A Review on Edge Detection Algorithms in Digital Image Processing Applications

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Abstract— Edge detection is one of the major step in Image segmentation, image enhancement, image detection and recognition applications. The main goal of edge detection is that to localize the variation in the intensity of an image to identify the phenomena of physical properties which produced by the capturing device. An edge might be characterized as a set of neighborhood pixels that forms a boundary between two different regions. Detecting the edges is an essential technique for segmenting the image in to various regions based on their discontinuity in the pixels. Edge detection has very important applications in image processing and computer vison. It is broadly used technique and quick feature extraction technique hence used in various feature extraction and feature detection techniques. There exists several methods in the literature for edge detection such as Canny, Prewitt, Sobel, Maar Hildrith, Robert etc. In this paper we have studied and compared Prewitt, Sobel, and Canny detection operators. Our experimental study shows that the canny operator is giving better results for different kinds of images and has numerous advantages than the other operators such as the nature of adaptive, works better for noisy images and providing the sharp edges with low probability of false detection edges.

Index Terms: *edges, Sobel, Prewitt, Canny edge detection Operators.*

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I.INTRODUCTION

Image enhancement is considered as standout amongst the most essential techniques in the image processing applications. The primary aim of enhancing the image is to improve the quality and to increase the visual appearance of a picture to get a better representation than the original image for automated image processing. It is important to upgrade the contrast and to remove the noise present in the image to enhance the image quality. The goal of image enhancement is to process the one image so that the result is apparently better than the original image for several applications such as edge detection, pattern and various object detection and recognition.

Edge detection is one of the major step in image segmentation, image enhancement, image compression etc. The goal of edge detection is to identify the intensity regions that are having a slighter or more discontinuity with the neighborhood. It is widely used technique and easy to extract the features in a given input image. The results of the edge detection must be reliable and accurate hence the efficiency of the final result of the sub sequent image processing operations depends on this. To meet this requirement the edge detection algorithms should provide the complete and significant information about the image derivatives. However, differentiation of an image is sensitive to various sources of noise, i.e., electronic, semantic and discretization or quantification effects. Hence to regularize the differentiation, the image must be smoothed. But there are undesirable effects associated with smoothing, i.e., loss of information and displacement of prominent structures in the image plane. Hence it is difficult to design a general edge detection algorithm which performs well in many contexts and captures the requirements of subsequent processing stages. Consequently, over the history of digital image processing a variety of edge detectors have been devised which differ in their purpose and their mathematical & algorithmic properties. This chapter makes a survey of some of the popular edge detection techniques.

Edge detection is basically image segmentation technique, divides spatial domain, on which the image is defined, into meaningful parts or regions. Edges characterize boundaries and are therefore a problem of fundamental importance in image processing [1]. Edges typically occur on the boundary between two different regions in an image. Edge detection allows user to observe those features of an image where there is a more or less abrupt change in gray level or texture indicating the end of one region in the image and the beginning of another. It finds practical applications in medical imaging, computer guided surgery diagnosis, locate object in satellite images, face recognition, and finger print recognition ,automatic traffic controlling systems, study of anatomical structure etc. Many edge detection techniques have been developed for extracting edges from digital images[2] .Gradient based classical operators like Robert, Prewitt, Sobel were initially used for edge detection but they did not give sharp edges and were highly sensitive to noise image .Laplacian based Marr Hildrith operators also suffers from two limitations : high probability of detecting false edges and the localization error may be severe at curved edges but algorithm proposed by John F. Canny in 1986 is considered as the ideal edge detection algorithm for images that are corrupted with noise. Canny's aim was to discover the optimal edge detection algorithm which reduces the probability of detecting false edge, and gives sharp edges [3].

There are mainly three stages in the edge detection process i.e. Filtering, Enhancement and detection. These techniques are explained as follows. Images are often corrupted by random variations in intensity values, called as noise. Some common types of noises are salt and pepper noise, impulse noise and Gaussian noise. For example, salt and pepper noise contains random occurrences of both black and white intensity values. These noises should be removed for effectual edge detection. Hence, filters are used for removing the noise. More filtering to reduce noise results in a loss of edge strength and hence there is always a trade-off between edge strength and noise reduction. In order to facilitate the detection of edges, it is essential to determine changes in intensity in the neighborhood of a point [Enhancement emphasizes pixels where there is a significant change in local intensity values and is usually performed by computing the gradient magnitude.

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

X-gradient (Gx)

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

Y-gradient (G_y)

Figure 1. Example masks in Horizontal and Vertical direction

Many points in an image have a nonzero value for the gradient, and not all of these points are edges for a particular application. Therefore, some method should be used to determine which points are edge points. Frequently, thresholding is used for edge detection.

In recent years, digital images plays an important role in different applications such as restorations and enhancements, image transmission and coding, color processing, remote sensing, robot vision, hybrid techniques, facsimile, pattern recognition, registration techniques, multi-dimensional image processing, video processing, high resolution display, high quality color representation and super high definition applications. Image segmentation process is important for these digital image processing applications because the raw images are captured by the digital camera or mobile camera with nonessential background scenes or noise [4]. The elimination of background images and noise is quite important to get accurate results. This process is a low level image engineering process which converts the raw images into segments are pixels or objects. These pixels are converted into vectors and analyzed or tested with the any one of the image segmentation process. The removal of noise from the images is performed using de- noising techniques such as filtering, enhancement, detection and localization for identifying the edges. These edges are analyzed with the help of mid and high – level image engineering processing methods. The adequate edges are identified by diverse edge detection techniques in several image processing applications such as object recognition, motion analysis, pattern recognition, computer- guided surgery, finger print recognition, automatic traffic controlling systems, anatomical structure and image processing [5]. Detecting the edges from noisy images or corrupted images is difficult in nature. In the past two decades' several edge detection techniques or algorithms are proposed, based on that the effective edges are evaluated or analyzed. The ultimate reason behind in these methods to restrict the false detection in the edges, edge localization and computational time. In this, canny optimal detection algorithm aims to discover the optimal edge which reduces the probability of detecting false edges, and gives sharp edges [6].

II.RELATED STUDY

Image segmentation is the method to simplify the digital image into segments or pixels which are easier to analyze and identify the effective edges in a complex image. The image engineering processes are sub divided into low level, mid-level, high level. In low-level engineering process, the raw image is taken as an input and the noises are eliminated. These raw images are transformed into pixels. The pixel is a collection of discrete cells in the particular image. The characteristics of color and texture are found as similarity in a pixel. Generally, the raw images are taken as a colored image which is needed to be modify into grayscale or black and white images, because the edges can be detected using the pixels. In the Mid –level, the output is presented in the form of attributes like edges, contours, and the identity of individual objects. In the High- level engineering process, involves making sense, of a recognized object in the image analysis and it performs the cognitive functions associated with computer vision.

A. Edge Types

An edge in an image is a significant local change in the image intensity, usually associated with a discontinuity in either the image intensity or the first derivative of the image intensity. Discontinuities in the image intensity can be either 'step edge', where the image intensity abruptly changes from one value on one side of the discontinuity to a different value on the opposite side, or 'line edge', where the image intensity abruptly changes value but then returns to the starting value within some short distance. Because of low frequency components or the smoothing introduced by most sensing devices, sharp discontinuities, like step and line edges, rarely exist in real.Because of low frequency components or the smoothing introduced by most sensing devices, sharp discontinuities, like step and line edges, rarely exist in realimages. 'Step edges' become 'ramp edges' and 'line edges' become 'roof edges', where intensity changes are not instantaneous but occur over a finite distance. Illustrations of these edge shapes are shown in Figure 2.

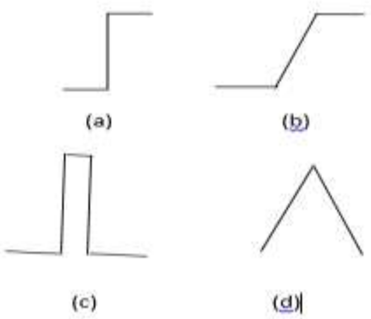

Figure 2. Edge types a. step edge b. Ramp edge c. line edge d. roof edge**.**

B. Edge Detection

Edge detection is a fundamental step in image segmentation, image recognition, image enhancement, restoration, image registration, image compression, and so on. The goal of edge detection is to localize the variations in the intensity of an image and to identify the physical phenomena which produce them. Edge detection is widely used in image processing as it is a quick and easy way of extracting most of the important features in an image. Edge detection must be efficient and reliable because the validity, efficiency and possibility of the completion of subsequent processing stages rely on it. To fulfill this requirement, edge detection should provide all significant information about the image including image derivatives. However, differentiation of an image is sensitive to various sources of noise, i.e., electronic, semantic and discretization or quantification effects. Hence to regularize the differentiation, the image must be smoothed. But there are undesirable effects associated with smoothing, i.e., loss of information and displacement of prominent structures in the image plane. Hence it is difficult to design a general edge detection algorithm which performs well in many contexts and captures the requirements of subsequent processing stages. Consequently, over the history of digital image processing a variety of edge detectors have been devised which differ in their purpose and their mathematical & algorithmic properties. This chapter makes a survey of some of the popular edge detection techniques.Edge detection contain three steps namely, filtering, enhancement and detection.

Filtering

Images are often corrupted by random variations in intensity values, called as noise. Some common types of noises are salt and pepper noise, impulse noise and Gaussian noise. For example, salt and pepper noise contains random occurrences of both black and white intensity values. These noises should be removed for effectual edge detection. Hence, filters are used for removing the noise. More filtering to reduce noise results in a loss of edge strength andhence there is always a trade-off between edge strength and noise reduction.

Enhancement

In order to facilitate the detection of edges, it is essential to determine changes in intensity in the neighborhood of a point. Enhancement emphasizes pixels where there is a significant change in local intensity values and is usually performed by computing the gradient magnitude.

Detection

Many points in an image have a nonzero value for the gradient, and not all of these points are edges for a particular application. Therefore, some method should be used to determine which points are edge points. Frequently, thresholding is used for edge detection.

C. Techniques used

Edge detection is the name for a set of mathematical methods which aim at identifying points in a digital image at which the image brightness changes sharply or, more formally, has discontinuities. The points at which image brightness changes sharply are typically organized into a set of curved line segments termed *edges*. In this paper three edge detection methods are used to find the better performance on various images. The list of edge detection operators are shown in Figure 3. In this paper we have studied Sobel, Prewitt, Canny Edge detection operators.

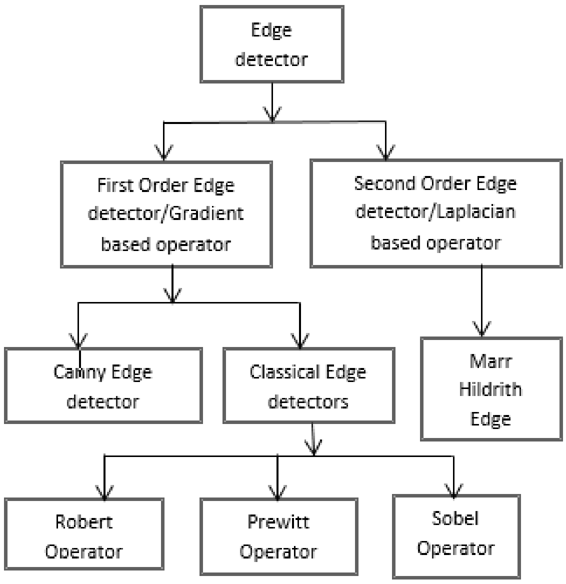

Figure 3. Types of edge detection operators

Most of the edge detection algorithms in the literature will read an input image and performed convolution operation with mask. Later the gradients are computed in both directions.i.e. Horizontal and vertical directions. Once the gradients are computed a thresholding is used to remove the pixels value above the specified threshold. If the pixel is greater than the specified threshold it is considered as an

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edge otherwise it is not an edge. The working flow of a generic edge detection algorithm is shown in Figure 4.

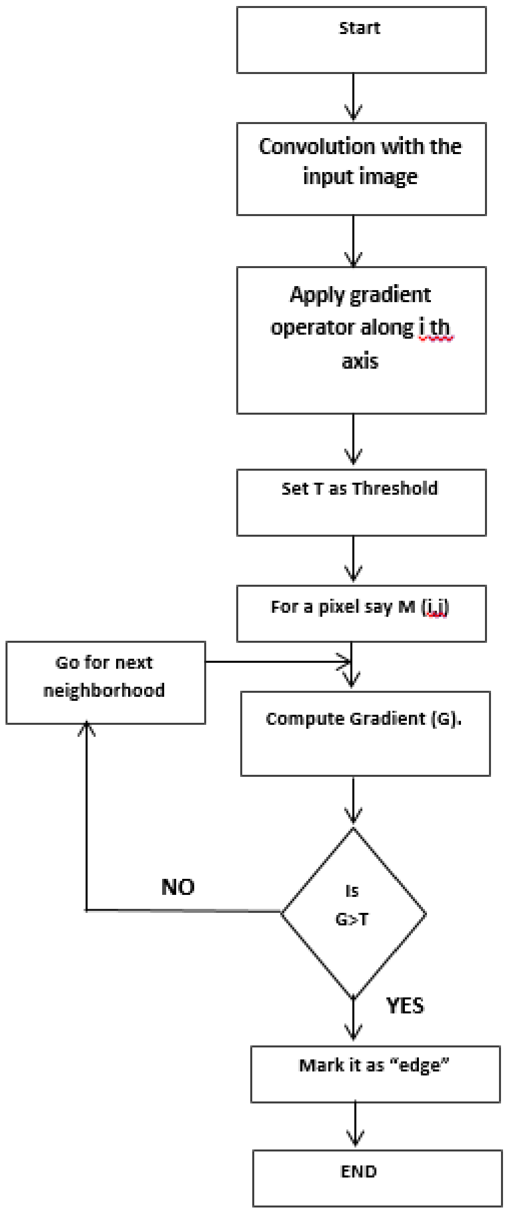

Figure 4. General flow of a conventional edge detection algorithm.

i) Sobel Edge Detection: In digital images, the approximate partial derivation in gradient is computed by the Sobel operator. In terms of computations, the edge is based on the edge convolving with the integer, separable and small valued filter in vertical and horizontal directions .Mathematically, the approximations of the derivative can be calculated by using two 3*3 kernels which are convolved with the original image.

A 3X3 kernel is used for enhancement. Maximum of edges are identified with respect to perpendicular angle. In this, one kernel is allowed to rotate with 90 degrees and another one kernel is stay on this position. The raw image is taken as an input. It detects two types of edges like Horizontal edges (Sy) and Vertical Edges (Sx). The Magnitude (M) is calculated by adding the partial derivatives of Sx and Sy. The threshold is added with the magnitude to get the output image. The Magnitude of the gradients (M) are calculated with Sx, Sy indicates vertical and horizontal positions. The Sx, Sy partial derivations are given below [7]

$$M=\sqrt{Sx^2+Sy^2}$$

The angle of orientation of the edge is given by:

ө= arctan (Sy/Sx)

Where ө is angle to find the direction.

Sx = (a2+Ca3+a4) – (a0+Ca7+a6)
Sy= (a0+Ca1+a2) – (a6+Ca5+a4)

ii) ***Prewitt Edge Detection:*** The maximum responses which are directly from the kernel are obtained by the use of Prewitt Edge Detector. The Prewitt edge operator or detectors are used for the measurement of two components i.e. horizontal edge components and vertical edge components. These two components (vertical and horizontal) are used different kernels.

Prewitt Operator:

Prewitt operator is quite similar to the Sobel Operator with the difference of the C value is 1.

The main advantage of this technique is to provide a better performance on horizontal and vertical edges in the images and higher responses for noisy images. The operator should have the following properties: one is

i) Both negative and positive values should be in the all convolution masks.

ii) The final results should be zero when sum is obtained.

It is widely used technique to evaluate the magnitude (M) of the edges.

The Sx, Sy partial derivations are given [8]

$$M=\sqrt{Sx^2+Sy^2}$$

Sx = (a2+Ca3+a4) – (a0+Ca7+a6)
Sy= (a0+Ca1+a2) – (a6+Ca5+a4)

Where the threshold value C=1 and a0, a1, a2, a3, a4, a5, a6, a7 are masks.

The original image pixel 12 is taken and the magnitude is calculated with Sx mask and the same procedures are followed to calculate the Sy mask. The final value of Sy mask is 20.

iii) Canny Edge Detection: The Canny Edge detection is introduced by John Canny (1983). Canny edge detection technique is one of the standard edge detection techniques. It is used many of the newer algorithms that have been developed. The noise can be reduced and suppression can be minimum are the stages of canny algorithms which are used in images.

This algorithm is focuses to separate the background noise from complex image and to find the effective edges for optimized solutions. It uses first derivative of an image. It is used to measures the mean square distance, error edge map and signals to noise ratio. The improved canny edge detection algorithm provides the better optimal solutions with respect to noisy images [9]. Canny edge detection steps are shown in Figure.

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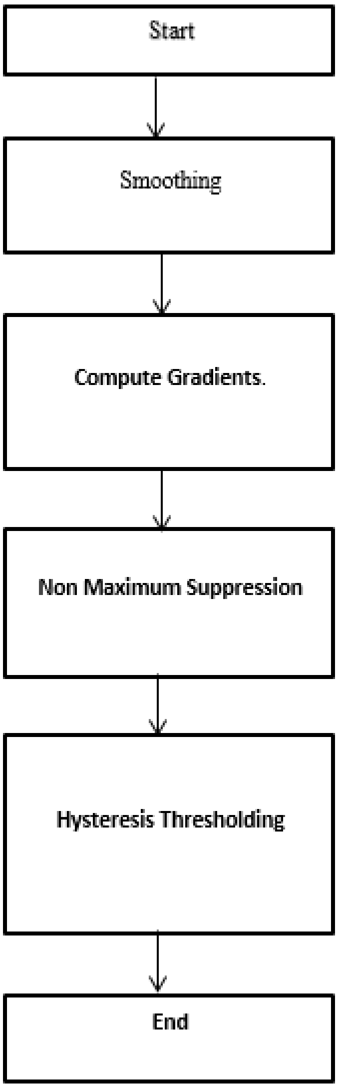
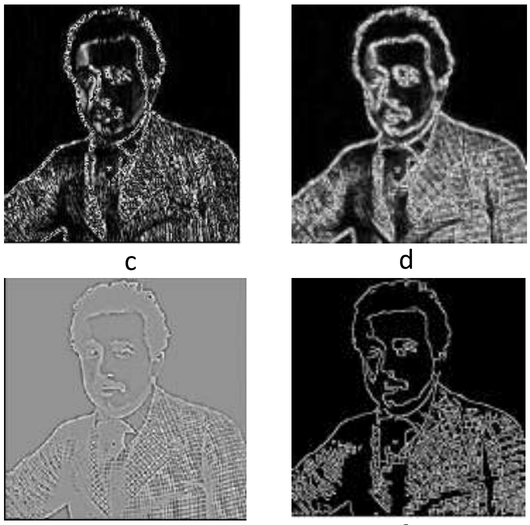


Figure 5. Working flow of canny edge detection algorithm.

IV.RESULTS & DISCUSSION

This section shows our works on the Dark Channel Prior and the edge detection algorithms. Our work has done on OpenCV environment using Python. In Figure 6 we have taken an image with frontal face and in Figure 7 we considered the image taken in outdoor i.e. building and the results for various edge detection algorithms are shown.

a b



c d

e f

Figure 6. Comparison of edge detection results.

Figure 6.a is the input image, Figure 6.b is the Prewit operator result and Figure 6.c and Figure 6.d are the results of Sobel operator in x direction and y direction and the Figure 6.e is the Laplacian result and Figure 6.d is the canny edge detection result. The same results are considered for outdoor image in Figure 7.

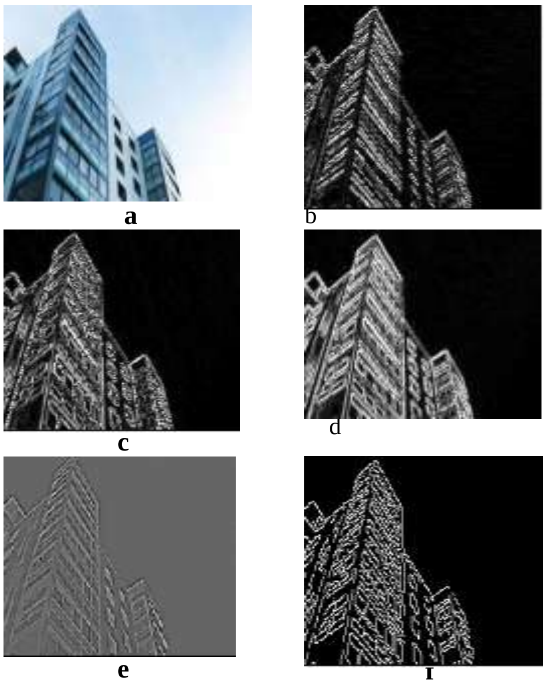


Figure 7. Comparison of edge detection results.

Table 1. Summary of the edge detection algorithm.

S.no	Edge Detection Operator	Sensitivity	Method	Merit	Demerit
1	Sobel	Medium	Edges are detected based on the perpendicular angle	Simple and smooth edges are detected	In accurate average results with respire to complex images.
2	Prewitt		Gives good results of horizontal and vertical edges		
3	Canny	High	Used to eliminate the noise and to find the effective edges	Better detection, Adaptive, Good Localization.	False Zero crossing

PARAMETERS FOR EVALUATION

Correlation Coefficient

The correlation coefficient a concept from statistics is a measure of how the trends in the predicted values follow trends in past actual values. It is a measure of how well the predicted values from a forecast model "fit" with the real-life data. The correlation coefficient is a number between 0 and 1. As the strength of the relationship between the predicted values and actual values increases so does the correlation coefficient. A perfect fit gives a coefficient of 1.0. Thus the higher the correlation coefficient the better [12].

Edge Detection Performance

The performance of the edge detection algorithm is computed based on determining the false edges i.e. those edges are not actual edges but the algorithm determined as the edges and finding the missed edges i.e. the those edges basically edges but that are not included in the result. The mean and square error determine the true edges. Finally the tolerance of the edges are also considered. The first two parameters are about to the edge detection and the rest of the two parameter denotes the edge localization. These Performance Ratio (PR), Miss Count (MC), Peak Signal to Noise Ratio (PNSR).

$$\text{PR} = \frac{True\ edges}{False\ edges}$$

$$\text{FoM}=\frac{1}{\max(\text{IA},\text{I1})}\sum_{i-1}^{\text{IA}}\frac{1}{1+d\propto 2}$$

To compare image compression quality MSE and PSNR is used [10][13].The PSNR and MSE are measured by the following equation.

$$\text{MSE}=\frac{\sum[I1(\text{m,n})-I2(\text{m,n})]}{M*N}$$

Where M and N are rows and column of an image $I1$ is considered as an original raw image and $I2$ is a considered as a detected output image [11].

$$\text{PSNR}=10\log_{10}\left(\frac{R^2}{MSE}\right)$$

V.CONCLUSION

In this paper, we have reviewed the edge detection algorithms such as Sobel, Prewitt, and Canny edge detection. Among these techniques each algorithms are suitable for a specific application. But the canny edge detection is giving the standout results in most of the applications. As our experimental results also shows that the canny algorithm is giving the best results for the tested input images. The other edge detection algorithm such as Robert's, Kirsch edge detection algorithms are to be analyzed in the future work and needed to apply the same techniques for poor contrast images as our future work.

REFERENCES

[1] James Clerk Maxwell, 1868 DIGITAL IMAGE PROCESSING Mathematical and Computational Methods.

[2] R .Gonzalez and R. Woods, Digital Image Processing, Addison Wesley, 1992, pp 414 - 428.

[3] S. Sridhar, Oxford university publication. , Digital Image Processing.

[4] Beant K, Anil G. Mathematical morphological edge detection for remote sensing images. IEEE Transactions. 2011; 324–7.

[5] Ireyuwa EI. Comparison of edge detection techniques in image processing techniques. International Journal of Information Technology and Electrical Engineering. 2013; 25–9.

[6] K. Bala Krishnan*, Shiva Prakash Ranga and Nageswara Guptha "A Survey on Different Edge Detection Techniques for Image Segmentation", Indian Journal of Science and Technology, Vol 10(4), DOI: 10.17485/ijst/2017/v10i4/108963 January 2017

[7] Khaire PA, Thakur NV. A fuzzy set approach for edge detection.International Journal of Image Processing. 2012;403–12.

[8] Lakshmi SJ, Prasanna. Image segmentation using variousedge detection techniques. International Journal of Emerging Technologies in Engineering Research. 2016; 129–32.

[9] Liu X, Dawn Z, Xu WWE. Image edge deduction algorithm based on improved wavelet transform. International Journal of Signal Processing, Image Processing and Pattern Recognition.2016; 9(4):435–42.

[10] Pradyna J, Usha J. Sobel edge detection implementation using FPGA. International Journal of Science and Research. 2015; 4(7):439–42.

[11] Ramn M, Aggarwal H. Study and comparison of various image edge detection techniques. International Journal of Image Processing. 2009; 3(1):1–12.

[12] Sos Agaian, Ali Almuntashri "Noise-Resilient Edge Detection Algorithm for Brain MRI Images", IEEE, 31st Annual International Conference of the IEEE EMBS Minneapolis, Minnesota, USA, September 2-6, 2009.978-1-4244-3296-7/09/$25.00 ©2009 IEEE.

[13] Jianjum Zhao, Heng Yu, Xiaoguang Gu and Sheng Wang. "The Edge Detection of River model Based on Self-adaptive Canny Algorithm And Connected Domain Segmentation" IEEE,Proceedings of the 8th World Congress on Intelligent Control and Automation July 6-9 2010, Jinan, China, 978-14244-6712-9/10/$26.00 ©2010 IEEE

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