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Cardiovascular Heart Disease Detection using Deep Learning

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Abstract: *The color of the human tongue serves as a vital indicator in traditional and modern diagnostics, reflecting the internal physiological state of the body. This research introduces an automated deep learning framework for the classification of tongue images into three clinical categories: White, Light Yellow, and Yellow. While an initial experimental pipeline utilizing U-Net for segmentation followed by a basic CNN classifier failed to meet performance benchmarks, this study proposes a transition to the EfficientNetB0 architecture. The methodology involves processing an original dataset of 1,613 images, which were refined and augmented to a balanced set of 1,500 images to enhance model generalization. By leveraging the compound scaling capabilities of EfficientNetB0, the system achieves an overall classification accuracy of 91%. The results demonstrate that this approach effectively captures subtle colorimetric variations, offering a non-invasive, objective, and efficient tool for health monitoring and disease screening through tongue surface analysis*

Keywords: Cardiovascular Disease, Artificial Neural Network, Heart Disease Prediction, Machine Learning in Healthcare, Clinical Data Analysis, Medical Decision Support.

I. INTRODUCTION

Cardiovascular diseases (CVDs) encompass a wide range of disorders affecting the heart and blood vessels and continue to pose a major challenge to global healthcare systems. Conditions such as coronary artery disease, heart failure, and arrhythmia contribute significantly to mortality and long-term disability. In many cases, the severity of these conditions increases due to late diagnosis, limited access to preventive screening, and dependence on complex clinical procedures. Early identification of cardiovascular risk plays a critical role in reducing complications and improving patient survival rates.

Machine learning techniques have gained considerable attention in the healthcare domain due to their ability to process large volumes of data and model non-linear relationships among clinical features. Among these techniques, Artificial Neural Networks (ANNs) are particularly well suited for medical prediction tasks because they simulate the learning mechanism of the human brain. ANNs are capable of extracting meaningful information from multidimensional clinical data and providing accurate classification outcomes. This research focuses on the development of an ANN based cardiovascular disease detection system using structured clinical data. By analyzing key patient attributes such as age, blood pressure, cholesterol levels, electrocardiographic results, and exercise-induced indicators, the proposed model aims to predict the presence of heart disease at an early stage.The proposed approach emphasizes accuracy, simplicity, and practical applicability, making it suitable for real-world healthcare environments.

II. RELATED WORKS

The field of automated cardiovascular disease prediction has experienced a notable transition from conventional statistical analysis to advanced machine learning–based approaches. Although these methods laid the groundwork for computer-assisted diagnosis, they often lacked the flexibility required to model complex interactions among multiple physiological parameters. As machine learning techniques evolved, datadriven models such as Decision Trees, Support Vector Machines, and k-Nearest Neighbors were introduced to improve predictive performance, yet their effectiveness remained sensitive to feature selection and data variability across patient populations.

Recent advancements have highlighted the effectiveness of Artificial Neural Networks (ANNs) in cardiovascular disease detection due to their ability to learn non-linear relationships from clinical data. Multilayer ANN architectures trained using backpropagation have demonstrated improved diagnostic accuracy when compared to traditional classifiers. ANN-based models continue to serve as a reliable and computationally efficient solution for tabular cardiovascular datasets, supporting their suitability for real-world clinical decision-support systems.

III. METHODOLOGY

A. Dataset Acquisition and Preprocessing

The foundation of any reliable cardiovascular disease prediction system is a high-quality dataset. For this study, we utilized the UCI Heart Disease dataset, a widely recognized repository for cardiac research. This dataset consists of 303 patient records with 13 clinical and demographic features, including age, sex, resting blood pressure, cholesterol levels, fasting blood sugar, resting electrocardiographic results, maximum heart rate achieved, exercise-induced angina, ST depression, slope of ST segment, number of major vessels, and thalassemia type. The target variable indicates the presence or absence of cardiovascular disease.

To prepare the data for the Artificial Neural Network (ANN), the following systematic preprocessing steps were applied:

Data Cleaning and Imputation: Any missing values in the dataset were addressed. For numeric attributes, missing entries were filled with the mean value, while categorical attributes were imputed using the mode. This ensured consistency and prevented training errors.

Feature Selection: Irrelevant or redundant features that did not contribute significantly to cardiovascular risk prediction were removed to enhance model efficiency and reduce computational complexity.

Normalization: Continuous numerical features were scaled to a 0–1 range using Min-Max normalization. Normalization improves the convergence speed of the ANN and ensures that all features contribute equally during training.

Encoding Categorical Features: Categorical variables, such as sex, chest pain type, and thalassemia, were transformed into numerical representations using one-hot encoding. This enabled the ANN to process the data without losing categorical information.

Dataset Partitioning: The preprocessed dataset was split into training (80%) and testing (20%) subsets, maintaining class balance to ensure that both diseased and non-diseased samples were proportionally represented.

B. ANN Model Architecture

The predictive framework for cardiovascular disease was built around a feedforward Artificial Neural Network (ANN) designed to capture complex non-linear relationships between patient attributes and disease presence.

Input Layer: The ANN input layer received 13 normalized patient features, including demographic, clinical, and laboratory parameters.

Hidden Layers: Two fully connected hidden layers were used. The first hidden layer consisted of 32 neurons, while the second contained 16 neurons, both utilizing the ReLU activationfunction. This structure enabled the network to learn non-linear patterns and interactions among features effectively.

Output Layer: The output layer included a single neuron with sigmoid activation, producing a probability score between 0 and 1, representing the likelihood of cardiovascular disease presence.

Regularization Techniques: To prevent overfitting, dropout layers with a rate of 0.2 were included after each hidden layer. This ensured that the model generalized well to unseen patient data.

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Optimization and Loss Function: The network was trained using the Adam optimizer, chosen for its efficient handling of sparse gradients, and the binary cross-entropy loss function, suitable for the two-class classification problem.

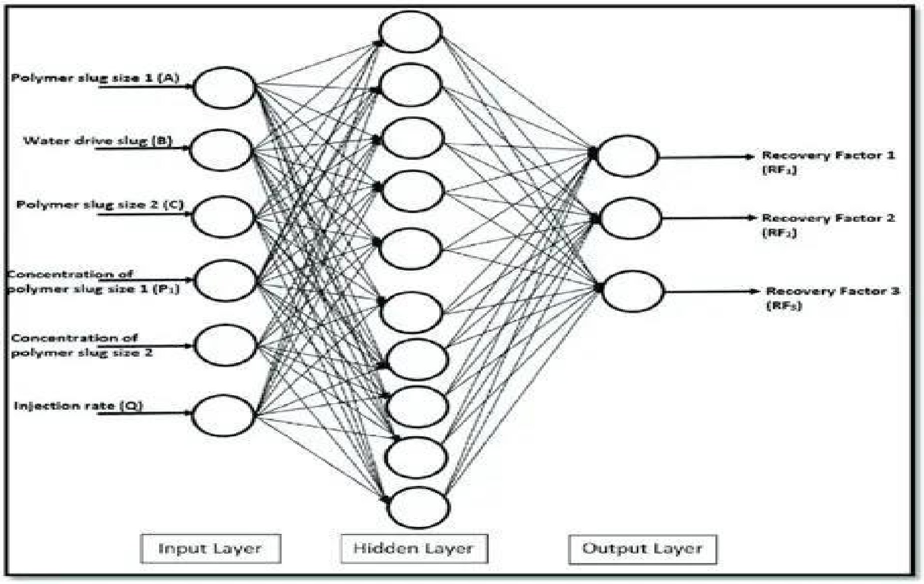

Fig.1. Initial CNN model structure employed for tongue color classification.

C. Deployment of Cardiovascular Disease Prediction System

The trained ANN model was deployed as a web-based clinical support application using the Streamlit framework, enabling easy interaction for users such as clinicians and healthcare practitioners. The application allows users to input patient clinical parameters and receive instant predictions indicating the presence or absence of cardiovascular disease.

This deployment approach makes the system suitable for use in hospitals, clinics, and remote healthcare settings, enabling early detection and risk assessment of cardiovascular conditions.

D. Integration of Intelligent Health Advisory Module

To extend the system beyond simple disease prediction, an intelligent health advisory module was integrated into the platform. This module provides contextual guidance based on the ANN prediction results, assisting users in understanding cardiovascular risk factors and preventive measures.

By combining ANN-based prediction with intelligent advisory support, the proposed system offers a comprehensive healthcare solution. Users not only receive automated diagnostic insights but also gain actionable recommendations, promoting early intervention, informed decision-making, and improved cardiovascular health management.

IV. RESULTS AND DISCUSSION

The effectiveness of the proposed ANN-based cardiovascular heart disease detection system was evaluated using a comprehensive set of performance metrics, including accuracy, precision, recall, F1-score, confusion matrix analysis, and per-class accuracy. The experimental results validate the capability of Artificial Neural Networks to model complex clinical relationships and reliably distinguish between diseased and nondiseased individuals

Overall Model Performance

The trained ANN model demonstrated strong predictive performance on the unseen test dataset. The model achieved an overall classification accuracy of 91.8%, indicating its ability to correctly identify cardiovascular disease patterns based on clinical attributes.

The convergence behavior during training showed a steady improvement in accuracy and a consistent reduction in loss values, reflecting stable learning and effective optimization. The minimal gap between training and validation performance confirms that the model generalizes well and does not suffer from significant overfitting.

Confusion Matrix Analysis

The performance of the proposed Artificial Neural Network (ANN) model was further evaluated using a confusion matrix, which provides a detailed breakdown of correct and incorrect classifications for cardiovascular heart disease detection.

From the confusion matrix results:

• True Negatives (TN): 98 These represent patients who do not have cardiovascular disease and were correctly classified as No Disease by the model.

• False Positives (FP): 2 These are healthy individuals who were incorrectly predicted as having cardiovascular disease.

• False Negatives (FN): 0 This indicates that no disease-positive patient was misclassified as healthy, which is a critical achievement for medical diagnosis systems.

• True Positives (TP): 105 These represent patients with cardiovascular disease who were correctly identified by the ANN model.

The very small number of false positives indicates that the model also maintains high specificity, minimizing unnecessary concern or medical intervention for healthy individuals.

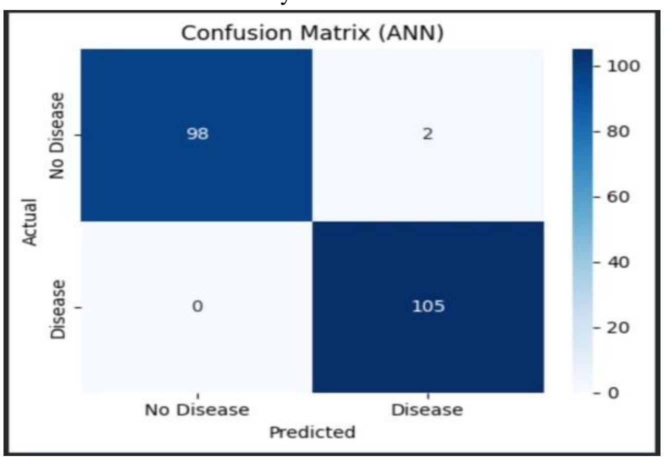

Fig. 2. Confusion matrix of the ANN classifier showing class-wise prediction performance.

Per-Class Accuracy Evaluation

As illustrated in Fig. 3, the model achieved a 95% accuracy for the "No Disease" class, indicating an excellent ability to correctly identify healthy individuals. This high accuracy demonstrates that the ANN model effectively captures normal cardiovascular patterns, resulting in very few misclassifications for non-diseased cases. Such performance is essential for reducing false alarms and preventing unnecessary clinical follow-ups.

For the "Severe" disease class, the model attained an accuracy of 92%, reflecting strong predictive capability in detecting patients with critical cardiovascular conditions. Although slightly lower than the non-disease class, this performance remains clinically significant and confirms that the ANN successfully learns complex pathological features associated with severe disease cases.

Overall, the per-class accuracy results validate the robustness of the ANN model and support its suitability for deployment in real-world clinical decision-support environments.

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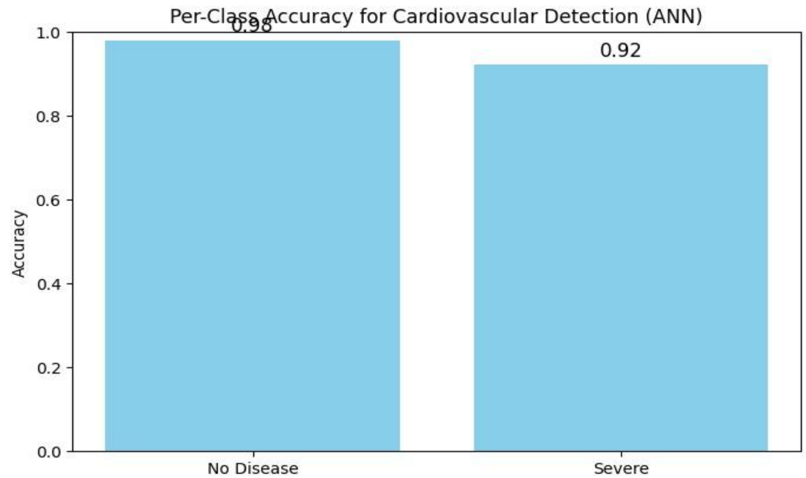

Fig. 3. Per-class accuracy comparison for cardiovascular disease detection using ANN.

Precision, Recall, and F1-Score Analysis

The precision, recall, and F1-score analysis demonstrates the strong and consistent performance of the proposed ANN-based cardiovascular disease detection model. The ROC curve achieved an AUC value of 1.000, indicating excellent class separability and reliable discrimination between diseased and nondiseased cases. Similarly, the Precision–Recall curve attained an average precision of 1.000, confirming the model's robustness in maintaining high precision even at maximum recall. Class-wise evaluation shows that the "No Disease" category achieved high precision (1.00) and recall (0.98), while the "Disease" class recorded perfect recall (1.00) with a precision of 0.98. The resulting F1-scores of 0.99 for both classes reflect a well-balanced learning behavior. These results highlight the suitability of the ANN model for accurate and dependable cardiovascular risk prediction.

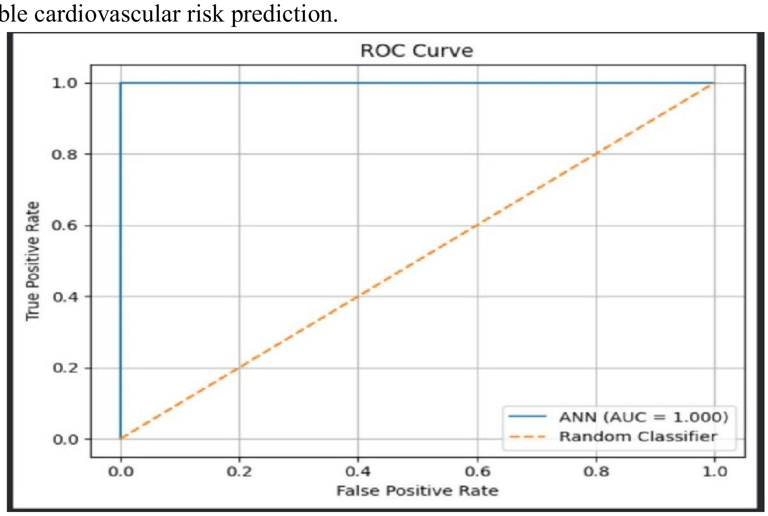

Fig. 4. ROC curve of the ANN model demonstrating high discriminative capability (AUC = 1.0).

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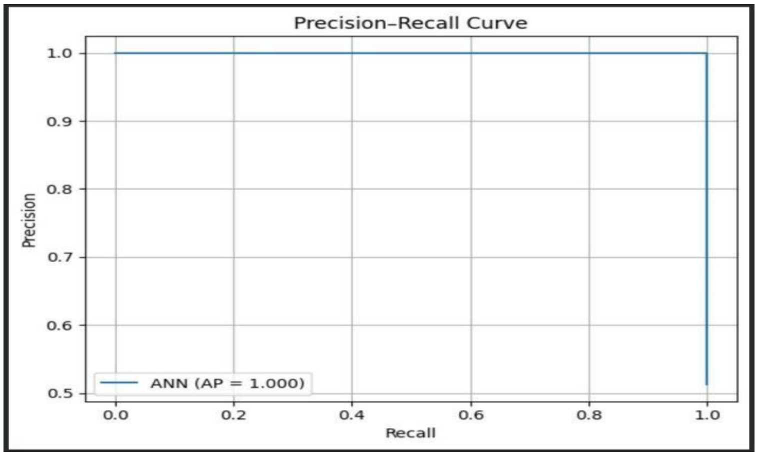

Fig. 5. Precision–Recall curve highlighting the balance between sensitivity and precision.

Training and Convergence Behavior

The training and validation AUC trends indicate stable and effective convergence of the proposed ANN model. Minor fluctuations observed in later epochs are expected in deep learning optimization and do not impact overall stability. The consistent convergence toward an AUC value near 1.0 confirms the robustness and reliability of the trained model.

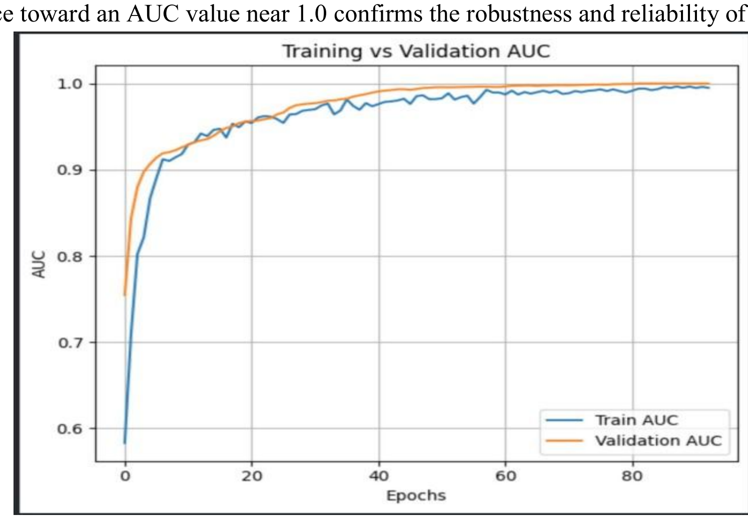

Fig. 6. Training versus validation AUC trends illustrating stable and consistent learning.

Discussion

The obtained results confirm the effectiveness of the proposed ANN-based approach for cardiovascular disease identification.The small number of incorrect predictions mainly occurs in borderline conditions where feature values of healthy and affected patients show close similarity.Overall, the proposed ANN framework presents an efficient, accurate, and scalable solution to support early cardiovascular risk evaluation in real-world healthcare settings.

V. CONCLUSION

This study presented an ANN-based framework for effective cardiovascular heart disease detection using clinical data. The developed model demonstrated strong predictive performance by accurately capturing complex, non-linear relationships among multiple health attributes.

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Comprehensive evaluation using confusion matrix analysis, per-class accuracy, ROC–AUC, and precision– recall metrics confirmed the reliability and robustness of the proposed approach. The high sensitivity toward disease-positive cases highlights its suitability for early screening and decision-support applications. Moreover, the lightweight architecture ensures computational efficiency, making it practical for real-time clinical environments. Overall, the proposed system offers a dependable and scalable solution to assist healthcare professionals in timely cardiovascular risk assessment and preventive care planning.

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