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U-NET BASED MEDICAL IMAGE SEGMENTATION ON BREAST CANCER MAMMOGRAMS

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THESIS ACCEPTANCE

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
CBIS-DDSM	Curated Breast Imaging Subset of the Digital Database for Screening Mammography
ABUS	Automated Breast Ultrasound
CNN	Convolutional Neural Network
FCN	Fully Convolutional Network
cGAN	Conditional Generative Adversarial Network
FrCN	Fully Resolution Convolutional Network
DS U-Net	Deeply Supervised U-Net
FS-Unet	Feature-Strengthened U-Net
HTU-Net	Hybrid Transformer U-Net
ROI	Region of Interest
TCIA	Cancer Imaging Archive
DICOM	Digital Imaging and Communications Medicine
CLAHE	Contrast-Limited Adaptive Histogram Equalization

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I. ABSTRACT

Breast cancer is still one of the main causes of cancer related mortality for the women throughout the world, where almost 670 000 reported death and over 2.3 million new cases in 2022. For improving the outcomes and reducing the treatment costs for patients, early detection of unhealthy lesions in breast medical images is quite important. In this study, using the Curated Breast Imaging Subset of the Digital Database for Screening Mammography (CBIS-DDSM) dataset a comprehensive deep-learning based segmentation pipeline is created to evaluate and solve challenges faced when working on high-resolution medical images, in this case breast mammograms with the help of U-Net deep learning architecture.

Starting with CBIS-DDSM dataset, the first addressed issue has been general preprocessing issues in the dataset such as combining full mammograms and region-of-interest (ROI) masks with the help of automated dictionary mapping for preparing them for augmentation. Augmentation step is done by cropping image mask pairs into $n \times n$ grids (for n ranging from 2 to 16) with the shape 256×256 . These pairs are then fed into a U-Net model optimized with a composite loss function which is a combination of binary cross-entropy and Dice loss.

During the inference, those patch-level probability maps are combined into a full size mammogram images and masks, and comprehensive pixel-count thresholding techniques such as intersection and union of them are employed. For each of the images inside the test set, the threshold value t which maximizes the Intersection over Union (IoU) is selected and compared to the original ROI mask of that exact image. Final achieved metrics values are: average IoU value of 0.60, average accuracy of 0.99, precision value of 0.72, recall value of 0.77, and finally F1 score of 0.71. According to those qualitative results, the model reliably detects the lesion boundaries even in some challenging scenarios where the mammogram have some dense tissues. It is noteworthy to highlight that cropping-based U-Net architecture might have a potential to work and improve with different mechanisms in the future.

II. INTRODUCTION

Definition of the Problem

Medical imaging is considered to be a modern approach in medicine, and it aims at visually demonstrating different organs and tissues within the human body. Being a less invasive, faster and more precise method compared with classical medical techniques, medical imaging is used widely nowadays and it evolved from being a diagnostic tool to a treating and predicting tool lately. Medical imaging has become an important component of modern healthcare, utilized in the diagnosis and management of various medical conditions, including but not limited to cancer, cardiovascular diseases, traumatic injuries, neurological disorders, and other numerous ailments.

Among all types of cancer, breast cancer can be considered one of the most commonly spread and life-threatening diseases which affect the women worldwide. Female breast has multiple lobes, and each of them contain many different lobules which produce milk, and they also have multiple ducts linked to each other and they transport milk to the nipple for breastfeeding. Cancerous unhealthy tissue generally occurs when a genetic mutation happens in a cell inside a lobule that makes it to grow excessively compared to other lobules. So, breast cancer is thought to affect the lobules and ducts that are responsible to produce and transport milk [1].

According to the Global Cancer Statistics in 2022 breast cancer led to approximately 670,000 deaths, whereas almost 2.3 million women are diagnosed with breast cancer each year [1]. It is thought that till 2040, the death rate is going to be increased to 50% of population while the amount of people with this disease is going to be increased by more than 40% surpassing 3 million cases considering the growth in human population and aging demographics. In the USA, 1 in 8, approximately 13% of the women are likely to be diagnosed with breast cancer at least once throughout their whole life [2].

Since major factors are genetics and age, there are other affecting factors like environmental exposure, hormonal imbalances and different lifestyle choices. Different studies demonstrate that early detection and treatment of the breast cancer cases help decreasing the mortality rates and

treatment costs. This highlights an urgent need for better prevention which might be done with the help of early diagnosis and new treatment strategies, but challenges still exist in accurate detection when using conventional imaging tools.

Currently, ultrasound and mammography are considered as two standard ways of detecting breast tumors. Despite that those two ways are quite different from each other and have some limitations. Firstly, two dimensional (2D) ultrasounds cannot screen the whole breast at once, and there is a possibility of missing the tumor. Because of that reason, Automated Breast Ultrasound (ABUS) is developed for scanning the entire breast providing with 3D view. Second and the primary tool for screening is mammography despite lacking sensitivity to detect dense breast tissues which may lead to false negatives or delayed diagnosis, especially in younger women.

Problem Statement

Despite the latest advancements in screening technologies, early and accurate detection of breast cancer still remains as a major issue, especially in mammograms with dense breast tissues. Since traditional image interpretations like ultrasound and mammograms rely highly on radiologists, there is a fact of increased workload and human error. Because of that reason, there is a need for accurate, automated, and efficient segmentation techniques for identifying unhealthy regions inside the mammograms to improve patient outcomes.

Generally, early detection of the cancer tissue plays a significant role to have high survival rate among the patients. According to the statistics in North America, percent of survival had increased over 80% and treatment costs are decreased thanks to early detection [3]. Despite this progress, low-income and middle-income countries still face the challenges regarding to access to effective screening and treatment methods. However, screening tools alone are not enough for early detection of the breast cancer. As a response to these challenges, tools that are created using artificial intelligence and deep learning algorithms are progressively being integrated into the diagnostic systems.

These AI-based tools help improving image interpretation, detecting anomalies, and support radiologists in making faster and more accurate assessments which lead to increased

workload on radiologists. In a recent study involving 50 active radiologists in the United States, approximately 90% of respondents reported an increased workload over the past three years, with 28% experiencing a workload surge of over 20%. The main reason based people doing the survey, 78% of those who has heavier workloads, was the rising number of scans [4]. This aligns with existing academic literature, emphasizing the growing demand for radiologists to maintain both speed and accuracy when interpreting scans.

Artificial intelligence (AI) with the help of Machine Learning (ML) tools, can help overcoming these issues. It also helps improving the accuracy of the results and bring significant advancements in the field of medical imaging [4]. To support high-quality dataset creation and assist radiologists in annotating tumor regions, we developed a custom labeling tool specifically tailored for breast cancer medical imaging. Our tool was designed to handle mammography images, offering a simplified interface where radiologists can load images, draw tumor boundaries using a rectangle brush, and save the resulting masks in a compatible format for model training.

The tool provides some functionalities such as zooming, erasing, and real-time drawing of the annotation on the original image, and ensures more accurate and efficient labeling. By streamlining the annotation process, the tool can play an important role in accelerating dataset preparation, improving label consistency, and generally enhancing the performance of the deep learning model [5].

Additionally, having human-computer interaction tools also support early and accurate detection of the cancerous tissue easily, helping the radiologists localizing the regions that they suspect to have unhealthy tissues. In conclusion, although significant improvements have been made in breast cancer detection area, there is still a need for continuous research in healthcare area for further reduce the consequences of this disease.

Objective of the Study

The objective of this study is to develop a deep learning based breast cancer mammogram segmentation pipeline using the CBIS-DDSM dataset with the help of a U-Net architecture. The goal is to create a preprocessing pipeline to resolve the inconsistencies inside the dataset, cropping large high-resolution mammograms into smaller $n \times n$

grids, training them using a U-Net model with a composite loss function (Binary Cross Entropy + Dice Loss) with the help of Kaggle TPUs, and evaluating the model performance with the help of metrics such as IoU, accuracy, precision, recall, and F1-score on full size reconstructed mammograms. In the end, the study focuses on improving automated lesion detection accuracy and contribute to the early diagnosis of the breast cancer mammograms using the deep learning algorithms.

III. LITERATURE REVIEW

Previous Results

As being the most common type of the cancer, and each year being a huge cause to the death of women, studies highlight the need of mammography checking for women quite frequently for reducing the mortality rate detecting the early appearance of the cancerous tissues before it spreads to other healthy tissues and organs. Each day, many mammograms are screened by the radiologists in order to detect place, shape, size, and the type of the tumor on the breast. Despite being an important work, it is expensive, time-consuming, and there is a possibility of misdetection, since some may be mistakenly detected, and missed due to excess workload of radiologists. Generally, thanks to medical image segmentation tasks, doctors can easily find and extract the information from the original mammograms, for further exploration of the suspicious tissues. According to research, latest computer vision algorithms were able to detect and segment medical images with lowest possible error rate and demonstrated quite remarkable results in this field [6].

Recent deep learning algorithms can easily detect and extract high-level details without an extra help of a human and other assistance. Research demonstrate that Convolutional Neural Networks (CNNs) are one of the architectures that displays highest results overall that are able to find the pixels that represent the unhealthy tissues having different forms, scales and shapes. Additionally, Fully Convolutional Networks (FCNs), encoder-decoder networks were also developed as medical image segmentation models, for further assistance to improve the segmentation job. They are known for their ability to detect fine-grained details inside the mammograms with extra complex backgrounds.