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A Review of Edge Detection and its Techniques in Digital Image Processing

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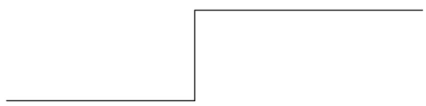
Abstract—Digital image processing is an important and crucial concept in computer vision for the purpose of effective image display and extraction of desired features as well as for editing and manipulating images. Edge detection is an authoritative concept in the digital image processing and is the initial step for image segmentation. Edges are detected for the purpose of creating a boundary or contour between an object and the background surface or different parts of a particular image. Detecting the edges include a number of different mathematical techniques that are used with the motive of identifying sharp discontinuities in a digital image. Edge detection is the fundamental concept used in image processing, machine and computer vision, image segmentation, and face recognition. In this paper, the major objective is to give a quick review of the edge detection process and the edge detection techniques.

***Keywords* : Edges; Edge Detection; Sobel; Prewitt; LoG; Canny.**

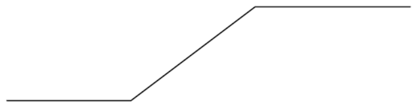
I. Introduction

Edge can be defined as a set of adjacently occurring pixel positions where a sudden change in the intensity, color or texture value occurs. Significantly, an edge represents the local changes of intensity in an image. Edge detection is the process of detecting the edges and the major goal of it is to extract the important features from the edges of an image such as lines, curves and corners; that will be used by higher level computer vision algorithms such as recognition. The edge detection process mainly involves four steps. The *filtering/smoothing* is the initial step for the processing of an image, that is being used to remove or suppress the noise as much as possible. The noises are of several types, but the general kind that are studied broadly are "impulse noise", "gaussian noise" and "salt and pepper" noise. There are many detectors that works quite good with the high quality images but generally are not fine enough for the noisy images as they are unable to detect the edges of different significance. So for this purpose the filtering is done as a primary step. Next is *enhancement/sharpening* process that basically is concerned with the improvement in the quality of a digital image. The process mainly focuses on the changes in local intensity of the pixels. The major objective of the enhancement techniques is to produce a more suitable and better image than the original one for a particular application. Third is the *detection* process that works on the pixels for which is to be considered as noise and which is to be retained. This means that all the points that are possible to become the edge points are extracted in this step. This is the main step in the processing of an image in case of edge detection for the purpose of getting a clear distinction of the object boundaries. The final step is *localization* that deals with the exact location and orientation of the edges where the necessity of localization being the edge thinning and linking. Thinning is a morphological operation that is used to remove selected foreground pixels from binary images and is related to the hit-and-miss transform. Linking is the way of grouping the edge points to form edges by considering each point's relationship to neighbouring edge points.

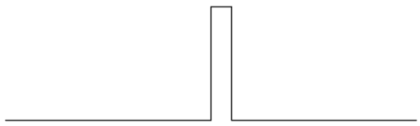
Edges mainly are the representation in an image that gives a clear picture of the various image elements and distinction between the object and the background. The main types of edges are defined as *ideal edges* and *noisy edges*. The *ideal edges* are the one's that do not contain any sort of noise and are generally of four types. In the step edge, the intensity changes suddenly from a particular value on one side to different value on the opposite side whereas ramp edges are the type of step edges where the change is over a finite distance but is not instant. In the case of line edges, the intensity value changes abruptly and then returns back to the starting point within a short distance whereas roof edges are the one in which the change occurs for a finite distance but is not abrupt. All these four types of ideal edges are shown below diagrammatically.



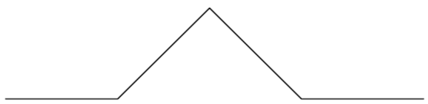
Ramp



Step



Roof



Line

And the *noisy edges*, as the name suggests, are those that create disturbances in the ideal edges and distorts their original formation. That is why in the edge detection process the initial step is the removal of noise.

Line or Roof

Step or Ramp

The edge detection methods can be classified broadly in three categories:

Gradient methods, Zero crossing and Optimal edge detection.

The gradient methods are first order derivatives that include Roberts, Sobel and Prewitt operators; Zero crossing are the second order derivatives that use the approaches Laplacian of Gaussian and Difference of Gaussian; and the optimal edge detection method uses the Canny edge detector.

A. Robert's cross edge detection

The Roberts edge detection was introduced by Lawrence Roberts in 1963. This edge detection scheme, as a differential operator, is one of the oldest technique and is simple to implement. The regions of high spatial frequency are highlights which correspond to edges. Unlike Prewitt and Sobel operator this operator is quite simple and much faster. Due to its fast computation and easy inclusion, it has a frequent application in hardware implementation. The input to the operator is a gray scale image the same as to the output is the most common usage for this technique. The operator consists of a pair of 2x2 convolution kernels as shown in the figure.

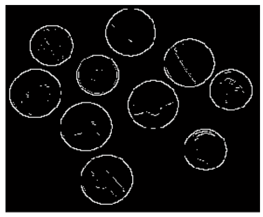
1	*0*
0	*-1*

Horizontal Mask (Gx)

0	*1*
-1	*0*

Vertical Mask (Gy)

One kernel is simply the other rotated by 90^0. These kernels are designed to respond maximally to edges running at 45^0 to the pixel grid, one kernel for each of the two perpendicular orientations. This edge detection technique gives results as shown.



Original image Robert edge detection

B. Prewitt edge detection

The Prewitt edge detection was proposed by Prewitt in 1970 and to estimate the magnitude and orientation this is the correct way. Prewitt edge detection operators are the one of the oldest and well understood operator for detecting edges in images. Edges are calculated by using difference between corresponding pixel intensities of an image. All the masks that are used for edge detection are also known as derivative masks. Because image can also be referred to as a signal, so changes in a signal can only be calculated using differentiation. So this is why these operations are also called derivative operators or derivative masks.

Basically, there are two kernels, one for detecting image derivatives in horizontal or X direction and another for detecting image derivative in vertical or Y direction.

-1	*-1*	*-1*
0	*0*	*0*
1	*1*	*1*

Horizontal Mask (Gx)

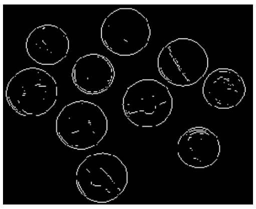
-1	*0*	*1*
-1	*0*	*1*
-1	*0*	*1*

Vertical Mask (Gy)

All the derivative masks must have the following properties :

- Opposite sign should be present in the mask.
- Sum of mask should be equal to zero.
- More weight means more edge detection.

To estimate the magnitude and orientation of an edge Prewitt is a correct way. It is limited to 8 possible directions; however knowledge shows that most direct direction estimates are not much more perfect. This gradient based edge detector is estimated in the 3x3 neighborhood for eight directions. All the eight convolution masks are calculated. This edge detection technique gives results as shown.



Original image **Prewitt edge detection**

C. Sobel edge detection

The Sobel edge detection method was introduced by Sobel in 1970 and it is a derivative mask used for edge detection. The sobel operator detects all the edges regardless of its direction. This edge detection operator gives an averaging and smoothing effect over the image thus making it takes care of the noise present in an image. It precedes the edges at those points where the gradient is highest. The Sobel technique performs a 2-D spatial gradient quantity on an image and so highlights regions of high spatial frequency that correspond to edges. A Sobel edge detection operation provides both a differencing and smoothing effect. It is used for detecting two types of edges in an image; vertical and horizontal. In sobel operator the coefficients of masks are not fixed and they can be adjusted according to our requirement unless they do not violet any property of derivative masks.

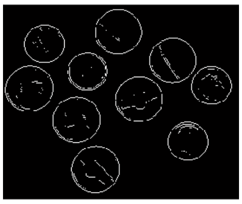
-1	*-2*	*-1*
0	*0*	*0*
1	*2*	*1*

Horizontal Mask (Gx)

-1	*0*	*1*
-2	*0*	*2*
-1	*0*	*1*

Vertical Mask (Gy)

The sobel kernels are more suitable to detect edges along the horizontal and vertical axis, whereas the Roberts kernels are able to detect edges run along the vertical axis of 45° and 135°. This edge detection technique gives results as shown.



Original image **Sobel edge detection**

D. Laplacian of Gaussian edge detection

The Laplacian of Gaussian (LoG) was proposed by Marr in 1982. The Laplacian operator is also a derivative operator which is used to find edges in an image. Laplacian operator is generally not used in edge detection because it reduces double edge effect and is very sensitive to noise. Therefore, before implementing the Laplacian operator the image is first smoothen using the Gaussian operator.

The major difference between Laplacian and other operators like Prewitt, Sobel, Robinson and Kirsch is that all these are the first order derivatives and the Laplacian is second order derivative. Another difference between Laplacian and other operators is that unlike other operators Laplacian didn't take out edges in any particular direction but it take out edges in the form of inward and outward edges.

The digital implementation of the Laplacian function is usually made through the mask shown in figure.

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

Horizontal Mask (Gx)

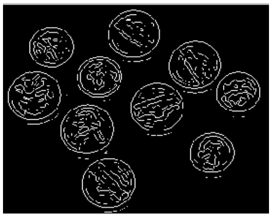
-1	*-1*	*-1*
-1	*8*	*-1*
-1	*-1*	*-1*

Vertical Mask (Gy)

The Laplacian operator works as two different kinds.

- *Positive Laplacian Operator :* In this we have a standard mask in which center element of the mask should be negative and corner elements of mask should be zero. The positive Laplacian is used to take out the outward edges in an image.
- *Negative Laplacian Operator :* In this operator also we have a standard mask, in which center element should be positive. All the elements in the corner should be zero and rest of all the elements in the mask should be -1. The negative Laplacian operator is used to take out inward edges in an image.

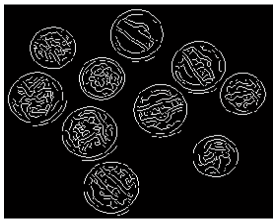
This edge detection technique gives results as shown.

Original image LoG edge detection

E. Canny edge detection

This basically is the standard edge detection technique, also known as optimal edge detection, 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 algorithm mainly aims to satisfy three criteria. First is *low error rate* that refers to a good edge detection of only existent edges. The second one is *good localization* that is the distance between detected edge pixels and real edge pixels have to be minimized and the third one is m*inimal response* that states only one detector response per edge. Canny is a technique to extract the useful structural information from the different vision objects and reduces the amount of data to be processed. The technique detects the edges by removing or suppressing noise from the image without affecting and disturbing the original features of the image. There are multiple steps involved in a canny's edge detection process. Initial step is *preprocessing;* the edge detectors are prone to noise and this initial preprocessing step helps in filtering out any sort of noise. The Gaussian filter is used for this purpose. Mostly the software packages don't do this step automatically, the user need to do this by self. Generally, a 5x5 Gaussian filter is used with standard deviation 1.4 for this purpose. After the removal or reduction of noise it comes to c*alculating gradients;* in this step the gradient magnitudes and directions are calculated at every single point in the image that helps to exhibit the changes in the intensity which indicates the occurrence of edges. A high gradient magnitude shows the rapid changes in colors implying the presence of an image whereas a low gradient magnitude shows inferior changes implying there is no edge presence. Further the next step is *non maximum suppression;* the edges will occur at points where the gradient is maximum. This step basically does exactly what it means, that is, if a pixel is not a maximum, it is suppressed. It removes pixels that are not considered to be a part of an edge, hence only candidate edges will remain. The last step is *thresholding with hysteresis;* this is the final step in canny edge detection. It basically involves two threshold values upper and lower. If the pixel magnitude is higher than the upper threshold, the pixel is accepted as an edge whereas if the pixel magnitude is below the lower threshold, than the pixel is rejected. This edge detection technique gives results as shown.

Original image Canny edge detection

II. Literature Survey

Jaspreet Kaur, Anand Sharma.., [1] The author states that the edge detection process gives a significant information of an image while reducing the amount of data and unwanted information without disturbing and manipulating the originality of that image. The information provided is then used to detect the object or different objects of the image. The edge detection mainly is the way of determining the sharp discontinuities, caused due to the change in intensity, from an image. The most common uses of edge detection are in the field of image registration, identification, segmentation and face recognition etc. The steps that lead to the complete edge detection process are filtering, detection and localization, in which the image is first filtered to reduce noise for detecting the discontinuities and finally the edges are selected with the help of pixels that are true member of the edge. Various edge detection techniques are discussed in this paper, as they can be used in different conditions. The sobel operator has simple operation but high signal to noise ratio whereas in case of Robert's cross edge operators detects edges and their orientation effectively but is inaccurate and more sensitive to noise. Laplacian of Gaussian finds right places of edges and area around pixel but it does not give any directional information about the edge whereas the canny edge detector gives more efficient texture based images and have good signal to noise ratio but it is time consuming and have greater computationally complexity.

Dr.S.Vijayarani, Mrs.M.Vinupriya.., [2] This research paper presents the process of edge detection as a way of catching sharp discontinuities in a digital image. Edge detection plays a crucial role in analysing images and acts as a key for solving various complex problems. The paper has also introduced the concept of face recognition that is basically stated as the process of identifying and verifying a person from a digital image automatically. Edge detection plays a key role in the face recognition. There are several edge detection mechanisms that have been developed in past few years, though no particular algorithm is there to suit all types of applications. In this particular paper the author has compared mainly the results of sobel and canny edge detector, where the results are calculated and compared in the form of accuracy and time. The results show that the sobel edge detector has the accuracy 75% whereas canny edge detector has the accuracy 87.5% and the time consumed by sobel edge detector was 34.9(seconds) whereas the time consumed by the canny edge detector was 34.7(seconds). Finally according to the conducted tests of comparisons the canny edge detector was found to be more efficient and reliable.

Sonam Saluja, Aradhana Kumari Singh, Sonu Agrawal.., [3] The authors explain that the separation of object and the background in an image is a very important step for the purpose of detecting edges and recognizing a particular object. There is are a large number of methods available for the purpose of segmenting an image but the edge detection techniques are the one's most commonly used for the purpose of image segmentation. Fundamentally an edge can be defined as the boundary between the object and background or two different regions. And the main aim of edge detection is to mark the regions separately where the changes in the luminous intensity are sharp. The author explains the comparison of different edge detection methods, where all different approaches can be used for the purpose of edge detection according to the need of segmentation. As discussed the gradient based approaches are most sensitive towards noise and the canny operator is comparatively less sensitive towards the noise.

Mamta Juneja , Parvinder Singh Sandhu.., [4] The paper basically discusses the comparison between various approaches used for the edge detection with the help of various experimental results, statistical evaluation and performance analysis. Author describes edge detection as the means of detecting an object or various objects in a digital image where the separation of image objects from its background is an important task in the digital image processing. . Generally, an edge can be defined as a means of creating differentiation between two separate regions in an image with the help of changing image amplitude attributes like different tristimulus values and constant luminance values in an image. The paper mainly describes the behavioural analysis of the zero crossing operators and gradient operator in accordance with their capability of detecting the edges in an image. While doing all this no specifications such as texture or shape are provided, the methods or operators are applied to the complete image. The results shown in the paper gives clearly idea that Sobel, Prewitt and Roberts results to low quality edge maps comparative to others. The Laplacian of Gaussian and Canny produces better as well as clear representations of the image, where the canny method has better capacity to detect both strong and weak edges being even superior than the Laplacian of Gaussian.

Poonam Dhankhar, Neha Sahu.., [5] In this research paper, the author has presented the overview of edge detection techniques in accordance with image segmentataion. The edge detection can be referred to as a part of image segmentation that states the presence of line or edge in a digital image. The main motive of detecting edges is to minimize the data processing amount by simplifying the image data. The segmentation basically is a process of differentiating the image objects from the background. The image can be segmented mainly using four techniques: threshold techniques, edge detection techniques, region-based techniques, and connectivity preserving relaxation methods. Among all these methods the one most commonly and widely used is the "edge detection" that results in successful segmentation of an image. The segmentation involves a series of steps as initially an input image is given whose gray scale image is taken; futher the noise reduction is done followed by the masking process; after that non maxima suppression is carried and finally the edges are detected. Detection of edges also has various techniques to carry out this work such as Sobel, Prewitt, Roberts, Canny and Laplacian of Gaussian(LoG). All these techniques can be used for detecting edges successfully but the most accurate and clear results are given by the canny method.

Muthukrishnan.R and M.Radha.., [6] The effective visualization of image content is considered to be as a matter of great importance in computer vision and more specifically in image processing. For efficient interpretation of image, segmentation is a crucial step that is supposed to make the object and the background separate. The image segmentation basically assorts an image into constituent objects and make them separate from background for the purpose of properly identifying the image content. Edge detection is the profound tool for segmentation. Edge detection refers to the process of sorting out and determining sharp discontinuities in an image where the discontinuities are the sudden changes in the concentration of pixels that makes the boundaries of objects distinct in a picture. Several popular edge detection techniques are discussed throughout the paper specifying their usage in accordance with different conditional requirements. Through the experimental results it is observed that Marr-Hildreth, Laplacian of Gaussian and Canny edge detectors virtually produces the similar edge maps but the results produced by canny better when compared to a number of selected images as different algorithms work better according to different conditions.

Firas A. Jassim.., [7] Edge detection basically is an important technique for the image processing or computer vision. The edge detection process provides a base for a lot of image processing applications such as face recognition, image segmentation, identification and registration. The concept of edge is considered to be the basic feature of an image as it gives the necessary information about the objects contained within an image. Through this paper, the author has proposed a method that combines median filter and simple standard deviation both in order to make edge detection process more superior in image processing. In this method, initially noise is removed from the gray scale image using a median filter in order to make the image smooth and remove the noisy pixels. After this, simple statistical standard deviation could be computed for specified window size and then if the value of standard deviation inside the window size is greater than the given threshold, the upper left pixel in the window represents an edge. The proposed method has been tested with various binary images. The results have been compared with the Sobel and Canny's edge detector, and the results give a clear significance that the proposed method gives satisfying results for various gray level digital images. The proposed algorithm gives even better results in case of the text images when compared to traditional detectors, so it is recommended for the images that contain text content because of its easy implementation.

S.Lakshmi and Dr.V.Sankaranarayanan.., [8] The paper gives a brief introduction to the different techniques of edge detection used for the purpose of segmentation computing. An edge is the basic feature of an image where edge detection is a process of distinguishing and locating sharp discontinuities in the image. The segmentation mainly is a way of separating an image into different regions or its component objects and this is a decisive step in the interpretation of a particular image. The image segmentation and extraction process has to deal with a lot of challenging things like the noise volume having a significant impact on shaping the edge, changes in lighting conditions, dynamic nature of the background, detection of a false edge, shifting in the actual position of the detected edge and the luminance features of the image. Edge detection is classified in three major categories. First are the gradient methods that include the Robert, Sobel and Prewitt edge detection techniques. Second are the zero crossing referred to as the second order derivatives using two basic approaches, Laplacian of Gaussian and Difference of Gaussian. And the third one is optimal edge detection having canny edge detection as its pillar technique. Various approaches for computing segmentation are also described including fuzzy based approach, wavelet approach, genetic algorithms, neural networks and morphology. The purpose of this paper basically is to present the theoretical study of various edge detection techniques, that has proved to be of great use with varying requirements, along with the different computing approaches of segmentation.

Himanshu Rana.., [9] In this paper the writer presents the study of edge detection process and a comparison between various edge detection techniques. Mainly, the edge detection process aims to make clear distinction between various objects and their varying boundaries in an image. The basic steps in edge detection are; Filtering, Enhancement/Sharpening, Detection and Localization. These four steps constitutes the working of an edge detection process, where in filtering the noise is reduced, sharpening focuses on the change in local intensity of the pixels, detection works on the pixels for which is to be considered as noise and which is to be retained, and the final step localization deals with the exact location of the edges where the necessity of localization being the edge thinning and linking. Various edge detection methods and operators are also discussed in this paper like Sobel, Roberts, Prewitt, Laplacian of

Gaussian and Canny. Among all of them the results given by canny are the most clear and of superior clarity. Canny operator is meant for detecting the edges by means of setting apart the noise present in the image without affecting the original features of edges in the image whereas it is comparatively less sensitive towards noise. Before creating or detecting the edges, canny edge detector initially smoothens the image and then afterwards it finds image gradient for highlighting the regions with spatial derivatives. The gradient array can further be reduced using the hysteresis; where hysteresis mainly uses two different threshold values. If the magnitude of a pixel is below the first threshold, the value is marked as zero and if the magnitude is above second threshold, then it is marked as an edge.

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