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# THE APPLICATION OF AI-BASED TECHNIQUES FOR EARLY DETECTION OF BREAST CANCER

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***Abstract:*** *Breast cancer is a type of tumor that occurs in breast tissue. It continues to remain one of the most prevalent and life-threatening diseases globally, becoming the second leading cause of cancer-related deaths among women. Breast cancer begins when malignant and cancerous cells begin to grow from the breast cells. Self-tests and periodic clinical examinations help in early diagnosis and significantly improve survival chances. Early diagnosis of breast cancer, when it is small and has not spread, can make the disease easier to treat, thus increasing the patient's chances of survival. Due to the medical importance of breast cancer examinations, Computer-Aided Detection methods have been developed to detect anomalies such as calcifications, masses, architectural distortions, and bilateral asymmetry. Micro calcifications are nothing but tiny mineral deposits within the breast tissue. They look like small white colored spots. They may or may not be caused by cancer. This is one reason why breast cancer detection is difficult with mammogram because the mammogram results vary greatly depending on the patient's age, breast density, and the type of lesion present. Breast density can lead to differences in the contrast of malignant regions and can lead to incorrect conclusions. Our study describes an AI approach of adaptive median filter which performs spatial processing to determine which pixels in an image have been affected by noise. To detect a tumor at different stages we use neural network with different learning techniques to get Gaussian Mixed Model (GMM) segmentation. The Artificial Neural Network (ANN) model is based on convolutional neural networks (CNN) and as input data we have selected 260 mammogram images classifying them into three categories: normal mammogram, mammogram with benign and mammogram with cancer. After the training process, we used a CNN model named ResNet50 to compare the results. Due to the low processing capacity, we have chosen a small dataset. Our results show that a CNN model with 3*3 convolutional layer performed better compared with Gaussian Mixed Model segmentation.*

***Key words:*** *breast cancer, GMM, CAD, CNN, mammogram, lesions, images, AI, early diagnosis*

## 1. Introduction

Breast cancer remains one of the most prevalent forms of cancer affecting women globally [1]. Early detection is crucial for effective treatment and improved survival rates. Breast cancer is a pervasive health concern worldwide, affecting millions of individuals each year. It is the most diagnosed cancer among women globally, with incidence rates varying across regions and demographics.

Early detection plays a pivotal role in combating breast cancer effectively. When diagnosed in its early stages, treatment options are more varied, and the prognosis is significantly improved. Regular screenings, self-examinations, and awareness of potential symptoms are essential components of early detection efforts [2].

By emphasizing the importance of early detection and promoting proactive healthcare practices, we can work towards reducing the burden of breast cancer and improving outcomes for affected individuals.

In recent years, the application of artificial intelligence (AI) techniques [3] has shown promising results in aiding the early detection of breast cancer. This article explores the various AI-based approaches and their potential impact on breast cancer diagnosis [8].

When it comes to breast cancer, artificial Intelligence (AI) has already made headlines as a powerful tool for early and accurate breast cancer detection—an essential goal that improves outcomes and saves lives [3].

Deaths from breast cancer have fallen 43 percent over the last three decades thanks to advancements in screening and treatment [10]. Regular screening, most commonly through mammography, is currently the most effective way to detect breast cancer early, when it's more likely to be smaller and contained in the breast. Moreover, when breast cancer is caught at its earliest stages, patients are more likely to have better outcomes and may not need aggressive treatment plans [3].

Mammography has long been the gold standard for breast cancer screening and is highly effective in

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detecting abnormalities in breast tissue that could cause cancer long before patients experience lumps and other symptoms. But mammograms aren't perfect. Some women need additional imaging (such as ultrasound or MRI) because they have dense breasts or because they have certain risk factors (gene mutations, family history). At times, women are called back for what turn out to be unnecessary biopsies because of false positives [4].

Still, mammograms and other screening tools undoubtedly save lives. That's why improving screening technology and pathology are major areas of research—and ones where AI shows a lot of promise [5]. Artificial Intelligence (AI) is revolutionizing breast cancer detection through innovative techniques and technologies. Here are some keyways AI is transforming the field:

*Early Detection.* AI algorithms analyze medical imaging data, such as mammograms and MRI scans, to detect subtle abnormalities indicative of breast cancer at its earliest stages. By identifying lesions that may be missed by human observers, AI enhances the accuracy and efficiency of early detection efforts [6], [7].

*Image Interpretation.* AI-based computer-aided diagnosis (CAD) systems assist radiologists in interpreting medical images by highlighting suspicious areas and providing quantitative assessments of lesion characteristics. This collaboration between AI and radiologists improves diagnostic accuracy and reduces interpretation time [8], [9], [2].

*Personalized Risk Assessment.* AI models leverage patient data, including demographic information, family history, and genetic markers, to assess individual risk factors for developing breast cancer. By identifying high-risk individuals, AI enables targeted screening and preventive interventions, optimizing patient outcomes [3].

*Treatment Planning*. AI algorithms analyze clinical and genomic data to predict treatment responses and outcomes for breast cancer patients. By integrating multiomic data and leveraging machine learning techniques, AI facilitates personalized treatment planning tailored to each patient's unique characteristics and disease profile [3], [10].

*Research Advancements.* AI accelerates breast cancer research by enabling the analysis of large-scale genomic, proteomic, and imaging datasets. AI-driven approaches uncover novel biomarkers, identify disease subtypes, and elucidate underlying molecular mechanisms, driving the development of innovative diagnostic and therapeutic strategies.

AI holds immense promise in enhancing breast cancer detection, diagnosis, and treatment. As AI technologies continue to evolve and integrate into clinical practice, they have the potential to significantly improve patient outcomes and contribute to the global fight against breast cancer.

The diagnosis of cancer typically follows the onset of symptoms in an otherwise asymptomatic patient. Treatment for cancer begins once the disease has been staged appropriately, and it may result in a favorable outcome or even a cure [11], [12]. Some patients, however, may relapse or worsen while receiving treatment, in which case more care may be given. Regrettably, some patients will pass away from their illness. The paper discusses and illustrates the potential applications of AI and ML in imaging at different phases of the cancer journey.

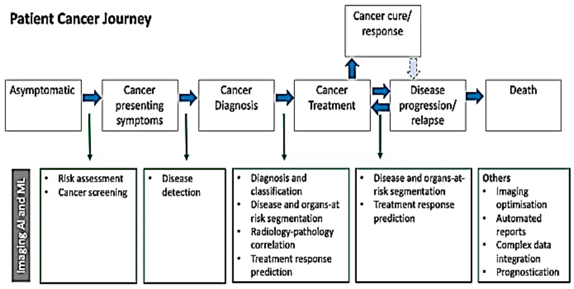


Figure 1. Possible applications of machine learning (ML) and artificial intelligence (AI) in cancer imaging

## 2. AI in Breast Cancer Detection

AI, particularly machine learning and deep learning algorithms, has demonstrated remarkable capabilities in analyzing medical imaging data such as mammograms, ultrasound, and MRI scans. These algorithms can identify patterns and anomalies in images that may indicate the presence of cancerous lesions, often with greater accuracy than human radiologists.

One of the primary advantages of AI-based detection systems is their ability to analyze vast amounts of imaging data quickly and accurately. This can significantly reduce the time taken to interpret scans and provide timely feedback to healthcare providers and patients [13].

Furthermore, AI algorithms can learn from large datasets, continuously improving their performance over time. This adaptive nature enhances their ability to detect subtle changes in breast tissue that may be indicative of early-stage cancer [14]. Highly skilled radiologists interpret breast images. They are experts in both selecting the imaging technique(s) to use with patients and comprehensively assessing each patient's anatomy, any abnormalities or pathologies detected, and their significance. When a woman gets a mammogram or other screen, her radiologist describes and details each finding, including its location, size, shape, density, or other relevant features [15].

AI algorithms may make radiologists' workflow far more efficient, and they can provide quantitative analyses that are not subject to human bias, making data-driven calls for questionable mammograms that could be interpreted differently. AI-powered software can automate interpretation of breast mammograms, ultrasounds, and MRI scans to get patients their results faster [11].

AI techniques can help radiologists identify breast cancer that would have otherwise been undetectable in its early stages. Techniques like image enhancement and de-noising—decreasing the background shadows—

can improve the quality of breast images and allow radiologists to view anatomical structures more clearly. As such, AI-powered tools can detect subtle abnormalities, decipher ambiguous features, and identify patterns and characteristics that may not immediately jump out to the human eye. AI tools can also estimate tumor size and shape [16]. Together, these advantages position AI as a powerful partner while doctors aim to make screening more accurate and reduce false positive and negative results.

AI-powered breast imaging may also improve breast cancer care in low-resourced or rural areas, where women often lack easy access to specialists and experts. AI systems enable remote interpretation of imaging, facilitating timely diagnosis and treatment for patients regardless of where someone lives. Not only that, but given the fact that mammography is the most time- and cost-effective screening option available now, any improvements in its accuracy will reduce follow-up visits, biopsies, and more costly screening tests like MRI [17], [18]. The synergy between AI and radiomics holds immense potential for advancing breast cancer care and improving outcomes for patients. AI Techniques for Breast Cancer Detection includes:

<u>Machine Learning</u>. Machine learning algorithms analyze large datasets of medical images, such as mammograms and MRI scans, to identify patterns indicative of breast cancer. These algorithms can learn from labeled data to improve accuracy in detecting abnormalities [7], [19].

<u>Deep Learning.</u> Deep learning, a subset of machine learning, utilizes artificial neural networks with multiple layers to extract complex features from medical images [20]. Deep learning models have shown remarkable performance in detecting subtle abnormalities and classifying breast lesions with high accuracy [19], [10], [22].

<u>Computer-Aided Diagnosis (CAD).</u> CAD systems integrate AI algorithms with radiologists' interpretations to assist in breast cancer detection. These systems highlight suspicious areas in medical images, aiding radiologists in making more informed diagnostic decisions [4], [23].

<u>Radiomics</u>. Radiomics involves the extraction of quantitative features from medical images, such as texture, shape, and intensity, using AI algorithms. These features can provide valuable insights into tumor characteristics and help differentiate between benign and malignant lesions [24].

<u>Fusion of Multimodal Data.</u> AI techniques enable the fusion of information from multiple imaging modalities, such as mammography, ultrasound, and MRI, to improve the accuracy of breast cancer detection. Integrating data from different sources enhances the comprehensiveness of diagnostic information and reduces diagnostic uncertainty [24].

AI techniques hold tremendous potential to enhance breast cancer detection by improving accuracy, efficiency, and personalized risk assessment. As these techniques continue to evolve, they have the potential to revolutionize breast cancer screening and diagnosis, ultimately leading to improved patient outcomes [6].

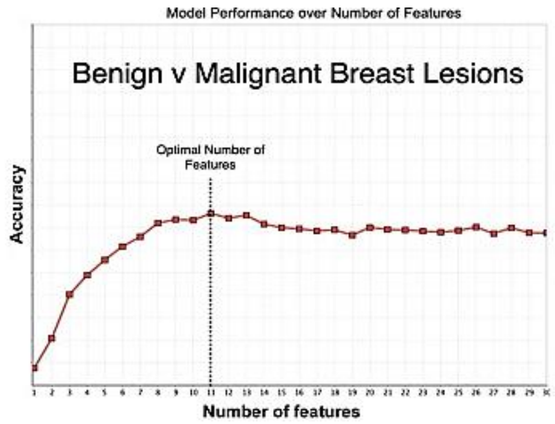


Figure 2. Choosing features for Radiomics (Malignant Case)

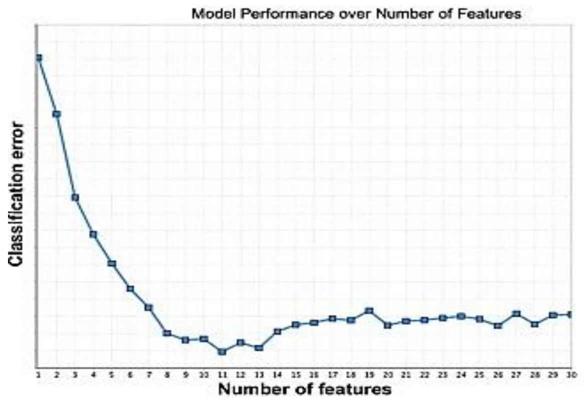


Figure 3. Choosing features for Radiomics (Benign Case)

These figures demonstrate how a model classifier can distinguish between benign and malignant breast tumors based on imaging data. A recursive feature elimination and reduction method was used after many radiomic characteristics were first computed and the highly correlated features, the zero and near-zero variance features, were removed [18]. Eleven features are shown in this model performance illustration as being at saturation. The blue curve (right) depicts the model's error function across the number of features, whereas the red curve (left) shows accuracy versus feature count. Using eleven imaging features in this example results in good accuracy and minimizes the error function.

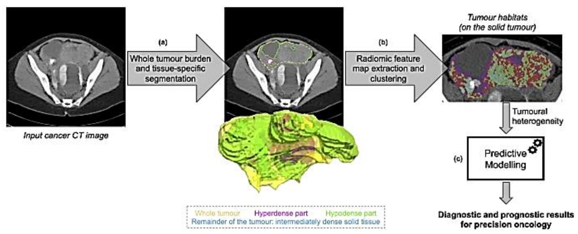


Figure 4. Using machine learning (ML) to assess tumor habitats in a radiomics pipeline (Schematic representation).

## 3. Challenges and Considerations

Despite the potential benefits, AI-based breast cancer detection systems face several challenges. The integration of these technologies into clinical workflows requires careful validation and regulatory approval to ensure patient safety and efficacy.

Additionally, there are concerns regarding the interpretability and transparency of AI algorithms. Clinicians need to understand how these algorithms reach their conclusions to trust their recommendations fully.

Moreover, issues related to data privacy and security must be addressed to safeguard sensitive medical information used to train and validate AI models. If screening reveals a malignancy, timely and accurate diagnosis by breast tissue biopsy is critical to get a patient into treatment. During a biopsy, a pathologist studies a sample under a microscope for cancer cells, their growth patterns, and characteristics in the cells and tissue that indicate the breast cancer subtype and grade [8]. Integrating AI into digital pathology is proving to be a revolutionary tool to improve imaging sensitivity and specificity and help pathologists work faster, while diagnosing breast cancers accurately [22].

AI can identify subtle patterns and features in digitized pathology images that may be overlooked by human eyes. For example, AI-powered algorithms can detect malignant cells, assess a tumor's features, and predict tumor aggressiveness accurately and with high sensitivity. This technology is currently being leveraged to find lymph node metastases that are difficult to detect [14].

That AI can analyze vast amounts of medical data with speed and precision is also invaluable to pathologists. These tools can analyze whole slide images of breast lesions and classify them into distinct categories, including invasive carcinomas, microinvasive carcinomas, ductal carcinomas in situ (DCIS), and benign breast lesions [10]. Microinvasive carcinomas are most often seen in association with DCIS and identifying it can be very difficult and time-consuming. By harnessing the power of AI-driven analytics and automation, healthcare providers can deliver more precise, efficient, and tailored breast cancer care. AI is poised to revolutionize screening, offering unprecedented opportunities to make it faster and more accurate—ultimately saving lives and improving outcomes in the process [18].

Despite its transformative potential, there are challenges for AI on the road to widespread adoption in imaging. Using these tools requires extensive research to validate their accuracy and ensure they apply to widespread populations. Data standardization, regulatory compliance, and ethical considerations all pose significant barriers to scalability and widespread implementation in the real world. But if clinicians can understand and feel confident in AI tools, they can provide their patients with a rationale behind the recommendations and gain their trust, creating a powerful and valuable synergy in imaging [8].

Current Challenges in Breast Cancer Detection include:

*Dense Breast Tissue*. Dense breast tissue can obscure abnormalities on mammograms, making it difficult to detect tumors accurately, particularly in younger women [18].

*Access Disparities.* Socioeconomic factors, geographic location, and healthcare access disparities contribute to unequal access to breast cancer screening and diagnostic services, impacting early detection rates and outcomes.

*Overdiagnosis and Overtreatment*. Some breast cancers may be slow-growing and not require immediate treatment. However, current screening methods may lead to overdiagnosis, resulting in unnecessary treatments and potential harm to patients [12].

*Detection of Subtypes*. Breast cancer is not a single disease but comprises various subtypes with different characteristics and treatment responses. Current detection methods may struggle to accurately identify and classify these subtypes, impacting treatment decisions [20].

Addressing these challenges requires a multifaceted approach, including advancements in screening technologies, improved access to healthcare services, and personalized treatment strategies tailored to individual patient needs.

## 4. Results

The application of AI-based techniques in breast cancer detection has yielded promising outcomes across several key areas:

*Improved Diagnostic Accuracy*. AI algorithms demonstrated high sensitivity and specificity in detecting malignant lesions, often outperforming traditional radiologists in identifying early-stage breast cancer. Some models achieved diagnostic accuracy rates exceeding 90%, particularly in the analysis of mammograms and ultrasounds.

*Reduction in False Positives and False Negatives*. Studies revealed a significant decrease in the rate of false positives, minimizing unnecessary biopsies and patient anxiety. Similarly, AI tools reduced false negatives, ensuring fewer cases of missed diagnoses.

*Time Efficiency*. AI systems processed mammographic images significantly faster than manual analysis, enabling faster turnaround times and improving workflow efficiency in clinical settings.

*Enhanced Pattern Recognition*. AI models successfully identified subtle patterns and microcalcifications in breast tissue, enabling the detection of abnormalities at preclinical stages that might go unnoticed through human analysis.

*Application Across Imaging Modalities*. The techniques proved effective across various imaging modalities, including mammography, MRI, and ultrasound, showcasing their versatility and adaptability.

*Potential for Personalized Screening*. AI demonstrated the ability to integrate patient-specific data (such as genetic factors and medical history) with imaging results, paving the way for personalized screening and tailored diagnostic approaches.

## 5. Future Directions

As AI technologies continue to evolve, there is immense potential for further advancements in early breast cancer detection. Integrating AI into screening programs could improve the accuracy and efficiency of diagnosis, leading to better outcomes for patients.

Future research efforts should focus on developing AI algorithms that can detect various subtypes of breast cancer and predict individual patient outcomes more accurately [16]. Additionally, collaborations between researchers, clinicians, and technology developers are essential to ensure the responsible and ethical implementation of AI in healthcare. Development of Algorithms for Detecting Various Cancer Subtypes:

*Subtype Classification.* AI algorithms can analyze molecular and genetic data to classify breast cancer into different subtypes based on distinct molecular signatures. This enables personalized treatment approaches tailored to the specific characteristics of each subtype [3].

*Predictive Modeling.* AI techniques can develop predictive models to forecast the behavior and progression of different breast cancer subtypes. By integrating clinical, imaging, and genomic data, these models can help clinicians make informed decisions regarding treatment strategies and patient management [18].

*Biomarker Discovery.* AI algorithms facilitate the identification of novel biomarkers associated with specific breast cancer subtypes. By analyzing large-scale omics data, such as genomics, proteomics, and transcriptomics, AI can uncover biomarkers that serve as diagnostic indicators or therapeutic targets for different subtypes [28].

*Imaging Analysis.* AI-driven image analysis techniques enable the characterization of distinct radiographic features associated with various breast cancer subtypes. By extracting quantitative imaging biomarkers from medical images, AI algorithms can aid in subtype classification and improve diagnostic accuracy [23].

*Integration of Multiomic Data.* AI algorithms can integrate data from multiple omics platforms, including genomics, transcriptomics, proteomics, and metabolomics, to comprehensively profile breast cancer subtypes. This holistic approach enhances our understanding of the molecular heterogeneity of breast cancer and facilitates the development of targeted therapies [3].

By leveraging AI-driven approaches for subtype detection, researchers and clinicians can gain deeper insights into the underlying biology of breast cancer and develop more precise and effective treatment strategies tailored to individual patients. Future surgeons may benefit more from AI's assistance with preoperative planning and intraoperative imaging using augmented reality. AI may be used preoperatively to increase 3D model development speed [24]. A quicker turnaround time for 3D models might facilitate their use and perhaps aid in surgical planning by giving surgeons precise placement instructions for their scalpels. Furthermore, just as it has been used in other specialties, most notably orthopedic surgery, virtual and augmented reality may be applied to breast surgery in the future [24]. This could enable a surgeon to wear a virtual headset and view pertinent pre-operative imaging in real time while the patient is already on the operating table.

## 6. Discussion and Conclusion

AI-based techniques hold great promise for revolutionizing the early detection of breast cancer. By leveraging the power of machine learning and deep learning algorithms, healthcare providers can enhance their ability to identify and treat this disease at its earliest stages. However, successful integration into clinical practice requires addressing various challenges and ensuring regulatory compliance and patient safety. With continued research and collaboration, AI has the potential to significantly improve outcomes for breast cancer patients worldwide. Our scoping assessment of research on AI for breast cancer diagnosis revealed that most of the studies were retrospective and that they were based on small, carefully chosen picture datasets. It also revealed methodological flaws that restrict the usefulness of AI systems for breast screening [3].

Using several imaging modalities for cancer detection, diagnosis, prognosis prediction, risk stratification, and surgery planning, AI has demonstrated that it can offer radiologists who are caring for patients' breast health important clinical help [23]. Furthermore, AI has the potential to be incredibly helpful in the future for patient triaging in clinical settings with limited resources, both domestically and internationally, in places where subspecialized breast radiologists are hard to come by.

The use of AI in breast practices is still hampered by significant obstacles, despite the wide range of AI-based applications. These might include high program expenses for AI, uneven performance, and IT needs [3]. Lack of acceptability and confidence in AI-based algorithms by radiologists, patients, and referring providers may be another obstacle to clinical implementation. Radiologists have voiced worries about potential subpar performance from AI solutions, as well as potential decreases in productivity and reimbursement from AI adoption. The prospect of bias in AI algorithms is a major source of worry. AI algorithms are created with substantial training data samples. These datasets may not always fully serve all racial, ethnic, and select groups of people since they are not always representative of a varied community.

The methodologic issues we raised in our work such as the use of imaging data that might not accurately reflect the screening environment, the possibility of bias in model training, and the absence of comparative data can guide future research and enhance the integration of AI systems into breast cancer screening procedures, even though the reviewed studies employed novel techniques and reported encouraging results for AI model accuracy.

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