Detection of Microcalcification Using Mammograms

by

Khairul Nisak Bt Md Hasan

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

JUNE 2004

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

Detection of Microcalcification Using Mammograms

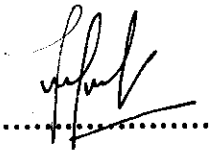
by

Khairul Nisak Bt Md Hasan

A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons)
(ELECTRICAL & ELECTRONICS ENGINEERING)

JUNE 2004

Approved by,

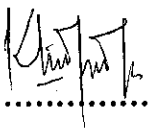


.....

(MS. ZAZILAH MAY)
Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.



.....

(KHAIRUL NISAK BT MD HASAN)

IC No: 810527-02-5146

ABSTRACT

Mammography is one of the most common and useful techniques used for early detection of the breast cancer. It is the low-dose x-ray examination performed to patient to detect the primary mass when it is still small and confined to the breast. The present of microcalcification is a highly indication of the cancerous tissues. Microcalcification is a tiny specks of calcium deposited in the breast. The problem encountered in detecting the microcalcification by using this method is the limitation of the mammogram image (x-ray) to detect the microcalcification due to mainly to their small size, low contrast, and the similarity of their radiographic appearance to dense tissue. Statistic had shown that approximately 10%–30% of breast cancers retrospectively visible on the mammograms were missed or misinterpreted due to human or technical factors [1].

This project focuses on the enhancement of the mammograms image by applying the image processing techniques to assist doctors in detecting the breast cancer disease. The aim is to provide a low-cost technology in detecting the breast cancer at the early stage. This project develops the program using MATLAB and Borland C++ to enhance the digitized mammograms image by using the image processing technique. The mammogram is first digitized and processed by the program developed to detect the microcalcification deposited in the breast. The morphological operation was a simple and suitable method in identifying the microcalcification.

The top-hat algorithm method that is a morphological operation was developed using MATLAB and successfully obtained the output image that shows the candidate microcalcification. The top hat method consists of four stages which are digitization of mammograms, image enhancement, image segmentation and feature extraction. Various image processing techniques were applied including filters, histogram generation, thresholding and edge detection. The top hat method was applied to mammograms samples of eight patients and able to detect the microcalcification. The results obtained were defined into three categories, below expectation, meet expectation and above expectation. In conclusion, the project had met an acceptable degree of accuracy level.

ACKNOWNLEDGEMENT

In The Name of Allah, Most Merciful and Compassionate

First and foremost, thank to Allah that with His blessing this project reached its completion.

I would like to express my heartiest gratitude to my supervisor, Ms. Zazilah May for her concern, help and guidance throughout the entire of my project work.

My wholehearted thanks to my co-supervisor, Prof. P.A Venkatachalam, for his advice and dedicated guidance in showing me the path of the project. Not to forget, Ms Kavitha, the Research Officer of Electrical & Electronics Department, UTP for her willingness to help me in understanding and providing me the information and advices.

I am also indebted to Dr. Chandra Moorthy, radiologist of General Hospital Kuala Lumpur (HKL) and Dr. Selliah of General Hospital Ipoh for their cooperation and openness in providing me the mammography samples and the information.

My sincerest thanks also goes to my dear roommate, Ms Suriati Bokhari for her generosity in sharing the knowledge and opinion to my project. Her enthusiasms keep forcing me forward. Special thanks also to both my partners, Ms Ziyadatina Abd Rahman and Faizah Othman for their help and support throughout the project.

My appreciation to Ms Siti Hawa, the assistant coordinator of Electrical & Electronics Final Year Project for her help. To all friends, bunches of thanks for giving me support that making this project a success and last but not least, to my parent and family for their understanding and encouragement.

Thank you to all.

LIST OF FIGURES

Figure 2.1 Location of the seed pixel and its 3 x 3 neighbourhood

Figure 2.2 The seed pixel growing towards its 4 adjacent neighbours

Figure 2.3 The seed pixel growing towards its 4 diagonal neighbours

Figure 2.4 The seed pixel growing towards its 8 surrounding neighbours

Figure 2.5 The block diagram of the filtering function

Figure 3.1 Flowchart of the project path

Figure 3.2 The step of the 'top-hat' method

Figure 3.3 The equipment used in the project

Figure 4.1 The 'top-hat' algorithm using MATLAB

Figure 4.2 The Graphical User Interface of the algorithm

Figure 4.3 The GUI shows the result for mammograms contained microcalcification

Figure 4.4 The histogram generated for the specified area

LIST OF TABLES

Table 2.1 The abnormalities in the mammograms and its indication

Table 4.1 List of mammograms samples

Table 4.2 Output image after 'top-hat' procedure

Table 4.3 The step by step of the 'top-hat' method

Table 4.4 The evaluation of the result

TABLE OF CONTENTS

CERTIFICATION OF APPROVAL

CERTIFICATION OF ORIGINALITY

ABSTRACT i

ACKNOWLEDGEMENT ii

LIST OF FIGURES iii

LIST OF TABLES iv

CHAPTER 1: INTRODUCTION

1.1 Background of study 1

1.2 Problem statement 2

1.3 Problem Identification. 3

1.4 Significant of the Project. 3

1.5 Objectives 3

1.6 Scope of study 4

CHAPTER 2: LITERATURE REVIEW

2.1 Mammography 5

2.2 Characteristic of the breast abnormalities. . . . 7

2.3 Segmentation of micro-calcification clusters in mammograms. 9

2.4 The Region Growing Technique. 11

2.5 Filtering Techniques. 13

2.5.1 Unsharp masking filter. 14

2.5.2 Top-hat filter. 14

2.6 Noise Removal Technique. 15

2.7 Edge Detection Techniques. 16

2.8 Contrast Enhancement/ Intensity Adjustment. . . 16

2.9 Threshold. 17

CHAPTER 3: METHODOLOGY

3.1 Procedure Identification. 18

3.2 Project Work 20

3.2.1 Top Hat Method 21

3.3 Tools. 28

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Results 29

4.1.1 Mammogram Samples 29

4.1.2 Program Developed 30

4.1.3 Result of Processed Image. 31

4.1.4 Graphical User Interface (GUI) 36

4.2 Discussions 39

4.2.1 Mammogram samples 39

4.2.2 Methodology of the Project 39

4.2.3 Evaluation of the Result 44

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions 47

5.2 Recommendations 47

REFERENCES 49

LIST OF APPENDICES 50

CHAPTER 1

INTRODUCTION

1.1 Background of Study

According to recently published statistics, breast cancer is the third most common cancer worldwide. Almost 1.1 million cases were reported worldwide with 373,000 deaths in the last year. In Malaysia, the International Agency for Research in Cancers (Globocan 2000) estimated that the incidence of breast cancer in Malaysia was 34.8 per 100,000 with almost 4,000 new cases in the year 2000 [2].

At present, the most reliable and practical method for early detection of small breast cancers is by screening mammography. Screening mammography is a low-dose x-ray examination of the breast that is performed on women who has no complaints or symptoms of breast cancer (asymptomatic) [3]. A fundamental measure of the quality of all mammography systems is the capability to resolve microcalcifications. Besides detection of microcalcification, mammograms also able to indicate the macrocalcification, masses and density abnormalities in the breast tissues. However, the present of microcalcification is highly indication of the cancerous tissues. Clustered microcalcifications are the single most common sign of early breast cancer and very often are the only sign. Screening requires highly sensitive imaging techniques because the detection of microcalcifications and subtle changes in soft tissue architecture are dependent on excellent spatial and contrast resolution. Differential x-ray attenuation of breast tumors, microcalcifications and distortions as compared to normal breast tissue can be properly visualized with film-screen techniques, thus providing an effective screening tool for breast cancer.

The study of the project will covered the enhancement of the mammograms image to aid the radiologist in analyzing the mammograms. This will be achieved by enhancing the image processing in detecting the presence of the microcalcification.

1.2 Problem Statement

Statistic had shown that approximately 10%–30% of breast cancers retrospectively visible on the mammograms were missed or misinterpreted due to human or technical factors [1]. This is caused by the limitation of the diagnosis of mammogram in detecting the presence of microcalcifications, which is invisible to the naked eye. Image of mammograms is sometimes misinterpreted as a cancer by the doctors with other type of breast abnormalities such as liason and duct. The study on the differences in the characteristic of the breast disease shown in the mammograms image carried out for the improvement in identification of breast cancer. The program using the MATLAB and Borland C++ is developed to apply the image processing technique to enhance the images and produced a clearer image to ease the interpretation. The program is also produced the output that identify the suspected are of microcalcification for the doctors to analyse.

1.3 Problem Identification

The analysis of the conventional x-ray by the radiologist might lead to misinterpretation due to human vision limitation. Furthermore, the detection of the clustered microcalcification on the mammogram is the main problem due to mainly to their small size, low contrast, and the similarity of their radiographic appearance to dense tissue which had led to missed detection of the cancer. These drawbacks of the conventional mammography lead to the development of the digital mammography that is currently getting large attention in medical area to aid the radiologist in interpreting the mammograms. This project focuses on the enhancement of the mammogram image quality and develops statistical techniques for computer-assisted interpretation of images

using the digital image processing. The characteristic of the microcalcification is used to differentiate it with other tissues and the area is enhanced to automatically detect it.

1.4 Significance of the Project

The significance of the project serves the student as well as the society, where:

1. Student is able to learn a new scope of study, which is the image processing and develop the source code using MATLAB and Borland C++.
2. Student can collaborate with the Universiti Teknologi Petronas Research Team on Image Processing and Telemedicine in doing research and finding.
3. The enhancement of the mammograms image is inline with the current need of the society for an accurate early detection of breast cancer.

1.5 Objectives

The objectives of this project are:

1. To identify the characteristic of the microcalcification in the mammograms and the image processing technique that is appropriate.
2. To acquire an image of the mammograms with the quality up to the original image by applying the digital image processing techniques.
3. To develop programs using MATLAB and Borland C++ to acquire a better quality image of the mammograms by applying the digital image processing techniques.
4. To produce an output image that able to detect the microcalcification and met the requirement of the doctors on the processed image of mammograms to a certain degree of accuracy level.

1.6 Scope of study

The project covered on the research related to the breast cancer medical information and the image processing techniques as well. The research is based on the various project and studied conducted previously. The knowledge and understanding about the breast cancer and the microcalcification with its characteristic that indicates cancerous case is

essential. The project also focused on the processing of the mammogram samples images obtained from the hospital by using the MATLAB and Borland C++ programming language. The study covered on the techniques of digital image processing in enhancing the quality of the mammograms in the image acquisition, restoration, segmentation, feature extraction and recognition in order to clearly detect the microcalcification.

CHAPTER 2

LITERATURE REVIEW / THEORY

2.1 Mammography

Mammography is the soft tissue radiology in the breast and is a most sensitive method for detecting breast cancer [4]. The techniques provide the radiologist with images which is called mammograms that are sufficiently detailed to enable subtle differences in the soft tissues to be recognized and to provide information regarding the shape, size and position of abnormalities. The radiation dose per examination used for mammography is approximately 0.1 – 0.8 radians. From the mammograms obtained, radiologist usually look for mammographic abnormalities which are discrete abnormalities, diffuse changes and alteration between successive film of the same breast. Discrete abnormalities includes cluster of microcalcification, local opacities and localized distortion. Diffuse changes appear as asymmetry between right and left breast image or widespread calcification. The alteration provide information of the growth of the diseases. The abnormalities shown on the mammograms is usually the very white or bright tissues due to its density that block the radiation wave going through the tissues. However, one of the limitation of film-screen mammography is the trade off between resolution and detector x-ray absorption efficiency [4]. This causes a reduction is spatial resolution and thus the mammographic system requires a high resolution and detection efficiency. This limitation had lead to the development of the digital mammography and the digital enhancement in interpreting the mammograms.

Table 2.1 summarized the discrete abnormalities found in mammograms and its indication.

Table 2.1: The abnormalities in the mammograms and its indication

Abnormalities	Indication
Microcalcifications	A tiny (less than 1/50 of an inch or ½ of a millimeter) specks of calcium in the breast. When many microcalcifications are seen in one area, they are referred to as a cluster and may indicate a small cancer. About half of the cancers detected by mammography appear as a cluster of microcalcifications. Microcalcifications are the most common mammographic sign of ductal carcinoma in situ (*an early cancer confined to the breast ducts*). Almost 90% of cases of ductal carcinoma in situ are associated with microcalcifications. An area of microcalcifications seen on a mammogram does not always indicate that cancer is present. The *shape* and *arrangement* of microcalcifications help the radiologist judge the likelihood of cancer.
Macrocalcifications	A coarse (large) calcium deposits that are often associated with benign fibrocystic change or with degenerative changes in the breasts, such as aging of the breast arteries, old injuries, or inflammation. Macrocalcification deposits are associated with benign (*non-cancerous*) conditions and do not usually require a biopsy. Macrocalcifications are found in approximately 50% of women over the age of 50.
Masses	It may occur with or without associated calcifications. A mass is any group of cells clustered together more densely than the surrounding tissue. A *cyst* (a non-cancerous collection of fluid in the breast) may appear as a mass on a mammogram film. A cyst cannot be diagnosed by physical exam alone nor can it be diagnosed by mammography alone, although certain signs can suggest the presence of a cyst or cysts. To confirm that a mass is a cyst, either breast ultrasound or aspiration with a needle is required. If a mass is not a cyst, then further imaging may be ordered. As with calcifications, a mass can be caused by benign breast conditions or by breast cancer. Some masses can be monitored with periodic mammography while others

	may require biopsy. The size, shape, and margins (edges) of the mass help the radiologist in evaluating the likelihood of cancer. Prior mammograms may help show that a mass is unchanged for many years, indicating a benign condition and helping to avoid unnecessary biopsy.
Density	The glandular tissue of the breasts, or breast density, shows up as white areas on a mammogram film. In general, younger women have denser breasts than older women. Breast density can make it more difficult to detect microcalcifications and other masses with mammography, since breast abnormalities also show up as white areas on the mammogram. After menopause, the glandular tissue of the breasts is replaced with fat, typically making abnormalities easier to detect with mammography. Therefore, most physicians do not recommend that women begin receiving annual screening mammograms until they reach 40 years of age unless they are at high risk of developing breast cancer.

2.2 Characteristic of the breast abnormalities

Microcalcification are small deposits of calcium, which may appear as single spots or grouped into clusters [5]. The presence of it usually is an early sign of breast cancer, however, it might indicate benign or malignant cases. Thus, the characteristic of the breast abnormalities found in the mammograms is important in identifying an appropriate technique to be applied for the image processing. The shape, size and the distribution is a factor to be considered since these characteristic indicates whether it is a cancerous or non-cancerous tissues. *Appendix 1A* shows the list of the characteristic for calcification. The calcification characteristic is the main concern where the result of mammograms image processing must be able to differentiate them. From the table, it clearly shown two type of calcicification that indicates the malignant type which are terminal duct and ductules and cyst-like dilated lobules.

2.3 Segmentation of micro-calcification clusters in mammograms

The literature review of the project is based on the project paper on '*Parameter optimization of a computer-aided diagnosis scheme for the segmentation of micro-calcification clusters in mammograms*' produced by Marios A. Gavrielides, Joseph Y. Lo and Carey E. Floyd, Jr. The purpose of the study is to develop a parameter optimization technique for the segmentation of suspicious microcalcification clusters in digitized mammograms.

The study had stated that the clinical significance of microcalcification clusters and the risk of misdiagnosis have prompted significant research in the breast cancer detection area. The methods typically include a pre-processing step for noise suppression and contrast enhancement, a feature extraction step for locating suspicious signals, and a feature analysis step to reduce the number of false positive signals. Pre-processing is usually done using conventional image processing and filtering methods. For the feature extraction, several techniques can be used, including difference-image technique, local area thresholding, wavelet transform-based methods, image fuzzification and morphological operators, statistical texture analysis, and Laplacian scale-space signatures. For this project, these steps are to be implemented with an additional of some steps. However, the algorithm used in this project will be the Visual C++ with the aid of the available image enhancement software.

From the paper, another important step is to extract the histogram features during the segmentation of images. The size selected is 16 x 16 pixels since breast cancers rarely produce calcifications larger than 1 mm, and most are under 0.5 mm in diameter. The test images were digitized at 105 mm per pixel, giving a 1-mm object an image size of about 10 pixels. The 16x16 pixels size is large enough to include calcifications of clinical interest as well as small enough to enable individual microcalcifications to affect the local histogram. This information is important to be considered in this project in order to be able to enhance the quality of the mammograms image. Further finding in the paper will be extracted and applied in this project where applicable.

2.4 The Region Growing Technique

The study also based on the paper titles '*The Region Growing Technique For Mammographic Classification Clusters*'; by OOi Thean Hai, Umi Kalthum Ngah, Noor Elaiza Abd. Khalid and P.A Venkatachalam

The paper focused on the detection of the microcalcification in the mammograms. Microcalcification is considered to the most important sign of breast cancer. The problems in analyzing and detecting the particles is that, they are very small, often appear in an inhomogeneous background and some of them have a very low contrast to the background. Marios A. Gavrielides, Joseph Y. Lo and Carey E. Floyd, Jr. state that; specifically, breast cancers rarely produce calcifications larger than 1 mm, and most are under 0.5 mm in diameter [6]. The study had shown that one of the major characteristic of microcalcification is the shape. Thus, the paper had proposed a segmentation technique, namely the region growing method to highlight the shape and configuration of clusters of microcalcification.

Image segmentation is the partitioning of an input image into its constituent parts or objects. It can be classified to boundary representation and regional representation. Each representation is identification of homogeneous regions or contours inhomogeneity respectively.

The region that are not uniform in terms of the grey values of their pixels but are perceived as uniform, are called textured region. Mammographic image is mainly of this type. For segmentation purposes, each pixel cannot only be characterized by its grey level value but also by numbers which quantify the variation of the grey values in a small patch around the pixel. We can envisage that each pixel is characterized not by one number but by a vector numbers, each component of the vector measuring something at the pixel position. Pixels belonging to the same region will have similar or identical values in their attributes and thus will cluster together. The region growing method is one of the segmentation methods that take into consideration the spatial proximity of pixels. In general, one starts from some seed pixels and attaches

neighbouring pixels to them provided that the attributes of the pixel in the region created vary within a predefined range [6].

The paper mentioned that the result of the growing process is a single region containing pixels with properties similar to those seed pixel. The result of the procedure are used to classify only the seed pixel and not all pixels in region grown.. This localized application requires the specification of two variables, which are the window-size and absolute difference in grey level between the pixel to be appended to the grown region and the seed pixel.

During the local region growing (LRG), procedure, every pixel in the image is chosen successively as the seed pixel and the growing is confined to a localized window cantered on the seed pixel. Once the growing process is terminated, two distinct regions are considered; the region growing and surrounding region. If the growing region has a greater average intensity than the surrounding region, then the seed pixel is classified as parenchymal tissue. The seed pixel is classified as fat if the region has a lower average intensity than the surrounding region.
There are several regions growing technique and the common techniques are seed-based, iterative and split & merge technique.

The seed-based Region growing technique

Seed-based region growing involves a seed which grow a region out from an image. Firstly, a seed pixel is located within an area of the image to be grown. The chosen seed is surrounded by a P x P neighbourhood and is at the centre of all its neighbours. See figure 2.1.

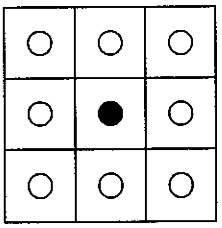


Figure 2.1: Location of the seed pixel and its 3 x 3 neighbourhood

The mean value for this P x P neighbourhood is calculated using equation:

$$\text{Mean} = \frac{\text{Total of gray level for all pixels in P x P neighbourhood}}{\text{Total of pixels in P x P neighbourhood}}$$

There are three possible way for a seed pixel to grow, as show on figure 2.2, 2.3 and 2.4 [7].

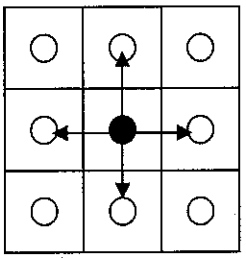


Figure 2.2: The seed pixel growing towards its 4 adjacent neighbours

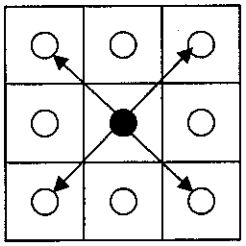


Figure 2.3: The seed pixel growing towards its 4 diagonal neighbours

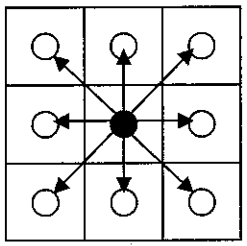


Figure2. 4: The seed pixel growing towards its 8 surrounding neighbours

From every growth from the seed pixel to its neighbours, a comparison is made between the calculated mean value and the grey level for this particular neighbour. If the absolute difference of the two is less than the pre-defined threshold, the neighbour pixel will be included into the growing region. The condition is represented by following equation:

$$|G_i - M| < T$$

G_i = Grey level of the particular neighbour pixel

M = calculated mean value of the growing region

T = pre-defined threshold

2.5 Filtering Techniques

In the images that are digitized, there will be noises such as the spark, Gaussian or others that incorporated in the images, which is unwanted. Filtering techniques are used to remove noise or to enhance edges and small details in an image. The filtering can be carried out in the spatial frequency domain or in the space domain. Digital images can be transformed into their spatial frequency components by using the two-dimensional discrete Fourier transform. The low-frequency components correspond to large objects and the overall background of the image, whereas the high-frequency components correspond to edges and small details in the image. Low-pass filter and high-pass filter are used to smooth the image or to enhance edges and small details. Basically, the frequency domain filtering can be explained by the convolution theorem. The filtering can be simply represented by an equation:

$$F(u,v) = H(u,v)F(u,v)$$

The process can be explained by the block diagram:

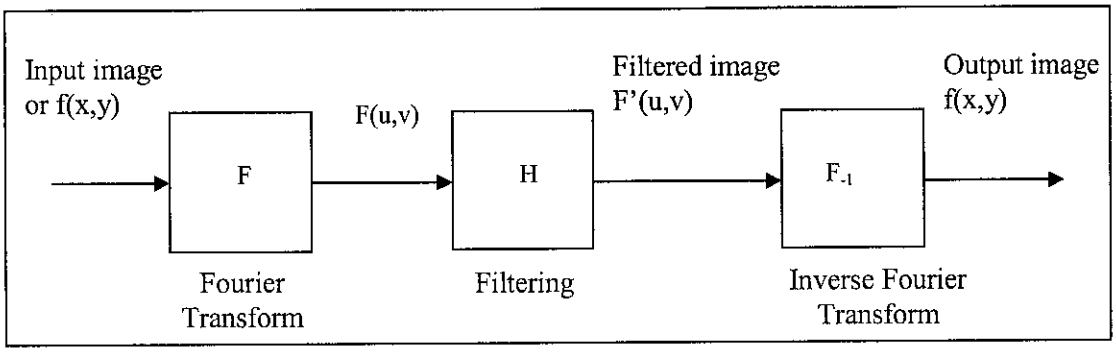


Figure 2.5: The block diagram of the filtering function

The low-pass filter is used to blur the images and usually used for noise removal. In low-pass filtering, the low-frequency coefficients are enhanced and the high-frequency coefficients are suppressed. The common low-pass filter used is he Butterworth filter with a smooth transfer function. The high-pass filter is used to sharpen the image where the small detail or boundary is highlighted. Edges and small details in images correspond to high-frequency coefficients. In high-pass filter, the low-frequency is suppressed and boosts the high-frequency detail. There are many more type of filters that is available, such as the minimum and maximum filter, sobel, prewitt and others. Some of the filter is used in the process of enhancement the mammograms images that has been digitized.

2.5.1 Unsharp masking filter

This technique is one of the method to sharpening the image through a multi-step process called unsharp masking. By using this technique, it produced a sharpened image and it is controllable with processing parameters. The algorithm is as follow:

$$S_{x,y} = (c/(2c-1)) \times A_{x,y} - ((1-c)/(2c-1)) \times A'_{x,y}$$

In this equation, A is the original image and A' is the original image that is filtered using low-pass filter, c is a weighting constant used to produce the resultant sharpened image, S [4]. Unsharp masking filter combine the use of low-pass filter, which is a neighbourhood operator with multiplication and division, which are point operators. This filter does not actually sharpen the image, but it increases the apparent sharpness by modifying the contrast between bright and dark area. Thus, it is also called an unsharp contrast enhancement filter.

2.5.2 Top-hat filter

The top hat filter is multiscale morphological opening filtering. It is implemented to remove the slow rate of variation of the image intensity values and to enhance

the image contrast. In morphology, filtering is performed using a kernel, and multi-scaling is performed by changing the size of the kernel.

For a given image *I*, the multiscale top hat operator ζ removes objects whose size is larger than the given kernel size. The kernel is taken to vary from the smallest to the largest size of individual microcalcifications. The multiscale top hat equation is:

$$\zeta_k(\mathbf{I}) - \mathbf{I}\varsigma_k(\mathbf{I})$$

where k is the kernel size [8].

The opening operation consists of erosion followed by dilation on a kernel that defines the size of the region over which pixel values are taken. Erosion replaces the pixel value at the center of the kernel by the minimum value of its neighborhood pixels, while dilation replaces it by the maximum value of its neighborhood pixels. The opened image is then subtracted from the original image. Square kernels whose sizes vary between one and five pixels is used.

2.6 Noise Removal Technique

Noise can be defined as any unwanted signal. There are different kind of noise, such as pepper-and-salt, Gaussian and white noise. In the process of digitizing the image, there might be some noise developed. The usage of improper equipment to digitize the image and other factors might caused the noise in images. These noise must be removed in order to minimized the percentage of error in detecting the right image. Many techniques has been developed for reducing and removing noise, including the low-pass filtering, median filtering, Maximum filtering, minimum filtering, Wiener filtering and others.

In median filtering method, the grey value of a pixel is replaced by the median of the grey levels in the neighbourhood of that pixel. For the 3 x 3 neighbourhood, the value of the pixel in the centre is replaced by one of the median value of its neighbour. Using this method, the noise is removed without blurring the image as compared to the averaging technique.

2.7 Edge Detection Techniques

Edge detection technique is to make edges of the image more visually prominent. A digital edge may be defined as the boundary between two regions that appears when brightness values of the two regions are 'significantly different' [9]. For this project, the technique is useful to detect the edges of the calcification or the mass since their brightness value is high as compared to others.

There are two types of edges, a step edge and a line edge. Step edge separate two regions in an image like the boundary between an object and the background while line edge represents lines or thin curves in the image. Edges are characterized by changes in gray values and can be detected by observing value of derivatives of the image function and the finite differences for digital image. There are many type of operator of the techniques that has been developed including Laplacian, Robert's, Sobel, Canny, and others. These operators can be defined in term of masks. Consider a region of size 3x3 as shown below with i as the central pixel. The gray values in the region can be represented by Z = (a,b,c ....i) while the weighting coefficient vector represented by W = (w_1, w_2,...w_9). Edges can be detected by fixing a threshold on the value of S, given by;

$$\mathbf{S = Z'W}$$

The threshold value of these operators can be select by users as required [4]. Lower threshold value yields thick edges and higher threshold value yield thin edges.

2.8 Contrast Enhancement/ Intensity Adjustment

The contrast and brightness adjustment is one of the important process in enhancing the image. Basically, the brightness adjustment is the addition and subtraction operation to the pixels of the images. To increase the brightness of the image which is represented by arrangement of the boxes with specific pixel values, the brightness factor chosen will be added to each pixel, hence increase the pixel value as well as the brightness of the image. While to decrease the brightness the pixel will be subtract by the factor chosen. Here, the value of the brightness factor is important to determine the brightness value.

The contrast adjustment is basically the multiplication of the each pixels value to the contrast factor selected. The multiplication will increase the value of each pixels hence increase the amplitude of the histogram (the vertical axis). The contrast factor must also be selected properly to produce a good contrast image.

2.9 Threshold

Thresholding transform a dataset containing values that vary over some range into a new dataset containing just two value. The input values that fall below the threshold value are replaced by one of the output values (0); and the input values at or above the threshold are replaced by other output value (1). The most common form of image thresholding makes use of pixel grey level. Grey level thresholding applies to every pixel; the rule are:

$$g(x,y) = \begin{cases} 0, & f(x,y) < T, \\ 1, & f(x,y) > T, \end{cases}$$

where T is the threshold value [10]. From this equation, 0 and 1 is the specified output values, but it is common to use 0 and 255 so that pixels appear black or white if the output image is displayed. Thresholding can be implemented in two ways. First, the equation above is applied to each grey level as we iterate over every pixel. The second alternative is the equation is applied once for all grey level and store the result in the look-up table, that is used to map the grey level of each pixel onto 0 or 1. In the equation, the bright pixel is consider 1 and the dark pixel is consider 0. The equation above is used if the goal is to detect a brighter features than everything else, but if the aim is to detect a darker feature, then the equation should be vice versa.

The success of thresholding depends critically on the selection of an appropriate threshold. An obvious solution is to rely on intervention by a human operator, who can vary the threshold until acceptable results are achieved. This is not possible in cases where fully automatic segmentation is required. Alternatively, one must be able to determine in advance a single, fixed threshold that will always give good result.

CHAPTER 3

METHODOLOGY/PROJECT WORK

3.1 Procedure Identification

The project work is mainly divided into six phases. The main part of the project is to design, develop, test and troubleshoot the image processing program using MATLAB and Borland C++ to the mammograms acquire from the hospital. Basically, the steps involved in the project are:

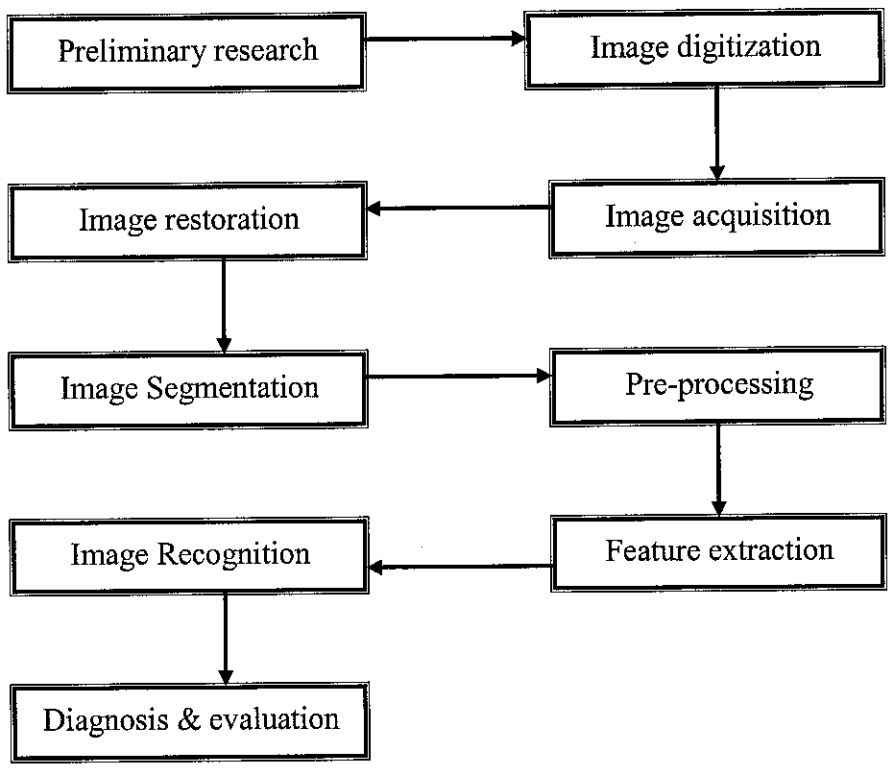


Figure 3.1: Flowchart of the project path

3.1.1 Preliminary Research

Preliminary research involved the research on the breast cancer information concerning the medical information, digital image processing itself and understanding the algorithm and source code. The information and knowledge gained from various sources including reference books, project papers, Internet website, knowledgeable people or expertise on the subject matter and other indirect sources.

3.1.2 Image Digitization

The mammogram's sample obtained from Kuala Lumpur General Hospital and Ipoh General Hospital is digitized using the high resolution scanner. The process is restricted by the reliability of the equipment.

3.1.3 Image acquisition

The sample of mammogram's images obtained is stored in the computer. The image is stored in TIFF format. The image compression might give a defect to the digitized image.

3.1.4 Pre-processing

The image enhancement technique is performed to obtain a clearer and better image. The image enhancement techniques used are histogram generation, filtering techniques, contrast and brightness adjustment, and segmentation. The image processing software used includes Eikona software, MATLAB, Adobe Photoshop and the Borland C++ program.

3.1.5 Image Segmentation

The segmentation of the image is to be performed to a specific area of interest on the mammogram's image. Basically, there three method of segmentation, the threshold, edge detection and clustered using region growing technique where

the objective is to focus on the affected area indicated by the presence of the cancerous tissues.

3.1.6 Feature extraction

The histograms features will be extracted by perform the segmentation of the individual microcalcification. This individual microcalcification will be evaluated and determined by their characteristic to confirm whether the tissues indicates malignant or benign type.

3.1.7 Image Recognition

Recognition is implemented as a classification process where the object of interest is recognized into a particular type. The output is merely the decision of to which group the object belongs. The student will run the program written and applied on the mammograms. The result of the successfulness in producing a clearer image is analysed.

3.2 Project Work

The clinical database used in this project comprises mammograms obtained referred to the General Hospital Kuala Lumpur and General Hospital Ipoh. There are 8 cases/patients with each patient had 2 mammograms that were processed in this study. Five samples of mammograms is taken from General Hospital Kuala Lumpur and three are obtained from General Hospital Ipoh. Each mammograms taken is attached with its report from the radiologist and the cases consist of normal, malignant and benign cases.

The project work is basically followed the flow shown in figure 3.1. In order to achieve the objective to produce an output image that is clearer and able to detect the microcalcification, a method using morphological operation was created. The method is using the top-hat filter with thresholding and edge detection. The method is called the 'top-hat' method and all the mammograms is tested using this program.

3.2.1 Top-Hat Method

The step involved in this method is basically shown in figure 3.2. After the mammograms images was obtained, the first stage is too digitized the mammograms image. The digitized image is then was enhanced using the filtering technique and top-hat algorithm to detect the microcalcification area. The third stage is applying the segmentation in order to further highlighted the clustered microcalcification. After the suspicious calcification is clearly detected, the numerical analysis of the microcalcification is conducted.

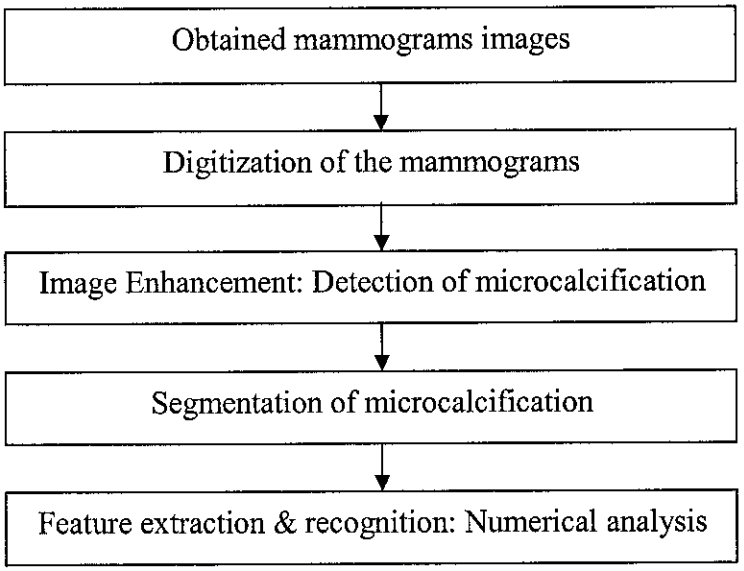


Figure 3.2: The step of the 'top-hat' method

Stage 1: Digitization of mammograms

Total of 16 mammograms images of 8 patients obtained were digitized using a high resolution scanner with 10000 dpi to scan the mammograms. The scanner is attached to the workstation as shown in the figure 3.3. Basically, figure 3.3 shows the equipment used in the project, which are the workstation, scanner and printer. The digitized image is stored in the workstation in the .tiff format. The compression of the file might causes some losses, but the effect is acceptable.

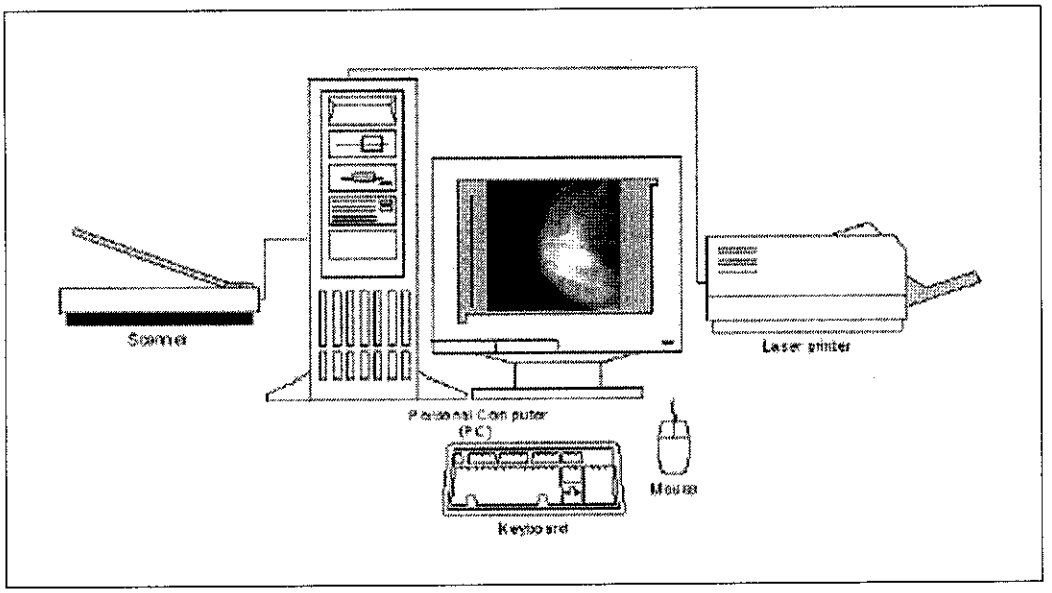


Figure 3.3: The equipment used in the project

Stage 2: Image Enhancement – Detection of Microcalcification

The histogram for the digitized image is generated using the MATLAB software or the Borland C++ program. The user can chose whether to crop the input image at the specific location or generate the histogram for the whole image. The histogram is a statistical representation of the data within an image that shows how many pixels there are at each of the possible value [2]. The horizontal axis is the possible values that a pixels can have that range from 0 to 255 for 8-bit image (refer the histogram). While the vertical axis indicates the number of pixels at each value. The importance of the histogram is that it shows the distribution of the data and indicates the overall brightness or darkness of the image. Since the cancerous tissues is a very white, the highest value of the pixels is the main interest. From here, we can estimate the interest pixels value that is important for the threshold value selection. The coding for histogram generation is in Appendix 2A.

The image, or the selected portion is then applied with unsharp masking filtering technique. This technique is one of the method to sharpening the image through a multi-step process called unsharp masking. By using this technique, it

produced a sharpened image and it is controllable with processing parameters. The algorithm is as follow:

$$S_{x,y} = \left[\frac{c}{2c-1}\right] x A_{x,y} - \left[\frac{1-c}{2c-1}\right] x A'_{x,y}$$

In this equation, A is the original image and A' is the original image that is filtered using low-pass filter, c is a weighting constant used to produce the resultant sharpened image, S [4].

The theory for unsharp masking is that the filter combine the use of low-pass filter, which is a neighbourhood operator with multiplication and division, which are point operators. A low-pass filtered version of an image is subtracted from the image, leaving high frequency information. A round kernel with diameter of several pixels is used to spatially average the original image. The image produced here is then spatially averaged again with another round kernel of the same diameter. This operation is carried out recursively. The result is a low-pass-filtered version of the original image which preserves round edges. The low-frequency result is then subtracted from the original image leaving the high-frequency components of the image. Thus, it is also called an unsharp contrast enhancement filter.

In the MATLAB programming software, the command h = fspecial('unsharp',alpha) will returns a 3-by-3 unsharp contrast enhancement filter. This fspecial command creates the unsharp filter from the negative of the Laplacian filter with parameter alpha. The alpha controls the shape of the Laplacian and it must be in the range 0.0 to 1.0. The default value for alpha is 0.2. The coding using MATLAB and Borland C++ is in Appendix 2B.

After image is filtered using unsharp masking filter, the top-hat algorithm is applied to the mammograms image. The top-hat operation is useful to eliminate

the background tissue because it is necessary to enhance the visibility and detectability of microcalcifications. A multiscale top hat morphological filtering to remove the slow rate of variation of the image intensity values and to enhance the image contrast. In morphology, filtering is performed using a kernel, and multi -scaling is performed by changing the size of the kernel. The local neighbourhood w ith respect to the operations are performed is defined by the shape and size of the kernel that is employed. The kernel used in this project is a circular disc of radius 7 pixels.

Basically, the top-hat algorithm comprises of two distinct step. The first step for top-hat filtering is to apply a morphological opening that consist of erosion and followed by a dilation. The second part of the top-hat algorithm involves subtraction of the opened image from the original image. Up to here, the resulting image shows the candidate microcalcification with eliminated background.

The image is enhance by contrast stretching, which is simplest method of increasing the contrast in an image is to adjust the image histogram so that there is greater separation between foreground and background gray level distribution. The contrast stretching applied to the image is a linear rescaling of the gray level distribution in the image. The input image gray scale is denoted by x, and the output gray scale values by y, the rescaling transformation is:

$$y = kx + m$$

Where k and m are non-zero. The contrast is increased or decreased depending on the specific values of k and m. In this project, the automatic contrast stretching is used, where the limit of the minimum and maximum of the pixel values is find and fraction of the values is calculated. The histogram of the image is then evenly distributed where the resulting histogram has a stretch effect indicates that the white particles is brighter. The coding for contrast stretching is in Appendix 2C.

Stage 3: Segmentation of Microcalcification

The filtered image is further processed by segmentation method that used the threshold technique. The step is to segment the image so that all potential objects will be given an equal value and everything else is given a value of zero. In order to automate thresholding, it is necessary to determine some statistics of an image so that a mathematical method can be used to compute a threshold value. This method uses a histogram of the data (number of pixels vs. intensity) and iteratively selects a value which divides the histogram so its two halves are ``balanced" around the chosen value. Applying this value to the image yields a segmentation result in which all microcalcifications are masked with a value of 1 and everything else in the image is black (value of 0) that is equivalent to 0 or 255 pixels.

The choice of threshold level is varied manually until microcalcification have been detected. When we specify the threshold value, let say 0.9, all the pixel value lower than that is converted to 0 (black) and the value higher than that is converted to 1 (white). The coding for threshold is in Appendix 2D.

After the microcalcification was threshold by an appropriate value selected manually, the edge detection of the microcalcification is carried out. Edge detection technique is to make edges of the image more visually prominent. A digital edge may be defined as the boundary between two regions that appears when brightness values of the two regions are 'significantly different'.

The types of edges detected in the mammograms is the step edge. Step edge separate two regions in an image like the boundary between an object and the background. Edges are characterized by changes in gray values and can be detected by observing value of derivatives of the image function and the finite differences for digital image. For this project, the edge detection is done for a binary image, which is after thresholding. Thus, the edge is detected by the differecnce between '0' and '1'. Consider a region of size 3x3 as shown below

with i as the central pixel. The gray values in the region can be represented by Z = (a,b,c ....i) while the weighting coefficient vector represented by W = (w_1, w_2,...w_9). Edges can be detected by fixing a threshold on the value of S, given by;

$$S = Z'W$$

The threshold value of these operators can be select by users as required [4]. Lower threshold value yields thick edges and higher threshold value yield thin edges.

After getting the edge of the microcalcification, the image is highlighted with the 'white' markers by multiplying with pixel value '255'. The resulting image is then overlay back on the original image by adding the two images. From here, the output image that shows the microcalcification with each one is mark by white edges is obtained.

Stage 4: Feature Extraction & recognition – analysis of images

From the output image obtained above, an analysis of the images can be performed to conclude that the case is malignant or benign. In this project, this stage are not performed practically, instead it is done theoretically due to unfortunate circumstances. The potential of using numerical analysis of individual microcalcification to distinguish between malignant and benign clusters is explored. The shape properties of the individual microcalcification and the properties of the clusters as a whole is determined in reaching the conclusion of the cases.

In order to reduce the number of false positives, the potential microcalcifications should be extracted from the original mammogram for feature extraction. Each object detected must be classified into one of three categories: innocuous microcalcification, suspicious microcalcification or artifact. These discriminant analysis can be applied to determine which combination of features gives conclusive information as to the diagnosis of a calcification. Therefore, the

following features on calcifications are measured with known diagnosis:

Davies, et al. [10] measured:

- Area, A
- Mean gray level
- Ratio of area to the square of the maximum linear dimension
- Shape parameter, $S = P^2/4\pi A$, where P is the perimeter of the object
- Edge Strength = mean value of the Roberts gradient, evaluated for each pixel-edge lying on the object's perimeter.

Microcalcification has been described as one o the major criteria for distinguishing malignant and benign clusters [11]. Mathematical morphology algorithm can be used to analyse the shape of segmented microcalcification according to the method by Lesty et al. The image analysis algorithm is rely on the number of pixels representing the microcalcification. Shape features that can be analysed are the presence or absence of infolding, elongation, narrow irregularities and wide irregularities. Clusters of microcalcification may also be described as total number, cluster shape and spatial distribution of microcalcification. The cluster shape can be determined by constructing a convex hull enclosing the microcalcification and the area of the clusters is taken from the area of polygon enclosed by convex hull.

3.3 Tools

The tools that are used in the project are divided into two categories, the software and hardware.

The software used are:

i. MATLAB software
ii. Borland C++ software
iii. Adobe Photoshop software
iv. ACDSee software
v. EIKONA software (image processing software)

The hardware used are:

i. High resolution scanner
ii. Personal Computer or workstation
iii. Mammograms images acquire from the hospital
iv. Laser Printer

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 RESULTS

The result obtained from the project is presented in four different sections which are the mammogram samples, the program developed, the output image after processed and the graphical user interface.

4.1.1 Mammogram samples

16 samples of mammogram images are processed using the above program. The samples are listed as follows:

Table 4.1: List of mammograms samples

No.	Patient	Mammograms
1.	Patient A	CC-view – Left/Right
2.	Patient B	CC-view – Left/Right
3.	Patient C	CC-view – Left/Right
4.	Patient D	CC-view – Left/Right
5.	Patient E	CC-view – Left/Right
6.	Patient F	CC-view – Left/Right
7.	Patient G	CC-view – Left/Right
8.	Patient H	CC-view – Left/Right

Table 4.1 shows the list of the mammograms sample tested in this project according to patient. The name of the patient is kept confidential and the report of every patient is referred to the doctor. The mammograms used are from

craniocaudal view, which is the projection of the breast where the compression applied from the top of the breast with the detector system is under the caudal surface. For every patient, mammograms for both side of the breast is available.

4.1.2 Program Developed

The 'top-hat' algorithm in the previous chapter is realized by using MATLAB software. The program is as shown in figure 4.1.

```
%This program is to detect the microcalcification using top-hat algorithm and segmentation

%Read the input image
I2 = imread('filename.tif');
%Select the area of interest
A=imcrop(I2);
%Display the cropped image
imshow(A), title('Original');
%Generate the histogram
figure,imhist(A);
pause
%Filter the region by median filter
L = medfilt2(A,[3 3]);
figure, imshow(L), title('median filter');
%Unsharp Masking Filter
J = fspecial('unsharp');
Un = imfilter(L,J);
figure,imshow(Un),title('Unsharp Masking Filter');
%Perform the top-hat algorithm
se = strel('disk',12);
J2 = imtophat(Un,se);
figure, imshow(J2), title('Tophat filtering');
%Contrast stretching
K2= imadjust(J2,stretchlim(J2));
figure, imshow(K2), title('Contrast adjustment');
%Generate histogram after contrast stretching
figure,imhist(K2);
%Thresholding
BW = im2bw(K2,1.0);
figure, imshow(BW), title('Threshold image');
%Edge detection
BWinv = ~BW;
perim = bwperim(BWinv);
F = imadd(imcomplement(A),immultiply(perim,255));
figure, imshow(F), title('Output image');

%%%%%---------- End Of Program ----------%%%%%
```

Figure 4.1: The 'top-hat' algorithm using MATLAB

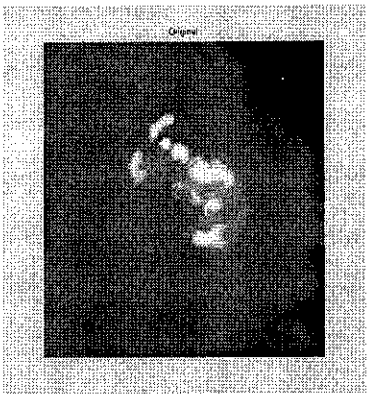
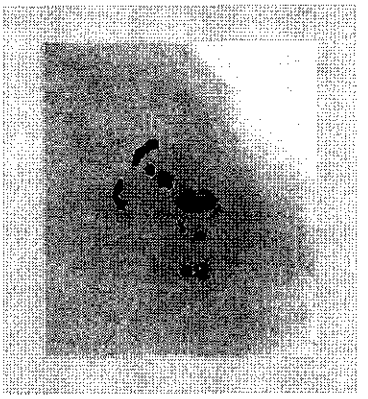
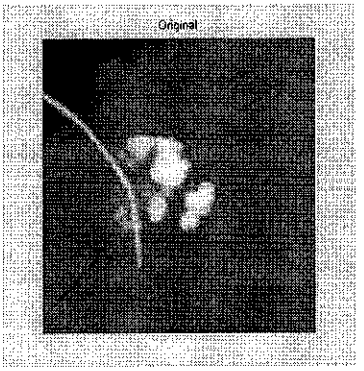
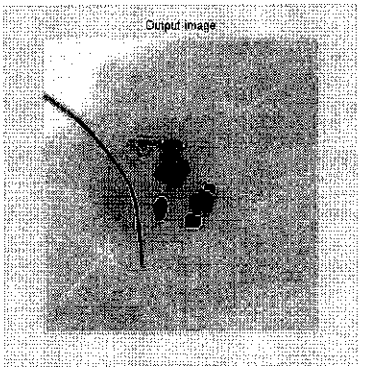
The 'top-hat' method was successfully developed using MATLAB. The program shown in figure 4.1 was arranged according to the step discussed in the previous chapter. Every digitized mammograms samples in tiff format is processed using

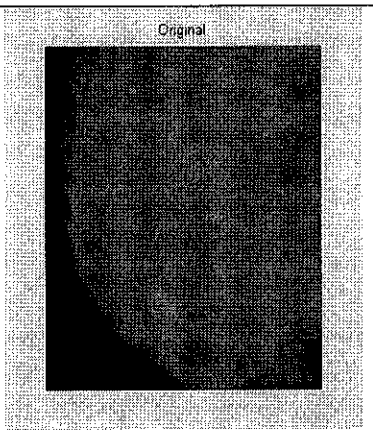
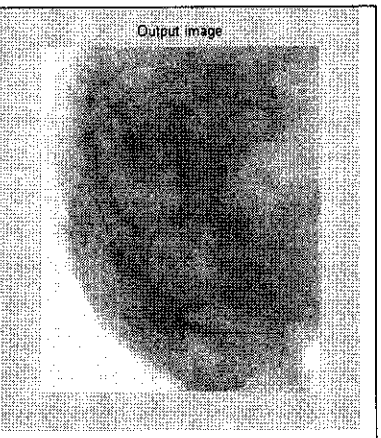
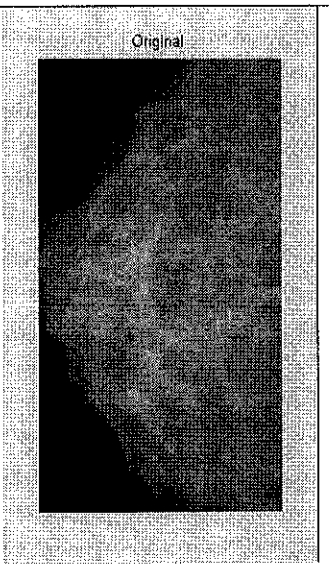
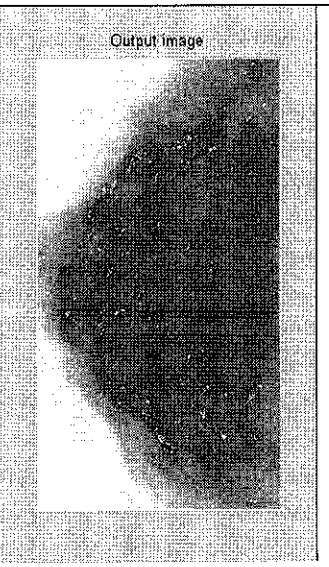
the above program. The input image is changed accordingly to the filename of the mammograms. The build in program in the MATLAB software for filter is an advantage to the student, which provide the student and user a friendly output.

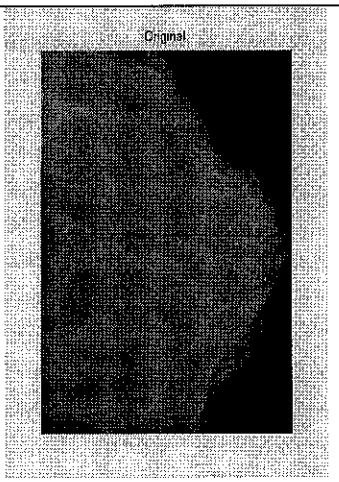
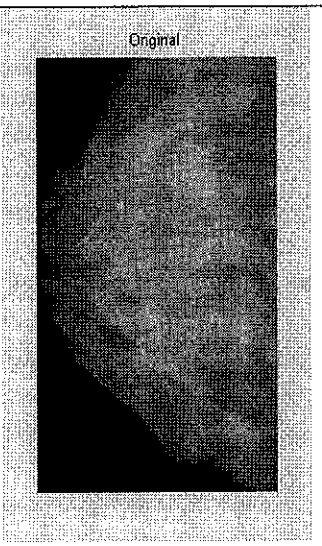
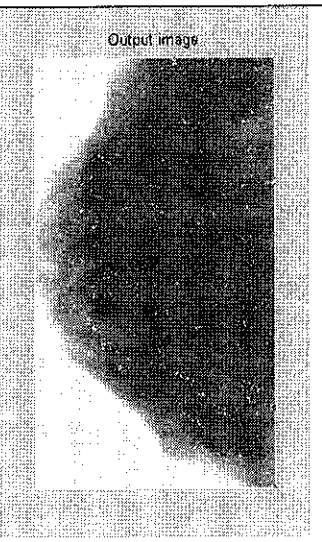
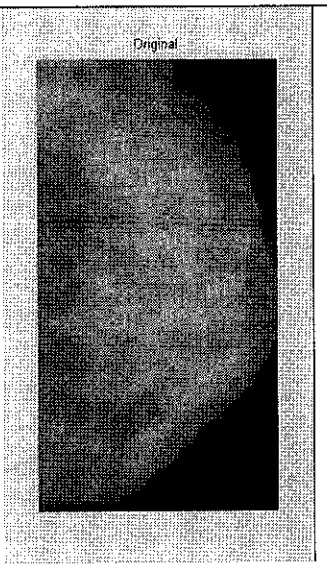
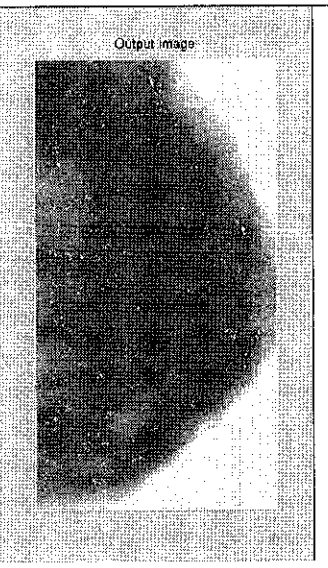
4.1.3 Result of Processed Image

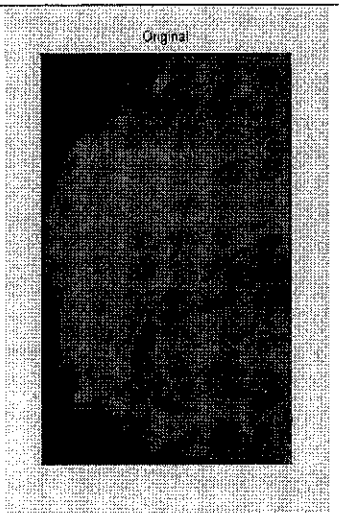
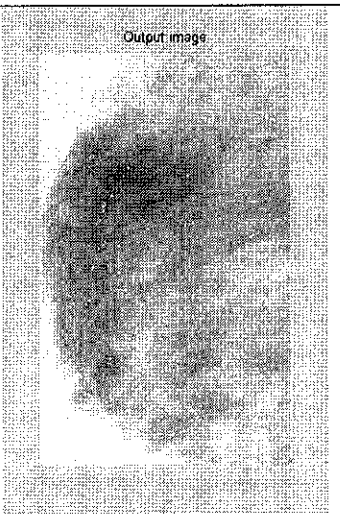
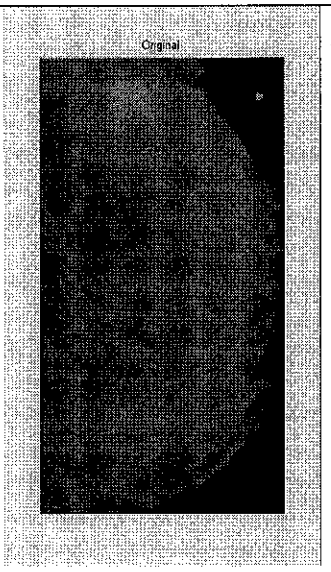
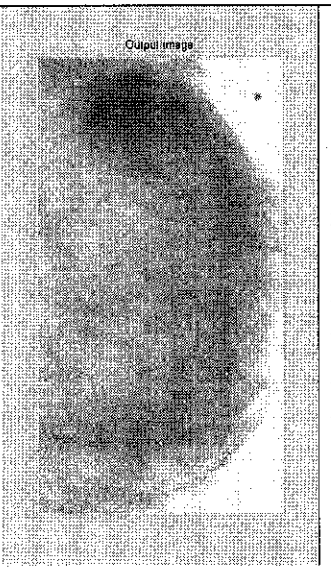
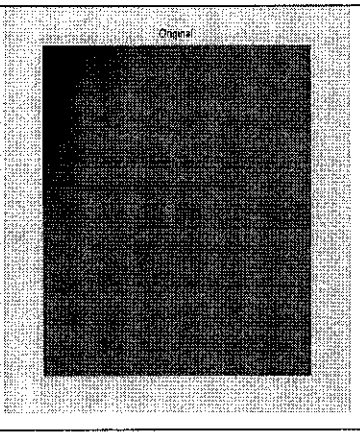
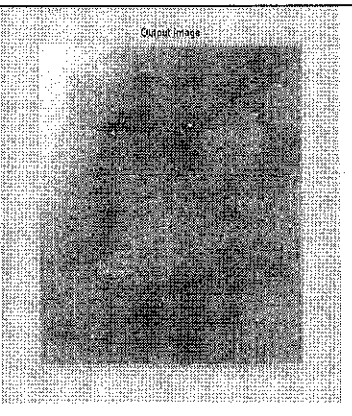
Table 4.2 shows final output image of every patient for both side of breast. The original image displayed here is the selected area of the breast. The original digitized mammograms is an A5 size for one side of the breast.

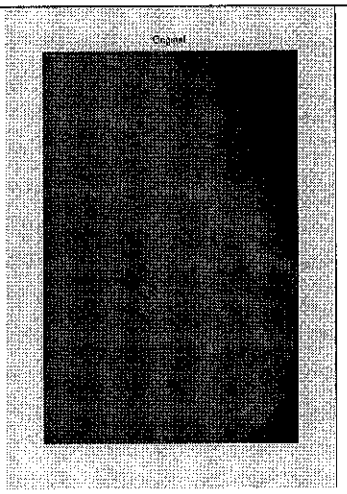
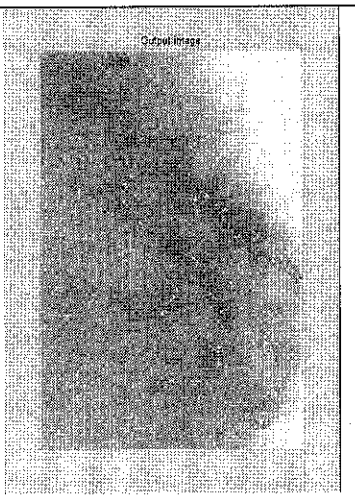
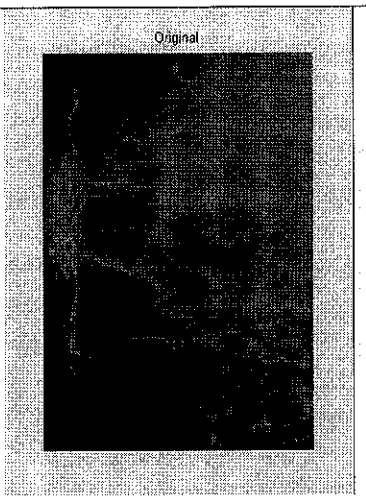
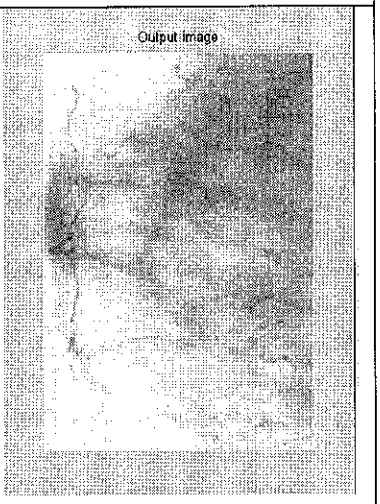
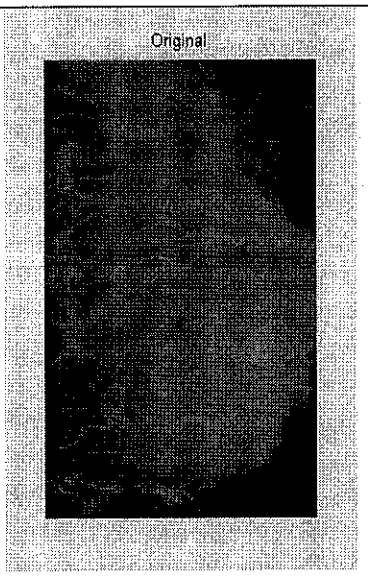
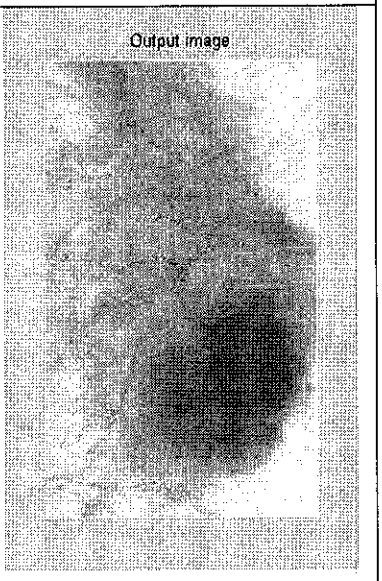
Table 4.2: Output image after 'top-hat' procedure

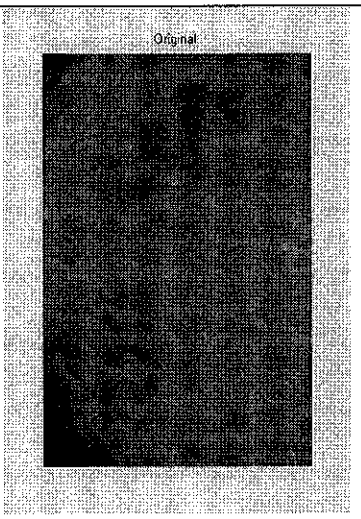
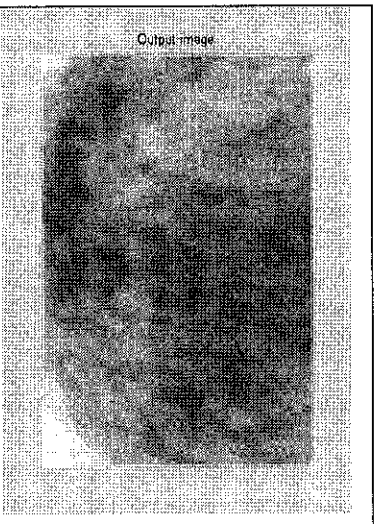
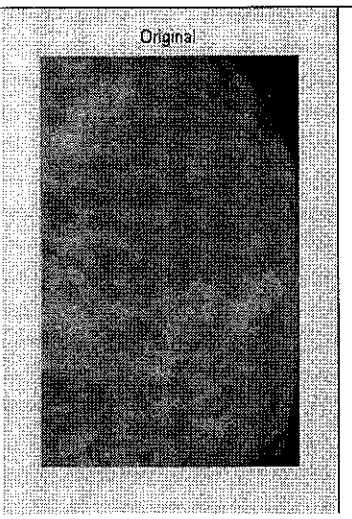
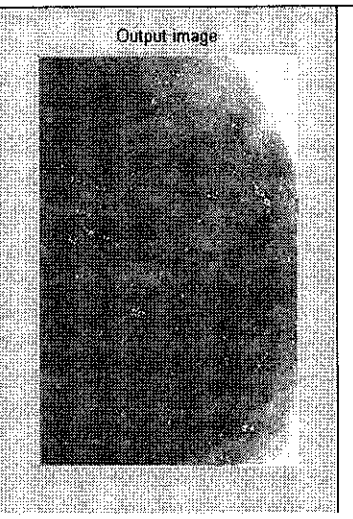
Patient	Side	Original	Output
Patient A	Right		
	Left		

Patient B	Right		
	Left		
Patient C	Right		

Patient C	Left		
Patient D	Right		
	Left		

Patient E	Right		
	Left		
Patient F	Right		

Patient F	Left		
Patient G	Right		
	Left		

Patient H	Right		
	Left		

From the table 4.2, the input image or the original image and the output after processed by top-hat method is displayed. The output image is a complement image of the original and the suspected area is marked by the white edges.

4.1.4 Graphical User Interface (GUI)

The graphical user interface for the program in figure 4.1 is developed to make the program more user-friendly and easy to use. The interface is using the GUI offered in the MATLAB software. The GUI coding for the above program is attached in the Appendix 3A. The output of the program developed is shown in figure 4.3 and 4.4. Two samples of the mammograms images is shown as an example.

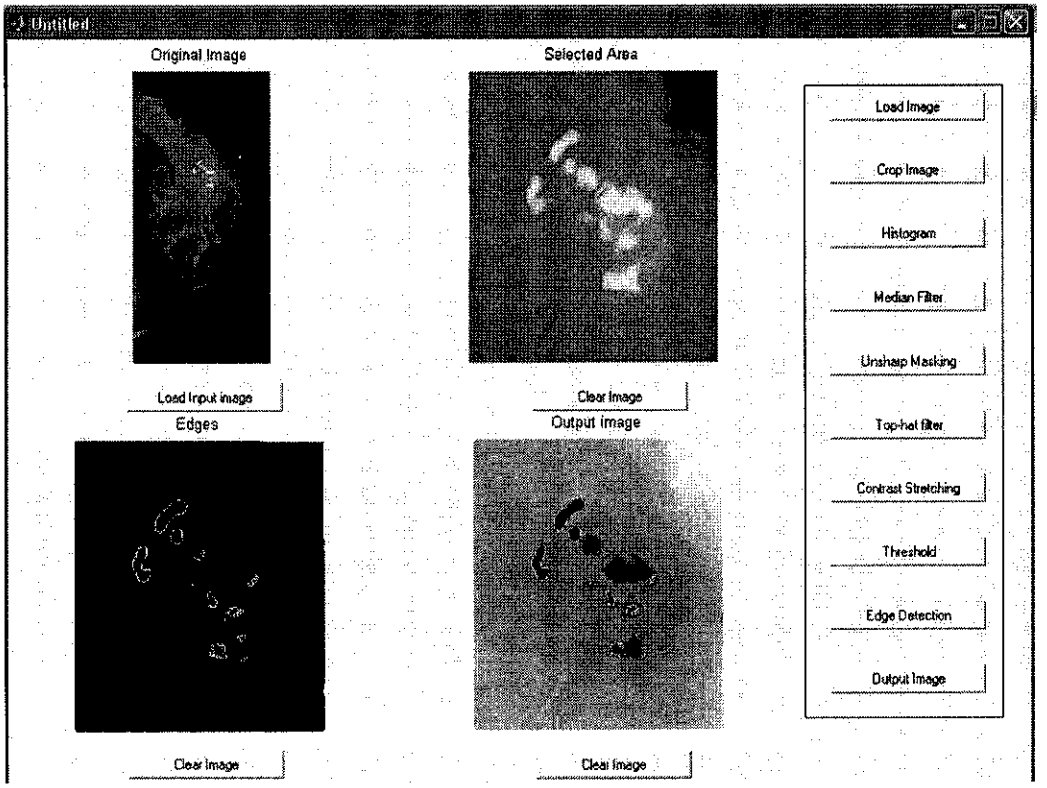


Figure 4.2: The Graphical User Interface of the algorithm

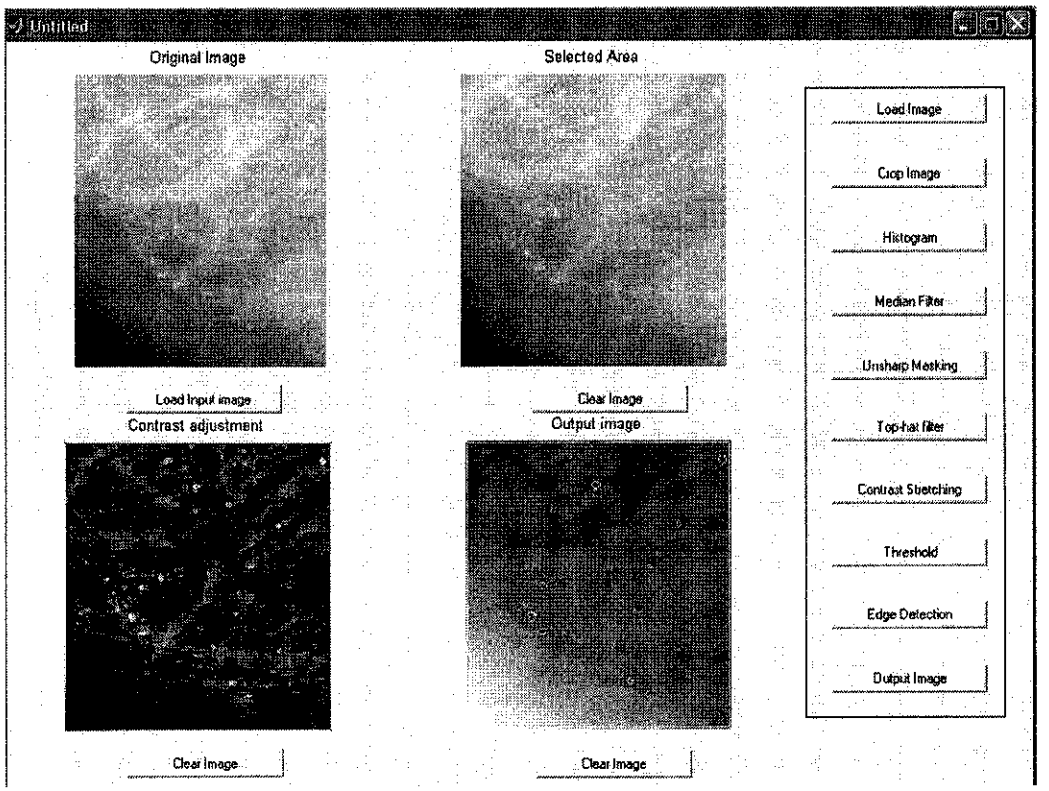


Figure 4.3: The GUI shows the result for mammograms contained microcalcification

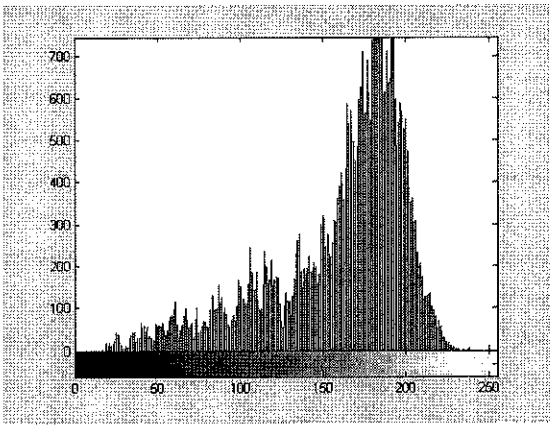


Figure 4.4: The histogram generated for the specified area

Referring to the window above, the GUI developed consist of 4 axes. The first axes is to display the input image by clicking the load input image button. The second axes is to display the image after cropping or the selected area of interest from the original image. User is first load the image to axes 2 by clicking the load image button and then the user can select the area of interest by choosing the crop image button. Usually, microcalcification is distributed or clustered at certain area of the breast and it is advisable that the user can specify the area of interest. User can further processed the image following the step discussed in the 'top-hat' method. The histogram of the specified area is generated by pressing the histogram button. Histogram will appear in different window as shown in figure 4.4. It gives the distribution of the pixels information in the image.

The median filter button is selected to perform the median filter to the image in axes 2 and the median-filtered image appeared in axes 3. The image is further processed by pressing the unsharp-masking filter and top-hat filter. The resultant image is on the axes 3. The contrast stretching of the top-hat filtered image is performed using the contrast stretching button. An image as shown in the axes 3 of figure 4.4 will appear where the candidate microcalcification is highlighted. The thresholding of image is then carried out following by the edge detection. The edge of the microcalcification is marked by white line and visible to user.

This image is then overlay on the complement of the image in axes 2 to makes it clearly visible to the user. The output image is display on the axes 4.

4.2 DISCUSSIONS

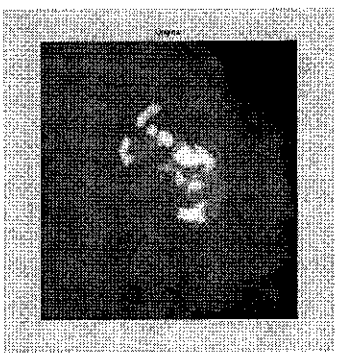
4.2.1 Mammogram samples

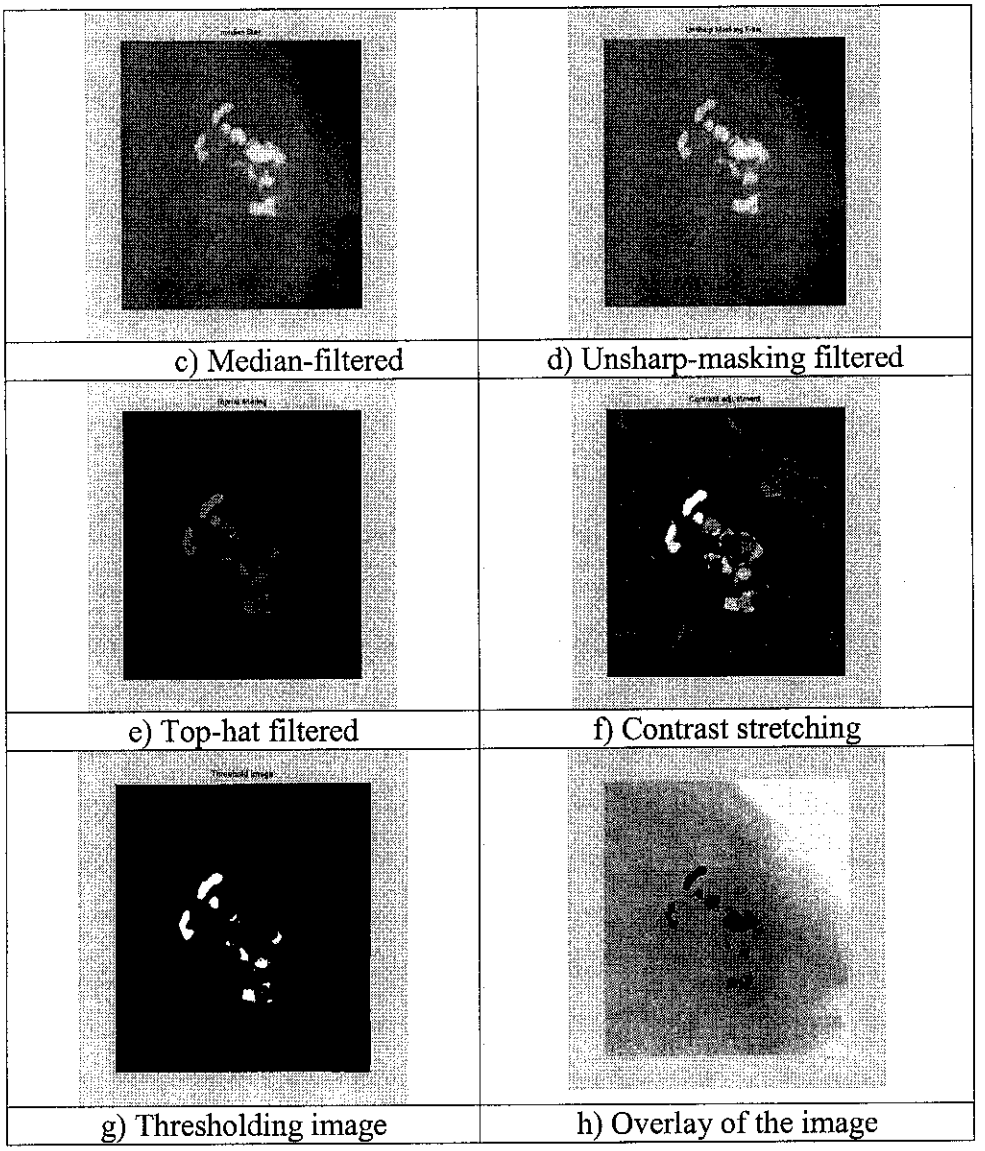
The film scanner used to digitize the mammograms is of 10000 dpi which is able to produce a good quality digitized mammograms with minimal error or noise. The normal flat bed scanner will produce a very bright digitized image because the effect of the lamp used. A film scanner provide a suitable light intensity thus avoid this error. The mammograms sample obtained from the hospital was very limited and the report attached is not in detail. Most of the mammograms are of the normal or benign cases that limit the student in identifying the microcalcification. However, student managed to get mammograms with microcalcification with confirmation from radiologist.

4.2.2 Methodology of the project

The step of top-hat algorithm was explained in detail in the previous chapter. Table 4.3 shows the step by step image by applying the top-hat method. The sample of Patient A is taken for the discussion.

Table 4.3: The step by step of the 'top-hat' method

The step by step of the 'top-hat' method in figure (a) to (h)	
	
a) The input image	b) The selected area after cropping



c) Median-filtered | d) Unsharp-masking filtered

e) Top-hat filtered | f) Contrast stretching

g) Thresholding image | h) Overlay of the image

Figure (a): Read input Image

The input image is read from its file by using the imread function. The type of file must be specified and in this project the Tag Image File Format (TIFF) is used. The program using C++ to read the write the file was developed and shown in Appendix 2A. TIFF is one of the most common and universally accepted formats available today [12]. This makes TIFF is an excellent choice and it offers flexibility as it can be used on MS-DOS, Macintosh and Unix computers. TIFF is not an image compression technique and it does not have the ability to save compressed data. The issues of lossless or lossy compression does not arise

here. The digitized mammograms using high resolution scanner is stored in TIFF format and re-write in TIFF format also.

Figure (b): Area of Interest

The input image displayed will be the whole of the mammograms image. The user might select a specific area of the breast to further processed. Microcalcification is usually clustered or distributed on certain area of the breast and it is an advantage for user to crop the image at certain area suspected to contain microcalcification. Size of the cropped image is depend to the selection by the user. The function used in the MATLAB is *imcrop* that crop image to a specified rectangle. The cropped image is displayed on the window and title as 'original image'.

Figure (c): Median-filtered

The median filtering is effective for removing the impulse noise which usually happened during the digitization of the image. It is performed by sliding a window across the pixels of a picture and ranking the pixel in the window in ascending order. The median or centre pixel will be placed in the output image in the location corresponding to the centre of the window. The principal function of median filtering is to force points with very distinct intensities to be more like their neighbours, thus eliminating intensity spikes [9]. The median filter is performed to all images and had shown a good output image. Referring to figure (c), it shows that the minimum filter gives a satisfactory result in filtering the images to remove unnecessary noise.

Figure (d): Unsharp Masking Filtered

Figure (d) displayed the image after filtered by unsharp masking filter or contrast enhancement filter. The resultant image is sharpen where the features in the images is increased in its contrast. The function of special filter and imfilter was used to create an unsharp masking filter. The filter used in this project is using a

round kernel with a diameter of 5 pixels to spatially average the original digitized image. The resulting image is then spatially averaged again with another round kernel of diameter 5. Recursively applying this operation with a small-diameter kernel serves to thoroughly smooth the image while sufficiently maintaining the edges.

The result is a low-pass-filtered version of the original image which preserves round edges. This low-frequency result is then subtracted from the original image leaving the high-frequency components of the image. It increases the apparent sharpness by modifying the contrast between bright and dark area. The microcalcification which is a very white particles in the tisues will be more prominent to its background. The imfilter function allow the multidimensional array of the median filtered image to be filtered with the multidimensional array of the unsharp masking, J. The resultant image of 'Un' is in the same size and array of the input image, L.

Figure (e): Top-hat

A high frequency features in the unsharp masking filtered image increase the effectiveness of the top-hat filter applied to the image. The top-hat algorithm that comprises of morphological opening and subtraction of the opened image from the original image produce the resulting image that shows the candidate of microcalcification with eliminated background. Before the top hat algorithm is applied, the morphological structuring element is created by using the command 'strel'. Various type of structuring element can be used with different neighbourhood. After various type and value of the neighbourhood applied to images, the disk type with 12 neighbourhood is found to be most suitable.

Morphological opening consist of erosion and followed by dilation. By perform the erosion to the image, the pixel value at the centre of the kernel is replaced by the minimum value of the neighbourhood pixels. This operation reduces regions of high signal intensity in the digitized image. After erosion the dilation is

applied and here, the pixel value at the centre of the kernel is replaced by the maximum value of the neighbourhood pixels. This operation restores regions of relatively high signal intensity that did not completely disappear as a result of erosion. The subtraction of the opened image from the original image is performed to get only the whitest features to left out. Since the microcalcification have been removed and the stromal tissue left relatively unchanged in the opened image, the predominant features in the subtraction image may be readily thresholded. The size of the features detected is controlled by varying the size of the opening and the degree of the contrast is controlled by varying the threshold level applied to the subtraction image. The value of threshold level is manually changed from 0.6 to 0.9 since the possible value of the candidate microcalcification is between these values.

Mathematical morphology is a branch of image analysis that has been developed by several institutes. An image is considered to be made-up of a collection of objects, and the top hat algorithm is ideally suited to automatically detecting and segmenting the object of interest.

Figure (f): Contrast Enhancement

Figure (f) shows clearly the contrast enhancement of the microcalcification candidate from its background. After the background of stromal tissues is eliminated, the enhancement of the image makes the white particles more prominent. The image is enhance by contrast stretching that adjusting the image histogram so that there is greater separation between foreground and background gray level distribution. The contrast and brightness is very important to enhance the mammogram images since it is a binary images, thus, the more contrast the white particle from the black particle the more clearer the white particles can be seen.

Figure (g): Threshold

The contrast image is threshold using the im2bw function. It produces binary images from indexed, intensity, or RGB images. The grayscale image is converted to binary image by thresholding. The output binary image BW has values of 0 (black) for all pixels in the input image with luminance less than 0.85 and 1(white) for all other pixels.

The choice of threshold level is varied manually until microcalcification have been detected. When we specify the threshold value, let say 0.9, all the pixel value lower than that is converted to 0 (black) and the value higher than that is converted to 1 (white). By applying various threshold levels to the images, it can be said that the suitable threshold value is varied between 0.75 to 0.9 for most of the images. The appropriate threshold level can be chosen by referring to the histogram data as shown in figure 4.4 for the pixel value to the right of x-axes. Applying this value to the image yields a segmentation result in which all microcalcifications are masked with a value of 1 and everything else in the image is black (value of 0) that is equivalent to 0 or 255 pixels.

Figure (h): Edge detection

Edge detection of the binary image produced after thresholding is performed by the function of bwperim. It returns a binary image containing only the perimeter pixels of objects in the input image. A pixel is part of the perimeter if it nonzero and it is connected to at least one zero-valued pixel. The connectivity used is 8 for two dimensions image with eight-connected neighbourhood. The output image that detected the edge of the microcalcification is then overlay on the complment image of the cropped image to make the calcification more visible.

4.2.3 Evaluation of result

The individual microcalcification stand out as high signal intensity peaks against a variable background of stromal tissues. This characteristic allow the top-hat method to be applied in identifying the microcalcification. From studies,

malignant clusters have been found to contain more microcalcification than benign clusters and occupy a larger area. In addition, malignant clusters posses microcalcification with a greater variety of shapes and sizes compared to benign clusters [11]. The visual inspection by the radiologist classify the cases by identifying the microcalcification according to this basic rule. By using the same consideration, the evaluation of the result obtained is carried out.

The top-hat method was applied to 8 samples of mammograms and the input and output image is shown in table 4.2. The resultant image obtained was compared to the inspection by the radiologist. The result is evaluated by putting it into three different groups as describe below:

Below expectation: The top-hat method applied did not detect all microcalcification that is visually identified by the radiologist during the visual inspection.

Meet expectation: By applying the top hat method, microcalcification identified by radiologist during visual inspection were successfully detected

Above expectation: By applying the top-hat method, microcalcification that is not identified by the radiologist or had uncertainty in visual inspection is successfully detected.

Table 4.4: The evaluation of the result

Patient	**Evaluation**
Patient A	Above expectation
Patient B	Meet expectation
Patient C	Meet expectation
Patient D	Meet expectation
Patient E	Meet expectation
Patient F	Meet expectation
Patient G	Meet expectation
Patient H	Meet expectation

From table 4.4, it shows that there are no mammograms that is classified under the below expectation, seven are meet the expectation and one had recorded to be above expectation. From the evaluation above, it can be said that the top-hat method can help the radiologist in enhancing the ability of the radiologist to interpret the mammograms. The project had achieved an appropriate level of accuracy.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

In conclusion, the objectives of the project had been successfully achieved within the time frame given. The characteristic of the abnormalities in the mammograms and the indication of the cancerous tissue was successfully identified. The samples of mammograms was able to be digitized and processed using the available image processing software and the C++ program. The method that is suitable to apply to the images in getting a clearer image to shows the cancerous tissue was also found.

The top-hat algorithm method was developed using MATLAB and successfully obtained the output image that shows the candidate microcalcification. The morphological operation was a simple and suitable method in identifying the microcalcification. Various image processing techniques were applied including the filter, histogram generation, thresholding and edge detection. From the result obtained, it was compared with the doctors view and had been concluded that the project had met an acceptable degree of accuracy level.

5.2 RECOMMENDATIONS

The author would like to suggest few recommendations for future enhancement:

i) Larger set of data

A larger set of data or mammograms sample that is used to be tested will increase the accuracy of the result obtained using this method. Thus, it should be applied to a larger set of data and investigate the causes for the percentage of

false positives and negatives. A detail report on each mammograms must be acquired and a cooperation from the doctors and radiologist in providing the information is a must.

ii) *Continuation on image analysis*

The current project had not developed the program for the image analysis for the candidate microcalcification found. Thus, it is suggested that the task can be performed as a continuity from the project.

iii) *Automatic thresholding*

The manually selected value for the threshold of the image is a limitation to the project. The value of the pixel need to be specified and the output must be evaluated. Thus, an automatic thresholding that can select an appropriate threshold level in the top-hat algorithm according to the image is recommended. Instead of applying a global threshold, a local thresholding technique could be used to reduce the number of false positives in the threshold stage.

iv) *Expert system – automatic recognition*

An automatic recognition of the cancerous cells in the breast is an advantage to the world in the future. Thus, an expert or intelligent system should be developed by integrating the digitized mammography with the image processing and the analysis of the image.

REFERENCES

[1] http://www.isis-innovation.com/licensing/medical.html

[2] http://www.mma.org.my (Malaysian Medical Association)

[3] http://www.imaginis.com

[4] Umi Kalthum Ngah, *An Expert System With Integrated Image Processing Features For the Diagnoses of Breast Diseases*, Thesis for Master, 1995

[5] Leonardo Bocchi, *Biomedical Engineering Laboratory*, University of Florence, 1999

[6] Marios A. Gavrielides, Joseph Y. Lo and Carey E. Floyd, Jr, '*Parameter optimization of a computer-aided diagnosis scheme for the segmentation of micro-calcification clusters in mammograms*', IEEE Trans, 1994

[7] OOi Thean Hai, Umi Kalthum Ngah, Noor Elaiza Abd. Khalid and P.A Venkatachalam, '*The Region Growing Technique For Mammographic Classification Clusters'*, Universiti Sains Malaysia, 1994

[8] Moti Melloul and Leo Joskowics, '*Segmentation of microcalcification in X-ray mammograms using entropy thresholding'*, The Hebrew University of Jurusalem, 1994

[9] Kenneth R. Castleman, *Digital image processing*, Prentice Hall, 1996.

[10] Nick E fford, *Digital Image Processing – a p ractical introduction u sing Java*, Addison-Wsley, 2000

[11] D Betal, N Robert and G H Whitehouse, '*Segmentation and numerical analysis of microcalcification on mammograms using mathematical morphology'*, The British Journal of Radiology, 1997, p 903-917

[12] Howard E. Burdick, *Digital Imaging; Theory and Applications*, McGrawHill, 1997

[13] Randy Crane, *Simplified Approach to Image Processing*, Prentice Hall, 1997

[14] Laura N. Mascio, Jose M. Hernandez and Clinton M. Logan, '*Automated analysis for microcalcifications in high resolution digital mammograms'* , 1996

[15] G.M Spyro, M.G Nikolaou, M. Koussaris, A. Tsibanis, S.D Vassilaros and P.A Lingomenides, *'A system for Computer Aided Early Diagnosis of Breast Cancer based on Microcalcification Analysis'*, 1999

[16] http://www.ece.purdue.edu

[17] http://www.alphatecltd.com

LIST OF APPENDICES

APPENDIX 1A: Gantt Chart (First Semester)

APPENDIX 1B: Gantt Chart (Second Semester)

APPENDIX 2A: Characteristic of Microcalcification

APPENDIX 2B: Histogram Generation

APPENDIX 2C: Unsharp Masking Filter

APPENDIX 2D: Contrast Stretching

APPENDIX 2E: Threshold

APPENDIX 3A: Matlab Program - GUI

APPENDIX 1A

GANTT CHART (FIRST SEMESTER)

No		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**Selection of Project Title for Final Year Project**		●												
	a) Selection of Topic from List of Approved Project Titles and Supervisors.	●													
	b) Discussion with respective Project Tittles and Supervisor		●												
	c) Selection, Prioritisation and Submission of Project Tittles		●												
	d) Project Award		●												
2	**Identification of Preliminary Research Work**			●											
	a) Identififfication of Background of Study														
	b) Definition of Problem Statement														
3	**Planning**				●										
	a) Plannning the Steps, Tools and Method for the Project														
4	**Preliminary Report**				●										
	a) Introduction to Project Tittle			●											
	b) Problem Statement of Project Tittle				●										
	c) Objectives of Project Tittle			●											
	d) Literature review				●										
5	**Submission of Preliminary Report**				●										
	a) Assessment/Approval of preliminary Report and Project Planning Proposal														
6	**Project Work**											●			
	a) Research on image processing and gathering information								●						

	b) Identification of image processing technique									•					
7	**Submission of Progress Report**								•						
	a) Assessment of Progress Report														
	b) Assessment of Project Work														
8	**Submission of the Interim Report Final Draft**												•		
	a) Assessment of Interim Report														
	b) Amendment of Interim Report														
9	**Oral Presentation**													•	
	b) Oral presentation														
10	**Submission of the Interim Report**														•

Legend:

Actual work :

Planning work :

APPENDIX 1B

GANTT CHART (SECOND SEMESTER)

No		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**Development of Program**											●			
	a) Digitization of images			●											
	b) Image enhancement							●							
	c) Image segmentation										●				
	d)Graphical User Interface											●			
2	**Evaluation of result**												●		
	a) Confirmation with radiologist											●			
	b)Analysis												●		
3	**Submission of First Progress Report**					●									
4	**Submission of Second Progress Report**										●				
	a) Assessmnet of Second Progress Report										●				
	b) Amendment of Second Progresss Report										●				
5	**Pre-EDX**												●		
6	**Submission of Final Report**													●	
	a) Assesment of Final Report												●		
	b) Amendment of Final Report													●	
7	**Oral Presentation**														
	a) Presentation material preparation														
	b) Oral presentation														●
8	**Submission of Hardbound Disertation**											2 weeks after presentation			

Legend:

Actual work :

Planning work :

APPENDIX 2A

CHARACTERISTIC OF MICROCALCIFICATION

Characteristics of Calcifications						
anatomical origin	*form*	*size*	*density*	*number*	*distribution*	*note*
terminal ducts and ductules		tiny	great variations within an individual particle and among adjacent particles	innumerable	usually clustered within an area of the breast, often within one lobe	malignant-type calcifications, extremely variable in form, size, density and number
		differ in length				
cyst-like dilated lobules	homogenous, solid, sharply outlined, spherical, pearl-like	very fine, powder-like	dense	numerous	scattered throughout much of the breast parenchyma	almost certain cystic hyperplasia, very rare lobular carcinoma in situ
	crescent-shaped or elongate on lateral view and circular, faint, opaque smudges on cranio-caudal view	variable saccular dilation of the lobules causes different sizes	differ according to size			
miscellaneous	ring surrounds dilated duct, oval or elongated when extends around and along duct		varying lucency center, very dense periphery	multiple	often bilateral, scattered, oriented towards the nipple, following the course of the ducts	benign intraductal calcifications have high and uniform density, generally wide caliber, and tend to follow the course of normal ducts
	linear, often needle like, occasionally branching	uniform, varying length and width	high, uniform density			
	ring-shaped, oval	same as skin pore	center is always radiolucent	very numerous	occur only within the skin	sebaceous gland calcifications
	small eggshell	up to a few mm in diameter	high, uniform periphery and lucent, often irregular center	range from solitary to numerous	may occur anywhere in the breast	usually subcutaneous, calcified micro-hematomas
	larger eggshell	variable, up to several cm	center radiolucent or of parenchymal density			almost invariably benign
	similar to raspberry	up to the size of a dilated duct	high, uniform but often contain small, oval-shaped lucent areas	solitary	tend to be central or retro-areolar	papilloma, papillomatosis
	coarse, irregular bizarre appearance		very dense	sharply outlined		fibroadenomas

APPENDIX 2B

HISTOGRAM GENERATION

```
//-----------------------------------------------MAIN PROGRAM-----------------------------------------------

main()
        {
        unsigned char *ir,*ig,*ib;
        unsigned char *or,*og,*ob;
        long  int i, x, y;
  long int maxr, maxg, maxb;
  long int hr[MAX], hg[MAX], hb[MAX];

        short int plane = 0;                                    //# of planes
        FILE *stream;
        FILE *stream2;
        long int fpi, fpo;
        TIFF_DATA td;                                           //File header information
        td.iimm = 0                                             //initialize variables
                td.planar_config = 1;
                td.rows_strip = 0;
                td.bits_sample[0] = 0;
                td.bits_sample[1] = 0;
                td.bits_sample[2] = 0;
        td.xresolution = 0;
        td.yresolution = 0;
        /* read the input image */
  //Display
  clrscr();
  printf(" ********************************************************\n\r");
  printf(" *          HISTOGRAM GENERATION PROGRAM          *\n\r");
  printf(" ********************************************************\n\r");
  printf(" \n\r");
  printf(" This program will generate the histogram of an input image\n\r");
  printf(" \n\r");
  printf(" Enter the input image file name :  ");
  scanf ("%s",&inputfilename);
  printf(" \n\r");   printf(" Enter the output image file name: ");
        scanf ("%s",&outputfilename);
        clrscr();

        //-------------------------------------------------------------------------------
        //Read TIFF Header File
        if((stream=fopen(inputfilename,"rb"))==NULL)
  {     printf("Cannot open file.\n");
                getch();
          exit(1);
  }
  fpi = fileno(stream);
        read_tiff_header(fpi,td,xsize,ysize,plane);
        //allocate input and output memory buffers
        ir = (unsigned char*)malloc(xsize*ysize);
  ig = (unsigned char*)malloc(xsize*ysize);
        ib = (unsigned char*)malloc(xsize*ysize);
        or = (unsigned char*)malloc(xsize*ysize);
        og = (unsigned char*)malloc(xsize*ysize);
        ob = (unsigned char*)malloc(xsize*ysize);
  //read the input memory buffers
```

```
        read_tiff_data(fpi,td,xsize,ysize,plane,ir,ig,ib);

close(fpi);                     //close file;
/*histogram collection begins here*/
        //histogram collection bins start at 0
for (i=0; i<MAX; i++)
{
hr[i] = 0;
hg[i] = 0;
hb[i] = 0;
}
// collect histogram data for each color plane
  for(y = 0; y < ysize; y++)
        {
   for(x = 0; x < xsize; x++)
        {
     i = ((ir[(y*xsize)+x])+(ig[(y*xsize)+x])+(ib[(y*xsize)+x]))/3;
     hr[i]++;
     hg[i]++;
     hb[i]++;
     }
   }
//find the max bin value for each color plane
maxr = 0;
maxg = 0;
maxb = 0;
for(i = 0; i < MAX; i++)
        {
   if(hr[i] > maxr) maxr = hr[i];
   if(hg[i] > maxg) maxg = hg[i];
   if(hb[i] > maxb) maxb = hb[i];
   }
printf("\nmaxr=%d\tmaxg=%d\tmaxb=%d\n",maxr,maxg,maxb);
//normalize all bins to max
for(x = 0; x < MAX; x++)
        {
   hr[x] = hr[x] * (MAX - 1) / maxr;
   hg[x] = hg[x] * (MAX - 1) / maxg;      hb[x] = hb[x] * (MAX - 1) / maxb;
   }
//generate rgb histogram image
for(x = 0; x < MAX; x++)
        {
   for(y = (MAX - 1); y >= 0; y--)
        {
     //draw red line
     if(y > hr[x])
        {
       or[((MAX - y - 1) * MAX) + x] = 0x00;
       }
     else
        {
       or[((MAX - y - 1) * MAX) + x] = 0xff;
       }
     //draw green line
     if(y > hg[x])
        {
```

```
      og[((MAX - y - 1) * MAX) + x] = 0x00;
      }
    else
       {
      og[((MAX - y - 1) * MAX) + x] = 0xff;
      }
    //draw blue line
    if(y > hb[x])
       {
      ob[((MAX - y - 1) * MAX) + x] = 0x00;
      }
    else
       {
      ob[((MAX - y - 1) * MAX) + x] = 0xff;
      }
    }
  }
//histogram collection ends here
        /* write the output image */
//create and open the output image file

        if((stream2=fopen(outputfilename,"wb"))==NULL)
{       printf("Cannot open file.\n");
                getch();
          exit(1);
}
        else
{       //write the output image
                fpo = fileno(stream);
        write_tiff_header(fpo,MAX,MAX,plane);
          lseek(fpo,604,SEEK_SET);
  write_tiff_data(fpo,MAX,MAX,plane,or,og,ob);
          close(fpo);
  printf("\nDone!\n");
}
        fclose(stream);
 fclose(stream2);
/* free memory buffers */
free(ir);
free(ig);
free(ib);
free(or);
free(og);
free(ob);
return 0;
}
```

APPENDIX 2B

UNSHARP MASKING FILTER

```
//-----------------------------------------------MAIN PROGRAM-----------------------------------------------
main(){
clrscr();
//Declaration of variables
long int fp;                                    //File pointer - input
long int fpo = 0;                               //File pointer - output
TIFF_DATA td;                                   //File header information
   td.iimm = 0;                                 //initialize variables
          td.planar_config = 1;
          td.rows_strip = 0;
          td.bits_sample[0] = 0;
          td.bits_sample[1] = 0;
          td.bits_sample[2] = 0;
   td.xresolution = 0;
   td.yresolution = 0;

long int xsize = 227;                                   //image width
long int ysize = 404;                                   //image length
short int plane = 0;                                    //# of planes
FILE *stream;
FILE *stream2;
float filter = 0;

//Memory buffers
unsigned char *ir,*ig,*ib;
unsigned char *lr,*lg,*lb;
unsigned char *or,*og,*ob;
unsigned char *i,*i1,*i2,*i3;
unsigned char *l,*l1;
unsigned char *o;
long int    x,y,c;
long int     xm, ym;
long int                    val;
float                               cp, cl, fval;

//Display

printf("************************************************\n");
printf("  UNSHARP MASKING FILTER\n");
printf("************************************************\n");
printf("  Enter the file name for input: ");
scanf ("%s",&inputfilename);
printf("  Enter the file name for output: ");
scanf ("%s",&outputfilename);

clrscr();
//Read TIFF Header File
          if((stream=fopen(inputfilename,"rb"))==NULL){
                    printf("Cannot open file.\n");
                    getch();
            exit(1);   }

  fp = fileno(stream);
          read_tiff_header(fp,td,xsize,ysize,plane);
          /* allocate input and output memory buffers */
  ir      =         (unsigned char *) malloc   (xsize*ysize);
```

```
  ig      = (unsigned char *)        malloc   (xsize*ysize);
  ib      =          (unsigned char *) malloc   (xsize*ysize);
  lr      =          (unsigned char *) malloc   (xsize*ysize);
  lg      =          (unsigned char *) malloc   (xsize*ysize);
  lb      =          (unsigned char *) malloc   (xsize*ysize);
  or      =          (unsigned char *) malloc   (xsize*ysize);
  og      =          (unsigned char *) malloc   (xsize*ysize);
  ob      =          (unsigned char *) malloc   (xsize*ysize);
  getch();          //pause

  //read the input memory buffers
          read_tiff_data(fp,td,xsize,ysize,plane,ir,ig,ib);
  close(fp);        //close file;

//*********************************************************/
/*  unsharp masking filter                */
/*********************************************************/

/* create low-pass filtered image */

  for (c = RED; c <= BLUE; c++)
   {   if (c == RED  ) i = ir;
   if (c == GREEN) i = ig;
   if (c == BLUE ) i = ib;
   if (c == RED  ) l = lr;
   if (c == GREEN) l = lg;
   if (c == BLUE ) l = lb;
   for (y = (LPASS/2); y < (ysize-(LPASS/2)); y++)
    {    i1 = i + (y*xsize) + (LPASS/2);
    l1 = l + (y*xsize) + (LPASS/2);
    for (x = (LPASS/2); x < (xsize-(LPASS/2)); x++)
     {
     i2 = i1 - ((LPASS/2)*xsize) - (LPASS/2);
     val = 0;
     for (ym = 0; ym < LPASS; ym++)
      {
      i3 = i2 + (ym*xsize);
      for (xm = 0; xm < LPASS; xm++)
       {
       val = val + ((long int)*i3++ & 0xff);
       }
      }
     *l1++ = (unsigned char)(val / (LPASS*LPASS));
     i1++;
     }
    }
   }
  /* calculate constants for image merge */
  cp = WEIGHT / ((2.0* WEIGHT) - 1.0);
  cl = (1.0 - WEIGHT) / ((2.0 * WEIGHT) - 1.0);
  /* process the red, green, and blue planes one at a time */
  for (c = RED; c <= BLUE; c++)
   {
   /* initialize pointers for current color plane */
```

```
    if (c == RED  ) i = ir;
    if (c == GREEN) i = ig;
    if (c == BLUE ) i = ib;
    if (c == RED  ) l = lr;
    if (c == GREEN) l = lg;
    if (c == BLUE ) l = lb;
    if (c == RED  ) o = or;
    if (c == GREEN) o = og;
    if (c == BLUE ) o = ob;

    /* merge the original and low-pass images */
    for (y = 0; y < ysize; y++)
     {
     for (x = 0; x < xsize; x++)
      {
      fval = (cp * (float)*i++) - (cl * (float)*l++);
      if (fval < 0.0)   fval = 0.0;
      if (fval > 255.0) fval = 255.0;
      *o++ = (unsigned char)fval;
      }
     }
    }
/*****************************************************************************/
 //create and open the output image file
          if((stream2=fopen(outputfilename,"wb"))==NULL){
                  printf("Cannot open file.\n");
                  getch();
            exit(1);
  }
          else{     //write the output image
                  fpo = fileno(stream);
          write_tiff_header(fpo,xsize,ysize,plane);
            lseek(fpo,604,SEEK_SET);
    write_tiff_data(fpo,xsize,ysize,plane,or,og,ob);
            close(fpo);
  }
  fclose(stream);
  fclose(stream2);
/* free memory buffer */
  free(ir);
  free(ig);
  free(ib);
  free(lr);
  free(lg);
  free(lb);
  free(or);
  free(og);
  free(ob);

}
```

APPENDIX 2C

CONTRAST STRETCHING

```
//-----------------------------------------------MAIN PROGRAM-----------------------------------------------
--

for(;;){                                        //LOOP FOR CONTINUING PROGRAM
clrscr();
//Declaration of variables
long int fp;                            //File pointer - input
long int fpo = 0;                         //File pointer - output
TIFF_DATA td;                           //File header information
   td.iimm = 0;                         //initialize variables
          td.planar_config = 1;
          td.rows_strip = 0;
          td.bits_sample[0] = 0;
          td.bits_sample[1] = 0;
          td.bits_sample[2] = 0;
   td.xresolution = 0;
   td.yresolution = 0;

#define xsize 277                               //image width
#define ysize 404                               //image length
#define max   256       //maximum no. of colors

//Declarations of variables
long int i,x,y, average;
short int plane = 0;                    //# of planes
//short int threshold_value;
//short int user_selection;
//double contrast_factor;
FILE *stream;
FILE *stream2;
//Memory buffers
unsigned char *input_red,*input_green,*input_blue;          //input buffers
unsigned char *output_red,*output_green,*output_blue;      //output buffers

//Program display

printf(" ********************************************************\n\r");
printf(" *          CONTRAST ADJUSTMENT PROGRAM          *\n\r");
printf(" ********************************************************\n\r");
printf(" \n\r");
printf(" This program will adjust the contrast of an image \n\r");
printf(" \n\r");
printf(" Enter the input image filename(.tif): ");
scanf ("%s",&inputfilename);
printf(" \n\r");
printf("  Enter the output image filename(.tif): ");
scanf ("%s",&outputfilename);
printf(" \n\r");
printf(" \n\r");
//cout << " Please press 1 to increase image contrast ";
//printf(" \n\r");
//cout << " Please press 2 to decrease image contrast ";
//printf(" \n\r");
//cout << " Please enter your selection : ";
//cin >> user_selection;
//printf(" \n\r");
```

```
//if (user_selection == 1)
 //cout << " Please choose contrast factor from 1.00 to 2.00 ";
 //else
  //cout <<" Please choose contrast factor from 0.10 to 0.99 ";
  //printf(" \n\r");
 //cout << " Please enter brightness factor : ";
 //cin >> contrast_factor;

clrscr();
//Read TIFF Header File
        if((stream=fopen(inputfilename,"rb"))==NULL){
                printf("Cannot open file.\n");
                getch();
          exit(1);
   }
   fp = fileno(stream);
        read_tiff_header(fp,td,xsize,ysize,plane);
        //allocate input and output memory buffers
        input_red       = (unsigned char*)malloc(xsize*ysize);
   input_green  = (unsigned char*)malloc(xsize*ysize);
        input_blue      = (unsigned char*)malloc(xsize*ysize);
        output_red   = (unsigned char*)malloc(xsize*ysize);
        output_green = (unsigned char*)malloc(xsize*ysize);
        output_blue  = (unsigned char*)malloc(xsize*ysize);
   getch();        //pause
   //read the input memory buffers
        read_tiff_data(fp,td,xsize,ysize,plane,input_red,input_green,input_blue);
   close(fp);      //close file;
/*********************************************************/
/*              Binary Image                             */
/*********************************************************/
 unsigned char lut[256];
 /* initialize look-up table  */
 for (i = 0; i <= 32; i++) lut[i] = 0;
    {
    for(i=33; i<=223; i++) lut[i] = (i-32)*1.33;
     {
     for (i=224; i<=255; i++) lut[i] = 255;
     }
      }
 /* apply look-up table to each pixel in image */
  for (y = 0; y < ysize; y++)
    {
    for (x = 0; x < xsize; x++)
     {
     output_red[(y*xsize)+x]    = lut[input_red[(y*xsize)+x]];
     output_green[(y*xsize)+x] = lut[input_green[(y*xsize)+x]];
     output_blue[(y*xsize)+x] = lut[input_blue[(y*xsize)+x]];

     }
    }
/*************************************************************************/
   //create and open the output image file
        if((stream2=fopen(outputfilename,"wb"))==NULL){
                printf("Cannot open file.\n");
                getch();
```

```
            exit(1);
  }
          else{     //write the output image
                    fpo = fileno(stream);
          write_tiff_header(fpo,xsize,ysize,plane);
            lseek(fpo,604,SEEK_SET);
    write_tiff_data(fpo,xsize,ysize,plane,output_red,output_green,output_blue);
            close(fpo);
  }
          fclose(stream);
  fclose(stream2);

  //free memory buffers
  free(input_red);
  free(input_green);
  free(input_blue);
  free(output_red);
  free(output_green);
  free(output_blue);

}//BIG FOR'S
          return 0;
}
```

APPENDIX 2D

THRESHOLD

```
//-----------------------------------------------------MAIN PROGRAM-----------------------------------------------
main(){
for(;;){                        //LOOP FOR CONTINUING PROGRAM
clrscr();
//Declaration of variables
long int fp;                            //File pointer - input
long int fpo = 0;                        //File pointer - output
TIFF_DATA td;                           //File header information
   td.iimm = 0;                         //initialize variables
          td.planar_config = 1;
          td.rows_strip = 0;
          td.bits_sample[0] = 0;
          td.bits_sample[1] = 0;
          td.bits_sample[2] = 0;
   td.xresolution = 0;
   td.yresolution = 0;
#define xsize 227                               //image width
#define ysize 404                               //image length
#define max  256                                //maximum no. of colors
//Declarations of variables
long int i,x,y, average;
short int plane = 0;                    //# of planes
short int threshold_value;
FILE *stream;
FILE *stream2;
//Memory buffers
unsigned char *input_red,*input_green,*input_blue;          //input buffers
unsigned char *output_red,*output_green,*output_blue;      //output buffers

//Program display
printf(" ********************************************************\n\r");
printf(" *          IMAGE THRESHOLDING PROGRAM          *\n\r");
printf(" ********************************************************\n\r");
printf(" \n\r");
printf(" This program will convert RGB image to binary image\n\r");
printf(" \n\r");
printf(" Enter the input image(.tif): ");
scanf ("%s",&inputfilename);
printf(" \n\r");
printf(" Enter the output image(.tif): ");
scanf ("%s",&outputfilename);
printf(" \n\r");
cout <<" Enter the threshold value (1 to 255): ";
cin >> threshold_value;
clrscr();
//Read TIFF Header File
        if((stream=fopen(inputfilename,"rb"))==NULL){
                printf("Cannot open file.\n");
                getch();
          exit(1);
  }
  fp = fileno(stream);
        read_tiff_header(fp,td,xsize,ysize,plane);
        //allocate input and output memory buffers
        input_red          = (unsigned char*)malloc(xsize*ysize);
  input_green  = (unsigned char*)malloc(xsize*ysize);
```

```
        input_blue      = (unsigned char*)malloc(xsize*ysize);
        output_red  = (unsigned char*)malloc(xsize*ysize);
        output_green = (unsigned char*)malloc(xsize*ysize);
        output_blue  = (unsigned char*)malloc(xsize*ysize);
  getch();          //pause
  //read the input memory buffers
        read_tiff_data(fp,td,xsize,ysize,plane,input_red,input_green,input_blue);
  close(fp);        //close file;
/*********************************************************/
/*              Binary Image                             */
/*********************************************************/
  unsigned char lut[256];
  /* apply look-up table to each pixel in image */
  for (y = 0; y < ysize; y++)
   {
   for (x = 0; x < xsize; x++)
    {
    average = ((input_red[(y*xsize)+x]) + (input_green[(y*xsize)+x]) + (input_blue[(y*xsize)+x] ))/3;
    if (average <=threshold_value)
    {     output_red[(y*xsize)+x] = 0;
          output_green[(y*xsize)+x] = 0;
          output_blue[(y*xsize)+x] = 0;
    }
    else
    {     output_red[(y*xsize)+x] = 255;
          output_green[(y*xsize)+x] = 255;
          output_blue[(y*xsize)+x] = 255;
    }
    }
   }
/*************************************************************************/
  //create and open the output image file
        if((stream2=fopen(outputfilename,"wb"))==NULL){
                printf("Cannot open file.\n");
                getch();
          exit(1);
  }
        else{     //write the output image
                fpo = fileno(stream);
        write_tiff_header(fpo,xsize,ysize,plane);
          lseek(fpo,604,SEEK_SET);
    write_tiff_data(fpo,xsize,ysize,plane,output_red,output_green,output_blue);
          close(fpo);
  }
        fclose(stream);
  fclose(stream2);
  //free memory buffers
  free(input_red);
  free(input_green);
  free(input_blue);
  free(output_red);
  free(output_green);
  free(output_blue);
}//BIG FOR'S
        return 0;
}
```

APPENDIX 3A

MATLAB PROGRAM - GUI

```
function varargout = Tophat(varargin)
% TOPHAT Application M-file for Tophat.fig
%   FIG = TOPHAT launch Tophat GUI.
%   TOPHAT('callback_name', ...) invoke the named callback.
if nargin == 0  % LAUNCH GUI
        fig = openfig(mfilename,'reuse');
        % Use system color scheme for figure:
        set(fig,'Color',get(0,'defaultUicontrolBackgroundColor'));
        % Generate a structure of handles to pass to callbacks, and store it.
        handles = guihandles(fig);
        guidata(fig, handles);
        if nargout > 0
                varargout{1} = fig;
        end
elseif ischar(varargin{1}) % INVOKE NAMED SUBFUNCTION OR CALLBACK
        try
                if (nargout)
                [varargout{1:nargout}] = feval(varargin{:}); % FEVAL switchyard
                else
                        feval(varargin{:}); % FEVAL switchyard
                end
        catch
                disp(lasterr);
        end
end
% --------------------------------------------------------------------
function varargout = pushbutton1_Callback(h, eventdata, handles, varargin)
axes(handles.axes2);
%Read the input image
I2 = imread('rahmah-L-cc.tif');
%Select the area of interest
imshow(I2), title('Input Image');
% --------------------------------------------------------------------
function varargout = pushbutton2_Callback(h, eventdata, handles, varargin)
axes(handles.axes2);
%Read the input image
I2 = imread('rahmah-L-cc.tif');
%Select the area of interest
A=imcrop(I2);
%Display the cropped image
imshow(A), title('Selected Area');
% --------------------------------------------------------------------
function varargout = pushbutton3_Callback(h, eventdata, handles, varargin)
axes(handles.axes2);
T = getimage(handles.axes2);
%Generate the histogram
figure,imhist(T);
% --------------------------------------------------------------------
function varargout = pushbutton4_Callback(h, eventdata, handles, varargin)
axes(handles.axes3);
T = getimage(handles.axes2);
%Filter the region by median filter
L = medfilt2(T,[3 3]);
imshow(L), title('median filter');
% --------------------------------------------------------------------
function varargout = pushbutton5_Callback(h, eventdata, handles, varargin)
axes(handles.axes3);
T = getimage(handles.axes3);
J = fspecial('unsharp');
B = imfilter(T,J);
imshow(B),title('Unsharp Masking Filter');
% --------------------------------------------------------------------
```

```
function varargout = pushbutton6_Callback(h, eventdata, handles, varargin)
axes(handles.axes3);
T = getimage(handles.axes3);
%Perform the top-hat algorithm
se = strel('disk',12);
J2 = imtophat(T,se);
imshow(J2), title('Tophat filtering');
% --------------------------------------------------------------------
function varargout = pushbutton7_Callback(h, eventdata, handles, varargin)
axes(handles.axes3);
T = getimage(handles.axes3);
%Contrast stretching
K2= imadjust(T,stretchlim(T));
imshow(K2), title('Contrast adjustment');
% --------------------------------------------------------------------
function varargout = pushbutton8_Callback(h, eventdata, handles, varargin)
axes(handles.axes3);
T = getimage(handles.axes3);
%Thresholding
BW = im2bw(T,0.7);
imshow(BW), title('Threshold image');
% --------------------------------------------------------------------
function varargout = pushbutton9_Callback(h, eventdata, handles, varargin)
axes(handles.axes3);
T = getimage(handles.axes3);
%Edge detection
BWinv = ~T;
perim = bwperim(BWinv);
imshow(perim), title('Edges');
% --------------------------------------------------------------------
function varargout = pushbutton10_Callback(h, eventdata, handles, varargin)
axes(handles.axes4);
T = getimage(handles.axes2);
T2 = imcomplement(T);
T1 = getimage(handles.axes3);
F = imadd(T2,immultiply(T1,255));
imshow(F), title('Output image');
% --------------------------------------------------------------------
function varargout = pushbutton11_Callback(h, eventdata, handles, varargin)
axes(handles.axes1);
%Read the input image
I2 = imread('rahmah-L-cc.tif');
imshow(I2), title('Original Image');
% --------------------------------------------------------------------
function varargout = pushbutton12_Callback(h, eventdata, handles, varargin)
axes(handles.axes2);
I2 = imread('rahmah-L-cc.tif');cla
% --------------------------------------------------------------------
function varargout = pushbutton13_Callback(h, eventdata, handles, varargin)
axes(handles.axes3);
I2 = imread('rahmah-L-cc.tif');cla
% --------------------------------------------------------------------
function varargout = pushbutton14_Callback(h, eventdata, handles, varargin)
axes(handles.axes4);
I2 = imread('rahmah-L-cc.tif'); cla
```