where G_x is the gradient calculated by using the following mask

$$\begin{bmatrix} -1 & -1 & 1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

Figure.5 Connected Neighbors of a pixel

Figure.5 is the gradient G_y using Laplacian operator on 3×3 mask with 8-connected neighbours. [2]

6. Experimental Results

Flowchart of the designed algorithm is shown in Figure.6. This algorithm is implemented by using VISUALBASIC.

Image Lena is chosen used for applying all operations in this paper (shown in Figure.7). Firstly Sobel operator result image is shown in Figure. 8a and its negative threshold are shown in Figure.8b. Figures shown that region is grown, so it offers very thick edges with remaining noise in some regions.

Secondly Laplace operator result image is shown in Figure.9a, and its negative threshold is shown in Figure.9b. Figure shown that very sharp edges with remaining noise in some regions of image.

To remove noise remained in Laplace resultant image, mean filter is used for smoothing image before using Laplace. Result of smoothing shown in Figure.10.

After smoothing Laplace operator is applied on smoothed image, the result is shown in Figure.11a and its negative threshold is shown in Figure.11b.

Figures shown that effect of noise is removed completely by using smoothing then Laplace edge detection operator with obtaining very precise and sharp edges.

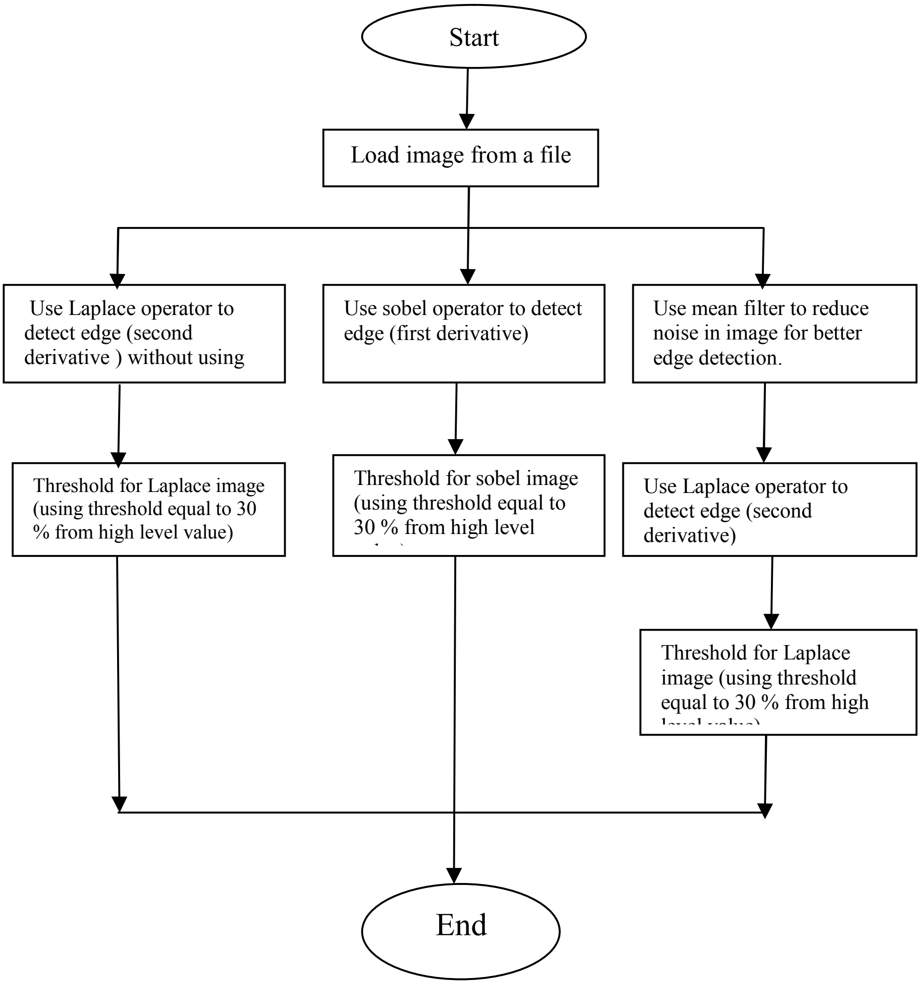


Figure.6 Block diagram of designed algorithm.

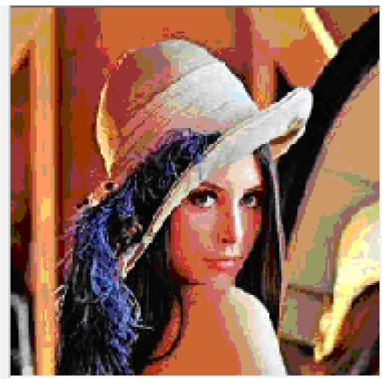
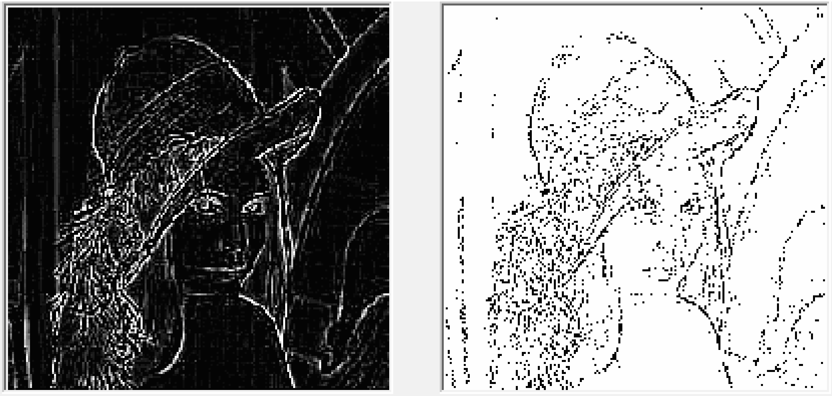
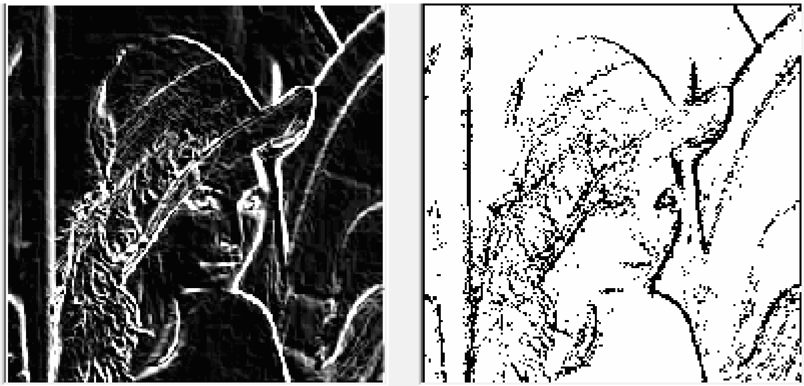


Figure.7 Original Image.



a b

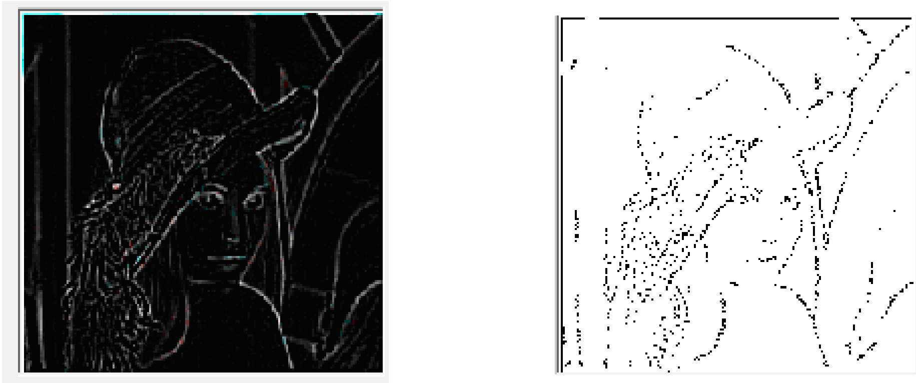
Figure.8 a. Result of Laplace Operator .
b. Laplace Image Threshold.



a b

Figure.9 a. Result of Sobel Operator
b. Sobel Image Threshold.

Figure. 10 Image after using Mean Filter.



a b

Figure.11 a. Result of Laplace Operator after using Mean Filter.
b. Laplace Image Threshold**.**

7. Conclusions

The following points are drawn from the results obtained in this paper:

1. Second derivative operator (Laplace) is more efficient than first derivative operator (Sobel) in edge detection.
2. Laplace offers sharp and precise edges with remaining some noise regions.
3. Sobel offers thick and non- precise edge with remaining noise regions.
4. Smoothing image before applying Laplace on it offers very good result with removing noise completely.

References

[1] Rupinder Singh, Jarnail Singh, "**Edge Based Region Growing**", Rupinder Singh et al, Int. J. Comp. Tech. Appl., Vol 2 (4), July-August, 2011.

[2] Dr. M. Nagabhushana Rao, Mr. M. Venkateswara Rao, "**Application of Edge Based Segmentation in Bio-Metric Security System**", International Journal of Advanced Engineering & Application, Jan, 2011.

[3] Jagadish H. Pujar, Pallavi S. Gurjal, "**Medical Image Segmentation based on Vigorous Smoothing and Edge Detection Ideology**", World Academy of Science, Engineering and Technology 68, 2010.

[4] Andres Solis Montero, Amiya Nayak**, "Robust Line Extraction Based on Repeated Segment Directions on Image Contours**", IEEE Symposium on Computational Intelligence in Security and Defense Applications, December, 2009.

[5] Krzysztof Strzecha, Anna Fabijańska, "**Application of the Edge-Based Image Segmentation** ", Lviv-Polyana, Ukraine, May, 2006.

[6] Ce Liu William T. Freeman, "**Noise Estimation from a Single Image** ", IEEE Conference on Computer Vision and Pattern Recognition, 2006.

[7] Andreas Koschan, "**A Comparative Study on Color Edge Detection** ", Berlin, Germany, Vol. III, pp. 574-578, December, 1995.
[8] Yan Liu, Kai Liu, "**A New Diagnosis Method on Insulators with Measuring Contact Angles**", International Journal of Intelligent Engineering and Systems, Vol.2, No.2, China, 2009.
[9] Wang Luo, "**Comparison for Edge Detection of Colony Images** ", IJCSNS, Vol.6 No.9A, China, September 2006.

دراسة مقارنة للكشف عن حافةِ الصورةِ الصاخبِة باستخدام مشغلي Sobel و Laplace

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الخلاصة:
بالإمكان إيجاد و استخدام العديد من الطرق للكشف عن الحافة الحادة في الصورة الملونة. على الرغم من ذلك يبقى السؤال كم تختلف النتائج عند استخدام التقنيات الحسابية المعقدة بدلاً من واحدة يسيرة. هذا البحث يقدم دراسة مقارنة على تقنيتين مختلفتين لكشف الحافة الحادة الغرض منها إزالة الضب في الصورة. هاتان التقنيتان هما Sobel و Laplac, علاوة على ذلك، قمنا بتقديم خوارزمية ذات كفاءة لتنفيذ التقنيتين. و قد تم تطبيق التقنيتين على صور حقيقية و النتائج موضحة في البحث, و قد تم إثبات أن جودة النتائج تزداد باستخدام تقنية الاشتقاق من الدرجة الثانية (تقنية Laplace). كذلك تم تقليص تأثير الصخب بنسبة كبيرة باستخدام (mean filter) لتنعيم الصورة قبل استخدام تقنية Laplace . فضلاً عن ذلك تم استخدام اختيار العتبة لرؤية النتائج بوضوح أكثر.