Study of Image Edge Detection: A Review

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Abstract- For object detection Edge detection is important part of image processing. So it becomes extremely important to have a good Knowledge of edge detection algorithms. An edge is the real or imagined line that marks the limit and divides of plane, object or appearance from other places or things. This means that if the edges in an image can be identified accurately, all of the objects can be located and basic properties can be measured. In this paper we discuses a classification of most important and mostly used edge detection algorithms, namely Sobel, Robert, Prewitt, Laplacian of Gaussian, Canny. The advantages and disadvantages dealt in individual study. Its application area is very wide i.e. from astronomy to photography, medicine to war.

Keywords- Edge Detection, Image processing, Laplacian of Gaussian, Prewitt, Robert, Sobel, Canny edge detector.

I. INTRODUCTION

- Edge detection is the name for a set of mathematical methods which aims identifying points in a digital image at which the image brightness changes sharply or, more formally, has discontinuities [2]. The points at which image brightness changes sharply are typically organized into a set of curved line segments termed edges. The same problem of finding discontinuities in 1D signal is known as step detection and the problem of finding signal discontinuities over time is known as change detection. Edge detection is a fundamental tool in image processing, machine vision and computer vision, particularly in the areas of feature detection and feature extraction [3].

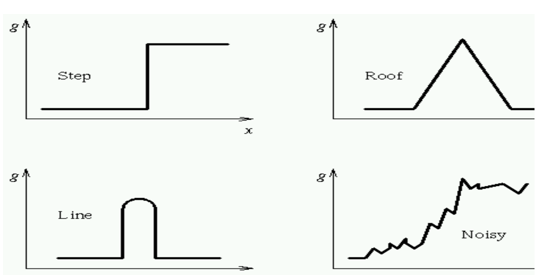

Fig.1 Typical edge profile

II. Flow Chart of Edge Detection [18]

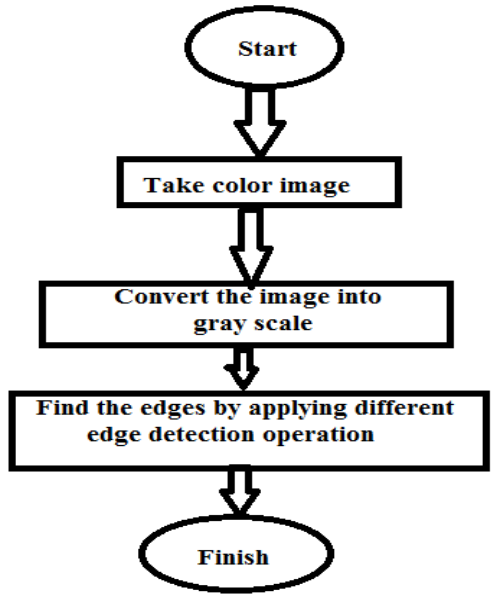

Fig.2 Flow chart for edge detection

A. Gradient based Edge Detection- The gradient method detects the edges by looking for the maximum and minimum in the first derivative of the image.

1) Prewitt- The Prewitt operator is used in image processing, particularly within edge detection algorithms. Technically, it is a discrete differentiation operator, computing an approximation of the gradient of the image intensity function. At each point in the image, the result of the Prewitt operator is either the corresponding gradient vector or the norm of this vector. The Prewitt 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. On the other hand, the gradient approximation which it produces is relatively crude, in particular for high frequency variations in the image. The Prewitt operator was developed by Judith M. S. Prewitt.

1.1) Simplified description- In simple terms, the operator calculates the gradient of the image intensity at each point, giving the direction of the largest possible increase from light to dark and the rate of change in that direction. The result therefore shows how "abruptly" or "smoothly" the image changes at that point and therefore how likely it is that part of the image represents an edge, as well as how that edge is likely to be oriented. In practice, the magnitude (likelihood of an edge) calculation is more reliable and easier to interpret than the direction calculation.

Mathematically, the gradient of a two-variable function (here the image intensity function) is at each image point a 2D vector with the components given by the derivatives in the horizontal and vertical directions [4]. At each image point, the gradient vector points in the direction of largest possible intensity increase, and the length of the gradient vector corresponds to the rate of change in that direction. This implies that the result of the Prewitt operator at an image point which is in a region of constant image intensity is a zero vector and at a point on an edge is a vector which points across the edge, from darker to brighter values.

At each point in the image, the resulting gradient approximations can be combined to give the gradient magnitude, using:

$$\mathbf{G = \sqrt{(H^2+V^2)}}$$

Using this information, we can also calculate the gradient's direction:

$$\mathbf{\Theta = atan2(V,H)}$$

where, for example, $\mathbf{\Theta}$ is 0 for a vertical edge which is darker on the right side.

2) Robert- The Roberts cross operator is used in image processing and computer vision for edge detection. It was one of the first edge detectors and was initially proposed by Lawrence Roberts in 1963. As a differential operator, the idea behind the Roberts cross operator is to approximate the gradient of an image through discrete differentiation which is achieved by computing the sum of the squares of the differences between diagonally adjacent pixels. Motivation-According to Roberts, an edge detector should have the following properties: the produced edges should be well-defined, the background should contribute as little noise as possible, and the intensity of edges should correspond as close as possible to what a human would perceive[15].

3) Sobel- This operator is used in image processing, particularly within edge detection algorithms. Technically, it is a discrete differentiation operator, it computing an approximation of the gradient of the image intensity function. 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 [2].

B. Laplacian based Edge Detection- The laplasian 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.

1) Canny's Detection- The Canny edge detector is an edge detection operator that uses a multi-stage algorithm to detect a wide range of edges in images. It was developed by John F. Canny in 1986. Canny also produced a computational theory of edge detection explaining why the technique works. Canny's aim was to discover the optimal edge detection algorithm. In this situation, an "optimal" edge detector means [8]:

- **Good detection-** It means algorithm should mark maximum edges in the image.
- **Good Localization-** It means algorithm should be mark as close as possible edge in the real image.
- **Minimal Response-** A given edge in the image only is marked once.

For above condition satisfaction Canny used the calculus of variations – this is a field of mathematical analysis that deals with maximizing or minimizing functional, which are mappings from a set of functions to the real numbers. In four step [10] this method is described, but it can be approximated by the first derivative of a gaussian.

1.1 Step first (Noise reduction)-The digitized image pixel (pixel is the smallest controllable element of a picture represented on the screen.) have been passed across the Gaussian filter. Because this detector is more susceptible to noise present in original image data, it uses a filter based on a Gaussian, where the raw image is convolved with a gaussian filter [8]. Gaussian filter is a filter whose impulse response is a Gaussian function. Gaussian filters have the properties of having no overshoot to a step function input while minimizing the rise and fall time.

1.2 Step second(Finding the intensity gradient)- An edge in an image may point in a variety of directions, so the Canny algorithm uses four filters to detect horizontal, vertical and diagonal edges in the blurred image. The edge detection operator (Roberts, Prewitt, Sobel for example) returns a value for the first derivative in the horizontal direction (H) and the vertical direction (V). From this the edge gradient and direction can be determined:

$$\mathbf{G = \sqrt{(H^2+V^2)}}$$

$$\mathbf{\theta = atan2(V,H)}$$

where atan2 is the arctangent function with two arguments. The edge direction angle is rounded to one of four angles representing vertical, horizontal and the two diagonals.

Given estimates of the image gradients, a search is then carried out to determine if the gradient magnitude assumes a local maximum in the gradient direction. From this stage referred to as non-maximum suppression, a set of edge points, in the form of a binary image, is obtained. These are sometimes referred to as "thin edges".

1.3 Step third (Tracing edges through the image and hysteresis thresholding)- High intense and low intense gradient both have equal importance in edge detection. It is in most cases impossible to specify a threshold at which a given intensity gradient switches from corresponding to an edge into not doing so. Therefore Canny uses thresholding with hysteresis.

Thresholding with hysteresis requires two thresholds – high and low. Making the assumption that important edges should be along continuous curves in the image allows us to follow a faint section of a given line and to discard a few noisy pixels that do not constitute a line but have produced large gradients. Therefore we begin by applying a high threshold. These marks out the edges we can be fairly sure are genuine. Starting from these, using the directional information derived earlier, edges can be traced through the image. While tracing an edge, we apply the lower threshold, allowing us to trace faint sections of edges as long as we find a starting point. Once this process is complete we have a binary image where each pixel is marked as either an edge pixel or a non-edge pixel [2]. From complementary output from the edge tracing step, the binary edge map obtained in this way can also be treated as a set of edge curves, which after further processing can be represented as polygons in the image domain.

1.4 Step Four (Differential geometric formulation of the Canny edge detector)- A more refined approach to obtain edges with sub-pixel accuracy is by using the approach of differential edge detection, where the requirement of non-maximum suppression is formulated in terms of second- and third-order derivatives computed from a scale space representation [5]. The Canny algorithm contains a number of adjustable parameters, which can affect the computation time and effectiveness of the algorithm.

C. Laplacian Of Gaussian- The laplacian is a two-dimensional isotropic measure of the second special derivative of an image. The laplacian of an image highlights regions of rapid intensity change and is therefore often used for edge detection. The laplacian is often applied to an image that has first been smoothed with something approximating a Gaussian smoothing filter in order to reduce its sensitivity to noise, and hence the two variants will be described together here. Since the input image is represented as a set of discrete pixels, we have to find a discrete convolution kernel that can approximate the second derivatives in the definition of the laplacian. Two commonly used small kernels are-

0	-1	0
-1	4	-1
0	-1	0

-1	-1	-1
-1	8	-1
-1	-1	-1

Using one of these kernels, the laplacian can calculated using standard convolution methods.

III. CONCLUSIONS

The purpose of this paper is to present a review of various approaches for segmentation based on edge detection techniques. The study of different edge detection technique and their experimental results shows the canny yield best results [1]. In this paper an attempt is made to review the edge detection techniques which base on discontinuity intensity levels. The relative performance of various edge detection techniques is not given the clear performance as clear as canny edge technique. Gradient based technique simple, easy and quick to compute and edges are detected along with their orientation but these are more sensitive to noise, so less reliable [19]. Canny improved signal to noise ratio, and gives better result in noisy conditions [7].

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