Analysis of the Performance of Various Edge Detection Techniques in Detecting Prominent Edges in Plant-based Images

Radhika Kamath*, Dr. Mamatha Balachandra** and Dr. Srikanth Prabhu***
*Assistant Professor, Department Of Computer Science and Engineering, MIT, Manipal, India.
radhika.kamath@manipal.edu
**Associate Professor, Department Of Computer Science and Engineering, MIT, Manipal, India.
mamtha.bc@manipal.edu
***Department Of Computer Science and Engineering, MIT, Manipal, India.
srikanth.prabhu@manipal.edu

Abstract: Edge detection is a process of detecting the sharp intensity discontinuity in digital images. More commonly these discontinuities are found on the boundary of the objects in images. So edge detection is the significant step in identifying the objects in the digital images or in segmenting the image. Edge detection in digital image processing is achieved by convolving a 2-D image with a spatial filter which may be based on first order or second order derivatives. There are many classic edge detecting operators like Canny, Sobel, Roberts, Prewitts..etc. The goal of this paper is to analyze the performance of various edge detecting techniques in detecting prominent edges in plant-based images with the intention of getting clear boundaries of the leaves. That is, in this case we are interested only detecting the prominent edges which form the boundaries of the leaves. Many plant-based images particularly agricultural images consists lots of overlapping. These overlapping may be complete or partial. For instance, the leaves of crop may be partially overlapped on the weed plant or weed leaves. So applying edge techniques on these images and analyzing their performance gives us good understanding of these edge detecting techniques and how well these techniques can be used as initial processing steps in computer vision system in segmenting the weeds among crops.

Keywords: Edge detection, precision agriculture, computer vision, segmentation, crop, weed.

Introduction

Technological advances in recent times have made a big difference in the way the agronomists, farmers can gather and analyze data. Automated livestock management, precision weed control and measurement of phenotypic characteristics of the plants and crops all allow us in attaining good yield and profit with less input. The main concept behind these systems is *Computer Vision.* It is defined as the process of analyzing images and videos to automatically obtain meaningful inference or measurements without human intervention. Precision Agriculture is defined as 'art and science of enhancing crop production using latest technology' [1]. Since many years we are using technology in agriculture such as mechanical harvester, various sensor networks to know about current environmental condition and also to predict environmental changes that may happen in near future. Now computer vision is the latest technology that is being used in the agriculture. Main reason of using computer vision in agriculture is to eradicate wide-scale application of chemical herbicides and to favor the development of environmental friendly and non-chemical methodologies.

The Since edge detection is in the forefront of computer vision system for detection of vegetables, fruits and food grains needs to quality inspection and evaluation, it is crucial to have a good understanding of edge detection algorithms. In this paper the performance analysis of various Image Edge Detection techniques is presented. Edge pixels are pixels at which the intensity of an image function changes abruptly and edges are sets f connected edge pixels. Edges are resulted due to various reasons like surface normal discontinuity, depth discontinuity, surface color discontinuity, illumination discontinuity. There are three steps performed in edge detection. They are

(i) Image smoothing for noise reduction: noise can have significant impact on the derivatives. So it is important to reduce the noise before using edge detection techniques.

(ii) Detection of edge points: this is a local operation that extracts from an image all points that are potential candidates to become edge points.

(iii) Edge localization: the objective of this step is to select from the candidate points only the points that are true members of the set of points comprising an edge.

There are many edges detecting operators with the help of which are based on first-or second-order derivatives, that is, gradient based or Laplacian.

Gradient-based
The gradient method detects the edges by looking for the maximum and minimum in the first derivative of the image.

Laplacian
The Laplacian method searches for zero crossings in the second derivative of the image to find edges. An edge has the one-dimensional shape of a ramp and calculating the derivative of the image can highlight its location.

Problem Statement and Research Questions

Problem Statement
Edge detection is one of the fundamental steps in image processing. It is one of the important steps in image segmentation in most of the cases. It is important to study the performance of various edge detection techniques to analyze which technique is appropriate in a given scenario. Also there is possibility that these techniques sometimes detects false edges, some of the true edges goes undetected , some of them detects too thick edges or too thin edges, that is, edge quality will not be good. Also presence of noise plays an important role. Most of the research work that has been carried out on the standard images which did not had any illumination problems. So determining edges is a smooth journey in this case. Many studies which has taken noisy images to evaluate the performance of the edges detection techniques have not used images which are plant-based. The point we are trying to make is that, in plant-based images as shown the below figure, which consists of rice crop and weed, we can see crop leaves and weed leaves overlapping.

Figure 1. Rice crop and weeds in a paddy field

In this type of images it is very difficult to segment crop and weed. No work has been carried out to analyze the performance of edge detecting techniques on these types of images which is crucial in Computer Vision application in agriculture or we can say precision agriculture which will be helpful in segmenting crop and weed. Also performance is not analyzed against ground truth information.

- The first purpose of this study is to investigate effectiveness of the edge detection techniques in detecting prominent edges in agricultural/plant-based images by comparing against ground truth images.
- The second purpose is to study the effect of non-uniform illumination on the performance of the edge detection technique.

Research Questions

1. Is analysis effective if done against ground-truth images?
2. What is the relation between illumination and quality of the edges?

Rationale for the Research

Segmentation is a process of differentiating objects from the background. We can say that intention of segmentation is to find the desired objects in the images. There are mainly four approaches to image segmentation. They are threshold techniques, edge detection techniques, region-based techniques, and connectivity preserving relaxation methods. Most popular and widely used technique amongst these four techniques is “edge detection”. The level of the subdivision has to stop when the object or image of interest have been partitioned. Picking up an appropriate technique for “good” segmentation is a challenging task.
Edge detection is a technique in which the points where image brightness changes sharply or formally are identified. These points are organized under line segments called edges. Edge detection also aims to classify and place discontinuities in an

image. Noise and image both have high frequency, hence edge detection becomes difficult. The main objective of studying various edge detection techniques and analyzing their performance is due to problems such as fake edge detection, noisy images, missing edges etc. For the computer vision system in agriculture which will detect and identify weeds to work efficiently is possible only if appropriate and suitable edge detection is used which detects the various edges and hence aids in segmenting the crop from weeds. So through this research study we will know which edge detecting techniques works better for agricultural images where partial overlapping of leaves belonging to crop and weed is very common and is able to find edges.

Literature Survey

[2] discusses the performance of three edge detection operators namely Sobel, Roberts and Prewitts. MATLAB R2013a. The limitations of each operator are identified and performance is done based on the obtained result. According to the paper, the Prewitt gives better result than Sobel and Roberts based on intensity value. While Sobel provides a better approximation to gradient magnitude, it locates the edges containing highest gradient. Since the filter is small, Roberts produces results very quickly than Sobel and Prewitt. Finally from the above analysis, it is observed that each operator is considered as the best under various conditions. The analysis is done only on three operators.

[3] Discusses the performance of edge detection operators namely Canny, Sobel, Roberts and Prewitt. The comparative analysis is done using Pratt figure of merit (PFOM) method. PFOM is used for mathematical comparison of edge detection techniques used in digital image processing. The value given by PFOM ranges from 0.1 to 1. The edge technique whose value is close to 1 is the one which gives best result. The paper says that Canny gives best result. The analysis is done for only noise parameters and other factors like illumination are not taken into consideration.

[4] Discusses the performance of edge detection techniques used in detecting the boundary of leaves. The paper compares novel approach called as Dyadic wavelet transform with Sobel, Canny, LoG, Roberts and Prewitt. It has been found that Dyadic wavelet transform performs well when compared to Sobel, Canny, LoG, Roberts and Prewitt and takes less time for giving the results. Here authors worked only with individual leaves and not with leaves on plant.

[5] A Survey on Monochrome Image Segmentation Methods, this paper discusses most of the edge detection techniques like Sobel, Robert, Prewitt, LoG, thresholding, multiple thresholding, optimal thresholding, local thresholding, Otsu, Canny edge detection technique. Work is implemented using MATLAB 7.12 for different monochrome image datasets which includes natural images, Aerial images, medical images, text images, Circuit board images. It is observed that execution time for methods based on second derivative is more when compared to first derivative based methods. Similarly execution time for multiple thresholding is more.

[6] A Survey on Various Edge Detector Techniques, discusses the performance of various edge detecting operators like Sobel, Prewitt, Robert, Canny, LoG (Laplacian of Gaussian), basic declivity operator and modified declivity operator. It is observed that modified declivity operator finds most of the true edges even from low contrast images and hence it performs better than other operators.

[7] this paper discusses about using edge detection techniques on square pixel images, hexagonal pixel images and enhanced hexagonal pixel images. It is observed that Canny, Sobel, Prewitt, Roberts gives low quality edges when compared to LoG. The comparison is done on two parameters MSE (Mean Square Error) and PSNR (Peak signal-to-noise ratio). It has been observed that having PSNR and MSE high yields in very effective edge detection. Also it has been observed that Laplacian of Gaussian works better in hexagonal pixel images and enhanced hexagonal pixel images by detecting both weak and strong edges.

[8] discusses the use of various edge detecting operators used in identification of cartridge case images. Identifying of firearms or cartridges from the images of crime scene will become most important step in resolving many forensic issues. In this paper, authors have worked with many edge detecting techniques on the images consisting of cartridge cases with aim of identifying the that might have been used in the crime. They have worked with both gradient-based and Laplacian-based techniques and have got good result for Canny edge detecting technique when compared to other such as LoG, Sobel, Prewitt ..etc.

[9] discusses various edge detecting operators by considering PSNR(peak signal-to-noise ratio) and MSR (mean square error). Implemented and evaluated in MATLAB and Java. As input to the experiment universally standard images were considered. MSE and PSNR were common for all images. It has been observed that Canny detected most of the edges hence its performance is good when compared to Sobel, Prewitt, Roberts, LoG. But processing time of Canny is more when compared to others and Prewitt operator took least time for giving the results.

[10] discusses the performance of various edge detecting operators used segmentation of different objects in digital and optical image processing techniques. The implementation is done in MATLAB and as input image, brain image is used. The edge detecting techniques that were evaluated for performance are classic edge detecting operators like Sobel, Prewitt, Roberts, and Canny and bipolar edge detection techniques which is mainly used in optical image processing. The conclusion in this paper is that Canny has superior performance when compared to others and it detected all edges.

In [11], the evaluation of performance of edge detection techniques is done for the input images which were colored. Three edge techniques were considered. They are Sobel edge detector which was extended from monochrome edge detection, Vector Range operator (VR) which is based order statistics and Difference vector operator (DV). Qualitative and quantitative measures are both used in evaluating the performance of above mentioned three edge detecting operators. Also performance evaluation with respect to noise and subjective evaluation is also done. Overall it has been found that DV and VR have good performance especially to noise but at the expense of cost in computing. Also it is found that the edge produced by DV is more clearly perceived by human eyes. These two operators were altered using suitable parameters for greater noise performance.

In [12], discusses the performance of various classic edge detecting operators like Sobel, Prewitt, Roberts , LoG and Canny. The evaluation is based on statistical evidence with respect to edge map. As there cannot be ground truth for edge maps, the edge maps created by each detector are studied relative to each other through statistical evaluation. It was found from this statistical analysis that Canny operator performed very well in most of the cases.

In [13] the comparison of various edge detection algorithms is discussed. As input image, an image of tree rings is taken for evaluation. As per the result, it has been found that Canny operator was able to detect most of the rings in the image when compared to other techniques.

In [14], discusses the comparison of various edge detecting techniques used for steganography. The secret information is added to the edges of images. As the edges appear in a random way, secret information also encoded in that way. The all secret information is retrieved fully if are able to detect the edges very efficiently. In this paper, each of the edge detecting techniques use Otsu's thresholding to detect the optimal edges which are then used to embed the secret message using LSB (least significant bit) algorithm. The output images where analyzed on payload capacity. Canny performs better because of its high payload capacity, low PSNR and high MSE.

In [15], comparative analysis of various edge detection techniques has been done in context of object extraction on satellite images. The satellite images were taken from Indian satellite agency covering Bhopal. It was found the Canny technique finds most of the edges. Other techniques like Sobel can be used because of its less time complexity. Bandwise analyses of the algorithms for the suitability for exact extraction various objects. Features which resemble straight lines can be well extracted by infra-red band.

In [16] images of dental x-rays are taken into consideration. Two edge detection operators are analyzed. They are Prewitt and Sobel. It was found that both gave nearer edge. It was also found that after applying Gaussian filter much clearer edges were detected which helped in improved feature extraction. Thus smoothening and sharpening have greater effect on in disease diagnosis in medical images.

In [17], author says that edge detection in Computer Vision (CV) applications reduces unwanted data from the images and is one of the important step in CV domain. Experimental tests were carried out using MATLAB. The result obtained showed that edge detection using declivity operator performs well when compared other operators like Canny and other operators. It gives most number of true edges even in low contrast images.

Research Objectives

Following are the two objectives set to address in this study.

1. To apply various edge detecting operators on the plant-based images and analyze its performance against ground truth information.
2. To study the effect of illumination on the performance of an edge detection technique.

Research Methodology

Research methodology used is Analytical research. Analytical research is used where we have to analyze the data quantitatively. In this study we use different edge detecting techniques, informally called as edge operators to get the test images and we compare them against a ground truth images using Confusion matrix. The comparison is done between each pixel of binary ground truth image and the pixel of the binary image got by applying edge operator. The following operators are used for analyzing the performance in getting prominent images.

Sobel Operator: It is based on first-order derivatives. It is implemented using the magnitude of the gradient. For a function f(x,y), the gradient of f at coordinates(x,y) is defined as the two-dimensional column vector.

$$\nabla f = \mathbf{grad(f)} = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} df/dx \\ df/dy \end{bmatrix} \quad \text{----------(1)}$$

Equation-1 shows the important geometrical property that points to the greatest rate of change of f at location (x,y). The magnitude of vector ∇f, is denoted as M(x,y) where

$$M(x,y)=mag(\nabla f)=\sqrt{Gx^2 + Gy^2} \quad \text{----------(2)}$$

is the value at (x,y) of the rate change in the direction of the gradient vector. The following shows the Sobel operator.

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

Gx

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

Gy

Figure 2. Showing Sobel's operator

Similarly, based on first order derivatives we have Robert's, Prewitt's operators.

+1	0
0	-1

Gx

0	+1
-1	0

Gy

Figure 3. Showing Robert's operator

$$h_1 = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$$

Gx

$$h_3 = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$$

Gy

Figure 4. Showing Prewitt's operator

Laplacian

The Laplacian is a 2-D isotropic measure of the 2nd spatial derivative of an image. The Laplacian of an image highlights regions of rapid intensity change and is therefore often used for edge detection. The Laplacian is often applied to an image that has first been smoothed with something approximating a Gaussian Smoothing filter in order to reduce its sensitivity to noise. 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:

$$L(x,y) = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2} \quad \text{----------3}$$

Since the input image is represented as a set of discrete pixels, we have to find a discrete convolution kernel that can approximate the second derivatives in the definition of the Laplacian. Three commonly used small kernels are shown in Figure 5.

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 5. Three commonly used discrete approximations to the Laplacian filter.

Laplacian of Gaussian (LoG)

It is based on 2D-Gaussian low-pass filter given by

$$G(x,y)=e^{-x2+y2/2\sigma2} \quad \text{----------4}$$

The LoG edge-detection is summarized as follows

1. Filter the input image with nXn Gaussian lowpass filter obtained by sampling equation 4.
2. Compute the Laplacian of the image resulting from step 1 using the following 3X3 mask.

1	1	1
1	-8	1
1	1	1

3. Find the zero crossings of the image from step 2.

Canny edge detector

The Canny edge detection algorithm consists of the following basic steps:

1. Smooth the input image with a Gaussian filter
2. Compute the gradient magnitude and angle images.
3. Apply nonmaxima suppression to the gradient magnitude image.
4. Use double thresholding and connectivity analysis to detect and link edges.

Creation of Ground truth Image and Test image.

The following shows the steps in creating ground truth image.

Figure 6. Showing Steps involved in creating ground truth images

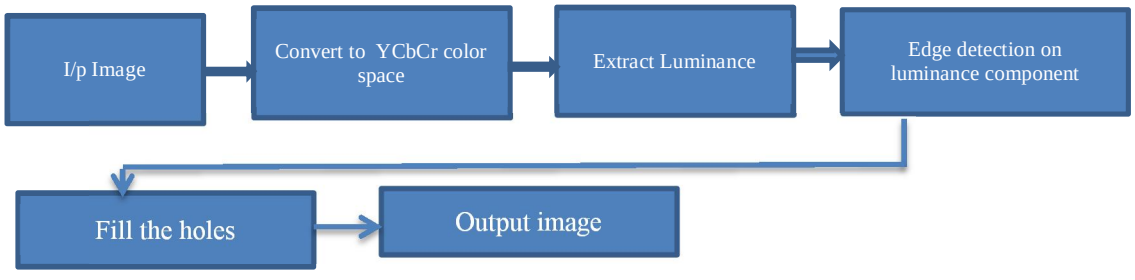
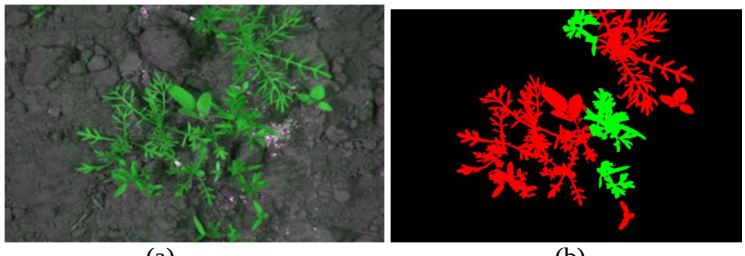


Figure 7. Showing Steps involved in applying edge detection on original images

Data Collection

Data is collected from the following online source http://github.com/cwfid, which is a benchmark dataset which can used in the evaluation of computer vision based precision agricultural task. The dataset consists of 60 images of carrot crop along with the weeds taken from field just before manual weeding was applied. The images were annotated after masking soil background. The crop is represented with green color and weed is represented by red color.



(a) (b)

Figure 8. (a) Showing original image of Carrot crop and weed and (b) Showing annotated image with green color representing crop and red color weed

Data Analysis

The images which were annotated were converted gray-scale and then to binary to get the ground truth images. The images which were not annotated (original) were converted to YCbCr color space and only luminance component is extracted. On this, edge detection technique is used and image is filled for quantitative analysis. The following figure consists of ground truth image obtained and result of various edge detection techniques used on the image.

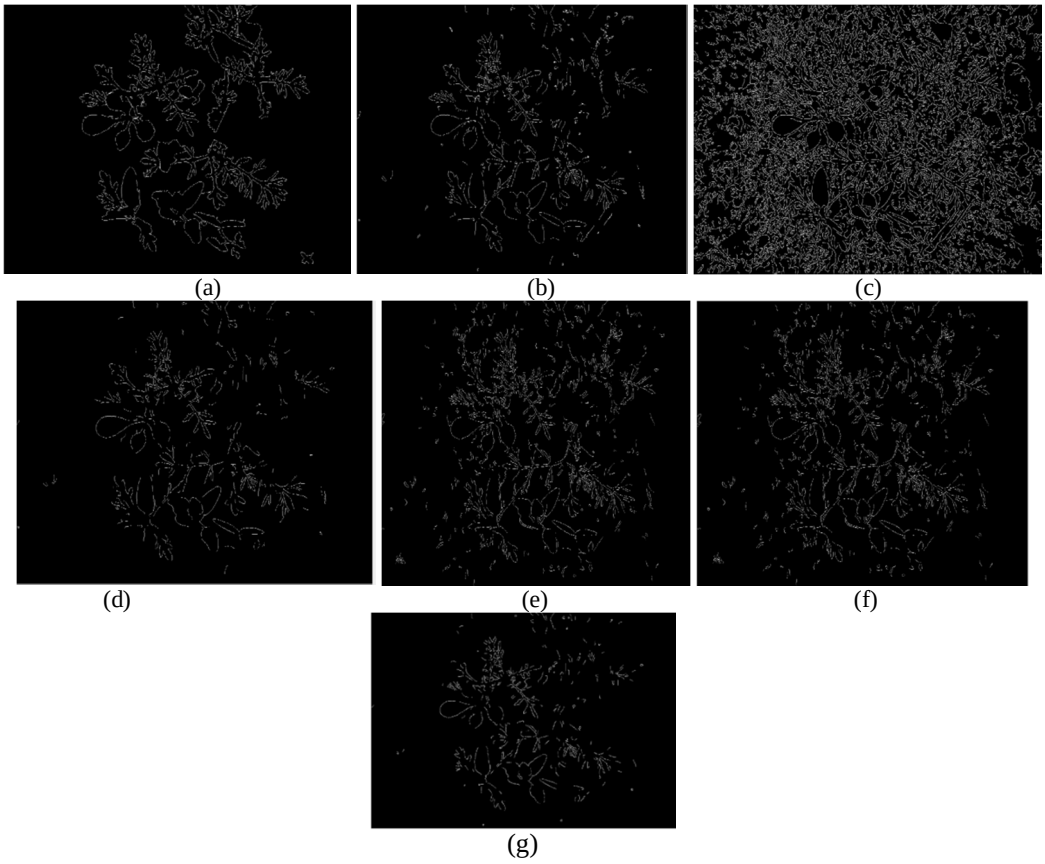


Figure 9. showing binary Ground truth images and test images

9(a) Ground Truth image sample 9(b) Edge detected using Prewitt's operator 9(c) Edge detected using Canny operator 9(d) Edge detected using Sobel operator 9(e) Edge detected using LoG operator 9(f) Edge detected using Roberts operator 9(g) Edge detected using Zerocross.

From the above figure, if we analyze manually the Canny and LoG gives too many unnecessary edges. Prewitt's result is close to the ground truth result. This is because, our aim was to find out which edge detection technique detects only prominent edges or edges as perceived by the human eye (visual significance) [18]. In that respect, Prewitt's operator based on gradient magnitude as an edge strength measure which encapsulates the property of visual significance being sensitive to luminance differences performs well This has been proved by using quantitative analysis discussed in the next section.

Quantitative performance measures of vegetation segmentation

The segmentation results were compared and evaluated at pixel level with human-labeled ground truth images. In this study, a set of quantitative measures based on the confusion matrix (Table 1) was used to assess the performance of the vegetation segmentation. Positive prediction value (precision), true-negative rates (specificity) were used.

Table 1. Confusion Matrix

	Algorithm - foreground	**Algorithm -background**
Ground Truth foreground	TP(True positive)	FN(False negative)
Ground truth background	FP(False positive)	TN(True negative)

$$\text{Precision} = TP/(TP+FP) \quad \text{---------- 5}$$

$$\text{Specificity} = TN/(TN+FP) \quad \text{----------6}$$

Precision indicates how many of the positively segmented pixels are relevant. Precision refers to the ability to minimize the number of false-positives. Specificity, on the other hand, specifies how well the segmentation algorithm performs in avoiding false-positive error, which also indicates the ability to correctly detect non-vegetation pixels that belong to non-vegetation regions (true-negative).

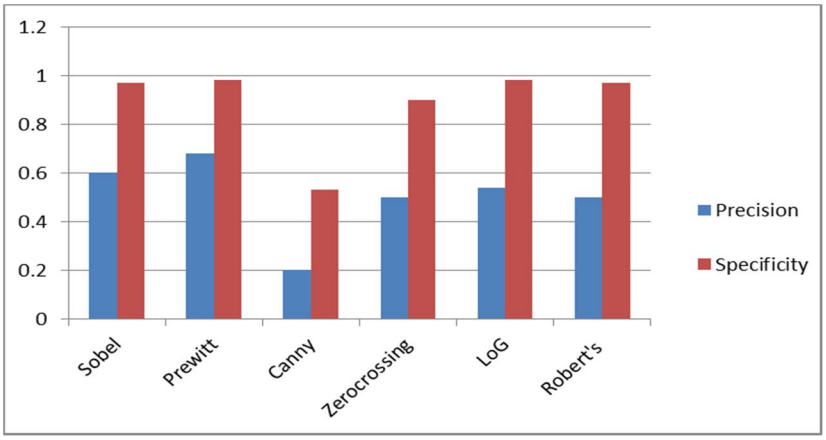


Figure 10. Showing average precision and specificity of various edge detecting operators

From the above figure we can conclude that if we have to detect only prominent edges, then the most suitable technique to use is Prewitt's operator. The analysis is done for 15 images and average is taken. Prewitt's has highest average precision of 0.69.

The illumination correction was applied and Canny detection was used to see whether any improvement in precision is there are not after illumination correction was used and results was verified by using paired-sample t-test. The result showed that after applying illumination correction precision improved significantly.

Table 2. Showing sample values of precision before and after illumination correction applied

Precision Before Illumination Correction for Canny edge Detection	Precision After Illumination Correction For Canny edge Detection
0.2348	0.68
0.21	0.70
0.25	0.68
0.10	0.21
0.12	0.34
0.10	0.34
0.21	0.734
0.22	0.4666
0.17	0.5414

Inferences and Conclusion

The following observations can be made about these edge detection techniques

1. Prewitt's operator gives highest precision of 0.69 when compared to other techniques. Canny gave too many edges which were not at all relevant to the studies.
2. Non-uniform illumination would decrease the performance of edge detection techniques by giving false or unnecessary edges.

3. Illumination correction applied on Canny gave improved result.

So for a computer vision (CV) application to be successful, it has to be developed according to particular environment where it will be used. That is, it is largely subjective. So we have to be familiar with the type of problems that will be encountered in an environment where CV application will be deployed and accordingly we have to use robust technique to get result which is near to desirable result.

References

[1] Adams, Matthew L., Simon Cook, and Robert Corner. "Managing uncertainty in site-specific management: what is the best model?." Precision agriculture 2.1 (2000): 39-54.

[2] Sujatha, P., & Sudha, K. K., "Performance analysis of different edge detection techniques for image segmentation", Indian Journal of Science and Technology, 2015, 8(14).

[3] Selvakumar, P., & Hariganesh, S, "The performance analysis of edge detection algorithms for image processing", International Conference on Computing Technologies and Intelligent Data Engineering (ICCTIDE), 2016, (pp. 1-5).

[4] Valliammal, N., & Geethalakshmi, S. N, "Performance analysis of various leaf boundary edge detection algorithms", In Proceedings of the 1st Amrita ACM-W Celebration on Women in Computing in India , 2010, (p. 34).

[5] Sridevi, M., & Mala, C. A survey on monochrome image segmentation methods. Procedia Technology, 6, 2012, 548-555.

[6] Campilho, A., & Kamel, M., Image Analysis and Recognition: 9th International Conference, ICIAR 2012, Aveiro, Portugal, June 25-27, 2012. Proceedings (Vol. 7325). Springer.

[7] Thakur, K., Gupta, E. P., & Pahwa, K., "Performance Evaluation of Edge Detection Techniques for Square Pixel and Hexagon Pixel images", Journal of Current research, Vol. 6, Issue, 11, 2014, pp.10008-10104.

[8] Nigam, R. K., Waghmare, N. P., & Gupta, A. K., "Evaluation and analysis of different type of edge detection techniques on cartridge case image". International Journal on Recent and Innovation Trends in Computing and Communication, 2(10), 2014, 3258-3261.

[9] Poobathy, D., & Chezian, R. M, " Edge detection operators: Peak signal to noise ratio based comparison", International Journal of Image, Graphics and signal processing, 2014, 6(10), 55.

[10] Bhuvaneswari, P., & Therese, A. B, "Edge Detection Techniques in Digital and Optical Image Processing", International Journal of Engineering Research and Applications www.ijera.com ISSN : 2248-9622, Vol. 4, Issue 5(Version 3), May 2014, pp.33-37.

[11] Zhu, S. Y., Plataniotis, K. N., & Venetsanopoulos, A. N. "Comprehensive analysis of edge detection in color image", processing". Optical Engineering, 1999, 38(4), 612-625.

[12] Juneja, M., & Sandhu, P. S. "Performance evaluation of edge detection techniques for images in spatial domain" international journal of computer theory and Engineering, 2009, 1(5), 614.

[13] Sundari, P. M., & Kumar, S. B. R, "Comparison of Various Edge Detection Techniques in Tree Ring Structure" International Journal of Computer Applications, 2014, 90(19).

[14] Sarkar, S., Basu, A., "Comparison of various Edge Detection Techniques for maximum data hiding using LSB Algorithm" International Journal of Computer Science and Information Technologies, Vol. 5 (3) , 2014, 4722-4727.

[15] Katiyar, S. K., & Arun, P. V, "Comparative analysis of common edge detection techniques in context of object extraction", arXiv 2014, preprint arXiv: 1405.613.

[16] Lakhani, K., Minocha, B., & Gugnani, N, "Analyzing edge detection techniques for feature extraction in dental radiographs", Perspectives in Science, Elsvier Publications, 2016, 8, 395-398.

[17] Bhardwaj, Saket, and Ajay Mittal. "A survey on various edge detector techniques." Procedia Technology 4 (2012): 220-226.

[18] Aydin, Tunç Ozan, Martin Čadík, Karol Myszkowski, and Hans-Peter Seidel. "Visually significant edges." ACM Transactions on Applied Perception (TAP) 7, no. 4 (2010): 27.