International Journal of Computing and Applications | **ISSN: 0973-5704**
Volume 13, Number 2, (July-December 2018), pp 211-219

COMPUTATIONAL COMPARISON OF VARIOUS EXISTING EDGE DETECTION TECHNIQUES FOR MEDICAL IMAGES

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Abstract: Segmentation separates the digital image into multiple segments (set of pixels) and each segment possesses different features such as texture, color, intensity and many statistical properties. It is a way to interpret an image in detail. In image processing and pattern recognition edge detection techniques plays an important role and used as a preprocessing step. Edges are the most essential part in the image because an image contains most important features such as corner, lines, curves etc on their edges. The edge detection in an image reduces the amount of data by filtering out useless information and preserves necessary properties. So, it is very important to choose a robust edge detection technique to obtain the best results in all the conditions. In this paper we have tried to give a comparative study on some commonly use edge detection techniques such as Sobel, Prewitt, Roberts, LoG and Canny.

Keywords: Segmentation, Sobel, Prewitt, Roberts, LoG, Canny.

1. INTRODUCTION

Image processing is a method to acquire an enhanced image by converting it into digital form in order to extract some meaningful information from it by performing many operations on an image. It takes image as an input and output may the features/ characteristics related to that image. It involves basically three steps- image acquisition with the help of acquisition tool, manipulation and analysis of the image and finds result on the basis of the image analysis. The purpose of the image processing is visualization of the image objects, image restoration and sharpening to create a better image, image retrieval to find ROI, measurement of various objects in the image and image recognition to distinguish image objects. [24]

Image analysis is the process of extracting meaningful information from an image by using automatic and semi-automatic image processing techniques and the final result of the image analysis is a numerical data rather than an image. Image analysis process involves the following phases: (a) image acquisition (b) pre-processing (c) image segmentation (d) feature extraction and feature selection (e) data analysis. Each phase is differing from another phase and each phase has the own process, methods and techniques. [1]

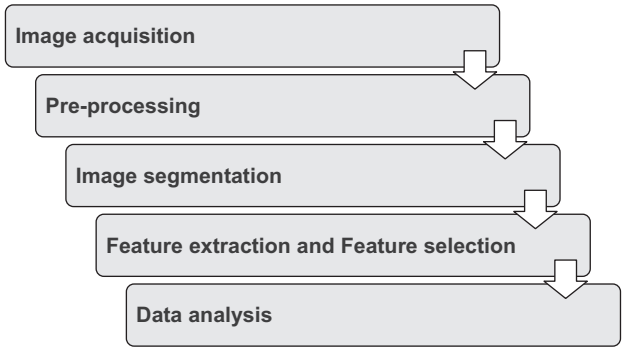


Figure 1: Pipeline of image analysis [1]

Image acquisition: Image acquisition is the very first step in image processing and analysis. High quality images are collected and stored for further diagnosis. Sampling and quantization processes are used to convert the continuous sensed data into a digital form. [1]

Pre-processing: Real time images are collected from publically available database. These are raw images

having various types of noise. These images are used for image classification and segmentation, so there is a need of suitable pre- processing methodologies to enhance the image quality. Image pre-processing is a basic operation on an image at the lowest level whose purpose is to improve the image data and remove the noise to improve the image features used for further processing. [1, 2, 3]

Image segmentation: Image segmentation involves separating a digital image into multiple meaningful regions (sometimes termed as region of interest (ROI)) and set of pixel regions that are strongly correlated with features and object of interest in the image.[1]

Feature extraction and feature selection: This phase is used to remove redundancy from the data. It is related to extracting most representative features from the raw image. On the other hand, to improve the classification accuracy feature selection involves searching most relevant features. Basically there are two kinds of features, statistical features such as pixel density, mathematical transformation and moment and structural features such as contour, number of circles and stroke. [1]

Data analysis: The extracted and selected features are then used to analyzed and expected to have relevant information from the input data. [1]

Among these phases here we mainly focus on the image segmentation techniques:

Segmentation of an image done to achieve mainly two objectives first is to construct an image into several parts to discover various image features and second is to extract meaningful information from an image and change the image representation into higher-level units that is much more meaningful for the future image analysis. Image segmentation involves separating a digital image into multiple meaningful regions (sometimes termed as region of interest (ROI)) and set of pixel regions that are strongly correlated with features and object of interest in the image. [4, 5] Region of interest used in image processing such as feature extraction, selection and disease classification. While segmentation, image is preprocessed which includes image enhancement, smoothening, filtering, restoration and pixel representation which is essential step to improve the segmentation process and noise filtering. [6, 7, 9] The segmented image is a set of contours that will rejoin to form the entire image and the level of segmentation is application dependent and also depends on the features that the image contained such as color, texture, shape, pixel intensity etc. [6, 8, 9, 23, 25]

Image is a very successful source for information transmission. There is no universally available method for image segmentation so it is a challenge to develop an efficient method which will facilitate to understand an image and mine information from them to execute various jobs such as extracting harmful tissues from body scan, finding cancer cells, detection of airport from remote sensing data, robot navigation etc. [10] Segmentation is very primary and essential process in many image processing steps and also useful in image interpretation and analysis because object specific knowledge is require for the image interpretation, so image segmentation is a very important step in image analysis, visualization and object representation. Segmentation used to detect, recognize and measure the image objects. The segmentation process is used to differentiate between low and high level image processing. However it is very hard to get consistent and correct segmentation of an image by automatic means. Image segmentation turn into very popular area because there are many practical application areas of image segmentation such as in medical imaging (locate tumors, diagnosis, study of anatomical structures), satellite images to classify terrains, optical character recognition (OCR), image compression, watermarking, machine vision, brake light detection, traffic control and industrial inspection and so on where it is such a unpractical thing to process whole image directly. [10, 11, 25]

Segmentation mainly define as grouping an image pixels into multiple non-overlapping regions (set of pixels) that have homogeneous attributes such as intensity, color, range, texture. The regions must be connected and the union of adjacent regions needs to be non-uniform with respect to the same characteristics. Segmentation consistently only extracts

those features or parts of the image that need to be analyzed further. [7] Discontinuity and similarity are the two basic properties of intensity and the image segmentation techniques are based on these two.

2. REVIEW OF LITERATURE

Jamil A. M. et. al.(2012): [5] Authors compares two segmentation techniques first is Otsu thresholding (based on similarity approach) and second is Canny edge detection (based on discontinuity approach) and tests their correctness and stability on variety of medical and other types of images. For the segmentation purpose these two algorithms are best but for the endoscopic images canny algorithm is more suitable because in these images objects are not clearly separable from the background.

Singh P. and Chadha S.R. (2013): [10] The study suggested a novel approach to divide the image into multiple pieces to get more efficient vision of the image. They adopt one of the segmentation technique based on edge detection of the image present in the background and foreground. According to their suggested approach, after having the edge detection, dilation is applied over it from which is correctness is achieved for all type of images but stability is not achieved in the case of .png format.

Tamilselvan K.S. et. al., (2015): [7] Here in this paper researchers proposed a idea which is suggested as combination of different techniques such as Wavelet, Curvelet (clearly used for denoising) and Multiple Kernel Fuzzy C Mean Algorithm (preferred for 2-D and curvy images), to identify and extract the defected region from the clinical CT Image. Experimentally after applying their proposed work in noisy medical CT scan images they found 96.5% increment in efficiency. As a future work they will try to implement an algorithm which is also suited for MRI, PET and SPET images.

Chandrakala M. and Durgadevi P. (2016): [4] By comparing the existing algorithm with their proposed work they suggested threshold based segmentation technique using block processing for removal of non-uniform illumination background. In their proposed algorithm, image is segmented into M*N block on which global threshold as applied for each block. They concluded their technique as it has been proven by giving better and relevant results as compared with contemporary methods.

Sambasivarao Ch. and Naganjaneyulu V. (2014): [12] Authors proposed a novel approach of boundary detection and image segmentation which is based on one of the common properties of image named as perceptual organization model. This work has to be proven for the outdoor images for their background recognition. The author's aim is to recognize the strictly structured objects (combination of constituent parts) to get the accurate and efficient segmented image.

Singh P. and Singh A. (2016): [10] Reviewed various segmentation techniques such as region based. Threshold based, cluster based and generic algorithm optimization based segmentation. They found region growing based segmentation well accurate as compared to other techniques except its limitation of having low intensity and complex background images. So by using fuzzy based modified shift and minimum spanning tree, they will probably improve multi spectral image segmentation.

3. IMPLEMENTATION

Image segmentation techniques are basically categorized into two categories: discontinuity approach (edge-based) and similarity approach (region- based) based on the two basic properties of the image. Segmentation method which is based on the discontinuity property of pixel, separate the image simply based on the sudden changes in intensity and it includes boundary or edge based techniques and the segmentation method based on similarity and homogeneity, partition the image by constructing the groups which are very analogous to each other and it uses methods like Thresholding, merging, region splitting and region growing. [12, 14, 5]

A. Pixel Based Methods

Thresholding: Thresholding is one of the simplest and broadly accepted tools for the image segmentation to separate light objects from the dark background

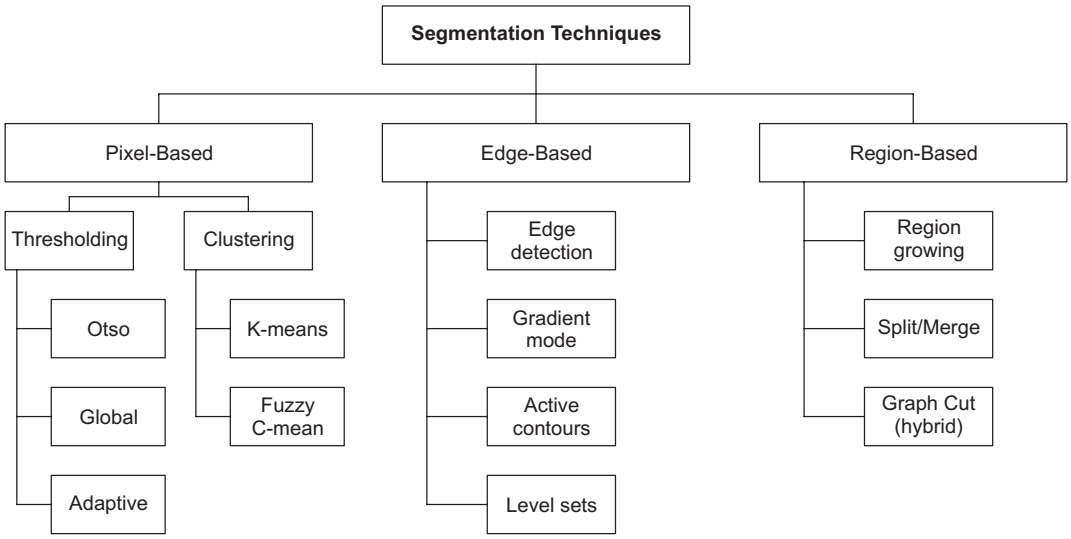


Figure 2: Segmentation techniques [13]

based on the image feature such as color, intensity and texture. [4, 5, 9] Intensity is a very common property that pixels of an image can share, so we use a natural way to segment image into regions is Thresholding. [5] This method separate the image into two parts, black as background and white as foreground by choosing a satisfactory threshold value T or we can say that it converts the image into binary form.

B. Region Based

Region based technique is also known as "similarity based segmentation" used to find out region directly. [15, 16] It partition an image into uniform sub-regions based on some properties such as texture, color, intensity etc. Pixels belong to same intensity characteristics and closed to each other can be group together and assumed to be in same object. Region contains more information because it covers more pixels than edges. To detect regions we use texture and it is not simple to handle it with edges. In noisy images where edges are difficult to get, region growing technique is used. Watershed algorithm, region split and merge algorithm and region growing algorithm are the some commonly used methods of region based technique.

C. Edge Based

Using edge detection operators this method used to find the edge information in the image and transform original image into edge images. Pixels between boundary of two regions form edge. Generally filtering, enhancement and detection of edge points are the three main steps to carry out edge detection process. [15, 17] Edges are the most essential part in the image because an image contains most important features such as corner, lines, curves etc on their edges. [18] Edge detection decreases the amount of data size to be processed and sort out the useless information and save essential structural properties in the image.[19, 11] Gradient based 1st order derivative (sobel operator, Prewit operator, Robert operator) and laplacian based 2nd order derivative (Laplacian of Gaussian, canny edge detection) are the two commonly used methods for edge detection. [18]

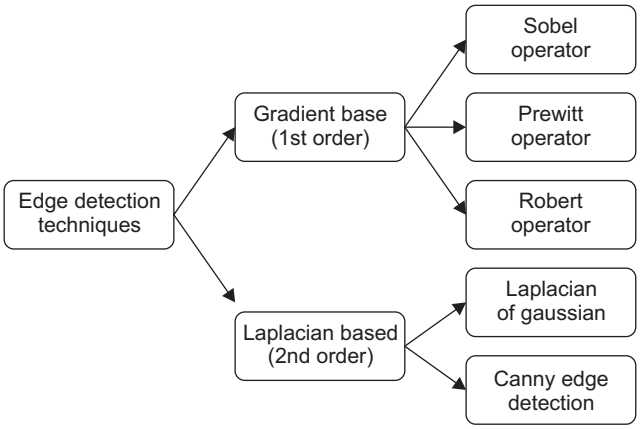


Figure 3: Edge based segmentation techniques [18]

Sobel operator: This operator is used to detect the edge strength and edge direction in the image. [15]

BW = edge (I, 'sobel') - is the formula for the sobel method and BW = edge (I, 'sobel', thresh) – it is for the threshold sensitivity for the sobel method. All the edges with lower value than thresh are ignored and if the thresh is not given than edge selects the value automatically. [11] Sobel is used to obtain the gradient measurement of the image from the original with the help of convolution mask of sobel operator. It is 3x3 convolution kernels. [22]

–1	0	1
–2	0	2
–1	0	1

1	2	1
0	0	0
1	–2	–1

Figure 4: Sobel mask [26]

Prewitt operator: It is a gradient based edge detector operator and approximate method to calculate the orientation and magnitude of an edge and estimate in the 3x3 neighborhood for 8 directions. BW = edge (I, 'Prewitt') – it is a formula for the Prewitt method and BW = edge (I, 'Prewitt', thresh)- calculates the thresholding sensitivity of the Prewitt method. All the edges with lower value than thresh is ignored and if the thresh is not given the method automatically selects the value of thresh. [22]

–1	0	+1
–2	0	+2
–1	0	+3

+1	+2	+1
0	0	0
–1	–2	–1

Figure 5: Prewitt mask [26]

Robert operator: It is a gradient based edge detector operator and provide a 2D spatial gradient measurement of an image and has 2x2 convolution mask. BW = edge (I, 'Roberts') – formula for the Robert operator and BW = edge (I, 'Roberts', thresh) gives the thresholding sensitivity of the Roberts method. All the edges that are not stronger than thresh is ignored and if the thresh is not given the method automatically selects the value of thresh. [22]

–1	0
0	–1

0	1
–1	0

Figure 6: Roberts mask [26]

Laplacian of Gaussian (LoG): BW = edge (I, 'log') – is the MATLAB formula for the log operator and BW = edge (I, 'log', thresh) tells the thresholding sensitivity of the log method. All the edges that are not stronger than thresh is ignored. Log of an image is a second order derivative and the digital implementation of the laplacian function is done by using the mask. It firstly smoothes the image and then computes laplacian. [22]

0	–1	0
–1	4	–1
0	–1	0

Figure 7: Laplacian of Gaussian (LoG) operator [26]

Canny edge detection: BW = edge (I, 'canny') – formula for the canny operator and BW = edge (I, 'canyy', thresh) specifies the thresholding sensitivity of the log method. In canny operator thresh has two elements- first is low threshold and second is high threshold. Canny edge detector is a widely acceptable method in image processing. It is very robust method to detect edges and less adaptable to noise and find edges in the image by removing noise from the input image. It takes less time than the other edge detection methods and extract features from the image without destroying image features. [22]

Canny is an optimal edge finding method. The algorithm followed in series of stages. There are three criterions to implement the canny algorithm and improve the edge detection methods. First is low error rate means minimum number of false edges or minimum response to non- edges. Second is localization means closeness between the edge pixel detected by the detector and the real edge is to be at a minimum and the third is one response to a single edge means one edge should be detected only once. In order to implement the canny edge detector algorithm, we use the following steps to find the edges present in the image. [20, 21, 22]

Step 1: The first step is smoothing of the image to create an intermediate image with the help of Gaussian convolution to reduce the noise from the original image before finding any edges in the given image. [20]

Step 2: Second phase is used to find out the edge strength by finding approximate absolute gradient

magnitude at every point. At this stage the sobel operator is used to find out the horizontal (rows) and vertical (columns) gradient. [20]

Gx =

–1	0	+1
–2	0	+2
–1	0	+1

Gy =

+1	+2	+1
0	0	0
–1	–2	–1

The image obtained from first stage is now convolved with a 3x3 sobel operator and gradient image is generated. Gx and Gy are the image with magnitude of the horizontal and vertical gradient respectively.

Step 3: The gradient in X and Y direction is used to calculate the direction of the edge. $\theta = \arctan(Gy/Gx)$ is used to find out the edge direction of each pixel in an edge direction image. [20]

Step 4: The next step is to relate the edge direction to a direction traced in an image. If 5x5 image pixels are aligned like this:

$$\begin{matrix} x & x & x & x & x \\ x & x & x & x & x \\ x & x & a & x & x \\ x & x & x & x & x \\ x & x & x & x & x \end{matrix}$$

By taking pixel "a" there are only four possible directions when describing the surrounding pixels-0 degree, 45 degree, 90 degree and 135 degree. [20]

Step 5: When the edge directions are known, then non-maximum suppression now has to be applied. It suppresses any pixel value (set it equal to 0) that is not marked as an edge. It will help to produce a slim line in final image.

Step 6: At the last stage of the canny edge detection algorithm we choose two threshold values, T1 (high) and T2 (low), it is known as Hysteresis thresholding. The edge selection and rejection is depends on the value of T1 and T2. [20]

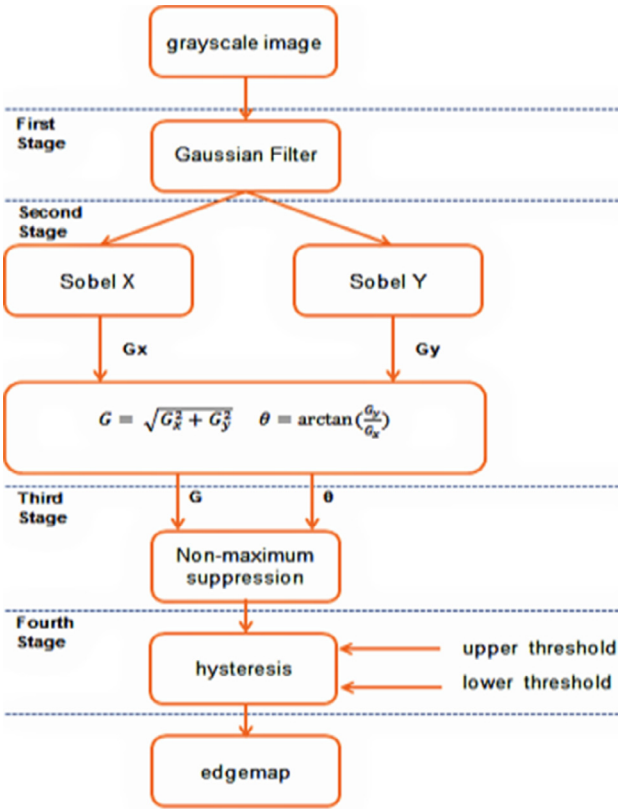


Figure 9: Block diagram of canny edge detection [20]

4. RESULT AND DISCUSSION

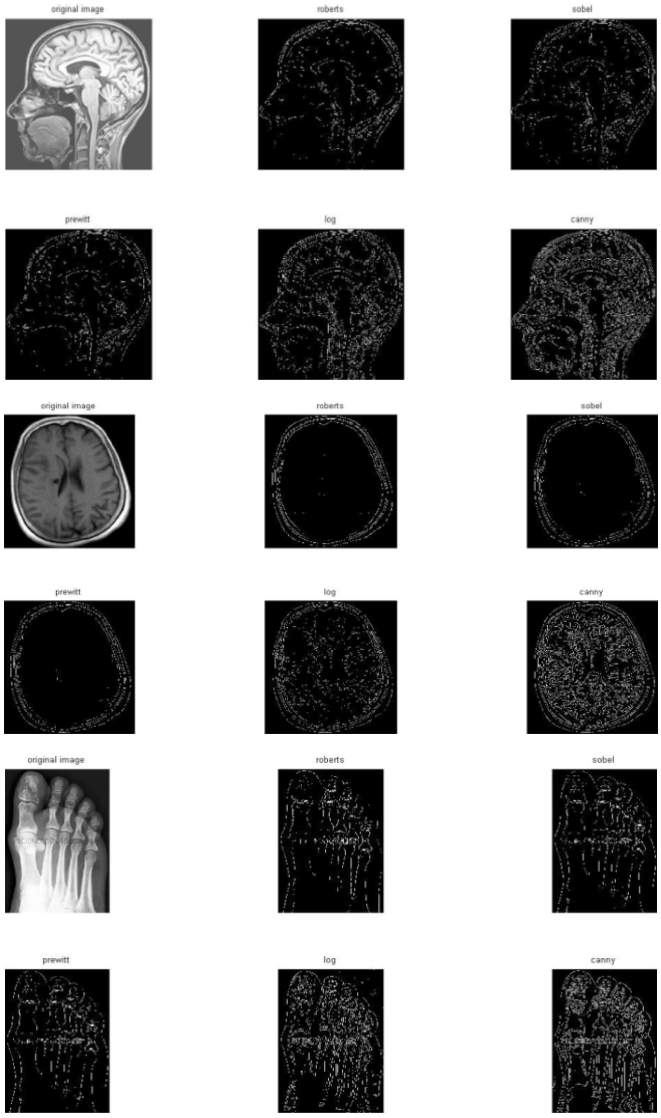
A. **Experimental environment:** The various edge detection techniques are experimented in this section on different-different images. Ten image Samples were experimented with the help of MATLAB R2013a on Intel(R) Core(TM) i3 CPU 540 @ 3.07GHz processor, 4.00GB RAM and 64-bit operating system. Here we choose three samples to show the results. Results may vary depending on the machine configuration

B. Comparison between various edge detection techniques:

Parameters	*Roberts*	*Sobel*	*Prewitt*	*LoG*	*Canny*
Noise Sensitivity	Sensitive to noise.	Very sensitive to noise.	Very sensitive to noise.	Gaussian Smoothing filter is used to reduce noise sensitivity.	Give better performance In the presence of noise
Execution Time	Quick to compute.	More time consuming.	Less time consuming.	Less time consuming.	Time consuming.

Parameters	*Roberts*	*Sobel*	*Prewitt*	*LoG*	*Canny*
Simplicity	Simple and easy to implement	Simple and easy to implement	Simple and easy to implement	Malfunctioning at corners and curves.	Complex computation and false zero crossing.
Edge correctness	Detect edges and their orientation when there is a sharp change in intensity values.	Detect edges and their orientation and response average change in intensity values.	Detect edges and their orientation and more sensitive to horizontal and vertical edges.	Tests wider area around the pixel and find the edges correctly and does not find edge orientation due to the use of Laplacian filter.	Mark all the possible edges especially in noise conditions and specifies three issues- error rate, localization and response.

5. RESULTS



Discussion: We have applied Sobel, Roberts, Prewitt, LoG and Canny algorithms on five medical images and results are shown above. The edge detection of an image reduces the amount of data to be processed while preserving the main structural properties of an image. In this study the edge detection techniques are compared on many medical images. The performance of the canny algorithm is better than all these operators and this algorithm mainly depends on two changing parameters- first is standard deviation for the Gaussian filter and second is its thresholds values. These adjustable parameters can affect the computation time and effectiveness of the algorithm.

6. CONCLUSION

To recognize an image object, edge detection is the initial step in image processing. It is very important to find out the merits and demerits of various edge detection techniques before using them. This paper mainly deals with comparative study of edge detection operators along with their experimental analysis. Canny edge detection technique produces higher accuracy in image object detection as compared to other edge detection techniques. Canny is an optimal edge detection technique which respond better in high resolution images but in noisy environment it gives false results. However, the canny's edge detection operator has a greater performance but it is more expensive as compared to the other techniques and from the above results, it is concluded that canny is a best operator for edge detection.

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