International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 10 Issue 7 July - 2026, Pages: 117-123

Breast Tissue Classification Using Artificial Neural Networks

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Abstract: *This research investigates the use of Artificial Neural Networks (ANNs) for breast tissue classification using the Breast Tissue dataset. The study applies Min-Max normalization as a preprocessing technique to improve data consistency and enhance model training performance. Several neural network architectures were evaluated using JustNN software to identify an effective model for classification. The results showed that the ANN model achieved high validation accuracy of approximately 95.45%, indicating its ability to learn complex patterns from medical data. Feature importance analysis revealed that Max IP, Area, and P were the most influential attributes in the classification process. The findings demonstrate that ANN can be an effective decision-support tool for breast tissue classification and may contribute to improving medical diagnosis accuracy.*

Keywords: Breast Tissue Classification, Artificial Neural Networks (ANN), Machine Learning, Medical Diagnosis, Breast Tissue Dataset, Pattern Recognition, Data Normalization, Classification Accuracy, Healthcare Informatics, Intelligent Decision Support Systems.

Introduction:

Breast tissue classification is an important area of medical research that supports the early detection and diagnosis of breast diseases. Accurate classification of breast tissue can assist healthcare professionals in distinguishing between different tissue types and identifying potential abnormalities. Early diagnosis is essential because it can improve treatment outcomes, reduce healthcare costs, and increase patient survival rates. With the rapid advancement of artificial intelligence and machine learning technologies, computerized diagnostic systems have become valuable tools in medical decision-making. These systems can analyse large amounts of medical data and identify patterns that may not be easily recognized by human experts. Among the various machine learning techniques, Artificial Neural Networks (ANNs) have gained significant attention due to their ability to learn complex nonlinear relationships and provide highly accurate classification results. The Breast Tissue dataset, obtained from the UCI Machine Learning Repository, contains electrical impedance measurements collected from breast tissue samples. These measurements provide important information that can be used to differentiate between various tissue classes. However, the complexity of the data requires advanced computational techniques capable of extracting meaningful patterns and relationships. In this study, Artificial Neural Networks are employed to classify breast tissue samples using normalized data. Min-Max normalization is applied during the preprocessing stage to improve learning efficiency and ensure that all input features contribute equally to the training process. The performance of the ANN model is then evaluated based on its classification accuracy and feature importance analysis. The results demonstrate the potential of neural network-based approaches in supporting intelligent medical diagnosis systems and improving breast tissue classification performance.

Objectives:

Specific objectives include:

1. To classify breast tissue samples using Artificial Neural Networks.
2. To preprocess the Breast Tissue dataset using Min-Max normalization.
3. To evaluate the performance of the ANN model in terms of classification accuracy and training error.
4. To compare different neural network architectures and determine the most effective structure.
5. To identify the most influential features affecting breast tissue classification.
6. To analyse the capability of ANN models in recognizing complex patterns within medical datasets.
7. To demonstrate the potential of machine learning techniques in supporting intelligent medical diagnosis systems.

Problem Statement:

Accurate classification of breast tissue is a critical challenge in medical diagnosis due to the complexity and variability of tissue characteristics. Traditional diagnostic methods often rely on manual interpretation by medical specialists, which may be time-consuming and subject to human error. As the volume of medical data continues to increase, there is a growing need for intelligent

and automated systems that can assist healthcare professionals in making accurate diagnostic decisions. The Breast Tissue dataset contains multiple tissue classes represented by electrical impedance measurements, making the classification task more complex. Conventional statistical techniques may not effectively capture the nonlinear relationships among the dataset features. Therefore, advanced machine learning approaches, particularly Artificial Neural Networks (ANNs), are required to improve classification performance.

This study addresses the problem of accurately classifying breast tissue samples by applying Artificial Neural Networks to normalized breast tissue data. The research aims to evaluate the effectiveness of ANN models in identifying tissue classes and improving diagnostic accuracy while reducing classification errors.

Breast tissue classification has become an important research area in medical diagnosis because of its potential to support early disease detection and improve clinical decision making. Accurate identification of breast tissue types can help physicians diagnose abnormalities more effectively and reduce the risk of diagnostic errors. As a result, researchers have increasingly explored machine learning techniques to develop intelligent systems capable of analysing complex medical data.

Literature Reviews:

Several studies have reported the successful application of Artificial Neural Networks (ANNs) in breast tissue diagnosis and classification. ANN models have demonstrated strong capabilities in recognizing complex nonlinear relationships among biomedical features, making them suitable for medical diagnostic tasks. Researchers have shown that ANNs can achieve high classification accuracy when distinguishing between different breast tissue types, thereby supporting early disease detection and clinical decision-making. The ability of ANN models to learn from historical data and generalize to unseen cases has made them one of the most widely used machine learning techniques in breast cancer and breast tissue analysis. Furthermore, studies have indicated that multilayer neural network architectures often outperform traditional statistical methods due to their capacity to capture hidden patterns within medical datasets. These findings highlight the effectiveness of ANN-based approaches as reliable tools for breast tissue classification and diagnosis.

Methodology:

This study adopted a quantitative experimental research methodology to evaluate the effectiveness of Artificial Neural Networks (ANNs) in classifying breast tissue samples. The research process consisted of data collection, preprocessing, neural network design, model training, and performance evaluation.

Dataset

The Breast Tissue dataset was obtained from the UCI Machine Learning Repository. The dataset contains 106 breast tissue samples represented by 9 numerical features derived from electrical impedance measurements. These features provide information that can be used to distinguish among different breast tissue classes.

Dataset Features Description

The Breast Tissue dataset consists of 106 samples collected from freshly excised breast tissues and categorized into six classes: Carcinoma (Car), Fibro-Adenoma (Fad), Mastopathy (Mas), Glandular (Gla), Connective (Con), and Adipose (Adi). The dataset contains nine numerical features extracted from electrical impedance spectroscopy measurements conducted at multiple frequencies ranging from 15.625 kHz to 1000 kHz. These features characterize the electrical properties of breast tissues and are used as input variables for the classification model.

The extracted features include:

* I0: Impedivity (Ω) at zero frequency.

* PA500: Phase angle measured at 500 kHz.

* HFS: High-frequency slope of the phase angle.

* DA: Impedance distance between spectral endpoints.

* AREA: Area under the impedance spectrum curve.

* A/DA: Area normalized by the impedance distance.

* MAX IP: Maximum value of the impedance spectrum.

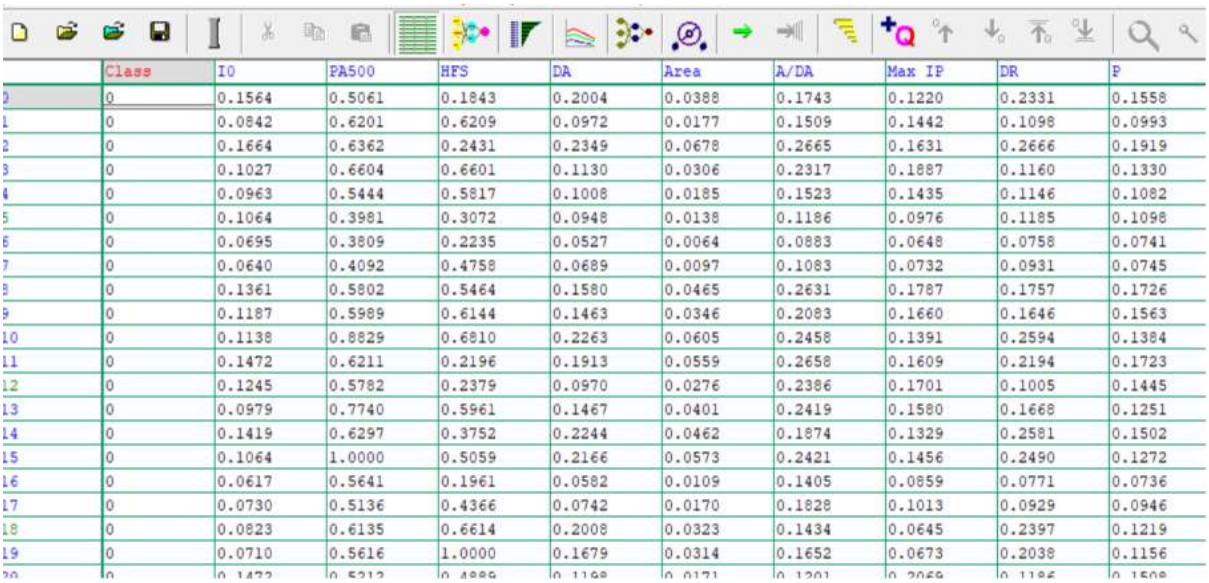
* DR: Distance between I0 and the real component of the maximum frequency point.

* P: Length of the spectral curve.

These features provide important electrical characteristics of breast tissue, enabling machine learning models such as Artificial Neural Networks (ANNs) to distinguish between different tissue types and improve classification accuracy.

Data Preprocessing

Before training the neural network, the dataset was pre-processed using Min-Max Normalization as shown in table 1. This technique scales all feature values into the range of 0 to 1, ensuring that no attribute dominates the learning process due to differences in measurement scales. Data normalization improves convergence speed and enhances the overall performance of neural network models.



	Class	I0	PA500	HFS	DA	Area	A/DA	Max IP	DR	P
0	0	0.1564	0.5061	0.1843	0.2004	0.0388	0.1743	0.1220	0.2331	0.1558
1	0	0.0842	0.6201	0.6209	0.0972	0.0177	0.1509	0.1442	0.1098	0.0993
2	0	0.1664	0.6362	0.2431	0.2349	0.0678	0.2665	0.1631	0.2666	0.1919
3	0	0.1027	0.6604	0.6601	0.1130	0.0306	0.2317	0.1887	0.1160	0.1330
4	0	0.0963	0.5444	0.5817	0.1008	0.0185	0.1523	0.1435	0.1146	0.1082
5	0	0.1064	0.3981	0.3072	0.0948	0.0138	0.1186	0.0976	0.1185	0.1098
6	0	0.0695	0.3809	0.2235	0.0527	0.0064	0.0883	0.0648	0.0758	0.0741
7	0	0.0640	0.4092	0.4758	0.0689	0.0097	0.1083	0.0732	0.0931	0.0745
8	0	0.1361	0.5802	0.5464	0.1580	0.0465	0.2631	0.1787	0.1757	0.1726
9	0	0.1187	0.5989	0.6144	0.1463	0.0346	0.2083	0.1660	0.1646	0.1563
10	0	0.1138	0.8829	0.6810	0.2263	0.0605	0.2458	0.1391	0.2594	0.1384
11	0	0.1472	0.6211	0.2196	0.1913	0.0559	0.2658	0.1609	0.2194	0.1723
12	0	0.1245	0.5782	0.2379	0.0970	0.0276	0.2386	0.1701	0.1005	0.1445
13	0	0.0979	0.7740	0.5961	0.1467	0.0401	0.2419	0.1580	0.1668	0.1251
14	0	0.1419	0.6297	0.3752	0.2244	0.0462	0.1874	0.1329	0.2581	0.1502
15	0	0.1064	1.0000	0.5059	0.2166	0.0573	0.2421	0.1456	0.2490	0.1272
16	0	0.0617	0.5641	0.1961	0.0582	0.0109	0.1405	0.0859	0.0771	0.0736
17	0	0.0730	0.5136	0.4366	0.0742	0.0170	0.1828	0.1013	0.0929	0.0946
18	0	0.0823	0.6135	0.6614	0.2008	0.0323	0.1434	0.0645	0.2397	0.1219
19	0	0.0710	0.5616	1.0000	0.1679	0.0314	0.1652	0.0673	0.2038	0.1156
20	0	0.1472	0.5212	0.4889	0.1198	0.0171	0.1201	0.2069	0.1186	0.1508

Table 1: dataset was pre-processed using Min-Max Normalization.

Neural Network Architecture

An Artificial Neural Network was developed using the JustNN software. The network architecture consisted of as shown in Figure 1:

• Input Layer: 9 neurons (representing the dataset features)

• Hidden Layer 1: 5 neurons

• Hidden Layer 2: 6 neurons

• Output Layer: 1 neuron

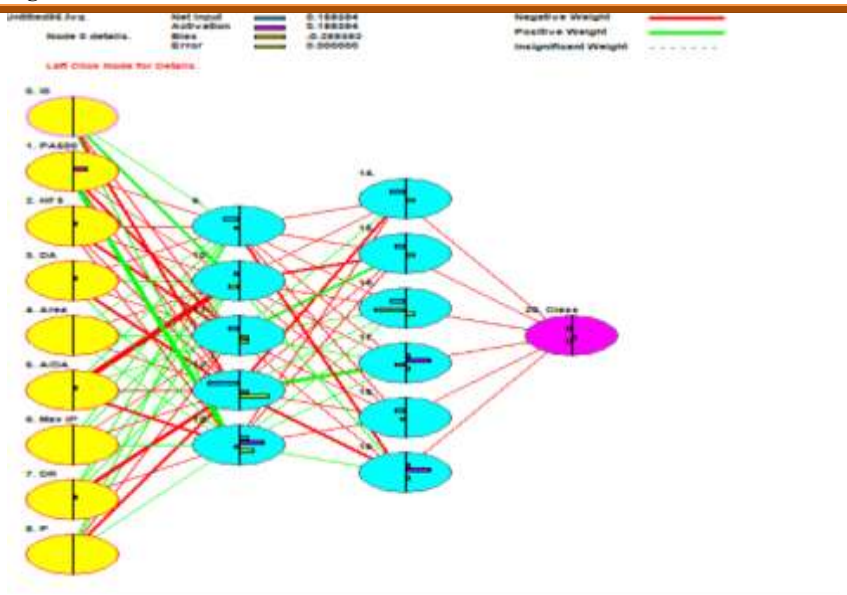


Figure 1: Architecture of the ANN used for breast tissue classification

The network was trained using the backpropagation learning algorithm. The learning rate was set to 0.6, while the momentum coefficient was set to 0.8 to improve training stability and accelerate convergence.

Training and Validation

The dataset was divided into two subsets:

• Training Set: 84 samples (80%)

• Validation Set: 22 samples (20%)

The training dataset was used to learn the underlying patterns within the data, while the validation dataset was used to evaluate the model's generalization capability on unseen samples.

Performance Evaluation

The performance of the ANN model was assessed using classification accuracy and training error. In addition, feature importance analysis was performed to identify the attributes that contributed most significantly to classification performance as shown in figure 2. The evaluation results were used to determine the effectiveness of the proposed ANN model in breast tissue classification.

Untitled95.tvq 31582 cycles. Target error 0.0100 Average training error 0.001893

The first 9 of 9 Inputs in descending order.

Column	Input Name	Importance	Relative Importance
2	PA500	96.2281	
6	A/DA	89.3401	
1	I0	64.3655	
9	P	52.3582	
3	HFS	48.0296	
4	DA	42.3222	
7	Max IP	39.2124	
8	DR	32.8397	
5	Area	19.0994	

Figure 2: Relative importance of input features used in breast tissue classification

Results:

The Artificial Neural Network (ANN) model was trained and evaluated using the Breast Tissue dataset after applying Min-Max normalization. The experimental results demonstrated that the ANN achieved a validation accuracy of approximately **95.45%** as shown in Figure 3, indicating strong classification performance. The model was trained using **84** samples and validated using **22** samples. The average training error was **0.002496**, showing that the network successfully learned the patterns within the dataset.

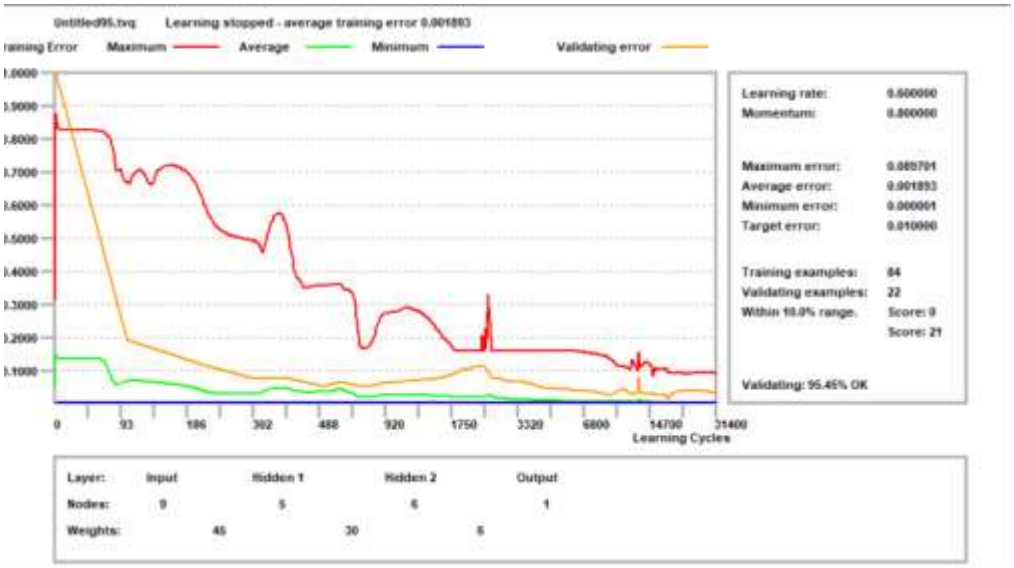


Figure 3: Performance of an ANN architecture achieving 95.45% validation accuracy

Feature importance analysis revealed that **Max IP, Area, and P** were the most influential attributes in the classification process. These features contributed significantly to the network's ability to distinguish between different breast tissue classes. The high accuracy and low training error suggest that the proposed ANN model is effective for breast tissue classification.

Discussion:

Two neural network architectures were evaluated using the Breast Tissue dataset as shown in figure 4. The architecture containing two hidden layers (9-5-6-1) achieved the best performance, obtaining a validation accuracy of 95.45% and correctly classifying 21 out of 22 validation samples. Although the single-hidden-layer networks produced slightly lower training errors, their validation accuracies were lower (86.36% and 90.91%), indicating reduced generalization capability. These results demonstrate that adding a second hidden layer improved the network's ability to model complex patterns within the dataset and resulted in superior classification performance.

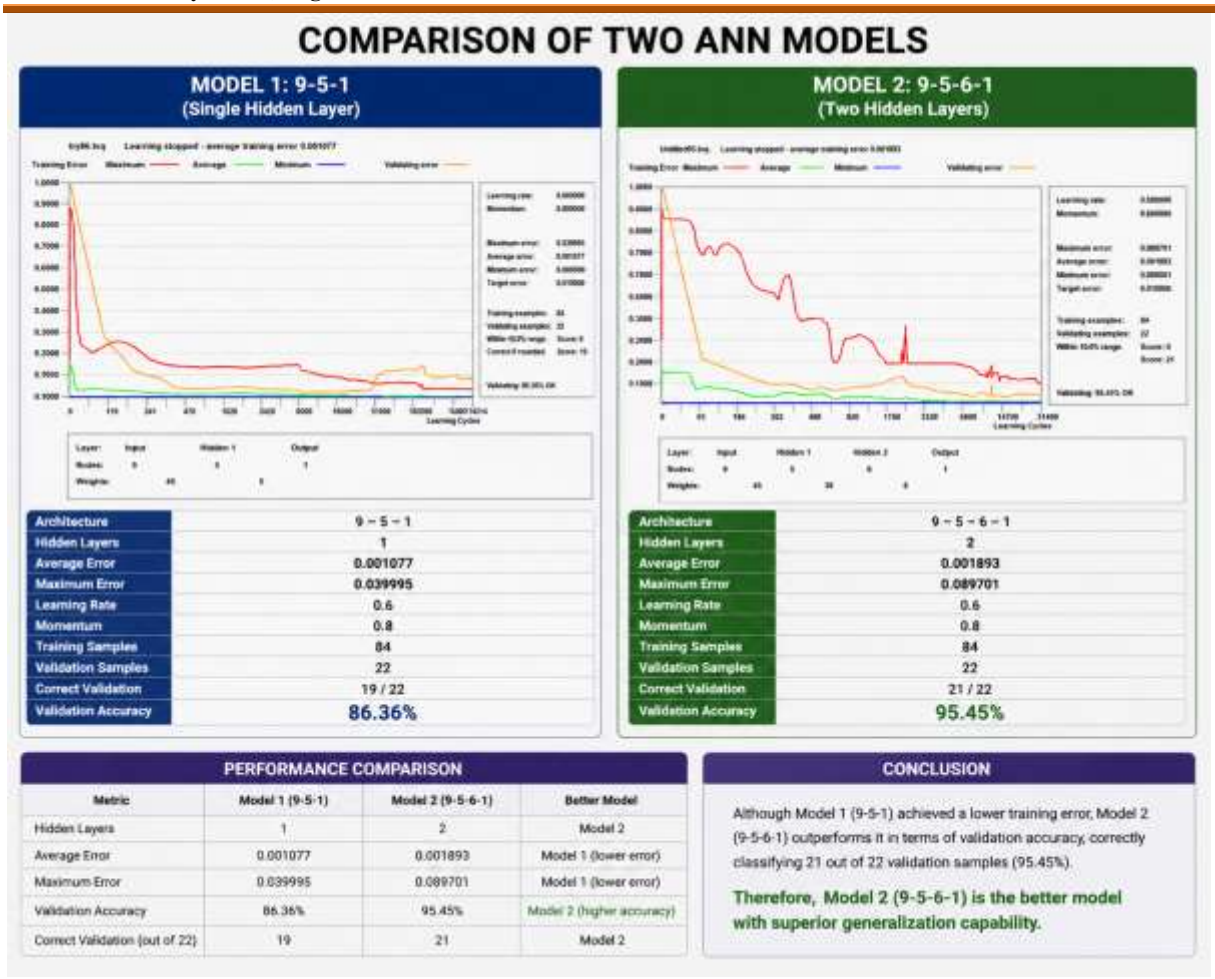


Figure 4: Performance of ANN architecture with one hidden layer verse two hidden layers

The results indicate that Artificial Neural Networks are highly effective in handling complex medical classification problems. The achieved validation accuracy of 95.45% demonstrates the capability of ANN models to learn nonlinear relationships among breast tissue features. The low training error further confirms that the network was able to converge successfully during the learning process. The use of Min-Max normalization played an important role in improving model performance by ensuring that all features contributed equally during training. Additionally, the feature importance analysis provided valuable insights into the most relevant variables affecting classification outcomes. The findings are consistent with previous studies that reported strong ANN performance in medical diagnosis and classification applications. Although the model achieved high accuracy, the relatively small size of the dataset may limit the generalization of the results. Future studies could utilize larger datasets .

Conclusion:

This study investigated the application of Artificial Neural Networks for breast tissue classification using the Breast Tissue dataset. After applying Min-Max normalization and training the ANN model, the system achieved a validation accuracy of approximately 95.45%, demonstrating excellent classification capability. The findings confirm that ANN models can effectively identify complex patterns within medical data and provide reliable classification results. Feature importance analysis highlighted Max IP, Area, and P as the most significant predictors for tissue classification.

Overall, the study demonstrates the potential of Artificial Neural Networks as a valuable tool for intelligent medical diagnosis and decision-support systems. Future work may focus on evaluating alternative machine learning techniques, optimizing network architectures, and applying the proposed approach to larger and more diverse medical datasets.

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