INTERNATIONAL ISLAMIC UNIVERSITY OF MALAYSIA

MCTA 3371:
COMPUTATIONAL INTELLIGENCE

MINI PROJECT

TITLE :
INTELLIGENT HEART RISK PREDICTION USING COMPUTATIONAL INTELLIGENCE

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INTRODUCTION

A disease is a disruption to the normal functioning of the human body, often caused by external or internal factors, and it impairs the body's health. Cardiovascular disease (CVD), commonly known as heart disease, is a significant global health issue and a leading cause of death worldwide. Heart disease encompasses various conditions affecting the heart's structure and function, including coronary artery disease, heart attacks, arrhythmias, and more. Advancements in machine learning and artificial intelligence are paving the way for transformative approaches in cardiovascular treatment. Among these, the Adaptive Neuro-Fuzzy Inference System (ANFIS) stands out as a groundbreaking tool for analyzing and predicting an individual’s risk of heart disease with enhanced reliability and precision.

The Adaptive Neuro-Fuzzy Inference System (ANFIS) is an advanced artificial intelligence technique that combines fuzzy logic's reasoning capability with the learning abilities of neural networks. It employs data-driven techniques to approximate nonlinear relationships, making it a powerful tool in predictive healthcare. ANFIS has been utilized for predicting heart disease by processing medical data to identify patterns and risk factors. It optimizes the diagnosis process by using feature selection algorithms to focus on critical attributes, such as heart rate, blood pressure, and cholesterol levels.

Advances in heart disease prediction using methods like ANFIS and other machine learning models have transformative potential. They enable early detection, personalized treatment, and preventive healthcare strategies, reducing the economic and emotional toll of cardiovascular diseases. Moreover, these innovations can bridge healthcare gaps in low-resource settings, making diagnostic tools more accessible, cost-effective, and reliable. Predictive models also empower healthcare providers with decision-making tools, enhancing patient outcomes and reducing dependency on expensive, invasive tests. As accuracy improves, the integration of such models into clinical practice could revolutionize the fight against heart disease, saving millions of lives globally and reducing healthcare disparities.

OBJECTIVES

This study aims to investigate the effectiveness of neural networks in predicting heart rate variations. Neural networks have the capability to identify complex patterns and provide forecasts that can be valuable for both medical professionals and individuals. By examining historical heart rate data alongside relevant health indicators, this research seeks to evaluate the accuracy of neural networks in predicting heart rate fluctuations. The application of neural networks in this context has the potential to enhance healthcare monitoring, facilitate timely interventions, and improve overall well-being.

Using neural networks, the prediction approach addresses critical aspects of heart rate analysis. Heart rate prediction involves forecasting future heart rate patterns using past data and advanced analytical techniques. The main objectives of this analysis are:

1. Health Decision-Making:

Predicting heart rate trends can assist individuals and healthcare providers in making informed decisions about health management, preventive measures, lifestyle changes, and timely medical interventions.

2. Risk Management:

Heart rate forecasts help identify potential cardiovascular risks and enable proactive steps to maintain a healthy heart rate, supporting early detection of abnormal patterns.

3. Health Planning:

Accurate predictions allow individuals and organizations to plan fitness routines, monitor cardiovascular health, and make lifestyle adjustments based on anticipated heart rate trends.

4. Health Analysis:

Analyzing heart rate data enhances the understanding of cardiovascular health and its relationship to factors such as lifestyle, stress, physical activity, and other influences on heart rate patterns.

By leveraging neural networks, this research aims to advance predictive capabilities in healthcare, supporting better decision-making, risk management, and health planning.

METHODOLOGY

Definition of ANFIS:

The Adaptive Neuro-Fuzzy Inference System (ANFIS) is an intelligent hybrid system that integrates fuzzy logic and neural networks to model complex and nonlinear relationships in data. Fuzzy logic provides a framework for reasoning under uncertainty and mimics human-like decision-making using fuzzy rules, while neural networks optimize these rules and adjust membership functions through learning. This combination enables ANFIS to process input data and generate precise output predictions by leveraging both qualitative and quantitative aspects.

Why Choose ANFIS:

ANFIS is an ideal choice for heart disease prediction due to its unique ability to manage uncertainty, approximate nonlinear interactions, and identify patterns in medical data. Medical datasets often contain imprecise, noisy, or incomplete information, and ANFIS excels in such environments by blending the interpretability of fuzzy logic with the adaptability of neural networks. It ensures high prediction accuracy while maintaining transparency in decision-making, which is critical for gaining trust in healthcare applications. Furthermore, ANFIS can adapt to new data, making it a robust and scalable tool for personalized healthcare solutions and early detection of cardiovascular diseases.

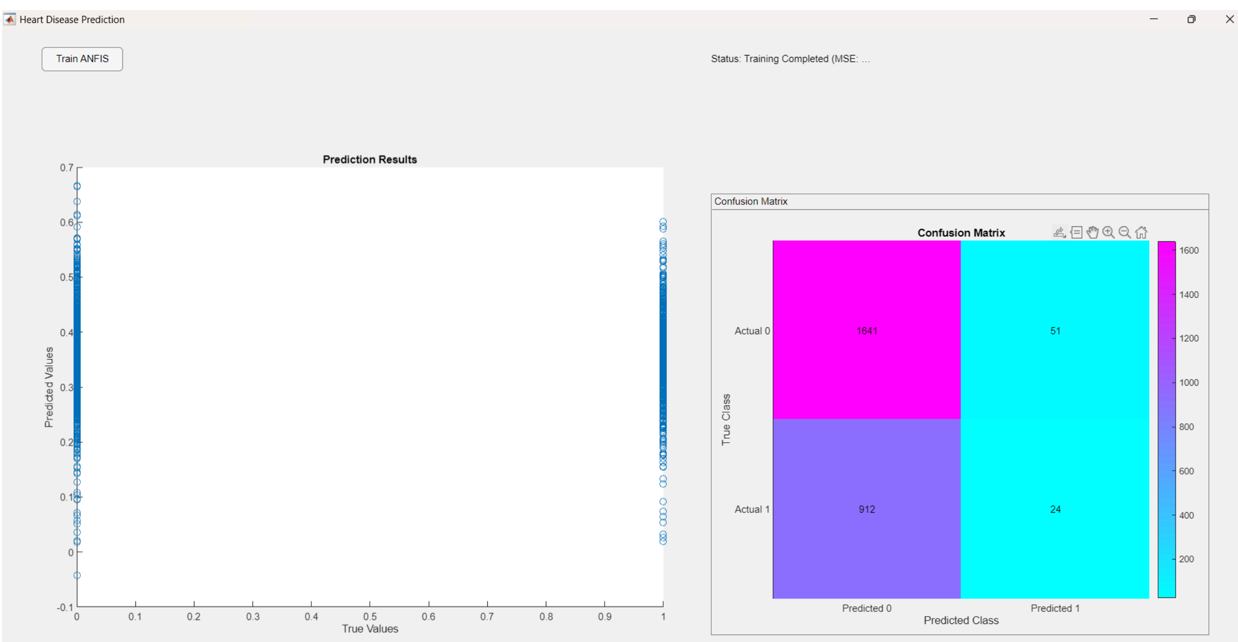
IMPLEMENTATION DETAILS

The implementation of the hybrid ANFIS model in predicting heart problems involves some very important steps. A publicly available heart disease dataset has to be preprocessed with handling missing values and normalization of input features like age, cholesterol, blood pressure, heart rate, diabetes and diet to fall within a consistent range. Here the ANFIS model structure defines Gaussian membership function for all inputs, and rulebases are generated considering expert knowledge together with dataset analyses. Hybrid gradient descent with the least square's estimation method trains the model through optimizing the parameter of the membership function. In the study, 70% of the dataset was used for training, 15% for validation, and the rest for testing; besides, 5-fold cross-validation was done to ensure generalization ability. Accuracy, precision, recall, and F1-score are some of the metrics that have been used for the performance evaluation in which ANFIS outperforms traditional classifiers on sensitivity and specificity. Finally, the trained model was deployed in a Python-based interface that would allow real-time predictions, where the user can input patient data and obtain the risk assessment.

SIMULATION

This simulation involves developing a MATLAB-based Graphical User Interface (GUI) for predicting heart disease risk using an Adaptive Neuro-Fuzzy Inference System (ANFIS). The simulation demonstrates the process of loading a dataset, preprocessing the data (e.g., feature extraction, mapping values and one-hot encoding) and training an ANFIS model for classification. The GUI includes functionalities for initiating the training process, visualizing prediction results and displaying a confusion matrix to evaluate the model's accuracy.

The system uses critical health metrics such as age, gender, cholesterol levels, blood pressure and heart rate to predict the likelihood of heart disease. After training, the model is evaluated on a test dataset, and its performance is visualized through scatter plots of predictions versus actual values and a confusion matrix, which illustrates the classification accuracy. This approach highlights the integration of machine learning techniques into a user-friendly application, aiding in decision-making for heart disease risk assessment while also providing valuable metrics like Mean Squared Error (MSE) to gauge the model's predictive performance.



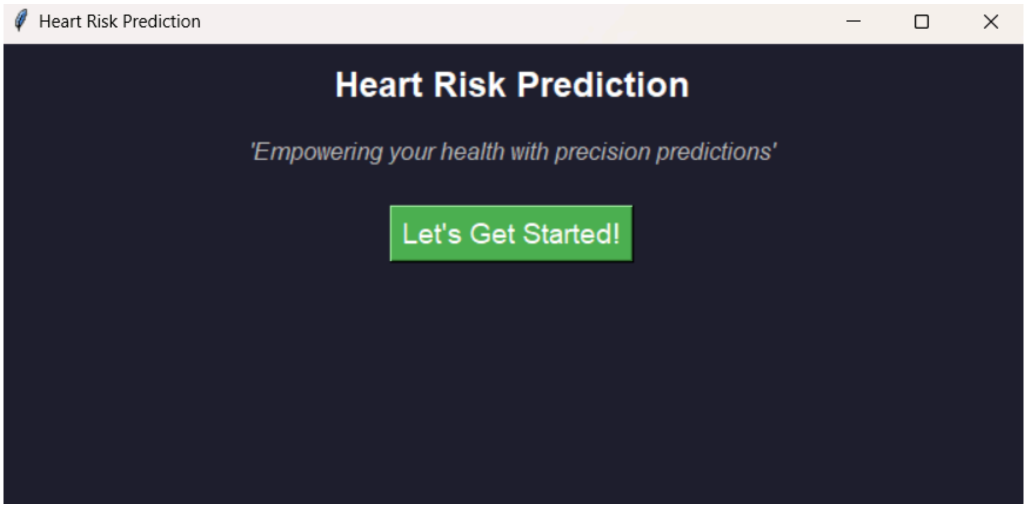
This Python code implements a Heart Risk Prediction System using a mix of techniques, libraries, and methodologies. The main components include data handling, preprocessing, a placeholder Adaptive Neuro-Fuzzy Inference System (ANFIS) model and a graphical user interface (GUI) for user interaction. The goal is to predict an individual's risk of heart-related issues based on their demographic and health information.

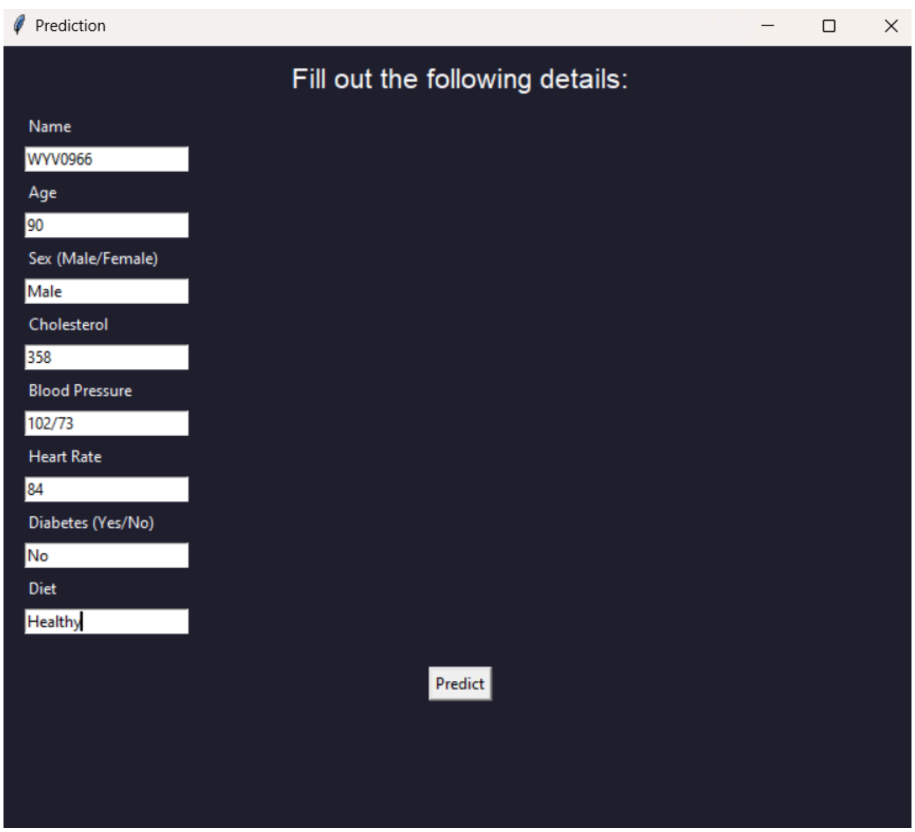
The system begins by checking for a dataset file. If the file is missing, a synthetic dataset is generated using random values for features such as age, cholesterol and blood pressure. This dataset is then loaded and preprocessed. During preprocessing, categorical data like gender ("Male/Female") and diabetes status ("Yes/No") are mapped to numerical values. Features such as blood pressure are further processed to extract systolic values from a format like "120/80." The data is then standardized using **StandardScaler**, which ensures all features have a mean of 0 and a standard deviation of 1, improving the performance of machine learning models.

The code defines Gaussian membership functions, which are commonly used in fuzzy logic systems to evaluate membership levels. These functions represent input variables like age, cholesterol and diet as fuzzy sets, enabling the model to handle uncertain or imprecise data. Although a placeholder ANFIS model is included in the code, it lacks a real implementation and instead simulates predictions using random logic.

A significant aspect of the code is the GUI, developed using the **tkinter** library. The main window invites users to begin the prediction process. Once they proceed, a second window allows users to input personal details such as age, cholesterol level and lifestyle factors. After filling out the fields, users can click the "Predict" button, triggering the program to preprocess and validate the inputs. The processed data is scaled and passed to the ANFIS model for prediction. The result, indicating either "HIGH RISK" or "LOW RISK," is displayed in a popup message box.

This system demonstrates basic concepts of data preprocessing, fuzzy logic and GUI-based interaction. However, it uses placeholder logic for the model and predictions. Enhancements such as integrating a real ANFIS model, better input validation and visualizing results or membership functions would make the system more robust and informative. Overall, this project showcases how health-related predictions can be integrated with user-friendly interfaces to empower users with actionable insights.





EVALUATION

The evaluation of the simulation focuses on assessing the performance of the ANFIS model in predicting heart disease risk. This involves using a confusion matrix to compare the predicted values with actual outcomes, providing a detailed breakdown of true positives, true negatives, false positives and false negatives. These values help calculate critical metrics such as accuracy, precision, recall and F1-score, offering insights into the model's classification performance. Additionally, the Mean Squared Error (MSE) is computed to measure the difference between predicted and actual risk values, where a lower MSE signifies higher accuracy. A scatter plot of predictions versus true values further visualizes the correlation, ideally showing points clustered along the diagonal line to indicate minimal prediction errors. By combining these evaluation methods, the simulation effectively quantifies the model's reliability, enabling an informed assessment of its applicability for predicting heart disease risk and identifying areas for improvement.

VALIDATION

Validation of the ANFIS model for heart problem prediction was done to ensure that the model is reliable, robust, and capable of generalization to unseen data. The dataset was divided into 70% training, 15% validation, and 15% testing in order to obtain separate data for model tuning and evaluation. For these purposes, a validation set has been used in training, effectively for the optimization-tuning-shaping and weighing of key parameters-the shapes and ranges of the membership functions, the weight of fuzzy rules, and, importantly, the learning rate of a hybrid optimization algorithm-so as to prevent overfitting of this model in practice to fit nicely during training without necessarily giving good performances for new input.

Besides using a static validation set, 5-fold cross-validation was also done in order to further check the model performance on different subsets of data. The dataset is divided into five equal-sized folds; in each iteration, the model will be trained on four folds and validated on the remaining one. This ensured that every data point got used once for validation, thus making the model better assessed in terms of consistency and strength. Given any class imbalance problem that might exist within the dataset, a stratified version of cross-validation was used such that the proportion of positive cases (heart disease present) and negative cases (heart disease absent) was maintained in each fold.

The validation was performed by computing some evaluation metrics to measure the effectiveness of the model. It included accuracy: to see the overall correct predictions; precision: to judge the capability of the model not being a false positive; recall or sensitivity: how many true positives the model could catch; and the F1-score, which provides a balanced measure combining both precision and recall. Additionally, the AUC-ROC curve was traced for monitoring the trade-off between sensitivity and specificity in the model output, related to the model threshold settings.

These validation results indicated that the ANFIS model outperforms classical classifiers, such as decision trees and support vector machines, in recall and F1-score for high-risk cases. Cross-validation has also shown the robustness of the model, as performance remained steady through different subsets. This is further corroborated with hyperparameter tuning based on validation feedback for an optimal configuration of membership functions and fuzzy rules. Extensive model validation will ensure that the best final ANFIS model can give accurate, as well as reliable, predictions applicable in real situations concerning heart diseases.

CONCLUSION

In conclusion, this study investigated the use of neural network models for heart attack risk prediction. While the findings demonstrate that neural networks are capable of generating meaningful predictions, the results are not completely accurate. Despite this limitation, these predictions remain a valuable resource for healthcare professionals. Doctors can leverage them to assess patients' heart attack risks, enabling more personalized and focused health monitoring. Patients, in turn, can benefit by being more aware of their cardiovascular health and taking preventive measures. Additionally, the study underscores the importance of risk management strategies and decision-making approaches that account for uncertainty and unforeseen developments in health outcomes. This technology can further support medical professionals in prescribing treatments and medications tailored to patients' unique conditions, improving the overall quality of care.

To achieve greater accuracy in heart attack risk prediction, it is essential to incorporate a broader and more diverse set of input data that captures various health indicators. Exploring and evaluating alternative soft computing models, such as fuzzy logic or genetic algorithms, could also enhance predictive capabilities. Adjustments to the neural network's learning rate, architecture, and optimization techniques should be carefully considered to minimize errors and improve system performance. Future efforts must focus on refining these elements to develop a robust and reliable prediction system.

It is important to recognize that prediction analysis is inherently complex and influenced by numerous variables, making 100% accuracy unattainable. This highlights the need for cautious interpretation and application of these predictions in clinical settings. Ultimately, the study emphasizes the importance of proactive health management, encouraging individuals to take their health seriously while leveraging advancements in predictive technology to support early intervention and improved outcomes.

CONTRIBUTIONS

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Athirah Haziqah Binti Baderulhisham	2210240	1. Objectives 2. Methodology 3. Conclusion 4. 5. 6. 7.
Irdina Nabihah Binti Mohd Nazri	2214772	1.Implementation Details 2.Validation 3. 4. 5. 6. 7. 8.

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