Journal of Innovative Image Processing (ISSN: 2582-4252)
www.irojournals.com/iroiip/

Early Detection of Breast Cancer using Versatile Techniques - A Study

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Abstract

Among all cancer types, breast cancer is the most prevalent. For females, it ranks as the second most common cause of cancer-related mortality. Every 1 person per 28 people in lifetime have a chance of developing breast cancer, according to statistics. Each year, it is estimated that over two million women encounter it. The high-risk group in India has an average age of 43–46 years, but in the west, women between the ages of 53 and 57 are more likely to get breast cancer. While there is no known cure for breast cancer, early detection and diagnosis significantly improves chances of survival. Treatment for breast cancer patients may be possible if the disease is identified and diagnosed early. Diagnosing benign from malignant tumours and determining whether a breast cancer case is early or progressed presents a number of challenges for cancer researchers. This study compares many methods for detecting breast cancer and provides a detailed analysis of each, highlighting the methods that are most accurate and economical. This study's primary goal is to comprehend the fundamental principles behind the various technologies used in breast cancer diagnosis. It is simple to save lives by spreading awareness of the latest and most varied detection and screening techniques.

Keywords: Breast Cancer detection, mammography, Machine Learning, Image processing, Mortality, Signal Processing, Artificial Intelligence.

DOI: https://doi.org/10.36548/jiip.2023.3.004
Received: 08.09.2023, received in revised form: 03.10.2023, accepted: 15.10.2023, published: 28.10.2023

1. Introduction

Mammography is a diagnostic tool that maps the density of the breasts and has demonstrated a high degree of sensitivity in detecting breast lesions. In addition to expensive costs, it could be a challenging and painful procedure. For diagnosing women with implants, magnetic resonance imaging (MRI) would be more helpful. Medical applications for microwave imaging have consistently been of subject of study for a very long period. The electrical property distributions throughout the body are mapped using microwave imaging. The physiological status of different tissues may be correlated with their electrical characteristics. Mammography, which produces an x-ray image of a compressed breast, is the most effective procedure for imaging the breasts. The process of "seeing" an object's interior structure using electromagnetic fields operating at microwave frequencies is known as microwave imaging. Microwave breast tumor detection has the capacity to find tiny cancers, according to technological considerations. In comparison to techniques like MRI and nuclear medicine, it is also anticipated to be less costly [1].

In developing countries, the prevalence of breast cancer is rising, mostly as a result of rising life expectancy, changing lifestyles, such as women having fewer children, and hormonal interventions, such as post-menopausal hormone treatment [2]. Nowadays, a number of imaging modalities are used to diagnose breast cancer; however, microwave imaging (MWI) is drawing a lot of interest as a potentially useful diagnostic technique for the early diagnosis of breast cancer. An efficient, quick, easy, safe, and non-invasive screening method is MWI. When used alone or in conjunction with other techniques, MWI has generally shown its efficacy as a screening tool for the identification of breast cancer. Researchers from all across the globe are becoming more interested in MWI as a method for early identification of breast cancer. There are many promising methods available for identifying breast cancer. [5].

Statistics show that women with high levels of the hormone estrogen are more likely to develop breast cancer. A woman's hormone estrogen rises with the length of her menstrual cycle. This risk factor may also be connected to non-pregnancy and childbearing. As early diagnosis would lead to early initiation of therapy and satisfactory outcomes identifying the optimal method for diagnosing becomes essential. The Cancer cells, if treated early, either in its first stage or the second stage, are likely to be easily eradicated. . The latter stages of the cancer requires a continuous monitoring and experienced physician to avoid the patient decease [6].

The purpose of this article is to suggest a deep learning model for categorizing and detecting breast cancer. The current dataset of eight types of breast cancer was fitted using a modified version of the Xception model. The dataset was gathered from Kaggle and enhanced by the use of Generative Adversarial Network (GAN) [8].

Biosensors have been developed by the disciplines of chemistry, biology, and engineering to find bioanalytical substances. The two main components of a biosensor are the transducer, which converts biological reactions into quantifiable output signals, and the bioreceptor, which is mounted on the sensor and detects the associated sample. Biomarkers are any molecules found in tissues, blood, or other body fluids that may be used to identify an abnormal process, disease, or other state. Biomarkers are important for the diagnosis and treatment of many types of cancer, according to recent studies [9-10].

This research reports on the creation of a novel wearable device based on textile antenna-based sensors for breast tumor detection. The suggested sensor has dimensions of 24 × 45 × 0.17 mm3 on a cotton substrate and is small and entirely composed of textiles to fit pleasantly and conformably on the breasts. This work produces ultra-wideband flexible sensors that are small by using two different technologies [11-14].

Infrared technology is used in thermography imaging, an efficient diagnostic method for the identification of breast cancer. In order to automatically separate and isolate the breast region from the rest of the body, which acts as noise in the breast cancer detection model, the U-Net network is initially used.

The primary goal of this review paper is to

- Examine the various tools and methods used in the early detection of breast cancer, including thermography, image processing, biosensors, and machine learning algorithms, in order to improve the choice of screening procedures.
- Compare and contrast the advantages of early identification of breast cancer with performance metrics.

The research papers for breast cancer detection were selected using a variety of techniques. The phrases "breast cancer and machine learning," "breast cancer and technology," and other concepts that are comparable in the context of non-invasive screening methods were employed. The fact that nearly all of the articles were selected from IEEE xplore, MDPI, and Springer publications further speaks to the quality of the most recent selections.

2. Methodology

This section has been divided into eight sections to aid in the explanation and comparison of the various operational principles. In order to have a better understanding about the techniques used for diagnoses

2.1 Breast Cancer Detection using Microwaves

The electrical property distributions throughout the body are mapped out using microwave imaging. In addition to the health risks associated with ionizing radiation exposure, many women find mammography to be unpleasant or uncomfortable. Microwaves heat tissues, and this power deposition process has been extensively studied for applications in heat stroke and mobile phones. A definition of microwave imaging is the process of "seeing" an objects inside structure using electromagnetic fields at microwave frequencies, which range from 300 MHz to 30 GHz. When a tumour is present, the electrical properties of the wave that is passing through the breast change and scatter the incident wave. Figure 1 illustrates how this scattering alters the energy levels observed at the transmitter and receivers [1]. Figure 2 depicts the UWB radar setup for detection of tumors in breast. [5]. MWI is a medical imaging method that has potential and might be less expensive than other currently available imaging modalities. Wearable technologies have made it possible to wear electronics or smart sensors (antennas) directly on the body. Using microwave imaging, it suggests a novel, cozy wearable device also known as “Smart Bra” that will enable women—especially young, densely breasted women—to undergo routine breast cancer screenings in a safe manner, is depicted in Figure 3 [11].

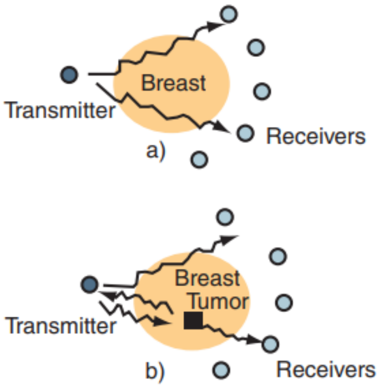

Figure 1. Detection of Breast Tumor [1].

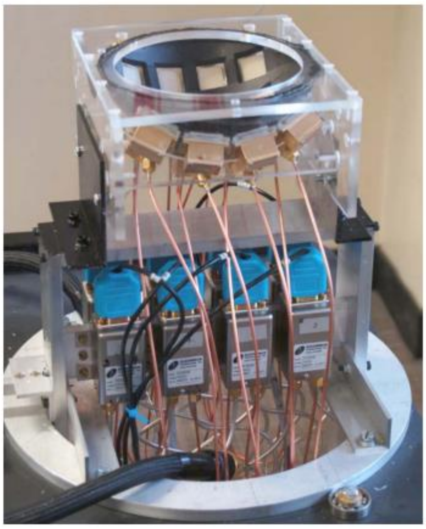

Figure 2. Setup of Ultra-Wideband Radar for Detection of Breast Cancer [5].

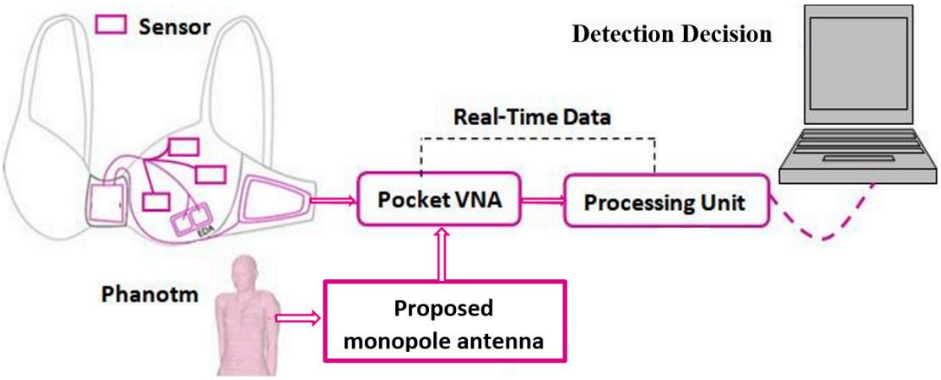

Figure 3. Block Diagram for Detection of Breast Cancer using Smart Wearable [11].

2.2 Breast Cancer Detection using Image Processing

A data collection from Wisconsin Diagnosis Breast Cancer served as the basis for this paper [2–3]. This will make it possible to classify images as either pathological or normal, which is the same as determining whether or not they have cancer. For this specific piece of work, only the frontal images with the arms up were used, since the other stances produced erratic outcomes. The zone that only comprised the patient's breast, or the region of interest (ROI), was then separated from each image in the database using a software application, shown in Figure 4 [7].

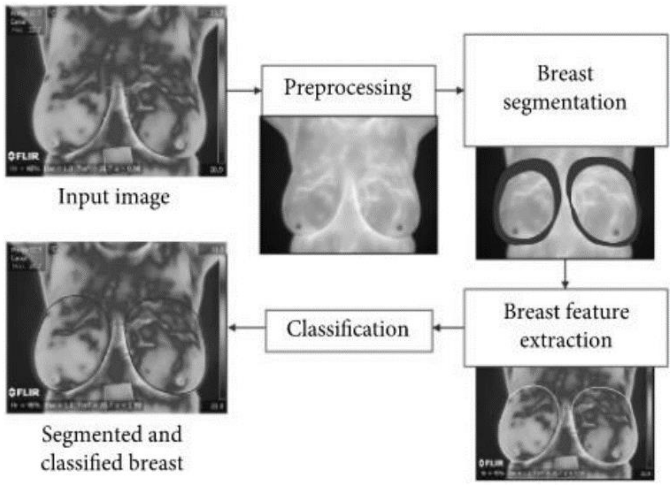

Figure 4. Block diagram of Breast Tumor Detection using Image Processing [11].

2.3 Breast Cancer Detection using Data Mining

One of data mining's main objectives is creating efficient categorization systems. The classification can serve as a foundation for developing new models and for statistically estimating the values of the unseen qualities if one has both a classification and a partial observation. There are three data mining methods through experimentation using the Weka toolbox. The Weka machine learning platform was used to conduct all the experiments in this study. Regression, clustering, association rules, visualization, and data classification were all supported by the Weka toolkit [4].

2.4 Breast Cancer Detection using Mammography

In this study, breast cancer was identified using mammography images. Using different deep CNN models, four mammography imaging datasets with a comparable amount of 1145 normal, benign, and malignant images were used. Tensor Flow and Keras are two deep learning models built to detect breast cancer using images from mammography that were classified as benign, malignant, and normal [9].

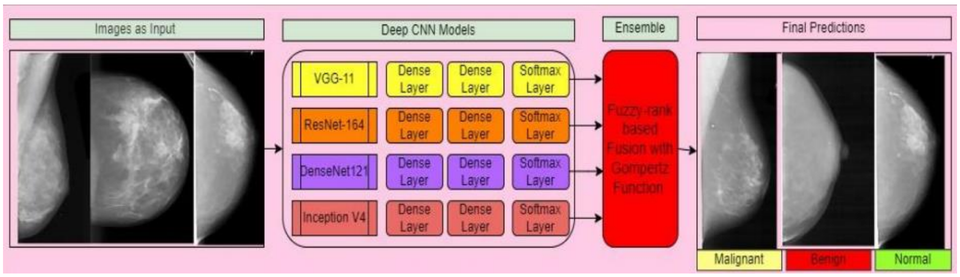

Figure 5. Framework of the System Architecture using Mammography [9].

2.5 Breast Cancer Detection using Magnetic Resonance Imaging (MRI)

MRI scans use deep learning classification models enhanced by transfer learning together with fine-tuning approaches to identify breast cancer. MRI images of the breast make up the training dataset. Once the model has reached the maximum accuracy, it will be saved in the cloud; if not, it will retrain and export to the online cloud. In order to provide the trained model with intelligent predictions, breast MRI images are obtained as input during the testing layer. A visit to a physician is advised if the trained model classifies the patient as "ill," otherwise it is not necessary [8].

2.6 Breast Cancer Detection using Biosensors

The component of a biosensor called a bio-transducer transforms the biological signal generated by the interaction of a target analyte and a bioreceptor into a signal that can be measured. The cellular components of proteins, DNA, or RNA are converted into electrical signals by biosensors so that they may be detected and analyzed to ascertain the existence of a particular biological analyte. The biological properties of tissues and bodily fluids may be measured using analytical tools called biosensors. Optical, piezoelectric, and electrochemical biosensors are a few types of biosensors that are available. The great sensitivity, simplicity, and compactness of DNA based biosensors and electrochemical DNA biosensors make them very appealing when compared to other biosensor types [10].

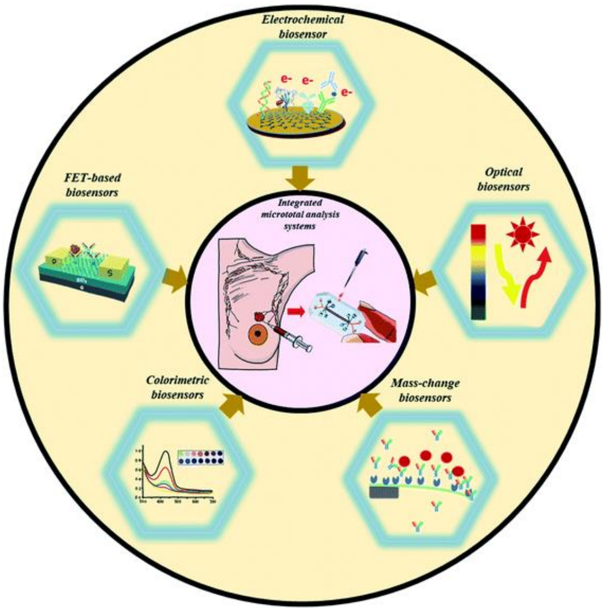

Figure 6. Different Biosensing Methods to Identify Breast Cancer [15].

2.7 Breast Cancer Detection using Thermography

Thermography is an increasingly popular less intrusive and more affordable technology. Keeping this in mind, the work's first goal is to develop convolutional neural network-based machine learning models that use several thermal images of the breast to identify breast cancer. Using a gadget that basically measures the skin's surface temperature, it takes a picture of the breasts. This screening procedure is a good screening technique since it involves no radiation, no patient-device touch, and no breast compression. Its foundation is on the understanding that cancer cells have a high metabolism, which enables them to develop and move quickly to other areas [12]. The thermal picture includes extraneous body features like the neck, shoulders, chess pieces, and other places that serve as noise in CNN models during training. This stage involves deleting undesirable areas and feeding the CNN model with the cancer-destined regions for training and testing [13]. Figure 7 shows the basic approach for detection of tumor based on thermography.

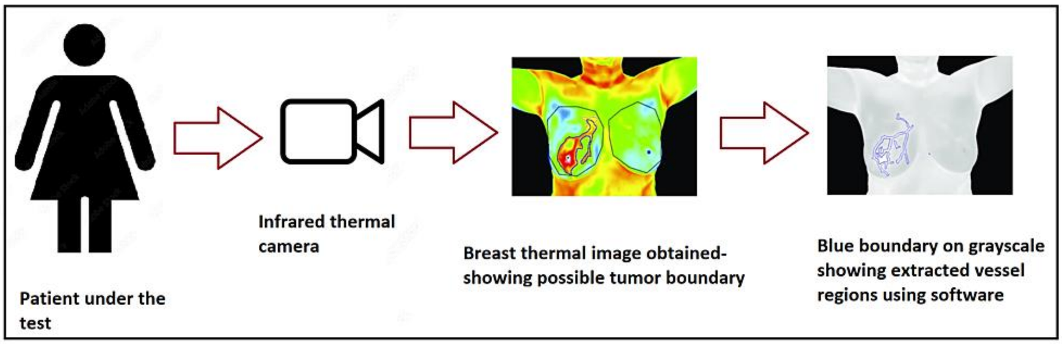

Figure 7. System Architecture for Breast Tumor Detection using Thermography [13].

2.8 Breast Cancer Detection using Spectroscopy

Using an FTIR mid-infrared spectrometer equipped with a platinum ATR single reflection diamond sampling module (Bruker Optics, Germany), the spectra of the breast samples were acquired. In a performance qualification (PQ) test, a completely automated validation approach for OPUS 8.0 software was utilised to confirm the quality and accuracy of spectral data. Three (3) feed forward neural networks (FNNs) with different layer sizes were constructed for the study. While this is happening, scientists are curious in how FTIR spectroscopy may be used in a clinical setting to improve the repeatability and accuracy of cancer diagnosis without necessitating the time-consuming and tedious clinical processing of tissue biopsy samples [14].

3. Analysis of the Articles Reviewed

In this section, the top four strategies for detecting breast cancer are discussed and contrasted based on a number of characteristics, including software algorithms, hardware used for experimentation, accuracy, and error rate.

3.1 Conventional Breast Cancer Screen Methods

In order to check for lumps or other strange sensations in the breast, the female does Breast Self-Examination (BSE) on herself while a doctor or other healthcare professional performs Clinical Breast Examination (CBE). Women often misunderstand their body, ignore the effects of BSE, and attribute it to other things like wearing tight clothing, getting their menstruation, exercising, and so forth.

An additional screening modality that is often suggested for younger women with thick glandular tissue is ultrasound (USG), particularly for those who have mammographic microcalcifications. Many thin cross-sectional pictures are merged with traditional X-rays in Digital Breast Tomosynthesis (DBT) to create three-dimensional (3-D) images. For ladies with thick glandular tissue, this approach is more advantageous. The absence of facilities for extensive population-based screening programs and its high cost make magnetic resonance imaging (MRI) an ineffective modality for breast cancer screening.

3.2 Breast Cancer Detection using Microwaves

The era of microwave technologies for cancer detection is approaching. The creation of a comprehensive wearable system for the diagnosis and monitoring of breast cancer, using flexible antennas as sensors in the microwave band, is presented in these works. This article presents a research that uses two technologies to build ultra-wideband flexible sensors that are tiny. Flexible Roger substrate is the first technique employed, while conductive fabric applied on cotton substrate is the second. The two methods are used to record and compare the suggested antenna-based sensor's performance. At frequencies lower than 7GHz, the simulations confirm that the suggested antenna-based sensor antenna using conductor fabric performs similarly. The performance indicators used to compare breast cancer detection methods are shown in Table 1.

Table 1. Performance Parameters of Breast Cancer Detection using Microwaves

Cited Work / Parameters	**[1]**	**[5]**	**[11]**
Objective of the cited work	Microwave imaging using radars	Microwave imaging using radars	Microwave antenna based “Smart Bra” for tumor detection
Accuracy (%)	80	90	83
Error rate (%)	20	10	17
Hardware employed	Radar transmitter and receiver	Radar transmitter and receiver	Antenna + conductive fabric

Algorithms / Software req.	-	CNN, RNN, SVM	LR, SVM, RF, DT

3.3 Breast Cancer Detection using Image Processing

The test and training dataset count and size are important for neural networks to perform as efficiently as possible. The classifiers described in this paper were all trained using the same training data set and assessed using the evaluation data set in order to compare the performance of the classifiers. Utilizing the Wisconsin Diagnosis Breast Cancer data set, a performance comparison of the machine learning algorithms methodologies was conducted. With regard to precision, accuracy, and the quantity of data utilised, it was shown that CNN outperforms the other methods now in use. Table 2 presents a comparative analysis of current image processing-based efforts on breast cancer.

Table 2. Performance Parameters of Breast Cancer Detection using Image Processing

Cited Work / Parameters	**[2]**	**[3]**	**[7]**
Accuracy (%)	98	95	90
Error rate (%)	2	5	10
Hardware employed	-	-	-
Algorithms / Software req.	SVM, kNN, RNN, CNN	kNN, RNN, NB	CNN, SVM, RF

In addition, image processing includes techniques like Computer Aided Diagnosis (CAD), which integrates physics, mathematics, and machine learning algorithms with image processing ideas to support radiologists in making decisions. Additionally, digital pictures from Fine Needle Aspirate (FNA) samples are employed. The samples obtained by FNA are then forwarded to pathologists for identification and nuclei analysis.

3.4 Breast Cancer Detection using Mammography

Worldwide, breast cancer is now the leading cause of death for women. By employing mammography, a breast cancer prediction enhanced by the fine-tuning model was able to distinguish between healthy and diseased breasts. The examined model, uses fuzzy logic based on the Gompertz function to attain 95.5% accuracy rate. The assessed performance characteristics for mammography-based breast cancer detection are shown in Table 3.

Table 3. Performance Parameters of Breast Cancer Detection using Mammography

Cited Work / Parameters	**[9]**
Accuracy (%)	95.5
Error rate (%)	4.5
Hardware employed	-
Algorithms / Software req.	CNN, Fuzzy logic based on Gompertz function

3.5 Breast Cancer Detection using Thermography

The approach under study uses thermal images to extract the breast area from the images using the U-Net network. It then suggests a deep learning model that has been trained to recognize abnormalities in breast tissue. The proposed method consists of three main stages: segmentation of the breast region, resizing, and deep learning model for classification. Data augmentation techniques are often used when the dataset is small in order to improve the model's learning efficiency. CNNs with multiple perspectives exhibit superior performance. Table 4 presents a comparison of the performance metrics of the research articles that were analyzed across several factors.

Table 4. Performance Parameters of Breast Cancer Detection using Microwaves

Cited Work / Parameters	**[12]**	**[13]**
Accuracy (%)	90	90

Error rate (%)	10	10
Hardware employed	-	-
Algorithms / Software req.	CNN	CNN, KNN, NB, RNN

4. Discussions

In this section, the advantages and disadvantages of the reviewed articles are succinctly and critically analyzed. Table 5 provides an overview of the many kinds of biosensors, their characteristics, analyte, and performance. Table 6 provides an overview of the techniques related to image processing, including an analysis of their applications, efficacy, and constraints.

Table 5. Summary of the Biosensors Utilised in Detection of Breast Tumors [9].

Name of Biosensor	Specification	Analyte	Performance (Detection limit)
FET biosensor	Transducer rGO-Encapsulated SiO2 NPs	HER2	1pM
Electrochemical	Hemin/miR/DNA-Au/probe	miR-21	6fM
EIS - Electrochemical	Gold electrode and iron redox probe	Progestrone (PR)	0.6fM
Surface Plasmom based sensor	Gold coated circular lattic PCF sensor	-	9000nM
Colorimetric Sensor	BSA Gold nanoclusters	Lipid Solution	5.82nM

Table 6. Summary of Image Processing-based Detection

Technique	Mammography	MWI	X-ray	Ultrasound	Thermography	CT
Accuracy (%)	95	93	90	80	84-91	80
Popularity	Medium, as the procedure can be stressful and can be painful during imaging.	Beginning to gain momentum.	Stopped	Low	Medium, not available at all hospitals	Medium, not suggested by all doctors due to low accuracy
Cost	Expensive	Cheap	Cheap	Cheap	Cheap	Economic
Limitations	Overtreatment Radiation Exposure Not usable for all women. False Negative and False Positives	Reconstructing becomes more challenging since microwaves scatter and reflect at many locations within the breast tissue.	Unable to identify lung metastases and does not provide an accurate reading.	Unable to detect breast tumor in obese female. Also, misses most of the tumors in early stages.	The warmth of a woman's body might sometimes lead to a false positive diagnosis of breast cancer.	Low resolution Dark images Misses most spots

Table 7. Advantages and Disadvantages of the Studied Articles based on Breast Cancer Detection.

Citation Number	Methodology (Dataset/Realtime)	Advantages	Disadvantages
1	Mammography – RT	Compared to mammography, this method is much more effective, affordable, and pleasant for women.	For the benefit of society, further study on this technology is encouraged.

2	Thermography - DT	Computational speed because ready datasets and methods are accessible.	In real-time scenarios, they often fail because of unanticipated events.
3	Spectroscopy - DT	Computational speed because ready datasets and methods are accessible.	In real-time scenarios, they often fail because of unanticipated events.
4	Image processing - DT	Computational speed because ready datasets and methods are accessible.	In real-time scenarios, they often fail because of unanticipated events.
5	Microwave Imaging – RT	The main goal of this research is to create a UWB radar utilising microwaves, which is a job that has been completed successfully and accurately in real time.	The events that identify tumours within thick breasts need stabilisation since the time it takes for reflection in dense material changes.
6	Microwave Imaging - RT	Higher accuracy is achieved by the use of data mining, which makes use of data sets from several methods including MRI, thermography, spectroscopy, and microwave imaging.	Although more datasets are available, they necessarily don’t mean faster interpretation as cases vary uniquely with assymetric breasts and small tumours present in dense breasts.
7	MRI – RT	MRI is a more effective procedure than mammography since it causes no discomfort to the female body.	Increased radiation exposure is not recommended. Long-term damage may result from the need for several scans.
8	Mammography – RT	Mammography is effective in tumour detection.	Expensive, Uncomfortable for the female breasts, also requires biopsy after imaging.
9	Biosensors – RT	Bio-sensors are a new arrival in the market and based on DNA, sweat, RNA and other protein lipids detect presence of tumours.	More research is encouraged in this field, also to make it in a economic and effective method.
10	Microwave Antenna based wearable - RT	Detects tumours in both dense and tiny breasts using the wearable "Smart Bra" concept, which has a	Even though it's designed to be a wearable, it tends to fail after extended use. pricey approach since every woman has different breast

		flexible antenna and cushioned material for comfort.	shapes and sizes that are impossible to generalise with a single gadget.

Based on this research, it is eventually concluded that women are often affected by breast cancer without realizing it, which may worsen their health and sometimes result in death. Using eight distinct approaches, this paper seeks to infer and evaluate several technologies for breast cancer diagnosis. Mammography is the least favored option among them, whereas thermography, microwaves, and biosensors are all utilised in real-time detection; the other choices are used extensively and at reasonable costs. In addition, while the idea behind the "Smart Bra" seems sound, it is difficult to fit and wear for women since their breasts and chests vary widely. A few software algorithms, including as CNN, RNN, KNN, SVM, NB, RF, and DT, were utilised in the majority of the studies for the pre-processing, segmentation, and classification of breast tumours.

4.1 Current Trends and Future Perspectives of Breast Cancer Screening Techniques

Current Trends

- **Digital Mammography**: Digital mammography has become the standard for breast cancer screening. It offers better image quality and allows for easier storage and sharing of images.
- **3D Mammography (Tomosynthesis):** This technology provides a more detailed view of breast tissue, reducing false positives and improving early cancer detection.
- **MRI Screening**: Magnetic Resonance Imaging (MRI) is increasingly used for high-risk individuals and those with dense breast tissue due to its superior sensitivity.
- **Artificial Intelligence (AI):** AI-based tools are being developed to assist radiologists in interpreting mammograms, improving accuracy and efficiency.

Future Perspectives

- **Liquid Biopsies**: Emerging techniques like liquid biopsies aim to detect breast cancer through blood tests, offering a less invasive and more convenient screening option.
- **Molecular Imaging**: Advancements in molecular imaging may allow for more precise detection and characterization of breast tumors.
- **Genetic Screening**: Genetic tests can identify individuals at higher risk, enabling tailored screening and prevention strategies.
- **Personalized Medicine:** The future may see a shift towards individualized screening schedules and treatments based on a person's unique risk factors and genetics.
- **Nanotechnology**: Nanoparticles and nanoscale imaging techniques hold promise for earlier detection and targeted therapy delivery.

In the coming years, breast cancer screening will likely become more precise, accessible, and patient-centered, thanks to these evolving trends and technologies. Early detection remains a cornerstone in the fight against breast cancer, and these innovations offer hope for improved outcomes and reduced healthcare burdens.

5. Conclusion

In summary, women's health is seriously threatened by breast cancer on a global scale. Early identification is important for managing and treating breast cancer, as several research studies have shown. Machine learning and deep learning are important to the processing and analysis of a vast amount of medical image data as a result of technological advancements in the field. Computer-aided diagnosis (CAD), which integrates algorithms or approaches from pattern recognition and digital image processing, has become more popular as a result of computers with expanded memory and processing capabilities. Despite being helpful, the imaging techniques now employed for breast cancer screening still have several drawbacks.

As may be seen, women of all ages mostly disregard the ineffectiveness of traditional breast screening techniques like BSE and CSE. They seldom notice changes in the consistency of the breast and often disregard the physicians' cautionary and preventative advise. In addition, smoking and alcohol use have contributed significantly to the rise in female breast cancer cases in metropolitan areas as a means of self-detoxification. It also has connections to several other illnesses and affects the heart, lungs, and esophagus. The fundamental issues may be avoided by implementing simple lifestyle adjustments.

Researchers from all across the globe are becoming more interested in MWI as a method for early identification of breast cancer. One or more of these systems are not anticipated to take the role of x-ray mammography as a screening instrument. But when combined, these methods may decrease false positive results and enhance detection. It is possible that a microwave system will be a helpful and painless low-risk diagnostic tool for young women for whom mammography is not advised. Because it translates the characteristics to a higher dimensional space, the SVM classifiers demonstrated excellent performance. In addition, the RNN, PNN, and CNN classifiers yielded positive findings. Supervised machine learning methods will thus play a major role in cancer research by helping with early cancer detection and cancer type prognosis As early diagnosis and treatment could lead to satisfactory outcomes and lessen the date rate

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