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An Extensive Survey on Edge Detection Techniques

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Abstract:

Edges characterize boundaries and are a problem of fundamental importance in image processing. Edge detection of images reduces the amount of data and filters unwanted information and preserves important structural properties of images. Edge detection is a process of locating boundaries of objects or textures present n an image. Data of edge detection is very large, so the speed of image processing is a very difficult problem. There are many techniques used for the purpose of edge detection depending upon the requirement of various applications. This paper provides an extensive review of various research work and methodologies which are applied in the field of edge detection.

Keywords — **Edge detection, canny edge detection, Advanced Ant Based Swarm Computing, AntColony Optimization.**

I. INTRODUCTION

Image edge is one of the most basic characteristic of image. It contains a large amount of information and also it is an important basis for the image analysis and image segmentation [2]. Edges are nothing but the boundaries between different textures. Detection of the edges for an image may help for image segmentation, image matching, data compression, feature extraction and so on [1].

The three fundamental steps of edge detection are: [3]

1. Image smoothening
2. Detection of edge points
3. Edge localization

Image smoothening is suppressing the noise as much as possible without destroying true edges. Detection of edge points determines the edge pixels to be discarded as noise and which should be retained. Edge localization determines the location of an edge. There are three basic types of discontinuities in a digital image:

1. Points 2. Lines 3.edgesEdges come in a image because of variation of discontinuities of the scene features usually brightness and give rise to edges. Edges can be describes based on edge strength, edge direction and edge position [4]. There are different types of edges like step edge, ramp edge.,roof edge ,ridge edge.

Edge detection techniques are grouped into two categories:

1. First order edge detection
2. Second order edge detection

Edge detection has been a challenging problem if image is affected by noise. It becomes more challenging considering a color image due to its multidimensional nature. Color images provide accurate information about objects of a scene than gray scale images [10].

II. First order edge detection Method

This method is also known as Gradient based edge detection. It detects the edges by looking for the maximum and minimum in first derivative of image [4]. For a continuous image $f(x, y)$ where x and y are the rows and columns co-ordinates respectively. We consider two directional derivatives $\partial_x f(x, y)$ and $\partial_y f(x, y)$. First derivative of gray level is positive at beginning of ramp edge and at point on

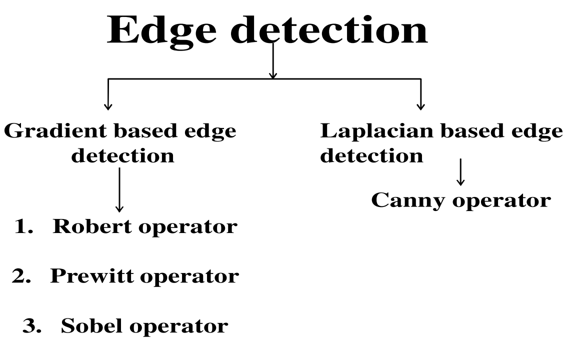


Figure 1: Types of edge detection methods

the ramp, zero in the areas of constant gray levels otherwise negative. Presence of edge is detected by magnitude of first derivative. In an image edge pixels have higher intensity value than its surrounding pixels.

Gradient magnitude is calculated as:

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

i. Robert Edge operator

The simple approximation to gradient magnitude based operator provides 2x2 neighborhood of the current pixel [5]. The Roberts operator is implemented using two convolution masks/kernels, eachdesigned to respond maximally to edges running at ±45º to the pixel grid, which return the image x-derivative and y derivative, Gx and Gy respectively[4] .

$$G_x = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$

Its general calling syntax is:[3]

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

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

$$\partial_x f(x,y) = Z_9 - Z_5 \quad \text{----} \quad (4)$$

$$\partial_x f(x,y) = Z_8 - Z_6 \quad \text{----} \quad (5)$$

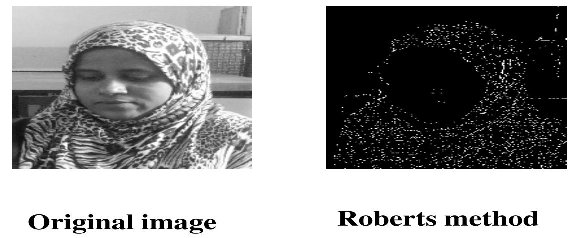


Figure 2: Robert operator mask

ii. Sobel operator

The Sobel operator performs a 2-D spatial gradient measurement on an image. It uses a pair of 3×3 convolution masks, one estimating the gradient in the x-direction (columns) and the other estimating the gradient in the y-direction (rows).These masks are designed to respond maximally to edges running vertically and horizontally relative to the pixel grid, one kernel for each of the two perpendicular orientations. The kernels can be applied separately to the input image, to produce separate measurements of the gradient component in each orientation (*Gx* and *Gy*). These can then be combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient [4]. This algorithm based on first derivative convolution, analyses derivatives and computes the gradient of the image intensity at every point, and then it gives the direction to increase the image intensity at each point from light to dark. It plots the edges at the points where the gradient is highest [5]. In theory at least, the operator consists of a pair of 3×3 convolution kernels .One kernel is simply the other rotated by 90°. This is very similar to the Roberts Cross operator[7].

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

Figure 3: Prewitt operator mask

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

III. SECOND ORDER EDGE DETECTION

This method is also called as Laplacian based edge detection. The second order or Laplacian method searches for zero crossing in the second derivative of the image to find edges. In general, first-order edge filters are not commonly used as a means of image enhancement [4]. Their main use is in the process of edge detection as a step in image segmentation procedures. A much more common means of image enhancement is through the use of a second-order derivative operator: - the Laplacian. The second-order derivative property that allows the Laplacian to produce a fine edge response corresponding to a change in gradient, rather than the less isolated response of the first-order edge filters, makes it suitable as the first stage of digital edge enhancement. Laplacian method works on zero crossings in the second order derivative of the image to detect edges. An edge has the one-dimensional shape of a ramp and calculating the derivative of the image can highlight its location [6].

i. Laplacian or Gaussian

The edge points of an image can be detected by finding the zero crossings of the second derivative of the image intensity. However, calculating the 2nd derivative of image intensity is very sensitive to noise. Before edge detection, this noise should be filtered out. This method combines Gaussian filtering with the Laplacian for edge detection. It is sometimes called Marr-Hildreth edge detector or Mexican hat operator [6].

In Laplacian of Gaussian edge detection there are mainly three steps [4]:

1. Filtering
2. Enhancement
3. Detection.

The Laplacian is often applied to an image which is firstly smoothed with something approximating a Gaussian Smoothing filter in order to reduce the noise. The detection criterion is the presence of a zero crossing in the second derivative with the corresponding large peak in the first derivative approach.

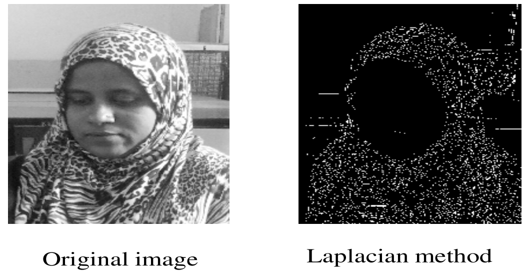


Figure 4: Laplacian or Gaussian

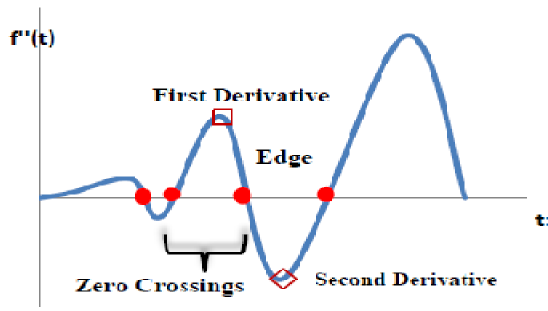


Figure 5: Edge transformative derivation [5]

In this approach,

1. Firstly noise is reduced by convoluting the image with a Gaussian filter.
2. Isolated noise points and small structures are filtered out. With smoothing; however; edges are spread.
3. Those pixels, that have locally maximum gradient, are considered as edges by the edge detector in which zero crossings of the second derivative are used.
4. To avoid detection of insignificant edges, only the zero crossings, whose corresponding first derivative is above some threshold, are selected as edge point.
5. The edge direction is obtained using the direction in which zero crossing occurs[6]

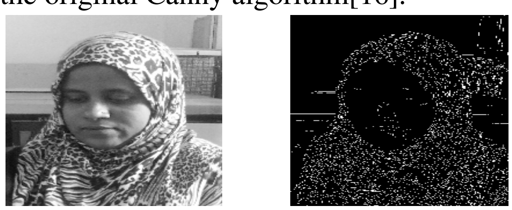
$$\begin{bmatrix} 1 & -1 & 1 \\ 1 & -8 & 1 \\ 1 & 0 & 1 \end{bmatrix} \qquad \begin{bmatrix} -1 & 2 & -1 \\ 2 & -4 & 2 \\ -1 & 2 & -1 \end{bmatrix}$$

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

Figure 6 : Three commonly used discrete approximations to the Laplacian filter.

ii. Canny edge detection

It is a method to find edges by isolating noise from the image without affecting the features of the edges in the image and then applying the tendency to find the edges and the critical value for threshold[11]. The canny edge detector first smoothens the image to eliminate noise. Then it finds the image gradient to highlight regions with high spatial derivatives. After that it perform tracking along these regions and suppresses any pixel that is not at the maximum . The gradient array at this moment can further be reduced by hysteresis which is used to track along the remaining pixels that have not been suppressed. Hysteresis uses two thresholds and if the magnitude is below the first threshold, it is set to zero. If the magnitude is above the high threshold, it is made an edge. Canny edge detection algorithm that results in significantly reduced memory requirements, decreased latency and increased throughput with no loss in edge detection performance as compared to the original Canny algorithm[16].



Original image Canny edge detection

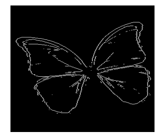
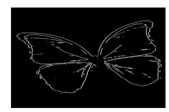
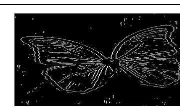
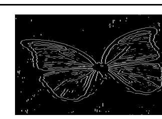
Figure 7 : Canny edge detection

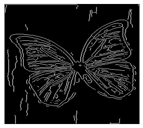
.Major application of canny edge detector is for remote sensing images which are inherently noisy [9].

This algorithm is known the optimal edge detector. In this situation, an "optimal" edge detector means following three criteria [12]:

a. Good detection: The algorithm should mark as many real edges in the image as possible.
b. Good localization: Marked edges should be as close as possible to the edge in the real scene.
c. Minimal response: A given edge in the image should only be marked once, and where possible, image noises should not create false edges.

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);	

IV. ANT COLONY OPTIMIZATION ALGORITHM BASED ON WEIGHTED HEURISTICS

Ant Colony Optimization (ACO) is a nature invigorate algorithm which is characterized by foraging behavior of ants. The algorithm is characterized by the fact how ants place pheromone while hunting for food.

ACO brings a pheromone matrix which generates the edge information present at every pixel position of image, shaped by ants bundle on image[15]. The movement of ants relies on local variance of image's intensity value. Thus by allocating the priority to the neighboring pixels, the ant judges in which route it can move. The method is put to work on Medical images[14]. The tria-and-error information is entirely dependent on the instance of the problem. Pheromone values are used and umodified during the search.

The algorithm has three main steps.

1. Process of initialization.
2. The iterative construction-and-update process, where the aim is to build the final pheromone matrix, every element of which correlate to a pixel of image and the values of this matrix give the edge information of a particular pixel. The construction-and-update process is corelated several times, once per iteration.
3. The decision process, where the edges are determined depending on the final pheromone values, it is computed using threshold values.

Figure 8.edge detected image by ACO

V. ADVANCED ANT BASED SWARM COMPUTING

An advanced ACO based image edge detection technique has been proposed called AASC when suitable parameters are provided to an image[15]. A technique resulting from features of ACS. One of the significant aspects of ACS is the form of decision rule used, the pseudorandom proportional rule. Several modifications have been proposed on the existing ACO algorithms: Initialization process: assigned to pheromone matrix, weights assigned to calculate the heuristic function ACS based rule for Construction process, modified decision process based on selection of threshold value calculated using Otsu‟s method and finally using the calculated threshold, pheromone matrix is used to classify each pixel either as an edge or a non-edge.

1. The quality of edge detection is highly dependent on lighting conditions, the presence of objects of similar intensities, density of edges in the scene, and noise. While each of these problems can be handled by adjusting certain values in the edge detector and changing the threshold value for what is considered an edge, no good method has been determined for automatically setting these values, so they must be manually changed by an operator each time the detector is run with a different set of data.
2. Effective way to calculate heuristic information.
3. Reduction of the computational time

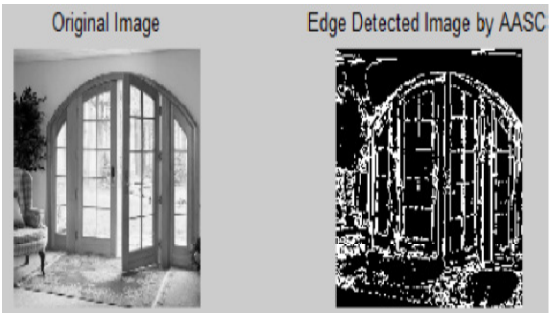


Figure 9: Edge detected image byAASC

VI. CONCLUSION

This paper provides an overview of the functionality of various edge detection methods. Each edge detection technique have its own advantages and disadvantages in various fields. Gradient- based or first order edge detection and laplacian based or second-order edge detection operators

are discussed in this paper can be implemented in MATLAB. Edge detection is a significant task for image segmentation used for object detection and many other applications. Gaussian–based edge detection is sensitive to noise. Canny edge detection algorithm is more costly in comparing to Sobel, Prewitt and Robert's operator. The main disadvantage with canny edge detection is high computation time and responsible to weak edges. It has been found that variation in edge detection methodologies can ensure the better and more accurate edge detection.

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