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An Explainable Attention-Based Deep Learning Framework for Breast Cancer Classification with Hyperparameter Tuning and Ablation Studies

Breast cancer remains one of the leading causes of mortality among women worldwide, necessitating the development of accurate and reliable computer-aided diagnostic systems. This study investigates the effectiveness of deep learning approaches for breast cancer classification using the Wisconsin Breast Cancer dataset. Baseline models, including a Multi-Layer Perceptron (MLP) and a Deep Neural Network (DNN), were implemented and compared with an attention-enhanced DNN architecture. Furthermore, hyperparameter optimization and ablation studies were conducted to evaluate the contributions of attention mechanisms, batch normalization, and dropout regularization to model performance. Experimental results demonstrate that the baseline MLP achieved the highest overall performance, obtaining an accuracy of 98.25%, an F1-score of 97.56%, and an area under the receiver operating characteristic curve (AUC) of 99.70%. The baseline DNN achieved an accuracy of 97.37%, while the tuned Attention-DNN attained 96.49% accuracy and an AUC of 99.27%, indicating that optimization substantially improved the performance of the attention-based model. Ablation experiments revealed that the removal of batch normalization had minimal impact on classification accuracy, whereas the absence of dropout resulted in severe performance degradation, reducing accuracy to 66.67% and the F1-score to 17.39%, thereby highlighting the importance of regularization in preventing overfitting. Overall, the findings demonstrate that conventional deep neural architectures provide highly competitive performance for breast cancer diagnosis, while carefully optimized attention mechanisms and regularization strategies can enhance model robustness and reliability. These results suggest that explainable and optimized deep learning frameworks have significant potential for supporting early breast cancer detection and improving clinical decision-making.

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