A REVIEW OF SPEED PERFORMANCE EVALUATION OF VARIOUS EDGE DETECTION METHODS OF IMAGES

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ABSTRACT - In image processing, edge detection is the essential process and the detection results directly affects the image analysis. Edge detection of an image minimizes appreciably the amount of data and discards information that are less important, keeping the important structural properties of an image. In this paper, various spatial domain edge detection approaches are discussed and their performance are compared on the basis of edge continuity and speed of operation, by using some images of different features. Edge detection algorithms basically works on gray levels of pixels, it is utilize to track targets, to compress data, in face recognition, in counterfeit detection of fake bills, in image analysis and in medical imaging.

Key Words: Image Processing, gray level of pixel, spatial domain edge detection, edge continuity and speed.

1. INTRODUCTION

An image is bi-directional function f(x,y) in which x and y are spatial co-ordinates, and the magnitudes of f is called as the intensity or gray level of the image. When the x,y and magnitude value of image is finite and discrete in nature then this image is called digital image. These finite elements are called as pixels.

Digital image processing is a field in which a digital image is processed by a digital computer to get some wothy information from it. It is a kind of signal processing whose input is an image and provide image as output or characteristics/features associated with that image. Nowadays, it is expanding technologies, researches are continue in this area to explore all engineering aspects.

The Edge retrieval methods usually applies in the initial steps of Image processing [1]. Image edge information is essentially one of the most significant information of image, which can describe the object boundary, its relative position within the target area, and other important information. Image edge detection methods drawing out edges from an image by identifying large intensity variations in the pixels. This will provide object outlines and object-background boundaries [2].

Edges can be detected by processing an image in spatial or in frequency domains as well. In spatial domain techniques, all the operation is done on the adjacent pixels of image whereas in frequency domain edge detection image is firstly transformed in frequency domain using discrete fourier transform and than it is processed to get edges of image.

Edge detection algorithms have application in many areas such as registration, segmentation, feature extraction, and identification of objects in a field [2] such as at night time, in underwater and in foggy environment etc.

Flow Diagram For Edge Detection [10]

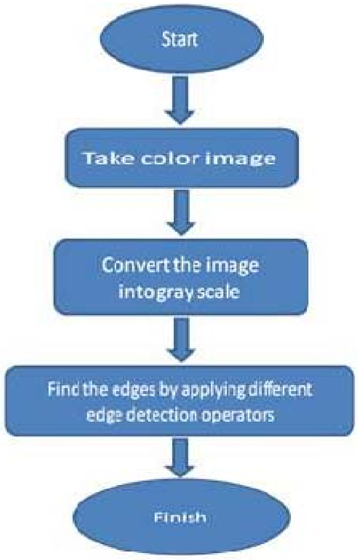


Figure 1: Flow diagram of edge detection process [10]

2. ALGORITHMS OF EDGE DETECTION

2.1. Edge Detection Based On Gradient Operator

The edge is the area where image grey value changes abruptly, using gradient operator edges are detected by perfoming first order derivative. It detect edges by computing the magnitude of gradient, and then going for local directional maxima of it by using an estimation of the local orientation of the edges, normally the gradient's direction [10]. For an image function f(x, y), the derivative of 'f' at coordinates (x, y) is denoted as the two directional column vector [10]

$$\nabla f = G[f(x,y)] = \begin{bmatrix} Gx \\ Gy \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix}$$

Magnitude of derivative of f ∇f denoted as M(x, y):

$$M(x,y) = magnitude(\nabla f) = |G| = \sqrt{Gx^2 + Gy^2}$$

Or by taking absolute values,

$$M(x,y) \approx |Gx| + |Gy|$$

The direction of the gradient is given as:

$$\theta = \tan^{-1}\left(\frac{Gy}{Gx}\right)$$

The gradient of 2D image is given as [10]:

$$Gx = f(x+1, y) - f(x, y)$$

And

$$Gy = f(x, y+1) - f(x, y).$$

Let Figure 2, denotes the image point's intensities in a 3x3 region. Function f(x, y) at any location (x, y) is denoted by center point Z5 [10].

z_1	z_2	z_3
z_4	z_5	z_6
z_7	z_8	z_9

Figure 2: Intensities of image points in a 3x3 region [10]

Here intensities z1 denotes f(x-1, y-1), z2 denotes (x-1, y), z3 denotes (x-1, y+1), z4 denotes (x, y-1), z6 denotes (x, y+1), z7 denotes (x+1, y-1), z8 denotes (x+1, y), z9 denotes (x+1, y+1).

There are some gradient operators as follows which are applied to find gradient of an image.

- Sobel Operator [9]:

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

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

Figure 3: Sobel mask [9]

- Prewitt Operator [9]:

1	1	1
0	0	0
-1	-1	-1

-1	0	1
-1	0	1
-1	0	1

Figure 4: Prewitt mask [9]

- Roberts Operator [9]:

-1	0
0	-1

0	1
-1	0

Figure 5: Roberts mask [9]

2.2. Edge detection based on laplacian operator

In laplacian based methods, edges are recognized by searching zero crossings in a 2nd derivative of the image. A pre-processing step is taken that is smoothing usually Guassian smoothing of image[10]. In smoothing, firstly convolution is performed between image and Guassian filter to minimize noise. Thereafter isolated noise pixels and small structures are filtered out. Laplacian of gaussian is also known as Marr-Hildreth Edge Detector. Laplacian of Gaussian function is abbreviated as LoG. The 2-D LoG function centres at zero and with Gaussian standard deviation σ has the form [1][10]:

$$LoG(x,y) = -\frac{1}{\pi\sigma^4}\left[1 - \frac{x^2+y^2}{2\sigma^2}\right]e^{-\frac{x^2+y^2}{2\sigma^2}}$$

LoG is unable to detect the orientation of edge and is also sensitivity to noise.

Unlike the Sobel operator, the Laplacian edge detector uses only one mask. It can compute second order derivatives in a one pass. The mask used for it is shown in Figure 6.

0	1	0
1	-4	1
0	1	0

1	1	1
1	-8	1
1	1	1

-1	2	-1
2	-4	2
-1	2	-1

Figure 6: Three common LoG masks [10]

2.3. Optimum Edge Detection Using Canny Operator [1]

The Canny Edge Detection has the following Steps:

Step 1: Smoothing of image by Gaussian filter.

Step 2: Evaluate the magnitude and orientation of gradient of image by taking finite-difference approximations for the partial derivatives.

Step 3: Nonmaxima suppression is applied to the gradient magnitude, and use double thresholding algorithm to detect and link edges.

The Nonmaxima Suppression is evaluated using the image magnitude array. In this way an edge is defined as a point that has locally maximum strength in the gradient direction. It is a stronger constraint to satisfy and is used to thin the ridges found by thresholding. This process, will results in a pixel wide ridges which is known as Nonmaxima suppression.

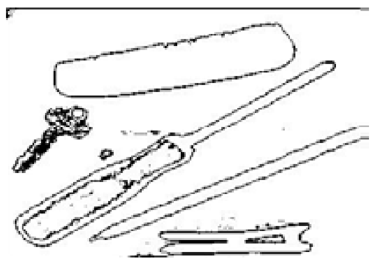
Canny edge detector proximate the operator will further optimizes the product of SNR ratio and localization.

The mere drawback is Time consumption because of complex computation to find optimum edges.

2.4. Entropic Threshold Based Detection Of Image Edge [2]

The proposed algorithm uses two entropies Shannon entropy and Tsallis entropy together, to calculate the local and global threshold values. Hence, this algorithm done better than the other algorithms of edge detection. It does not provide all thin edges. The presence of thick edges at some locations needs to be addressed by the proper choice of parameter q. The weak edges are not eliminated but for some applications, these may be required. It reduces the time consumption for computation and generate high quality of edges.

Original Image



Resultant Image

Figure 7: Edge detection using Entropy based threshold [2]

Steps for proposed algorithm are as follows:

Step1: Shannon entropy is used to find the global threshold (t_1).The image is segmented by t_1 into two parts, object and the background.

$$t^*(1) = \underset{t \in G}{Arg\max}[S^A(t) + S^B(t)].$$

Step2: Produce binary image by choosing appropriate threshold value obtaining through Tsallis entropy.

$$S_q^A(t) = \frac{1}{q-1}\left(1 - \sum_{i=1}^{t} p_A^q\right)$$

$$\text{and} \quad S_q^B(t) = \frac{1}{q-1}\left(1 - \sum_{i=t+1}^{k} p_B^q\right)$$

When $S_q(t)$ is at its high value, the luminance level t that maximises the function is supposed to be the optimum threshold value.

$$t^*(q) = \underset{t \in G}{Arg\max}[S_q^A(t) + S_q^B(t) + (1-q).S_q^A(t).S_q^B(t)].$$

Step3: Applying Edge Detection Procedure with threshold values *t*1, *t*2 and *t*3.

Step4: Merge the resultant images of step 3 in final output edge image [2].

Total required time to perform edge detection operation is represented by using graphs in figure 8 and 9 which gives a comparative measure about speed of operators[2].

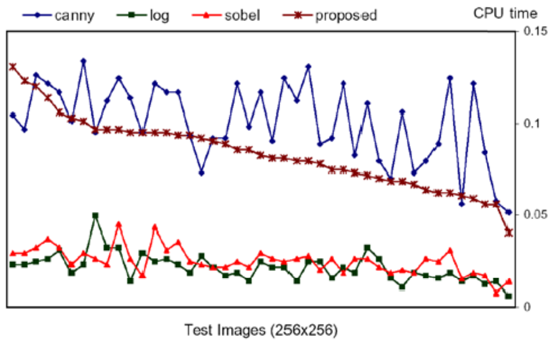


Figure 8. CPU time of Canny, LOG, Sobel, and proposed Method With 256 x 256 pixel image [2]

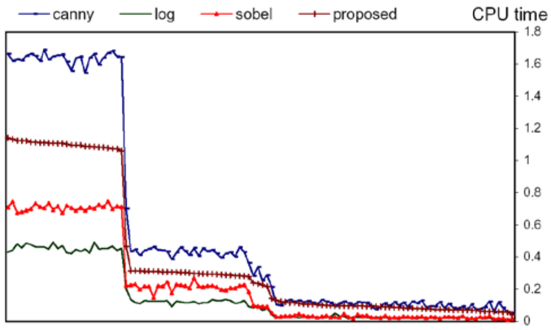


Figure 9. CPU time of Canny, Sobel and entropy method with different size images [2]

2.5. Image Edge Detection Using Morphology [3]

Morphological edge identification selects suitable structure element of the processed image and uses basic operation of morphology including erosion, dilation, opening and closing operation and the synthesize to get clear image edge. In this process, the synthesize modes of the operations and the characteristic of structuring element affects the result of the processed image.

Image edge which is denoted by Ed (*F*), is given as the difference set of the dilation domain of *F* and the domain of *F*. This is also called as dilation residue edge detector:

$$Ed\,(F) = F \oplus B - F$$

Similarily, the erosion residue edge detector is written as:

$$Ee\,(F) = F - F \ominus B$$

This method can be applied in real time application purpose because it is less time consuming process and it detect edges continuously. Efficiency of this method is based on shape and size of morph structure used.

Table 1: Statistical comparison [3]

Method	MAE	MSE	PSNR
Sobel	152.1551	2.930*10^4	3.4615
Canny	152.0696	2.927*10^4	3.4652
Morphology	49.3498	9.412*10^3	8.3936
Proposed	120.7843	2.084*10^4	4.9458

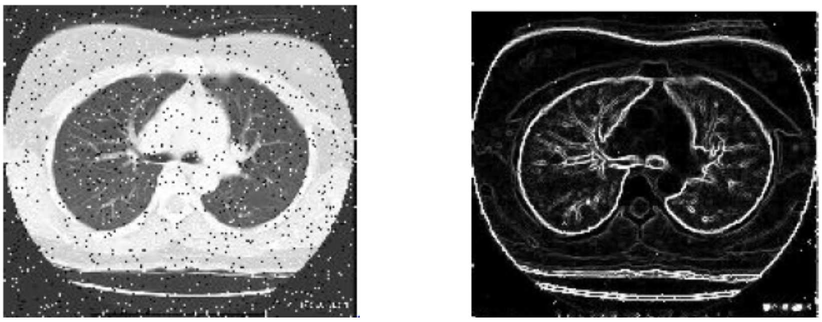


Figure 10: Morphology based edge detection [3]

2.6. QUANTUM METHODOLOGY FOR EDGE DETECTION [4]

In this method, basic operators are applied in some quantum manner so as to produce efficient edges of images in less time such that it may be used to produce edges in real time. Quantum function that has the property of superposition correlates each and every pixel with other pixels that helps to get the edge continuity in an image which further helps in image enhancement techniques. The same function if applied to other edge retrieval techniques yields better results and may be produce better edge continuity in a random image.

Original Image Resultant Image

Figure 11: Quantum method [4]

2.7. Center Of Mass Based Edge Detection Method [5][8]

This method can be utilized as framework for multi-scale edge detectors when aim is to acquire fast performance. The gradient-based edge detectors lack scalability in the filter size. Multi-scale detection of edges face a runtime complication that when scale increases this results in linear or quadratic increase of time consumption.

The general way of edge detection is to first obtain gradient by convolution of the input image with a filter. The complexity of this approach per pixel is in the order of *O*(n) or *O*(n2), where *n* is the filter width. COM edge detector uses integral image to evaluate center of mass in constant time *O*(1).

The location of COM is given by the equation[5][8]

$$X_{COM} = \frac{\sum m_i x_i}{\sum m_i}$$

This is a vector equation that gives each dimension of image in the real world. Then approximate the gradient of image intensity by the distance between Center of mass and the region center:

$$Gx' = c(XCOM - xc)$$

where *c* is a constant and *Xc* is region center.

The gradient calculated by COM provide step changes in intensity of image. However, the local peak of gradient are not exactly located on the step edge. Digital image is discrete object where each pixel as a particle has its own mass. This mass is known as intensity in image processing. This algorithm provides a good methodology to speed up multi-scale detection.

Original Image Resultant Image

Figure 12: Center of Mass method [5][8]

2.8. Boundary Detection Using Edge Field Vector Based On Law's Texture And Canny Method [6]

The proposed edge detection approach uses the information from intensity gradient using the vector model and texture gradient using the edge map model to get boundaries of object. To obtain complete description of an image considering both directions and magnitudes of image edges vector image model is used.

The proposed edge field vector is produced by averaging magnitudes and directions of the vector image. The edge map is derived from Law's texture feature and the Canny edge detection. The image vector model and the edge map are applied to extract the best edges.

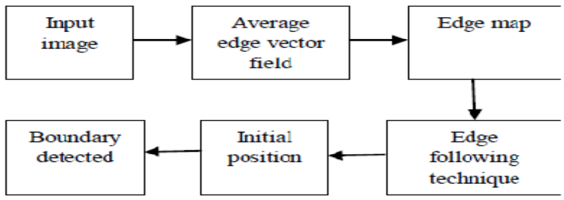
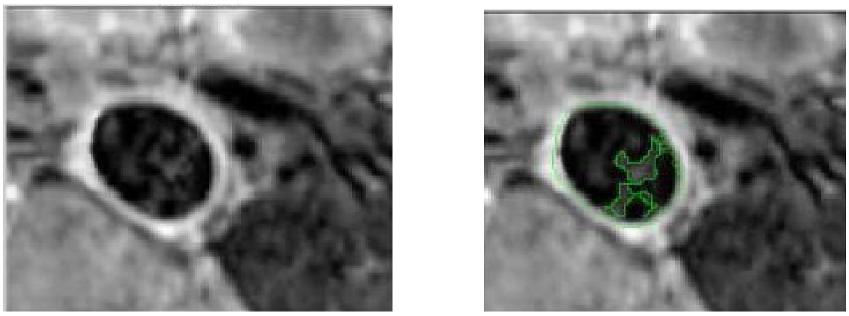


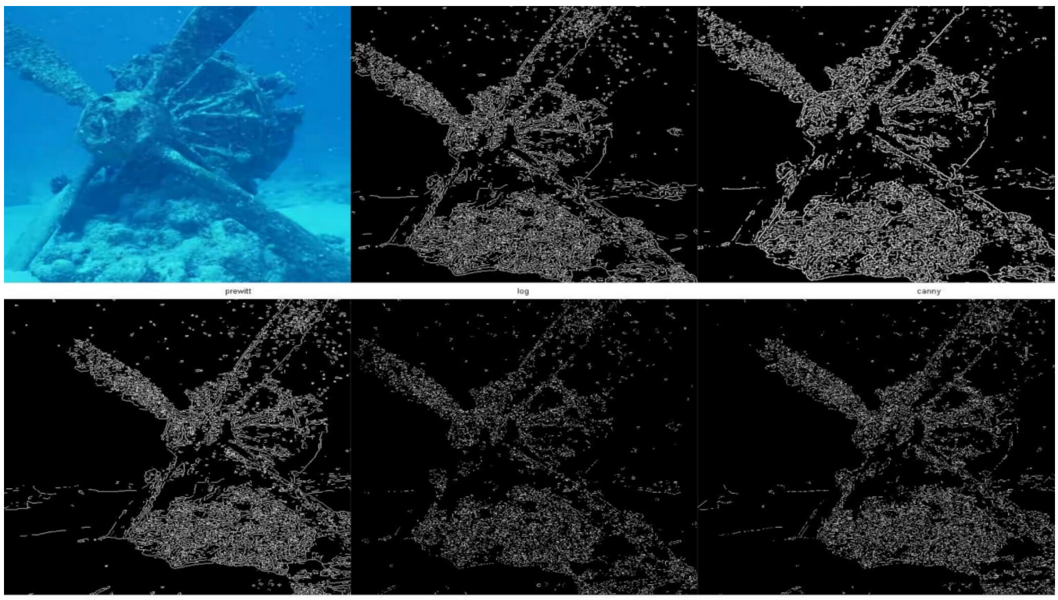
Figure 13: Block diagram of proposed algorithm [6]



Original Image | Resultant Image

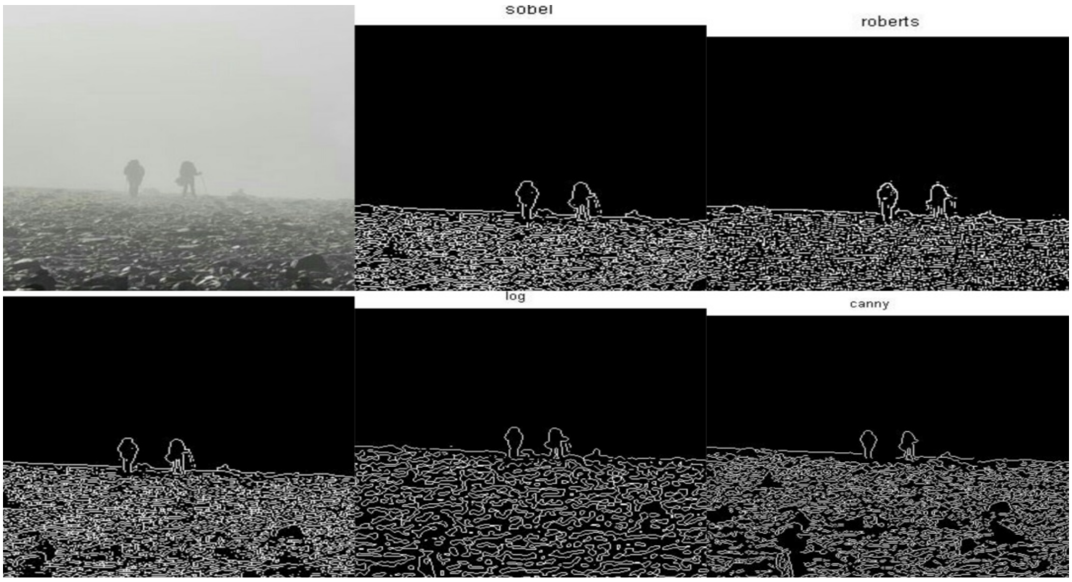
Figure 14: Edge vector field based method [6]

In this paper we use some images which are taken in different weather condition to analyze gradient operator, LoG operator and canny operator results at different threshold values. These are some images which are tested



a	b	c
d	e	f

Figure 15: a) Underwater Image b) Sobel mask c) Roberts mask d) Prewitt mask e) LoG mask f) Canny mask

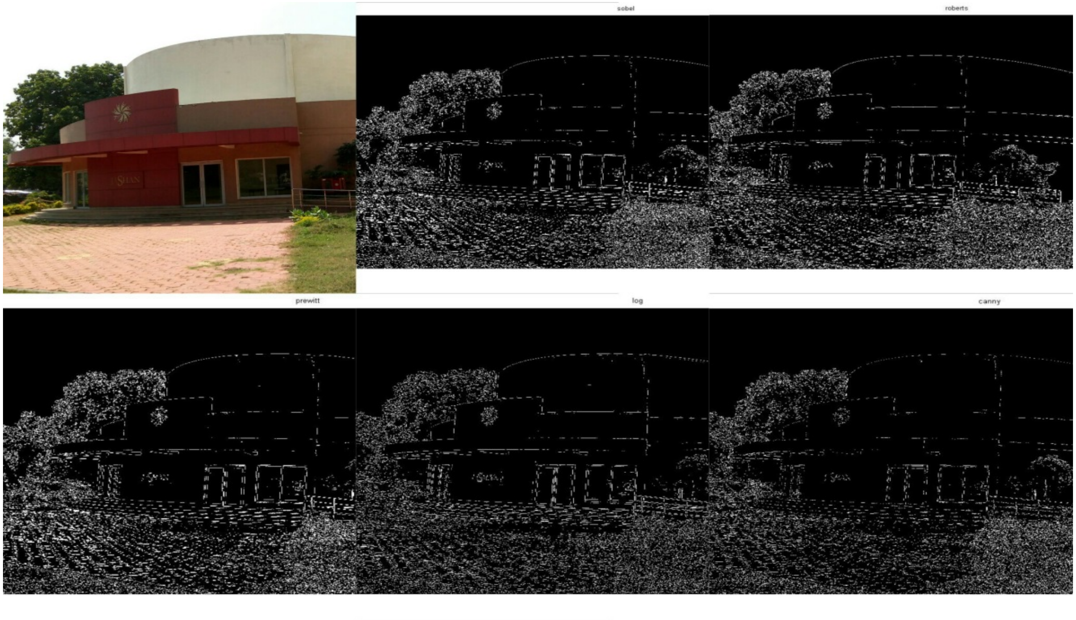


a	b	c
d	e	f

Figure 16: a) Winter season b) Sobel mask c) Roberts mask d) Prewitt mask e) LoG mask f) Canny mask

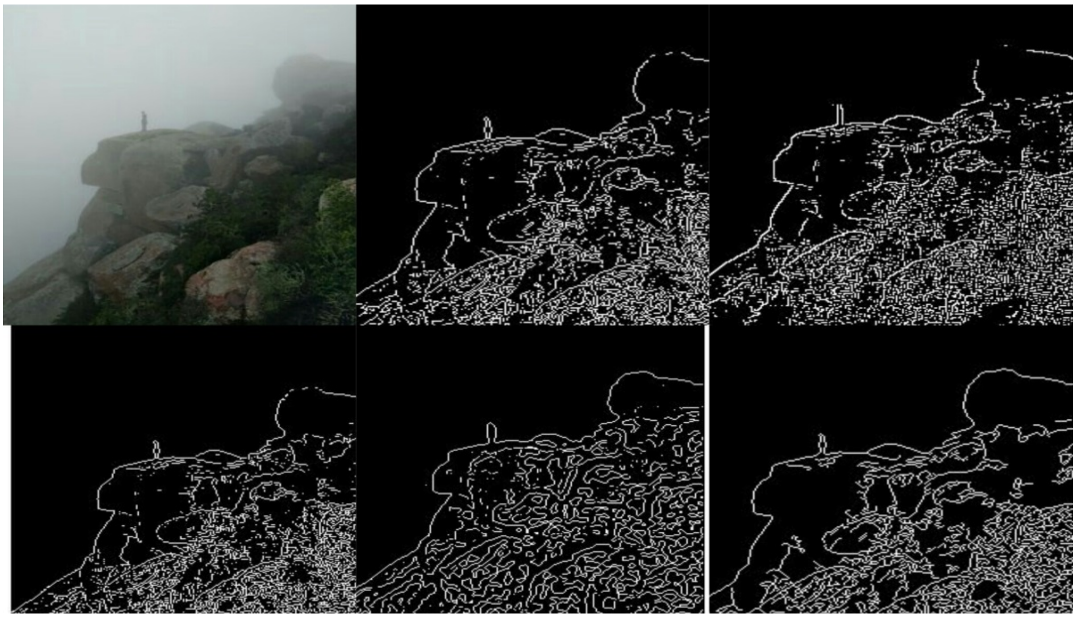
a	b	c
d	e	f

Figure 17: a) Flower in rain b) Sobel mask c) Roberts mask d) Prewitt mask e) LoG mask f) Canny mask



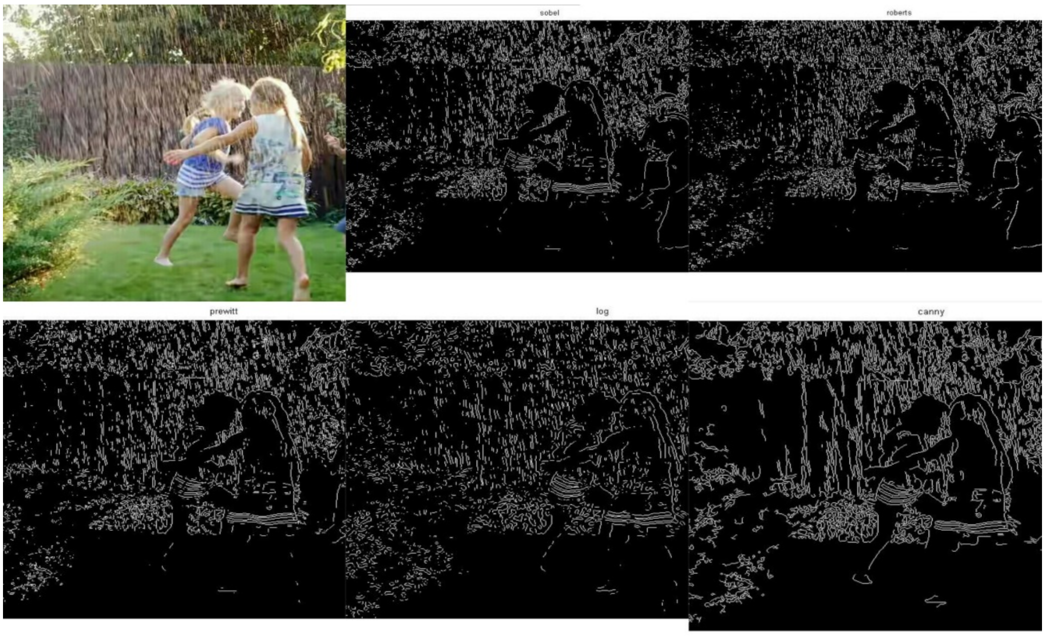
a	b	c
d	e	f

Figure 18: a) Jashan auditorium b) Sobel mask c) Roberts mask d) Prewitt mask e) LoG mask f) Canny mask



a	b	c
d	e	f

Figure 19: a) Foggy weather b) Sobel mask c) Roberts mask d) Prewitt mask e) LoG mask f) Canny mask



a	b	c
d	e	f

Figure 20: a) Rainy season b) Sobel mask c) Roberts mask d) Prewitt mask e) LoG mask f) Canny mask

Above all images are analysed on the basis of edge continuity and elapsed time in seconds which is tabulaed in table 2 and table 3 as follows.

Tabel 2: Time elapsed by masks in seconds

SN	IMAGE	SOBEL	ROBERTS	PREWITT	LoG	CANNY
1.	Underwater	0.07	0.0823	0.0708	1.3646	2.4243
2.	Winter	0.4922	0.1019	0.0415	0.5586	0.7593
3.	Flower	0.0597	0.0502	0.0663	0.06072	0.7898
4.	Jashan	0.2783	0.3463	0.3032	1.5384	10.402
5.	Foggy	0.4294	0.0686	0.0148	0.6294	0.6716
6.	Rainy	0.5582	0.1517	0.0757	0.5018	1.0782

3. COMPARISON TABLE

Table-3: Comparison between various approaches of edge detection

S.No.	Reference Paper	Algorithm Used	Advantages	Disadvantages
1.	[1][3][5]	Gradient based Sobel, Roberts, Prewitt operator	• Easy to implement. • Orientation is possible.	• Discontinuity in edges. • Sensitive to noise. • Can't meet real time Requirement.
2.	[1]	Laplacian based LoG operator	• Orientation is possible. • Fixed characteristic in all Direction. • Uses Guassian smoothing operator to suppress noise	• Very sensitive to noise. • Less accurate in finding Orientation of edges.
3.	[1][5][7]	Optimum detection using Canny operator	• Better performance in case Of Noise. • Improve SNR and localization By Nonmaxima suppression.	• Complex computation. • Low operational speed.
4.	[2]	Entropic threshold based	• Threshold value provide high quality edges.	• Fails to provide all thin edges.

			• Robust & flexible. • Retains texture of original image. • Less computation time.	
5.	[3]	Morphology with different shaped structure elements	• Detect edges continuously. • Suppress noise effectively. • Used for real time application.	• Complex computation than general morphology. • Shape & size of Structure element affects edges.
6.	[4]	Quantum functioning of Gradient operators	• Gives edge continuity. • Reduce computation time Effectively. • Operational speed increases.	
7.	[5][8]	Center of mass method	• Speeds up multi-scale detection. • Time consumption is Invariant to region size. • Perform faster than classical Methods for large region size.	• Edge thinning and thresholding is not used.
8.	[6]	Edge field vector based On Law's texture & Canny method	• Robust, can be used in Noisy image without prior Knowledge of noise component • Better performance in case Of Ill-defined edges. • Vector image model and edge map are used to select best edges.	• Boundary must be in closed loop.

4. CONCLUSION

In this paper, various edge detection methods is critically reviewed and results of Sobel, Roberts, Prewitt, LoG and canny masks are observed by using some images in MATLAB. By analyzing comparison table it is concluded that Canny's edge detection algorithm has a better performance under noisy condition compared to other classical method. Entropic threshold based method find threshold using entropy which provide high quality edges and decreases computation time. For medical application we prefer morphology based and edge vector field based method since they provide image denoising also. Morphology and quantum based methods can be used for real time applications. Since gradient operator provide discontinuous edges of image it affects the overall performance of system so in future work there is scope of getting continuous edges by using such a basic operator in real time.

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