

Study on Edge Detection

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Abstract: Edge detection is a very important part in digital image processing. Using edge detection we can segment an element from an image or differentiate between elements. Edge detection plays a vital role in reconstruction in 2D or 3D images. It also helps to compress an image. We can find edges in an image using different types of linear and non-linear based edge detection method. In this paper, a brief study had done on Robert, Sobel, Prewitt, Canny, Log, Fuzzy logic based, Artificial Neural Network and Wavelet based edge detection methods. Compare different edge detection methods using MATLAB tools and analysis their performance. Briefly study on related work done on different field using edge detection method.

Keywords: Edge Detection, Robert, Sobel, Prewitt, Canny, Log, Fuzzy Logic, Artificial Neural Network, Wavelet

1. Introduction

An image nothing but a two dimensional (2-D) array of pixel where for a 8-bit gray pixel intensity value is in between 0-255, where 0 represents black and white and 255 represents white color pixel. In Digital image processing, we can store an image or signal in less memory and enhance the image. In image enhancement method, a blurry or noisy image can transform into a sharper image. An image can be segmented by three ways which are edge based, region based and threshold base method. Edge means boundary of an image. Edge can be identified by high intensity of an image or sharp discontinuity between two objects in an image. Boundary of an object or edge helps to identify obstacle, face detection, image compression or target recognition etc. To identify edge, edge detection operator required which identifies vertical, horizontal, step or corner edges. True edge detection highly depends on noise, object with same intensity, lighting condition and density on the edge in the image. These problems can be solved by increasing or decreasing threshold value or adjusting various parameters. There are different types of edge detection method in image processing like Sobel, Prewitt, Canny, Laplacian edge detection algorithms. Through edge detection method we can segment the element or object from an image.

2. Background

Edge can be detected by using first order, second order derivative on each pixel or gradient based operator on continuous pixel on x and y direction [1]. Processing of image using gradient based operator or derivative on pixel convert an image from grey scale image into binary image, from this binary image edge can be searched by looking local maxima or discontinuity at the image. Edge detection method can help to identify object detection, recognition of object in an image.

Reducing noise from image results in burred and distorted image as both edge and noise have high intensity pixel value. There are many ways to find edge in an image, but mainly two groups we apply for edge detection.

2.1. Gradient or First order Derivative

In gradient method of edge detection it finds edge to locate maximum or minimum value of first derivative in an image or signal. First order derivative method takes more computation time. So this method can't be used in real time system [13].

2.2. Laplacian or Second Order Derivative

Laplacian edge detection method finds edge to locate zero crossing value of second derivative in an image or signal [14]. In figure-1 represents a signal with jump of intensity of the picture present edge of the image.

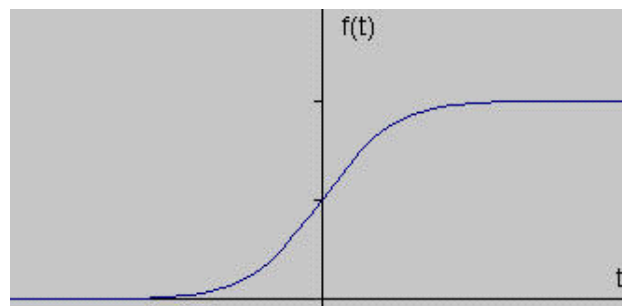


Figure 1: Original Signal [13]

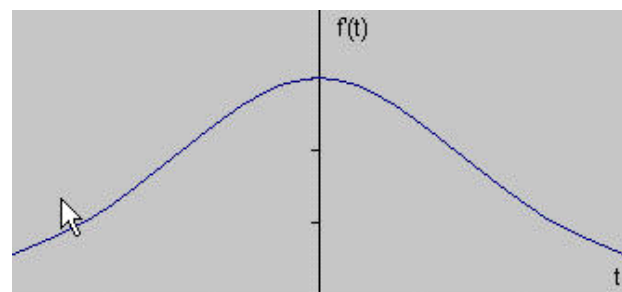


Figure 2: First Derivative of the Signal. [13]

Figure-2 represents first derivative of the signal presented at Figure-1. This type of method to find edge in an image is called gradient filter. In gradient filter the edge is detected when pixel intensity value greater than some threshold value [14]. Figure-3 represents second derivative or Laplacian

filter edge detection method of the signal. Edge can be identified by zero crossing of the signal.

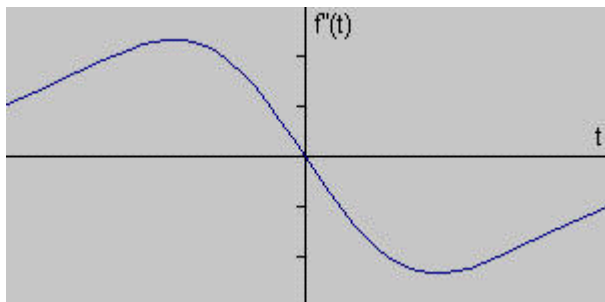


Figure 3: Second Derivative of the signal [13]

2.3. Threshold point

Selection of threshold point is playing a vital role of finding edge in an image. Based on the threshold point in an edge detection method true edge or false edge are generated [13]. IF threshold point is low then many thick edge are generated and if threshold point is high then many true edge are not able to generated or edge are segmented. Ostu threshold segmentation methods and maximum entropy method are used to achieve good results but these methods have also shortcoming such as big computational complexity and low computational efficiency [7].

3. Linear Edge Detection Operator

3.1. Robert's Cross Operator

Robert's cross operator is a 2-D Gradient operator which is applies on a gray scale image [15]. This method is very simple and quick to compute the resultant gray scale image or edge. The following kernel uses in the Robert's cross Operator which is given below:

G_x

+1	0
0	-1

G_y

0	+1
-1	0

This kernel designed to apply on the edge running 45 degree to the pixel grid [3]. This two 2x2 kernel can be applied to image separately and produce separate gradient (G_x and G_y) of the image.This can be combined together to find absolute magnitude of the gradient at each pixel and gradient direction of edge.

$$[G] = G_x + G_y \tag{1}$$

$$\text{Or } [G] = [G_x] + [G_y] \tag{2}$$

[G_x], [G_y] are two gradient in x and y direction [2].

Gradient direction of the edge is given by:

$$\theta = \arctan \frac{[G_y]}{[G_x]} - 3\pi/4; \tag{3}$$

The disadvantage of Roberts cross operator is it used small kernel so it is highly sensitive to noise and currently it not a

popular edge detection method as many more strong edge detection operator are available like Sobel, Log, And Canny edge detection operators. Roberts operator also a 2x2 masks or even dimensional mask, so it have to allocate center of masks to the corner. But in case of odd dimensional mask or a 3x3 mask it can allocate center to desire position[13].

3.2. Prewitt's Operator

In Prewitt edge detection method, 3x3 mask are used in x and y direction compare to Robert's cross operator where 2x2 marks used in x and y direction although this method is sensible to noise. Consider the pixel intensity around the pixel a[i,j] are given below:

A0	A1	A2
A7	a[i,j]	A3
A6	A5	A4

The partial derivative can be computed by calculating G_x and G_y, where

$$G_x = [A_2 + cA_3 + A_4] - [A_0 + cA_7 + A_6] \tag{4}$$

and

$$G_y = [A_6 + cA_5 + A_4] - [A_0 + cA_1 + A_2] \tag{5}$$

Here c is a constant which gives priority to pixel closer to Centre of the mask. In equation given above putting the value of c=1, we get Prewitt operator which is given below:

G_x

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

G_y

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

3.3. Sobel Operator

3x3 gradient operator are used inSobel edge detection method like Prewitt edge detection method but compare to Prewitt edge detection operator, Sobel operator is less sensitive to noise. In Sobel edge detection the value of c=2 or value of the mask are variable. The gradient of Sobel edge detection methods are given below:

G_x

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

G_y

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

An advantage of using larger size of mask is that it reduces the effect of noise by local averaging of neighbor pixel of the center pixel. An advantage of using odd length mask is that it provides estimate based on center pixel. In Sobel edge detection it is best to convert a RGB image to a gray scale image [15].

80	80	210	210
80	85	210	210
80	80	201	210
80	80	210	210

 $*$

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

 $=$

-80
-160
-80
+210
+420
+201
=511

3.4. Kernel Convolution

In Sobel detection operator to check each pixel belongs to edge or not, it takes all surrounding eight pixels and multiplies with kernel mask. For each pixel convolving with kernel mask in each direction or Calculating Gradient operator in x and y direction (G_x and G_y), combining this two gradient operator to find whether the value more than threshold value. If the value more than threshold value, it is marked as edge else it is discarded.

In Sobel edge detection method or other method, the final process images have lot of noise. So using averaging filter to the image before applying the Sobel operator can reduce some noise.

3.5. Canny Edge Detector

There are several algorithms present but for noisy image Canny edge detection is one of the best edge detection methods [2]. Though it is a very old method invented by John F. Canny in 1986, till now this method is being used in research purpose and very effective for noisy image compare to other edge detection methods like Sobel, Prewitt, Robert edge detection methods.

John F. Canny develop the algorithm to detect the real edge of an image and remove the false edge or noise by increasing signal to noise ratio. In Canny edge detection method, edge can be detected by five steps which are smoothing, finding gradient, non-maximum suppression, double thresholding, and edge tracking by hysteresis [2].

In **smoothing** the noise present in the image are reduced by applying a Gaussian filter with standard deviation $\sigma=1.4$ [2] as noise have high intensity. So if noises are not reduced from the image, in edge detection method noises will be assume as edge as they have high intensity.

Next step in Canny edge detection method is to **find the gradient** in x and y directions by applying kernel to the smooth image. In this method find edge of a where grayscale intensity of the image change the most by applying operator to each pixel throughout the image [2]. Kernels are given below:

$KG_x=$

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

$KG_y=$

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

The gradient magnitude or edge strength calculate by law of Pythagoras or summing up gradient in x and y direction which is given below

$$[G] = G_x + G_y$$

$$\text{Or } [G] = [G_x] + [G_y]$$

$$[G] = G_x, G_y \text{ are two gradient in x and y direction [2].}$$

In non-maximum suppression blurred edge of the image convert to sharp edge by taking local maxima gradient value and remove other values. In the Figure 5, a simple example of non-maximal suppression where using color and number it presents edge strength, gradient direction is presented as arrow. As in the figure given below, gradient directions of maximum pixel are in north direction, so it compare gradient of the pixel with top and below pixel. Maximal values are preserved as local edge and remaining pixel will remove.

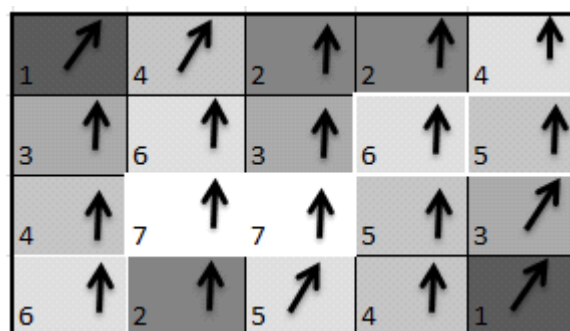


Figure 5: Example of non-maximasuppression

Edge strength shown by color and numeric values, edge gradient is shown by arrows. Resulting edge is given as pixel with white border. After non-maxima suppression the next step to find true edge in canny edge method is double thresholding. In the presence of noise or due to rough surface between two objects, intensity of that pixel is higher. In threshold method when strength of a pixel is higher than some predefined intensity value, it will mark as edge and less than the predefined intensity value will discard. In Canny edge detection method there are two threshold values used. When Intensity of a pixel is more than higher threshold value will mark as strong edge. When intensity of a pixel is between two thresholds values will mark as weak edge, other will be discarded [13]. After double threshold next step is to find edge using hysteresis. In this step, all the weak edges connected with strong edges will be marked as true edges. Other weak edges will be discarded as noise or variation of color of higher intensity values.

3.6. LOG

In **LOG (Laplacian of Gaussian)** edge detection method, first apply Gaussian filter to the image for smoothing then apply Laplacian operator for image enhancement and detect

edge based on second order derivative zero crossing. In Log method a 5*5 template issued in Figure 6:

0	0	-1	0	0
0	-1	-1	-1	0
-1	-2	16	-2	-1
0	-1	-2	-1	0
0	0	-1	0	0

-2	-4	-4	-4	2
-4	0	8	0	-4
-4	8	24	8	-4
-4	0	8	0	-4
-2	-4	-4	-4	-2

Figure 6: Log Template

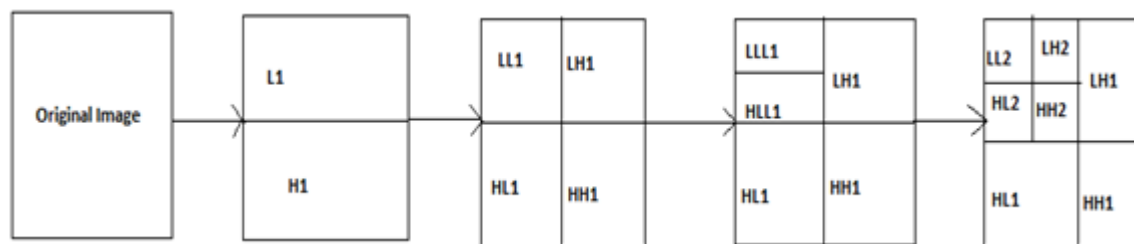


Figure 7: Wavelet Transform

Wavelet transform decomposes an image into four parts. Top left part (LL1) is approximation of the image which is similar to original image only on $\frac{1}{4}$ the scale. Other three parts HL1, LH1 and HH1 are gives information about horizontal, vertical and diagonal edges. Top left part (LL1) can further decompose into four parts. It is used in various fields such as radar, earthquake detection, turbulence, computer vision and image processing. There are different types of Wavelet such as Har, Daubechies, Bio-Orthogonal, Morlet, Coiflet, Symlets and Maxican Hat Wavelet [9].

4.2. Fuzzy Logic Based Edge Detection

The word ‘Fuzzy’ means vagueness, Fuzzy logic introduced by Lofti A. Zadeh in 1965 . A Fuzzy set is an extension of crisp set. In crisp set, membership of an element is either 0 or 1, but in fuzzy set membership of an element is in between 0 and 1. The word ‘young’, ‘tall’, ‘good’, ‘rich’ are fuzzy. For someone 20 year ages are young but other it is 30. For someone Rs 1 million means rich but others it is Rs 1 billion. In crisp set, membership value of 20 year age in young either 0 or 1. But in fuzzy set, membership value of 20 year age in young can be 0.7 or 0.65. Fuzzy logic can be used to detect edge in an image as non-linear filter. Fuzzy image processing are divided into three steps, they are image fuzzification, defuzzification and membership modification. The fuzzification method are used to convert crisp set image

4. Non Linear Edge Detection Operator

4.1. Wavelet Based Edge Detection

Wavelet based edge detection is a multi-resolution, scaling and non-linear method where it separates lower frequencies and higher frequencies very easily. Wavelet method is very effective to find edge in noisy and fuzzy image [9]. Wavelet is a signal which can be plot infrequency and time domain.

value to fuzzy set and defuzzification methods are used to convert fuzzy set to crisp output set[11]. Mainly if-then rules are used to calculation, comparison central pixel value to neighbor pixel value or membership modification.

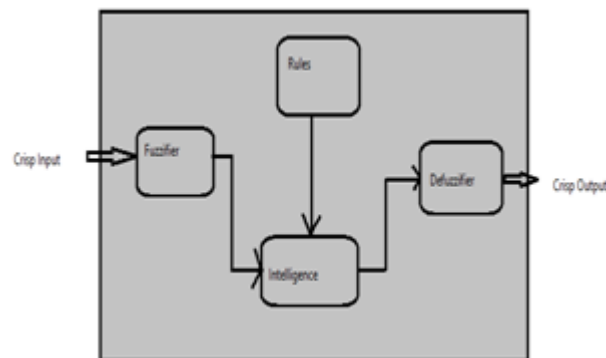


Figure 8: Steps involved in Fuzzy Image Processing [11]

4.3. Artificial Neural Network Based Edge Detection

Artificial Neural Network (ANN) represents human brain artificially using computer programs and tries to simulate the functional behavior of human brain. Like human brain, ANN consists of neurons whose function is to process the information and based on threshold function neuron send signal to the next node or neuron [10].

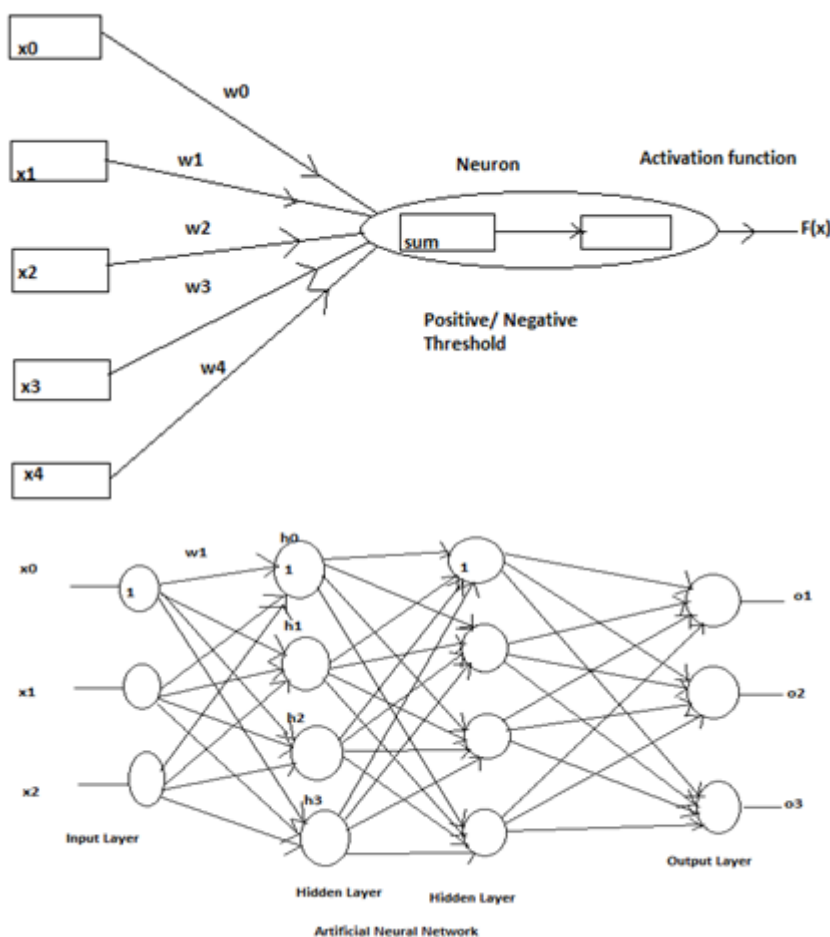


Figure 9: Model of an Artificial Neuron Network [10]

ANN consists of Input layer, Output layer and one or more hidden layer. X_0, X_1 etc are the weights of nodes and w_1, w_2 etc are weights of the signal from one node to other. Usually, a neuron transmits signal to next neuron if $\sum w_i \cdot x_i + b$ greater than some threshold value, here b is bias (default value normally 1). There are different types of ANN, which is Single Layer Feed Forward Neural Network, Multilayer Feed Forward Neural Network, Multilayer Perceptron and Feedback Artificial Neural Network based on the number of hidden layers or whether its neuron retransmits or back-propagates the signal which modifies the weight of the signal. In ANN edge detection method, it sends signal to 9 input nodes for a 3×3 filter and 16 nodes for a 4×4 filter. It will detect a pixel an edge or not based on activation function or threshold value.

5. Applications of Edge Detection

5.1. Remote Sensing and GIS

Edge detection helps to analyze different fields of GIS and Remote Sensing. Shi Guiming et al. detect edge of port and road remote sensing image using an improved Canny edge detection method with help of Otsu method [16]. In this method where lower and higher threshold points need to be set manually, it sets the threshold point adaptively. This helps to erase false edges. Using edge of GIS image taken from different times, we can compare between them to know

the changing structure of land, river or mountain. We can prevent hazards using information of structural change.

5.2. Healthcare

There are many applications of edge detection in Healthcare. Ionel-Bujorel Pavaloiu et al. presented a neural network architecture and procedure to extract edge and segment the element from Cone Beam Computer Tomography (CBCT) dental data [17]. The proposed neural network used standard deviation, gradient, maximum value, distance between the max value pixels, polar coordinate and order as input for a 3×3 block surrounding the candidate edge pixel [17]. Using edge detection method we can find tumors in brain. Nowadays it is a concern for the health of senior people. As some countries like Japan, Germany, Italy, Slovenia etc. have more average age or senior people than other countries. Countries like India have only 5 beds per 10,000 people. So it is a general concern globally and a research area where IOT-based surveillance systems automatically detect a senior citizen who feels uneasy or unwell. In these types of surveillance systems, edge detection plays a vital role.

5.3. Segmentation

Edge can segment different objects in an image which helps to further work on object identification, pattern recognition etc.

5.4. Stereo Matching

An image can be taken from different angle or sides using two or more camera and join them based on common point or edge of that image. We get 3D or more real view using stereo image.

5.5. Image Compression

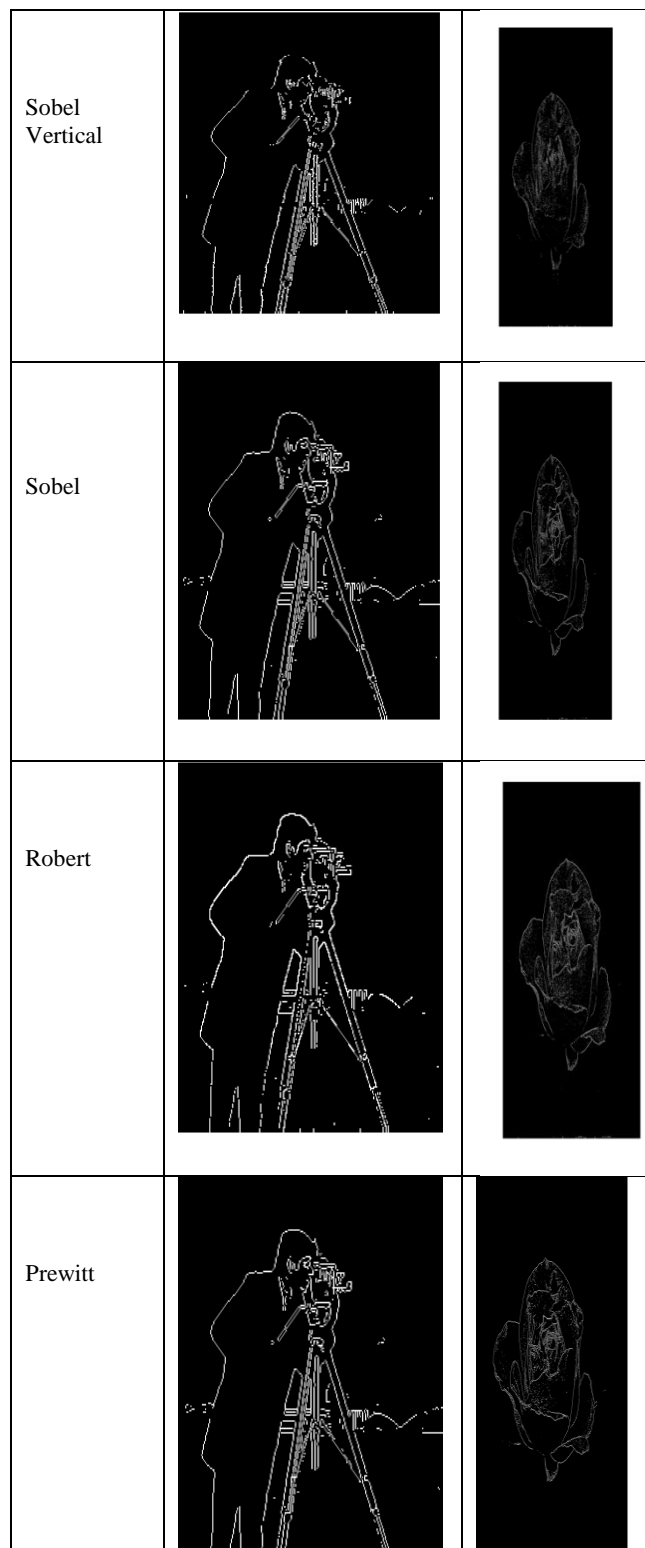
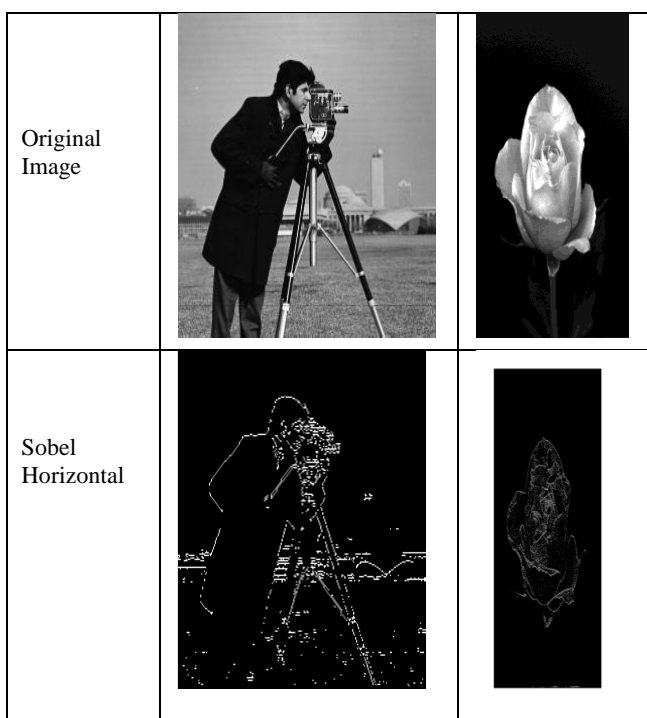
Compression means to reduce number of pixel or bit needed to present the image. In many cases detection of edge needed as edge represent basic structure of the image. Wavelet transform have proved to be an effective way to perform edge detection and compression of an image [18].

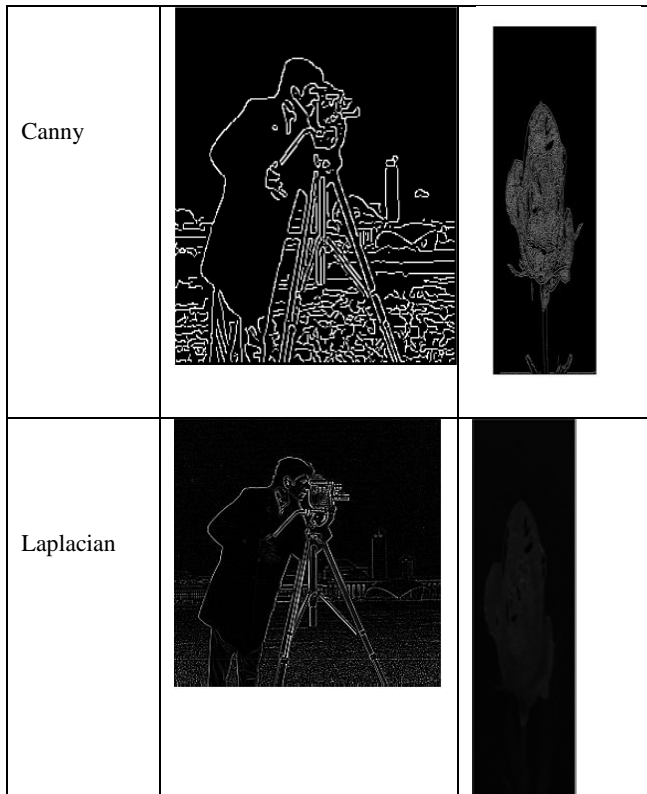
5.6. Machine Vision

Machine vision or computer vision play important roles in industry where a machine or robot can able see and predict the object like a human being. This has different parts like capturing an image using digital sensor, analyze the image, take action according to that etc. There edge detection plays a vital role [19]. Machine Vision play a vital role in industries nowadays like driverless car like tesla, defect product analysis automatically by machine or robot, theft detection in surveillance system etc.

6. Result and Discussion

Images after applying different Edge detection operators on cameraman and rose are given below:





Peak signal to noise ratio (PSNR), Structural similarity index (SSIM), Entropy, Mean square error (MSE) of segmented image after applying different edge detection operator are given below table.

	<i>psnr</i>	<i>ssim</i>	<i>Entropy</i>	<i>MSE</i>
<i>Robert</i>	13.2944	0.8309	0.7675	3045
<i>sobel</i>	13.2996	0.8304	0.797	3042
<i>prewitt</i>	13.2906	0.8299	0.7962	3048
<i>canny</i>	13.243	0.8291	0.8393	3082
<i>Laplacian</i>	13.4897	0.8191	1.329	2911

7. Conclusion

In this paper discuss about varies linear (Robert, Sobel, Prewitt, Canny, Log etc) and non-linear (Fuzzy, ANN, Wavelet etc) edge detection methods. Sobel edge detection generates less edges compare to other methods. In Robert edge detection, generated edges are more than others but not smooth enough and also contain lots of false edges as noise also have high intensity. Prewitt edge detection methods are generating more clear edges than Robert and Sobel method but not as good as Canny method. In LOG method, edges are quite similar to Canny method but not clear as Canny[8]. Compare to linear edge detection non-linear edge detection like ANN perform well on noisy or fuzzy images. ANN also has adaptive characteristics. There is a limitation of normal edge detection as threshold value is fixed. It is a challenge of select edge using dynamic threshold value.

8. Future Work

We want to segment different objects in an image using edge detection methods. Then identify different object using pattern recognition based on object texture, colour, feature or object motion. Train the computer about features of some

objects and try to match that object presence in an image based on those features.

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