UNIVERSITY POLITEHNICA BUCUREȘTI

Faculty of Electronics, Telecommunications and Technology of Information

PROJECT

Breast cancer detection methods using medical imaging techniques

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1. Introduction

Breast cancer is the second leading cause of cancer deaths among women. Over 1.5 million women (25% of all women with cancer) are diagnosed with breast cancer every year throughout the world[1]. It is a metastatic cancer and can commonly transfer to distant organs such as the bone, liver, lung and brain, which mainly accounts for its incurability, and its prevention remains challenging in the world.

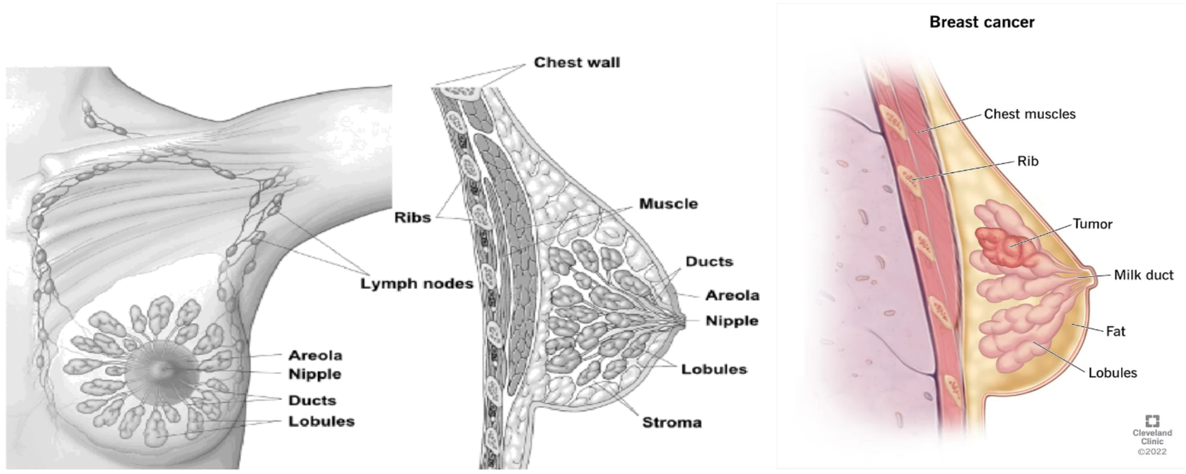

Fig. 1.1 Normal breast tissue (left) vs breast cancer (right)

Breast cancer can spread when the cancer cells get into the blood or lymph system and then are carried to other parts of the body. The clear lymph fluid inside the lymph vessels contains tissue by-products and waste material, as well as immune system cells. The lymph vessels carry lymph fluid away from the breast. In the case of breast cancer, cancer cells can enter those lymph vessels and start to grow in lymph nodes. Most of the lymph vessels of the breast drain into: lymph nodes under the arm (axillary lymph nodes), lymph nodes inside the chest near the breastbone (internal mammary lymph nodes), lymph nodes around the collar bone (supraclavicular [above the collar bone] and infraclavicular [below the collar bone] lymph nodes). If cancer cells have spread to the lymph nodes, there is a higher chance that the cells could have traveled through the lymph system and spread (metastasized) to other parts of the body. Still, not all women with cancer cells in their lymph nodes develop metastases, and some women with no cancer cells in their lymph nodes might develop metastases later[2].

There are different kinds of breast cancer. The kind of breast cancer depends on which cells in the breast turn into cancer. The most common kinds of breast cancer are: *invasive ductal* *carcinoma* (the cancer cells begin in the ducts and then grow outside the ducts into other parts of the breast tissue; invasive cancer cells can also spread, or metastasize, to other parts of the body) and *invasive lobular carcinoma* (cancer cells begin in the lobules and then spread from the lobules to the breast tissues that are close by; these invasive cancer cells can also spread to other parts of the body)[3].

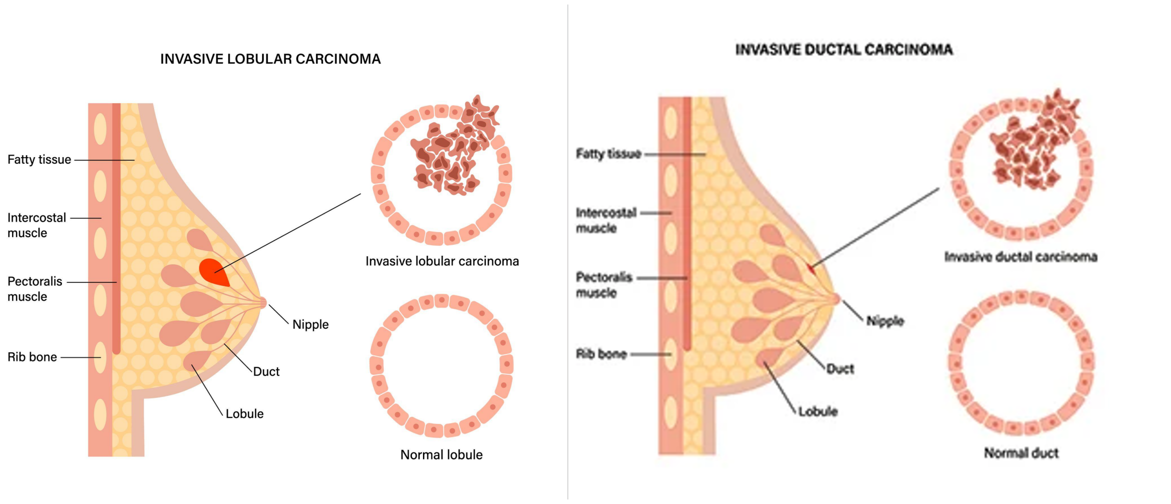

Fig.1.2 The most common kinds of breast cancer - invasive lobular carcinoma (left) and invasive ductal carcinoma (right)

Experts know breast cancer happens when breast cells mutate and become cancerous cells that divide and multiply to create tumors. They aren’t sure what triggers that change. However, research shows there are several risk factors that may increase someone’s chances of developing breast cancer. These include: sex (women and people AFAB are much more likely to develop the condition), aging (50 or older), family history (if parents, siblings, children or other close relatives have breast cancer, you’re at risk of developing the disease), reproductive factors, hormonal causes, genetics (genetic mutations), lifestyle.

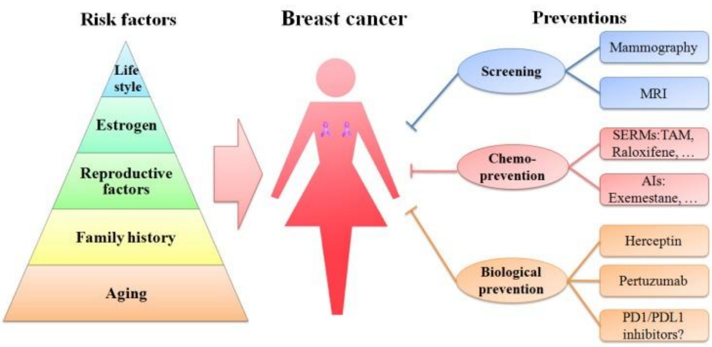

Fig. 1.3. Schematic diagram of risk factors and preventions of breast cancer.

Thus far, great advances have been made in clinical and theoretical studies of breast cancer. The current prevention methods including screening, chemoprevention and biological prevention are more direct and effective than those in the past. The mortality of breast cancer has decreased. However, breast cancer is still the first leading cause of cancer death among females aged 20-59 years.

The most reliable way to diagnose breast cancer is through a 'triple test'. The triple test is positive if the result of any component of it is suspicious, indeterminate or malignant (cancerous). If the result of any one test differs from the others then the diagnosis is uncertain and further investigation is required. Only when all three tests are negative (no evidence of cancer) can cancer be ruled out with 99% accuracy. This triple test includes: medical and personal history and clinical breast exam (the doctor will examine the patient's breasts for any signs of cancer, and talk about their medical and personal history), imaging (mammogram, ultrasound and sometimes MRI are the most commonly used to diagnose breast cancer; other tests, such as CT scans, bone scans, or PET scans might sometimes be done to help find out if breast cancer has spread; newer types of tests are now being developed, such as breast tomosynthesis (3D mammography)), and biopsy (the removal of a tissue sample, which is then sent to the laboratory for analysis, required to accurately diagnose breast cancer)[4].

2. Methods of detection

1. What methods are used in order to detect breast cancer and in what condition

It is often needed to have additional tests in order to diagnose breast cancer. The most common of them are: Diagnostic mammogram, Breast ultrasound, Breast magnetic resonance imaging and Biopsy. They are all non-invasive tests, meaning they do not require surgical intervention in order to be conducted.

The Mammogram is an essential breast cancer screening and diagnostic tool. It is using low-dose X-rays in order to show abnormal areas or tissues in the breast and can help detect cancer before you have symptoms. In order to obtain an X-ray image, an X-ray radiation is passed through the body. In radiography a single image is recorded for later evaluation, and mammography is a special type of radiography. Fluoroscopy is a continuous X-ray image displayed on a monitor allowing for real-time monitoring of a procedure or passage of a contrast agent ("dye").

Figure 2.1. Mammogram image obtained using radiography method

A screening mammogram is a routine that healthcare providers recommend to look for signs of cancer or abnormal breast tissue before you have symptoms. Screening mammography helps with early detection of breast cancer. Healthcare providers order a diagnostic mammogram if a screening mammogram shows abnormal tissue. While both types of mammograms use the same machines, diagnostic mammography uses additional imaging such as spot compression, supplementary angles or magnification views.

An ultrasound is an imaging test that uses high-frequency sound waves to take pictures of the internal organs and tissues. It uses the property of reflectivity of the tissue in order to achieve that. A breast ultrasound provides pictures of the insides of the breast. This test gives more information about small areas of interest within the breast that may be difficult to see in detail on a mammogram, which uses X-rays.

Figure 2.2 Ultrasound image of a breast

Typically, healthcare providers don’t use breast ultrasound on its own to screen for breast cancer. More often, they recommend an ultrasound to follow up on suspicious areas seen on a mammogram. The ultrasound method is also used for pregnant women in conjunction with the physical exam in order to avoid irradiation of the fetus from the mammogram.

Just as mammograms are done using x-ray machines specially designed for the breasts, breast MRI also requires special equipment. This MRI machine has a special device called a dedicated breast coil to image the breasts. Not all hospitals and imaging centers have dedicated breast MRI equipment. If you are having a breast MRI, it's important to have it at a facility that has dedicated equipment and can do an MRI-guided breast biopsy if needed, or a facility that partners with one that can. MRI is not recommended as a screening test by itself, because it can miss some cancers that a mammogram would find. Breast MRI might sometimes be done if breast cancer is suspected. Other imaging tests such as Diagnostic mammogram and Breast ultrasound are usually done first, but MRI might be done if the results of these tests aren't clear.

If breast symptoms or the results of an imaging test from the above suggest that a person might have breast cancer, a biopsy might be needed. During a biopsy, a doctor removes small pieces of breast tissue from the suspicious area so they can be looked at in the lab to see if they contain cancer cells.

2. Mammogram cancer detection by using SalCor method

In order to detect breast cancer, medical image segmentation aims to identify important or suspicious regions within the medical images. However, many challenges are usually faced while developing neural networks for this type of analysis. First, preserving the original image resolution is of utmost importance for this task where identifying subtle features or abnormalities can significantly impact the accuracy of diagnosis.

The state of the art for this kind of detection is to use CNN (convolutional neural networks) in order to predict and segment a region of interest. There seems to be this important aspect of providing an image of good resolution as input to the neural network in order to improve its performance. In order to do this, there is a SalCor model[5]. that can handle noise robustly by leveraging the local correntropy-based K-means clustering. In the cited article, the approach is evaluated on synthetic and real images.

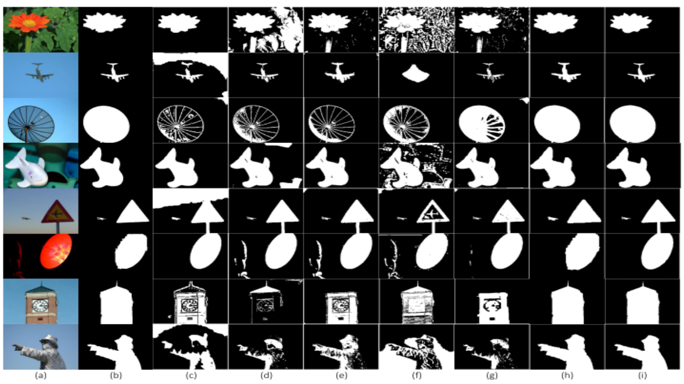

Figure 2.3 Example of SalCor method (the one most to the left) of segmentation compared to the others

This approach enables it to extract objects with complex backgrounds effectively regardless of noise and intensity inhomogeneity. The statistical analysis confirms the SalCor model's exceptional precision and efficiency. These outcomes indicate that SalCor holds great potential for detecting brain tumors and mammogram tumors in MRIs and early diagnosis of COVID-19.

Another method is cited in the first article[6]. It uses double-dilated convolution modules in order to maintain the local spatial resolution and improve the receptive field size. It also uses the Grad-CAM (Gradient weighed Class Activation Map) in order to conduct qualitative evaluations of the results after the neural networks are trained on a specific data set.

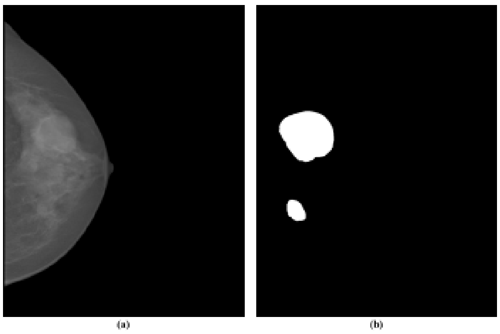

Figure 2.4 Example of segmentation by using filtered images with double-dilated convolution filters

Segmentation of tumors is considered the most difficult task in medical imaging. Boundaries of the tumor tissue and the rest of the tissue are not always clear, therefore it is not trivial to define a clear contour to follow. If only the intensity based information is used, then the problem of overlapping tissues cannot be solved as easily. The SalCor model is able to address the problems posed by significant non uniform intensity and noise in images. A novel energy function is formulated to extract objects efficiently, even with complex backgrounds and high noise levels.

In the article, an analysis was conducted and it resulted that the accuracy of this SalCor method is very high, compared to the other methods analyzed. The accuracy was of 0.98, Sensitivity of 0.97 and the Specificity of 0.98.

3. BI-Rads categories

Depending on whether you got a breast MRI for screening purposes, diagnostic purposes or to evaluate known cancer, your MRI report may look different. In any case, your provider who ordered the breast MRI will discuss your results with you.

Radiologists all use the same standardized system to describe screening and diagnostic breast imaging (including mammogram, ultrasound and MRI) results. This system is called the Breast Imaging Reporting and Data System (BI-RADS). This system categorizes results on a scale of 0 through 6.[9]

BI-RADS category	Definition	Explanation
0	Incomplete.	This result means the radiologist may have seen a possible abnormal area, but they need further images to evaluate it, such as a diagnostic mammogram or an ultrasound. This result may also mean that the radiologist wants to compare your most recent breast MRI with older ones to see if there've been changes in the area over time.

1	Negative.	This result means the radiologist didn't find a significant abnormality on the images.
2	Benign (noncancerous) finding.	This result means that the radiologist found a benign (noncancerous) area in your breast, such as benign cysts, lymph nodes or fibroadenomas. The radiologist records this finding to help when comparing it to future breast imaging tests.
3	Probably benign finding.	The findings in this category have a greater than 98% chance of being benign (noncancerous). But as it's not proven to be benign, the radiologist wants to monitor it to be sure it doesn't change over time. You'll likely need additional imaging (such as MRI) in six months.
4	Suspicious abnormality.	This result means a finding(s) is not normal and has suspicious features suggesting it could be cancer. The radiologist will recommend a breast biopsy to get more information. The findings in this category can have a 2% to 95% chance of being a cancer.
5	Highly suggestive of malignancy.	The term "malignancy" refers to the presence of cancerous cells. This result means the findings look like cancer and have at least a 95% chance of being cancer. The radiologist will strongly recommend a breast biopsy of these findings.

6	Known biopsy-proven malignancy.	Radiologists use this result for findings on a mammogram or MRI that have previously been biopsied and are a known cancer. Healthcare providers use MRIs in this way to see the extent of the cancer and/or how well it's responding to treatment.[9]

4. MRI Technique in breast cancer detection

Breast MRI serves various purposes in different scenarios. In the case of women deemed at high risk for breast cancer, it is advised to undergo both a screening breast MRI and an annual mammogram. However, relying solely on MRI as a screening test is not recommended due to its potential to overlook certain cancers detectable by mammograms. While MRI has the capability to identify some cancers undetected by mammograms, it also has a higher likelihood of detecting non-cancerous abnormalities, leading to false positives.

Essential Information on Undergoing a Breast MRI

Similar to how mammograms utilize specialized x-ray machines designed for breast imaging, breast MRI also necessitates specific equipment. The MRI machine employed in breast imaging is equipped with a dedicated *breast coil* designed to capture detailed images of the breasts. It's crucial to note that not all medical facilities possess dedicated breast MRI equipment.

Unlike radiation-based imaging, MRI relies on powerful magnets to generate highly detailed, cross-sectional images of the body. The MRI scanner captures images from various angles, resembling slices of the body from the front, side, or above the head. This imaging technique excels at producing detailed images of soft tissue structures that might be challenging to visualize with other diagnostic tests.

In contrast to mammograms or breast ultrasound, a breast MRI involves the injection of a contrast dye into a vein (via an IV line) before image capture. This enhances the visibility of any abnormal areas in the breasts, making them more discernible in the resulting images.

How it is done:

To begin the procedure, an IV line will be inserted into a vein in your arm to facilitate the injection of contrast material(known as *gadolinium)*.This infusion enhances the visualization of any abnormal areas within the breast tissue. Subsequently, you will recline face down on a slender, flat table with your arms positioned above your head. Your breasts will hang through an opening in the table, allowing for scanning without compression. The table then slides into a long, narrow tube. Although the test itself is painless, it necessitates remaining still within the confined tube. Certain segments of the examination may require you to hold your breath or maintain complete stillness.[7]

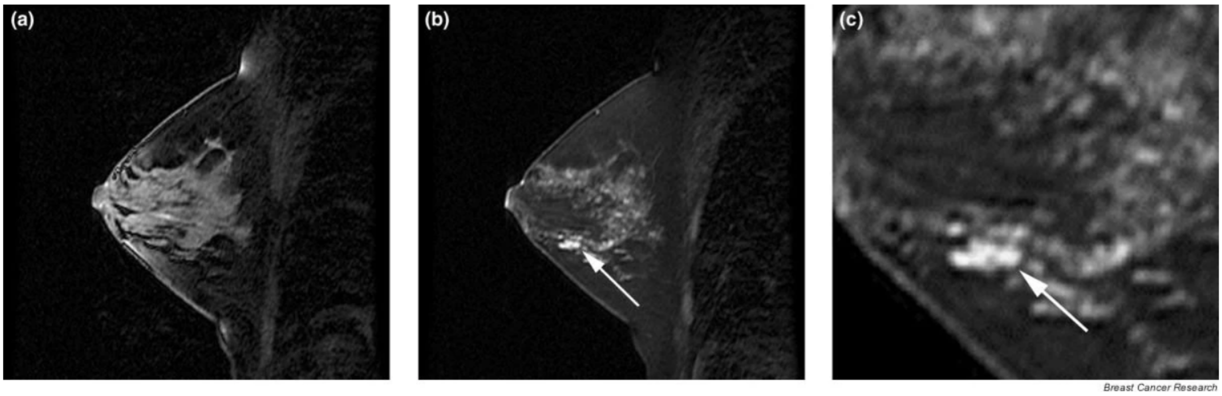

Fig 2.5 Breast MRI images[8]

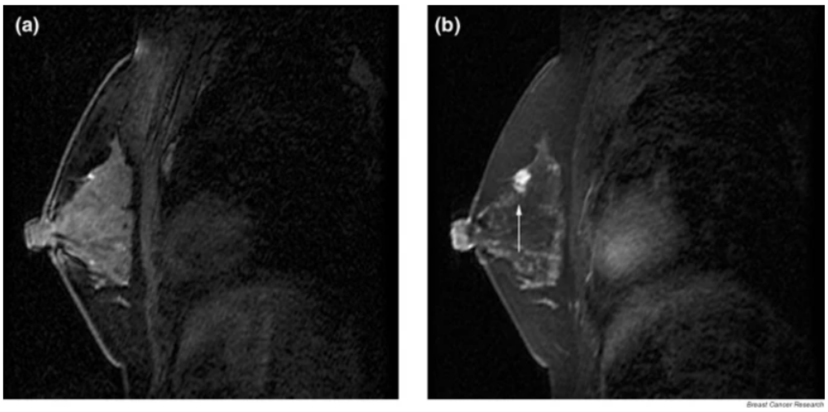

Fig 2.6 Breast MRI images enhanced[8]

3. Proposed methods of detection

1. Contrast transformation

Linear contrast enhancement

Linear Contrast Enhancement is an image processing method that adjusts the intensity values of pixels in a linear manner, expanding the overall contrast range. This technique aims to improve the visual appearance of an image by making darker regions darker and brighter regions brighter, resulting in a more visually appealing and perceptually clear image.

$$T(x) = \begin{cases} \frac{T_a}{a} x, & x \in [0, a] \\ T_a + \frac{T_b - T_a}{b-a}(x-a), & x \in [a, b] \\ T_b + \frac{L-1-T_b}{L-1-b}(x-b), & x \in [b, L-1] \end{cases}$$

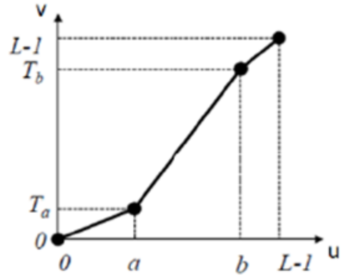

Fig 3.1 Linear Contrast Enhancement operation

Particular case contrast stretching

Contrast stretching, also known as intensity or contrast normalization, is a technique that expands the range of pixel intensity values in an image. It involves linearly scaling the original intensity values so that the minimum and maximum values span the full available range. This process enhances the contrast of an image, making details more distinguishable and improving overall visibility.

$$T_a = 0$$
$$T_b = L - 1$$

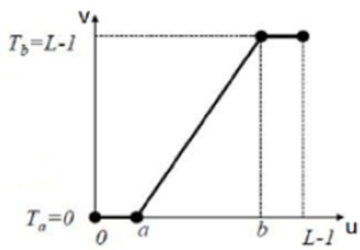

Fig 3.2 Contrast stretching

Nonlinear contrast enhancement - exponential function

Nonlinear contrast enhancement using an exponential function involves applying an exponential transformation to the pixel intensity values of an image. This method enhances contrast by emphasizing differences in the mid-range intensity values while compressing extreme values. The exponential function effectively amplifies details in the mid-tones, leading to a visually enhanced image with improved perceptual clarity.

$$v = T(u) = (M-1)\frac{e^\wedge u - 1}{e^{M-1} - 1}$$

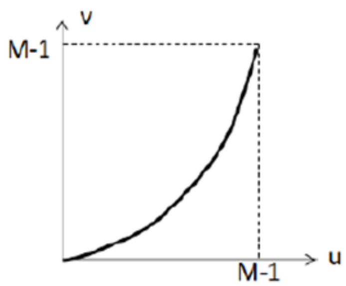

Fig 3.3 Exponential function

2. Segmentation transformation

Slicing

Grey level slicing is equivalent to band pass filtering. It manipulates groups of intensity levels in an image up to a specific range by diminishing rest or by leaving them alone. This transformation is applicable in medical images and satellite images such as X-ray flaws, CT scan. Two different approaches are adopted for gray level slicing, but for this project we used only one, gray level slicing without background. It displays high values in the specific region of an image and low value to other regions by ignoring background. A range [A, B] of gray levels is highlighted by reducing all others to a constant level.[10]

Binarization

Image Binarization, also known as Image Thresholding, is a technique to create a binary image from a grayscale or RGB image that can be used to separate the image's foreground from its background. Image thresholding is one of the most fundamental ways to extract useful information from a given image or segment a region of interest.

Image thresholding is usually performed on grayscale images. Once the image is converted to a grayscale image, each pixel value is compared with a threshold value where, if the pixel value is less than the threshold; the pixel value is set to zero; else, it is set to the maximum possible value(255).[11]

Otsu's Method

Otsu method[12] is a global thresholding method that converts gray scale image into bi-level image. This technique divides the pixels into two classes one is foreground and the other is background. It chooses an optimal threshold that separates the image into two different classes. The threshold value is chosen such that the within-class variance is minimized and the between-class variance is maximized.

3. Morphologic transformation

Erosion

In the last stage of the transformation pipeline, I chose to do the following morphological operations: erosion, dilation and morphological gradient. The erosion is a morphological operation that is used to remove or erode the boundaries of objects in a binary image. The term "binary image" refers to an image where each pixel can have only one of two values, typically 0 or 1, representing background and foreground, respectively.

The erosion operation involves sliding a structuring element (also known as a kernel or a mask) over the input image. At each position of the structuring element, if all the pixels underneath it in the input image are set to 1 (foreground), then the corresponding pixel in the output image remains 1; otherwise, it is set to 0 (background). The process can be described as follows:

1. Place the structuring element over the first pixel of the input image.
2. Check if all the pixels underneath the structuring element in the input image are 1.
3. If yes, set the corresponding pixel in the output image to 1; otherwise, set it to 0.
4. Repeat the process for all pixels in the input image.

The python function makes use of the library scipy.ndimage.morphology. At first, it defines a structuring element of 10x10 pixels and then it does the erosion algorithm, returning the resulting image.

Dilation

Dilation is another morphological operation in image processing that is used to expand or dilate the boundaries of objects in a binary image. Like erosion, dilation also involves a structuring element (kernel) and operates on binary images where pixels have values of 0 (background) or 1 (foreground).

The dilation operation can be described as follows:

1. Place the structuring element over the first pixel of the input image.
2. Check if at least one pixel underneath the structuring element in the input image is set to 1.
3. If yes, set the corresponding pixel in the output image to 1; otherwise, set it to 0.
4. Repeat the process for all pixels in the input image.

As in the case of the erosion, the python function makes use of the library scipy.ndimage.morphology. At first, it defines a structuring element of 10x10 pixels and then it does the erosion algorithm, returning the resulting image.

Morphological gradient

The morphological gradient is a morphological operation in image processing that combines aspects of dilation and erosion to highlight the boundaries of objects in a binary or grayscale image. This operation is particularly useful for edge detection and feature extraction. It is computed as the difference between the dilation and erosion of an image. The process involves the following steps:

1. Dilate the original image.
2. Erode the original image.
3. Subtract the eroded image from the dilated image.

In this case, the python function makes use of the computer vision library “opencv-python”. From which it uses morphologyEx function to compute the obtained image.

4. Software implementation

The whole project can be referred to on GitHub by using the following link. Since the source code is too long to be added in this document, the main function is presented in the following paragraph.

```
# import py libraries
import sys
import matplotlib.pyplot as plt
sys.path.append("library")

# import custom library
import helper as hp

# make a list db with image info
imageInfoList = [];
with open('../breastcancer_database/Info.txt') as f:

    # list containing lines of file
    lines = f.readlines()

    for line in lines:
        # remove leading/trailing white spaces
        line = line.strip()

        # append dictionary to list
        imageInfoList.append(line)

def main():

    # FIRST IMAGE
    # running mdb003 through the transformation pipeline
    path     = r'../breastcancer_database/mdb003.pgm'
    img_in   = plt.imread(path)
    plt.plot()
    plt.imshow(img_in, cmap = 'gray')
    plt.show()
    img_out_list = []
```

```
# run contast_transform library
img_out_list = hp.runPipelineSegment(1, img_in);
plt.show()

# let user to make a choice
user_choice = int(input('Choose an image from 1 to 3 \n'))

# run segmentation_transform library
img_out_list = hp.runPipelineSegment(2, img_out_list[user_choice - 1])
plt.show()

# let user to make a choice
user_choice = int(input('Choose an image from 1 to 3 \n'))

# run morphologic_transform library
img_out_list = hp.runPipelineSegment(3, img_out_list[user_choice - 1])
plt.show()

# let user make a choice
user_choice = int(input('Choose an image from 1 to 3 \n'))

# show the final result and the pathology based on the Info.txt
plt.figure()
plt.imshow(img_out_list[user_choice - 1], cmap = 'gray')
plt.show()
hp.returnPathologyForImage('mdb003', imageInfoList)


# SECOND IMAGE
# running mdb0028 through the transformation pipeline
path     = r'../breastcancer_database/mdb028.pgm'
img_in   = plt.imread(path)
plt.plot()
plt.imshow(img_in, cmap = 'gray')
```

```
plt.show()
img_out_list = []

# run contast_transform library
img_out_list = hp.runPipelineSegment(1, img_in);
plt.show()

# let user to make a choice
user_choice = int(input('Choose an image from 1 to 3 \n'))

# run segmentation_transform library
img_out_list = hp.runPipelineSegment(2, img_out_list[user_choice - 1])
plt.show()

# let user to make a choice
user_choice = int(input('Choose an image from 1 to 3 \n'))

# run morphologic_transform library
img_out_list = hp.runPipelineSegment(3, img_out_list[user_choice - 1])
plt.show()

# let user make a choice
user_choice = int(input('Choose an image from 1 to 3 \n'))

# show the final result and the pathology based on the Info.txt
plt.figure()
plt.imshow(img_out_list[user_choice - 1], cmap = 'gray')
plt.show()
hp.returnPathologyForImage('mdb028', imageInfoList)

# THIRD IMAGE
# running mdb099 through the transformation pipeline
path     = r'../breastcancer_database/mdb099.pgm'
img_in   = plt.imread(path)
```

```
plt.plot()
plt.imshow(img_in, cmap = 'gray')
plt.show()
img_out_list = []

# run contast_transform library
img_out_list = hp.runPipelineSegment(1, img_in);
plt.show()

# let user to make a choice
user_choice = int(input('Choose an image from 1 to 3 \n'))

# run segmentation_transform library
img_out_list = hp.runPipelineSegment(2, img_out_list[user_choice - 1])
plt.show()

# let user to make a choice
user_choice = int(input('Choose an image from 1 to 3 \n'))

# run morphologic_transform library
img_out_list = hp.runPipelineSegment(3, img_out_list[user_choice - 1])
plt.show()

# let user make a choice
user_choice = int(input('Choose an image from 1 to 3 \n'))

# show the final result and the pathology based on the Info.txt
plt.figure()
plt.imshow(img_out_list[user_choice - 1], cmap = 'gray')
plt.show()
hp.returnPathologyForImage('mdb099', imageInfoList)


# FOURTH IMAGE
```

```
# running mdb021 through the transformation pipeline
path     = r'../breastcancer_database/mdb021.pgm'
img_in   = plt.imread(path)
plt.plot()
plt.imshow(img_in, cmap = 'gray')
plt.show()
img_out_list = []

# run contast_transform library
img_out_list = hp.runPipelineSegment(1, img_in);
plt.show()

# let user to make a choice
user_choice = int(input('Choose an image from 1 to 3 \n'))

# run segmentation_transform library
img_out_list = hp.runPipelineSegment(2, img_out_list[user_choice - 1])
plt.show()

# let user to make a choice
user_choice = int(input('Choose an image from 1 to 3 \n'))

# run morphologic_transform library
img_out_list = hp.runPipelineSegment(3, img_out_list[user_choice - 1])
plt.show()

# let user make a choice
user_choice = int(input('Choose an image from 1 to 3 \n'))

# show the final result and the pathology based on the Info.txt
plt.figure()
plt.imshow(img_out_list[user_choice - 1], cmap = 'gray')
plt.show()
hp.returnPathologyForImage('mdb021', imageInfoList)
```

```
# run the program
if __name__ == "__main__":
    main()
```

5. Results and conclusions

Exponential Transformation:

It can be observed that the white tones have been darkened, leaving only the details of interest in shades of gray or stronger white tones.

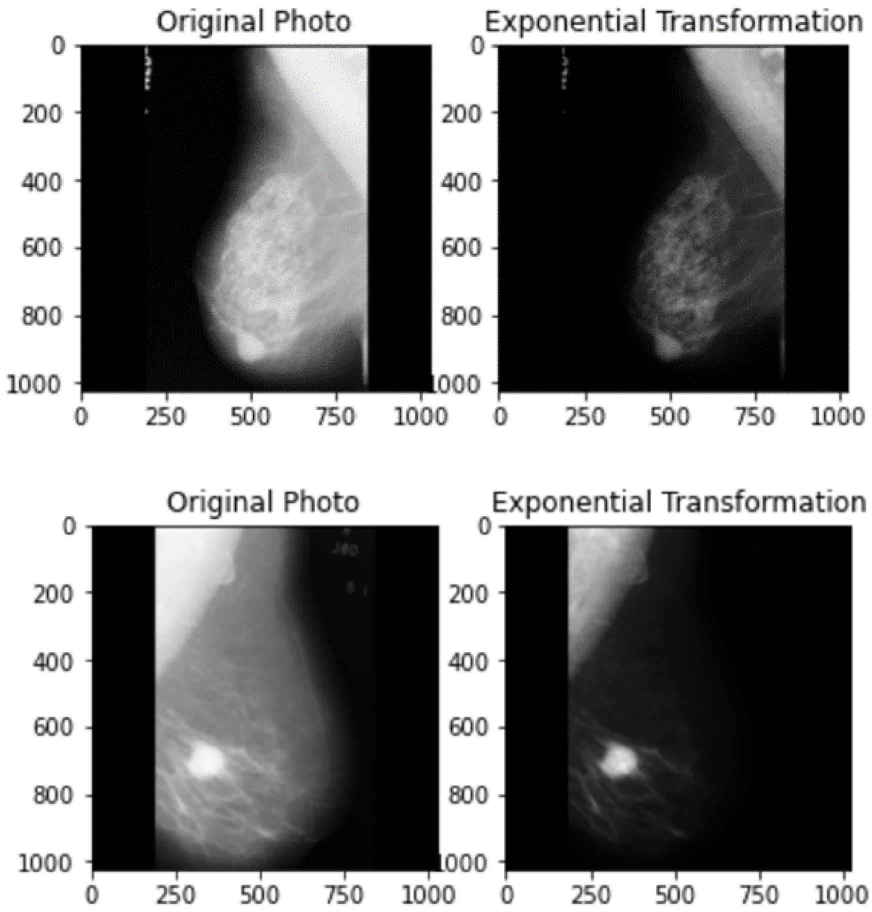

Fig 3.4 Original mammogram compared to the exponential transformed one

For both pictures, we can observe that the areas of interest are very well accentuated through dark tones, allowing for a good measurement of the condition. The gray areas or edges are eliminated.

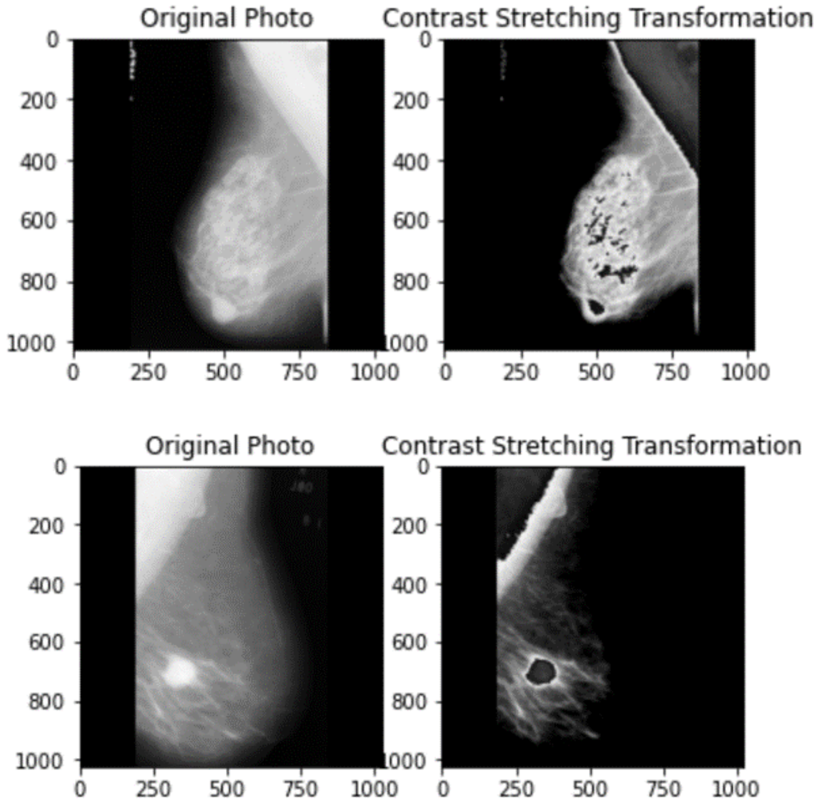

Fig 3.5 Original mammogram compared to the contrast stretched one

Using this transformation, the white tones are highly accentuated, and the edges are eliminated. All three methods are effective in detecting breast tumors, but depending on the type of tissue, one method may be more or less efficient. For example, dense tissue with a condition at the bottom of the breast is presented, and applying the above methods, the Contrast Stretching method highlights other parts of the tissue that are not of interest. A better emphasis on the condition can be observed in the Exponential method. On the other hand, in the image mdb028, normal tissue with a condition on the left side is presented, and applying the transformations, the regions of interest are best accentuated in the Exponential and Contrast Stretching methods because other parts of the tissue are not overly highlighted. The Linear Transformation method is not very useful as it accentuates much of the tissue and does not well delineate the affected area.

In the case of segmentation transform it can be observed that for all three methods there is a clear separation based on the threshold chosen in each method, but the results vary. If we consider the gray level slicing, it enhances the specific intensity range that might correspond to important features or abnormalities in breast tissue. In this image, it highlights specific details, making clear the observation of microcalcifications or subtle tissue density variations, which may be indicative of early signs of breast cancer.

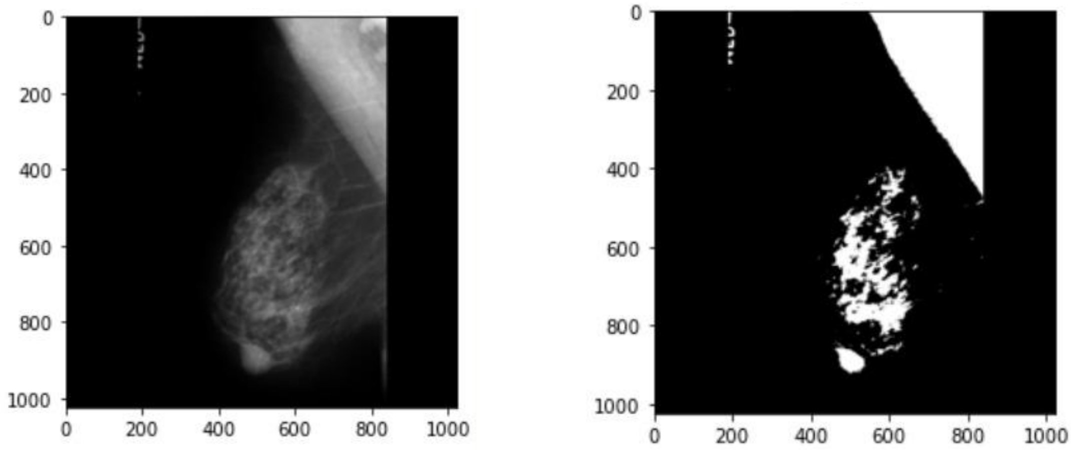

Fig 3.5 Slicing applied to the left mammogram

In the case of binarization, it is clear that this is essential in mammography for segmenting breast tissue from the background and identifying potential abnormalities. IT can be observed in this image that it separates the breast tissue from the surrounding structures and facilitates the detection of the lesions, but it can lose some important information or details, depending on the chosen threshold value. The tumor can be easily observed, but the details on the density of the tissue do not offer the same information as before.

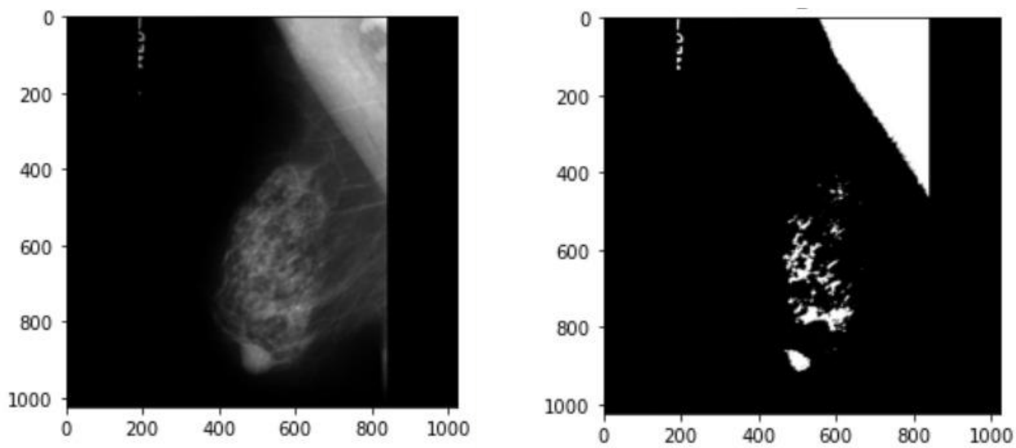

Fig 3.6 Binarization applied to the left mammogram

Otsu's method is particularly useful in mammography for automatically determining an optimal threshold for binarization, which can be crucial for detecting subtle abnormalities with varying intensity levels. Even though Otsu’s method gives its best performance for only those images that have clear bi-modal pattern, this might be the best option of these three because of its ability to determine the threshold value. Mammographic images can contain subtle features, such as microcalcifications or tissue density variations, which may not result in a distinct bi-modal histogram, but this method loses the least amount of details, by highlighting the tumor part and the higher density tissue.

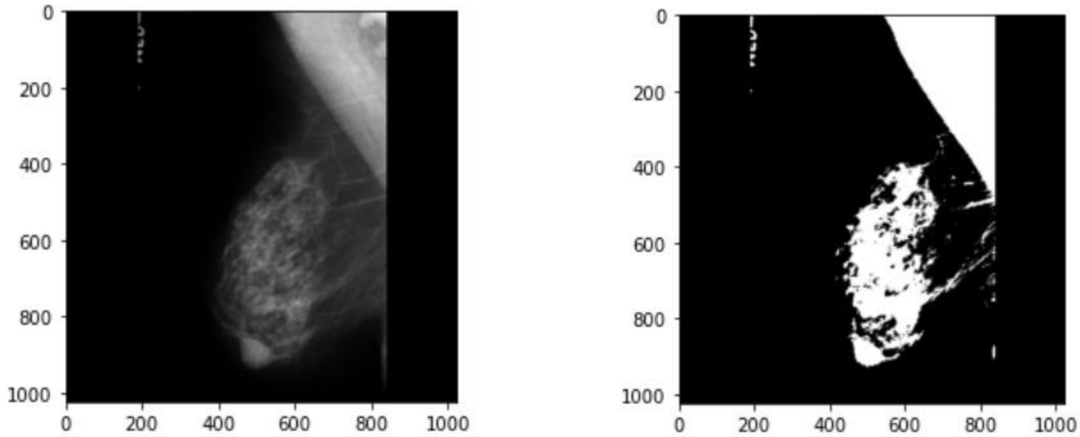

Fig 3.7 Otsu applied to the left mammogram

In the case of erosion, dilation and gradient morphologic transform the images resulting from the proposed methods differ from case to case and the definition of the morphological transform is not so trivial. In some cases, when the tissue is healthy, the dilation method might be a good choice.

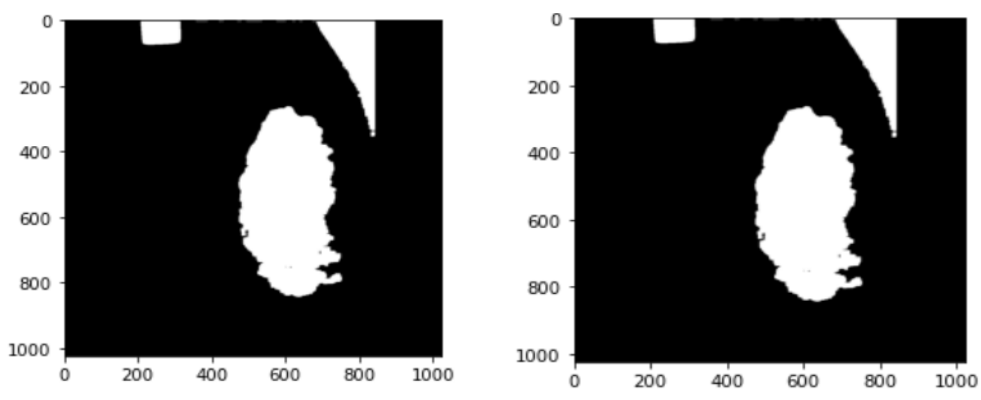

Figure 3.8. Left input image, right output dilated image

However, there are cases when the morphological expansion can come into place, and be the better option. These cases include images in which the tumor is brighter than the tissue and can be extracted via the preceding operations. Afterwards, it is a good option to have a way of seeing the shape of the tumoral tissue in order to determine if it is malign or benign.

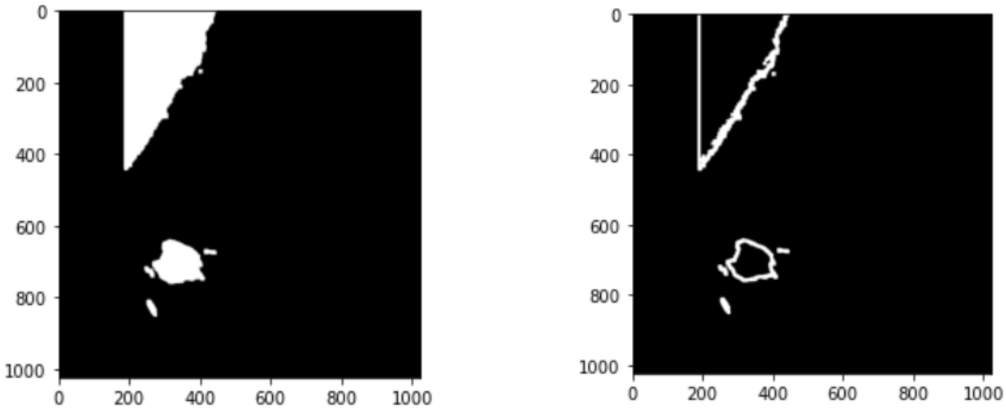

Figure 3.9. Left input image, right output morphological gradient image

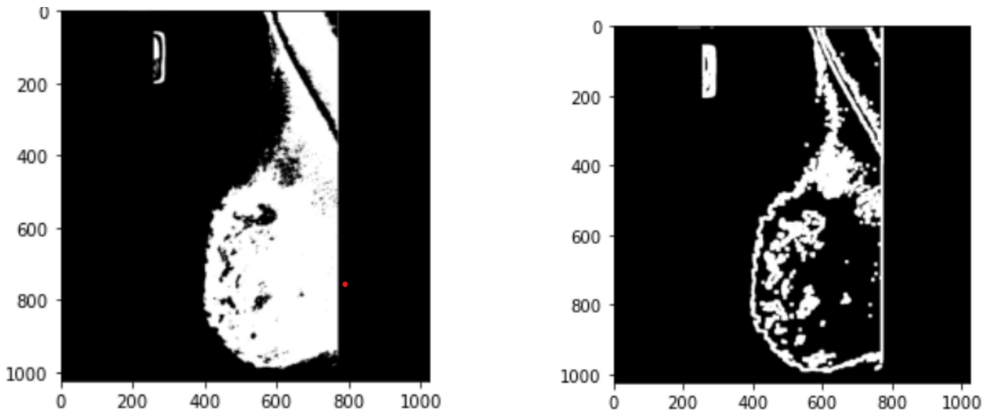

Figure 3.10. Left input image, right output morphological gradient image

But there are also cases when none of the processes result in a good post processed image.
For example when the following input image is given to the morphologic operation stage of the pipeline the following results yield.

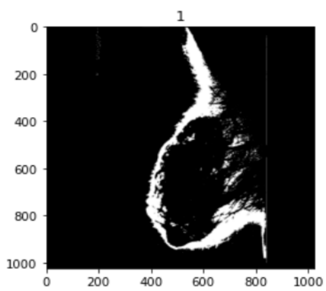

Figure 3.11. Input image, malign pathology

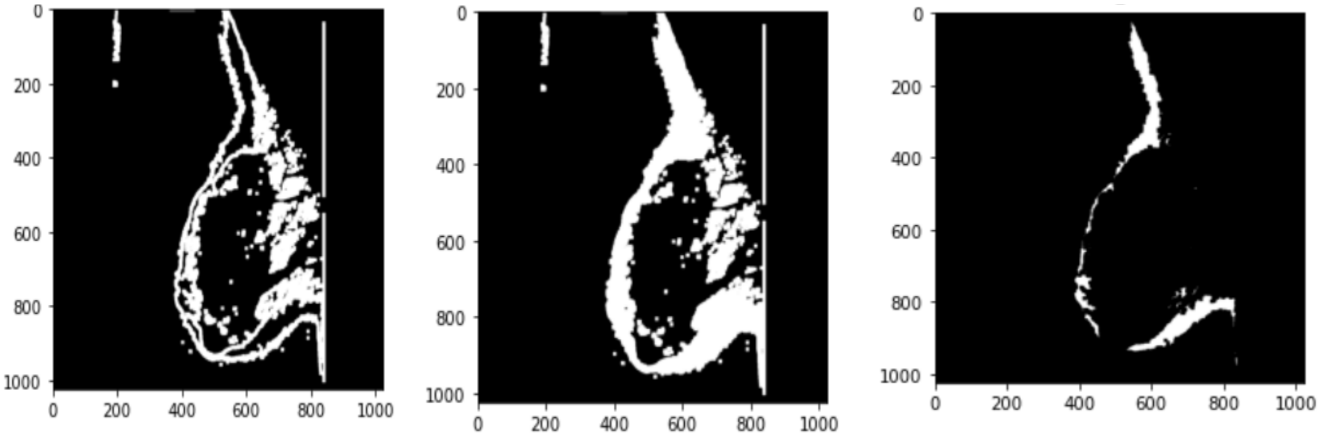

Figure 3.12. Resulting images

Synthesizing the findings above, the recommended implementation algorithm unfolds as follows:

1. Initiate the processing of the mammogram through the exponential transform.
2. Subsequently, refine the resulting image through the Otsu transform.
3. Further enhance the image by applying the erosion transform.
4. Culminate the process to obtain the final image.

In conclusion, we can observe that the most successful implementation consists in multiple methods of image processing, starting with Exponential transform of contrast enhancement, followed by the Otsu's Method of segmentation and finalized with the erosion morphologic transform.

In all of our images, the tumor and the surrounding breast tissue can be easily differentiated because of their difference in intensity. Mammographic images can contain subtle features, such as microcalcifications or tissue density variations, which can be highlighted by using the right methods in order to do a better analysis. Sometimes, the tumor can overlap with a higher density tissue, which can make it harder to detect it.

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