



NOISE REMOVAL FROM DIGITAL MAMMOGRAM

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ABSTRACT

Cancer is one of the most virulent diseases in the modern world that still remains a challenge, yet to be fully understood and conquered. Since exact cause of this disease still remains an enigma, preventive measures remain non-existent. It has been reported by several medical scientists that modern day lifestyles, pollution and exposure to hazardous environment may result in mutation of healthy living cells causing cancer. Genetic disorder is also known to cause cancer. Cancer can be found in different parts of the body and is named after the region of their origin like brain cancer, breast cancer, cervical cancer to name a few. Late detection fallouts in higher grade cancer detected with very poor prognosis, consequences into high mortality within few months. Early detection is the only hope for better prognosis and treatment. Breast cancer affecting the women is known to cause high mortality unless detected in time. Detection requires a simple procedure of Mammography followed by biopsy of the tumour or lesions present in the breast tissue. Contemporary Mammographic hardware has incorporated digitization of output image accordingly increasing the scope for implementation of computational methods towards Computer Aided Diagnosis. CAD systems require Medical Image Processing, a multi-disciplinary science that involves development of computational algorithms on medical images. □ All mammogram images contain artefacts in terms of patient related data that needs to be removed before any further processing can be performed. The proposed system is capable to remove all such artefacts and suppress the pectoral region i.e. devoid of any breast tissue, for further analysis.

KEYWORDS: Breast Cancer, Artefacts, Medical Image Processing and Computer Aided Diagnosis.

INTRODUCTION

Cancer is one of the most dreaded diseases of modern world although multidisciplinary scientific investigations are making best efforts to combat this disease, but the curative medicine for perfect cure is yet to be brought into world medicine.^[14] Around 5000 years ago Ayurvedic doctors treated patients with problems of abnormal growth or tumours^[5], two well-known Ayurvedic classics, describe cancer as inflammatory or non-inflammatory swelling and mentioned them as either Granthi (minor neoplasm) or Arbuda (major neoplasm). Malignant tumours (Tridosaja) are very harmful because all the three major bodily systems i.e. the nervous system (Vata or air), the venous system (Pitta or fire) and the arterial system (Kapha or water) lose mutual coordination and thus cannot prevent tissue damage, resulting in a deadly morbid condition.^{[5][14]} According to the modern medical point of view the definition of cancer is referred to a large number of conditions that is characterised by abnormal cell division. The multiplications of cells are progressive, uncontrolled and the cells of cancer infiltrate and destroy surrounding healthy tissue. They have the ability to metastasize and spread throughout the body.

Cancer is a group of diseases that causes cells in the body to change and grow out of control. Most types of cancer cells eventually form a lump or mass called a tumour, and are named after the part of the body where the tumour originates. Breast cancer begins in breast tissue, which is made up of glands for milk production, called lobules and ducts that connect lobules to the nipple. Breast cancer is the second most common type of cancer and the fifth most common cause of cancer-related death. So, it is a significant public health problem in the world for female. There are some rare cases of breast cancer in male also.

Normally, breast cancer develops from cells lining the milk ducts and slowly grows into a lump or a tumour. It is thought that it takes about 10 years for a tumour to become 1 cm in size starting from a single cell. A malignant tumour has the ability to spread beyond the breast to other parts of the body via the lymphatics or the blood stream.^[1-5] Breast cancer may be invasive or non-invasive. Invasive cancer spreads from the milk duct or lobule to other tissues in the breast, whereas, non-invasive ones lack the ability to invade other breast tissues. Non-invasive breast cancer is called “in situ” and may remain inactive for entire lifetime.

Computer technology has had a tremendous impact on medical imaging. Computer-Aided Diagnosis (CAD) is a relatively young interdisciplinary technology combining elements of digital image processing with medical image processing. CAD techniques in X-ray, Mammogram, MRI and Ultrasound diagnostics yield a great deal of information, which the radiologist has to analyse and evaluate comprehensively in a short time. The interpretation of medical images, however, is still almost exclusively the work of humans but in the next decades this is expected to change. Computers will be used more often for image interpretation. This research area is called Computer-Aided Diagnosis (CAD).

The obtained results have been compared with results of different national and international research in the related field. In the process of development of algorithms, the complexity of algorithm in terms of time are critically reviewed. The objective of the proposed methods is not to replace the radiologist or pathologist but to assist them for early and efficient diagnosis of human breast cancer. In conclusion, it is hoped that the algorithms and ideas presented in this thesis contribute not only to the field of breast cancer diagnosis, but also find application in other image processing problems specifically in the field of medical image processing.

Review Works

The English word "Breast" originated from the old English word *brēost* (breast, bosom) from Proto-Germanic *breustam* (breast), from the Proto-Indo-European base *bhreus-* (to swell, to sprout).^[11] The breast spelling conforms to the Scottish and North English dialectal pronunciations.^[1] According to the Oxford dictionary, the word Breast derived from old English *brēost*, of Germanic origin; related to Dutch *borst* and German *Brust*.^[3] The literal meaning of breast is either of the two soft, protruding organs on the upper front of a woman's body which secrete milk after childbirth.^[6-8] In scientific term breast is referred as mammary gland. With reference to the Merriam-Webster dictionary the Breast is either of the pair of mammary glands extending from the front of the chest in pubescent and adult females of humans and some other mammals. It is also either of the analogous but rudimentary organs of the male chest especially when enlarged. It is placed fore or ventral part of the body between the neck and the abdomen.^[9-13] According to Walter Bock, Professor of Evolutionary Biology, Department of Biological Sciences, Columbia University, New York, the human mammary gland, usually well developed in the adult female but rudimentary in the male. Each adult female breast contains 15 - 20 separate, branching glands that radiate from the nipple. During lactation their secretions are discharged through separate openings at the base of the nipple.

The different technologies which are used to view the human body in order to diagnose, monitor or treat medical conditions are referred to as Medical Imaging.

Specific technologies are used to investigate and analyse different information about the explicit area of the body being studied or treated, related to possible disease, injury or the helpful for medical treatment. There are several medical imaging technologies that are used nowadays like X-ray, Ultrasonography (USG), Computer Tomography (CT) and Magnetic Resonance Imaging (MRI) etc. In breast cancer diagnosis several imaging technologies are used including Mammography, Ultrasonography and Magnetic Resonance Imaging. Mammogram is one of popular technique to identify breast cancer. According to the Cancer Facts and Figures 2012, US, mammography can often detect breast cancer at an early stage, when treatment is more effective and a cure is more likely.^[5] Several researches have shown that early detection with mammography saves lives and increases treatment options. One of the main advantages of mammography is the comparative cost effectiveness and availability.

The breast is one of the most dynamic organs in human. Breast change happens in female in different stages throughout the life, first before birth, again at puberty and during the childbearing years. The basic morphological structures of male and female breasts are determined during the prenatal development stage. For a female, breast development is started at the beginning of puberty due to the influence of female sex hormones principally estrogen. It promotes the sprouting, growth and development of the breasts. The rate at which breasts develop differs greatly and is diverse for each young female. The structure of the female breast varies significantly at different times during a woman's life - before, during and after adolescence, for the duration of pregnancy, during the menstrual cycle and after menopause.

The breast is prone to various benign and malignant conditions. The most common benign conditions are puerperal mastitis, fibrocystic breast changes and mastalgia. The latter part is very serious in nature that is Breast Cancer. Breast cancer, a malignant tumour developed from breast cells is considered to be one of the major causes for the increase in mortality among women, especially in developed and developing countries. More specifically, breast cancer is the second most common type of cancer and the fifth most common cause of cancer-related death. So, it continues to be a significant public health problem in the world.

Cancer is a group of diseases that cause cells in the body to change and grow out of control. Most types of cancer cells eventually form a lump or mass called a tumour, and are named after the part of the body where the tumour originates. Breast cancer begins in breast tissue, which is made up of glands for milk production, called lobules and the ducts that connect lobules to the nipple.

Most masses are benign, that is, they are not cancerous, do not grow uncontrollably or spread and are not life-

threatening. Some breast cancers are called in situ because they are confined within the ducts (ductal carcinoma in situ) or lobules (lobular carcinoma in situ) of the breast. Nearly all cancers at this stage can be cured. Many oncologists believe that lobular carcinoma in situ (also known as lobular neoplasia) is not a true cancer, but an indicator of increased risk for developing invasive cancer in either breast.

Some cancerous breast tumours are invasive or infiltrating. If the cancer has broken through the basal membrane and spread into the surrounding tissue it is called invasive.

These cancers start in the lobules or ducts of the breast but have broken through the duct or glandular walls to invade the surrounding tissue of the breast. The seriousness of invasive breast cancer is strongly influenced by the stage of the disease, that is, the extent or spread of the cancer when it is first diagnosed.^[4]

Proposed Method

With the revolutionary development in the field of digital technology and optical electronics in later part of the twentieth century, Digital mammography came into existence and promises a fully digital solution. Digital mammography is a technique for recording x-ray images in digitised code instead on x-ray film as with conventional mammography. The images are displayed on a computer monitor and the image can be processed before they are printed on film. Images can also be manipulated; the radiologist can magnify or zoom in on an area. From the patient's perspective, the procedure for a mammogram with a digital system is the same as for conventional mammography.^[3]

Digital mammography has advantages over conventional mammography. The images can be stored and retrieved electronically which makes long-distance consultations with other mammography specialists easier. Because the radiologist can adjust the images, subtle differences between tissues may be noted. Despite these benefits, studies have not yet shown that digital mammography is more effective in finding cancer than conventional mammography. The first digital mammography^[9] system received U.S. Food and Drug Administration (FDA) approval in 2000.

The projection of the breast can be made from different angles. The two most common projections are medio-lateral oblique (MLO) and cranio-caudal (CC). The medio-lateral oblique projection orientated along the horizontal axis shows the entire gland where the cranio-caudal projection, which is positioned along the vertical axis of the body, shows central and inner breast tissue. In the MLO views there is one non-breast region may be present in the left or right corner of the image called pectoral muscle.

The mammogram image segmented the breast regions according to density of the tissues that is represented on image by intensity of pixel. X-ray radiation is attenuated at a greater rate by more dense regions such as muscles, fibro-glandular tissue, malignant and benign masses and vascular tissue. In contrast, less dense material, such as fat tissue or skin attenuates X-rays less resulting manifests as dark regions.

Now a day's computer is a tool used in every discipline of study to solve critical problems. Different inter-disciplinary subject are evolving which is dealing with super specialised area of knowledge. Computer technology has had a tremendous impact on medical imaging. Radiology is using computer in the field of image interpretation process which introduces new flexibility into the system. This inter-disciplinary field is known as medical image processing and computer aided diagnosis (CAD) is the outcome of the same. By definition a CAD is a set of automatic or semiautomatic tools developed to assist radiologists in the detection and / or evaluation of medical images. Digital mammography accompanied with CAD can reduce huge work load on radiologists. CAD systems are not intended to replace radiologist but rather to assist them during image evaluation by prompting suspicious regions of breast.

The preparation of medical image is a significant step before actual processing in automatic system. The accuracy of the automatic system depends on the efficiency of preparation. Standardisation of image is key to any image processing algorithm. The general methods of image preparation can be divided into three parts: orientation, artefact removal and de-noising. The mammogram images of breasts are not homogeneously oriented in common projection of mammogram in MLO view. The images contain left and right orientation of breast. For automatic processing it is important to make them homogeneous to reduce the additional algorithmic complexity.

Pre-processing can be defined as the basic operations on the medical images towards extraction and detection of desired features by CAD. The primary operation of pre-processing includes image registration, enhancement, pectoral muscle suppression, edge detection, ROI (region of interest) extraction by determining the contour. The incidences of artefact on mammographic images are typical problem. Artefacts are in the form of identification labels, markers and wedges in the unexposed air-background (non-breast) region. Such artefacts are radiopaque and resulting high intensity impression on the image causing failure of automatic detection of abnormalities.

The primary objective of registration is to align one image to another by finding the optimal transformation or mapping function. It involves a searching plan to enhance a similarity measure. This similarity measure is determined using certain characteristics of the images.

Feature space, transformation, similarity measure and search strategy constitute a typical registration framework.^[7]

The purpose of image enhancement is to increase the interpretability or perception of information in images. Enhanced image provides improved input for automated image processing systems like CAD. Broadly, the enhancement of mammogram is performed by intensity and contrast manipulation, noise reduction, background removal, edge sharpening, filtering etc.

Mammogram segmentation is to extract breast ROIs containing all anatomical regions including the suspicious mass or micro-calcification. The aim of segmentation of suspicious regions is to extract the location and classify the apprehension into benign or malignant.^[5] The abnormal area of a mass has almost undeviating intensity, higher than the surrounding and a regular shape with various size and fuzzy boundaries.^[13] Scientists have used different segmentation methods or their combinations to segment the mammogram image accurately. Commonly applied segmentation schemes are region growing, edge detection, wavelet, statistical methods, mathematical morphology, the fractal model, Fuzzy methods to segment a ROI in digital mammograms.

The feature extraction and decision making is the final step of CAD. The image registration followed by enhancement and segmentation processes improve the image quality and separate the different areas. Now it is easier to extract the desired features and draw a conclusion by decision making systems. The features to be extracted from the mammogram image is different types of abnormal mass or masses, micro-calcification along with different morphological and anatomical properties related to cancer detection. The extracted feature can be categorised into three different sections namely intensity features, shape features and texture features.

Noise reduction is considered to be the most important pre-processing technique for any automatic CAD. As discussed earlier, mean filters, median filters, Laplacian filters and Gaussian filters are commonly used method to encounter noise. These techniques are very common for mammogram image pre-processing. Removal of noise in histopathological slide is much more important since the relevant features are microscopic and difficult to extract. Presence of noise may mislead the decision making.

The thresholding is considered to be most trivial method for noise reduction. It is generally followed by background correction and filtering. Background correction is a standardisation technique of images using an empty image to reduce the effect of different image acquisition environments like different lighting conditions.

The automatic cancer diagnosis systems are depending on the variation of the cell structures and the deviations in the cell distribution. The properties are extracted to measure these variations in a given tissue. To quantify the deviances at the cellular-level, morphological, textural, fractal and intensity based features can be applied. In breast cancer detection morphological, textural, fractal based and intensity based variations can be applied. There are two different types of information exist in the image. First one is the intensity values and other one is their spatial interdependency. Most of the feature extraction methods used the intensity values whereas very few applied the spatial dependency between them.

The recent introduction of digital mammography represents a significant technological advance in breast imaging. However, these images may contain artefacts. Commonly encountered artefacts include patient-related artefacts, hardware-related artefacts, detector-associated artefacts, collimator misalignment and underexposure and grid lines. Software processing artefacts like vertical processing bars, loss of edge and high-density artefacts can also be present. Although some of these artefacts are similar to those seen with screen-film mammography, many are unique to digital mammography. Such artefacts and noise in mammogram images is the major obstacle to develop fully automated Computer Aided Diagnosis (CAD) systems. This affects the result and accuracy of algorithms. Hence it is essential to perform preparation steps to suppress these artefacts and noise from background and enhance the breast region.

Artefacts are common to digital mammograms. Recognition of these artefacts is critical for achieving optimal image quality. Digital mammography systems differ in the way they acquire, process, and display images, and artefacts can be a result of problems involving any one of these components. Many artefacts specific to screen-film mammography have been well documented and are recognisable on patient images. Some examples include dust artefacts, pickoff, processor roller artefacts, static artefacts, and fogging artefacts.

Some artefacts may be seen at both screen-film mammography and digital mammography, such as patient-related artefacts and hardware-related artefacts.

External artefacts are represented by tapes and other identification marks that are used on the mammogram to identify the patient and related data that may be required for identification of the mammogram. These markings provide high intensity regions on the mammogram and are inconsequential to the investigation of abnormalities within the mammogram. Presence of such artefacts also changes the intensity levels of the mammogram image significantly that may affect statistical analysis on the image. In this chapter the algorithm proposed by me attempts to remove all such artefacts, markings on the non-breast region of the mammogram and replace them

with the background colour. The resulting image is free from any other object except the breast region.

To achieve the desired goal a new algorithm has been introduced by the combination of modified seeded region growing with Thresholding. It has been observed that in MLO mammogram images, the breast portion is placed in the middle of the object irrespective of left and right breast. As per the characteristic feature of mammogram, breast region is represented by high intensity pixels, where as background consist of chest wall and skin to air are represented by ideally zero intensity or by very low intensity i.e. not more than 10 in grey scale images. The external artefacts and other irrelevant object are present in background, more specifically in the skin to air part of mammogram image.

The proposed algorithm is to search a seed from breast region of mammogram. It has been observed that the pixel that is located at height/2, width*3/4 may always lie in the breast region of mammogram with higher intensity value.

Initially this pixel is considered as the seed of region growing algorithm. Otherwise, it will continue to search a new location given by height/2, width*5/8 and if necessary height/2, width/2. It is observed that in all the cases the seed will be obtained from these locations. This is shown in figure 1.

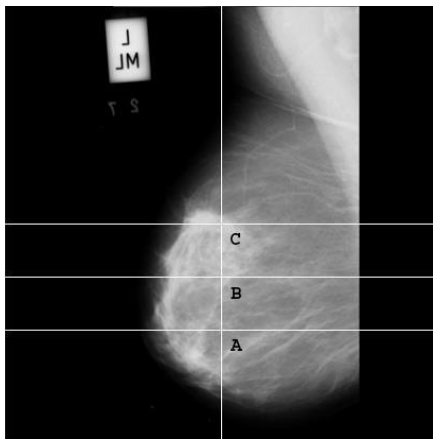


Figure 1: Original Mammogram showing the preferred pixel location (A, B and C) to collect seed for region growing algorithm.

After finding the seed for a region, next objective is to extract only the breast region from the background, leaving the background with artefacts behind and copying the breast region on another blank image. The seed pixel is copied to the new image at the same location of the pixel in the original image. This seed pixel is being coloured black in the original image. It is known that the breast regions of the mammogram have high intensity values whereas the background contains low or zero intensity. The algorithm starts searching for pixels that bounds the seed pixel. For each seed pixel the four boundary pixels located north, east, west and south of the

pixel is also checked to find out whether they have high intensity value. Here algorithm uses the thresholding technique to divide the breast region pixel with background. If the pixels are with high intensity value, these will be used by the algorithm as seed for further searching. A stack is used to store the seeds to be investigated. The process continues by popping a seed from the stack and checking its intensity. If the seed is of high intensity value becomes the next seed. The value of intensity is copied to the new image at the same location of the pixel in the original image and the pixel is coloured black in the original image. This process continues till the stack is empty. The region grows from the single seed and stops when the entire breast region is blackened on the original image and the corresponding entire breast region is copied to the new image. The output image consists of only the breast region and remaining artefact are left behind in the original image. Now the external artefact free mammogram image will be the input for next processing.

Algorithm: Proposed Seeded Region Growing Artefact Removal Algorithm

SEEDED-REGION-GROWING (OrgImage, ImgWidth, ImgHeight)

$\Delta t \leftarrow 10$

If OrgImage[ImgHeight/2, ImgWidth*3/4]. Intensity > Δt
Then GROW-REGION (OrgImage, ImgHeight/2, ImgWidth*3/4, Δt)

Else If OrgImage[ImgHeight/2, ImgWidth*5/8]. Intensity > Δt

Then GROW-REGION (OrgImage, ImgHeight/2, ImgWidth*5/8, Δt)

Else If OrgImage[ImgHeight/2, ImgWidth/2]. Intensity > Δt

Then GROW-REGION (OrgImage, ImgHeight/2, ImgWidth/2, Δt)

Else Error

Return

GROW-REGION (OrgImage, h, w, Δt) Stack \leftarrow New Empty Stack
NewImage \leftarrow New Blank Image
Stack.Push (h)

Stack.Push (w)

While Stack \neq Empty

Do $x \leftarrow$ stack.Pop () $y \leftarrow$ stack.Pop ()

GreyValue \leftarrow OrgImage[x,y].Intensity

If GreyValue > Δt

Then NewImage[x, y].Intensity \leftarrow GreyValue
OrgImage[x, y].Intensity \leftarrow 0

If $x-1 > 0$ AND OrgImage[x-1, y].Intensity > Δt

Then Stack.Push (y)

Stack.Push (x-1)

If $x+1 <$ OrgImage.height AND OrgImage[x+1, y].Intensity > Δt

Then Stack.Push (y)

Stack.Push (x+1)

If $y-1 > 0$ AND OrgImage[x, y-1].Intensity > Δt

Then Stack.Push (y-1)

```

Stack.Push (x)
If y+1 < OrgImage.width AND OrgImage[x,
y+1].Intensity > Δt
Then Stack.Push (y+1) Stack.Push (x)
Return (NewImage)

```

Complexity Analysis of Algorithm

Here the image size is $N*N$. But there is no iteration in the algorithm to read the entire image. So, complexity will never exceed n^2 . The pixels are traversed directly

using x and y value. The numbers of pixels accessed on the image depend on the area covered by the breast region. By observation, it is found that half of the mammogram image is covered by the high intensity breast region. So, it may be said that half of the pixels out of $N*N$ pixel are traversed by the algorithm. Hence the average time complexity of the algorithm will be approximately $n^2/2$. Right Mammogram and Mammogram after Flipping 180° is shown in figure 2.

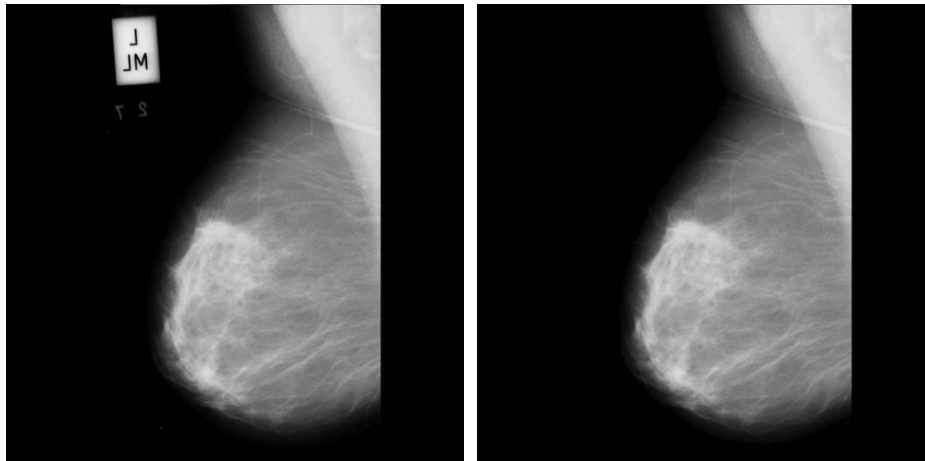


Figure 2: Right Mammogram and Mammogram after Flipping 180°

Noise Suppression

There are different types of noises, which appear in digital mammogram images. High intensity noise is characterised by high values of optical densities like shadows presenting themselves as horizontal running strips or ghost images of previously performed mammography. These noises are embedded to the breast region of the mammogram thus resulting in loss of information from the breast region. These noises also make detection process for an automated CAD process to yield false results or negative detection. Such noise must be removed from the image to provide accurate results in the detection processes. In this paper the well-known Gaussian filter is used to remove such noise by blurring these noises before performing edge detection or other processing on the mammogram images.

The Gaussian smoothing operator is a 2-D convolution operator that is used to 'blur' images and remove detail and noise. It uses a kernel that represents the shape of a Gaussian ('bell-shaped') hump. For 2-D, an isotropic (i.e. circularly symmetric) Gaussian form is used for the proposed method. It is shown in equation 1.

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \quad [1]$$

The idea of Gaussian smoothing is to use this 2-D distribution as a 'point-spread' function and this is achieved by convolution. Since the image is stored as a collection of discrete pixels it is needed to produce a discrete approximation to the Gaussian function before it

can perform the convolution. In theory, the Gaussian distribution is non-zero everywhere which would require an infinitely large convolution kernel but in practice it is effectively zero more than about three standard deviations from the mean and so the kernel is truncated at this point. Once a suitable kernel is obtained then the Gaussian smoothing can be performed using standard convolution methods. In this proposed method, 7×7 kernel has been taken as a convolution filter. The mammogram images are broadly categorized into 3 categories namely Fatty, Fatty- Glandular and Dense- Glandular depending on the density of fatty tissues and abundance of glands in the breast. Close observation of all the mammograms reveal that each category of mammogram displayed a varied intensity value which is distinct for each category. This property of the mammograms has helped the choice of value of deviation (Ω) for each category, thus able to adjust the level of smoothening for each category. The 2-D Gaussian distribution is shown in figure. Figure 4 shows result after smoothing.

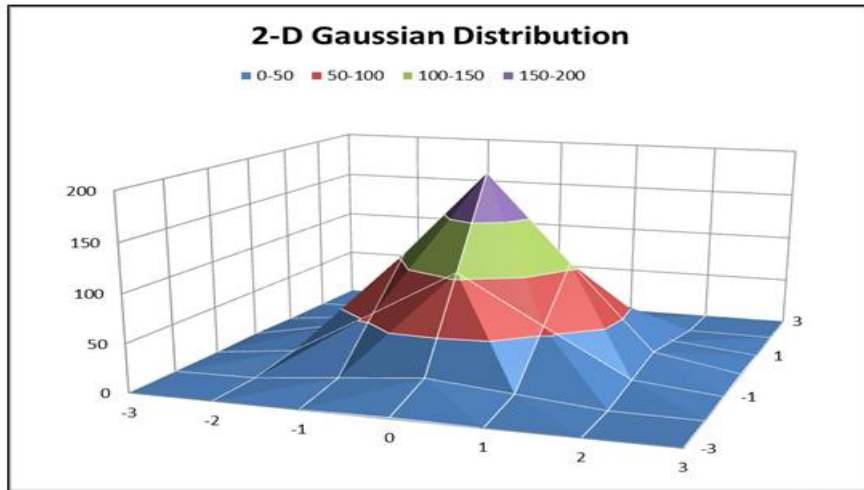


Figure 3: Proposed Method uses 7×7 kernel as a Convolution Filter.

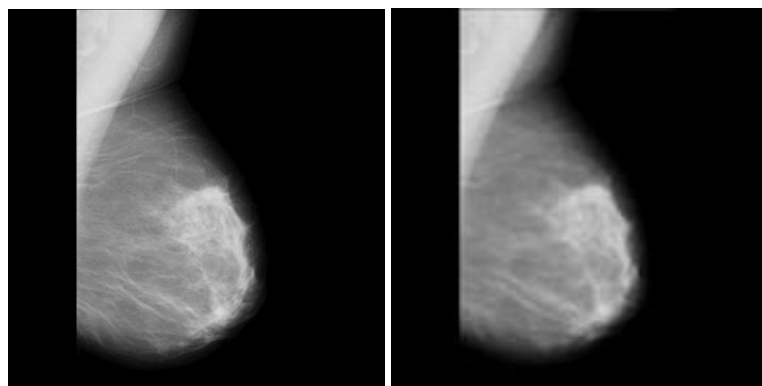


Figure 4: 'Mammogram' before 'and' after 'Gaussian' Smoothing.

Experimental Results

The algorithms have been tested with several mammographic images including on all mammograms from MIAS mammogram database and other available databases containing normal and abnormal cases. Almost

all cases output is as expectation. Some of the appropriate test results are depicted here with the mammograms taken from the MIAS database to prove the accuracy of the algorithm. Figure 5, figure 6, figure 7 and figure 8 shows the results.

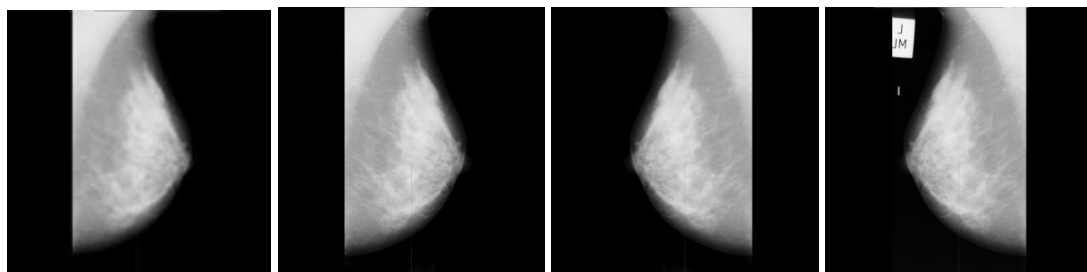


Figure 5: Images showing Original Mammogram (MIAS197.R) followed by image after Artefacts Removable, Flipping and Noise Removable (Images from left to right).

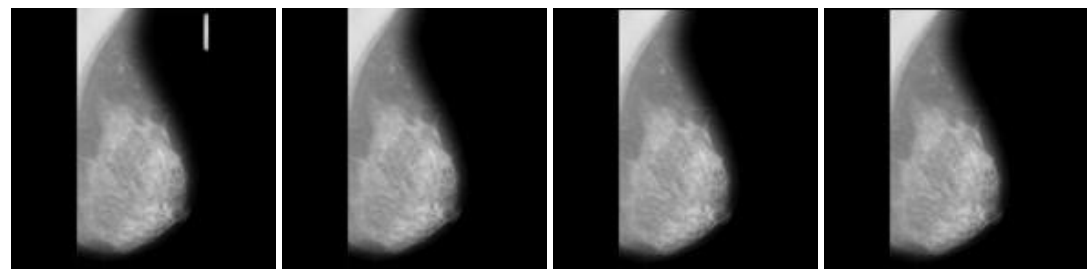


Figure 6: Images showing Original Mammogram followed by image after Artefacts Removable, Flipping (no change) and Noise Removable (Images from left to right).

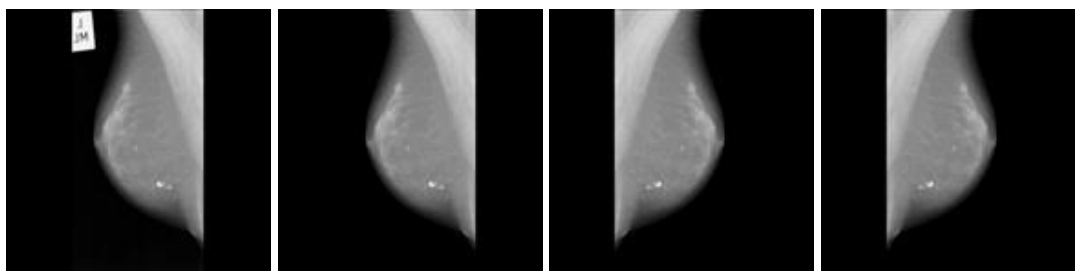


Figure 7: Images showing Original Mammogram followed by image after Artefacts Removable, Flipping and Noise Removable (Images from left to right).

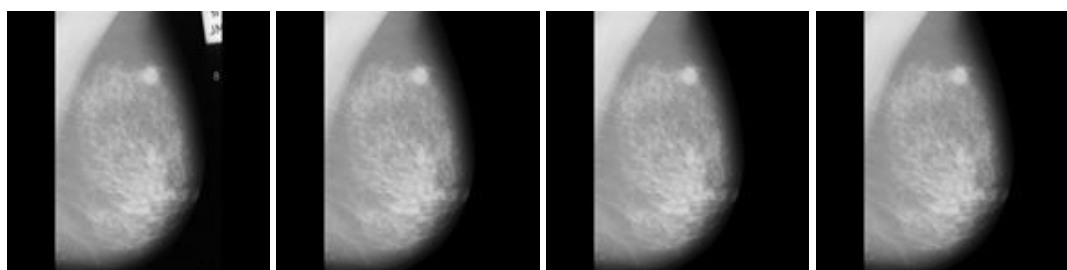


Figure 8: Images showing Original Mammogram followed by image after Artefacts Removable, Flipping (no change) and Noise Removable (Images from left to right).

CONCLUSION

The fully automated and accurate elimination was achieved by the proposed Seeded Region Growing Algorithm (SRGA). This algorithm removes the external artefacts in most cases.

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