Multispectral Edge Detection Techniques Analysis
Neha Chhattani
VLSI Design, RCOEM, Nagpur
Email: neha.chhattani18@gmail.com

Abstract:

The characteristics of image boundaries is determined by edges. For processing images and extracting image information, edge detection plays a vital role as it filters out the useful information of an image. A GUI is created in NetBeans 8.1 IDE for analysing various multispectral edge detection methods. The multispectral edge detection package consists of different edge detection techniques such as Sobel, Robert’s Cross, Prewitt, Frei & Chen, Laplacian and Laplacian of Gaussian edge detectors. Depending on the requirement, appropriate edge detection method is applied to recognize objects and extract information. Analysis shows that Sobel edge detection takes less time, high space and is less sensitive to noise while Robert’s Cross edge detection is most sensitive to noise. Frei-Chen edge detector is less sensitive to noise when compared with Sobel edge detector. Also, the edges that have smaller gradients can be detected with this method. Laplacian of Gaussian is least sensitive to noise and test wider area around the pixel while Laplacian have fixed characteristics in all directions.

Keyword: Edge Detection Methods; Frei & Chen; Laplacian; Multispectral; Edge; Sobel; Perwitt; Robert Cross

1. INTRODUCTION

The object boundaries are identified via edge detection. An edge is detected whenever there is sudden change in the gray level intensity in image. Operators that are sensitive to the change in gray levels can be used as edge detectors [1]. It can also be defined as discontinuities in image intensity from one pixel to another. Detection of edges for an image may help for image segmentation, data compression, and also help for well matching, such as image reconstruction and so on [2]. Variables involved in the selection of an edge detection operator include Edge orientation, Noise environment and Edge structure [3]. In noisy images, edge detection is difficult as there are high-frequency content in both noise and edges. First order and second order derivative of image intensity is done to determine edges.

In high resolution remote sensing data products, it is necessary to understand and extract the hidden structural information. Edge detection is important in computer vision, image understanding, object and pattern recognition in color images and multispectral images. Edge detectors are multi scale and include three processing steps i.e. smoothing, differentiation and labelling. A variety of edge detection methods based on first order and second order derivative of images have been proposed for different applications. Edge detection such as Sobel, Roberts Cross, Prewitt Gradient and Frei & Chen are based on first order derivative while Laplace operator and Laplace of Gaussian (LoG) operators are based on second order derivative. These operator consists of kernel mask which are convolved with the original image which then detects the edges based on abrupt changes in the gray level. The multispectral edge detection is used for extracting natural objects such as mountain, desert, lake, etc. and artificial man-made objects such as roads, places, electricity lines, urban areas, etc. Processing and interpretation of this images based on specific feature is done [4].

Sobel operator is one of the most commonly used detection methods and returns edges at points where the gradient of image intensity is maximum [5]. Prewitt method determine edges where there is maximum change in the intensity of image when
derivation is performed. The Laplacian method searches for zero crossings in the second derivative of the image to find edges since the second derivative is zero when the first derivative is at maximum [6]. However, it is sensitive to noise, which should be filtered out before edge detection. Based on the filter used, Laplacian of Gaussian edge detection technique is used. Robert’s Cross edge detection is sensitive to noise while Frei & Chen edge detection is less sensitive to noise.

NetBeans platform is used to design GUI using java in which we can browse various images of formats jpeg, png, gif, bmp, tif, tiff, wbmp, raw, pnm and different edge detection technique can then be applied to extract image information and pattern recognition.

In the second section various methods for edge detection has been explained. The third section includes implementation and results and the forth section explains the conclusion.

II. MULTISPECTRAL EDGE DETECTION METHODS
Remote sensing is a process where the information about the earth surfaces and phenomenon which are not in direct contact with surfaces and phenomenon is collected [7]. The images collected from remote sensing may not give useful information unless proper processing and analysis is done [8]. In satellite images, to extract exact features and objects, proper edge detection technique is to be carried out. Also noise should be considered as it can omit a part of shape or add a part to it [9]. It is primary step in image enhancement process. An edge is detected if there is a sudden change in the intensity of gray level [10].

The various edge detection methods used are Laplacian, Laplacian of Gaussian (LoG), Sobel, Robert’s Cross, Prewitt, Frei & Chen.

A. Laplacian Edge Detector
The second spatial derivative of the image is measured by the Laplacian edge detector. The Laplacian \( L(x, y) \) of an image with pixel intensity values \( I(x, y) \) is given by [11]:

\[
L(x, y) = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2}
\]  

(1)

The regions of sudden intensity change is highlighted by Laplacian operator. Laplacian operator is noise sensitive. For this reason, the image is first smoothed with Gaussian smoothing filter then the Laplacian filter is applied so as to reduce noise. The convolution kernel of Laplacian edge detector is given by

![Fig.2. Laplacian Mask](image)

B. Laplacian of Gaussian Edge Detector (LoG)
In LoG edge detector, the image is first smoothed by applying Gaussian filter which reduces the high frequency noise, then Laplacian filter is applied. As convolution is associative, Gaussian filter is convolved with Laplacian filter and then this hybrid filter is convolved with the original image which detects the edges in an image. The 2-D LoG function center as zero and standard deviation as Gaussian is represented by [12].

\[
L_{0G}(x, y) = -\frac{1}{\pi \sigma^4} \left[ 1 - \frac{x^2 + y^2}{2 \sigma^2} \right] e^{-\frac{x^2 + y^2}{2 \sigma^2}}
\]  

(2)

A discrete kernel that approximates this function (for a Gaussian \( \sigma = 1.4 \)) is shown in Figure 3 [13]

![Fig.3. Discrete approximation to LoG function with Gaussian \( \sigma = 1.4 \)](image)
The second spatial derivative of an image is calculated using LoG operator. The LoG response will be zero in the area where the image has constant intensity while whenever there is a change in intensity the LoG response will be positive on the darker side, and negative on the lighter side [14].

C. Sobel Edge Detector

The edges along the horizontal (180 degree) and vertical (90 degree) is detected using the Sobel Edge detection technique. The method involves convolving the original image with small filter with integer value. [15]. Thus Sobel operator is an approximation of first order Gaussian derivative. Convolution is both cumulative as well as associative as shown in below equation.

\[
\frac{\partial}{\partial x} (f * G) = f * \frac{\partial}{\partial x} G
\]  

(3)

Convolution is done by applying 3x3 kernels to the original image. The output image shows an omnidirectional outline of the objects in the input image [16]. The regions having constant brightness are highlighted.

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Vertical Mask

Horizontal Mask

Fig. 4.

The high spatial frequency regions corresponding to edges are emphasized using Sobel operator. The kernel is such that it smoothes the original image, which reduces the noise. Thus, the operator is less sensitive to noise. Sobel operator produces higher output values for similar edges but has slower computations than Roberts Cross edge detection [17].

D. Robert’s Cross Edge Detection

Robert’s Cross edge detector is the simple and oldest method. The image edges are extracted by taking the combined differences of directions at right angles to each other [16]. Roberts kernels are diagonal elements derivatives. Mathematically, Roberts operator approximation is given as:

\[
gx = \frac{\partial f}{\partial x} = (z_9 - z_5)
\]  

(4)

\[
gy = \frac{\partial f}{\partial x} = (z_8 - z_6)
\]  

(5)

Magnitude of vector is given by –

\[
f(x, y) = \text{mag}(\nabla f(x,y)) = [(gx)^2 + (gy)^2]^{1/2}
\]  

(6)

In Roberts Cross edge detection, a 3x3 kernel is applied in the vertical and horizontal direction. These vertical and horizontal edges when combined together gives resulting edge detection. The resulting image appears as fairly coarse directional outline of objects in an image. The brightness regions which are constant becomes black whereas the brightness regions that are changing are highlighted when applying Robert’s Cross edge detection [16]. The Robert Cross kernels are small and also highly susceptible to noise. For similar edges, it produces very weak output.

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Vertical Mask

Horizontal Mask

Fig. 5.

E. Prewitt Edge Detector

Prewitt edge detection method is used to detect edges along vertical and horizontal directions. The edges are extracted along directions north, northeast, east, southeast, south, southwest, west, or northwest (dx) and vertical mask detects image derivatives in y (dy) direction. The edges highlighted at a given
location is the square root of the sum of the squares of these two derivatives [16]. The resulting image shows the directional outline of the objects in an image where constant brightness region becomes black while changing brightness regions become highlighted [18].

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Vertical Mask       Horizontal Mask

The Prewitt method takes the central difference of the neighbouring pixels. The computation is approximated by the change in image intensity. The differentiation is discrete in Prewitt method [19]. The magnitude and orientation of the edge are approximately estimated by Prewitt’s operator.

**F. Frei & Chen Edge Detector**

The Frei and Chen edge detector uses vertical and horizontal mask as shown in Figure 5. It is more sensitive to a configuration of relative pixel values that is independent of the brightness magnitude when compared to other edge detectors [16]. Frei-Chen edge detector can detect edges even for small variation in intensity level, thus performing better than Sobel edge detector [17].

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Vertical Mask       Horizontal Mask

The multispectral edge detection package GUI is created in NetBeans 8.1 using java. The GUI consists File and Methods interface. On clicking File here are three options – Open, Revert, Exit. On click “Open”, user can browse image from his/her desktop in which edge detection is to be done. “Revert” resets to original image and “Exit” closes the application. On clicking “Methods” various techniques to detects edges are there. On clicking particular technique, edge is detected.
the edge enhanced image using the various edge detector mask. The object is recognized and information is extracted using these edge enhancements. Analysis shows that Laplacian have fixed characteristics in all directions while Laplacian of Gaussian is least sensitive to noise and test wider area around the pixel. Sobel edge detection takes less time, high space and is less sensitive to noise while Robert’s Cross edge detection is most sensitive to noise. Prewitt edge detector detects edges where there is maximum change in the intensity of image. It takes less time and lower space. Frei-Chen edge detector is less sensitive to noise when compared with Sobel edge detector. Also, the edges that have smaller gradients can be detected with this method.

IV. CONCLUSION

The multispectral edge detection package has been implemented in NetBeans 8.1 in java. The package shows various edge detection techniques. Depending on the application and user’s requirements, appropriate edge detection methods is applied to the image so that object can be recognized and information is extracted. Analysis shows that Laplacian of Gaussian is least sensitive to noise but it malfunctions at the corners and curves where grey level intensity function varies. The Sobel also detects the various features and is computationally more efficient but with more false edges. Sobel is optimum for objects with Strong edges as roads, bridge etc. The other algorithms as Robert and Prewitt also detect the various features but fails in case of smaller features and the range of usable threshold is very low. Frei & Chen detects better edges as they have small gradients.

V. REFERENCES


[16] cit.wta.swin.edu.au

[17] www.dsi.unive.it