INVESTIGATION OF EDGE DETECTION TECHNIQUES BASED ON BRAIN TUMOR IMAGES

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by

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LIST OF ABBREVIATIONS

AD	Average Deviation
CT	Computed Tomography
DICOM	Digital Imaging and Communications in Medicine
GUI	Graphical User Interface
HVS	Human Visual System
IF	Image Fidelity
JPEG	Joint Picture Experts Group
LoG	Laplacian of Gaussian
MAE	Mean Absolute Error
MD	Maximum Difference
MRI	Magnetic Resonance Imaging
MSE	Mean squared error
NIFTI	Neuroimaging Informatics Technology Initiative
NK	Normal Cross-Correlation
PMSE	Peak Mean Square Error
PSNR	Peak signal to noise ratio
SC	Structural Content
SSIM	Structural Similarity index

ABSTRAK

Pemprosesan imej perubatan telah menjadi satu teknik penting yang boleh menggambarkan bahagian dalaman badan manusia untuk diagnosis yang lebih baik dan pengekstrakan struktur anatomi. Pemprosesan imej mempunyai kelebihan yang diterbitkan semula data asal secara berulang-ulang tanpa apa-apa perubahan yang membantu pakar radiologi untuk analisis. Magnetic Resonance Imaging (MRI) adalah salah satu modaliti pengimejan perubatan yang bergantung kepada teknologi komputer untuk mencipta imej terperinci otak. Output imej dengan MRI perlu menjalani beberapa teknik pengimejan untuk mendapatkan maklumat yang penting dengan tepat. Dalam kertas kerja ini, semua imej input MRI otak berada di dalam format DICOM. Imej-imej yang menjalani tiga langkah asas teknik pengesanan kelebihan. Pengendali pengesanan pinggir digunakan untuk mengesan tumor otak adalah Robert sifar-persimpangan, pengendali Sobel, pengendali Prewitt, operator Canny dan algoritma Canny diubah suai. Keputusan visual dari setiap pengendali dianalisis menggunakan ukuran kuantitatif dan kualitatif. Parameter kuantitatif yang digunakan untuk menilai pengendali persembahan adalah PSNR, MSE dan SSIM. Berdasarkan analisis kuantitatif, Canny algoritma baru berjaya menghasilkan imej berkualiti tinggi dengan ralat kurang. Walau bagaimanapun, dari perspektif visual, pengendali Sobel dihasilkan peta kelebihan lebih baik daripada tumor otak berbanding algoritma Canny yang diubahsuai.

ABSTRACT

Medical image processing has become an important technique that can visualize the interior of a human body for better diagnosis and extraction of an anatomical structure. Image processing has an advantage which reproduced original data repetitively without any changes that helps radiologist for analysis. Magnetic Resonance Imaging(MRI) is one of the medical imaging modalities that depend on computer technology to create detailed images of the brain. The output image by MRI need to undergo several imaging techniques to extract the important information accurately. In this work, all input MRI brain images are in DICOM format. The images undergo three fundamental steps of edge detection techniques. The edge detection operators used to detect the brain tumor are Robert zero-crossing, Sobel operator, Prewitt operator, Canny operator and modified Canny algorithm. The visual results from each operators are analyzed using quantitative and qualitative measurement. The quantitative parameters used to evaluate the operators performances are PSNR, MSE and SSIM. Based on the quantitative analysis, the new Canny algorithm successfully produced high quality image with less error. However, from visual perspective, Sobel operator produced better edge maps of the brain tumor compared to the Modified Canny algorithm.

CHAPTER 1

INTRODUCTION

This chapter introduces the background of this work as well as problem statement. The objectives and research scopes also presented in this chapter. The overview in this chapter will gave general ideas that are related to this work.

1.1 Research Background

Medical image processing has become an important technique in order to visualize the interior of a body for an easy clinical analysis with the availability of computational resources such as computed tomography (CT), magnetic resonance imaging (MRI), ultrasound, thermography and various techniques based on nuclear emissions. The development of these technologies helps to reveal useful clinical information of the inner side and functions of certain tissues and organs in the form of an image. Besides that, medical imaging help doctors to diagnose and identify abnormalities in a patient's body. Thus, processing of medical images has become one of the most important parts of digital image processing (Choubey, 2014).

A brain is one of the most complex organs that serves as the center of a human nervous system as it made up of many cells that have their own functions. When normal cells grow old or damaged, they die and new cells will form and take their place (Veer and Patil, 2015). A brain tumor is a mass of abnormal cells in the brain that form when there are new cells grow even though the body does not need them and old or damaged cells do not die as they should. Brain tumor can be categorized as a primary tumor or secondary tumor. The primary brain tumors originate in the brain while secondary brain tumor originated in another part of the body such as lung or breast and spread to the brain. The primary brain tumor can be cancerous (malignant) or noncancerous (benign). The benign type of tumor grows slowly and rarely spread to other parts of the body. They usually have obvious border or edge and can be removed through surgery. The malignant tumor is more serious because it grows rapidly than the benign tumor (Sharma, Diwakar and Choudhary, 2012). The cancer cells may break away from the malignant brain tumors and spread to other parts of the brain or spinal cord.

Among the medical imaging modalities, MRI is frequently employed for brain tumor detection. Compared to other imaging modalities, MRI uses magnetic fields and radio waves to generate the detailed images of the brain. MRI generates three type of images which are T1-weighted, T2-weighted and proton density images (Hesselink, n.d).

In this research the MRI images need to apply several imaging techniques to extract the important information. However, there are various techniques are proposed by different researchers for the brain tumor detection. Therefore, the most suitable edge detection technique will be determined and help the doctors to obtain a clear edges image to evaluate the patient's condition.

1.2 Problem Statement

Digital image processing play an important role in medical field to assist in diagnosing patients. There are various image processing techniques that available for medical purposes such as neural networks, segmentation, wavelets and many more techniques. These techniques can be used as a second opinion and assistance by the radiologist in improving the diagnosis accuracy. Furthermore by depending to the experts alone to perceive the images, it will consume longer time to diagnose and will cost expensive. There are estimated between 3% to 5% of day-to-day rate of error and discrepancies during radiology examination (Brady, 2017). Besides that, noise is an inherent property of medical imaging, and it tends to reduce the image resolution and contrast. Thus, raw medical image are not suitable for analysis because the image quality is reduced (Somkuwar and Bhargava, 2013). This work will discussed about one of segmentation component which is edge detection that commonly applied to detect the region of brain tumour in medical imaging.

Recently, many researchers working on developing effective edge detection algorithm for brain tumor detection. A number of different studies (Rajesh and Bhalchandra, 2012; Mustaqeem, Javed, and Fatima, 2012) proposed an algorithm using watershed, thresholding and morphological operations to extract brain tumour. Both studies performed preprocessing to enhance the images and morphological operation in order to extract the tumor. The results obtained from both presented algorithms showed the location of the tumor. The tumor extracted was detected as white portion in the final output images. Although the tumor was successfully extracted, both research papers did not provide the results for image quality measurements to measure the effectiveness of the proposed algorithm. Besides that, Mustaqeem, Javed, and Fatima (2012, p.34) used a compressed file format image, JPEG for the research. Thus, without the image quality assessment, the result may lead to misunderstanding for the radiologist during screening process.

Therefore, this work proposed a new Canny edge detection algorithm to extract brain tumor from MRI images. The output images will be analyze by using quantitative analysis in order to measure the image quality and the effectiveness of the proposed algorithm.

1.3 Objectives

The objectives of this work are :

1. To proposed a new Canny edge detection algorithm that able to detect brain tumor
2. To investigate the performances of Robert operator, Prewitt operator, Sobel operator, Canny algorithm and modified Canny algorithm by using quantitative analysis

1.4 Scope of Research

Different MRI brain tumor images of Digital Imaging and Communications in Medicine (DICOM) format that available online are used in this work. The images will undergo image processing technique which is edge detection to locate the tumor edges. The operators used for the edge detection techniques are Roberts operator, Prewitt operator, Sobel operator, Canny algorithm and modified Canny algorithm. For the image quality evaluation, objective measurement such as MSE, PSNR and SSIM are used to evaluate the tumor edge detected. The images will be simulated and evaluated by using MATLAB R2017b software.

1.5 Thesis Outline

This paper work consists of five chapters that will discusses and evaluates the edges detect based on each edge detection techniques applied in this work. The edges image will be obtain through simulation of MRI brain tumor images available in the internet. Chapter 2 presents the literature review from previous studies that relevant to this research. This chapter is divided into several subtopics. The first subtopic reviewing some of pre-processing algorithms that commonly uses for medical image processing. Next are the review of edge detection operators and image evaluation metrics used by the researches. Subsequently, Chapter 3 discusses the details of each methodology applied in this research. All the related theories and mathematical algorithms for the methodologies will be presented in this chapter. In Chapter 4, the results obtained from the simulation will be analyzed and evaluated by using the objective measures to evaluate the edges image. Lastly, Chapter 5 will conclude the overall outcome of this research and provides some suggestions for possible future improvements.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Medical image processing has become the core innovation for medical imaging. This chapter will focused on previous research related to edge detection techniques. Edge detection is one of the fundamental tool in image processing, machine vision and computer vision, especially in features extraction and features detection (Nosrati et al., 2013). As stated by Muthukrishnan and Radha (2011, p.259), edge detection significantly helps to reduce the amount of data and filters out useless information, while preserving the important structural properties in the image. The most common methods are Canny algorithm, Laplacian of Gaussian (LoG), Roberts operator, Prewitt operator, Sobel operator, Robinson operator, Kirsch operator, and Marr-Hildreth. Image evaluation assessment used by other research to evaluate edge detection results will be presented in Section 2.2.

2.2 Edge Detection Techniques

Muthukrishnan and Radha (2011, p.259) studied the performance of common edge detection techniques and compared each techniques results. The most commonly used edge detection techniques are Roberts, Sobel, Prewitt, Kirsh, Robinson, Marr-Hildreth, LoG and Canny edge detections. The objective of the experiment is to produce a clean edge map by extracting the principal edge features of an image. The experiment was carried out by using MATLAB software and tested with a building image. Based on the results of each techniques shows in Figure 2.1, Canny edge detection produced the best result followed by Marr-Hildreth and LoG that produced almost the same edge map. It stated that Canny works better under different conditions compared to other techniques.

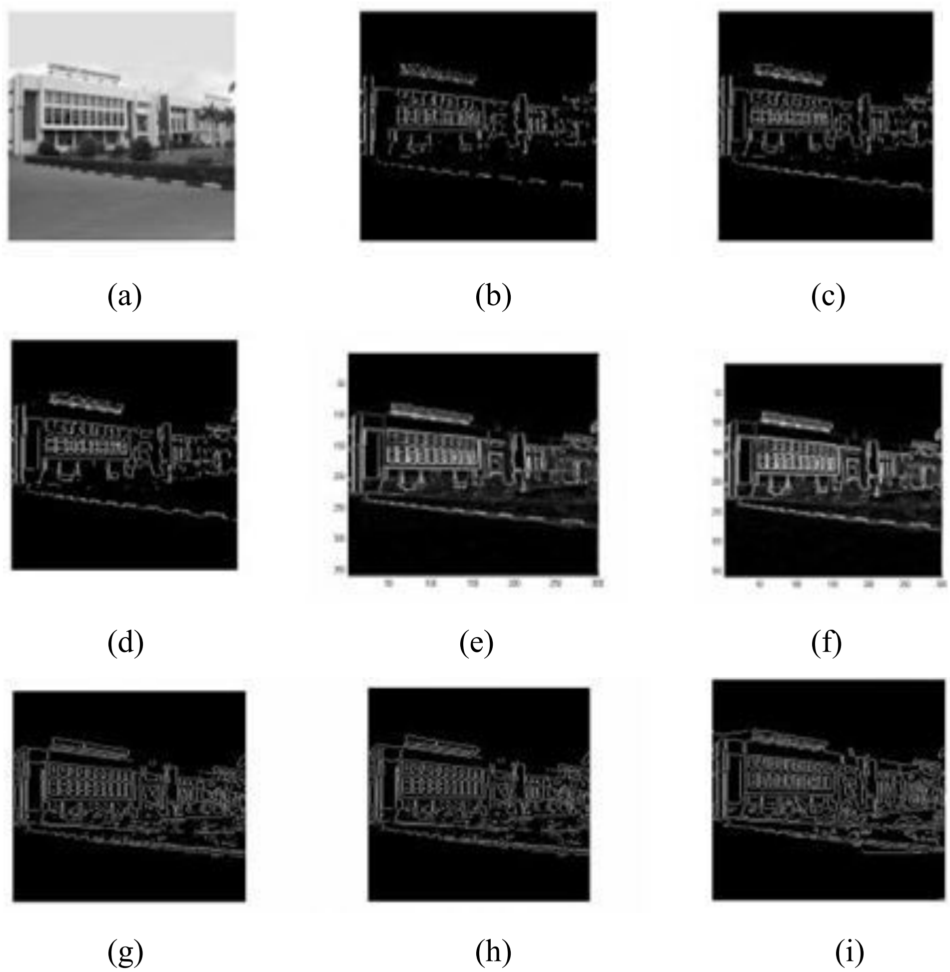
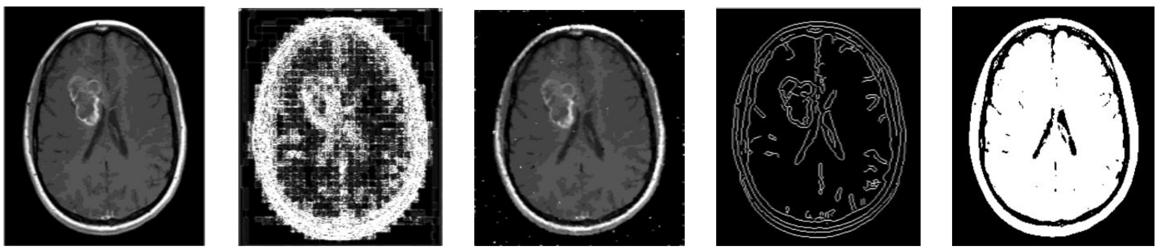


Figure 2.1: Result of various edge detection techniques (a) Original image (b) Robert (c) Sobel (d) Prewitt (e) Kirsch (f) Robinson (g) Marr-Hildreth (h) LoG (i) Canny (Muthukrishnan et al, 2011)

According to Savant (2014, pp.5898-5900), edge detection is useful for discontinuity based image segmentation technique and the paper reviewed various edge detection such as gradient-based and laplacian-based techniques. For this paper, the techniques reviewed are Sobel, Roberts, Prewitt, Laplacian, LoG, Zero crossing and Canny edge detectors. Edge detection significantly helps to filter out useless information while maintains important properties in an image by applying three fundamental edge detection steps, image smoothing, detection of edge points and edge localization. It is stated that this techniques are grouped into two categories which are gradient-based and Laplacian-based.

Gradient-based detection are Sobel, Roberts, Prewitt and Laplacian edge operators which are computed by using the first-order derivative while Laplacian-based is obtained using the second-order derivative. LoG and Zero crossing are includes in Laplacian operator. Canny edge detector is implemented based on three criteria which, low error rate, good edge localization and single edge point response.

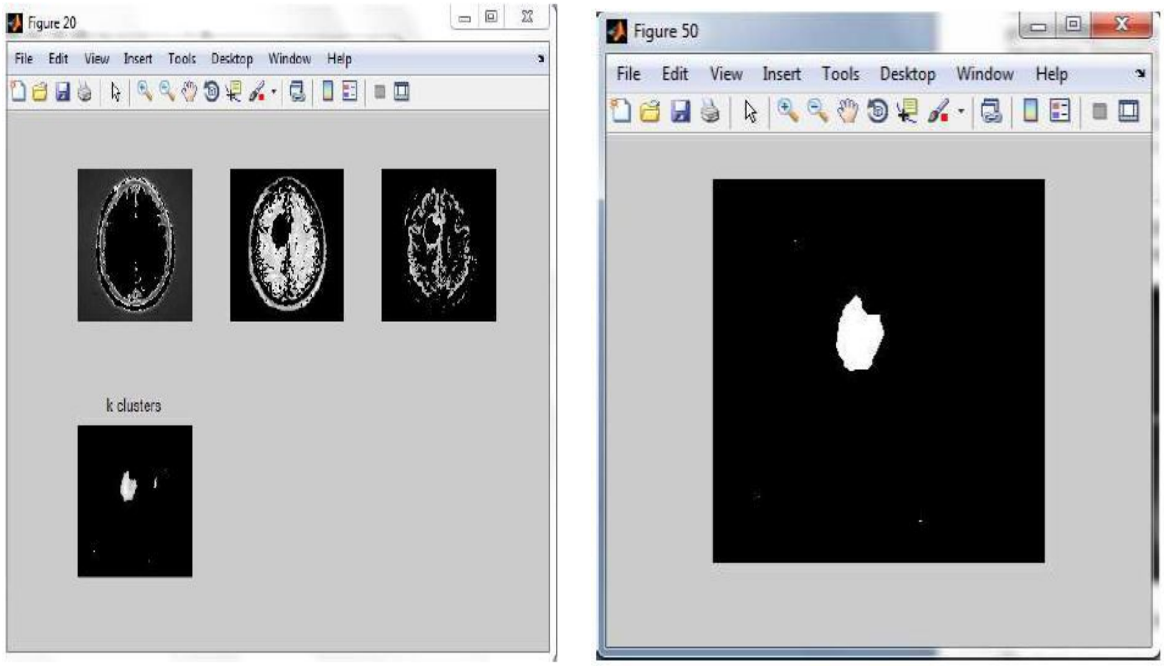
In Manasa, Mounica, and Tejaswi (2016) paper work has proposed a method to detect the best contour of the brain tumor and calculated the area of the tumor. The proposed method involved four main modules which are preprocessing, segmentation, feature extraction and approximate reasoning. For the preprocessing module, filtering techniques such as Gaussian filter and Median filter is used to suppressed unwanted distortions and enhanced the image features for the segmentation step. Gaussian filter helps to filter small objects and thin bars cleaner while Median filter are used to remove noise. The segmentation is done by using Canny edge detection algorithm. Lastly, a thresholding technique is applied to the image in approximate reasoning. Outputs from all the steps stated are shown in Figure 2.2. The results are evaluated using Peak signal-to-noise signal (PSNR) and Mean Square Error (MSE) parameter. According to the paper, the measurement are most commonly used to measure the quality of reconstruction of lossy compression codecs.



(a) (b) (c) (d) (e)

Figure 2.2 : The results (a) Original image (b) Gaussian filter (c) Median filter (d) Edge based segmentation (e) Thresholding (Manasa et al., 2016)

Joseph, Singh, and Manikandan, (2014, pp.1-5) proposed a new algorithm using K-means clustering method and morphological filtering to detect the location of brain tumor. Clustering algorithm is one of segmentation tool in image processing that classified as unsupervised technique because the algorithm automatically detects object based on user's criteria. The researchers used MATLAB Graphical User Interface (GUI) to make the system user-friendly in order to implement the algorithm to simulate the input image and detect the tumor location. The proposed clustering steps is shown in Figure 2.3(a) and the final result is as shown in Figure 2.3(b). Based on the final result, it shows that the algorithm able to segment the tumor from the brain MRI images.



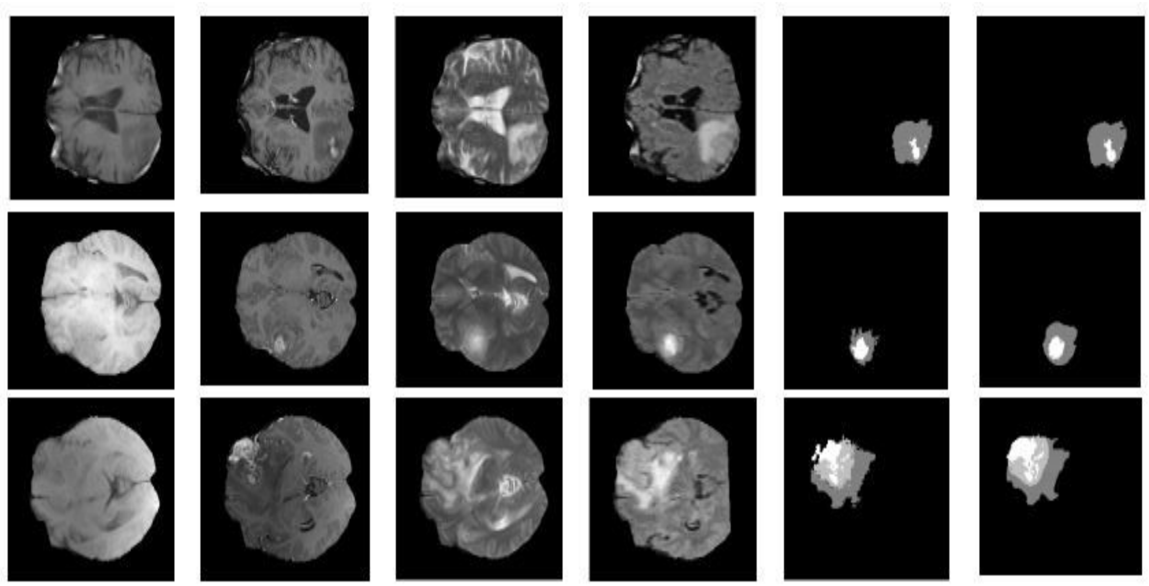
(a) (b)

Figure 2.3 : Result shows in GUI (a) Clustering of brain tumor

(b) Tumor detected (Joseph et al., 2014)

2.3 Image Quality Evaluation

Abbasi and Pour (2014, pp. 269-274) presented a segmentation method for three-dimension (3D) MRI brain image to extract tumor from the image. The method is divided into two stages which are clustering that used to find the region of interest and segmentation stage for segmented cluster. The paper work used MRI brain tumor images that obtained from Brats2013 database and the images are shown in Figure 2.4.



(a) (b) (c) (d) (e) (f)

Figure 2.4 : Segmented tissues (a) T1, (b) T2, (c) T1contrast (d) Flair.
(e) Segmented image f) Ground-truth (Abbasi and Pour, 2014)

The results from the proposed method are evaluated using three-fold cross validation between the ground truth and Dice-Jaccard parameters. Jaccard and Dice parameters can be expressed using Equation 2.1 and Equation 2.2 respectively.

$$J(A,B) = \frac{|A \cap B|}{|A \cup B|} \quad \text{Equation 2.1}$$

$$D(A,B) = \frac{2|A \cap B)}{|A|+|B|} \quad \text{Equation 2.2}$$

Based on result obtained, Dice coefficient for all categories varies between 0.91 to 0.96 with low standard deviation, 0.01 to 0.02 indicates that the method offered a consistency in the results.

Venkat and Rao (2014, p.56), presented the analysis of comparison between various quality metrics for medical image processing purposed. In this work, three medical imaging that commonly used in medical image processing are tested with different levels of compression, noise powers, contrast and blur. MRI images corresponding to the changes of noise power is shown in Figure 2.5 and the values of various quality metrics are shown in Table 2.1. Ultrasound images with variation of contrast are in shown Figure 2.6. The parameters that are used for evaluation are Mean Square Error (MSE), Peak Signal-to-Noise Ratio (PSNR), Average Deviation (AD), Maximum Difference (MD), and Mean Absolute Error (MAE), Normal Cross-Correlation (NK), Structural Content (SC), Image Fidelity (IF), Peak Mean Square Error (PMSE) and Structural Similarity Index (SSIM) parameters.

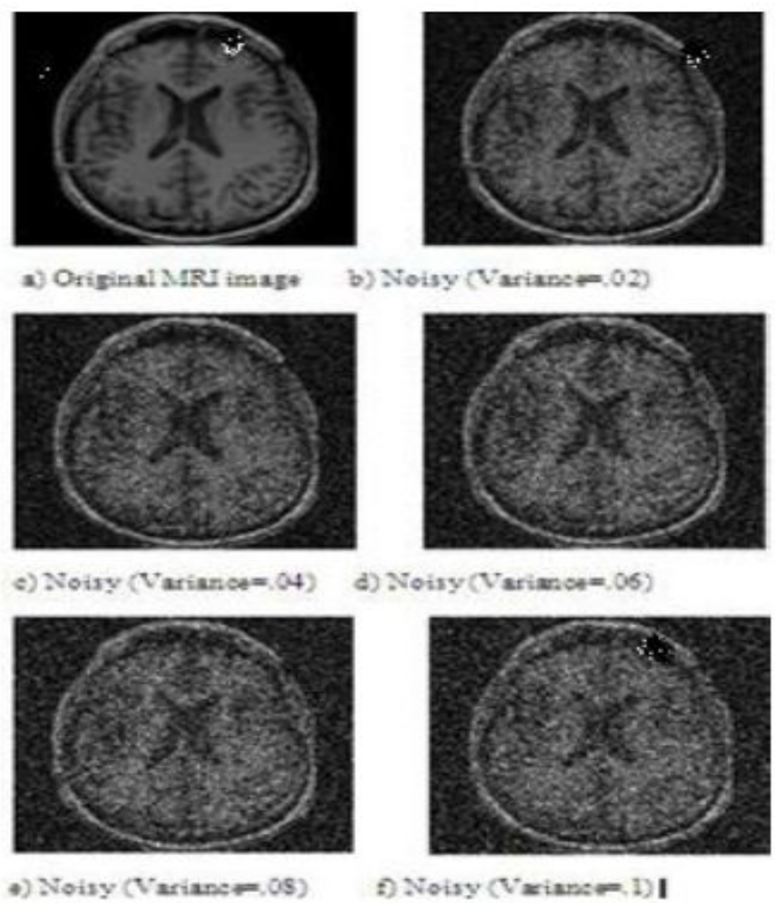


Figure 2.5 : MRI images (Venkat and Rao, 2014)

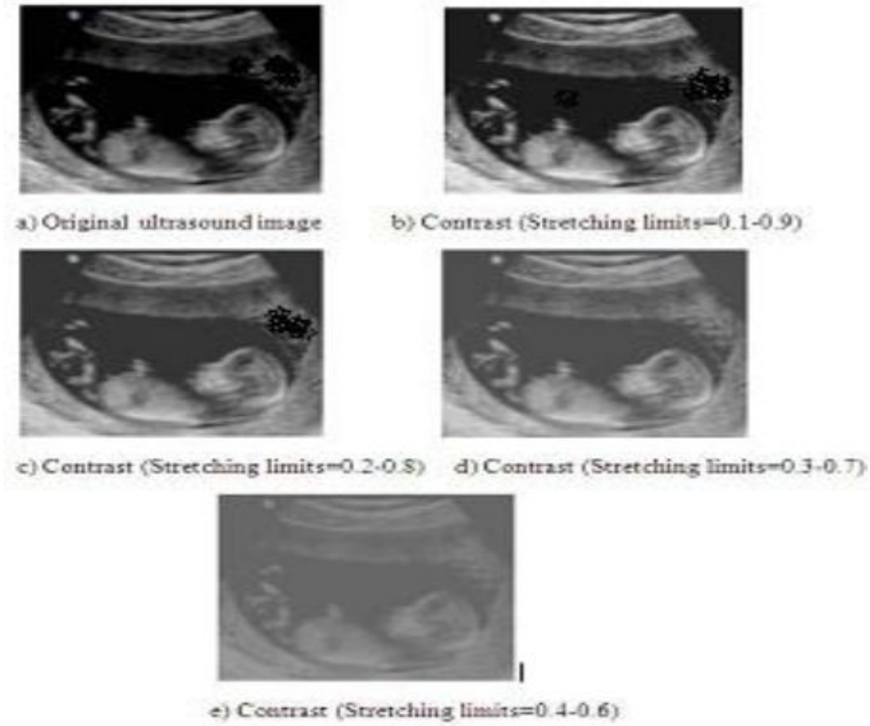


Figure 2.6 : Ultrasound images (Venkat and Rao, 2014)

Table 2.1 : Comparison for Noisy MRI Image

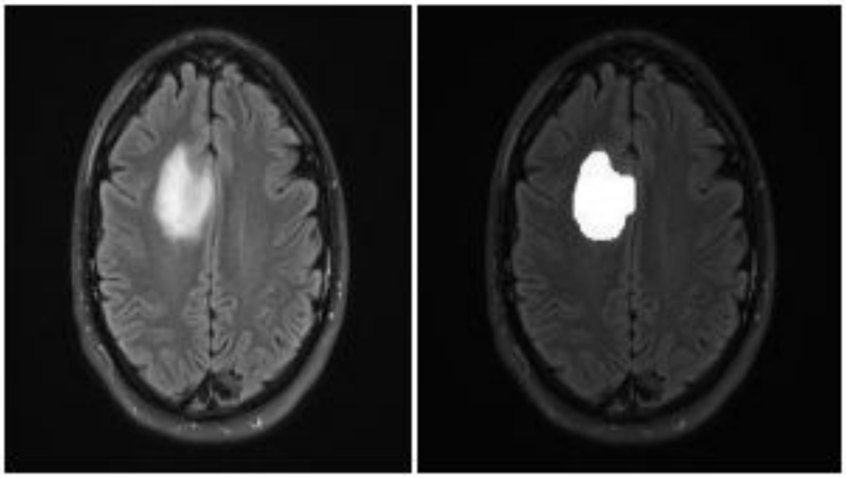
Variance	MSE	PSNR	AD	MD	MAE	NK	SC	IF	PMSE	SSIM
0.02	58.4048	39.2986	-6.6495	153	22.4545	1.0146	1.3525	.7066	.0012	.2036
0.04	63.9898	39.1042	-10.0501	190	30.5875	1.0263	1.5972	.4554	.0012	0.1327
0.06	65.2490	39.0579	-13.766	239	36.6935	1.0598	1.9323	.2172	.0013	.1072
0.08	66.5353	39.0155	-16.6531	255	41.4679	1.0829	2.1662	0.0084	.0014	.0882
0.1	68.3621	38.9567	-18.5784	255	45.1500	1.0900	2.3725	-0.1925	.0013	.0741

Table 2.2 : Comparison for dissimilar Contrast of Ultrasound Image

Stretch limits	MSE	PSNR	AD	MD	MAE	NK	SC	IF	PMSE	SSIM
0.1-0.9	.00289	60.8371	-31.3843	45	31.3858	1.3491	1.8728	.8241	5.1434E-08	.6849
0.2-0.8	.2238	51.3915	-41.5258	51	41.5541	1.3248	1.9363	1.0040	3.7094E-06	.6130
0.3-0.7	1.9789	46.6198	-52.1702	79	52.5986	1.2892	2.1567	.4233	3.5211E-05	.5215
0.4-0.6	10.607	43.1039	-62.4971	101	64.9350	1.2503	2.4578	1.0030	1.7661E-04	.3726

Based on the result from Table 2.1 and Table 2.2, the comparative analysis of various quality metrics has been explored. From Table 2.1, all metrics acknowledge the changes of noise power. MD metrics is the most sensitive of noise power compared to other metrics and SSIM give results with greater accuracy. Based on Table 2.2, NK, SC and IF metrics shows little differences in image contrast application and SSIM elevated the accuracy of the results. From the research work, it shows that SSIM metrics is capable of expressing the quality and produced the best performance and provides a high-quality approximation of quality measurement but with moderate computational time.

In Joseph, Singh, and Manikandan, (2014, pp.1-5) and Mustaqeem, Javed, and Fatima (2012, p.34) paper works, the proposed algorithms are successfully extracted the brain tumor. The results for both paper works are in Figure 2.3 and Figure 2.7. However, although the results shows the tumor position, the results are not evaluated by using any parameters. Without any evaluation, the algorithm is no reliable to be used in medical image processing. Mustaqeem, Javed, and Fatima (2012, p.34) stated that the tumor is detected based on the high intensity areas in the image.



(a) (b)

Figure 2.7 : Extract tumor (a) Original image (b) Tumor detected as white portion (Mustaqeem et al., 2012)

2.4 Summary

In this chapter, several research works related to edge detection techniques, brain tumor detection and evaluation parameters have been presented. There are also some researches that have drawbacks been reviewed in this chapter. Based on the literature reviewed, the edge detection techniques and evaluation parameters that will be applied in this work has been determined.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter discussed about the procedures in comparing the performance of each edge detection gradient operators including the proposed edge detection algorithm. The main goal of this project is to identify the best edge detection technique to detect the edge of the brain tumor accurately. This project can be divided into several phases which are pre-processing, computer simulation, and performance analysis. Each step that applied in this phase will be explained briefly in this section. The performance analysis are the comparison between the existed and modified edge techniques which are Robert operator, Sobel operator, Prewitt operator, Canny algorithm and Modified Canny algorithm. The measurement that will be used in this research are MSE, PSNR and SSIM.

3.2 Project Implementation Flow

The flowchart in Figure 3.1 shows the overall flows that will be implemented in this research. The input images are MRI brain tumor in DICOM format that available in internet. Then, the image will undergo the pre-processing phase by using Gaussian filter to improve the input image quality. Next, the gradient operators for the selected edge detection techniques will be applied to the improvised image through computer simulation. The final output image will be analyzed by using quantitative measurement in order to measure the performance of each techniques.

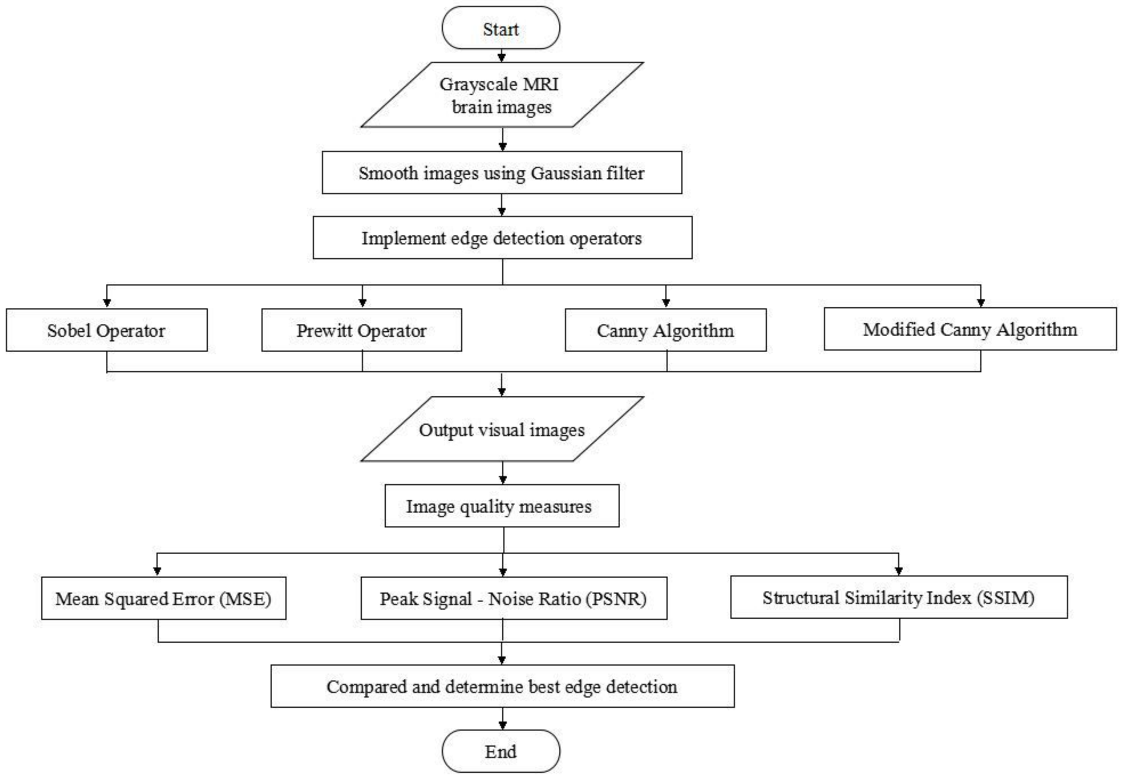


Figure 3.1 : Overall flowchart for this research

3.3 Edge Detection Techniques

Edge is a significant local changes in image intensity while edge detector is designed to detect the boundaries or the local changes in image intensity of objects in image. Besides that, edge detection also can be describe as the changes of a single image pixel in a gray area. It is one of the image segmentation algorithm that usually used in image processing. This technique is performed based on three fundamental steps which are:

1. Image smoothing for noise removal
2. Detection of edge point
3. Edge localization.

3.3.1 Pre-processing

Gaussian smoothing filtering is a 2-D convolution operator that used to smooth image to reduce the level of noise in an image. The noise is reduced by convolving Gaussian mask with the image. Gaussian mask are sampled from 2D Gaussian equation below. The values of the mask depend on the value of σ.

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \qquad \text{(Equation 3.1)}$$

Where : σ = standard deviation of the distribution.

Wider mask caused the sensitivity to noise become lower and the localization error in the detected edges slightly increase.

3.3.2 Detecting Edges

There are two generic approach that can be used to detect the edges which are differential detection and model fitting. Differential detection method is illustrated as in Figure 3.2 where a spatial processing will be performed to determine the pixel locations of significant differential and most performed differential are the first- and second-order derivative. Model fitting involves the edge local region of pixel values to be fitted with the edge values in an assigned model (Pratt, 2007). However for this research, the first-order derivative from differential detection methods will be implemented to detect the tumor edges.

Based on Gonzalez (2008, p.692), there are three requirements that need to be obey when the first-order derivative approximation is applied.

1. The areas in constant intensity must be zero
2. The onset of an intensity edge or ramp must be nonzero
3. The points along the an intensity ramp must be nonzero

The important components in edge detection are to find edge strength and direction at position *(x,y)* of an image, F is the gradient ∇F and defined as the vector:

$$\nabla F \equiv \begin{bmatrix} g_x \\ g_y \end{bmatrix} = \begin{bmatrix} \frac{\partial F}{\partial x} \\ \frac{\partial F}{\partial y} \end{bmatrix} \qquad \text{(Equation 3.2)}$$

where:

$$g_x = f(x+1, y) - f(x, y) \qquad \text{(Equation 3.3a)}$$
$$g_y = f(x, y+1) - f(x, y) \qquad \text{(Equation 3.3b)}$$

The gradient is calculated for each pixel location in the image. There are several gradient operator that can be used to obtain the gradient of the image. The gradient operator that will be implemented in this research are Roberts cross-gradient operator, Prewitt operator and Sobel operator. All three operators used masks to obtain the gradients of g_x and

g_y and the coefficients of all masks are sum to zero to give a zero response in constant intensity area. The derivatives are formulated based on the masks in Figure 3.2.

z_1	z_2	z_3
z_4	z_5	z_6
z_7	z_8	z_9

Figure 3.2 : 3x3 masks

Spatial gradient magnitude can be expressed by using Equation 3.4.

$$M(x,y)=\sqrt{g_x^{\ 2}+g_y^{\ 2}} \qquad \text{(Equation 3.4)}$$

3.3.2.1 Roberts Operator

Roberts operator is one of the earliest two-dimensional (2-D) masks with diagonal preference. The derivatives for Roberts 2 X 2 masks are based on the diagonal differences and can be expressed by using Equation 3.5a and Equation 3.5b. Figure 3.3a and Figure 3.3b shows the edge gradient for horizontal, g_x and vertical, g_y masks for Roberts operator. One of the mask can be obtain by rotate the other by 90°.

$$g_x=\frac{\partial f}{\partial x}=(z_9-z_5) \qquad \text{(Equation 3.5a)}$$

$$g_y=\frac{\partial f}{\partial y}=(z_8-z_6) \qquad \text{(Equation 3.5b)}$$

+1	0
0	-1

(a)

0	+1
-1	0

(b)

Figure 3.3 : Roberts masks (a) g_x (b) g_y

However, the size of the this Roberts zero-gradient masks are not preferable to compute edge direction because the smallest masks that symmetric about the center point are of size 3 X 3.

3.3.2.2 Prewitt Operator

Prewitt operator is a discrete differentiation operator that compute the approximation of the gradient for image intensity. It consider the differences between the third and first rows of the g_x masks in the x-direction and for y-direction mask, g_y, the derivative finds the differences between the third and first columns to compute the gradient approximation. The partial derivatives that used for this operator are given by

$$g_x \approx \frac{\partial f}{\partial x} \approx (z_7 + z_8 + z_9) - (z_1 + z_2 + z_3) \quad \text{(Equation 3.6a)}$$

$$g_y \approx \frac{\partial f}{\partial y} \approx (z_3 + z_6 + z_9) - (z_1 + z_4 + z_7) \quad \text{(Equation 3.6b)}$$

The horizontal and vertical gradient mask for Prewitt operator are shown in Figure 3.4a and Figure 3.4b.

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

(a)

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

(b)

Figure 3.4 : Prewitt masks (a) g_x (b) g_y

3.3.2.3 Sobel Operator

Sobel operator is differs from Prewitt operator where the slight difference is that Sobel masks uses a weight of 2 in the center coefficient and returns edges at points where the gradient value is at maximum. Equation 3.7a and Equation 3.7b shows the partial derivative implemented in Sobel operator and Figure 3.5a and Figure 3.5b are the Sobel edge gradient masks in x- and y-directions.

$$g_x \approx \frac{\partial f}{\partial x} \approx (z_7 + 2z_8 + z_9) - (z_1 + z_2 + z_3) \qquad \text{(Equation 3.7a)}$$

$$g_y \approx \frac{\partial f}{\partial y} \approx (z_3 + 2z_6 + z_9) - (z_1 + 2z_4 + z_7) \qquad \text{(Equation 3.7b)}$$

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

(a)

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

(b)

Figure 3.5 : Sobel masks (a) g_x (b) g_y

The masks works exactly the same as Prewitt operator. However, the major difference between these two operators is Sobel masks have better noise-suppression characteristics compared to Prewitt masks.

3.3.3 Thresholding

After the edge gradient is formed, the gradient is compared with threshold values to determine if the edge is exists. The pixels with gradient that higher than the threshold are considered as edges. The threshold values control the sensitivity of the edge detector.

3.3.4 Advanced Technique of Edge Detection

Advanced edge detection techniques is an improvised techniques of the simple edge detection that has been discussed before. It takes the image noise and the nature of edges into consideration. There are two techniques which are Marr-Hildreth edge detector and Canny edge detector. However, only Canny algorithm is discussed in this research paper.

3.3.4.1 Canny Algorithm

Canny operator is a multi-stage algorithm that designed to be an optimal edge detector based on the following three criteria.

1. *Low error rate.* All edged should be found and should be no spurious responses.
2. *Good edge localization.* The edges must be detected relatively small difference with the true edges.
3. *Single edge point respons*e. The detector should only detect a single response for each true edge point.

Canny edge detection algorithm consists of five-stages which are smoothing, finding gradient, non-maxima suppression, double thresholding and hysteresis. Figure 3.6 shows the flowchart of the multi-step Canny algorithm.

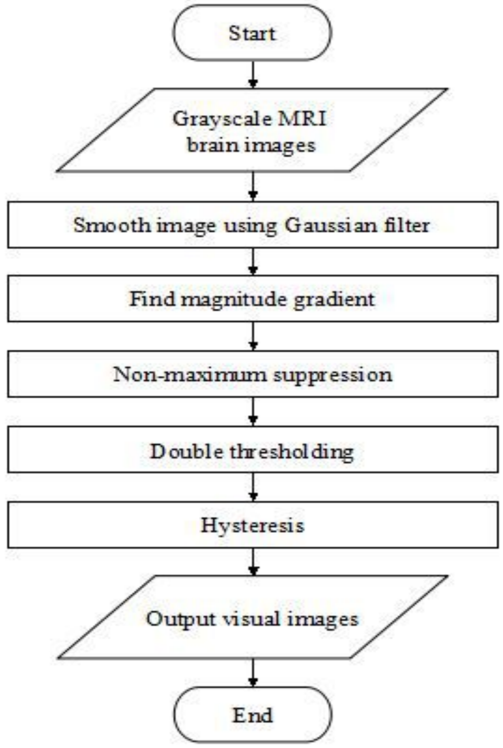


Figure 3.6: Canny multi-steps algorithm flowchart

3.3.5 Modified Canny Algorithm

Modified Canny algorithm is consists of six stages compared to the traditional Canny algorithm. The difference between the traditional and new algorithms is the pre-processing stage. Size of 5 X 5 mask for median filter is added in the pre-processing stage. The overall flowchart for the new algorithm is shown in Figure 3.7.