

Overview and Comparative Analysis of Edge Detection Techniques in Digital Image Processing

Chinu¹ and Amit Chhabra²

*Dept of Computer Science and Engineering,
G.N.D.U, Amritsar, Punjab, India*

Abstract

Edge detection is one of the most frequently used operations in image analysis. If the edges of images could be recognized accurately, all of the objects can be located efficiently and performance can be measured easily. It reduces the complexity of image processing algorithms by reducing the amount of data to be processed. The quality of image is affected when there is a jump in intensity from one pixel to the another. Thus important objective is to detect an edge while preserving the important structural properties of an image. In order to analyze various edge detection techniques, comparative analysis of these techniques based on certain parameters like type of edge, edge localization, nature, cost, role etc are discussed in this paper.

Keywords - Edge Detection, Gradient based edge detection; Laplacian based edge detection; Techniques; Comparison.

1. Introduction

Digital image processing has become a functional as well as popular research area that goes from specialized photography to several different fields such as astronomy, meteorology, computer vision, medical imaging, among others. The main goal of digital image processing is to improve the pictorial information. The area of digital image processing refers to processing digital images by means of a digital computer [1]. Numbers of edge detectors are developed each year. Effects such as refraction or poor focus can result in objects with boundaries defined by steady change in intensity. So, there are problems of false edge detection, missing true edges, edge localization, high computational time and problem due to noise [3]. In order to significantly reduce the complexity of image processing algorithms, edge detection is used as the preprocessing step which helps in reducing the amount of data to be processed

[2]Therefore our objective is to compare and analyze the performance of various edge detection techniques based on various parameters like role ,type of edge, nature, , edge localization.

2. Edge Detection

Edge detection refers to the process of identifying and locating sharp discontinuities in an image. Edge is the area of major change in the image intensity or contrast and Edge Detection is locating areas with strong intensity contrasts We use edge detection –because it helps in extracting information about the image. E.g. location of objects present in the image, their shape, size, image sharpening and enhancement [7]. Edge detection is used for image segmentation based on abrupt changes in intensity. In a continuous image, a sharp intensity transition between neighboring pixels is considered as an edge [4].

Three steps in edge detection are:

- *Image smoothing*: for noise reduction this step involve filtering the image for improving the performance of edge detector.
- *Detection*: This step involves extracting all edge points that are possible candidates to become edge point.
- *Edge localization*: This step involves selecting from the candidate edge points only the points that are true members of set of points comprising an edge [4].

We mainly used two types of operators in edge detection which are:

2.1 Gradient Based Edge Detection

The gradient method detects the edges by looking for the maximum and minimum in the first derivative of the image. When the gradient is above the threshold there is object in the image. The popular edge detection operators are Roberts, Sobel , Prewitt .They are all defined on a 3x 3 pattern grid, so they are efficient and easy to apply.

2.2. Laplacian Based Edge Detection

The Laplacian 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. eg LOG ,Canny .

3. Edge Detection Techniques

3.1 Traditional Edge Detection techniques:

3.1.1 Robert's cross Edge Detection Roberts edge detection method is one of the oldest method and is used often in hardware implementations where simplicity and speed are dominant factors [5].Roberts edge detection operator is based on the principle that difference on any pair of mutually perpendicular direction can be used to calculate the gradient. Difference between diagonally adjacent pixels is used to process the image [6].

3.1.2 Sobel Edge Detection

Sobel operator [5] is used in image processing techniques mainly in edge detection. The sobel operator is based on convolving the image with a small, separable, and integer valued filter in horizontal and vertical and is thus comparatively cost-effective in terms of computations. Mathematically, the operator uses two 3×3 kernels which are convolved with the original image to calculate approximations of the derivatives—one for horizontal changes, and one for vertical.

The differences are calculated at the center pixel of the mask. The 3×3 convolution mask smoothes the image by some amount, hence it is less susceptible to noise. But it produces thicker edges. So edge localization is poor.

3.1.3 Prewitt Edge Detection

Prewitt operator edge detection masks are the one of the oldest and best understood methods of detecting edges in images. Basically, there are two masks, one for detecting image derivatives in X and one for detecting image derivative in Y. To find edges, a user convolves an image with both masks, producing two derivative images (dx and dy). The Prewitt edge detector is an suitable way to estimate the magnitude and orientation of an edge. Although differential gradient edge detection needs a rather time consuming calculation to estimate the orientation from the magnitudes in the x- and y-directions, the Prewitt edge detection obtains the orientation directly from the kernel with the maximum response. The set of kernels is limited to 8 possible orientations; however experience shows that most direct orientation estimates are not much more accurate [5].

3.1.4 Laplacian of Gaussian:

LOG is the Second-order differential algorithm which uses pre-smoothing with Gaussian low-pass filter on the image first. Then this arithmetic identifies the image edge of the steep with Laplacian algorithm. At last it generates closed and connected contours with zero-gray value by exclusion of all internal points. It could filter the noise and also smooth the edge [8]. The operator normally takes a single gray level image as input and produces another gray level image as output. The Laplacian $L(x,y)$ of an image with pixel intensity values $I(x,y)$ is given by:

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

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 .

3.1.5 Canny Edge Detection Algorithm

J.F Canny in [9] has proposed an Computational Approach to Edge Detection which is known as optimal edge detector .The Canny's intentions were to enhance the many edge detectors already out at the time he started his work. He was very successful in achieving his goal and his ideas and methods can be found in his paper, "An Computational Approach to Edge Detection "[9].The algorithm runs in 6 separate steps:

1. Smoothing: Blurring of the image to remove noise
2. Finding gradients: The edges should be marked where the gradients of the image has magnitudes
3. Direction calculation: In this step, direction of edge should be calculated.
4. Non maximum suppression: Only local maxima should be marked as edges
5. Double thresholding: Potential edges are determined by thresholding.
6. Edge tracking by hysteresis: Finally edges are determined by suppressing all edges that are not connected to very certain (strong) edge .

3.2 Edge Detection Based on Soft Morphology

Shang Junna and Jiang Feng in [8] have presented the mathematical morphology edge detection algorithm which can overcome the shortcomings of the traditional edge detection algorithm. Mathematical Morphology is a new kind of nonlinear algorithm, using a certain form of structural elements to measure and extract the shape of the corresponding image in order to achieve the image analysis and identification purposes. It is more suitable for visual information processing and analysis, and the type of interaction are completed by the basic operations of Erosion and Dilation as well as Open and Closed operations. The traditional morphological edge detection algorithm has analyzed and compared, put forward a modified soft morphological edge detection algorithm, which can effectively detect image edge, while restrain the impact of noise, which has strong robustness.

3.3 Edge detection based on human visual feature

Mingxiu Lin and Shuai Chen in [6] have proposed the new prediction method for edge detection which is based on human visual feature. The edge detection rate is relatively high by the traditional edge detection operators like Roberts, Sobel, Canny due to which some special features of the edge points hidden in the edge detection. So, new edge detection algorithms has been proposed in order to accurately extract the characteristics of the sausage casing Laceration defect. The rapid detection of Edge features of the abnormal changes in the region in a relatively smooth area is achieved in the proposed prediction method by setting the parameter to filter the edge which we do not want to leave, and retain the edge information. The experimental results have shown that proposed method has retained the exception of edge points generated by the sausage laceration defect, and its real-time performance is suitable for industrial practical applications.

3.4 Haar based Prewitt edge detection

The Haar wavelet is also the simplest possible wavelet. The Haar wavelet operates on data by calculating the sums and differences of adjacent elements. Shashidhar Ram Joshi and Roshan koju in [3] have presented an Study and Comparison of various Edge Detection Algorithms. Basically, not all edges involve a step change in the intensity. Effects such as refraction or poor focus can result in objects with boundaries defined by gradual change in intensity. So, there are problems of false edge detection,

missing true edges, edge localization, high computational time and problem due to the noise. So, fusion of Haar wavelet and Prewitt operator have discussed in order to compare its performance with frequently used gradient edge detection algorithms and canny edge detection method in the different conditions. Haar based Prewitt method of edge detection does not perform better than classical edge detectors. Canny edge detection algorithm is implemented with adaptive parameters. It has been shown that canny edge detection algorithm with adaptive parameters performs better in almost all conditions in comparison to other operators in the expense of its execution time.

3.5 Bilateral Filtering Based Edge Detector

Chandra Sekhar Seelamantula and Abin Jose in [10] have proposed BILATERAL EDGE DETECTORS. Classical bilateral filtering is a nonlinear technique that smoothes an image while preserving the edges. The bilateral filtering operation is carried out on the spatial neighborhood of a pixel using domain and range kernels. The domain kernel, aimed at smoothing the image, is a Gaussian function, which weighs pixels depending on the spatial distance from the central pixel at location a. Edge preservation is achieved by means of the range kernel, which takes into account the radiometric distance of the pixels from the central pixel. Thus, adaptive smoothing of the image is accomplished by taking the intensity variations into consideration .To design a bilateral edge detector, demands the following conditions to be satisfied:

1. Edges correspond to high frequency content in an image. Thus, we require a domain kernel that performs derivative operation.
2. The range kernel must be such that it attaches weights varying directly as the pixel intensity difference, so that it emphasizes dissimilar regions .

As among all traditional operator Canny edge detection is known as the optimal edge detection so we compare canny with rest of edge detection operators.

Table 1: Comparative Analysis of Edge Detection Techniques

Techniques	Edge Detection Parameters					
	Category	Role	Type Of Edge	Noise	Use of Gaussian low-pass filter	Nature
Canny	Derivative of Gaussian	Canny is a kind of filtering method which is a compromise method between smoothing and filtering through Gaussian smoothing	Detecting edges in very robust manner and real weak-edges can be detected .	The real weak-edge can be detected and the noise will be less susceptible. But some edge information also will be smoothed.	Yes	Complex

Techniques	Edge Detection Parameters					
	Category	Role	Type Of Edge	Noise	Use of Gaussian low-pass filter	Nature
		filter				
Edge Detection Based on Soft Morphology	Non Linear Technique	It uses a certain form of structural elements to measure and extract the shape of the corresponding image.	Effectively detect image edge under strong noise conditions.	Restrain the impact of noise	No	For the edge detection of image, performance enhancement based on the cost of complexity.
Edge detection based on human visual feature	Based on human visual feature	The rapid detection of Edge features of the abnormal changes in the region in a relatively smooth area is by setting the parameter to filter the edge which we do not want to leave, and retain the edge information.	Retained the exception of edge points generated by the sausage laceration defect	Retained the exception of edge points generated by the sausage laceration defect, and its real-time performance is suitable for industrial practical applications.	No	The results in [6] shows that Canny has the longest execution time, and than predict method has a good real-time performance.
Haar based Prewitt method	The Haar wavelet is also the simplest possible wavelet.	The Haar wavelet operates on data by calculating the sums and differences of adjacent elements	It can reduce the most of noise of image but the real edges of the image are also mixed with much noise, so fusion of Harr and Prewitt operator is applied.	Reduce the most of noise of image but it can perform better in blur condition .it does not perform better in noise environment .	No	Haar based Prewitt method of edge detection does not perform better than classical edge detector

Techniques	Edge Detection Parameters					
	Category	Role	Type Of Edge	Noise	Use of Gaussian low-pass filter	Nature
Bilateral Filtering Based Edge Detector	Non linear technique	The bilateral filtering operation is carried out on the spatial neighborhood of a pixel using domain and range kernels.	Edge preservation is achieved by means of the range kernel, which takes into account the radiometric distance of the pixels from the central pixel.	Noise removal capability of this method is not very strong, as it only considers those pixels as noise points, which have intensity difference of more than 50% with neighboring pixels.	The domain kernel, aimed at smoothing the image, is a Gaussian function.	This method consumes less computational power because it is non- iterative.

4. Conclusion and Future Scope

This paper surveys the various state of art of Edge detection techniques in digital image processing. All techniques and algorithm have their own advantages and disadvantages. The analysis of various edge detection techniques are done on the basis of certain parameters. Fast processing response is the main requirement in many image processing applications. The operations performed by image processing algorithms can be computationally costly due to their manipulating large amount of data. To make a program execute in real time, data needs to be processed in parallel and often a great deal of optimization needs to be utilized. In future work parallelizing an edge detection algorithms, provides better performance results for image-processing applications.

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