# Using The Canny Edge Detector for Feature Extraction and Enhancement of Remote Sensing Images

Mohamed Ali David Clausi

Systems Design Engineering, University of Waterloo
{dclausi, maali }@engmail.uwaterloo.ca
Waterloo, ON, N2L 3G1, Canada
Tel:+1(519) 888- 4567 x.2604

Abstract-- **Edges are important features in an image since they represent significant local intensity changes. They provide important clues to separate regions within an object or to identify changes in illumination.**

**Most remote sensing applications, such as image registration, image segmentation, region separation, object description, and recognition, use edge detection as a preprocessing stage for feature extraction. Real images, such as remote sensing images, can be corrupted with point noise. The real problem is how to enhance noisy remote sensing images and simultaneously extract the edges.**

**Using the implemented Canny edge detector for features extraction and as an enhancement tool for remote sensing images, the result was robust with a very high enhancement level.**

***Index Terms*—Canny edge detector, Edge detection, Image enhancement.**

## I. INTRODUCTION

Remotely sensed data and the land cover/land use classification of urban areas set their own requirements for feature extraction [1]. Features should be easily computed, robust, insensitive to various distortions and variations in the images, rotationally invariant, and they should support the discrimination of the land cover/land use classes.

Land cover/land use classes of urban areas typically consist of regions of varying sizes and shapes as depicted in remotely sensed imagery. For instance, transportation networks (e.g. roads and railways), are delineated objects, whereas airports, industrial buildings, and green parks are spatially defined regions. Ideally, the feature extraction process should provide a compact feature space for the task; that is, the within class variation of the features should be small, whereas the variation of features between different classes should be high. Unfortunately, for land cover/land use classification it is a difficult task to determine such optimal feature extractors due to the diversity of the desired classes. In this case, a natural approach is to extract many different types of potentially suitable features, and to evaluate their usefulness in the later stage of processing.

Directional, or edge detection filters are designed to highlight linear features, such as roads or field boundaries. These filters can also be designed to enhance features that are oriented in specific directions. These filters are useful in applications such as remote sensing, for the detection of linear geographic structures.

Unfortunately, real images, especially remote sensing images, are corrupted with noise. An effective edge detector must be able to differentiate between real intensity transitions and sudden (and possibly random) noise transitions. This is an important problem and each algorithm treats it differently.

Most remote sensing applications, such as image registration, image segmentation, region separation, object description, and recognition, use edge detection as a preprocessing stage for feature extraction. Image edges are usually found where there is a sudden change in image intensity. This will result in local minima or maxima of the first derivative of the intensity. Alternatively, this same location will have a zero-crossing of the second derivative.

The organization of this paper is as follows. Different edge detection techniques in image processing are reviewed in section II. The Canny edge detector, its implementation and proposed enhanced technique are introduced in Section III. Finally, a discussion and some concluding remarks are given in Section IV.

## II. EDGE DETECTION

Lim [2] defines an edge 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 thresholding. A survey of the differences between particular edge detectors is presented by Schowengerdt [3]. 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.

The extraction of features such as edges and curves from an image is useful for many purposes [4]. Features, such as edges and curves are useful in i) texture analysis ii) 3-D surface restructuring iii) segmentation iv) image matching .

Edges can be detected in many ways such as Laplacian Roberts, Sobel and gradient [5 ]. 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.

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. 'A more powerful approach is to use a set of first or second difference operators based on neighborhoods having a range of sizes (e.g. increasing by factors of 2) and combine their outputs, so that discontinuities can be detected at many different scales' [4].

Usually, gradient operators, Laplacian operators, and zero-crossing operators are used for edge detection. The gradient operators compute some quantity related to the magnitude of the slope of the underlying image gray tone intensity surface of which the observed image pixel values are noisy discretized samples. The Laplacian operators compute some quantity related to the Laplacian of the underlying image gray tone intensity surface. The zero-crossing operators determine whether or not the digital Laplacian or the estimated second direction derivative has a zero-crossing within the pixel.

There are many ways to perform edge detection. However, the most may be grouped into three categories, gradient (Approximations of the first derivative), Laplacian (Zero crossing detectors) and Image approximation algorithms.

Edge detectors based on gradient concept are the Roberts [6], Prewit and Sobel [7] Fig. 1 (b) , 1 (c), 1 (d) show the effect of these filters on the remote sensing images. The major drawback of such an operator in segmentation is the fact that determining the actual location of the edge, slope turnovers point, is difficult. A more effective operator is the Laplacian, which uses the second derivative in determining the edge.

The gradient of image intensity is the vector

$$\nabla \mathbf{f} = \left[ \frac{\partial \mathbf{f}}{\partial \mathbf{x}} + \frac{\partial \mathbf{f}}{\partial \mathbf{y}} \right]^t = \left[ \mathbf{G_x}, \mathbf{G_y} \right]^t \tag{1}$$

and the magnitude and direction of the gradient are:

$$\mathbf{G} = \sqrt{\mathbf{G_x^2} + \mathbf{G_y^2}} \qquad \boldsymbol{\theta} = \tan^{-1} \frac{\mathbf{G_y}}{\mathbf{G_x}} \tag{2}$$

## III. CANNY EDGE DETECTION

The Canny edge detector [8] is based on computing the squared gradient magnitude. Local maxima of the gradient magnitude that are above some threshold are then identified as edges. This thresholded local peak detection method is

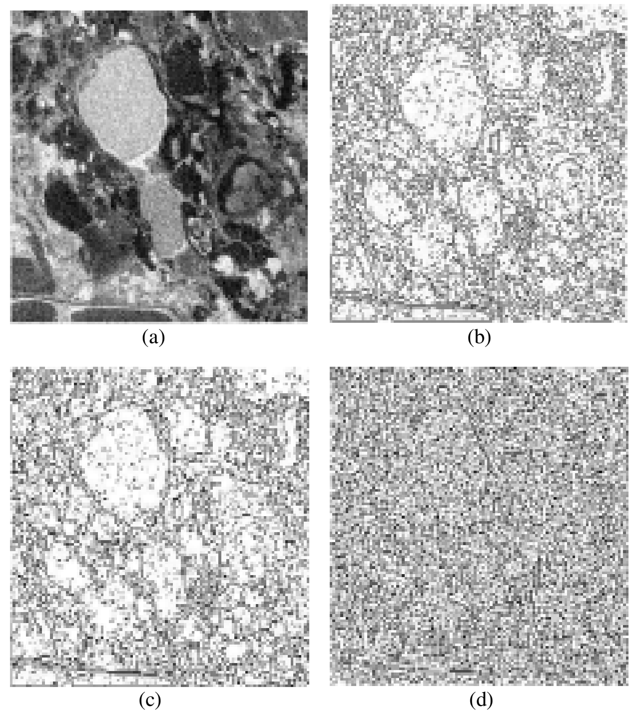



Fig. 1. (a) Noisy remote sensed image (b) Edge map using Sobel operator (c ) Edge map using Prewitt operator (d) Edge map using Roperts operator.

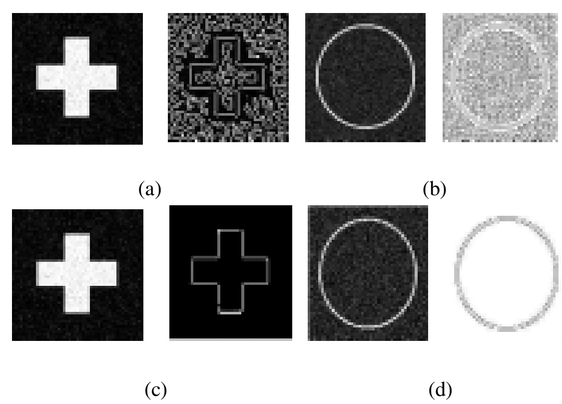
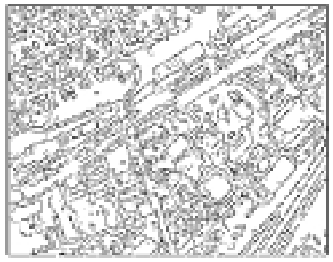



Fig. 2. A comparison between Canny and Marr-Hildreth edge detectors on noisy image (a) and (b) using Marr-Hildreth , (c) and ( d) using Canny

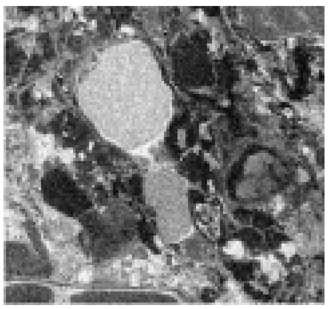
called non-maximum suppression, or NMS. The motivation for Canny's edge operator was to derive an "optimal" operator in the sense that minimizes the probability of multiply detecting an edge, minimizes the probability of failing to detect an edge and minimizes the distance of the reported edge from the true edge.

The first two of these criteria address the issue of detection, that is, given that an edge is present will the edge detector find that edge (and no other edges). The third criterion addresses the issue of localization, that is how accurately the position of an edge is reported. There is a tradeoff between detection and localization -- the more accurate the detector the less accurate the localization and vice-versa.

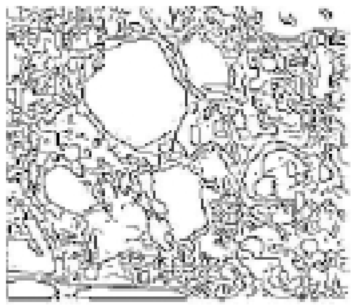
(a)



(b)



(c)



(d)

Fig. 3. (a) Original Arial Urban remote sensing image (b) Edge map using Canny (c) Original remote sensing image (d) Edge map using Canny

The objective function was designed to achieve the following optimization constraints:

1. Maximize the signal to noise ratio to give perfect detection. This favours the marking of true positives.
2. Achieve perfect localization to accurately mark edges.
3. Minimize the number of responses to a single edge. This favours the identification of true negatives, that is, non-edges are not marked.

These criteria seem to be reasonable candidates for filters comparison. Fig. 2. shows a comparison between Canny edge detector and Marr-Hildreth [9]. The features extracted from a real remote sensing images are clear in Fig. 3.

A system to use the Canny edge detector in remote sensing image enhancement is proposed. First, Gaussian filter was used to perform image smoothing. Then, the sharp edge map produced by implemented Canny edge detector is added to the smoothed noisy image to generate the enhanced image. Fig. 4. shows the proposed block diagram to image enhancement. The application of this technique is applied on a real remote sensing image and the result is shown in Fig. 5.

## IV. DISCUSSION AND CONCLUSION

Standard edge detectors methods failed to perform adequately in such applications due to the noisy nature of remotely sensed data. Neither the Roberts Cross, the Sobel operator, nor Prewitt operator are able to detect the edges of the object while removing all the noise in the image. Since

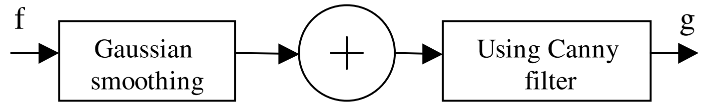



Fig. 4. Block diagram of image enhancement (sharpening and de-noising) using Canny edge detector

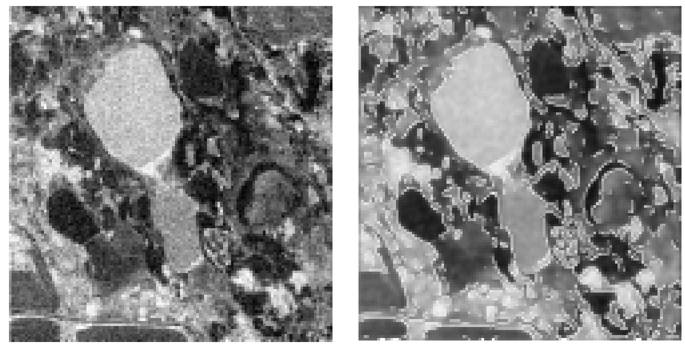


Fig. 5. Image enhancement (Sharpening and de-noising) using Canny edge detection Noisy remote sensing image (left). Enhanced image (right)

the LoG filter is calculating a second derivative of the image, it is quite susceptible to noise, particularly if the standard deviation of the smoothing Gaussian is small. Thus it is common to see many spurious edges detected away from any obvious edges. One solution to this is to increase the smoothing of the Gaussian to preserve only strong edges.

The implemented Canny edge detector presented the best performance both visually and quantitatively based on the measures such as mean square distance, error edge map and signal to noise ratio. The Gaussian smoothing in the Canny edge detector fulfills two purposes: first it can be used to control the amount of detail that appears in the edge image and second, it can be used to suppress noise. Using the implemented Canny edge detector as an enhancement tool for remote sensing images, the result was robust and achieved a very high enhancement level.

## REFERENCES

[1] Hui Li, B. S. Manjunath ,"A Contour-Based Approach to Multisensor Imge Registration,". *IEEE Trans. On Image processing Vol. 4 NO. 3, pp. 320-334 1995.*

[2] J. S. Lim, "Two Dimensional Signal and Image Processing, "Prentice Hall, Englewood Cliffs, New Jersey, 1990.

[3] Robert A. Schowengerdt," Remote sensing, Models and Methods for Image Processing," 1997.

[4] D.H. Ballard and C.M. Brown," *Computer Vision*," Prentice--Hall, New Jersey, 1982.

[5] Berzins, "V.*Accuracy of Laplacian Edge Detector* Computer Vision, Graphics, and Image Processing,," Vol. 27, pp. 195-210, 1984.

[6] J. M. S. Prewitt, "Picture Processing and Psychpictorics," B.S. Lipkin and A. Rosenfeld Eds, Academic Press, New York, 1970.

[7] R. O. Duda. and P. E. Hart, "Pattern Classification and Scene Analysis," Wiley, New York, 1973.

[8] J. F. Canny,"A computational approach to edge detection," *IEEE Trans. Pattern Analysis and Machine Intelligence*, 8:679-698, 1986.

[9] Marr and E. Hildreth," Theory of edge detection, " Proc. R. Society B207, pp. 187--217, 1980.