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A Review on Comparative Study of Different Edge Detection Techniques

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Abstract - *Edge Detection is a vital step for image processing. Edge Detection is a tool to recognize different properties of an image such as shape, contrast, color, scene analysis, image segmentation, etc. Edges are very important to found to recognize all the edges accurately. It is important for object recognition, pattern recognition medical image processing and motion analysis, etc. There are many edge detection operators available in image processing. This paper presents a comparative study of different edge detection techniques which is widely used in image processing such as Canny, Prewitt, and Sobel.*

Key Words: **Edge Detection, image processing.**

1. INTRODUCTION

Images contain different information about the object or scene such as size, shape, color, and it's orientation. The result of changes in light, color, shade, and texture called edge. When an image is corrupted by the noise the detection of edges is very difficult to obtain and the process will become time taking. The objects can be found well planned and executed easily only when edges of images could be recognized efficiently. Edge detection is one of the main techniques used in image processing. The application of edge detection used in image processing is broad such as pattern recognition, object recognition, medical image processing, and motion analysis, etc [7].

In digital image processing, edge detection is one of the most frequently used techniques. To reduce the amount of data to be refined, an edge detector is applied to an image that separates irrelevant or less relevant information from an image while preserving the structural properties of an image. The edge detection techniques are categorized into two types that are Gradient-based edge detection techniques and laplacian based edge detection techniques [5]. Figure 1 shows the difference between the original image and the image after refining edges of that image by applying different edge detectors:

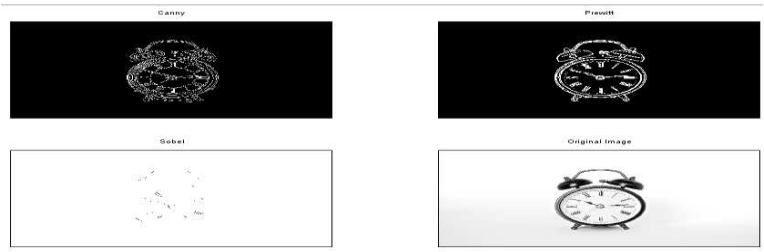

Figure.1 edge detection techniques on real-time image

There are different type of variables which affect the edge detector such as noise environment, edge structure, edge orientation, and luminance [7]. There are certain performance parameters such as PSNR (Peak Signal to Noise Ratio), Mean Square Error, Maximum Squared Error, and L2RAT, etc which affect the performance of edge detectors [8].

There are different edge detection techniques available such as Canny, Sobel, Prewitt, Robert, and Log. To fulfill this requirement edge detectors have been proposed over the history of digital image processing, which is different in their purpose and their algorithmic and mathematical properties.

So many research works have been done to detect edges more accurately and efficiently and various techniques have been developed and have its pros and cons. There are different type of method comes in existence to detect edges such as K mean

clustering algorithm, Otsu's thresholding method, Ant colony optimization method, and least squares support vector machine, etc.[11].

1.1 Edge Detection Technique:

- Canny edge detector was invented by Canny John F. in 1986 and was designed to be an optimal edge detector. It maximizes the conventional signal to noise ratio to detect a particular edge. The Canny edge detector is computationally more expensive as compared to other edge detectors.
- Sobel was invented by Sobel Irwin Edward in 1970. It is very fast to compute and detect thick edges. Sobel operator cannot detect diagonal edges of any image.
- Prewitt detector was discovered in 1970 by Judith M. S. Prewitt. It is similar to Sobel and less sensitive. It detects the edges horizontally and vertically and very inexpensive in terms of computation [6].
- Robert was invented by Robert Lawrence Gilman in 1965. It is very sensitive to noise. It uses the discrete method to compute the gradient. It measures the 2D point very quickly in a spatial gradient [16].
- Laplacian of Gaussian (LoG) was discovered by David Marr and Ellen C. Hildreth also known as Marr-Hildreth edge detector and it smoothens the images [6].

Edge detection techniques are based on error minimization, genetic algorithm, neural network, and Fuzzy logic, etc. [3]

By considering the three steps of the edge detection process i.e. filtration, enhancement, and detection edge detection algorithm are processed in the following steps:

1. Take color images as an input.

2. Remove the noise as much as possible without disturbing the true edges of that image, this process is known as refining.

3. To enhance the quality of an image apply differentiation, a process known as intensification.

4. To reject the noisy edge pixels and to confine other edges, the edge magnitude threshold is used.

5. To detect the location of an edge, the spacing between pixels and subpixels localization is required.

6. Get the output image with refining edges.

1.2 Flow Chart of Edge Detection:

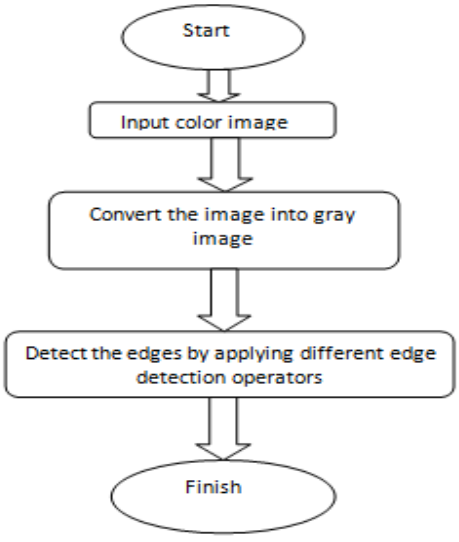

Figure.2 Flow chart of edge detection

The rest of this paper is organized as Section 2 presents review literature showing the research work in this field then section 3 concluded the paper and future work.

2. Review Literature

Zhang Jin-Yu et. al. (2009) proposed a new automatic threshold algorithm based on genetic algorithms and improves Sobel operators. Also, results are compared to the classical Otsu method which is better. The new automatic threshold algorithm overcome over-segmentation and sensitivity, it has strong calculation speed and anti-noise capability also very effective. It increases efficiency by 38.7%.

Yuan Yang et. al. (2009) proposed an improved Rothwell edge detection method to represent the topological relations of the extracted edges, which are more reliable than the traditional one. Gaussian smoothing followed by differentiation makes Rothwell algorithm similar to the Canny algorithm. The key difference is Rothwell algorithm used dynamic thresholding instead of hysteresis and edge thinning as a post edge detection process. This algorithm required three parameters:

1. Smoothing amount

2. Edge threshold

3. A parameter which adapts the edge threshold to increase the detection of pixels that is near other edges.

The result of this paper shows that these algorithms correct the distortion of the original image effectively, and for the higher-level processing (such as automatic target reorganization, etc.) the extracted edge features could be sent as the reliable element of topology structure, it retains more accurate geometry feature and generates more stable topology than the original image.

G.T. Shrivakshan et. al. (2012) analyzed both gradient-based and laplacian based algorithm for identifying a shark fish type through image processing; also discuss their advantages and disadvantages. The author uses morphological features to identify the shark type. The study shows that the gradient-based algorithm is more prone to noise. Laplacian based algorithms mostly suffer from mismapping the lines. The author uses some parameters which are standard deviation for the Gaussian filter and their threshold values.

Poonam Dhankar ET. al. (2013) analyzed edge detection techniques based on the discontinuity intensity levels. By using the MATLAB software the result produces almost the same edge map for Log and Canny edge detectors. Canny works superior under different conditions compared to other operators. By using non-maximal suppression canny capitulate thin lines for its edge. Canny also adapt hysteresis with thresholding.

Shubhashree Savant et. al. (2014) provides a review on edge detection techniques for image segmentation. This paper gives an idea about image segmentation in which segmentation is either discontinuity based or region based but edge detection useful for discontinuity based image segmentation technique. This paper presents a review of various edge detection techniques like gradient-based and laplacian based techniques.

Parminder Kaur et. al. (2014) proposed a comprehensive survey and empirical study of the comparison of various edge detection techniques and the visual performance analysis of the various techniques in the noisy condition is performed by using the different methods such as Canny, LoG, Robert, Prewitt, Sobel, Laplacian and wavelet.

Inderjeet Kumar et. al. (2014) show the comparison of edge detection techniques under different conditions showing the advantages and disadvantages of these algorithms.

Anphy Jose ET. al. (2014) analyzed different edge detectors like Sobel, Prewitt, Roberts, and Canny based on performance parameters such as PSNR (Peak Signal to Noise Ratio), MSR (Mean Square Ratio), MAXERR (Maximum Squared Error), and L2RAT. The author uses two images as input having a low frequency and high frequency. Canny operator possesses high processing time in both cases which are approximately 730ms. Canny gives an optimal result in all cases.

Liying Yuan et. al. (2015) proposed an improved algorithm by combining two methods which are global and local edge detection methods to extract the edges. Using an adaptive smooth filter algorithm which is based on canny operator, global edge detection can obtain the whole image. Whereas local edge detection uses a distance weighted average method which is based on k- average method to overcome the effect of outliers on clustering effectively. This paper combines the local edge detection algorithm and improved canny operators smoothing algorithm to detect edges. The improved canny operator does not contain a false edge and is complete and rich. The result of this paper shows that the algorithm extracts the image edges

very effectively and has a very powerful anti-noise ability. It extracts the edges in detail, more accurate positioning compare to traditional canny edge detection algorithm.

Guanghui Deng et. al. (2015) proposed Self Quotient Image (SQI) algorithm to obtained illumination invariant of the originality of the images and to smooth the image. It is based on QI and MSR (Multi-Scale Retinex). The advantage of using MSR is its better color fidelity but it cannot contain the natural color of the images. It is concluded that all images are slightly affected due to the existence of a certain degree of noise.

Amit Patel et. al. (2016) proposed the Ant Colony Optimization heuristic algorithm(ACO) with Dual-Tree Complex Wavelet Transform (DT-CWT) using two different threshold techniques which are Fuzzy c- mean clustering and K-means clustering algorithm. The original image is decomposed in four sub-bands using Discrete Wavelet Transform (DWT) then ACO algorithm is separately applied on that four sub-bands. The combination of DT-CWT with ACO removes the disadvantages of DWT such as overemphasized, distortion, and less visible image. And by using threshold techniques it is decided that pixels are edges or not. Distortion and noise occur when the ACO+DT-CWT method is used but ACO+DT-CWT removes distortion and gives a better result than other better orientation capabilities.

Tapan Sharma et. al. (2016) devised a distributed system HDFS (Hadoop Distributed File System) and uses Spark architecture for big data like satellite images by using edge detection techniques such as Canny, Sobel, and Laplacian of Gaussian. By comparing the statistical performance and scalability of these algorithms on different image sets it is concluded that the Canny operator takes time to compute but it scaled better than others. The main concept of RDD (Resilient Distributed Datasets) and its three properties (distributed, lazy and persistency) makes it achieving the high performance for Apache spark.

Chutiwan Boonarchatong et. al. (2017) analyzed different edge detection of different types of satellite images. In this paper, the data is taken from a THEOS satellite and the data images are the seashore in the Samut Prakan province, the river line in Ayuthuya province, and the fruit garden in the Chantuburi province. The parameters used for this paper are Signal to Noise Ratio (PSNR), Mean Square Error (MSE), and processing time. The THEOS satellite used for bands calls B1, B2, B3, and B4 and each band provides less field survey cost. The original images of the satellite are extracted to an 8-bit grayscale image then parameters are applied to each satellite images to find the best-suited edge detection algorithm. The data was derived from the THEOS satellite with the TOP2 sensor in MS sensor mode. The results showed that the canny edge detection and Laplacian of Gaussian algorithm give the best result with reducing MSE value on seashore and riverway images whereas all edge detection algorithms did not give a good result with a fruit garden and green areas, the boundary of these images are not clear. Being sensitive to noise LOG is a filter of noise and reduces sensitive noise and gives the second-best result after canny edge detection.

J. Vijyakumar et. al. (2017) analyzed different edge detection techniques using some parameters such as accuracy, PSNR (Peak Signal to Noise Ratio), and executing time. On comparison of different edge detectors, it is concluded that canny gives the best result as compared to other nuts it gives poor execution time. Log, Sobel operators give more accuracy, and the Prewitt operator is quickly computed. Sobel operator is less sensitive to noise and Robert operators are highly susceptible to noise. Log operators detect false edges while Canny operators reduce the probability of false and sharper edges.

Md Khurram Monir Rabby et. al. (2018) proposed a modified algorithm of canny edge detection algorithm to detect the basic features such as color and shape of the fruits. This modified canny edge detection method is used to develop fruit recognition by extracting its two features color and shape to identify fruit classes and fruit types. The input images included only two fruits apple and orange. This paper is basically for automated sorting which works on some basic features like color, intensity, shape, size, and texture, etc; that is widely used in the food industry. Canny edge detection is a standard edge detection algorithm to detect the local maxima and minima of the gradient of intensity function, also it maintains a low error rate, filter out unwanted information from the original image. The result of this paper shows that the MCED algorithm detection rate is higher than the traditional approach and also it is easy to computationally implement within a limited training dataset.

Table 1. Review Analysis

Author/Researcher	Work	Technique used	Operator used	Result
Zhang Jin-Yu et. al. (2009)	Edge detection of images based on improved Sobel Operator and Genetic algorithms	An automatic threshold algorithm is proposed based on Genetic algorithm and improved Sobel operator	Sobel	The result shows that it is effective and better than classical OTSU

				method and gives stronger edges
Yuan Yang et. al. (2009)	An improved Edge Detection Method based on Topology	Rothwell Edge Detection method is used with distance transform and B-spline interpolation	Canny	Results show that Rothwell edge detection retain accurate geometry with stable topology
G. T. Shrivakshan et. al. (2012)	Comparison of various Edge Detection Techniques used in Image Processing	Observe shark fish classification using Gradient and Laplacian based filter	Robert, Sobel, Prewitt, Canny	Results show that Laplacian does better than Gradient and Canny perform better in noisy condition
Poonam Dhankar et. al. (2013)	A Review and Research of Edge Detection Techniques for Image Segmentation	Comparative study of different edge detection based on the discontinuity intensity level	Sobel, Prewitt, Robert, Canny, LoG	Edge map of LoG and Canny edge detector is same, Canny result superior as compare to others
Shubhashree Savant et. al. (2014)	A Review on Edge Detection Techniques for Image Segmentation	Review of different Edge Detection techniques for image segmentation	Sobel, Prewitt, Robert, Canny, LoG, ZeroCrossing	The result of edge detection techniques varies from a set of images.
Parminder Kaur et. al. (2014)	Comparison and Analysis of Edge Detection Technique	Comparison based on visual performance analysis and 1D and 2D edge detection techniques are used	Canny, LoG, Robert, Prewitt, Sobel, wavelet	The low-quality images can be detected by LoG and Canny operator easily, Canny can detect noisy images better than other methods
Indrajeet Kumar et. al. (2014)	A Conventional Study of Edge Detection Technique in Digital Image Processing	Comparative study of the different edge detection technique	Sobel, Robert, Prewitt, Canny	Prewitt is very sensitive to noise whereas Canny depends on the adjustable parameter
Anphy Jose et. al. (2014)	Performance Study of Edge Detection Operator	Different performance parameters are used to detect edges	Sobel, Robert, Prewitt, Canny	Parameters vary according to image statics, Canny selected as an optimal edge detector
Liying Yuan et. al. (2015)	Adaptive Image Edge detection Algorithm based on Canny Operator	Combines Canny operator smoothing algorithm with local edge detection algorithm, It combines Adaptive	Canny, Sobel	It extracts the edges richer in detail, more accurate positioning and

		filtering improved canny operator with local weighted K- average method		more unaffected by noise
Guanghui Deng et. al. (2015)	Comparison and Analysis for Edge Detection Algorithm based on SQI Image Enhancement	Proposed Self Quotient Image algorithm based on QI and MSR	Robert, Sobel, Prewitt, LoG, Canny	Gives a theoretical basis and contribute to actual graphics work
Anil Patel et. al. (2016)	Performance Enhancement in Edge Detection Technique	Proposed Ant Colony Optimization method combined with DT-CWT with k-mean clustering algorithm and Fuzzy C-means algorithm	Wavelet	It removes distortion and gives better orientation capabilities also extracts all the edges with enhancing and better B/W edge result
Tapan Sharma et. al. (2016)	Performance Comparison of Edge Detection Algorithms for Satellite Images using Bigdata Platform Spark	Bigdata platform Apache Spark is used on remote sensing images	Canny, Sobel, LoG	While scaling well canny took more time than others but storing and processing larger files are not good enough
Chutiwan Boonarchatong et. al. (2017)	Performance Analysis of Edge Detection with THEOS Satellite Images	THEOS Satellite Images taken for different edge detection technique focusing on PSNR< MSE and time consumption	Canny, LoG, Sobel, Prewitt	Canny and LoG produced the best result with less MSE value
J. Vijayakumar et. al. (2017)	A Review and Performance Analysis of Image Edge Detection Algorithms	Coronal disease images are taken for edge detection	Canny, LoG, Sobel, Prewitt, Robert	Canny gives the best result with poor execution time while LoG and Sobel are more accurate and Prewitt is quickly computed
Md Khurram Monir Rabby et. al. (2018)	A modified Canny Edge Detection and Classification	Modified Canny Edge Detection Algorithm is used for fruit detection	Canny	Detection rate is higher than the traditional approach and easy to compute

3. CONCLUSIONS

This paper presents a comparison study of different edge detection techniques and a study about edge detection. Edge detection is important to found accurately and error-free because it an important part of image processing which is used in many applications. All edge detection techniques have properties that differentiate them from each other. Canny is very expensive in terms of computation but gives the best result with a low error rate, Sobel technique gives more accurate edges

and Prewitt is quickly computed. The future proposed work for edge detection is to detect edges of different edge detection techniques using Scilab. The advantage of using Scilab is, it is an open-source tool and which is freely available on the Internet and it is an alternative FOSS (free and open-source software) of MATLAB because mostly MATLAB license is pirated one or the original one is very expensive. Scilab comes with 95% compatibility with MATLAB. It has an open programming environment that allows creating your functions and libraries. This work opens new possibilities for using open source tools.

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