Review and Approximate Analysis of Edge Detection Algorithms using MATLAB

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Abstract **- The primary objective of image processing system is to understand the content of image efficiently and tracks the significant and important information from it. The first step in an image processing system is the edge sensibility in a digital image [1]. Edge detection is one of the most important parts of image processing. The fundamental feature of an image is its edges, and it can be formed from the outlines or boundaries of the object. An edge is used to mark or identify the outer lines or borders and make a division of plane and from other plane appearance of an object. There are different types of algorithms available for detecting the edges. In this paper, the comprehensive study is done on the several edge detection techniques such as Prewitt, Sobel, Canny, Roberts and Laplacian of Gaussian (LoG).**

Index Terms **- Edge sensibility, Edge detection, Prewitt, Sobel, Canny, Roberts and Laplacian of Gaussian.**

INTRODUCTION

Digital image processing has become a practical as well as accepted research area that goes from specialized photography to several different field such as medical industry, Computer vision and other**.** In recent years edge detection becomes an important and active field of the image processing. Predecessors have developed many edge detection operations, such as Prewitt, Sobel, Canny, Roberts and Laplacian of Gaussian (LoG). Kirsch operator and so on that are directly on the image intensity of the light. An image consists of different types of information like contour of the object, its orientation, size and color. So, to find the shape of the object, the edges involved in that object must be identified. The objectives of edge detection are to detect the shape information of the object and the reflectance in the image. Edge detection is the useful technique in image processing as it can locate significant variations of gray image. It decreases the size of image and filter out the unuseful information, so only significant structures are maintained. Edge detection uses an approach where the intensity point varies. It is a series of actions used to identify the points in an image where clear and defined changes occur in intensity [1]. But it is very complicated to perform edge detection operation in a noisy image because noise and image both of them having high frequency component.

EDGE DETECTION TECHNIQUE

Edge detection uses differential operators to detect changes in the gradients of the grey levels. It is divided into two main categories:

a. Gradient Based Technique
b. Laplacian Based Technique

Again, Gradient based technique is divided into Sobel, Prewitt and Robert Operator whereas Laplacian based technique is divided into Laplacian of Gaussian (LoG) and Canny operator.

a. Gradient Based Technique: In gradient based edge detection, edges are detected and computed by taking first order derivative of the original image. The gradient method finds edge by looking into the maximum and minimum points. The popular edge detection operators are Robert, Sobel, and Prewitt. The magnitude of the gradient is the most powerful technique that forms the basis for various approaches to sharpening. The gradient vector points in the direction of maximum rate of change [1].

For a function f (a,b), the magnitude of the gradient of f at coordinates (a,b) is defined as

$$\nabla f(\mathrm{a,b}) = \left(\partial_x f(a,b)\right)_2 + \left(\partial_y f(\mathrm{a,b})\right)_2 \quad \ldots\ldots\ldots\ldots 1$$

while the gradient orientation is given by

$$\angle\nabla f(a,b) = \arctan\left(\partial_y f(x,a,b)\ \partial_x f(a,b)\right) \text{.....2}$$

b. Laplacian Based Technique: In Laplacian based technique, edges are detected and computed by taking second order derivative which has a zero-crossing. An edge has the shape of a ramp that is one-dimensional, and location can easily highlighted by calculating derivative of the particular image. The popular edge detection operators are LoG and Canny. Zero-crossing operator is used to locate zeros on the second derivatives of f(a,b).

The differential operator is used in the so-called zero crossing edge detectors.

$$\nabla 2f = \partial^2 f/\partial a^2 + \partial^2 f/\partial b^2 \text{ .....3}$$

Threshold process gives better result when it compares with grayscale image. For the image f(a,b), the threshold image g(a,b) is defined as

g(x, y) =1 { if f (a,b) > T
0 if f (a,b) ≤ T}

Where T is the threshold value.

- In 1965, Robert Lawrence Gilman had developed Robert edge detection technique which is very noise sensitive.
- In 1970, Sobel Irwin Edward had invented Sobel edge detection algorithm. It is very fast for computing. It is also used to detect thick edges but failed to detect diagonal edges.
- In 1970, Judith M. S. Prewitt had discovered Prewitt, which is similar To Sobel technique and also be able to detect edges in every direction.
- In 1979, David Marr and Ellen C. Hildreth have developed Laplacian of Gaussian (LoG) operator that used for smoothing the image.
- In 1986 Canny John F had invented Canny edge detector technique that was designed and developed as an optimal edge detector. The Canny edge detector is computationally more expensive as compared to other edge detectors [4].

STEPS FOR EDGE DETECTION

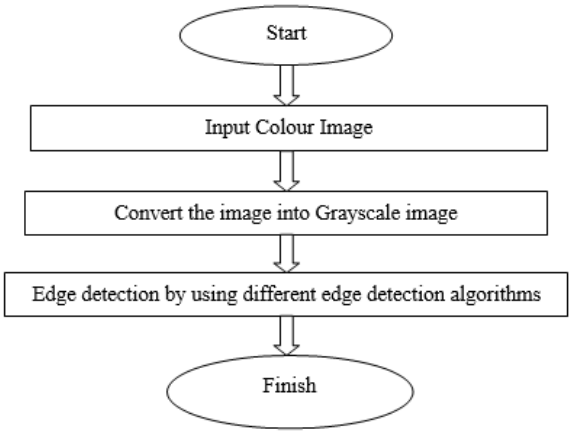
a. Filtering: There are few classical edge detectors that operate with high quality images, but they are not good enough for noisy pictures. Noise is unpredictable activity on the original image. There are various types of noise, but the most broadly studied two kinds are white noise and ―salt and pepper‖ noise [6]. Generally, this type of noise has an effect on a small number of image pixels.

b. Enhancement: Digital image enhancement techniques are concerned with improving the quality of the digital image [6]. The main objective of enhancement steps is to develop an image that is better and more suitable than the original image. Mainly image enhancement problems have been solved by using linear filters.

c. Detection: There are so many points of an image that have a nonzero value for the gradient. These points are not used for edge detection, then some different methods have been used to detect edges.

FLOWCHART FOR EDGE DETECTION

The following flowchart process we are using for edge detection process.



REVIEW OF LITERATURE

S Saluja et al [1] presented a theoretical study of edge-based image segmentation that uses Gradient based and Laplacian based edge detection.

M. A. Ansari et al [2] presented a paper where they have studied and compared different edge detection techniques and calculate their edge detection performance parameters like PSNR and MSE and made a conclusion that second order derivatives are working properly then first order derivatives. But LOG operator has an exception over Canny operator only.

P Dhankhar [3] proposed various approaches for image segmentation that depends on different edge detection technique. The review has been made based on discontinuity intensity levels.

R Kumari et al [4] presented a paper where comparison studies of different edge detection techniques have been covered.

Ramnarayan et al [5] presented review paper on Canny edge detection technique that minimizes the effort of detection process.

P Ameta et al [6] presented a paper that demonstrates the review on different edge detection techniques like Gradient Based Technique and Gaussian Based technique and discussed their advantages and disadvantages.

G Jain et al [7] proposed a method using genetic algorithm in image segmentation than better edge effect that have been observed but actually the resulted image has lots of amount of noise.

S Savant [8] presented a paper that studies different edge detection techniques like Gradient, Sobel edge operator, Robert edge operator, Prewitt edge detector, Laplacian of Gaussian, Zero Crossing and canny edge detector.

G.M.H Amer et al [9] proposed some gradient based edge detection technique and discussed their performances in presence of sensitive noise.

R Muthukrishnan [10] presented a paper that discussed theoretical and mathematical studies of different edge detection techniques like Sobel, Prewitt, Kirsch, Robinson, Marr-Hildreath, LOG and Canny using MATLAB.

R. Jayakumar et al [11] presented a paper that studied different edge detection methods for Remote sensing image processing technique.

Dharampal et al [12] presented a paper where they have studied edge detection technique based on certain parameters like threshold and σ. Also they have studied fuzzy logic based edge detection method that supposed to provide flexible structure with a little bit of amount of complexity and offers more advantages.

Chinu et al [13] presented a paper where they have discussed Gradient based, Laplacian based and traditional edge detection techniques. They have also studied edge detection based on Soft morphology, human visual feature, Haar based edge detection and bi-lateral filtering based edge detection and their comparative analysis based on different parameters like noise, nature etc.

D.Marr et al [14] presented a paper that discussed different edge detection techniques that based on discontinuity intensity levels.

Y Zheng [15] presented a paper that has studied different edge detection differential operator method like Robert ,Sobel, Prewitt , LOG, Canny and also studied mathematical morphology method like Dilation Operation, Erosion Operation, Open Operation, Closure Op but as a result noise had not remove completely.

S Das [16] proposed a comparison of different edge detection techniques for object detection and Canny has prove itself to be a better detector for outer and inner lines of object than Sobel, Prewitt and Roberts. But for detecting of face, morphological edge detection proves best result.

P Ganesan et al [17] presented a paper that compares five edge detection algorithm like Sobel, Canny, LOG, Prewitt and Robert based on performance operator like MSE and PSNR.

B.K. Shah et al [18] presented a paper where they have studied and computed different edge detection techniques and and calculates MSE and PSNR of that particular image.

P.H.Pawar et al [19] proposed a system that describes and demonstrate Canny and Beamlet edge detection technique using MATLAB simulink model based on the parameters MSE and PSNR and beamlet shows better transformation compared to canny.

Shou-Ming Hou et al [20] proposed a system that describes different edge detection technique

P.P. Acharjya et al [21] presented a paper that discussed comparison of different edge detection techniques and Canny edge detection has the highest accuracy.

D Adlakha et al [22] presented a paper that depicts the performance between Sobel and Prewitt and analysed that Prewitt is much better than Sobel.

S Bhardwaj et al [23] presented a survey paper where they have compared different detectors. They have analysed that first order derivative are very much noise sensitive compared to second order derivative.

M Joshi et al [24] presented a paper that compare Canny edge detection with Sobel and Prewitt and concluded that Canny's edge detector gives good results for detection on horizontal and vertical edges .Prewitt and Sobel produced good results for detecting horizontal and vertical edges.

R Chandwadkar et al [25] presented a paper that compare between Sobel and Canny edge detection methods where Sobel gives faster performance in terms of computation.

G.T. Shrivakshan et al [26] presented a paper that compares between different edge detection algorithm and after evaluation it has been seen that under the noisy conditions, Canny, LoG, Sobel, Prewitt, and Roberts's are exhibited better performance, respectively.

S Mohanty et al [27] presented a paper that compares between different edge detection algorithms and conclude that Sobel operator was proved to be more effective in defining the lines. Because of being too sensible against noise 'Laplacian Method' was not used.

D.R.Waghule et al [28] presented a paper that review on different edge detection methods for image segmentation.

G Yang et al [29] presented a paper that depicts the Log_Sobel algorithm that makes the texture clear. This algorithm is compared with other algorithms like Roberts algorithm, Prewitt algorithm and Sobel algorithm.

S Kaur et al [30] presented a paper that studies a wide range of methods of edge detection for image segmentation. They completed that this different edge detection methods can be implemented as per the need of segmentation of image.

DIFFERENT EDGE DETECTION TECHNIQUE

There are different techniques used for edge detection:

1. Sobel Edge Detection:
2. Prewitt Edge Detection:
3. Robert Edge Detection:
4. Laplacian of Gaussian Edge Detection:
5. Canny Edge Detection:
6. Zero-cross Edge Detection

1. Sobel Edge Detection: In 1970, Irwin Sobel had proposed an edge detection process named as Sobel edge detection technique. It is a well-known edge detection technique in which 3*3 convolution masks have been used in horizontal and vertical directions. It is a simple approximation to the concept of gradient with smoothing. The Sobel operator performs a 2-D spatial gradient measurement on an image and so emphasizes regions of high spatial frequency that correspond to edges [1]. In Sobel edge detection, they have used concept of Kernels that uses 3*3 convolution mask. One kernel is simply the other rotated by 90. It is a row edge detector. The kernel can be applied separately to input image for obtaining gradient component in each orientation i.e. G_X and G_Y.

The magnitude is given by:

$|G|=\sqrt{G_{X2} + G_{Y2}}$

And its approximation is done by:

$|G|=|G_X| + |G_Y|$.

The orientation of angle is given by:

$O = \arctan(G_X/G_Y)$.

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

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

Fig 1: Sobel Edge Detection Mask

2. Prewitt Edge Detection: In 1970, Prewitt had proposed an edge detection process named as Prewitt edge detection technique. Prewitt edge detection method is almost similar to Sobel operator. In this

edge detection technique, 3*3 masks are used to find the gradients in horizontal and vertical directions. Prewitt approximation is applied on the derivatives of intensity function [24]. Derivatives should have the following properties:

• 3*3 masks should contain the opposite signs.

• Resultant addition of mask should be zero.

Prewitt operator generates two masks, one for detecting edges in horizontal direction and other for vertical direction. The result of Prewitt edge operator is either the corresponding gradient vector or normal vector. It totally depends on the convolution between an image and an integer value in horizontal and vertical direction. Advantages of Prewitt are it is a cheap system and contain faster speed of processing. It also has some disadvantages that Prewitt edge operator is not properly working in noisy area.

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

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

Fig 2: Prewitt Edge Detection Mask

3. Robert Edge detection: In 1965 Lawrence Roberts has proposed the Roberts edge detection technique for detecting the edges of an image. Robert Edge detection is mostly similar to Sobel and Prewitt Operator. It is a 2-D spatial gradient measurement of an image. The Roberts Cross edge detector performs an easy method for calculating 2-D spatial gradient measurement on an image and highlights those regions of high spatial frequency. Firstly, it is used to calculate the sum of the squares of the difference between diagonally adjacent pixels through discrete differentiation and then compute the approximate value for gradient of the image. This edge detector uses following 2 x2 two kernels: one of the kernels is designed in such a way that it responds maximally to edges running at 45°. Another kernel is simply the other rotated by 90°.The kernels can be applied separately to the input image and used to produce separate measurements of the gradient component in each orientation (call these Gx and Gy).

The gradient magnitude is given by:

$|G| = \boldsymbol{Gx}^2 + \boldsymbol{Gy}^2$

An approximate magnitude is computed using:

$|G| = |Gx| + |Gy|$

Speed of computation is very much higher. The angle of orientation of the edge giving rise to the spatial gradient (relative to the pixel grid orientation) is given by: $\theta = \arctan(Gy/Gx) - 3\pi/4$. This Edge detection technique has an advantage that it is very simple to design, but it has a small size kernel. Another big advantage of this technique is it is very much sensitive to noise.

1	0
0	-1

Gx

0	1
-1	0

Gy

Fig 3: Robert Edge Detection Mask

4. Laplacian of Gaussian (LoG) Edge Detection: In 1982, Marr and Hildreth had proposed an edge detection technique known as Laplacian of Gaussian (LoG). The LoG of an image f(x,y) is a second derivative as discussed earlier in this paper. It is used to do smoothing the image first and then computes the Laplacian. In this edge detection technique, initially amount of noise is eliminated by convoluting the image with a Gaussian filter. After that smoothing is used to isolate the noise points and gradient pixels. Those pixels are contemplated as edges by the edge detector in which zero crossings of the second derivative are used. The direction of zero crossing used to provide the edge direction. The LoG edge detection operator is used to take a single gray-level image as input and provides another gray-level image as output.

The LoG of an image f(x,y) is a second derivative defined as: $\nabla^2 f = \boldsymbol{\partial}^2 f/\boldsymbol{\partial x}^2 + \boldsymbol{\partial}^2 f/\boldsymbol{\partial y}^2$

LoG also used linear interpolation to locate the sub pixel location of the edge. 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 [11]:

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

The digital implementation of the Laplacian function is made using the following mask given in below figure.

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

Fig 4: Laplacian of Gaussian Mask.

5. Canny Edge Detection: In 1983 John Canny proposed a new edge detection technique, canny edge

detection technique. Among all the edge detection methods, Canny edge detection method is one of the most important methods. It is the only method to work in presence of noise. Canny edge detection technique considers a number of adjustable parameters which can affect the computation time and effectiveness of the algorithm. There are three important criteria that need to be considered for Canny edge detection algorithm. The first criterion is to detect all the important edges in the source image. The second criterion is to find the edge points as close as possible to the true edge, called localization. Third and last criterion is not to have more than one response to a single edge. Canny edge detector is one of the most commonly used edege detection algorithm used in image processing. It is used to detect edges in a very healthy way. Unlike Roberts Cross and Sobel, the canny operation is not very susceptible to noise.

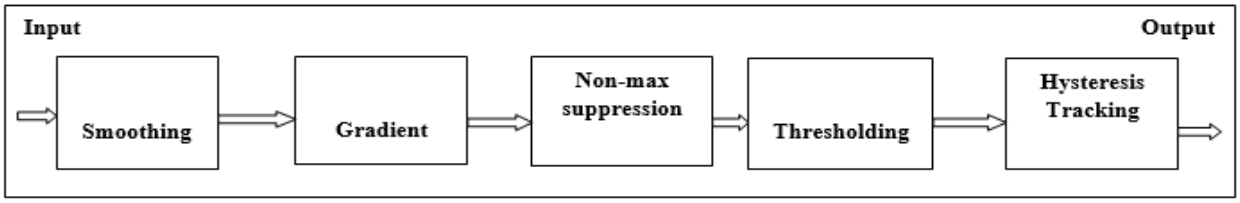


Fig 5: Block Diagram Canny Edge Detector

Working Operation of Canny Edge Detection: Canny Edge detection algorithm maintains few steps:

a) Smoothing: The input raw images from camera must contain some amount of noise that affect the original image. To solve out this problem, firstly the input image must be converted into gray to remove the noise. So, the first step is to filter out the noise in the original image to make the location and detection edges efficient. The image pixel and convolution mask is convoluted with each other to create an intermediate image.

b) Finding gradients: Gradient of the image is computed with the sharp change in gray level values. The gradient is a unit vector which points in the direction of maximum intensity change. In the process, initially the vertical and horizontal components of the gradient are computed and then the magnitude and direction of the gradient is computed [6]. For each pixel of the image, partial gradient towards x and y direction is determined respectively by applying the kernels given in fig.5. In this step, the blurred image obtained from the 1st step is used to convolved with a 3x3 Sobel operator. It consists of two 3x3 kernels for calculating the horizontal and vertical gradients respectively.

The edge strength G is…….|G|=|Gx| +|Gy|

The edge direction is calculated using the gradient in the x and y directions. The formula for finding the edge direction is just: ----θ=arctan(Gy/Gx) (4)

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

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

Figure 6: Canny edge detection mask

c) Non-maxima suppression: In this step the detector converts the thick edges to approximately thin and sharp edges which can be further used for recognition purpose. Thinning process of edge is performed in non-maxima suppression. In this process the image is scanned along the direction of edge and discards any pixel value that is not considered to be an edge which will result in thin line in the output image.

d) Double Thresholding: Followed after the non-maximum suppression step, the edge pixels are still marked with their strength pixel-by-pixel. Many of these pixels may be true edges of the image, but some might be caused by noise variations for instance. In order to overcome of such disagreeable situation, we can apply thresholding. In the double thresholding process, edge pixels which are stronger than the high threshold are marked as strong; otherwise, the edge pixels that are weaker than the threshold are going to be minimized and edge pixels between the two thresholds are identified as weak.

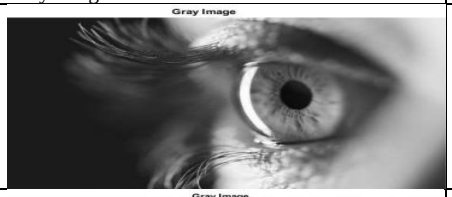
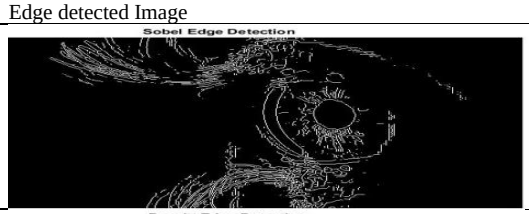
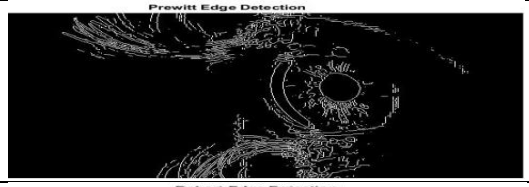
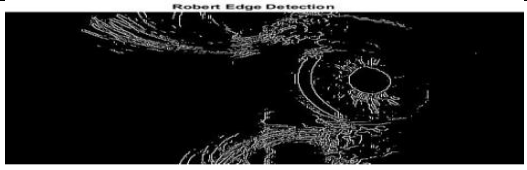
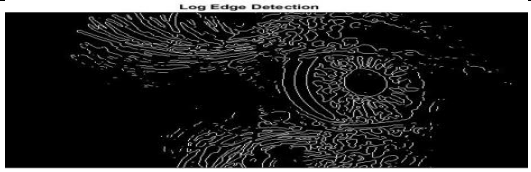
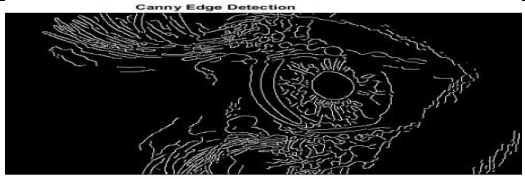
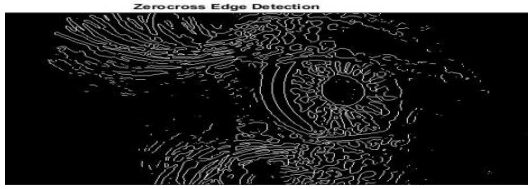
e) Edge tracking by hysteresis: Weak edges which do not connect to a very certain (strong) edge are eliminated in the final output image. Certain edges are called strong edges will included in the final image. Strong edges will (almost) only be due to true edges in the original image. The weak edges can either be true

edges or due to variations of noise. Final edges are determined by removing all the edges that are not connected to a certain edge. Hysteresis is used to track the edge by modifying weak edge to a strong edge if both ends of a weak edge are connected to strong edges.

6. Zero cross Edge detection: It uses second derivative, and it includes Laplacian operator. This is sensitive to noise. Haralick proposed the use of zerocrossing of the second directional derivative of the image intensity function. The general calling syntax is: [g, t] = edge (f, 'zerocross', T, H); where H is the filter function [8].

EXPERIMENTAL RESULTS

Different edge detection techniques that discussed in the paper were applied on the samples of eye. By applying MATLAB different parameters have been calculated like 1. Threshold, 2. Entropy, 3.Mean, 4.Variance. The main point of attention was the results were best in case of Canny Edge detection and Laplacian Edge Detection. In Log edge detection, threshold value is minimum than all other threshold value and also for that entropy is minimum For Sobel and Prewitt results are mostly same. Mean variance of Canny and Log edge detection algorithm is mostly same compared to other edge detection algorithm. In every case, for minim um threshold value, entropy is minimum. Low variance of standard deviation signifies that pixel intensities are closer to mean and converging too.

Edge detection techniques	Gray Image	Edge detected Image
SOBEL		
PREWITT		
ROBERT		
LOG		
CANNY		
ZEROCROSS		

Sl. No	Edge Detection techniques	Threshold	Entropy	Mean	Standard Deviation
1	Robert	0.028	0.2381	0.0729	0.2600
2	Prewitt	0.028	0.2366	0.0388	0.1930
3	Sobel	0.03	0.2272	0.0367	0.1881
4	Canny	0.08	0.3146	0.0568	0.2314
5	Log	0.0008	0.2910	0.0511	0.2202
6	Zero-cross	0.0007	0.3029	0.0539	0.2259

Fig:8 Table of Calculation

CONCLUSION

In this paper, different types of edge detection algorithms are studied and compared based on few parameters. After the analysis using MATLAB, it is found that the second order derivatives (Canny and Log) are working well in comparison to first order derivatives (Sobel, Prewitt and Roberts). The Log and Canny edge detection method producing good results for entropy and standard deviation and also the quality of the image is good. Low variance of standard deviation signifies that pixel intensities are closer to mean and converging too. Here, Sobel edge detection technique proves better for discovering better outer lines. In future , to get better enhanced image, we likely to reduce noise with new filter.

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