

IMPLEMENTATION OF A STAND-ALONE TOOL FOR SEGMENTATION OF  
PARENCHYMAL TISSUE AND CALCULATION OF THE PERCENTAGE OF  
BREAST DENSITY IN A DIGITAL MAMMOGRAPHIC IMAGES

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Degree Work to qualify for the title of  
Electronic Engineering

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## RESUMEN

**TÍTULO:** IMPLEMENTACIÓN DE UNA HERRAMIENTA INDEPENDIENTE PARA LA SEGMENTACIÓN DEL TEJIDO PARENQUIMATOSO Y CÁLCULO DEL PORCENTAJE DE DENSIDAD MAMARIA EN IMÁGENES MAMOGRAFICAS DIGITALES \*

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**PALABRAS CLAVE:** IMAGENES MAMOGRAFICAS, PROCESAMIENTO DE IMAGENES, PROCESAMIENTO DE SEÑALES, BIOINGENIERIA.

### DESCRIPCIÓN:

El cáncer de mama es el cáncer más común en mujeres en el mundo y es responsable de la muerte de miles de mujeres cada año. Para disminuir el número de muertes, la investigación se ha centrado en los mecanismos de detección temprana reduciendo aproximadamente el 40 % las cifras de muerte comparada con las cifras de los años 90's, como la identificación de mujeres con alto riesgo de desarrollar cáncer de mama. El riesgo de desarrollar cáncer de mama se puede evaluar a partir de diferentes fuentes, como el análisis de imágenes, datos clínicos e información genética. El análisis de imágenes de mamografía computarizada (análisis parenquimatoso) ha mostrado un buen potencial para la evaluación de riesgos. Por este motivo, actualmente existen y se desarrollan varias herramientas para el análisis del parénquima. Sin embargo, algunas de estas herramientas no están implementados en software libre, no son de código abierto o no tienen una interfaz gráfica para interactuar con el usuario.

Para fomentar el acceso a estas herramientas de software, este trabajo consiste en la migración de tareas básicas para realizar de evaluación de riesgo desde la compilación OpenBreast (Validada clínicamente en la evaluación de riesgo) y desarrollo de una suite de análisis de parénquima, llamada OpenBreast1.0, que cuenta con tareas como la anotación de anomalías o excepciones. La migración se realiza a una plataforma de código abierto en Python integrando la herramienta con una interfaz gráfica de usuario desarrollada en el framework abierto Qt.

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\* Trabajo de grado

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## **ABSTRACT**

**TITLE:** IMPLEMENTATION OF A STAND-ALONE TOOL FOR SEGMENTATION OF PARENCHYMAL TISSUE AND CALCULATION OF THE PERCENTAGE OF BREAST DENSITY IN A DIGITAL MAMMOGRAPHIC IMAGES \*

**AUTHOR:** MARLY DANIELA GALLO PEREZ \*\*

**KEYWORDS:** MAMMOGRAPHY IMAGES, IMAGE PROCESSING, SIGNALS PROCESSING, BIO-ENGINEERING.

### **DESCRIPTION:**

Breast cancer is the most common cancer in women in the world and is responsible for the death of thousands of women each year. To reduce the number of deaths, research has focused on early detection mechanisms, reducing death figures by approximately 40 % compared to the figures from the 1990s, such as the identification of women at high risk of developing breast cancer. The risk of developing breast cancer can be assessed from different sources, such as image analysis, clinical data, and genetic information. Computed mammography image analysis (parenchymal analysis) has shown good potential for risk assessment. For this reason, several tools currently exist and are being developed for the analysis of the parenchyma. However, some of these tools are not implemented in free software, are not open source, or do not have a graphical interface to interact with the user.

To promote access to these software tools, this work consists of the migration of basic tasks to perform risk assessment from the OpenBreast compilation (clinically validated in risk assessment) and the development of a parenchyma analysis suite, called OpenBreast1.0, which has tasks like logging anomalies or exceptions. The migration is carried out to an open-source platform in Python integrating the tool with a graphical user interface developed in the open Qt framework.

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\* Bachelor Thesis

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## INTRODUCTION

Breast cancer has become common cancer in the world, surpassing lung cancer for the first time in 2020 <sup>1</sup>. It is the leading cause of cancer death in less developed countries and the second leading cause of cancer death in American women, claiming the lives of more than 42,000 women in 2020 alone <sup>2</sup>. The percentage of deaths from breast cancer has been declining since the 1990s by almost 40 % until 2017 <sup>3</sup>. The decrease in breast cancer mortality has been attributed to both improvements in treatment and earlier detection <sup>3</sup>.

For early detection, mammography is the most utilized image modality in screening programs worldwide. In the last decades, studies have focused on the identification of high risk population due to its relevance in early detection <sup>4</sup>. Breast cancer risk assessment seeks to identify a smaller group of women at risk to carry out a more detailed follow-up of this risk population to reduce cases of late detection.

Breast cancer risk is assessed from different sources such as clinical data, genetic information, and image analysis<sup>5</sup>. Risk assessment based on mammography ima-

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<sup>1</sup> American Cancer Society. *Cancer Facts & Figures 2020*. [www.cancer.org/research/cancer-facts-statistics/all-cancer-facts-figures/cancer-facts-figures-2020.html](http://www.cancer.org/research/cancer-facts-statistics/all-cancer-facts-figures/cancer-facts-figures-2020.html). 2020.

<sup>2</sup> Breast Cancer Research Foundation. *Breast Cancer Statistics And Resources*. <https://www.bcrf.org/breast-cancer-statistics-and-resources>. 2021.

<sup>3</sup> Pamela HALLQUIST. "The American Cancer Society's Facts Figures: 2020 Edition". En: *Journal of the Advanced Practitioner in Oncology* 11.2 (2020). DOI: 10.6004/jadpro.2020.11.2.1.

<sup>4</sup> Aimilia GASTOUNIOTI, Emily F. CONANT y Despina KONTOS. "Beyond breast density: a review on the advancing role of parenchymal texture analysis in breast cancer risk assessment". En: *Breast Cancer Research* 18.1 (2016). DOI: 10.1186/s13058-016-0755-8.

<sup>5</sup> Lora D. BARKE y Mary E. FREIVOGEL. "Breast Cancer Risk Assessment Models and High-Risk Screening". En: *Radiologic Clinics of North America* 55.3 (2017), págs. 457-474. DOI: 10.1016/j.rc1.2016.12.013.

ges, known as *parenchymal analysis*, has shown a positive association with the development of the disease in the general population <sup>6</sup>. The parenchymal analysis consists of the automatic quantitative characterization of all the texture patterns in mammography images. <sup>7</sup>.

Currently, due to the importance of parenchymal analysis in risk assessment, there are publicly available tools for this purpose such as OpenBreast <sup>8</sup> that has been clinically validated <sup>9</sup>. Despite this tool being open-source, it is implemented in non-free software (Matlab), which means that developers or open source users cannot contribute to it. Moreover, OpenBreast has not a graphical user interface for interaction. These limitations make it difficult to validate the tool in clinical practice and to reach a wider population. An important feature of a publicly available open-source implementation is that the community can validate, catch bugs, and submit or develop enhancements to the tool, making tool development collaborative. Finally, it is also important that the developments are focused on being friendly with the end-users and that their use can be carried out easily, so it is useful and pertinent to integrate a graphical user interface.

In this work, we develop the first version of the open-source migration to python of OpenBreast <sup>8</sup>. This version was updated with a user interface to reach a wider population and facilitate its usage. The migration will be called OpenBreast10. In OpenBreast10 the basic tasks of the platform were migrated since the complete

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<sup>6</sup> KOMEN, Susan G. *Estimating Breast Cancer Risk (Gail Model)*. Oct. de 2021.

<sup>7</sup> Breast Cancer Research Foundation. *Breast Cancer Statistics And Resources*. Ago. de 2021.

<sup>8</sup> Said PERTUZ y col. "Open Framework for Mammography-based Breast Cancer Risk Assessment". En: *2019 IEEE EMBS International Conference on Biomedical Health Informatics (BHI)*. 2019, págs. 1-4. DOI: 10.1109/BHI.2019.8834599.

<sup>9</sup> Said PERTUZ y col. "Clinical evaluation of a fully-automated parenchymal analysis software for breast cancer risk assessment: A pilot study in a Finnish sample". En: *European Journal of Radiology* 121 (2019), págs. 108710. DOI: <https://doi.org/10.1016/j.ejrad.2019.108710>.



migration is outside the scope of the project. Furthermore, we contribute with an ImageJ plugging for manual annotation of lesions.

## **1. OBJECTIVES**

### **1.1. GENERAL OBJECTIVES**

- To implement a stand-alone and assisted tool for the manual annotation of parenchymal tissue, dense tissue and breast anomalies by a radiologist and calculation of the percentage of breast density in digital mammograms.

### **1.2. SPECIFIC OBJECTIVES**

- To design an algorithm for interactive dense tissue segmentation in digital mammogram.
- To design an algorithm for interactive segmentation of anomalous findings in digital mammograms.
- To integrate the algorithms previously developed into a stand-alone, platform-independent interface.

## 2. MATERIALS AND METHODS

OpenBreast is a tool for breast cancer risk assessment that was developed at Universidad Industrial de Santander in cooperation with Tampere University of Technology, Brigham and Women's Hospital, and Tampere University Hospital in 2019. This tool was clinically validated for its utilization in breast cancer risk assessment in <sup>9</sup>. OpenBreast was originally implemented in Matlab <sup>10</sup>.

OpenBreast is a compilation of algorithms for different mammography processing tasks, such as automatic breast segmentation, detection of regions of interest, extraction of texture features, and prediction of risk models.

### 2.1. OpenBreast10 Migration

In the process of migration of OpenBreast functionalities, the Python programming language was chosen. The python programming language has increased its applications in recent years, especially in software development. This is due to the wide development and acceptance that it has had by the scientific community as it is an open-source programming language <sup>11</sup>.

The functionalities migrated from OpenBreast <sup>10</sup> are the following:

**Contrast Enhancement** Contrast enhancement aims to improve the visualization of mammograms. To improve contrast, we use contrast limited adaptive histogram equalization (CLAHE)<sup>12</sup>. In this method, the image is divided into tiles. For each

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<sup>10</sup> Said PERTUZ. *OpenBreast*. Ago. de 2019.

<sup>11</sup> Org Python. *Applications for Python*. 2021.

<sup>12</sup> Paul HECKBERT. *Contrast Limited Adaptive Histogram Equalization*. AP Professional, 1994.

tile his histogram is equalized, i.e. the pixels in the brightest region are mapped in the entire region in the histogram. To avoid amplification of noise, contrast limiting is applied, i.e., if any histogram bin is above the specified contrast limit, those pixels are clipped and distributed uniformly to other bins before applying histogram equalization<sup>13</sup>.

**Background detection** For background detection, we implemented the method proposed in **PaperBS** for full-field digital mammography (FFDM) imaging. In that work, the background is detected simply by setting the threshold of the input image based on the highest mode of the intensity histogram. The detection of the mammary area is carried out based on the intensity of the image histogram, thus separating the breast into two regions: background and foreground.

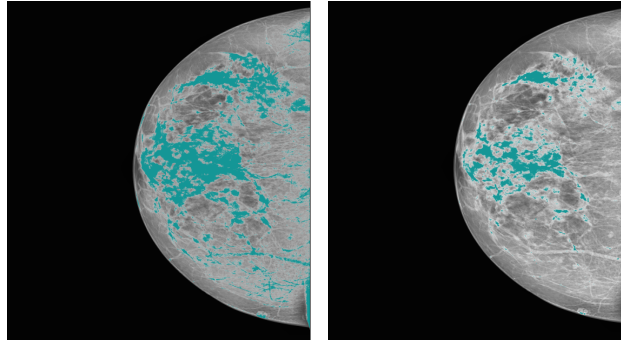
**Chest Wall Segmentation** For the first version of the migration tool, semi-automatic detection was used, which requires user interaction. The original OpenBreast implementation is fully automatic. The user selects some points on the contour of the chest wall so that by interpolation of each two points an approximation of the chest wall is drawn. The greater the number of points that the user contributes, the better the detection of the chest wall.

**Density Estimation** Breast density estimation was implemented using an interactive thresholding technique used in<sup>9</sup>. This technique allows a radiologist to segment dense parenchymal tissue from non-dense tissue by manually adjusting the intensity threshold on the mammogram. Fig. 2.1 shows tissue segmentation for intensity threshold values at 70.1 % and 90.2 %.

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<sup>13</sup> Docs.opencv.org. *OpenCV: Histograms - 2: Histogram Equalization*. 2021.

Figure 2.1. Dense Tissue Segmentation with different intensity threshold



## 2.2. OpenBreast10 Upgrades

In research tasks as well as in some clinical applications, it is necessary for the radiologist to manually select regions within the image for subsequent analysis. Because the original OpenBreast does not include interactive user interfaces, we updated OpenBreast10 by including manual annotation features.

**Manual segmentation of lesions** The QT5 framework used allows the use of different types of *pens* available in an open-source library (with the QPen class). These pens can be configured depending on the application <sup>14</sup>, we use this property to annotate anomalies with the pen configured freehand. This annotation must be done manually by the user of the tool.

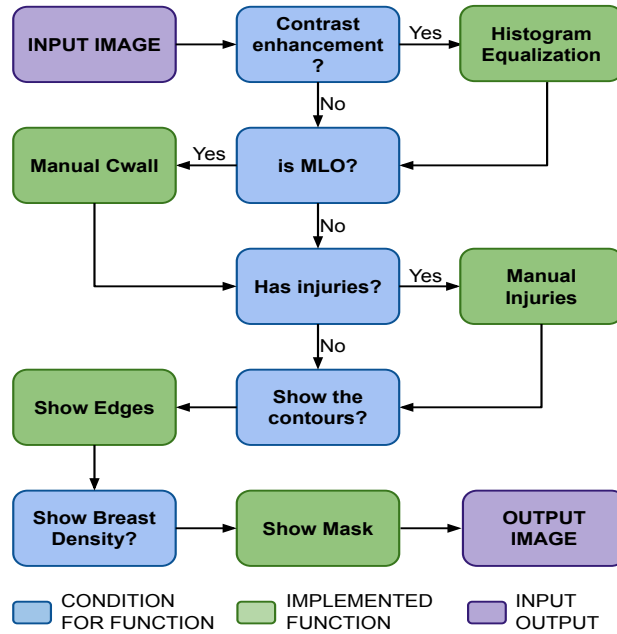
Analysis with OpenBreast10 can be performed on images by following the workflow shown in Fig. 2.2. This flow shows which of the implemented functions satisfies each requirement according to the image being processed. The "Breast Contour Show" condition is linked to the user being able to observe the ROI to be analyzed after the segmentation of the chest wall and the annotations. The "Show Edges" function shows the resulting ROI after the process of breast segmentation and lesion anno-

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<sup>14</sup> Doc.qt.io. *QPen* — *Qt for Python*. 2021.

tation. The "Breast Density Adjustcondition is linked to the threshold adjustment that the user can make to segment the dense tissue that is within the ROI. Finally, The "Show mask"function shows the dense tissue that is inside the ROI.

Figure 2.2. Workflow for manual annotation of regions of interest



OpenBreast10 is a semi-automatic tool so it requires certain inputs from the user, so it was pertinent to add a graphical user interface. The implementation of a graphical user interface was carried out in the open-source QT5 framework for python pyqt5<sup>15</sup>. This allows for easy use by users of the new version and for the user to perform the interactions required for the analysis.

<sup>15</sup> PyPI. *PyQt5*. 2021.

### 3. RESULTS

In this section we present the results obtained after the implementation of OpenBreast10. Different scenarios will be presented below with each of them to exemplify the results obtained.

To validate the correct functioning of the methods implemented in OpenBreast10, it is necessary to have access to a dataset of mammograms. In the framework of this project, we use InBreast <sup>16</sup>, a public database that has a total of 412 images corresponding to 103 female patients. For each patient, there are four images, two medio-lateral oblique (MLO) and two craniocaudal (CC) views. The types of images in the dataset are shown in Fig. 3.1

Fig. 3.2 illustrates some of the functionalities described in previous section: histogram equalization, breast segmentation, chest wall detection, manual annotation of lesion, and dense tissue is estimation.

The implemented interface layout is shown in Fig. 3.3.

Zone A is the file zone in which you can open the folder of the images in which you are going to work, save the image with the annotations made, access the help section in which there is a small user guide, and exit the tool. Zone B is the image display area, where the image is initially loaded and each processing step can be viewed. Zone C are the sliding bars, the vertical bar is the adjustable threshold for the segmentation of dense tissue. The horizontal bars are area filter, chest gap, and skin gap respectively. With "area filter"(corresponding to the area of the Gaussian filter) the user can soften the contrast of the image he is observing, i.e., this bar allows the user to adjust the results obtained from the CLAHE. With "Chest Gap", and "Skin

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<sup>16</sup> Ting LIN. *Dataset of Breast mammography images with Masses*. Jul. de 2020.

Figure 3.1. InBreast data-set sample images

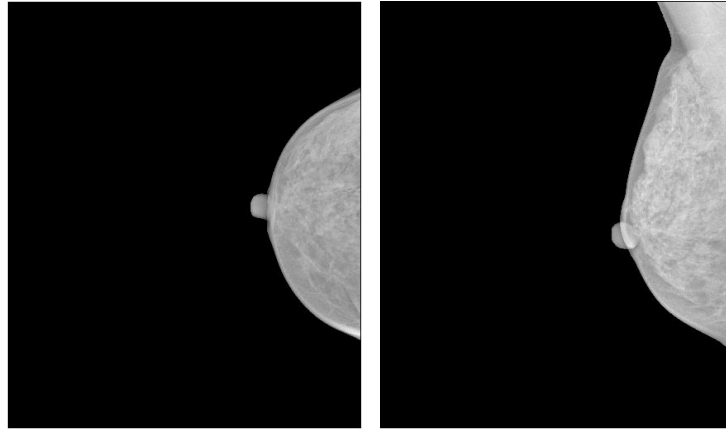


Figure 3.2. Basic processing tasks on MLO view mammogram. From left to right: input mammogram, histogram equalization, contour detection, chest wall detection, manual annotation of lesions and density estimation.

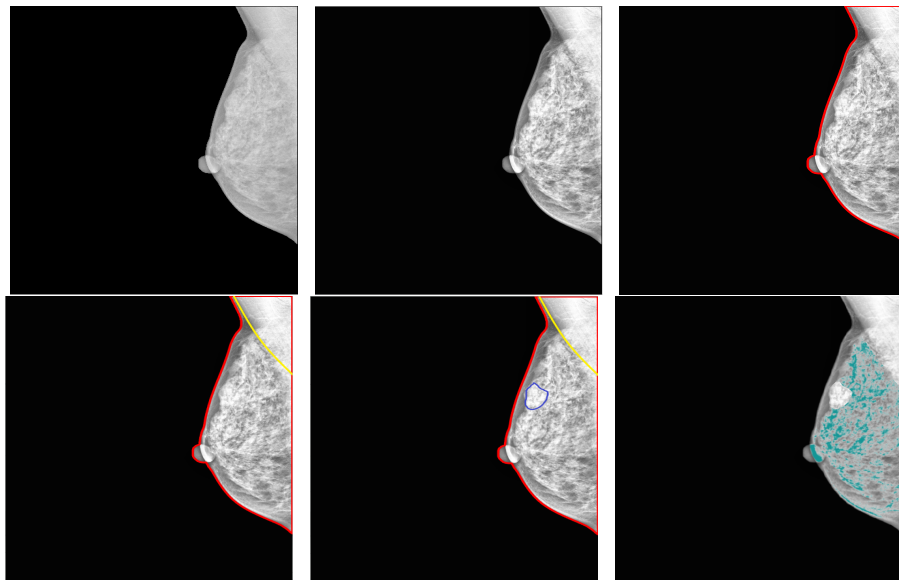
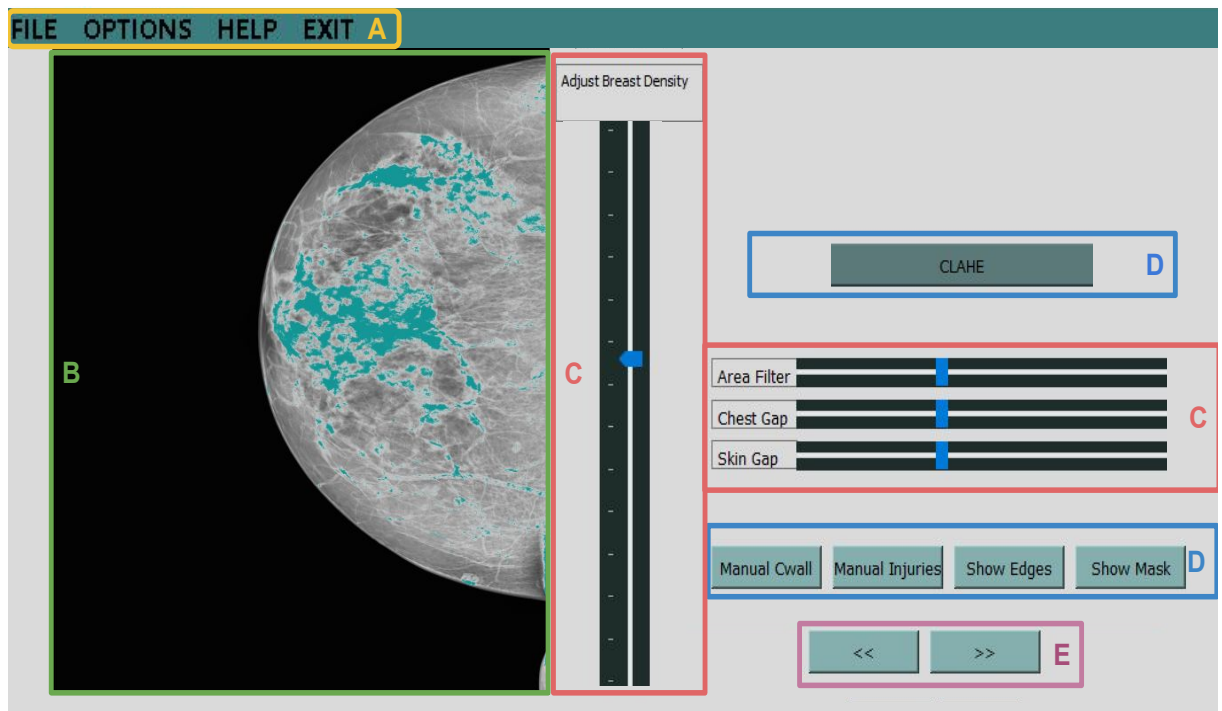




Figure 3.3. Implemented GUI. The interface allows the segmentation of dense tissue and manual annotation of chest wall



Gap"the user can adjust the ROI. Chest Gap allows you to slightly adjust the position of the detected chest wall, and "Skin Gap" allows you to leave a space between the linear of the detected breast (in the background detection process) and where the ROI begins in which the dense tissue is going to be segmented. Zone D contains several controls for the visualization and annotation of lesions and chest wall. Finally, zone E is the navigation zone to move forward or backward in the dataset with each of the arrows. This is used to navigate in the folder where the initially loaded image is located.

#### 4. FURTHER CONTRIBUTIONS

One of the limitations when training algorithms for automatic tasks related to early cancer detection is the reduced amount of data for training and validation. We also decided to contribute to the development of a plugin in ImageJ to make annotations of mammography images to facilitate the creation of databases for algorithm training. ImageJ is an open-source tool that has been widely used for image processing <sup>17</sup>, due to its large number of developers and collaborators, it has its own bank of execution codes through its internal language known as a macro language, which allows for programmers to adapt different processes that the tool already has for the different utilities that are necessary <sup>18</sup>. For ImageJ, we implemented several functionalities related to image contrast enhancement, manual annotation of lesions and navigation for batch processing of several images. A detailed description of this implementation can be found in Appendix I.

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<sup>17</sup> Miura KOTA. *Bioimage Data Analysis*. Olympus, 2016.

<sup>18</sup> Image.sc forum. *Image Processing and analysis in Java*. 2021.

## 5. SUMMARY

The assessment of breast cancer risk in digital mammograms has shown a strong association with the development of Breast Cancer. This paper presented the migration of OpenBreast, a risk assessment tool, into an open-source version in Python. Our new open-source version can perform basic image processing tasks to include the following functionalities: contrast enhancement, breast detection, semiautomatic chest wall segmentation for medial-lateral oblique (MLO) images, manual segmentation of anomalies, and detection of dense tissue with the adaptive threshold method. The developed version does not include advanced cancer risks assessment features, such as radiomic feature extraction and risk modeling. These tasks should be tackled in future work. Finally, to contribute to the creation of data for algorithm training, the implementation of a plugin for ImageJ with different techniques and contrast enhancement functionalities was presented to facilitate the work of annotating mammography images. The works presented here seek to contribute to the early detection of breast cancer.

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## A. Appendix

- AHE. Adaptive histogram equalization (AHE) is a widely used algorithm in image processing to improve contrast. It consists of the recursive calculation of different histograms to enhance the contrast of sections of the image, according to the pixels that are in the vicinity of it. This function, however, in some images can increase noise, which is why a CLAHE enhancement was also implemented to solve this problem.
- CLAHE. The method is the same used in OpenBreast10 (implemented another programming language). The code taken from <sup>19</sup>.

Implementations were also made to navigate forward or backward in the middle of working images. An option was also implemented to restore the original contrast of the image or erase the annotations made previously. The Back and Forward buttons store the annotation automatically (avoiding repetitive work such as saving the drawing made each time it is annotated), and show the annotations that the current image has that has been made in a previous session. Annotations are automatically saved in a text document in XY format with the location of the annotated pixels. The start menu is shown in Fig. A.1

This plugin also contains a function to save the last annotation session and thus continue where the previous session ends immediately, avoiding waste of time and resources for health professionals, this is shown in Fig. A.2

In Fig. A.3 annotations made for AHE and CLAHE contrast applications are shown, and the user can choose which one fits the needs of each image being evaluated. The annotations made were made by the student, for illustrative purposes only.

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<sup>19</sup> Stephan SAALFELD. *CLAHE (Contrast Limited Adaptive Histogram Equalization)*. 2017.

Figure A.1. Into Start Menu, From left to right are the buttons to go back, forward, apply AHE, apply CLAHE, and finally delete annotations and/or restore to the original image.

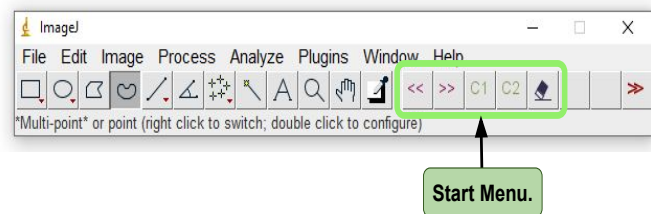


Figure A.2. Last File Plugin

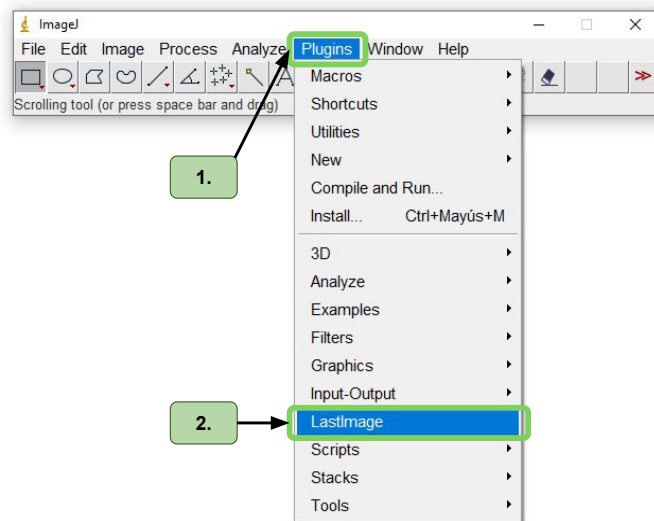


Figure A.3. Annotation of images with different contrast enhancement

