CANNY EDGE AND HARRIS CORNER DETECTION TO IDENTIFY BRAIN TUMOR PHASE

NATASHA NAZRIN BINTI RAZALI

Bachelor Degree of Computer Science
(Software Engineering)

UNIVERSITI MALAYSIA PAHANG

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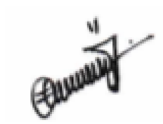

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Full Name : Natasha Nazrin binti Razali

ID Number : CB16128

Date : 07/01/2020

CANNY EDGE AND HARRIS CORNER DETECTION TO IDENTIFY BRAIN TUMOR PHASE

NATASHA NAZRIN BINTI RAZALI

Thesis submitted in fulfillment of the requirements
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Name	: Natasha Nazrin binti Razali		
Project Title	: Canny Edge and Harris Corner Detection to Identify Brain Tumor Phase		
Year/Program	: 4th / Bachelor of Computer Science (Software Engineering) with Honors		
Matrix No	: CB16128		
E-mel	: natashanazrin@outlook.com	Tel No	: 014-5351765
Date	: 10 December 2019	Signature	: ....

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DR. RAMDAN BIN RAZALI
SENIOR LECTURER
FACULTY OF ELECTRICAL & ELECTRONICS ENGINEERING
UNIVERSITI MALAYSIA PAHANG
26600 PEKAN
PAHANG DARUL MAKMUR
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SENIOR LECTURER
FACULTY OF ELECTRICAL & ELECTRONICS ENGINEERING
UNIVERSITI MALAYSIA PAHANG
26600 PEKAN
PAHANG DARUL MAKMUR
TEL : 09-424 6096 FAX : 09-424 6111

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ABSTRAK

Kebelakangan ini, kes tumor otak semakin meningkat. Oleh itu, banyak ujian pengimejan telah diperkembangkan untuk membantu mengesan tumor otak dalam otak pesakit seperti ujian imbasan CT dan MRI. Walau bagaimanapun, kajian yang sedia ada hanya bertumpu kepada mengesan tumor otak, bukan mengira fasa tumor yang sangat penting dalam bidang perubatan. Selain itu, Pengesanan Sudut Harris tidak mementingkan maklumat domain otak, justeru banyak sudut yang dikesan adalah sia-sia. Untuk menangani masalah ini, kaedah Pengesanan Pinggir Canny dicadangkan untuk segmentasi otak sebelum menggunakan Harris untuk mengesan sudut. Seterusnya, kawasan tumor dikira berdasarkan titik yang dipetakan untuk menentukan fasa tumor. Keputusan eksperimen menunjukkan bahawa kaedah pengesanan pinggir dan sudut yang dicadangkan dapat mengenal pasti tumor otak dan menentukan fasa tumor.

ABSTRACT

Brain tumor cases have escalated furiously in the recent years. Thus, many imaging tests is developed in order to help detecting the brain tumor in patient's brain such as CT and MRI scan. However, the existing studies only focus on detecting brain tumor, not calculating the phase of tumor which is very crucial in medical field. Moreover, the Harris Corner Detection does not regard the information about the brain domain that contributes to multiple useless corners and the loss of important information. To address this problem, Canny Edge Detection method is proposed for brain segmentation before utilizing Harris for detecting corner. Next, the area of tumor is calculated based on the mapped points to determine the phase of the tumor. Experimental results show that the proposed method of edge and corner detection able to identify brain tumor and predict the phase of tumor.

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LIST OF ABBREVIATIONS

GI	Grayscale Image
MRI	Magnetic Resonance Imaging
CT	Computed Tomography
GUI	Graphical User Interface
2D	2-Dimensional
GM	Gradient Magnitude
MSP	Mid-Sagittal-Plane

LIST OF FORMULAS

(1)	$GM = \sqrt{} \, G_x^2 + G_y^2$
(2)	$D (x, y) = \sqrt{} \, (x1 - y1)2 + (x2 - y2)2$

CHAPTER 1

INTRODUCTION

1.1 Introduction

Brain tumor is an abnormal cell that develops inside the brain where the cancerous cells are tested using Magnetic Resonance Image (MRI) and Computed Tomography (CT) scan. The latter is more preferred because it is easier to normalize the brain images rather than MRI scan. CT scan helps to determine the size, region and location of the brain tumor. This enables a simple, efficient and accurate diagnosis to prepare a surgery for removal of tumor. In the existing research, only tumor detection is possible, not calculation of tumor's spreading area.

Hence, this study proposed the Canny Edge Detection algorithm and threshold technique to locate the origin of tumor, spread area, and phases of tumor cells within the brain. The brain images are obtained from CT scan as a dataset. Preprocessing method was then applied with Gaussian filtering technique to remove noise from the image. Upon preprocessing, a noiseless image is now obtained. The second method requires a non-maximum suppression, where, by using the object strength gradient, the weak and strong edges of the images are detected. Only then the origin of tumor is located using Harris Corner Detection technique and the tumor phases are measured based on Euclidean Distance. Experimental results are shown to evaluate the proposed edge and corner detection and Euclidean Distance on brain medical image classification.

1.2 Problem Statement

Corner detection is a fundamental step in many vision tasks such as image matching, recognition and tracking. One of the classical corner detection methods is Harris, which is widely used in many situations due to its benefits of rotation, translation and illumination invariance. However, it tends to produce many useless corners, and is sensitive to the corner response threshold when utilized over a whole image. Moreover, it only preserves the coordinates of corners, resulting in the loss of significant medical image information.

Specifically, brain medical images have the uncertainty and structure, and the uncertainty of each pixel varies in different degree, which is not employed in the corners detected by Harris. To overcome the limitation of Harris, Canny Edge Detection method is considered for brain segmentation and edge extraction before Harris is utilized. The drawback of the existing study also does not consider the calculation of spreading area and prediction of tumor phases. In order to solve this problem, Euclidean Distance is implemented in this research to calculate area of tumor then predict the phases.

1.3 Objectives

The objectives of our study are:

i. To develop Canny Edge Detection for brain segmentation and edge extraction.
ii. To identify brain tumor using Harris Corner Detection method.
iii. To investigate the effectiveness of Euclidean Distance on determining tumor phase.

1.4 Scope

The scopes of this research:

i. Brain medical images only selected from CT scan images.
ii. Brain medical images are converted to grayscale image.
iii. Size of brain medical images are set to 350 x 420.

1.5 Thesis Organization

There are five chapters in this thesis:

Chapter 1, Introduction where it consists of the following: introduction, problem statement, objectives of the study, scopes and the thesis organization. This chapter briefly describes the objective and goal of the research followed by a brief outline of the thesis.

Chapter 2, Literature Review discuss about the methods that will be used, elaborating the sources from the research, and deciding the best tools that will be used to implement the method's algorithm.

Chapter 3, Methodology includes the research design, the procedure for data collection and analysis. Research design is a description of the conditions for data collections and analysis.

Chapter 4, Result and Discussion explains the collected results from the analysis and tests. It includes the explanations, implications and applications of the results of the collected data.

Chapter 5, Conclusion summaries all previous chapter and includes an overview of the research as well as the restatement of the problem, the procedures and the findings.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This thesis is about corner detection and matching methods of brain medical image. The vital purpose of this research work is to produce the structure of brain medical images based on its domain knowledge. This chapter contains of two sections, where section 2.2 concisely discussed the existing research while section 2.3 explained the conclusion of the chosen method.

2.2 Existing Methods Review

The following section discussed the implementation details of existing methods.

2.2.1 Tumor Region Extraction using Sobel Edge Detection

This paper discussed the automated approach to detect brain tumor in MRI images using edge detection method. The MRI is primarily taken into account as the device is directly connected to a magnet that provides a clear 2D image of the internal parts of the skull and the tumor in it. The process captures an image of MRI that precisely locates the tumor. The image is first converted to a grayscale image, then preprocessing is applied to remove noises in the image. Next, the standard deviation is calculated based on the filtered image to segmented the tumor region. Using the same deviated standard, the average intensity of the pixels above this standard deviation is calculated where this measured average intensity is used as a threshold to continue with the MRI image. It segmented the part of the tumor. Eventually, to get the tumor border region, the Sobel edge filter is used. Figure 2.1 is the flowchart for the proposed method.

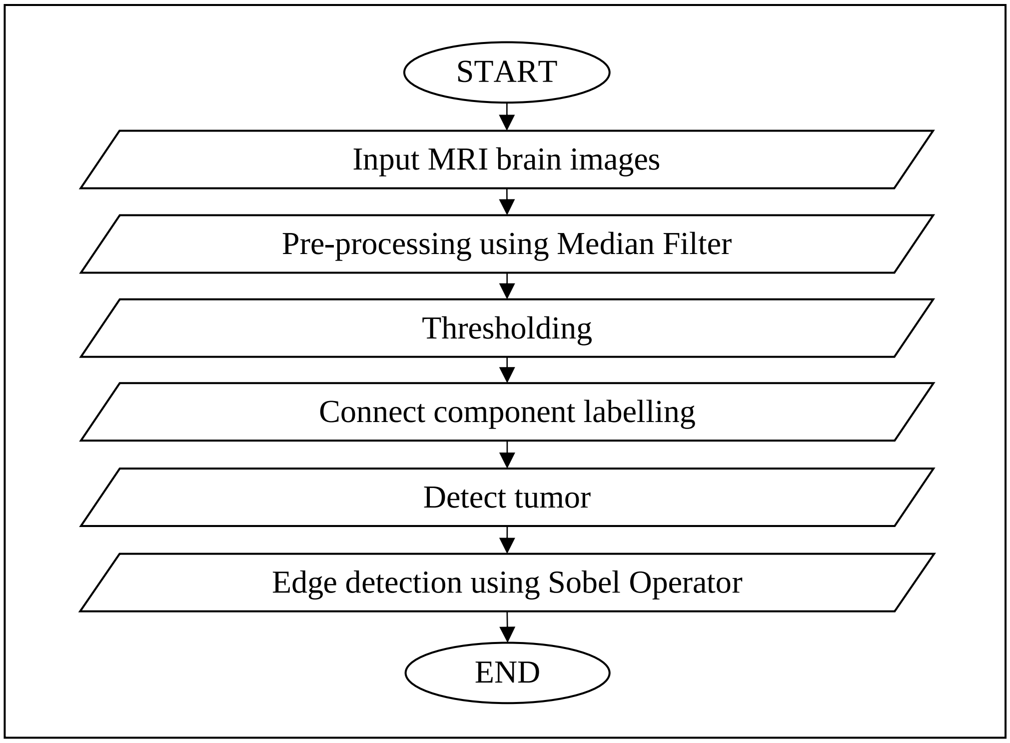
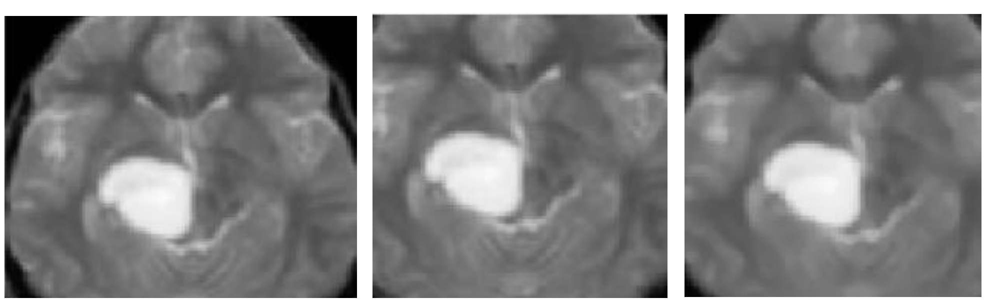


Figure 2.1 Flowchart for tumor region extraction using Sobel edge detection

Preprocessing using Median Filter

The first step in this work is to smooth the input image and remove noise by preprocessing using median filter. Median filter is used due to its excellent noise reduction features mostly in the case of salt and pepper noise. It also reduces the blurring and increases the perseverance of edges in the image. Figure 2.2 shows the output of brain image after being preprocessed.



(a) (b) (c)

Figure 2.2 Preprocessing of MRI brain image

(a) Original image (b) Grayscale image (c) Filtered image

Calculate Standard Deviation

Next, the standard deviation is calculated based on the filtered image. To calculate the image’s mean intensity, the column mean of the image must be found first. Then the original image's standard intensity deviation is calculated. However, with respect to other brain tissues, the tumor's frequency rate is quite high. Therefore, when the standard deviation is measured, the result will be weak, indicating that the pixel intensity is very similar to the mean, but the tumor pixels are far from the mean. It is therefore impossible to distinguish the tumor from other brain tissues by the measured standard deviation. So, the measured standard deviation is used to conduct an intensity map. When it is less, the intensity is set above or equal to the standard deviation to 255 and 0.

Extract the Tumor Region

To extract the tumor, the objective is to determine the threshold value that must be very close to the tumor region's intensity value. So, the standard deviation is recalculated from the intensity map, yet the result is very big and the data points are far away from the mean. As a result, an average pixel intensity that are above the original image standard deviation is calculated. If the intensity value is greater than or equal to the threshold value, the intensity value is set to 255, otherwise it is set to 0.

After segmentation, there will be some unwanted artifacts in the output image together with the observed tumor. The pixel area of all objects in the image is measured separately to eliminate unwanted objects. If the area of any object is greater than some predefined value, it can be identified as a tumor. For the object value that is below the pre-defined value, it will be discarded. The tumor is likely to be the largest object. The predefined value will vary for many input images, in which helps to discard small objects and identify the tumor part. The removal is done my morphological operations where it extracts only useful information that is used to represent its shape and area. It is very useful in gray images to remove small objects. Morphological operation takes as input the binary image or component of structuring. The structuring item can be our option mask and can be a column, disk or any other specified values.

(a)

(b)

Figure 2.3 Extracted tumor region (a) tumor with unwanted objects (b) tumor

Detect Border of the Tumor Area using Sobel

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

G_x

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

G_y

Figure 2.4 Sobel Operator Masks

Sobel filter identify the edges by finding the image's derivatives; gradients of x and y. These masks are mostly used to work in a vertical and horizontal direction that is further connected to image pixels. Such masks can be added distinctly to the object of the source. Both masks give an individual measure in different direction to say gradients (G_x and G_y). Ultimately, these can be used in conjunction to find the exact measure of gradient and its direction at the appropriate point. Below is the formula to calculate gradient magnitude:

$$GM = \sqrt{G_x^2 + G_y^2} \quad (1)$$

The formula above indicates the gradient's change in orientation. The Sobel operator is implemented to better smooths the random noise. It senses the edges in both directions due to its functioning in both x and y direction and thus gives thicker and clearer edges. This reduces the image’s blurring to a higher level of reduction. Therefore, it can detect the border of the tumor region more effectively and precisely. Figure 2.5 display the image of the tumor’s border after Sobel filter is applied to the extracted tumor.

Figure 2.5 Border of tumor

2.2.2 Brain Image Using Symmetry Features

The symmetry analysis was regarded as one of the favorable techniques in conventional scanning for the automatic extraction of pathological brain slices for brain medical images. It is also having a crucial characteristic in identifying the object’s structure.

A healthy brain shows a bilateral symmetry that causes MSP (Mid-Sagittal-Plane) reflected region to look identical, while pathology-affected areas seem unalike. The MSP must be estimated prior to the calculated symmetry characteristics. After the MSP is known, only then the contralateral reflection of every point can be measured. (Bianchi, V.Miller, Tan, & Montillo, 2013).

The first step in defining the symmetry axis is based on the symmetry character of brain CT scan. Figure 2.6 below shows the bilateral symmetry in brain images. If the brain is normal or the tumor size very small, the symmetry axis can be defined as a straight-line x = k, (y >= 0), which separates the image into two bilateral symmetry parts. (Sachin & Khairnar, 2013).

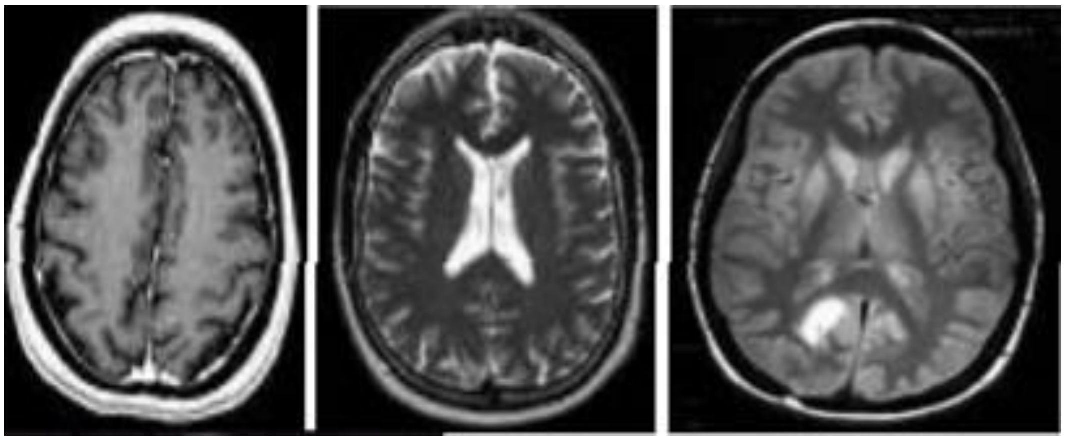


Figure 2.6 Bilateral symmetry in brain medical images

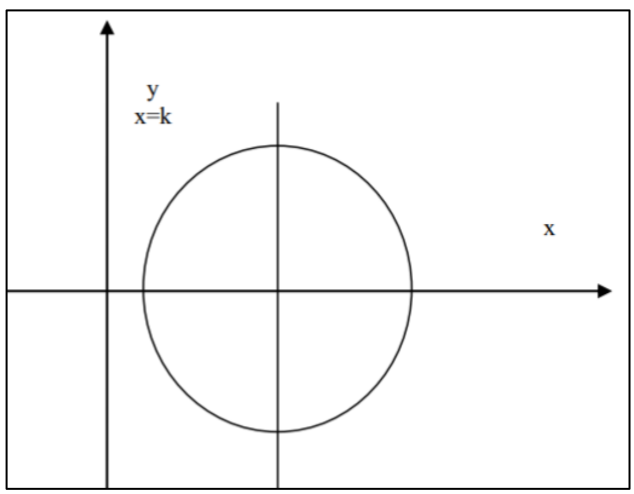
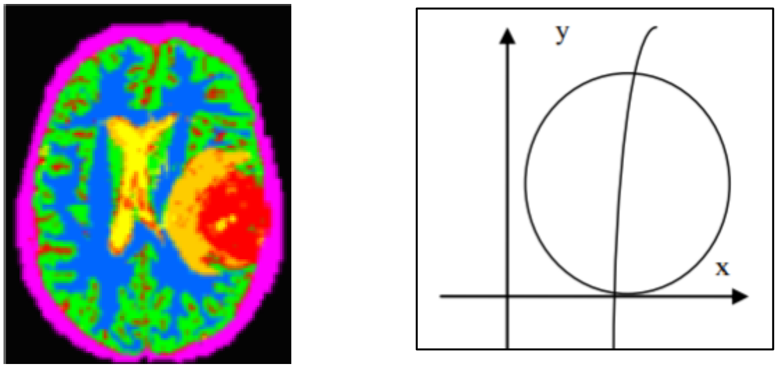


Figure 2.7 Straight line to define bilateral symmetry axis of normal brain

For the brain with a slightly distorted symmetry characteristic, it shows the existence of the brain tumor. So, in order to describe this symmetry axis with a curve line, a formula y = f(x), x > 0, y > 0) is defined.



(a) (b)

Figure 2.8 Curve line to define bilateral symmetry of abnormal brain

(a) Brain image with a tumor (b) Bilateral symmetry axis of abnormal brain

2.3 Conclusion

All information about the possible methods to produce brain medical images are being collected and studied in this stage. There are lots of methods to analyze CT and MRI scan images; not only brain medical images, but also other medical images such as face, arms and body. The existing methods that has been explained in this chapter are Tumor Region Extraction using Sobel Edge Detection and Symmetry Features method.

CHAPTER 3

METHODOLOGY

3.1 Introduction

As explained in the previous chapter, edge detection and corner detection method are used to detect brain tumor. Next, Euclidean Distance is used to calculate the area of brain tumor to determine the phase. This chapter comprise of seven section in which section 3.2 presents the research work framework. Next, section 3.3 explained about the experiment set up. For section 3.4, it mostly discussed about the methodology of the research work while section 3.5 shows how edge detection and corner detection methods are implemented. In section 3.6 discussed about the software and hardware requirement. At last, section 3.7 discussed the summary of the methodology.

3.2 Research Framework

Figure 3.1 is the workflow of the research on the effectiveness of edge detection and corner detection method for detecting brain tumor.

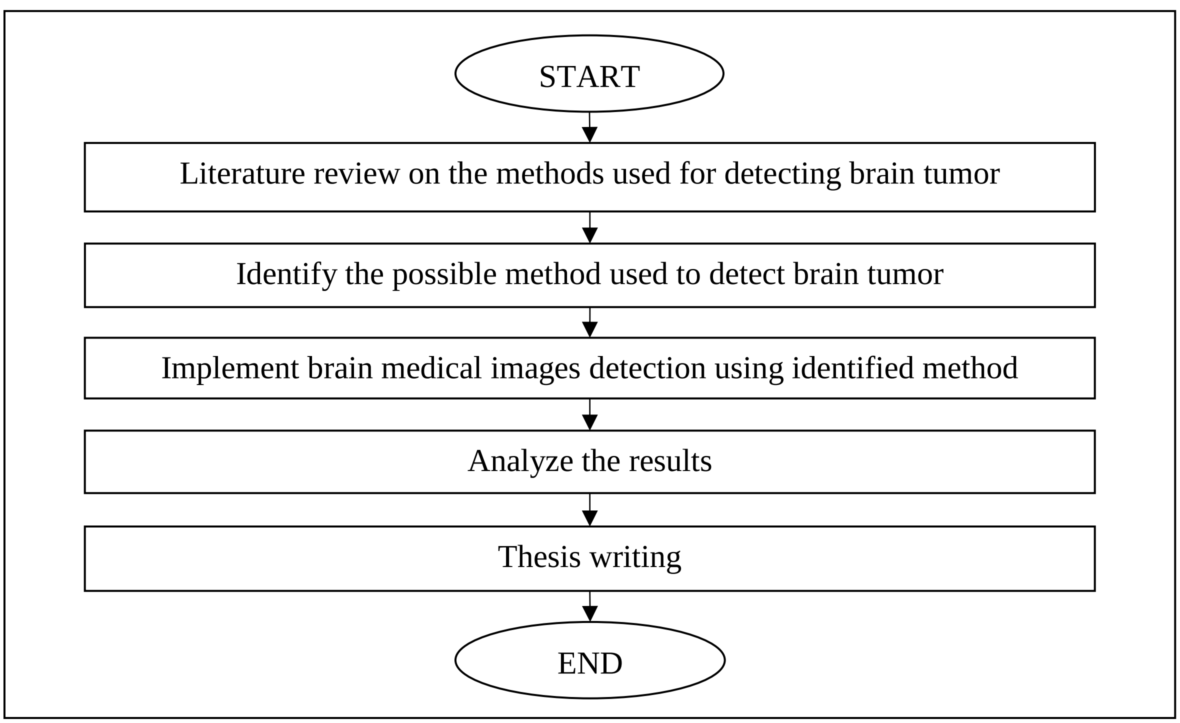


Figure 3.1 Research workflow

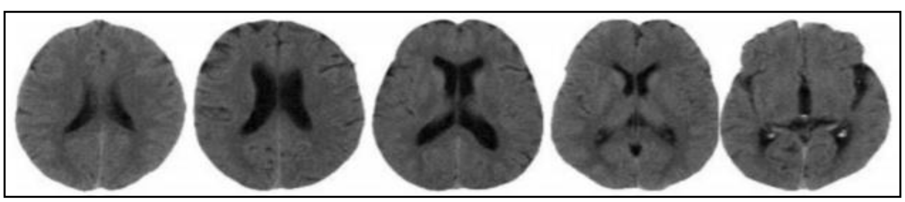
3.3 Experiment Set up

This experiment was followed by several requirements, such as data preparation and developer prototype, for the sake of fulfilling the objectives of this research.

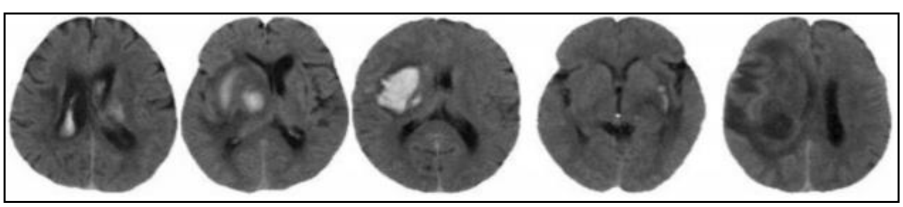
3.3.1 Data Preparation

In this study, 7 brain medical images are used from CT scan as it consists of two image types; first is normal brain, and second is the abnormal brain. The dataset is obtained from Radiopedia.org medical website for the research work. The images must be in a grayscale format *GI*, and image must be converted to gray format if it is colored as this technique cannot function well for uniformly colored image or repeating patterns. The gray range is 0–255, where 0 is white and 255 is black.

CT scan images are more suitable than MRI scan images because MRI gives detailed images of soft-tissue structures that are not necessary in this research work. This is why CT scan images are more suitable to be used in experiments because the tumor can be seen more clearly without any interference from other brain tissues. Moreover, it is easier to edit CT scan images for skull stripping as the brain is nicely shaped. In comparison with MRI images, the skull stripping is a bit difficult because the brain shape is not formed properly and interfered by other tissues in between skull and brain. Figure 3.2 shows the example of normal and abnormal brain in in CT images.



(a)



(b)

Figure 3.2 Example of (a) Normal and (b) Abnormal brain in CT images

Source: http://adni.loni.usc.edu/

3.3.2 Developer Prototype

For this research work, MATLAB is the main software that is used. It is a numerical computing environment with multi-paradigms that allows matrix manipulation, function and data plotting, algorithms implementation and another language-written interface creation program. One of MATLAB's functions is that GUI (Graphical User Interface) can be used. Drag and drop technique in designing the interface is also provided where it can be a simple toolbox drag interface. The toolbox used for this research is the Computer Vision System toolbox and Image Processing toolbox as it is available in MATLAB.

3.4 Methodology

As been discussed in Chapter 2, edge and corner detection method are used to fulfill the research work objectives. The details of the methods implementation are discussed in the section below.

3.5 The Implementation of Edge and Corner Detection Method to Investigate the Images

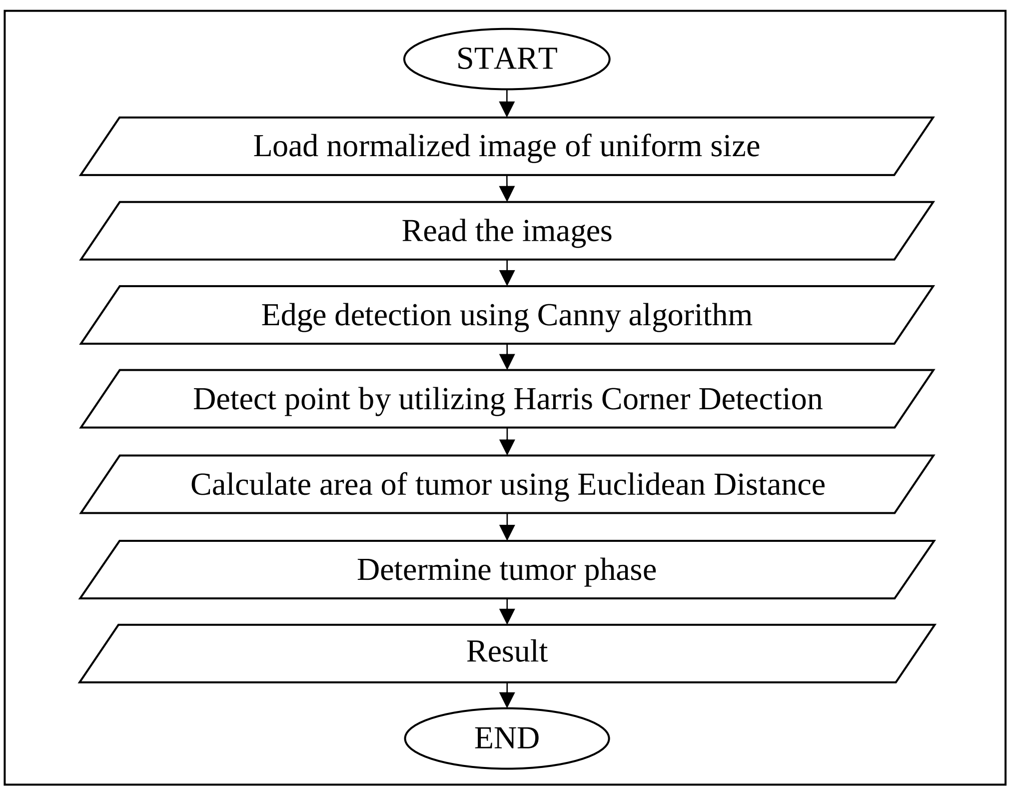
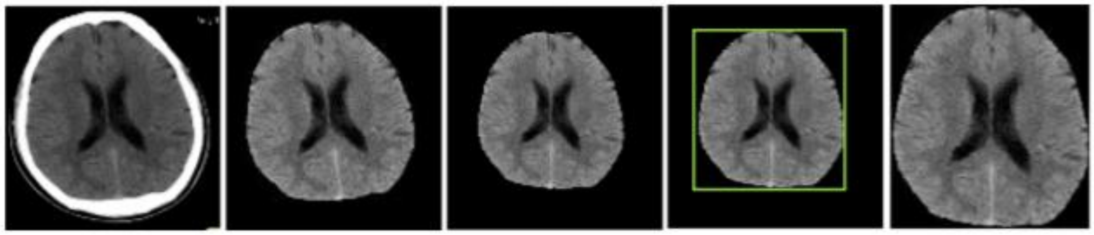


Figure 3.3 The flowchart of Edge Detection and Corner Detection method process

Edge and corner detection method is used to reach the objective of this research, to detect brain tumor. In addition, it is also used to investigate its efficacy regarding the corner pairs of brain structure. Then, area of spreading tumor is computed using Euclidean Distance to determine the phases of tumor. Computer Version System toolbox and Image Processing toolbox are the main software used to implement this method using MATLAB version 2017. The edge and corner detection required the images to be in the form of grayscale image *GI*. The edge detection is used to find strong edges in brain and corner detection is deployed to detect points in brain images. The Euclidean Distance is then utilized to investigate the detected corner.

3.5.1 Normalization of Brain Medical Image

Usually, medical images of original brain are produced in various sizes and angles and it print some pointless information as well. Original brain medical images contain three portions; background, skull and intracranial portion. The background is useless for diagnosis as it normally focused on the intracranial portion and always contains noise. So, the original image is preprocessed manually using Paint to extract the intracranial portion. First, the intracranial portion is extracted where the skull is cropped from image. Then, the image is rotated into vertical direction and the unimportant background is removed from the image. All CT brain images are then normalized to 350 x 420 size. Figure 3.4 is the example of brain CT image normalization. Figure 3.4(a) is the brain image of a skull with background, 3.4(b) is the extracted intracranial portion, 3.4(c) shows the vertically rectified image in a correct angle. Then, Figure 3.4(d) display the amend image that is cropped and merged into $Width \times Height$ size. Figure 3.4(e) is the grayscale image that has been normalized.



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

Figure 3.4 Example of brain CT image normalization

(a) Original image (b) Extracted intracranial portion image (c) Rotated image

(d) Vertical external matrix image (e) Final normalized grayscale image

Source: http://adni.loni.usc.edu/

3.5.2 Canny Edge Detection

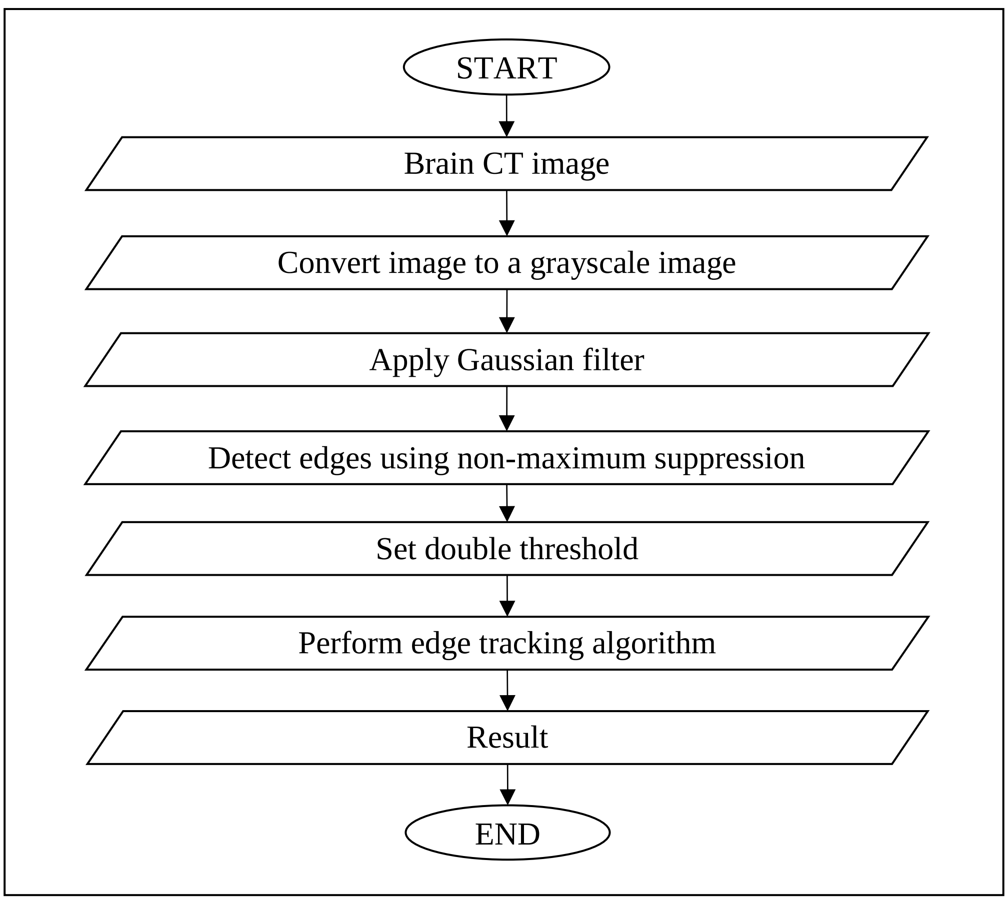
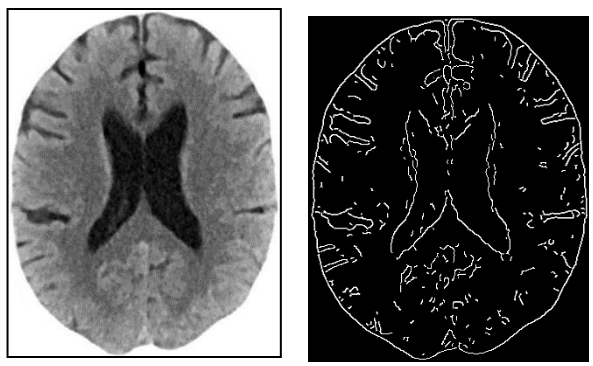


Figure 3.5 Applying Canny Edge Detection

Canny edge detector is an operator of edge detector. There are five steps in the canny edge detection process. First, the image is converted to a grayscale image where the pixels intensity values are 8 bit and range between 0 to 255. Second, the Gaussian filter is performed by smoothing the image to remove the noise and find the image's intensity gradient. Third, apply non-maximum suppression to thin out the edges. Fourth, set a double threshold, high and low threshold to detect edges. Lastly, perform an edge tracking algorithm to rid the weak edges and determine the actual one. Figure 3.6 demonstrate the edge detection using Canny.



(a) (b)

Figure 3.6 Example of Canny edge detection.

(a) Grayscale image (b) Canny of the grayscale image

Source: Google Images

3.5.3 Harris Corner Detection

Harris Corner Detector is one commonly used corner detection operator to locate corners and infer object features in computer vision algorithms. Hypodense and hyperdense structures have more data in brain images than others, for example, corners on these structures are more important than others. Harris is based on a signal's local auto-correlation function which the local auto-correlation function estimates local signal changes with patches moving in different directions by a small amount. It also provides a mathematical approach to determine the type of the region; edge, flat or corner.

So, Harris Corner Detection approach is proposed using this domain knowledge where corners are detected over Canny by utilizing Harris. Due to Harris weaknesses in detecting the corner in brain structure, the Canny algorithm is utilized first to make it easier for Harris to detect points based on the edge extraction of brain that was produced by Canny. Figure 3.7 is the example of useless corners detected by Harris algorithm on brain images.

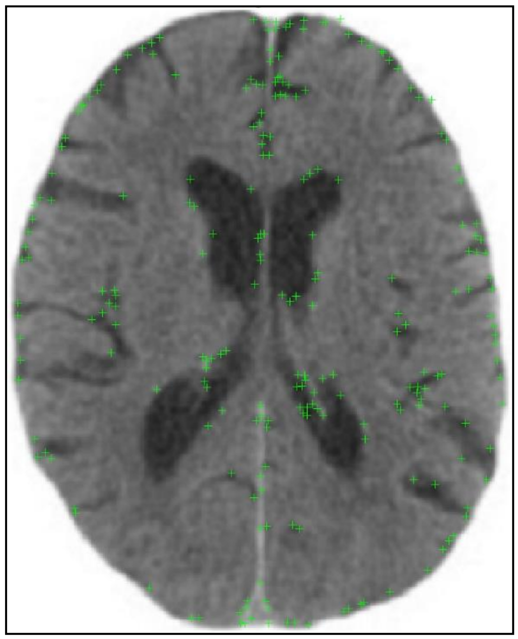


Figure 3.7 Corners detected by Harris on brain image

3.5.4 Euclidean Distance on Calculating Area of Tumor

The predict the phase of tumor, geometer distance concept is used. The area of brain tumor is calculated when the tumor spreading space is detected by Harris. The Euclidean distance between two points in 2-dimensional space measures the length of a segment connecting the two points, to represent distance between two points. The Pythagorean Theorem can be used to calculate the distance between two points, as shown in the figure below.

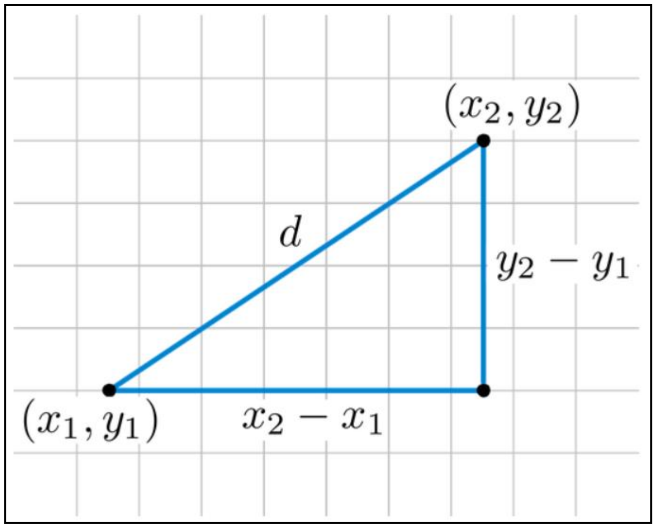


Figure 3.8 Pythagoras Theorem to calculate distance between two points

The square distance between two vectors x = [x_1, x_2] and y = [y_1, y_2] is that their coordinates have maximum square variations. The dx and y notation is used to denote the vector x and y space. This last statement will therefore be published as follows:

$$D\,(x, y) = \sqrt{}\,(x_1 - y_1)^2 + (x_2 - y_2)^2 \qquad (2)$$

After area of tumor is computed using above equation, the phases of tumor will be predicted as follows:

i. 1st phase: Area of tumor range between 50 -150
ii. 2nd phase: Area of tumor range between 151 - 250
iii. 3rd phase: Area of tumor range between 251 - 350
iv. 4th phase: Area of tumor range between 351 – 450

3.5.5 Experiment Conducted Based on the Type and Size of Tumor

The sizes of tumor differed in each abnormal brain. This study focuses on calculating the area of tumor to get the desired results on the basis of Canny and Harris algorithm in detecting the brain tumor. The experiment conducted with respect to three common types of tumor; glioblastoma, meningioma and metastatic tumor.

Glioblastoma is a type of astrocytoma, called astrocytes, a cancer that develops in the brain from star-shaped cells. For adults, the cancer usually begins in the cerebrum that is the largest part of human brain. Meanwhile for meningioma, the tumor forms within the skull on membranes that cover the brain and spinal cord. In particular, it forms on the meninges; three layers of membranes. Lastly, the most common brain tumor in adults; metastatic brain tumor. Approximately 85% of metastatic lesions are in the top, which is the brain's largest component and another 15% are in the bottom, that take place at the back part of the brain. Table 3.1 shows the experiments that will be conducted on different brain images.

Table 3.1 Experiment conducted on different brain images

<table>
<tr><th colspan="2">Experiment</th><th>Brain Images</th></tr>
<tr><td colspan="2">1</td><td>Normal brain</td></tr>
<tr><td rowspan="2">2</td><td>A</td><td>Abnormal brain (glioblastoma_1)</td></tr>
<tr><td>B</td><td>Abnormal brain (glioblastoma_2)</td></tr>
<tr><td rowspan="2">3</td><td>A</td><td>Abnormal brain (meningioma_1)</td></tr>
<tr><td>B</td><td>Abnormal brain (meningioma_2)</td></tr>
<tr><td rowspan="2">4</td><td>A</td><td>Abnormal brain (metastatic_1)</td></tr>
<tr><td>B</td><td>Abnormal brain (metastatic_2)</td></tr>
</table>

3.5.6 Input and Normalize CT Scan Brain Images

There are two types of brain images that has been used in this research; normal and abnormal brain. Figure 3.9 shows the coding to load and read an image in MATLAB. Each image is stored under a same folder with the coding files. In the second line, the coding calls the image by using the 'imread' function. All images are standardized to 350 x 420 size in 'imresize' function. If the image is colored, it must be converted to a grayscale format (RGB to gray) under the 'rgb2gray' function. After it is converted, the result of the image will be displayed.

```
%Input image
I = imread('glioblastoma_1.png');

%Resize image
img = imresize(I, [420,350]);

%Show input image
figure, imshow(img);
img = rgb2gray(img);
```

Figure 3.9 Coding for input and normalize brain images

3.5.7 Extract Edges using Canny Algorithm

Figure 3.10 below display the coding for extracting edges in brain images. Canny Edge Detector is one of edge detection operator where it uses a multi-stage algorithm to detect a wide range of edges in images. By using Canny, it is able to detect then extract the edges from original brain image. Figure 3.10 is the coding for applying Gaussian filter to smooth the image and remove noises, Figure 3.11 is the non-maximum suppression coding to thin out the edges, next Figure 3.12 is the coding for Hysteresis Thresholding to set double threshold for detecting edges and lastly, Figure 3.13 is the output of Canny edge detection.

```
%Gaussian Filter Coefficient
B = [2, 4, 5, 4, 2; 4, 9, 12, 9, 4;5, 12, 15, 12, 5;4, 9, 12, 9, 4;2, 4, 5, 4, 2 ];
B = 1/159.*B;

%Convolution of image by Gaussian Coefficient
A = conv2(img, B, 'same');

%Filter for horizontal and vertical direction
KGx = [-1, 0, 1; -2, 0, 2; -1, 0, 1];
KGy = [1, 2, 1; 0, 0, 0; -1, -2, -1];

%Convolution by image by horizontal and vertical filter
Filtered_X = conv2(A, KGx, 'same');
Filtered_Y = conv2(A, KGy, 'same');

%Calculate directions/orientations
arah = atan2 (Filtered_Y, Filtered_X);
arah = arah*180/pi;
pan = size(A,1);
leb = size(A,2);

%Adjustment for negative directions, making all directions positive
for i = 1:pan
    for j = 1:leb
        if (arah(i,j)<0)
            arah(i,j) = 360+arah(i,j);
        end
    end
end
arah2=zeros(pan, leb);

%Adjusting directions to nearest 0, 45, 90, or 135 degree
for i = 1  : pan
    for j = 1 : leb
        if ((arah(i, j) >= 0 ) && (arah(i, j) < 22.5) || (arah(i, j) >= 157.5) && (arah(i, j) < 202.5) || (arah(i, j) >= 337.5) && (arah(i, j) <= 360))
            arah2(i, j) = 0;
        elseif ((arah(i, j) >= 22.5) && (arah(i, j) < 67.5) || (arah(i, j) >= 202.5) && (arah(i, j) < 247.5))
            arah2(i, j) = 45;
        elseif ((arah(i, j) >= 67.5 && arah(i, j) < 112.5) || (arah(i, j) >= 247.5 && arah(i, j) < 292.5))
            arah2(i, j) = 90;
        elseif ((arah(i, j) >= 112.5 && arah(i, j) < 157.5) || (arah(i, j) >= 292.5 && arah(i, j) < 337.5))
            arah2(i, j) = 135;
        end
    end
end
figure, imagesc(arah2); colorbar;

%Calculate magnitude
magnitude = (Filtered_X.^2) + (Filtered_Y.^2);
magnitude2 = sqrt(magnitude);
BW = zeros (pan, leb);
```

Figure 3.10 Coding for Gaussian filter

```
%Non-Maximum Supression
for i=2:pan-1
    for j=2:leb-1
        if (arah2(i,j)==0)
            BW(i,j) = (magnitude2(i,j) == max([magnitude2(i,j), magnitude2(i,j+1), magnitude2(i,j-1)]));
        elseif (arah2(i,j)==45)
            BW(i,j) = (magnitude2(i,j) == max([magnitude2(i,j), magnitude2(i+1,j-1), magnitude2(i-1,j+1)]));
        elseif (arah2(i,j)==90)
            BW(i,j) = (magnitude2(i,j) == max([magnitude2(i,j), magnitude2(i+1,j), magnitude2(i-1,j)]));
        elseif (arah2(i,j)==135)
            BW(i,j) = (magnitude2(i,j) == max([magnitude2(i,j), magnitude2(i+1,j+1), magnitude2(i-1,j-1)]));
        end
    end
end
BW = BW.*magnitude2;
figure, imshow(BW);
```

Figure 3.11 Coding for Non-maximum suppression

```
%Value for Thresholding
T_Low = 0.075;
T_High = 0.175;

%Hysteresis Thresholding
T_Low = T_Low * max(max(BW));
T_High = T_High * max(max(BW));
T_res = zeros (pan, leb);
for i = 1  : pan
    for j = 1 : leb
        if (BW(i, j) < T_Low)
            T_res(i, j) = 0;
        elseif (BW(i, j) > T_High)
            T_res(i, j) = 1;
        %Using 8-connected components
        elseif (BW(i+1,j)>T_High || BW(i-1,j)>T_High || BW(i,j+1)>T_High || BW(i,j-1)>T_High || BW(i-1, j-1)>T_High || BW(i-1, j+1)>T_High || BW(i+1, j+1)>T_High || BW(i+1, j-1)>T_High)
            T_res(i,j) = 1;
        end
    end
end
edge_final = uint8(T_res.*255);
```

Figure 3.12 Coding for Hysteresis Thresholding

```
%Show final edge detection result
figure, imshow(edge_final);
```

Figure 3.13 Output of Canny edge detection

3.5.8 Detect Strongest Points using Harris Algorithm

Figure 3.11 shows the detection of brain image strongest points after utilizing Canny algorithm. Harris Corner Detector is one of the operators for corner detection that is usually used in computer vision algorithms. It is used mainly to extract corners and infer features of an image. This study set the value up to 300 points for the strongest value.

```
%Load and read the Canny image
im = imread('canny_glioblastoma_1.png');
im = im(:, :, 1);

%Detecting features point
points = detectHarrisFeatures(im);

strongestPoints = points.selectStrongest(300);
figure;
imshow(im);
title('Harris Strongest Features');
hold on;
plot(strongestPoints);
```

Figure 3.14 Harris corner detection coding

3.5.9 Analysis of Results

This section discussed about the analysis of the results from the experiment conducted in MATLAB. The results from those experiments are the calculation of tumor’s spreading area. Hence, the phases of tumor can be predicted from the calculated area. The Euclidean Distance equation is as follows:

$$\text{Area of tumor} = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2} \quad (2)$$

3.5.10 Area of Tumor for Predicting Tumor Phases

In medical field, there are four phases of brain tumor based on the sizes of spreading area:

i. 1^{st} phase: Area of tumor range between 50 -150
ii. 2^{nd} phase: Area of tumor range between 151 - 250
iii. 3^{rd} phase: Area of tumor range between 251 - 350
iv. 4^{th} phase: Area of tumor range between 351 – 450

Thus, the Euclidean Distance formula can be used to calculate area of tumor and predict the phases of tumor.

3.6 Required Software and Hardware

Research requirements are divided into two parts; software applications and hardware tools. Both requirements make an important contribution to this research.

3.6.1 Software Applications

Table 3.2 is the list of software applications that are used in this research work.

Table 3.2 Software Applications

Software	Purpose
Microsoft Windows 10 (x64) Operating System	The OS selected gives stability and compatibility to operate with MATLAB.
Microsoft Office Word 2019	Create and edit this project's report documentation.
Microsoft Office Excel 2019	Application used to create the Gantt Chart.
Microsoft OneDrive	Application used to backup and store the research data and documents.
Google Chrome	Search all needed information regarding the methods implemented in this research.
Paint	Application for image cropping, rotating and resizing.
Snipping Tool	To snap and crop coding from MATLAB.
MATLAB	Conduct experiment on brain medical images.

3.6.2 Hardware Tools

Table 3.3 is the list of the hardware tools used in this research work.

Table 3.3 Hardware Tools

Hardware	Purpose
Lenovo Ideapad 330 (64 bit) Laptop	To carry out the research test and prepare this research's documentation.
Dell Inspiron 14 3000 Series (64 bit) Laptop	
Canon E410 Series Printer	To print all drafts and PSM final report.
Kingston 16GB USB 3.0 Pen drive	To store all data and documents.

3.7 Summary

In conclusion, this chapter explained the methodology used for detecting brain tumor and calculating the area of tumor to determine its phases. There are two steps in detecting brain tumor; Canny Edge Detection and Harris Corner Detection. Then, the detected tumor points are calculate using Euclidean Distance to determine the phases of tumor. The software applications and hardware tools also have been chosen as the important requirements to ensure the process of research work running smoothly. Next chapter will explain the collection of result and discussion.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the results of the experiment are presented and discussed with reference to the aim of the study, which was to detect the brain tumor and determine the phases of the tumor. The provided system functionality is used to define the testing process. The results are obtained and analyzed after the testing process has been completed. The analysis will be presented to demonstrate whether the goals are being fulfilled or not.

4.2 Results of Experiments on Obtaining Strongest Brain Tumor Points

The experiments are discussed in section 3.5.5 until 3.5.10.

4.2.1 Normal Brain Image

Experiment 1 has been conducted on normal brain image. The results are shown in Table 4.1.

4.2.2 Abnormal Brain with Tumors

Experiment 2 until 4 have been conducted on abnormal brain images with three different types of tumor. Due to the uncertainty of brain structure, the area of tumor is calculated based on four different points of x and y. Then, the average value is taken as the final value for the area of tumor in order to predict the phase of brain tumor. The results can be seen in Table 4.2 for abnormal brain (Glioblastoma tumor), Table 4.3 abnormal brain (Meningioma tumor) and Table 4.4 (Metastatic tumor).

Table 4.1 Experiment conducted on normal brain image

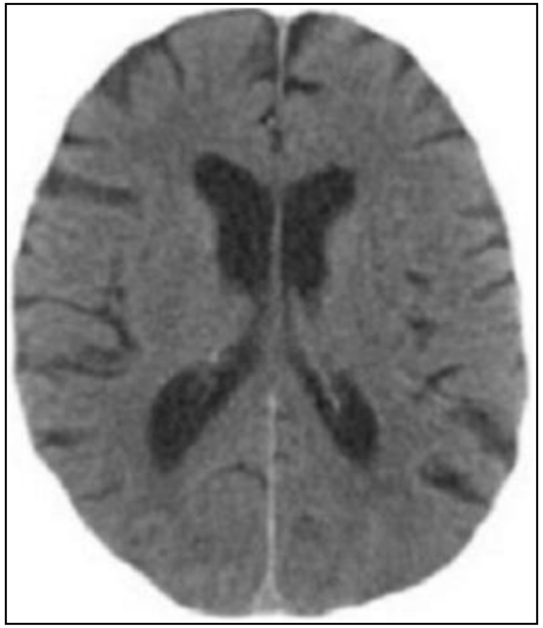
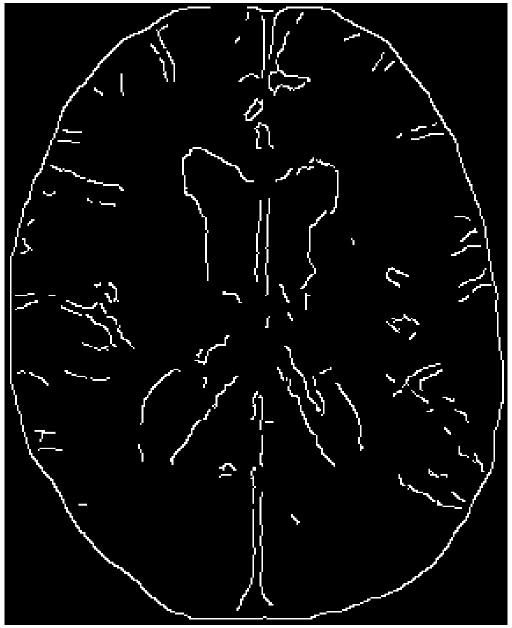
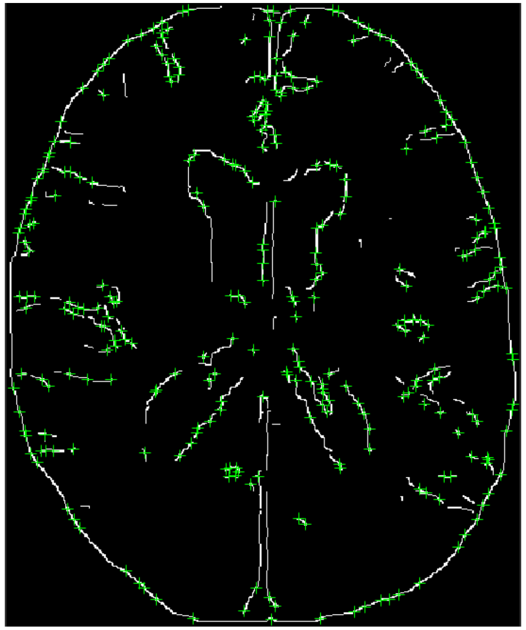
Experiment	Original image	Canny edge detection	Harris corner detection
1	normal_brain 	canny_normal 	harris_normal 

Table 4.2 Experiment conducted on abnormal brain images (Glioblastoma)

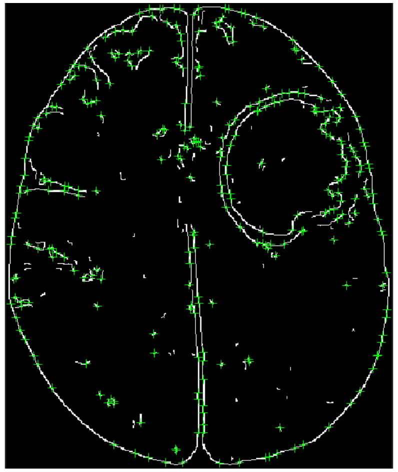
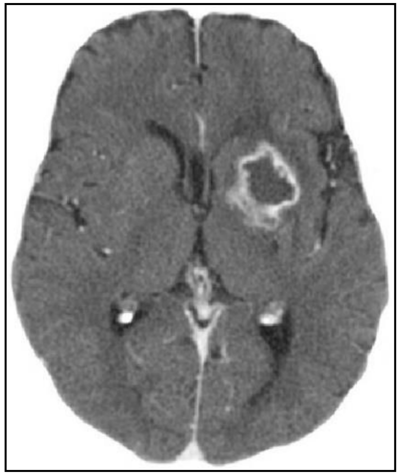
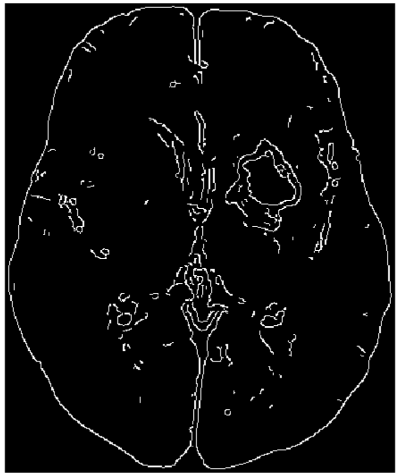
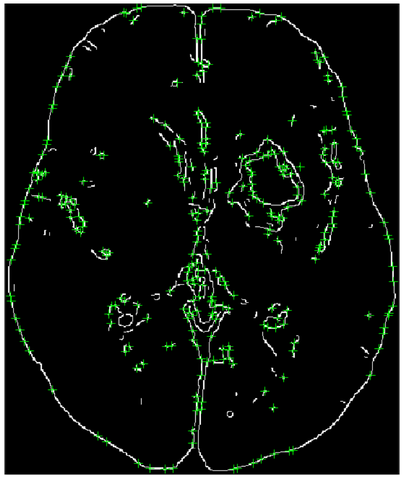
Experiment	Original image	Canny edge detection	Harris corner detection	Detected points
2A	glioblastoma_1 	canny_glioblastoma_1 	harris_glioblastoma_1 	First points $x_1 = 296.5, y_1 = 276.3$ $x_2 = 380.1, y_2 = 121.1$ Second points $x_1 = 316.7, y_1 = 274.6$ $x_2 = 358.6, y_2 = 110.2$
2B	glioblastoma_2 	canny_glioblastoma_2 	harris_glioblastoma_2 	First points $x_1 = 296.1, y_1 = 255.7$ $x_2 = 311.2, y_2 = 169.2$ Second points $x_1 = 273.1, y_1 = 240.1$ $x_2 = 293.8, y_2 = 155.1$

Table 4.3 Experiment conducted on abnormal brain images (Meningioma)

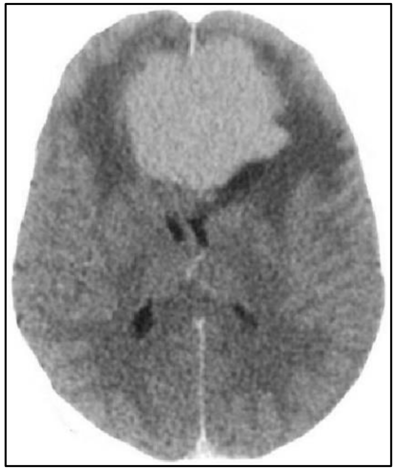
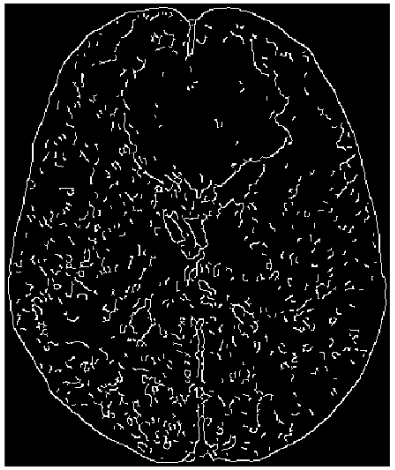
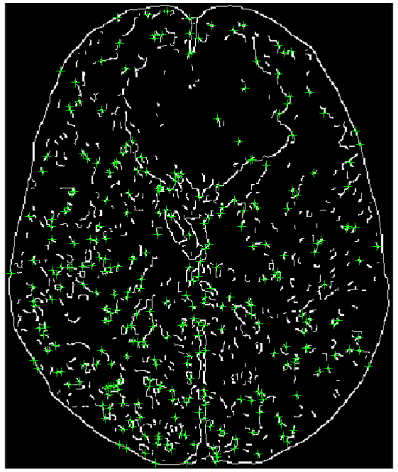
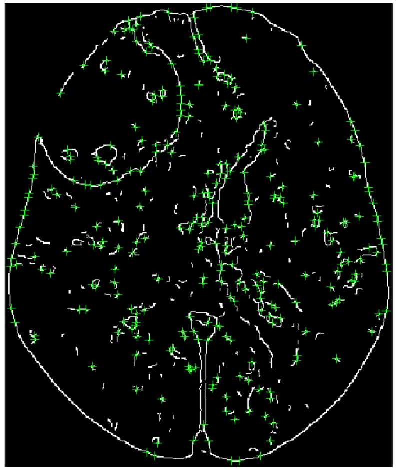
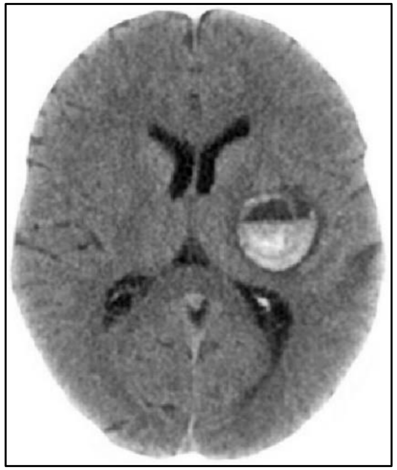
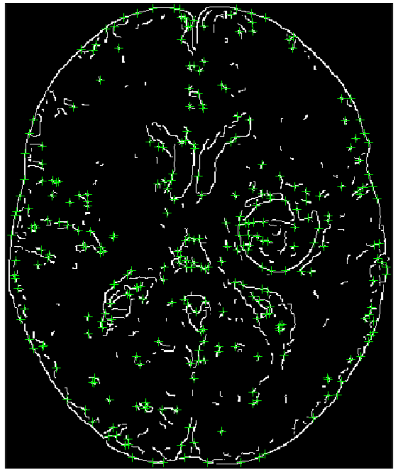
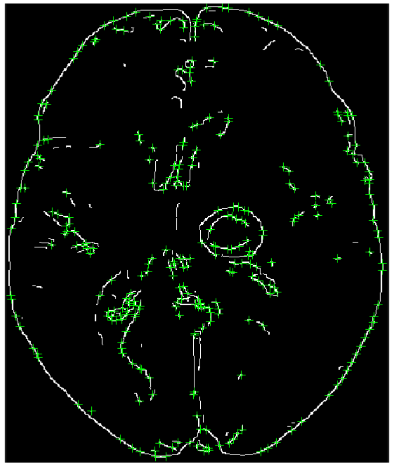
Experiment	Original image	Canny edge detection	Harris corner detection	Detected points
3A	meningioma_1 	canny_meningioma_1 	harris_meningioma_1 	First points $x_1 = 188.3$, $y_1 = 213.9$ $x_2 = 310.9$, $y_2 = 51.96$ Second points $x_1 = 151.3$, $y_1 = 191.9$ $x_2 = 316.8$, $y_2 = 60.45$
3B	meningioma_2 	canny_meningioma_2 	harris_meningioma_2 	First points $x_1 = 93.01$, $y_1 = 209.1$ $x_2 = 168.6$, $y_2 = 53.48$ Second points $x_1 = 80.06$, $y_1 = 204.5$ $x_2 = 138$, $y_2 = 34.43$

Table 4.4 Experiment conducted on abnormal brain images (Metastatic)

Experiment	Original image	Canny edge detection	Harris corner detection	Detected points
4A	metastatic_1 	canny_metastatic_1 	harris_metastatic_1 	First points $x_1 = 318.7$, $y_1 = 304.6$ $x_2 = 301.7$, $y_2 = 222.3$ Second points $x_1 = 350.9$, $y_1 = 273.3$ $x_2 = 267.1$, $y_2 = 243.7$
4B	metastatic_2 	canny_ metastatic_2 	harris_metastatic_2 	First points $x_1 = 264$, $y_1 = 300.5$ $x_2 = 279.5$, $y_2 = 240.9$ Second points $x_1 = 241.6$, $y_1 = 290.5$ $x_2 = 268$, $y_2 = 235.9$

4.2.3 Analysis and Discussion for Abnormal Brain Experiments (2A, 2B, 3A, 3B 4A and 4B)

Table 4.5 below summarized the obtained results from experiment for abnormal brain. Column two and three are the calculated area of spreading tumor in brain images while column four is the average area of tumor based on two calculated area; area 1 and area 2. Area 1 and area 2 use different points of x and y, in which the average area will be used as final value to predict the phases of tumor.

Table 4.5 Results of Calculated Tumor Area using Euclidean Distance

Experiment		Area 1	Area 2	Average	Phase
2	A	259.7865	251.9424	255.8645	3rd phase
	B	147.6352	142.5717	145.1035	1st phase
3	A	260.2024	259.5451	259.8738	3rd phase
	B	163.4916	161.9013	162.6965	2nd phase
4	A	80.6422	81.0513	80.8486	1st phase
	B	53.1245	60.3686	56.7466	1st phase

CHAPTER 5

CONCLUSION

5.1 Introduction

Many approaches have been recognized in identifying brain tumor phase, however, Canny and Harris algorithm is used in this research work. Its emphasis on evaluating the method's efficacy in predicting the phase of tumor at different positions and sizes in brain images. The effectiveness is defined as the brain tumor successfully tested using Canny and Harris algorithm. The phases (range between 50-151 as first phase, 151-250 as second phase, 251-350 as third phase and 351-450 as fourth phase) are also able to be predicted using Euclidean Distance. This research work has proposed a simple equation to determine the phases of tumor as explained in section 3.5.4.

In the experiment conducted under section 3.5.5, six abnormal brain images with different types and sizes of tumor shows various phases predicted based on the area of spreading tumor. The average area of tumor in first and third abnormal brain image is 255.8645 and 259.8738, hence the tumor is already in 3rd phase. For the second, fifth and sixth abnormal brain image, the average value is 145.1035, 80.8486 and 56.7466 respectively. So, the tumor is categorized under 1st phase. Lastly, fourth abnormal brain image is predicted as 2nd phase because the average value (162.6965) is under 2nd phase category.

The research focusses primarily on the effectiveness of Canny and Harris algorithm to identify brain tumor. Using MATLAB version 2019, the coded of Canny and Harris is written and simulated. From the simulation, it was found that the different size of the brain tumor would influence the phases of tumor. The results of the simulation shown in Table 4.3 has successfully approached the objectives of this research as stated in chapter 1; to detect brain tumor using Canny Edge and Harris Corner algorithm and identify phases of brain tumor using Euclidean Distance with respect to the size of brain tumor. With the help of MATLAB application software, the implementation of all methods has been conducted successfully.

5.2 Research Constraints

There are a few constraints faced on completing this research. Below are the lists of constraint in this research:

i. Limited source of high-quality brain images

This research used CT scan brain images as it is more suitable with the proposed method; Canny and Harris algorithm. However, the sources are very limited because the dataset from most medical website only contains brain images form MRI scan.

ii. Image limited to 2D format

The images from CT scan are provided in 2D format and not available in 3D format.

iii. Resizing the image cannot be done in Paint

To resize the image, it must be done in MATLAB using a specific code for resizing image in $Width \times Height$ pixel size. In Paint, when the horizontal value is assigned, the vertical value is automatically specified based on the image. So, the image size may be varied and not valid to use for calculating the area of tumor.

iv. Brain image can be used from CT scan only

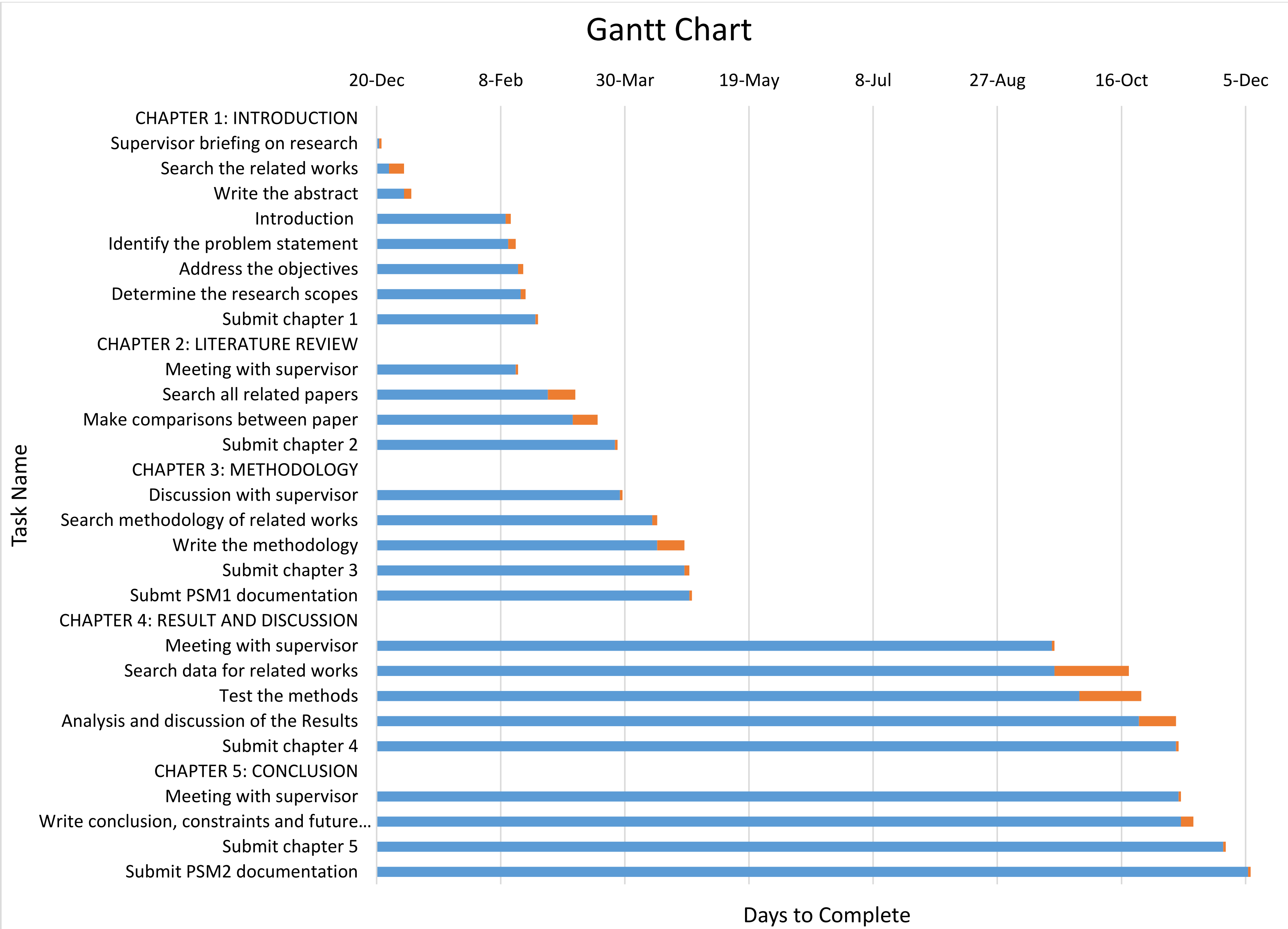
To conduct the experiment on brain medical images, the data must be collected form CT scan only, not MRI scan. This is because MRI gives a detailed image of soft-tissue structures which are unimportant in this research work. Meanwhile for CT scan, the tumor in brain images can be seen more clearly without any interference from other brain tissues. In addition, the editing process is much easier for CT scan images to extract brain from skull as the brain is nicely shaped. In comparison with MRI images, the extraction can be difficult due to the shape of the brain that is not formed properly and interfered by other tissues in between skull and brain.

5.3 Suggestions for Future Work

Generally, this research work has been successful. On the contrary, there are some improvements that can be implemented in the future.

i. Add more types of brain pictures using MRI scan.
ii. Upgrade image formatting from 2D to 3D image so that more data can be detected and collected from each edge of the images.
iii. Utilize other features detection algorithm such as Speeded-up Robust Features (SURF) and Scale Invariant Feature Transform (SIFT) for corner detection.
iv. Calculation for area of spreading tumor can be developed and computed in coding.

APPENDIX



Gantt Chart
20-Dec
8-Feb
30-Mar
19-May
8-Jul
27-Aug
16-Oct
5-Dec
CHAPTER 1: INTRODUCTION
Supervisor briefing on research
Search the related works
Write the abstract
Introduction
Identify the problem statement
Address the objectives
Determine the research scopes
Submit chapter 1
CHAPTER 2: LITERATURE REVIEW
Meeting with supervisor
Search all related papers
Make comparisons between paper
Submit chapter 2
CHAPTER 3: METHODOLOGY
Discussion with supervisor
Search methodology of related works
Write the methodology
Submit chapter 3
Submt PSM1 documentation
CHAPTER 4: RESULT AND DISCUSSION
Meeting with supervisor
Search data for related works
Test the methods
Analysis and discussion of the Results
Submit chapter 4
CHAPTER 5: CONCLUSION
Meeting with supervisor
Write conclusion, constraints and future...
Submit chapter 5
Submit PSM2 documentation
Task Name
Days to Complete

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