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PERFORMANCES ANALYSIS OF DIFFERENT EDGE DETECTION METHODS ON ROAD IMAGES

Monica Avlash*

Dr. Lakhwinder Kaur**

Abstract: *This paper is concerned with the study of various edge detection techniques like Sobel, Prewitt, Robert's Cross, Zerocross and Canny on various road images to detect edges and to extract some road features. This paper also outlines definition of edge detection, different types of edges, steps in edge detection. A comparison between these edge detectors have been examined and numerical and visual results are outperformed. It has been observed that the Canny's edge detector yields better results than all other edge detectors although it is complex and time consuming method.*

Keywords: *Digital image processing, Edge detection, Sobel, Robert's Cross, Prewitt, ZeroCross, Canny, Road Map.*

*Student, Computer Engineering Department, University College of Engineering**,** Punjabi University, Patiala, Punjab, India

**Professor, Computer Engineering Department, University College of Engineering, Punjabi University, Patiala, Punjab, India.

I. INTRODUCTION

Roads play an important role in transportation infrastructure and travelling system. It supports various applications like urban planning, traffic management and vehicle navigation etc [12].Road Extraction is the process of extracting road features to separate road pixels from background so that road and non-road regions can be differentiated[7].Edge detection is a very important and fundamental step in the field of Computer Vision and Digital Image Processing[2][7]. Edge is a part of an image which contains significant variation of intensity[5]. Edges describes the boundaries between an object and the background in an image, which helps in segmentation and object recognition[2]. Edge detection is useful in image segmentation which identifies whether a line or an edge is present or not and depicts them in an suitable way[14]. It is defined as the process of identifying and locating sharp discontinuities, boundaries of objects or textures depicted in an image (i.e. edges)[7]. These discontinuities are rapid variations in pixel intensity which characterize objects boundaries in an image[11]. The goal of edge detection is to extract the important features like lines, corners, curves etc. from the edges of an image[13]. The main motive of edge detection is to discard the unnecessary information and preserves the essential information and thus it reduces the amount of data which needs to be processed. The important characteristics of edges are position of subarea, amplitude and direction. Based on these characteristics, the detector has to decide whether each of the examined pixels is an edge or not[14]. The motivation of edge detection is significant, often sharp, contrast variations in images caused by illumination and surface boundaries[1]. Noise, objects with similar intensity, edge density and lightning conditions are the important factors on which quality of edge detection depends upon. All these problems can be handled by adjusting certain values in the edge detector and changing the threshold value[2]. The threshold and edge detection method of image processing has been holden an important status in the image segmentation application because of its simplicity and intuitiveness. Image segmentation is the process of partitioning a digital image into multiple regions or sets of pixel or separation of the object of interest(same texture or color) from the background. The set of areas that envelopes the whole image will give the result of segmentation[9]. The segmentation simplifies and changes the illustration of a scene into more meaningful way and hence it is easier to detect the image. Discontinuity and similarity

are generally the two basic properties on which image segmentation algorithm is based upon[3].

There are an extremely large number of edge detection operators available like Sobel, Robert, Prewitt, Zerocross, Canny etc.[7][11]. Structure of edge, direction of edge and noise conditions are the factors which are involved in selection of different edge detection operators. Poor concentration and refraction effects can moderately change the object boundaries which can lead to problems like noise susceptibility, false edge detection and high computational time.

Our purpose is to do the comparison of various edge detection techniques on different road images and visualize the results of the different edge detection operators[11].

II. EDGE DETECTION METHODOLOGY

With the help of edge detection, a more perceptible information can be taken out by knowing the physical and geometrical changes in an input image[5].

A. Various Types of Edges

Various physical actions like discontinuity in object boundary, surface direction and in geometry cause changes in intensity[13].

Edges can be shaped according to their amplitude changes as follows:.

- *Step Edge*: The intensity of the image suddenly varies from one value to one side of the breakage to a different value on the other side.
- *Ramp Edge*: When the intensity change is not spontaneous and appears over a limited distance then step edges become ramp edges
- *Ridge/Line Edge*: The intensity of an image suddenly changes values and then returns to the initial point within short distance.
- *Roof Edge*: When the intensity change is not spontaneous and appears over a finite distance usually generated by connectivity of surfaces then line edges become roof edges[13].

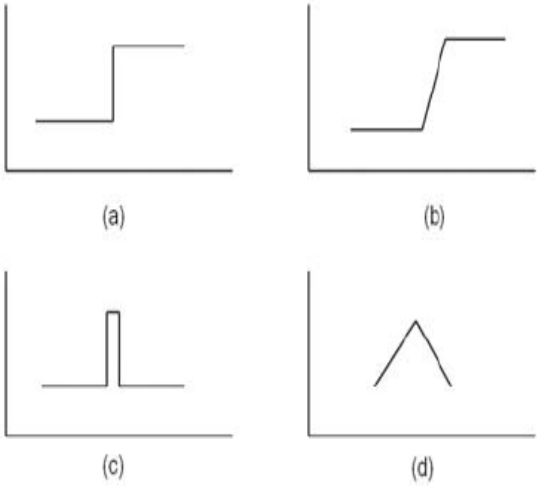

Fig.1. Different Types of edges a).Step Edge b).Ramp Edge c).Ridge/Line Edge d).Roof Edge[9].

B. Categories of Edge Detection

Edge detection is most common approach for finding discontinuities in amplitude values. By applying first and second order derivatives, these discontinuities can be identified[3]. The edge detection can be categorized in two different parts as follows:

- *Gradient Edge Detection:* Gradient is the first order derivative used in digital image processing[3]. Edges are detected by looking for the maximum and minimum value in the first derivative of the image. eg. Sobel, Robert.
- *Laplacian Edge Detection:* The second order derivatives in image processing are generally computed using Laplacian. To find the edges in an image, the laplacian method looks for zero crossings **(***i.e.* places where the sign of Laplacian changes) in the second order derivative. An edge is the one-dimensional ramp shaped and the position of edge can be identified by computing the second order derivative of the image.

  Eg. Zerocross[11].

C. Steps in Edge Detection

Edge detection contains mainly four steps which are depicted in following fig 2.

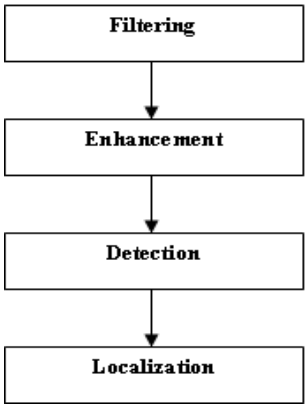

Fig 2. Flowchart for Edge Detection[9][13]

These steps in edge detection are described as follows:

- *Filtering:* Images are generally distorted by some haphazard variations in intensity values, known as noise. Various types of noise like Gaussian, impulse, salt and pepper noise frequently occur in an image[9]. Filtering or smoothing suppress as much noise as possible, without destroying the edges[13].
- *Enhancement:* Enhancement emph- -asizes upon pixels where there is a significant variations in local intensity values and is generally done by calculated the magnitude of gradient vector[9].
- *Detection:* It detects the edges by using the thresholding criteria that which edge pixels should be discarded as noise and which should be retained[13].
- *Localization*: It identifies the proper position of an edge in an image. Edge linking and edge thinning are usually essential in localization[13].

III . VARIOUS EDGE DETECTION TECHNIQUES

A. Sobel Operator

To find edges in an input image, the Sobel operator makes use of derivative approach by returning those edges where the gradient of the image is maximum. The horizontal and vertical gradient matrices with 3x3 dimensional kernel for the Sobel method has been generally used in the edge detection operations[11].[11]

-1	0	+1
-2	0	+2
-1	0	+1

Gx

+1	+2	+1
0	0	0
-1	-2	-1

Gy

Fig.3. 3*3 Masks used by Sobel Operator[11]

These masks can be put separately to the original image and produces the gradient component in each direction (say these *Gx* and *Gy*). Finally, these are collected at the end to find the gradient magnitude and direction[11]. An edge pixel is explained firstly by the gradient magnitude feature and secondly by gradient direction(angle)[4].

The magnitude of gradient vector is specified by:

$G=(Gx^2+Gy^2)1/2$ [11]

Generally, the magnitude is calculated by using the formula as follows:

$$|G| = |Gx| + |Gy|$$ [11]

The angle of gradient vector is given by:

$$\theta = \arctan(Gy / Gx)$$ [11]

where, Θ is 0 for a vertical edge which is darker on the right side.

B. Prewitt's Edge Detector

To identify vertical and horizontal edges in an input image, Prewitt operator is used which is very similar to the sobel operator. Here Gx and Gy are defined as the horizontal and vertical derivative approximations and are calculated using following mask[10].

-1	0	+1
-1	0	+1
-1	0	+1

Gx

+1	+1	+1
0	0	0
-1	-1	-1

Gy [10]

Fig.4. Prewitt edge detector matrix for Gx and Gy [1]

C. Robert's cross operator:

To perform fast computation with Robert's cross edge detection, convolve the input image with the following two matrix as shown below:

+1	0
0	-1

Gx

0	+1
-1	0

Gy [11]

Fig.5 Masks used by Robert's Cross edge detector[11]

This operator is similar to the sobel detector to some extent. These masks can be put separately to the original image and produces the gradient component in each direction (say these *Gx* and *Gy*). Finally, these are collected at the end to find the gradient magnitude and direction [11].

The magnitude of gradient vector is specified by:

$G=(Gx^2+Gy^2)1/2$ [11]

Generally, the magnitude is calculated by using the formula as follows:

$|G| = |Gx| + |Gy|$ [11]

The angle of gradient vector is given by:

$\theta = \arctan(Gy / Gx) - 3\pi / 4$ [11]

D. Zerocross Edge Detector

The Zerocross operator searches for places in the laplacian of an input image where the laplacian values passes through zero i.e. points where the laplacian changes sign. These points frequently occur at edges(where intensity changes instantaneously) of the images[10]. Zerocross helps in edge detection and in finding the edge direction but it gives response to some edges only and it is susceptible to noise[11].

E. Canny Edge Detector

The Canny edge detector may also called as the optimal edge detector. An "optimal" edge detector means it should mark all possible edges. Marked edges are traversed only once and possibly are the only edges not any raw data[8]. The Canny operator works in a multiple steps[10]. The Canny operator was implemented by John F. Canny in 1986 whose approach is based on the three objectives for an 'optimal' edge detector:

a) Low Error Rate.

b) Edge points should be well located.

c) Corresponding to one edge point, there should be a single response[8].

The algorithm constitutes the following basic steps:

1).Input image is smoothen with the help of gaussian filter and noise is removed.

2).The magnitude and direction of gradient is then calculated using partial derivatives.

3).Apply non-maxima suppression to the gradient magnitude and then suppress any pixel value and give a thin line to the original image.

4).Canny makes use of hysteresis method to identify and join edges. Hysteresis eliminates the breakage in contouring of edges in an image by using high and low threshold values say T1 and T2. Those pixels which have values greater than threshold T1 will be considered as edge pixels and those having values greater than T2 are also marked by connecting edges with those edge pixels[8][10][11].

IV . EXPERIMENTAL RESULTS

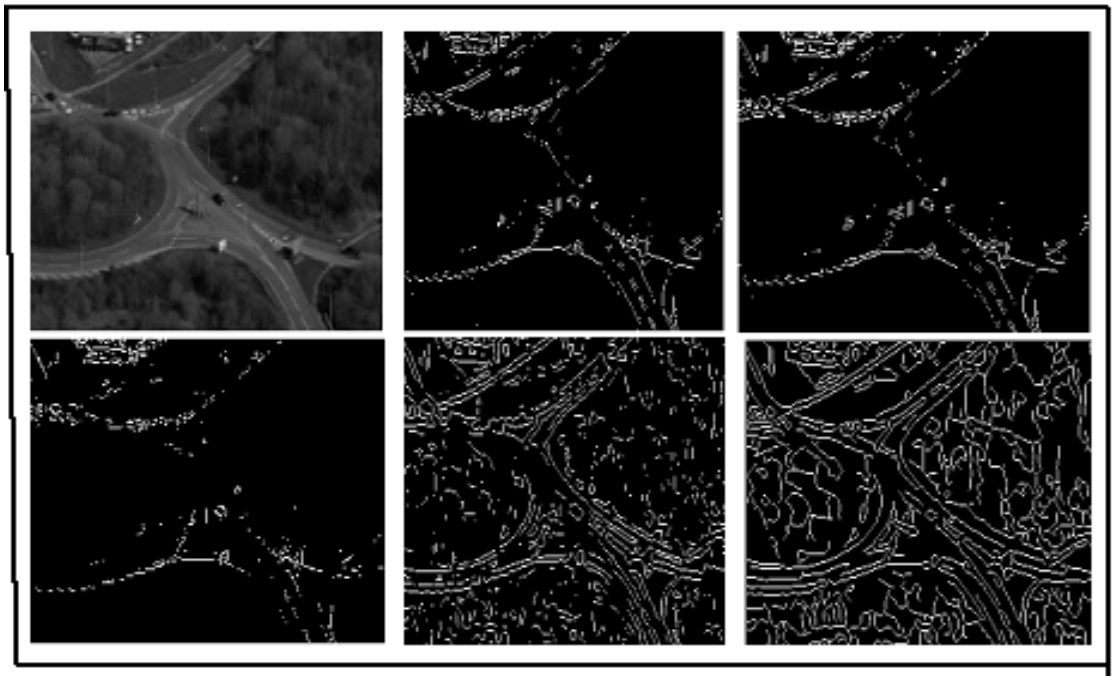

Fig.6. Comparison of Edge Detection Techniques a) Original Image (road1.jpeg) b) Sobel c) Prewitt d) Robert's Cross e) ZeroCross f) Canny

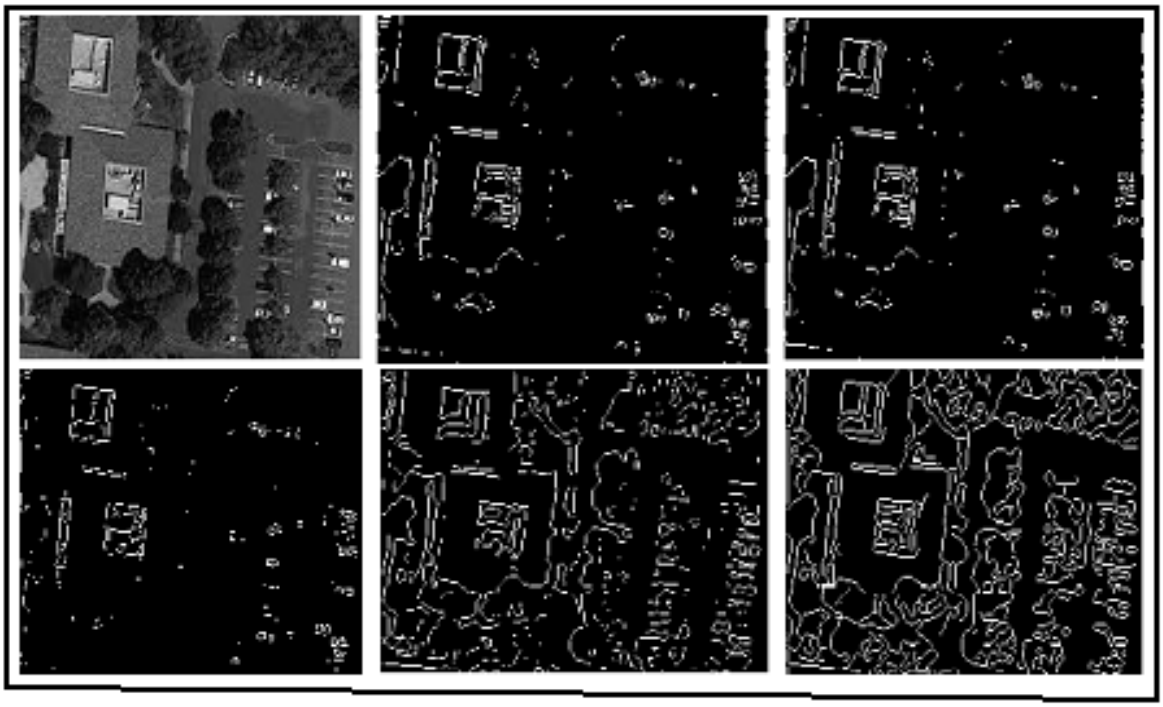

Fig.7 Comparison of Edge Detection Techniques a) Original Image (road2.jpg) b) Sobel c) Prewitt d) Robert's Cross e).ZeroCross f) Canny

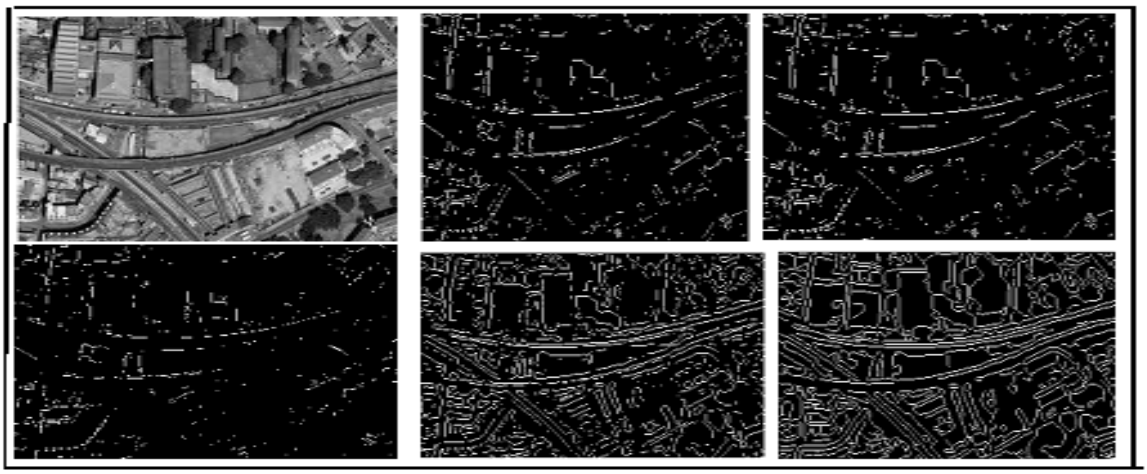

Fig.8 Comparison of Edge Detection Techniques a) Original Image (road3.jpg) b) Sobel c) Prewitt d) Robert's Cross e) ZeroCross f) Canny

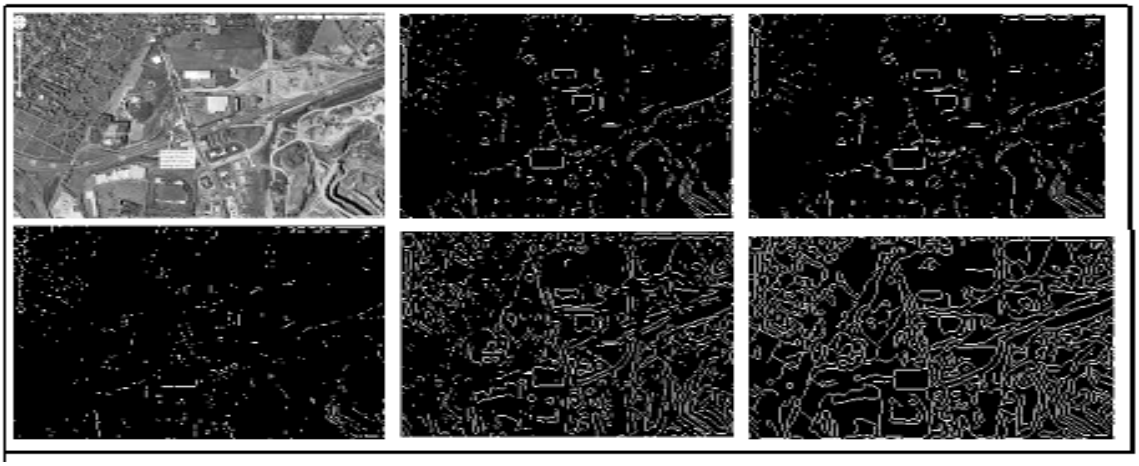

Fig.9 Comparison of Edge Detection Techniques a) Original Image (road4.jpg) b) Sobel c) Prewitt d) Robert's Cross e) ZeroCross f) Canny

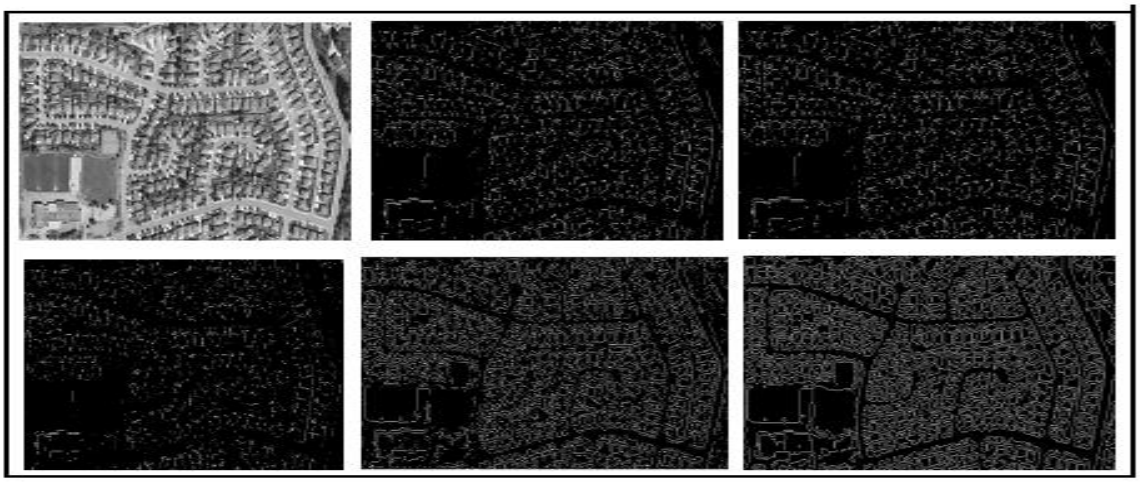

Fig.10. Comparison of Edge Detection Techniques a) Original Image (road5.jpg) b) Sobel c) Prewitt d) Robert's Cross e) ZeroCross f) Canny

V. COMPARISON OF DIFFERENT EDGE DETECTION METHODS

Five different edge detection methods have been experimented for detecting edges on five different road images. Figure 6,7,8.9 and 10. shows the comparison of the these five edge detection methods for the images of road1.jpeg,road2.jpeg, road3.jpeg,road4.jpeg, road5.jpeg respectively. Sobel and Prewitt yields same result to some extent and there is some discontinuity and breakage of lines. Robert's Cross yields response with respect to some edges only. Robert's Cross gives less detailing even than sobel and prewitt. ZeroCross gives more fine points than robert's cross and classical (sobel and prewitt) operators. But canny provides more emphatic and notable results than Zero Cross. Thus, canny gives accurate demonstration of the original images and road features are visible as there are no discontinuities of lines and shows proper road areas.

VI. ADVANTAGES AND DISADVANTAGES OF EDGE DETECTION METHODS

The first advantage of the sobel and prewitt operators is intuitiveness and easiness. Sobel edge detector method is somewhat tough than prewitt edge detector. But prewitt produces slightly noisy results. Robert edge detector is one of the simplest edge detectors in digital image processing but it is preferably less in use than other edge detectors as it gives minor details. The sobel, prewitt and zerocross operators are used for the edge detection and finding directions of gradient magnitude as the approximation of gradient magnitude is easy. The disadvantages of Sobel and Prewitt operators are noise susceptibility in edge detection and in direction of gradient magnitude and unreliabilty[4] whereas cross operator gives response to some edges only. Canny edge detector is the most dominant operator than others detectors[3]. Canny detects edges more efficiently even in noisy images and shows road features. Thus improves signal to noise ratio, but it is more complicated and time consuming[11].

VII. CONCLUSION

In this paper, different road images have been studied for detecting edges using various types of edge detection methods and to extract some road areas. Two categories of gradient-based and laplacian based edge detection have also been discussed. Sobel, prewitt, roberts, zerocross, canny edge detectors have been experimented to identify the edges by using the MATLAB(Matrix Laboratory) software. The result are analysed and compared. Sobel edge detector method is somewhat tough than prewitt edge detector. But prewitt

produces slightly noisy results. Robert edge detector gives minor details about image. Zerocross gives more detailing and fine edges in every direction. Canny edge detector gives the most prominent results than other detectors and makes the road features properly visible.

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