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Deep Learning for Early Breast Cancer Detection and Personalized Treatment Strategies

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Abstract
Breast cancer remains one of the most prevalent malignancies worldwide, where early diagnosis significantly improves survival rates and treatment outcomes. Recent advances in artificial intelligence (AI) and deep learning have demonstrated substantial potential to enhance histopathological image analysis and support precision oncology. This study presents an extended deep learning framework for early breast cancer detection using histopathological images and explores its potential application in personalized treatment strategies. The publicly available IDC_regular dataset comprising 277,524 image patches extracted from 162 whole-slide breast cancer specimens was utilized. A Convolutional Neural Network (CNN)-based architecture was employed for feature extraction and binary classification of invasive ductal carcinoma (IDC) positive and negative cases. The proposed framework incorporated image pre-processing, OpenCV-based transformations, data normalization, model training, and evaluation using precision, recall, F1-score, and accuracy metrics. Experimental results achieved an overall classification accuracy of 92%, with precision and recall values demonstrating reliable detection performance. Furthermore, saliency mapping techniques were introduced to improve interpretability and localize diagnostically relevant regions. The extracted deep features provide a foundation for future multi-class tumour characterization, risk stratification, and treatment response prediction. The findings suggest that AI-assisted pathology can reduce diagnostic workload, improve detection efficiency, and support personalized clinical decision-making. Future work will focus on integrating clinical, genomic, and treatment datasets to develop comprehensive precision oncology systems.

Keywords: Breast Cancer, Deep Learning, Convolutional Neural Network, Histopathology, Artificial Intelligence, Precision Oncology.

Introduction
According to the World Health Organization, breast cancer is among the most frequently diagnosed cancers globally and remains a leading cause of cancer-related mortality among women. Early diagnosis substantially increases treatment success and patient survival. Traditional histopathological diagnosis requires extensive manual examination by expert pathologists and may be influenced by inter-observer variability, workload, and diagnostic complexity. Artificial Intelligence (AI) (Mesquita, 2021), particularly Deep Learning (DL), has emerged as a transformative technology capable of automating image analysis while maintaining high diagnostic accuracy.

In our study, a CNN-based framework was developed using histopathological images from the IDC_regular dataset. While the model achieved promising results, limitations related to computational resources, class imbalance, and restricted binary classification remained. This work extends that research toward a broader oncology perspective by investigating how deep learning can contribute not only to early cancer detection but also to future personalized treatment planning.

Related Work
Recent advances have demonstrated that deep learning models outperform conventional machine learning techniques in medical image classification.

Notable architectures include [Malik, 2024; Uzila, 2022; Vina, 2025; Karim, 2019]:
- GoogleNet
- ResNet
- DenseNet
- AlexNet
- VGGNet (VGG-16)
- LeNet-5
- Inception-v1
- EfficientNet

These models have been successfully applied in [Zhou et al., 2021; Sarvamangala & Kulkarni, 2022; Kumar et al., 2025]:
- Histopathology image classification
- Tumour segmentation
- Radiomics
- Treatment response prediction
- Precision oncology

The growing availability of digital pathology datasets has accelerated the adoption of AI-assisted diagnostic systems.

Materials and Methods

Dataset

In this experiment, we proposed a Deep Learning algorithm, a convolutional neural network (Deepanshi, 2025) for diagnosing breast cancer using image processing (Image Processing in Python (n.d.). During this work, we used the IDC_regular dataset (the breast cancer histopathology image dataset) from Kaggle (Breast Histopathology Images (n.d.).

This dataset contains 277,524 patches of size 50×50 extracted from 162 whole-mount slide images of breast cancer specimens scanned at 40× magnification. Of these, 198,738 tested negative and 78,786 tested positive for IDC.

This experiment is divided into three parts – first, we collected the dataset and applied a pre-processing algorithm to scale and filter the data; then, we split the dataset for training and testing; and finally, we generated graphs for data visualization.

Table 1: The IDC Regular Dataset

Parameter	Value
Total Images	277524
IDC Negative	198738
IDC Positive	78786
Image Size	50x50 pixels
Whole Slide Images	162
Magnification	40x

Data Processing Pipeline

Image Acquisition
↓
Cancer / Non-Cancer Labeling
↓
OpenCV Transformation
↓
Normalization & Scaling
↓
Training / Testing Split
↓
CNN Training
↓
Model Evaluation
↓
Saliency Mapping
↓
Clinical Decision Support

CNN Architecture

Input Image (50×50×3)
↓
Convolution Layer (32 Filters)
↓
ReLU Activation
↓
Max Pooling
↓
Convolution Layer (64 Filters)
↓
ReLU Activation
↓
Max Pooling
↓
Flatten Layer
↓
Dense Layer (128 Neurons)
↓
Dropout (0.5)
↓
Output Layer (Cancer / No Cancer)

Architecture Explanation

- Convolution Layers: Extract texture, shape, and tissue patterns.
- Pooling Layers: Reduce dimensionality and improve computational efficiency.
- Dense Layer: Learns higher-level cancer characteristics.
- Dropout Layer: Prevents overfitting.
- Output Layer: Produces final classification probabilities.

Results and Discussion

After completion of the task using Python, the results are shown in Table 2 and Figure 1.

From the results, it can be observed that no-cancer detection achieved a precision of 94% with support from 33,328 samples. Cancer detection achieved a recall of 64% with support from 6,065 samples. The available CPU resources were insufficient for completing all 30 training epochs. With additional computational resources and extended training, model performance may improve further.

Our prime target was the early detection of cancer because early detection can help improve treatment outcomes. Therefore, we propose a saliency detection system with the help of advanced deep learning techniques such that the machine can emulate the actions of histopathologists for the localization of diagnostically pertinent regions.

Table 2: Result after computation EPOCH 18/30

	Precision	Recall	F1 score	Support
0 (No cancer)	0.94	0.97	0.95	33328
1 (Cancer)	0.79	0.64	0.71	6065
Accuracy			0.92	39393
Macro average	0.86	0.80	0.83	39393
Weighted average	0.91	0.92	0.91	39393

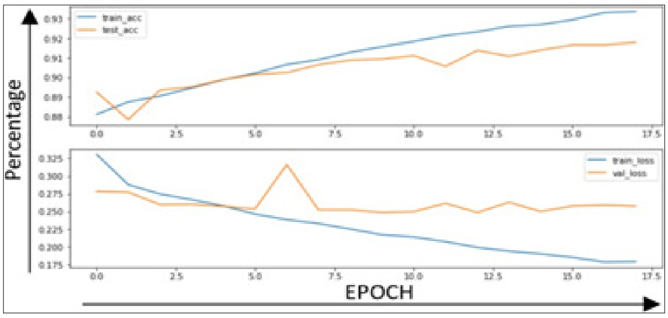

Figure 1: EPOCH execution by CPU up to 18/30

- The first graph is about training accuracy and testing accuracy
- The second graph is about training loss and validation loss
- There are some abnormalities but with more EPOCH training the percentage of accuracy is improving

The study demonstrates the significant role of deep learning in assisting breast cancer diagnosis. By automating feature extraction and classification, CNN models can reduce pathologists' workload while improving diagnostic consistency. The incorporation of saliency mapping further enhances model transparency by identifying diagnostically relevant regions, thereby increasing clinician trust and supporting explainable AI principles.

Personalized Treatment Strategies

Although the current model focuses on detection, deep learning can support personalized treatment through:

Risk Stratification

- Low-risk tumours
- Intermediate-risk tumours
- High-risk tumours

Treatment Recommendation Support

AI-derived imaging biomarkers may assist clinicians in:

- Chemotherapy selection
- Radiation planning
- Hormone therapy decisions
- Follow-up scheduling

Precision Oncology Framework

Histopathology Images
+
Clinical Data
+
Genomic Data
↓
Deep Learning Model
↓
Risk Prediction
↓
Personalized Treatment Plan

Future Work

Future improvements should focus on:

- Multi-class tumour recognition
- Transfer learning using ResNet/EfficientNet
- Explainable AI (XAI)
- Clinical metadata integration
- Treatment outcome prediction

Conclusion

Breast cancer detection by histopathology means the microscopic examination of a biopsy or surgical specimen. As early breast cancer detection is a major prevention, as it will help any patient or doctor for further treatment. But in reality, no AI program is 100% accurate for any activity, but these AI can help in the medical sector for primary detection. Our challenge was to provide at least false positive for cancer detection; we could not achieve more than 64% for positive cancer detection, and 94% for no cancer detection. In the future, we will try to improve this program further.

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