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A Comprehensive Review of Edge Detection Methods

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Abstract

Boundaries are typified by edges, which pose a basic challenge in image processing. Images with edge detection have less data, less extraneous information filtered out, and key structural elements preserved. Finding the borders of objects or textures in a picture is the process of edge detection. The speed of image processing is a highly challenging problem since edge detection data is very huge. Various approaches are employed for edge detection, contingent on the needs of different applications. This study offers a thorough analysis of numerous studies and approaches used in the edge detection field.

Index Terms: Edge detection, canny edge detection, Advanced Ant Based Swarm Computing, Ant Colony optimization.

1. INTRODUCTION

One of an image's most fundamental characteristics is its edge. It is a substantial source of information and serves as a foundation for image segmentation and analysis [2]. All that edges are are the lines dividing distinct textures. Finding an image's edges can be useful for a variety of tasks, including feature extraction, data reduction, picture matching, and segmentation[1].

The following are the three basic steps in edge detection: [3]

1. Smoothing of images
2. Finding edge points
3. Localization of edges

The goal of image smoothing is to reduce noise as much as possible while maintaining real edges. The edge pixels that should be kept and those should be eliminated as noise are determined by the detection of edge points. An edge's location is determined by edge localization. In a digital image, there are three main kinds of discontinuities:

1. Points 2. Rows 3. Corners

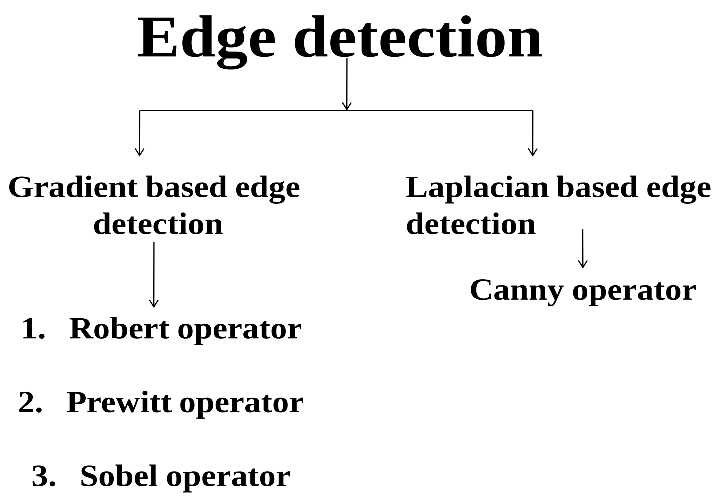


Figure 1: Types of edge detection methods

A picture has edges because discontinuities vary in them. The brightness at the scene's edges frequently gives rise to edges.

Edge strength, edge direction, and edge position can all be used to characterise an edge [4]. There are various kinds of edges, including ridge, step, ramp, and roof edges.

Techniques for detecting edges fall into two categories:

1. First-order edge recognition
2. Detection of second order edges

When noise is present in the image, edge identification has shown to be a difficult task. Because a colour image is multidimensional, it becomes more difficult to consider. Grayscale photographs are less precise than colour images at revealing details about the objects in a scene. [10]

2. METHOD FOR FIRST-ORDER EDGE DETECTION

Gradient based edge detection is another name for this technique. In order to identify the edges, it searches for the image's maximum and lowest in the first derivative [4]. x and y represent the row and column coordinates, respectively, in a continuous picture. We take into account the two directional derivatives, and. The grey level's first derivative is positive near the ramp's edge and at a specific point along it; it is negative in places where grey levels are constant. The first derivative's magnitude indicates the presence of an edge. The edge pixels in an image have a higher intensity value than the surrounding pixels. The calculation for gradient magnitude is:

$$mag\Delta f(x,y) = \sqrt{\partial(x,y)^2 + \partial_y f(x,y)^2} \text{ ---- (1)}$$

A. *The Robert Edge Operator*

The 2x2 neighbourhood of the current pixel is provided by the straightforward approximation to gradient magnitude based operator [5]. Two convolution masks/kernels, each intended to react maximally to edges running at ±45° to the pixel grid, are used to implement the Roberts operator. These masks/kernels yield the image's x- and y-derivatives, Gy and Gx, respectively[4]. Its general calling syntax is:[3]

[g, t] = edge(f, 'Roberts', T, dir) ---- (3)

Original image Roberts method

Figure 2: Robert operator mask

The Robert operator is given by the equations (4), and (5):

$\partial_x f(x,y) = Z_9 - Z_5$ ---- (4) $\partial_x f(x,y) = Z_8 - Z_6$ ---- (5)

B. The Sobel operator

An image's 2-D spatial gradient is measured using the Sobel operator. The method makes use of two 3x3 convolution masks, one of which estimates the gradient in the x-direction (columns) and the other in the y-direction (rows).These masks, with one kernel for each of the two perpendicular orientations, are made to react as much as possible to edges that run vertically and horizontally with respect to the pixel grid. The input image can be subjected to distinct kernel applications to provide discrete gradient component measurements for each orientation (Gx and Gy). These can then be added together to determine the gradient's orientation and absolute magnitude at each position [4]. This approach, which is based on first derivative convolution, computes the gradient of the picture intensity at each location and evaluates derivatives to determine which way to raise the image intensity from bright to dark at each point. The edges are plotted at the gradient's highest points [5]. The operator is composed of two 3x3 convolution kernels, at least in theory.To put it simply, one kernel is the other 90° rotated. This and the Roberts Cross operator are extremely similar[7].

[g, t] = edge(f, 'Prewitt', T, dir) ---- (6)

$$G_x = \begin{bmatrix} -1 & 0 & +1 \\ -1 & 0 & +1 \\ -1 & 0 & +1 \end{bmatrix} Gy = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ +1 & 0 & -1 \end{bmatrix}$$

Original image Prewitt method

Figure 3: Prewitt operator mask

3. THE DETECTION OF SECOND ORDER EDGES

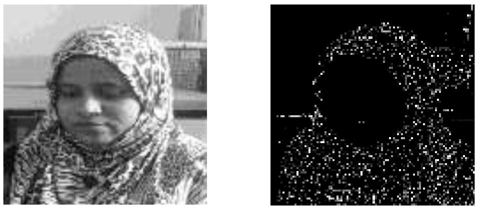
Laplacian based edge detection is another name for this technique. The second order, or Laplacian, approach locates edges by looking for a zero crossing in the image's second derivative. Generally speaking, first-order edge filters are not frequently employed to improve images [4]. They are mostly employed in the edge detection phase of picture segmentation processes.An even more popular method of improving images is to apply the Laplacian, a second-order derivative operator. The Laplacian is suited as the initial stage of digital edge enhancement because of its second-order derivative property, which enables it to generate a fine edge response matching to a change in gradient as opposed to the less isolated response of the first-order edge filters. The Laplacian approach detects edges by focusing on zero crossings in the image's second order derivative. An edge can be identified by its location by computing the derivative of the image, which has the one-dimensional shape of a ramp [6].

i. Gaussian or Laplacian

By locating the zero crossings of the second derivative of the picture intensity, one can determine the edge points of an image. The second derivative of picture intensity calculation is highly susceptible to noise, though. It is necessary to filter out this noise before detecting edges. This technique for edge detection combines the Laplacian with Gaussian filtering. It is also known as the Mexican hat operator or the Marr-Hildreth edge detector [6].

Three phases make up the Laplacian of Gaussian edge detection[4]:

1. Screening
2. Improvement
3. Identification



Original image   Laplacian method

Figure 4: Laplacian or Gaussian

In order to minimise noise, a picture is frequently smoothed using a technique that approximates a Gaussian smoothing filter before the Laplacian is applied. The existence of a zero crossing in the second derivative and a corresponding significant peak in the first derivative approach serve as the detection criteria.

In this method,

1. First, noise is minimised by applying a Gaussian filter to the image.
2. Tiny structures and isolated noise spots are eliminated. On the other hand, edges widen with smoothing.
3. The edge detector uses zero crossings of the second derivative to identify pixels with locally maximum gradients as edges.
4. Only zero crossings whose associated first derivative is over a threshold are chosen as edge points in order to prevent the detection of inconsequential edges.
5. The direction of the zero crossing is used to determine the edge direction.[6]

$$\begin{bmatrix} 1 & -1 & 1 \\ 1 & -8 & 1 \\ 1 & 0 & 1 \end{bmatrix} \quad \begin{bmatrix} -1 & 2 & -1 \\ 2 & -4 & 2 \\ -1 & 2 & -1 \end{bmatrix} \quad . \begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & -1 \\ 0 & 1 & 0 \end{bmatrix}$$

Figure: Three often employed discrete approximations for the Laplacian filter.

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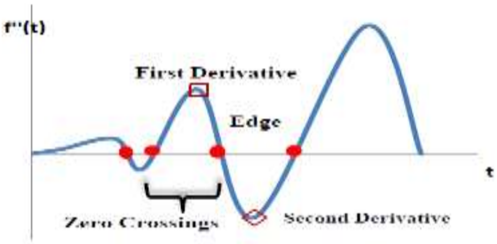


Figure 5: Edge transformative derivation [5]

ii.Canny edge detection

a. This technique locates edges by first removing noise from the picture without changing the characteristics of the edges, and then using tendency to locate the edges and threshold's critical value[11]. To remove noise, the clever edge detector smoothes the image first. It then locates the gradient in the image to draw attention to areas that have high spatial derivatives. Next, tracking is carried out along these zones, and every pixel that is not at the maximum is suppressed. Hysteresis, which is used to track along the remaining pixels that have not been suppressed, can now further reduce the gradient array. Hysteresis employs two thresholds; the first threshold sets the magnitude to zero if it is below it. An edge is created if the magnitude is higher than the high threshold. Compared to the original Canny algorithm, the Canny edge detection approach yields far lower memory needs, latency, and throughput without sacrificing edge detection performance[16].The primary use of canny edge detectors is in the processing of naturally noisy remote sensing images [9].

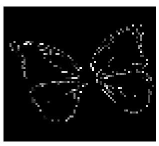
The optimal edge detector is the name given to this approach. An "optimal" edge detector in this case would satisfy the following three requirements [12]:

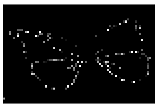
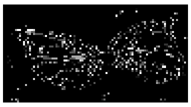
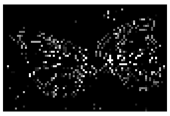
a. Good detection: The algorithm ought to identify the majority of the image's genuine edges.
b. Accurate localization: The marked edges have to be as near to the actual scene's edge as feasible.
c. Minimal response: Wherever possible, picture noises should not produce false edges, and each edge in the image should only be marked once.

4. WEIGHTED HEURISTICS-BASED ANT COLONY OPTIMISATION ALGORITHM

Ant Colony Optimisation (ACO) is an algorithm inspired by nature that takes its cues from the way ants forage. The way ants position pheromones when looking for food is what defines the algorithm. ACO provides a pheromone matrix that creates edge information shaped by ant bundles on the image at each pixel point[15]. Ant motion is dependent on the local variance of the image's intensity value. The ant determines which path it

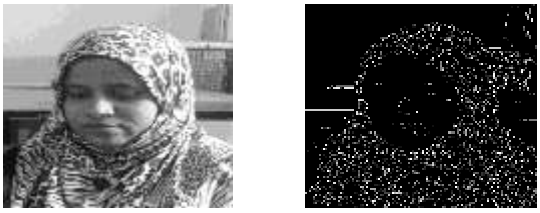
Table 1. Result for the various edge detectors with Matlab code

1	**Prewitt method** BW1=edge(A,'prewitt'); figure,imshow(BW1);	
2	**Sobel method** BW1=edge(A,‘sobel'); figure,imshow(BW1);	

3	**Roberts method** BW1=edge(A,'roberts'); figure,imshow(BW1);	
4	**Laplacian method** BW1=edge(A,'log'); figure,imshow(BW1);	
5	**Zero crossing** BW1=edge(A,'zerocross'); >> figure,imshow(BW1);	
6	**Canny edge** BW1=edge(A,'canny'); figure,imshow(BW1);	

can go by giving precedence to the pixels that are adjacent to it. Medical image processing is used to test the method[14]. The tria-and-error data is totally reliant on the specific problem instance.

Three primary steps comprise the algorithm.
1. The initialization procedure.
2. The iterative process of building and updating the final pheromone matrix, each element of which corresponds to a pixel in the image, and the values of which provide edge information specific to a given pixel. Once per iteration, the construction and update processes are coupled many times.
3. Threshold values are used to compute the decision process, which determines the edges based on the final pheromone values.



Original image Canny edge detection

Figure 6 : Canny edge detection

5. ADVANCED ANT BASED SWARM COMPUTING

When a picture contains the appropriate parameters, an advanced ACO-based edge detection method known as AASC has been proposed[15]. A method derived from ACS characteristics. The pseudorandom proportional rule, which is the decision method utilised in ACS, is one of its key features.

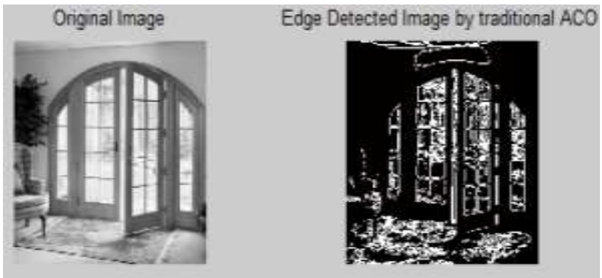


Figure 7.edge detected image by ACO

Numerous changes to the current ACO algorithms have been suggested: Weights are assigned to the pheromone matrix during the initialization step in order to compute the heuristic function. The Construction process uses an ACS-based rule, and a modified decision-making process based on choosing a threshold value determined by Otsu's technique. After the threshold is determined, each pixel is classified as either an edge or a non-edge using a pheromone matrix.

Figure 8: Edge detected image by AASC

1. The amount of noise, objects with similar intensities present, edge density in the scene, and illumination all have a significant impact on the quality of edge recognition. Each time the detector is run with a new set of data, an operator must manually change the threshold value for what constitutes an edge and adjust certain values in the edge detector to address each of these issues. Unfortunately, there is currently no effective way to automatically set these values.
2. A methodical approach to computing heuristic data.
3. Shortening of the processing time

6. CONCLUSION

An overview of several edge detection techniques' functionalities is given in this paper. In different sectors, each edge detection technique has pros and cons of its own. This paper discusses edge detection operators that can be implemented in MATLAB, including gradient-based or first-order edge detection and laplacian-based or second-order edge detection operators. One important task for image segmentation, which is utilised for object detection and many other applications, is edge detection. Noise affects edge detection using a Gaussian algorithm. Compared to Sobel, Prewitt, and Robert's operator, the Canny edge detection algorithm is more expensive. High calculation times and weak edges are the primary drawbacks of clever edge detection. Variation in edge detection approaches has been proven to guarantee more accurate and superior edge detection.

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