Current Journal of Applied Science and Technology

Volume 42, Issue 24, Page 22-31, 2023; Article no.CJAST.104822
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Real-time Comparison of Performance Analysis of Various Edge Detection Techniques Based on Imagery Data

Rajshree Kumari [a] and Divyanshu Chandra [b*]

[a] Teaching Personnel, Department of Computer Engineering, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India.
[b] Teaching Personnel, M.C.A. Programme, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2023/v42i244178

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/104822

Original Research Article

Received: 03/06/2023
Accepted: 05/08/2023
Published: 12/08/2023

ABSTRACT

Edge Detection is one of the most essential steps for image processing to identify and detect discontinuity in intensity variation. It is an effective and an efficient tool to recognize different properties of an image such as shape, contrast, color, scene analysis, image segmentation etc. The technique is very important to recognize all the edges accurately. It helps in object recognition, pattern recognition, medical image processing, motion analysis etc. There are many edge detection operators available in image processing. This paper illustrates the performance analysis of the most commonly used edge detection techniques including Canny, Sobel and Prewitt, highlighting their advantages and disadvantages with respect to different types of datasets. After analyzing various parameters like Accuracy, Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), Edge Detection Processing Time and Qualitative Human Visual Perception on two diverse type of datasets, varied results are found with respect to the techniques used. Among them, the most

**Corresponding author: E-mail: divyanshuchandraarya@gmail.com;*

accurate and fast computed edge detection technique which gives better results on both type of datasets is concluded. Although the Sobel edge detection technique gives relatively poor result and weak performance of detection of edges, however it can be modified and further improved with respect to future work. The entire analyzing process was done under Scilab software.

Keywords: Edge detection; image processing; canny edge detection; edge detection techniques; image enhancement.

1. INTRODUCTION

Edge detection is a fundamental tool, which is commonly used in many image processing applications to obtain information from images and frames. [1] In the region of an image itself, the change of the pixel value is relatively stable, while the change of the pixel value at the edge is usually intensive and transitional [2]. An image is composed of different information; this information contains the different properties of an image such as shape, size its orientation, and color of the image. An edge can be defined as the changes in texture, shade, color, and light, etc. The separation of the image into object and background is a critical step in image interpretation [3]. Edge detection is difficult when an image is corrupted by noise and this process takes time to detect edges. In an Image, objects can be found easily and more accurately when edges of images could be recognized easily and efficiently [4]. In image processing edge detection is a very important and main technique for the whole process, and the application of edge detection techniques is very broad in image processing fields such as pattern, object recognition, motion analysis, and the medical field, etc. [5]. Edge detection is used in the area of object recognition, image analysis, computer vision, image segmentation and image processing [6]. Edge detectors can be affected by different variables such as noise environment, edge structure, edge orientation, and luminance, etc. The different edge detection techniques are Canny, Sobel, Prewitt, LOG and Robert, etc. to affect the performance of these edge detection techniques certain performance parameters are there such as PSNR (Peak Signal to Noise Ratio), Mean Square Error, L2RAT, and Maximum Squared Error, etc. So much research work, studies, and analysis have been done to detect edges more efficiently and accurately and to remove the drawbacks of the previous research work various techniques have been developed and have their pros and cons.

1.1 Edge Detection

An edge is known as the discontinuity or lack of continuity occurs in an intensity. The edge component consists of edge normal, direction, position or center and edge strength. There are different types of edge detection type such as step, line, step and junction edge. edge detection uses a method of intensity variation and abrupt changes in pixel intensity gray level value. in a conceptual point of view edge detection techniques are categorized into two groups; contextual and non- contextual approaches. Contextual methods are guided by a theoretical knowledge and work accurately only in exact context about the edge. The non- contextual method guided theoretically knowledge and not limited to specific image.

1.2 Edge Components

- **Edge Normal:** It is a unit vector in direction of maximum intensity change which is depicted in Fig.1 .

$$e\_o(i,j) = atan\, jx|Jy$$

Fig. 1. Edge normal formula

(Where: i & j are the image co-ordinates.)

- **Edge Direction:** unit vector perpendicular to the edge normal.
- **Edge Position or Center:** it is a position of an image where edge is located.
- **Edge Strength:** local image contrast along the normal depicted in Fig.2.

$$e_{s(i,j)} = \sqrt{J_x^2}(i,j) + J_y^2(i,j)$$

Fig. 2. Edge Strength Formula

1.3 Related Work

So many studies have been done to obtain the best and most efficient edge detection techniques for image processing to be used in different fields whether it is for small regions or large areas. Every detector detects edges for a specific region some find the fine edges, and others find the thick edges. these edge detectors with different properties can be used in wide

technologies, so it is important to study these edge detectors in a different dataset to know their property more accurately.

Tapan, Chutiwan and Guanghui evaluated the performance of different edge detectors for different dataset such as THEOS Satellite images, Big data Platform Spark and SQI images respectively. Based on their result they had concluded that Canny took more time for computation while other edge detectors scaled very well. They have also noticed that there is some noise in all real life images in a certain degree. By using some performance parameters, they have concluded that Canny and LOG algorithm gives best result with lowest MSE value.

On the other hand, many conventional studies have been done in edge detection techniques on the basis of their performance. Indrajeet kumar and P. Selvakumar conclude in their analysis that Prewitt have a major drawback of being very sensitive to noise and canny depends on the adjustable parameters. They concluded that blurring is very important for noisy image to detect larger images. Canny edge detection technique is very flexible to several noisy stages comparing to other edge detection technique with minimum processing time.

2. MATERIALS AND METHODS

The tool used here is scilab software which has an open environment to change the data dynamically. Also the data used for real time dataset from our own surrounding. Only three type of edge detection techniques are used here which are Sobel, Canny and Prewitt. The following methods have been used for edge detection comparison and analysis.

Steps involved in Edge Detection: It consists of three major steps which are filtering, enhancement and detection:

- **Filtering: -** Images are often corrupted by noise which is a variation on intensity values, common types of noise are salt and pepper, impulse and Gaussian noise. Salt and pepper noise contains random variation of both black and white intensity values. However, the more filtering done to reduce noise result in loss of edge strength [7].
- **Enhancement: -** To facilitate the detection of edges, it is important to determine changes in intensity in the neighborhood of a point. Enhancement emphasizes pixels where there is significant change in local intensity values and it's performed by computing the gradient magnitude [8].
- **Detection: -** Points in image have a non-zero value for the gradient and not all of these points are edges for a particular application. So a method is created to determine which points are edge points. Frequently, Thresholding provides the criteria used for detection [9].

Edge Detection Techniques: There are different type of edge detection techniques categorized into two types Gradient based and laplacian based edge detection technique [10]. Some of them are following:

- **Sobel:** Sobel edge detection techniques comes under the Gradient based edge detection technique. It was invented by Sobel Irwin Edward in 1970. Sobel edge detection technique uses maximum points during the process of edge detection. Sobel operator used the technique in which output pixel values are simple linear combinations of input pixel values. This operator is used to detect thicker edges only horizontal and vertical gradients. Sobel did not detect any diagonal edges and it operates on 3*3 convolution kernels as shown in Eq.1. The sobel kernals are more suitable to detect edges along the horizontal (180 degree) and vertical axis (90 degree) [3]:

$$Gx = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \quad Gy = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \qquad (1)$$

- **Prewitt:** Prewitt edge detector also comes under the gradient based edge detection technique. It was discovered by Judith M. S. Prewitt in 1970. It is similar to sobel and less sensitive to noise as compare to Robert edge detection technique. It detects edge horizontally and vertically. It uses the fundamental of intensity measurement of an image by increasing the intensity from dark and light. The 3*3 kernel convolution masks used in prewitt operator prevents the blurring and extra obstacles occur in an image shown in Eq. 2. It is used to calculate magnitude and orientation of an image.

$$Gx = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \quad Gy = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \qquad (2)$$

- **Canny:** Canny operator comes under the laplacian based edge detection technique. It was invented by Canny John F. in 1986. It is complex in nature but gives better and advanced results. Canny detects the edges by extracting the features without disturbing the features of an image and it is less susceptible to noise. The aim of canny is low error rate and it consumes more time to compute. Eq. 3 shows the 3*3 kernel pairs which can be used to calculate the density of gradient. Also it uses Gaussian filter before applying the mask to overcome the noise defect.

$$Gx = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad Gy = \begin{bmatrix} -1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \qquad (3)$$

Parameters Used for Analysis:

- **Peak Signal to Noise Ratio:** Peak Signal to Noise Ratio (PSNR) is used in image processing for quality measurement between original image and compressed image and measured in decibels. To increase the quality of the compressed image the PSNR value should be high. It can be calculated by using this equation (Fig.3):

$$PSNR = 10 \llbracket log \rrbracket \_10 \ (R\hat{}(2)/MSE)$$

Fig. 3. Formula for peak signal to noise ratio

R is the maximum fluctuation in the input image data type. For every gray level image, the value of R is taken as 255 where the value of every pixel is represented as 8-bit integer [11].

- **Mean Square Error:** It represents the increasing squared error between the compressed and original image. The lower value of MSE represents a low error rate. Fig. 4 represents the formula for Mean Squared Error.

$$MSE = (\sum\_(M,N) \llbracket ((I1(m,n) - I2(m,n)) \rrbracket \hat{}2)/(M * N))$$

Fig. 4. Formula for Mean Squared error

Where M, N are the number of rows and columns [12].

Tool used: The comparison analysis is done using Scilab software. Scilab stands for Scientific Laboratory. Scilab is a numerical, programming and graphics environment available free from the French Government's "Institit Nationale de Recherche en Informatique et en Automatique-INRIA (National Institute of Informatics and Automation Research) since 1990. Scilab has an open environment for programming where the libraries and function creation are completely in users' hand. In the interpreted environment interfaced with FORTRAN and C subprograms that allow using standardized packages and libraries. For The biggest feature of scilab is its free multiplatform available for Windows, Linux and MacOS X.

Methodology:

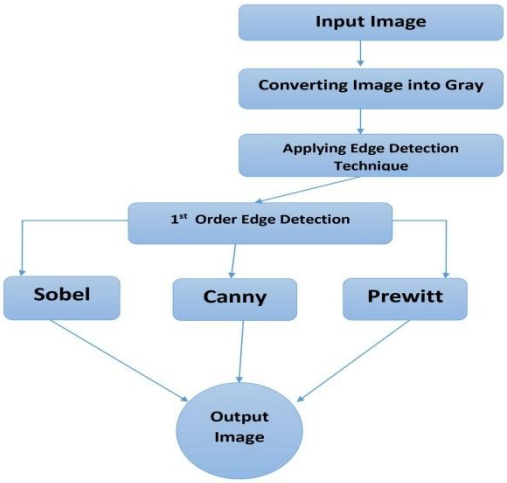

Fig. 5. Flow chart of methodology

For detecting edge of any image there are many ways and techniques are available, in this research main algorithms are applied i.e. Canny Sobel and Prewitt which are 1st order edge detection techniques.

Step 1: First read the color image and save into any variable.
Step 2: Now converting the color image into gray scale image for detecting edges.
Step 3: Applying edge detection operators one by one
Step4: Comparing the all edge detectors results and identifying the best edge detector in terms of sharp and false edges and noise.

3. RESULTS

3.1 The Comparison and Analysis of Simulation Result

In each of the dataset (real life or standard) the main workflow remains as it is. We checked the performance of each edge detector under different criteria such as performance parameters, threshold and computation time. Here we used two type of datasets; real life datasets and standard dataset.

The image shown below in Fig.6 is a comparative window of result. In which it shows the Image of edge detection comparison window, image after applying threshold and the histogram analysis of an image.

Table 1 represents the values of maximum, minimum and mean of the time taken by the real time image and standard images, the table shows that in real time image time is always approximately constant whereas in standard images vary a lot as compare to real time images.

The graphs show the performance parameters we used such as PSNR (Peak Signal to Noise Ratio) and MSE (Mean Square Error). Fig.8 and Fig. 9 represents the PSNR (Peak Signal to Noise Ratio) performance analysis, the higher value of PSNR gives better quality of an image, so the PSNR value should be high. we can see that real life image dataset has the highest PSNR value which comes under the Prewitt edge detection.

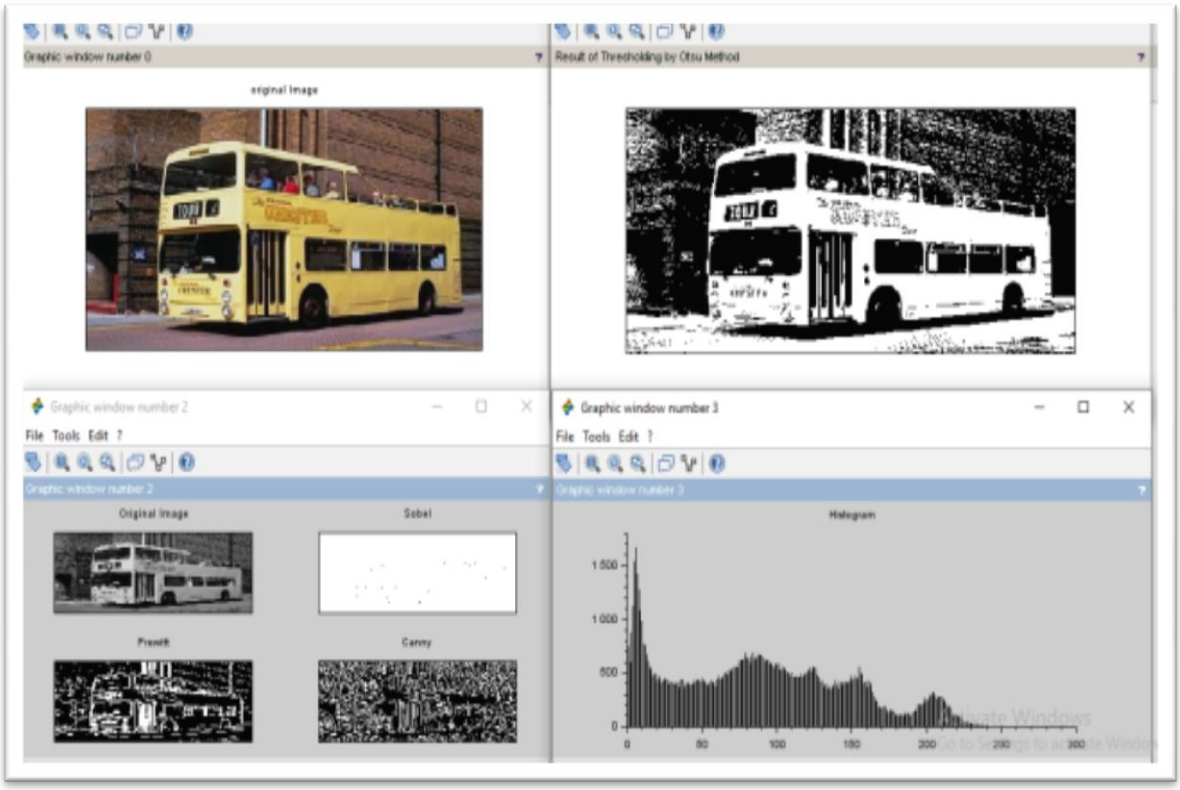

Fig. 6. Comparative window of result

Table. 1 Table of minimum, maximum and mean time of images

Image	Real time Images			Standard Images		
	min(t)	max(t)	mean(t)	min(t)	max(t)	mean(t)
1	0.051248	0.069269	0.0.11803	0.048582	0.076444	0.064197
2	0.043926	0.062518	0.052936	0.059733	0.070929	0.065577
3	0.04254	0.051047	0.0473	0.044677	0.069312	0.053682
4	0.048864	0.065915	0.060363	0.046225	0.063295	0.056314
5	0.046745	0.05402	0.049694	0.042686	0.057747	0.050952
6	0.041253	0.048561	0.045347	0.048397	0.100325	0.064249
7	0.042731	0.058528	0.051385	0.040162	0.068511	0.055006
8	0.04294	0.052131	0.046922	0.049396	0.065685	0.057388
9	0.042483	0.052464	0.048774	0.039026	0.055704	0.048569
10	0.042608	0.054929	0.047072	0.044367	0.05933	0.053655

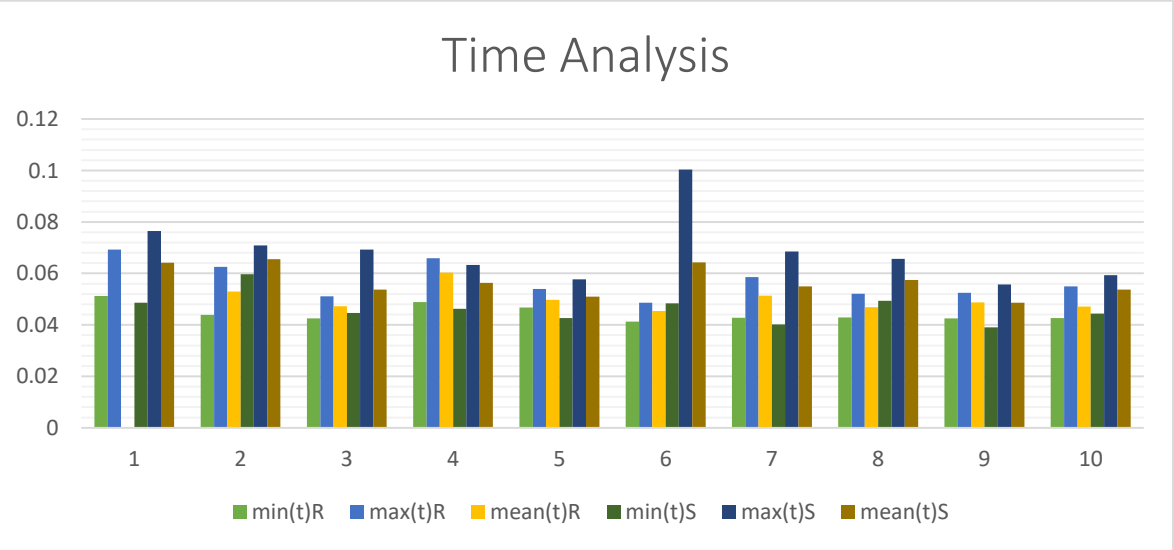

Fig. 7. Minimum, maximum and average time of process

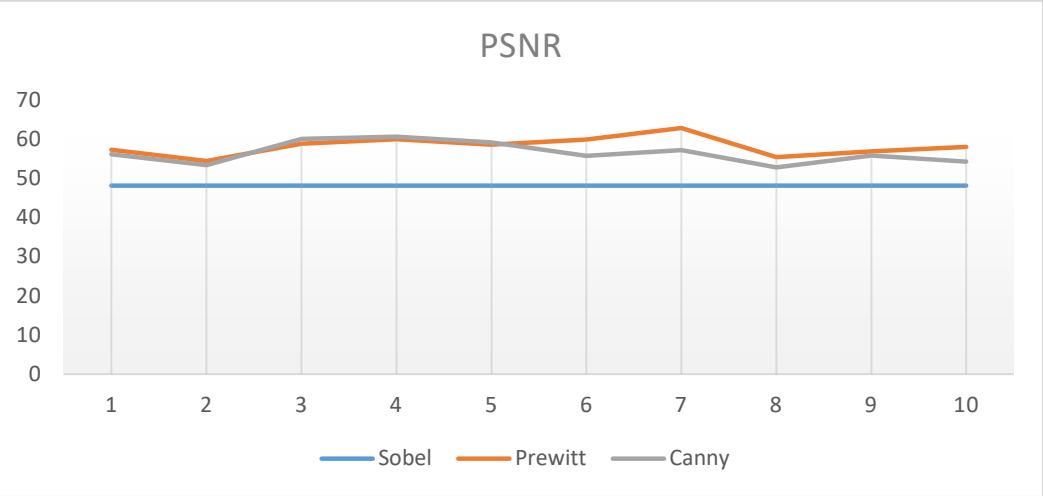

Fig. 8. PSNR graph of Sobel, Prewitt and Canny(real images)

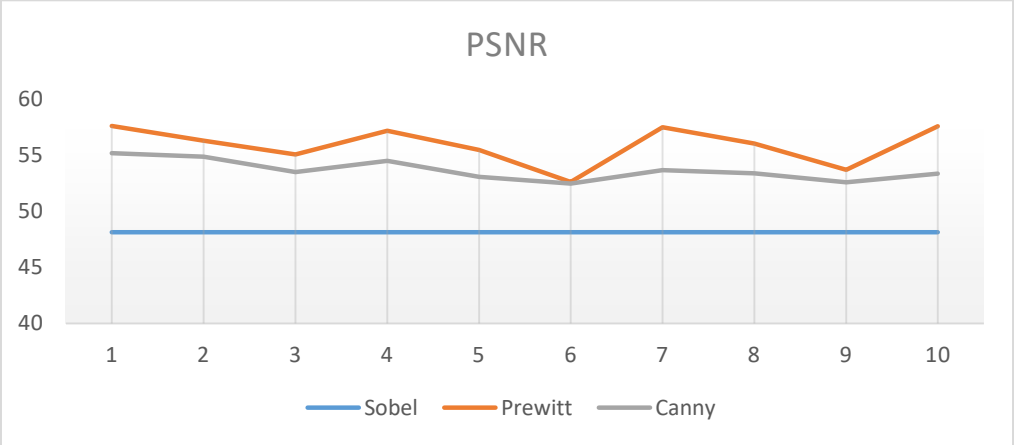

Fig. 9. PSNR graph of Sobel, Prewitt and Canny (Standard Images)

In Fig.10, It represents the MSE (Mean Square Error) performance analysis, the lower the value of MSE giver lower error rate, so it must below. As our result shows that the Real life images has the lowest MSE value which indicates the lower error rate.

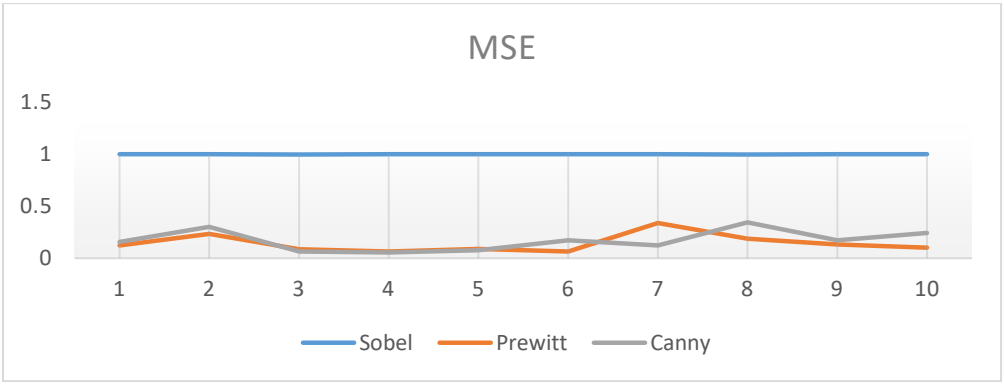

Fig. 10. MSE graph of Sobel, Prewitt and Canny(real images)

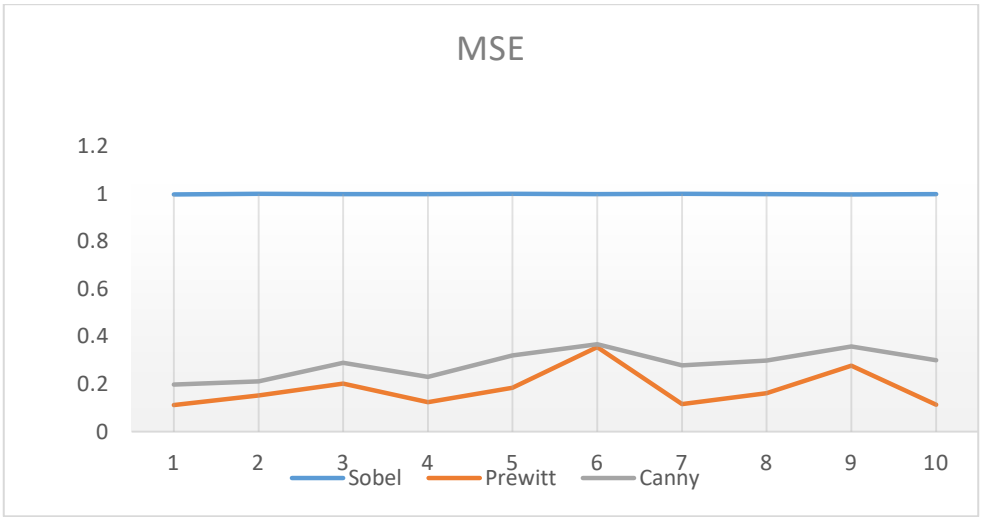

Fig. 11. MSE graph of Sobel, Prewitt and Canny(Standard Images)

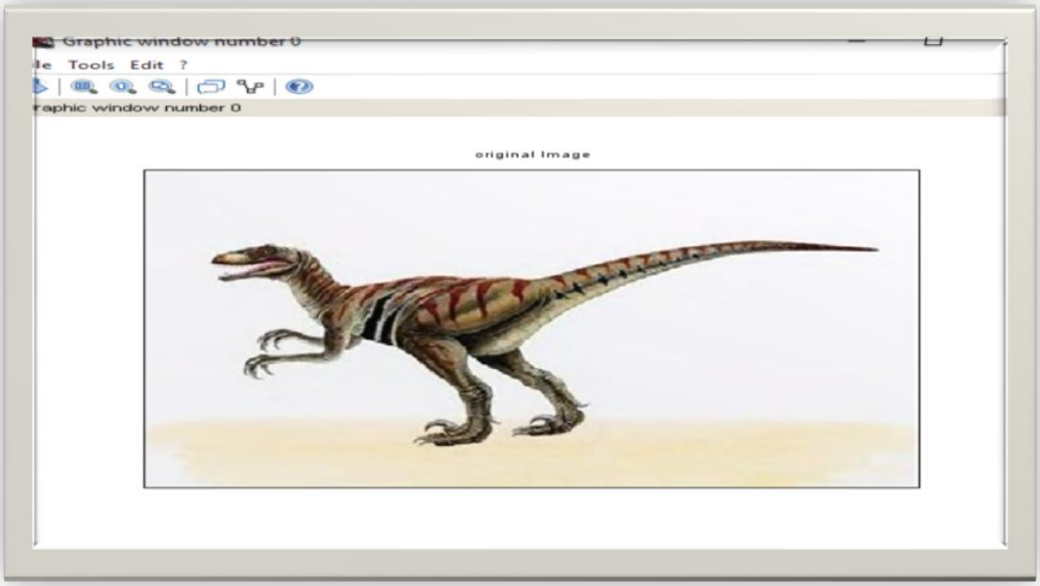

Fig. 12. Object image (Standard Image)

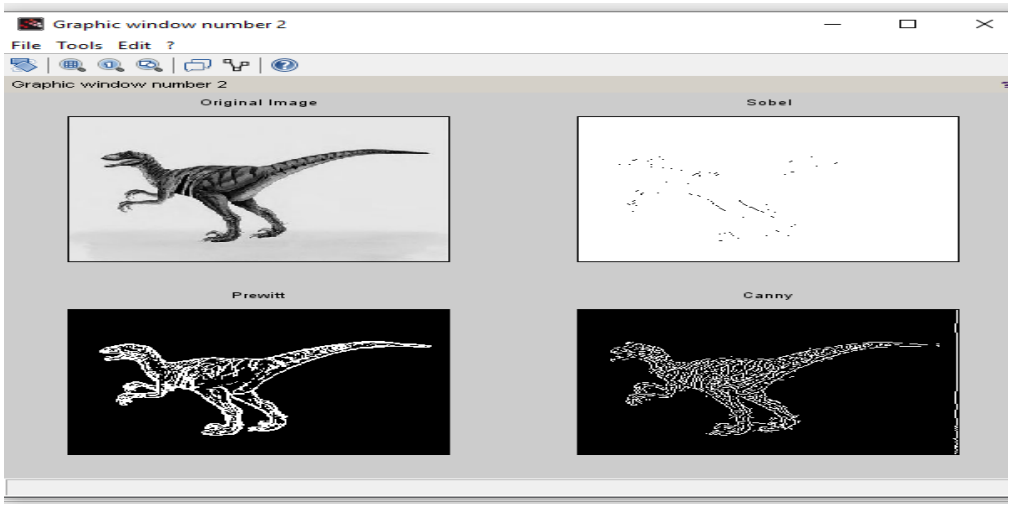

Fig. 13. Comparison window of edge detection techniques

The above Fig.12 and Fig.13 shows the example of standard image dataset. In which the edge detection analysis is done. As we can see in our result that Canny edge detection provides most of the fine edges in which it is hard to identify the object but Prewitt edge detection shows the combination of thin and thick edges which is useful to distinguish the object which clearly shows that prewitt works better and find edges more accurately.

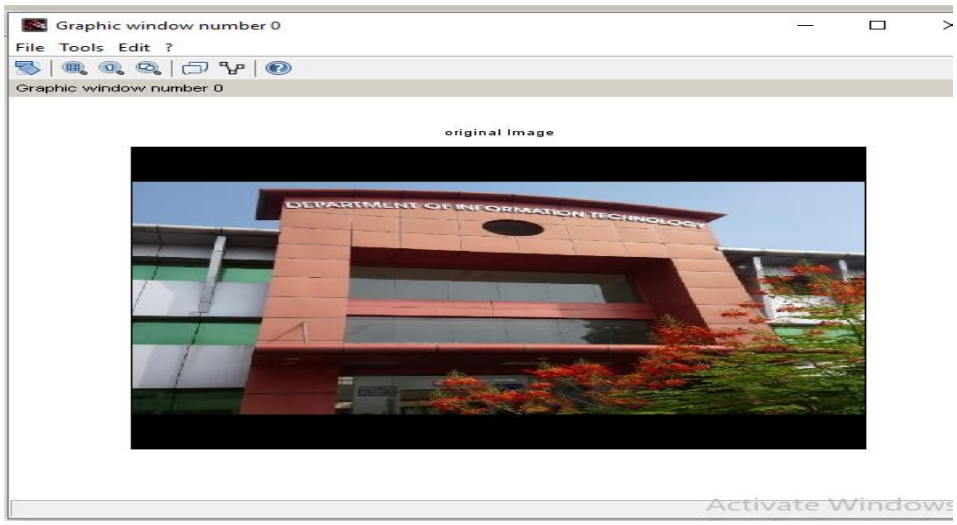

Fig. 14. Object image (Real Image)

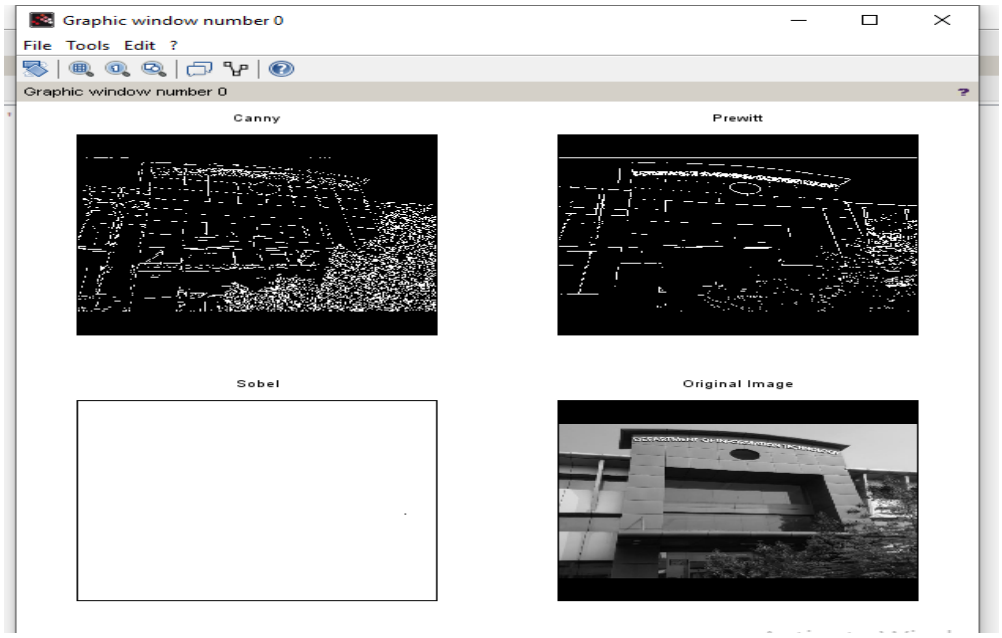

Fig. 15. Comparison window of Edge detection techniques

The above Fig.14 and Fig.15 shows the real life image of Department of Information Technology of Pantnagar University. In which the edge detection analysis is done. The goal of edge detection is to make something that looks like a line drawing of an image [13]. We can see in our result that Canny edge detection provides most of the fine edges in which it is hard to identify the object but Prewitt edge detection shows the combination of thin and thick edges which is useful to distinguish the object.

4. DISCUSSION

In both the cases real life dataset perform better in performance with higher PSNR and lower

MSE value. On the other hand, the comparison analysis of edge detection shows that Prewitt works better in real life images as well as standard images whether in performance analysis or detecting edges. Prewitt can find both type of edges whether they are thin or thick edges, and because of this combination it gives better object recognition. Canny works well also but it can be used for detecting very thin edges with the disadvantage of it cannot detect object very precisely because of detecting small amount of intensity variation. Sobel gives a very bad performance for small objects because it is used for detecting thick edges so sobel is best fit for detecting satellite images of large geographical area images.

5. CONCLUSION AND FUTURE SCOPE

In our proposed work we have used two type of image dataset for comparison some further research can be done by using more than two type of image database or big amount of database. In addition, future research can be done using other edge detection techniques or different types of parameters can be used for comparison and one can apply it on any cloud computing platform containing millions of images. Future work can also be done for video edge detection and an improved sobel edge detection technique can be proposed which can detect thin edges also to overcome the disadvantage of limitation of geographical area. In future work the platform of comparison can also be change.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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