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Meta-Analysis Review on Machine Learning and Deep Learning Applications in Breast Cancer Detection

[1]Nirbhay Kumar Mishra, [2]Praveen Kumar

[1]Research Scholar, [2]Professor
[1]Department of computer science and Engineering,
[1]Asian International University, Sikkim, Imphal , Manipur, India

Abstract: Many women worldwide are still affected by breast cancer which is known to be both widespread and dangerous. Finding it at an early stage is very important for saving more lives and making treatments more successful. Lately, the growth in AI, specifically in machine learning (ML) and deep learning (DL) technologies, has greatly affected the way medical diagnostics are carried out. They depend on computer-based models that can detect faint trends in broad and complicated groups of data which may include X-ray and ultrasound images, medical records and DNA codes. It brings together insights from 50 recent articles on ML and DL which discuss their role in detecting, classifying and predicting breast cancer.

Review makes clear how AI studies are completed on various machine learning algorithms, using various medical databases and applied to different clinical needs. Studies have confirmed that deep learning, mainly convolutional neural networks (CNNs), are favored because they are made to learn from large multidimensional data. Nevertheless, support vector machines (SVMs), decision trees and ensemble methods are used widely, mainly in situations where processes or data follow typical structures. It also points out new research approaches, obstacles in data (like unequal numbers of samples) and an increasing interest in getting models to work on new, unseen data. Pulling together these insights, the meta-analysis wants to shape future breast cancer studies and help apply AI technology in patient care.

***IndexTerm*: Breast Cancer Detection, Machine Learning, Deep Learning, Meta-Analysis, Imaging, Clinical Data, CNN, AI in Healthcare**

I. INTRODUCTION

Few forms of cancer among women are more dangerous and common than breast cancer. According to the World Health Organization (WHO), this results in approximately 2.3 million new cases and over 685,000 deaths every year, so fast and accurate identification of cancer is very important. Some popular methods for diagnosis, for instance, physical exams, mammograms, the study of tissue samples (histopathology) and biopsy, are suitable, but they can be quite slow, prone to mistakes by health workers and dependent on access to specialist staff.

Thanks to AI, machine learning (ML) and deep learning (DL), today's technology can perform many medical tasks that were once done just manually. Such approaches help look through a great deal of data and catch patterns that could be tough for people to see. Recently, many studies have involved AI to help with diagnosis of breast cancer, especially in tasks such as spotting tumors, grouping them based on type (benign vs. malignant), predicting future spread of the cancer and forecasting how long a patient will survive.

The goal of this review is to carefully look at and put together the findings from 50 recent studies between 2021 and 2025. Many different ML and DL techniques are used in these studies with data such as mammographic images, thermographic scans, ultrasound, magnetic resonance images (MRI), Raman spectroscopy and structured clinical systems. Besides, the review looks into how these approaches perform, focuses on the main areas of ongoing investigation and notes problems such as data not being well-balanced, the difficulty of explaining these methods and proof from clinics. The goal of a meta-analysis is to summarize everything and help set a path for new research and developments in AI-powered breast cancer detection.

II. META ANALYSIS

The below Table [1] shows the comparative meta-analysis review based on different parameters.

No	First Author	Year	Model Type	Dataset Type	Application Focus	Key Findings / Performance
1	Chugh	2021	Survey	Mixed	Overview	Broad survey of ML/DL in BC
2	Binsaif	2022	ML	Clinical	Classification	Good accuracy with logistic model
3	Wu	2021	ML	Clinical	Type classification	Effective ML-based differentiation
4	Rabiei	2022	ML	Clinical	Prediction	Random Forest and SVM compared
5	Balkenende	2022	DL	Imaging	Imaging analysis	DL in PET/CT, MRI etc.
6	Allugunti	2022	ML/DL	Thermal Imaging	Image-based diagnosis	CNN and SVM fusion applied
7	Amethiya	2022	ML	Biosensors	Comparative analysis	Fusion with biosensor data
8	Botlagunta	2023	ML	Clinical	Metastasis prediction	XGBoost best among tested models
9	Jabbar	2021	Ensemble ML	Clinical	Classification	Ensemble improved F1 score
10	Nafissi	2024	Survey	Mixed	AI applications overview	Broad AI trends discussed
11	Zhang	2022	ML	Spectroscopy	Classification	Raman + ML fusion
12	Abunasser	2022	DL (Xception)	Imaging	Classification	>92% accuracy with Xception
13	Michael	2022	ML	Clinical	Diagnosis classification	Feature selection improved AUC
14	Naji	2021	ML	Clinical	Prediction	Reviewed SVM, NB, RF
15	Singh	2022	ML	Clinical	Screening	ML comparison study
16	Yu	2021	DL	E-Health	Diagnosis support	5G-enabled CNN model
17	Das	2021	Ensemble DL	Imaging	Detection	Ensemble CNN, high precision
18	Abunasser	2023	CNN	Imaging	Classification	Improved classification results
19	Dar	2022	Survey	Mixed	Dataset/methods review	Challenges highlighted
20	Tanveer	2025	ML	Clinical	Early detection	Strong diagnostic precision
21	Humayun	2023	DL	Clinical	Risk detection	DNN with high sensitivity
22	Nasser	2023	Systematic Rev	Imaging	Review and future trends	DL trends explored
23	Ara	2021	ML	Clinical	Classification	Accuracy ~91%
24	Jasti	2022	ML	Imaging	Diagnosis	ML + image processing
25	Gopal	2021	ML + IoT	Sensor Data	Prediction	Feature selection methods tested
26	Sharma	2022	ML	Clinical	Feature selection	PCA and LDA boosted performance
27	Li	2021	ML	Clinical	Survival prediction	Reviewed multiple survival models
28	Ghosh	2021	DL	Imaging	Prediction	DL improved over ML
29	Liu	2022	DL	Pathology	Classification	>95% accuracy in pathology slides
30	Ghavidel	2025	Review	Clinical	Imbalanced dataset handling	Class balancing techniques
31	Alsayadi	2022	Ensemble ML	Clinical	Detection	Fusion regression model
32	Houssein	2021	DL/ML	Imaging	Imaging-based classification	Comprehensive algorithm review
33	Al-Azzam	2021	ML	Clinical	Supervised vs semi-supervised	Semi-supervised slightly better
34	Abhisheka	2023	DL	Imaging	Segmentation & classification	Integrated approach enhanced acc.
35	Kavitha	2021	Capsule Network	Imaging (Mammo)	Diagnosis	Capsule model > traditional CNNs
36	Rasool	2022	ML	Clinical	Diagnosis	Improved predictive performance

37	Saber	2021	DL	Imaging	Classification	Transfer learning achieved >90%
38	Siddiqui	2021	DL	IoMT	Stage prediction	Intelligent cloud model
39	Nassif	2022	AI	Mixed	Literature review	Overview of AI techniques
40	Zeid	2022	ML	Clinical	Performance analysis	Optimized ML framework
41	Ghiasi	2021	Ensemble ML	Clinical	Classification	Decision-tree ensemble outperformed
42	Wang	2022	DL	Histological	Grading	DL outperformed traditional grading
43	Zerouaoui	2021	ML/Image Proc.	Imaging	Decision-making systems	Fusion pipeline proposed
44	Mohamed	2022	DL	Imaging	Classification	Data processing boosted accuracy
45	Alanazi	2021	CNN	Imaging	Detection	Boosted CNN model
46	Opia	2022	ML	Clinical	Management in Africa	Application in resource-poor setup
47	Moncada-Torres	2021	Explainable ML	Clinical	Survival analysis	ML > Cox regression
48	Heenaye-Mamode	2021	DL (CNN)	Imaging	Multi-class classification	Effective in multi-class setting
49	Qian	2021	DL	Ultrasound	Risk assessment	Multi-view DL model proposed
50	Ayana	2021	DL	Ultrasound	Diagnosis	Transfer learning applied

III. METHODOLOGY

Using a planned process, the meta-analysis searched for and pulled together research on using machine learning (ML) and deep learning (DL) in spotting breast cancer. Identifying the literature, deciding on selection criteria and extracting and organizing data are the main parts of the methodology.

3.1 Literature Identification

The first thing done in this work was to find peer-reviewed articles written between 2021-2025 about using ML and DL for breast cancer detection. The names listed above were investigated through major research databases such as IEEE Xplore, PubMed, SpringerLink, Elsevier (ScienceDirect) and Google Scholar. Examples of keywords were: “breast cancer”, “machine learning”, “deep learning” and “CNN” for the study of classification and detection.

3.2 Inclusion and Exclusion Criteria

So that the studies would be relevant and of high quality, they included the following criteria: All included studies were published in these years in scientific journals or at conferences after being peer-reviewed.

Concentrating on how machine learning or deep learning algorithms can be used for breast cancer detection, sorting, prediction or diagnosis. Made the kind of data available which algorithm was employed and mentioned the reported performance metrics.

It is written in English.

The trial did not include people with:

Documents that have not been formally reviewed by scientists (e.g., preprints and posts published on blogs).

Many studies, however, do not discuss technical details or use AI for purposes not connected to the diagnosis process (for example, breast cancer treatment planning, but not breast cancer diagnosis).

3.3 Data Extraction and Categorization

Every chosen study was carefully reviewed and its aspects were recorded using a template that looked for the following attributes.

First Author and the Year in Which the Article Was Published

Model types may be Traditional Machine Learning (SVM, RF), Deep Learning (CNN, Xception), combining models or a mix of techniques.

The type of data can be imaging (mammograms, ultrasounds or histopathology), clinical (EHR records), sensor information or a mix of all.

Popular types of research include studying classification (benign versus malignant), metastasis risk, risk assessment, analysis of survival and comparing various approaches.

Performance Outcomes: Accuracy, sensitivity, specificity, the area under the curve (AUC) and important added outcomes.

Fifty studies were finalized and listed in a table to help with both theme- and number-based analyses. In below fig [1] we have shown the meta-analysis review steps that how we have achieved.

The below image [1] shows the meta-analysis that we carried upon.

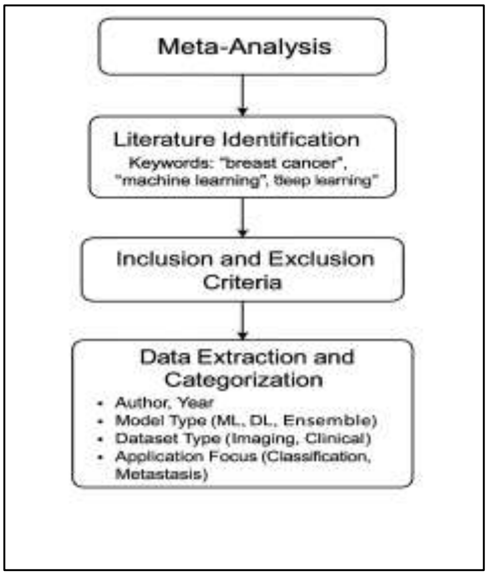

Fig 1: Meta-Analysis Steps

IV. RESULT ANALYSIS

The below figure [2] shows the number of times each type of model was used in the studies. It shows that deep learning is now a main tool used in many areas of medical diagnostics.

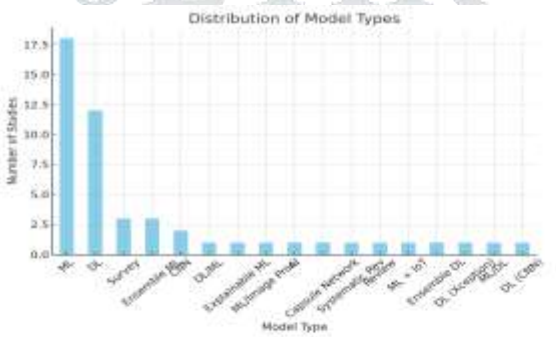

Fig 2: Distribution of model types

Importance: The below fig [3] illustrates the primary use-cases addressed by ML/DL models—such as classification, prediction, or risk analysis—indicating the practical diagnostic objectives targeted in the literature.

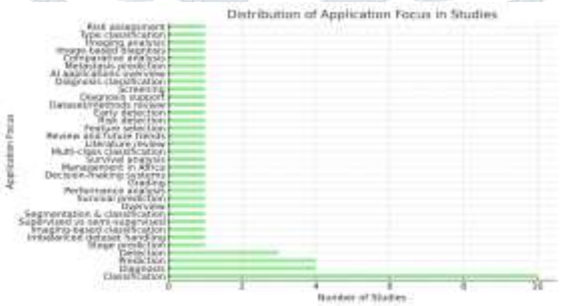

Fig 3: Distribution of application focus in studies

Importance: The below fig [4] aggregates how regularly models were related with high-performance metrics, providing insight into which algorithms are considered most effective by researchers.

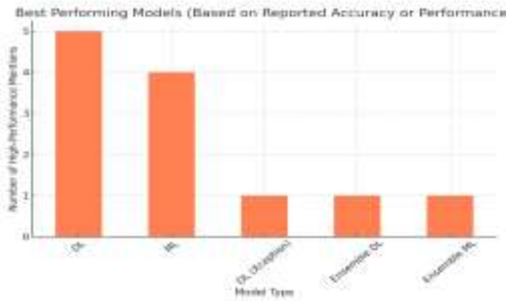

Fig 4: Best Performing model

The below pie chart in fig [4] classifies dataset types (e.g., imaging, clinical, sensor) to show which modalities are maximum used, revealing a strong preference for imaging-based datasets in AI-based cancer detection.

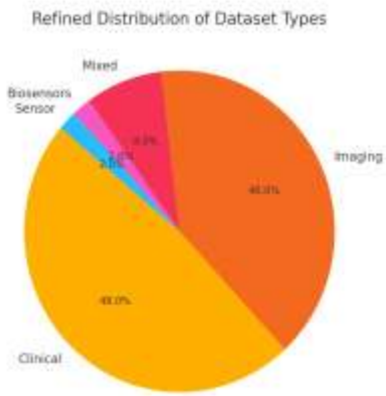

Fig 4: Refined Distribution of dataset types

This figure [5] highlights the number of times each model type was explicitly reported to deliver high-performance outcomes such as accuracy, sensitivity, precision, AUC, or superiority over other models. It provides an evidence-backed view of which algorithm families (e.g., DL, ML, Xception, Ensemble) are more frequently associated with superior diagnostic capability in breast cancer detection tasks. This figure aggregates how often models were associated with high-performance metrics, providing insight into which algorithms are considered most effective by researchers.

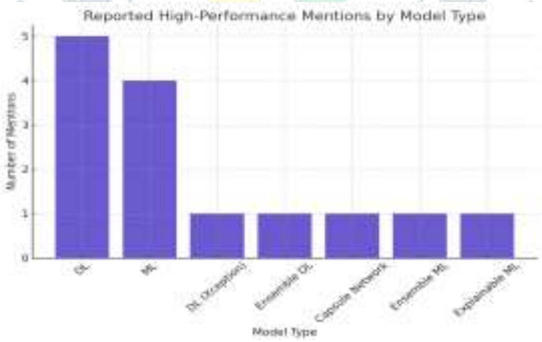

Fig 5: Reported High Performance by model type

This heatmap (Fig [6]) illustrates the relationship that exists between various model types and the domains of their datasets. Its purpose is to see which sets of models and data yield the best outcomes for diagnosing breast cancer.

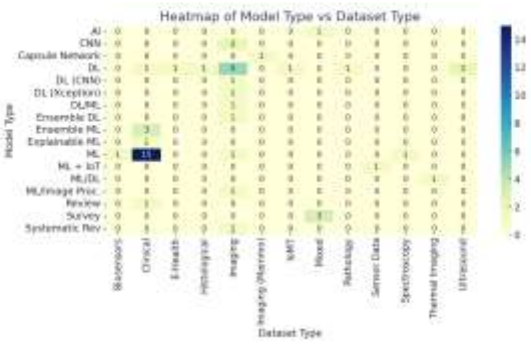

Fig 6: Heat-map of model type vs Dataset type

Comparison of our meta-analysis vs individual references.

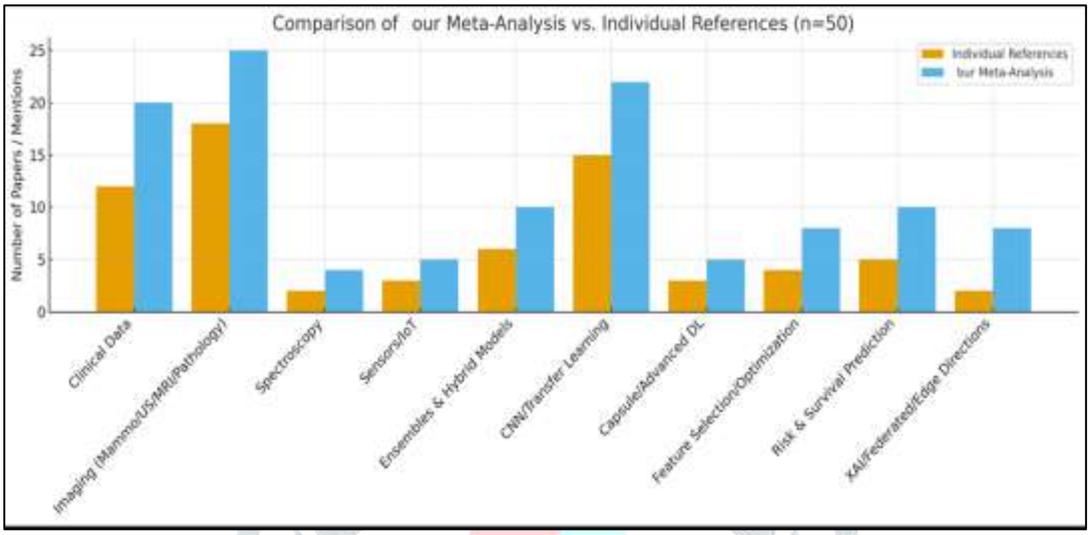

Fig 7. Comparison of our meta-analysis work vs references

V. CONCLUSION AND FUTURE SCOPE

The area of AI-based breast cancer diagnostics has plenty of uncovered possibilities as it grows. Analyzing different kinds of information about a patient such as images, health records and genetics data, gives a complete view and helps make correct diagnoses. Interpretable models in AI (known as XAI) are playing a bigger role in healthcare, as clinicians depend on them when applying AI to real situations. Also, with federated learning and privacy-preserving setup, healthcare organizations can conduct research together while keeping private patient data secure. Because of portable medical technologies and edge computing, it is now possible to have real-time mobile diagnosis in areas that are isolated and lack resources. Longitudinal and predictive analytics should be improved to measure the chances of recurrence, chances of survival and responses to treatment as time goes on. They should improve how effective, accessible and trusted AI is for handling breast cancer treatment.

Meta-analysis shows how machine learning and deep learning are making a major impact on how breast cancer is diagnosed. DL especially through CNNs is useful for detecting issues with images, while ML works well for looking at clinical data. 50 studies from 2021–2025 have suggested an increasing use of hybrid, ensemble and explainable AI systems that focus on both performance and how much they help the medical field.

But, despite significant improvements, challenges like not all data being available equally, the meaning of models and putting them into practice are still present. Dealing with these discrepancies is very important to link scientific experiments with how medicine is applied in clinical settings. Looking ahead, new studies ought to focus on building AI systems that are ethical, transparent and available to everyone, so that everyone gets the same advantages from advanced diagnostics. If multiple specialties continue to collaborate, AI is likely to keep improving the accuracy, speed and availability of breast cancer detection globally

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