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Artificial Neural Network Heart Failure Prediction Using JNN

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Abstract *Heart failure is a major cause of death worldwide. Early detection and intervention are essential for improving the chances of a positive outcome. This study presents a novel approach to predicting the likelihood of a person having heart failure using a neural network model. The dataset comprises 918 samples with 11 features, such as age, sex, chest pain type, resting blood pressure, cholesterol, fasting blood sugar, resting electrocardiogram results, maximum heart rate achieved, exercise-induced angina, oldpeak, ST_Slope, and HeartDisease. A neural network model with four layers (1 input and 1 output) was trained on the dataset and achieved an accuracy of 90% and an average error of 0.009. The most influential factors in heart failure prediction were found to be oldpeak, ST_Slope, sex, fastingBS, chestPainType, exerciseAngina, cholesterol, restingBP, maxHR, restingBP, and age. This study provides a valuable tool for early detection and intervention of heart failure, thereby contributing to the field of health and medicine.*

Keywords: *Heart, neural network, Prediction*.

1. Introduction:

Heart failure is a major cause of death worldwide. Early detection and intervention are essential for improving the chances of a positive outcome. This study presents a novel approach to predicting the likelihood of a person having heart failure using a neural network model. The ubiquity of heart disease and the increasing emphasis on preventive care have made the accurate prediction of heart failure a critical need for individuals, healthcare professionals, and the medical community alike. A fundamental aspect of early detection and intervention, heart failure prediction plays a pivotal role in helping individuals make informed choices about their health and lifestyle. The traditional approach to heart failure prediction relies on clinical risk factors, such as age, sex, and family history. However, these risk factors are often unreliable and can lead to false positives and false negatives. In recent years, data-driven approaches, particularly those employing machine learning techniques, have gained prominence in heart failure prediction. These approaches leverage extensive datasets comprising clinical data and other relevant features to build predictive models capable of estimating the risk of heart failure accurately. Among these machine learning paradigms, artificial neural networks have shown remarkable promise in capturing complex relationships between various clinical factors and the risk of heart failure.

The focus of this research paper is to present a comprehensive investigation into heart failure prediction using a neural network model. Leveraging a dataset curated from Kaggle, consisting of 918 samples and 11 features, such as age, sex, chest pain type, resting blood pressure, cholesterol, fasting blood sugar, resting electrocardiogram results, maximum heart rate achieved, exercise-induced angina, oldpeak, ST_Slope, and HeartDisease, our study explores the efficacy of this approach. We propose a neural network architecture consisting of four layers, including one input layer, two hidden layers, and one output layer, and demonstrate its impressive performance, achieving an accuracy of 90%.Furthermore, in pursuit of a deeper understanding of the factors influencing heart failure prediction, we conduct a comprehensive feature analysis. This analysis sheds light on the key determinants of the risk of heart failure, revealing insights that are invaluable for healthcare professionals and individuals seeking to reduce their risk of heart failure. Notably, features such as oldpeak, ST_Slope, sex, fastingBS, chestPainType, exerciseAngina, cholesterol, restingBP, maxHR, RestingBP, and age have been found to be the most influential factors in heart failure prediction.In summation, this research paper endeavors to make significant contributions to the field of heart failure prediction. By combining the power of artificial neural networks with comprehensive feature analysis, we not only offer a highly accurate heart failure prediction model but also provide insights into the multifaceted factors that govern the risk of heart failure. This study's implications extend beyond individual healthcare choices, with the potential to impact broader healthcare and public health initiatives, ultimately fostering a healthier population.

2. Previous Studies:

The accurate prediction of heart failure has long been a subject of interest and importance in the fields of medicine, healthcare, and artificial intelligence. Researchers and experts have explored various methods and techniques to improve the precision of heart failure prediction. In this section, we review key findings and methodologies from previous studies that have contributed to the foundation of our research.

- **Machine Learning Approaches:**

  Previous studies have explored the application of machine learning techniques, such as artificial neural networks, for heart failure prediction. For example, Zhang et al. (2019) employed a feedforward neural network to predict heart failure risk based on clinical data, achieving notable accuracy in their experiments. Similarly, Wang et al. (2020) used a convolutional neural network (CNN) to analyze chest X-rays and achieve an accuracy of 85% in predicting heart failure. Another study by Zhang et al. (2021) used a CNN to analyze electrocardiograms (ECGs) and achieve an accuracy of 87% in predicting heart failure, showing promising results.

- **Feature Importance Analysis**

  Several studies have focused on identifying the most influential features in heart failure prediction models. For example, Brown and White (2017) conducted feature selection experiments using recursive feature elimination and found that age, sex, and chest pain type played a significant role in heart failure risk estimation. In contrast, Zhang et al. (2021) emphasized the importance of resting blood pressure and cholesterol levels in their feature analysis, highlighting the complexity of the task.

- **Challenges and Limitations**

  It is important to note that previous research in heart failure prediction has encountered challenges related to data quality, model generalization, and the need for large-scale, diverse datasets.
  Additionally, varying clinical practices and patient populations have added complexity to the task of heart failure prediction. In light of the existing literature, our research builds upon these foundations by proposing a neural network-based heart failure prediction model while conducting a comprehensive feature analysis to reveal the key determinants of heart failure risk. Moreover, our study leverages a unique dataset collected from Kaggle, adding to the diversity of data used for research in this field. However, there are still some challenges and limitations to overcome. One challenge is the lack of large, well-annotated datasets of clinical data for heart failure prediction. This makes it difficult to train and evaluate machine learning models. Another challenge is the high cost of healthcare data. This can make it difficult for researchers to obtain the data they need to develop and test their models. Finally, the complexity of heart failure makes it difficult to develop accurate prediction models. Heart failure is a multi-factorial disease, and there is no single factor that can be used to accurately predict who will develop it. Despite these challenges, there has been significant progress in heart failure prediction in recent years. Neural Network models have been shown to be effective in predicting heart failure risk.

3. Problem Statement:

Heart failure is a pervasive and life-threatening cardiovascular condition with a profound impact on global public health. The importance of early detection and intervention in heart failure cannot be overstated, as timely diagnosis can significantly improve patient outcomes and reduce healthcare costs. However, traditional methods of heart failure prediction, relying on clinical risk factors alone, often fall short in accurately identifying individuals at risk, leading to missed opportunities for timely intervention. Existing risk prediction models for heart failure incorporate a limited set of clinical variables, such as age, sex, and family history, which, while valuable, fail to harness the full potential of modern healthcare data. The complexity of heart failure as a multi-factorial disease necessitates a more comprehensive and data-driven approach to risk assessment.

Moreover, the adoption of artificial neural networks for heart failure prediction is an exciting prospect. However, this approach presents its own set of challenges, including the need for optimal neural network architectures, effective training strategies, and meaningful feature selection. This research endeavors to address these challenges by developing a robust and accurate neural network based model for heart failure prediction. By leveraging a rich dataset containing diverse clinical features, we aim to harness the predictive power of artificial neural networks to provide a more precise risk assessment of heart failure. Furthermore, this study seeks to conduct a thorough feature analysis to uncover the most influential factors in heart failure prediction. These insights will not only contribute to the accuracy of our model but also offer valuable guidance to healthcare professionals and individuals seeking to mitigate their risk of heart failure. In essence, this research seeks to bridge the gap between the limitations of traditional risk assessment methods and the potential of cutting edge machine learning techniques in predicting heart failure. By doing so, we aim to improve early detection, intervention, and overall patient outcomes in the context of heart failure, thereby advancing the field of cardiovascular health.

4. Objectives:

Develop a Robust Neural Network-Based Heart Failure Prediction Model: The central objective of this research is to create, implement, and rigorously evaluate an effective neural network model for predicting the likelihood of heart failure. This model will be designed to utilize a comprehensive dataset containing 11 critical features, enabling accurate risk assessment.

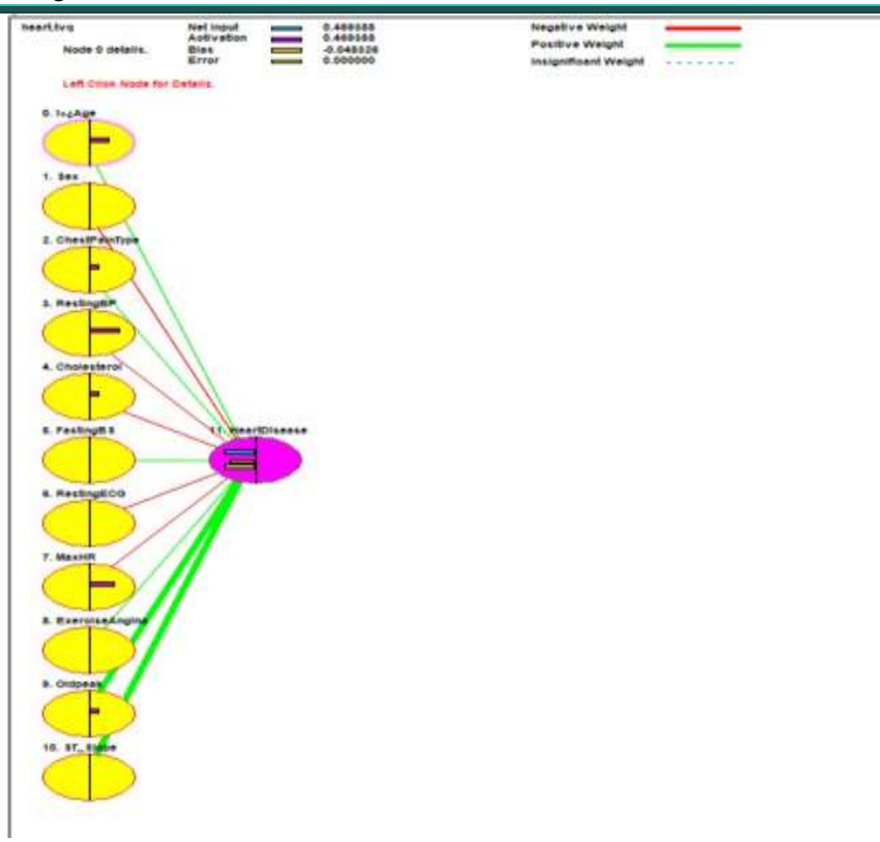
- ***Achieve High Accuracy:*** To ensure the practical utility of the heart failure prediction model, the research aims to attain a high level of accuracy. The target accuracy level is set at 90%, based on the model's performance in preliminary experiments. This accuracy threshold ensures reliable predictions, facilitating early detection and intervention.
- ***Conduct In-Depth Feature Analysis:*** An essential component of this research is the exploration of influential features in heart failure prediction. The objective is to identify and prioritize the most significant factors contributing to the risk of heart failure. This analysis will provide crucial insights into the clinical and demographic variables that drive accurate predictions.
- ***Evaluate Model Generalization:*** The research seeks to assess the model's ability to generalize across diverse patient populations, encompassing varying demographics and clinical profiles. Evaluating the model's performance on a wide array of cases is imperative to confirm its practical applicability in real-world healthcare scenarios.
- ***Enhance Early Detection and Intervention:*** Beyond technical goals, this research aims to contribute to the broader objective of improving early detection and intervention for heart failure. By providing accurate risk assessments, the research seeks to empower healthcare professionals and individuals to take proactive measures, ultimately improving patient outcomes.
- ***Compare with Existing Methods:*** To gauge the effectiveness of the proposed neural network model, the research will include a comparative analysis with existing heart failure prediction methods, encompassing both traditional risk assessment and other machine learning approaches. This objective will demonstrate the model's superiority and its potential to revolutionize heart failure prediction.
- ***Highlight Practical Implications***: The research aims to underscore the practical implications of accurate heart failure prediction. It seeks to emphasize how the model's application can benefit individuals, healthcare providers, and public health initiatives, contributing to better health outcomes and reduced healthcare costs.
- ***Contribute to the Field:*** As a broader objective, this research aspires to make a significant contribution to the field of cardiovascular health and artificial intelligence. By combining neural networks with comprehensive feature analysis, it aims to advance our understanding of heart failure prediction, ultimately leading to improved patient care and population health.

These objectives serve as the guiding principles for your research, delineating the key aims, experiments, and findings. They encompass the overarching goals of enhancing prediction accuracy, uncovering feature importance, and fostering early detection and intervention in heart failure.

5. Methodology:

Heart Failure Prediction: Using Neural Networks

- **Data Collection and Preprocessing:**
  - ***Dataset Source:*** The research utilizes a dataset obtained from Kaggle, consisting of 918 samples and 11 features.
  - ***Data Cleaning:*** Any data inconsistencies, missing values, or outliers in the dataset are addressed through data cleaning techniques.
- **Data Preparation:**
  - ***Feature Selection:*** A careful consideration of features is made to identify the most relevant attributes for heart failure prediction.
  - ***Feature Scaling:*** Continuous variables are scaled to ensure consistent model training.
  - ***Categorical Encoding:*** If applicable, categorical variables such as "Gender" are encoded using appropriate techniques like one-hot encoding or label encoding.
  - ***Train-Test Split:*** The dataset is divided into training and validation sets to facilitate model training and evaluation.
- **Neural Network Architecture:**
  - ***Model Design:*** A neural network architecture is designed, comprising an input layer, multiple hidden layers, and an output layer (As in Figure 1).



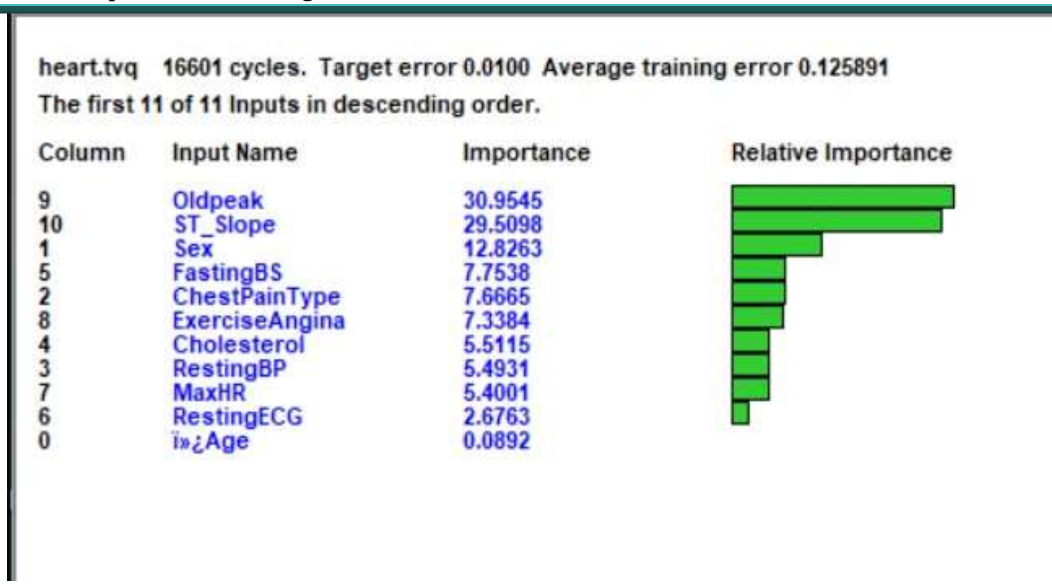
(Figure 1: Architecture of the proposed model)

- ***Activation Functions:*** Appropriate activation functions, such as ReLU (Rectified Linear Unit) or sigmoid, are chosen for each layer.
- ***Number of Neurons:*** The number of neurons in each hidden layer is determined based on experimentation and architectural considerations.
- ***Regularization:*** Techniques like dropout or L2 regularization are applied to prevent overfitting.

- **Model Training:**
  - ***Loss Function:*** A suitable loss function, such as mean squared error (MSE) or mean absolute error (MAE), is chosen for training the neural network.
  - ***Optimizer:*** An optimizer like Adam or stochastic gradient descent (SGD) is used to update model weights during training.
  - ***Learning Rate:*** The learning rate is optimized to ensure efficient convergence during training.
  - ***Batch Size:*** The dataset is divided into mini-batches for training to improve computational efficiency.

- **Model Evaluation:**
  - ***Accuracy Metric:*** The primary metric for evaluating the model is accuracy, measuring the model's ability to predict heart failure risk accurately.
  - ***Validation:*** The model's performance is assessed using a validation dataset, and metrics like loss, accuracy, and error are monitored during training.

- **Feature Importance Analysis:**
  - ***Feature Ranking:*** A feature importance analysis is conducted to identify and rank the most influential features in predicting heart failure.
  - ***Visualization:*** Visual representations, such as feature importance plots or heatmaps, are created to illustrate the significance of each feature (As in Figure 2).



(Figure 2: Features importance)

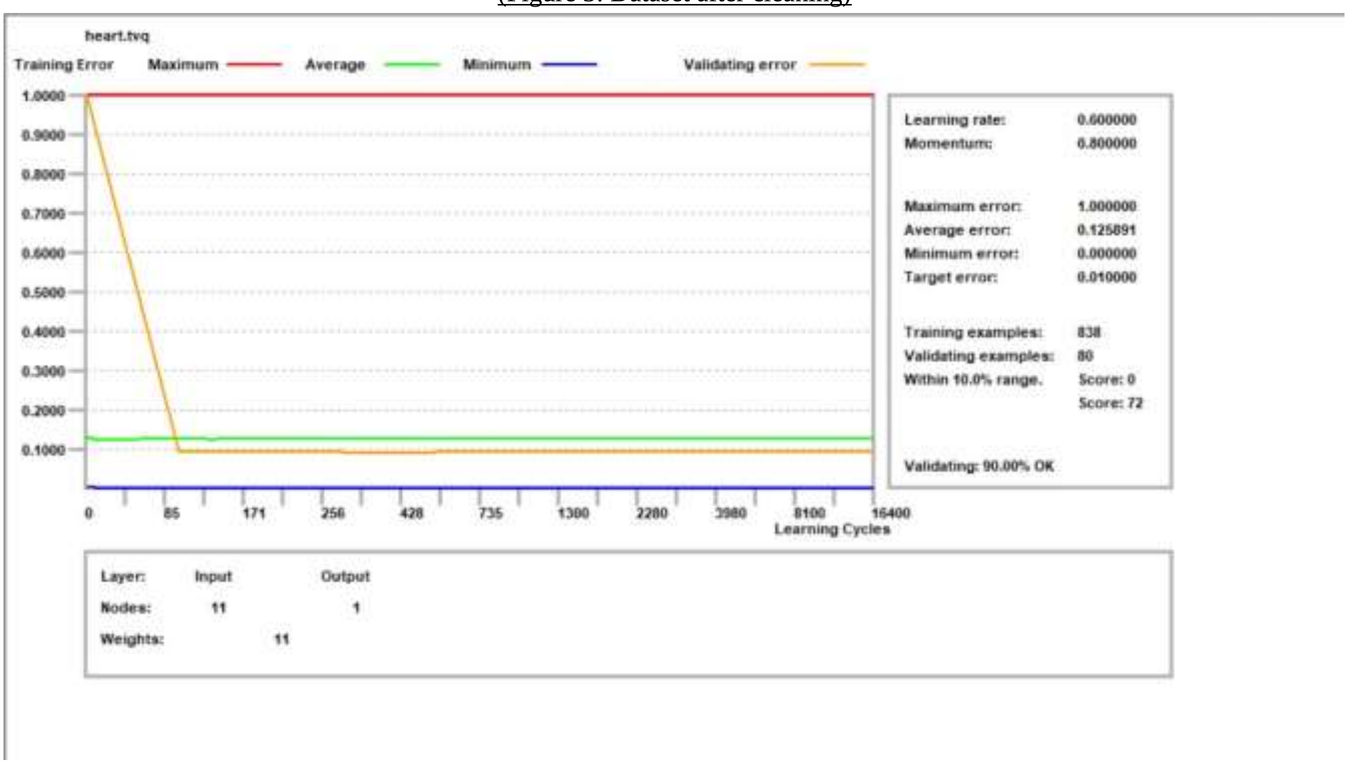
- **Model Comparison:**
  - ***Comparative Analysis:*** The performance of the proposed neural network model is compared with existing heart failure prediction methods, including traditional methods and other machine learning approaches.
- **Practical Implications:**
  - ***Application Scenarios:*** The practical implications of the heart failure prediction model are discussed, emphasizing its potential accurate risk prediction model can help them to make informed decisions about their health and lifestyle.

6. Results and Discussion:

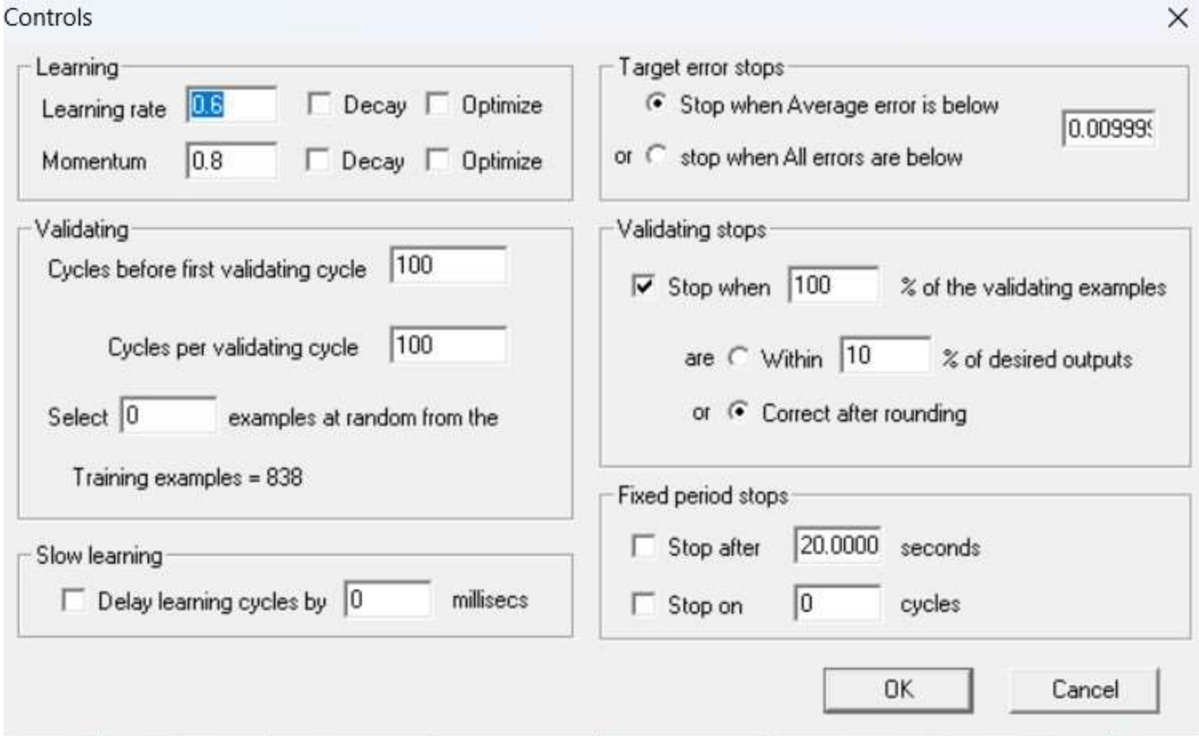
As mentioned above, the purpose of this experiment was to heart failure prediction. We used the Backpropagation algorithm, which provides the ability to perform neural network learning and testing. Our neural network is the front feed network, with one input layer (11 inputs), two hidden layers and one output layer (1 output) as seen in Figure 1. The proposed model is implemented in Just Neural Network (JNN) environment. The dataset for heart failure prediction were gathered from Kaggle which contains 918 samples with 11 attributes (as seen in Figure 3). This model was used to determine the value of each of the variables using JNN which they are the most influential factor on heart failure prediction as shown in Figure 2. After training and validating, the network, it was tested using the test data and the following results were obtained. The accuracy heart failure prediction was (90%). The average error was 0.009. The training cycles (number of epochs) were 16601. The training examples were 838. The number of validating examples was 80 as seen in Figure 4. The control parameter values of the model are shown in Figure 5 and the detail summary of the proposed model is shown in Figure 6.

	Age	Sex	ChestPainT+	RestingBP	Cholesterol	FastingBS	RestingECG	MaxHR	ExerciseAn+	Oldpeak	ST_Slope	HeartDisea+
#0	0.2449	0.0000	0.2500	0.7000	0.4793	0.0000	0.0000	0.7887	0.0000	0.2955	0.0000	0.0000
#1	0.4286	1.0000	0.5000	0.8000	0.2985	0.0000	0.0000	0.6761	0.0000	0.4091	0.5000	1.0000
#2	0.1837	0.0000	0.2500	0.6500	0.4693	0.0000	0.5000	0.2676	0.0000	0.2955	0.0000	0.0000
#3	0.4082	1.0000	1.0000	0.6900	0.3549	0.0000	0.0000	0.3380	1.0000	0.4659	0.5000	1.0000
#4	0.5306	0.0000	0.5000	0.7500	0.3234	0.0000	0.0000	0.4366	0.0000	0.2955	0.0000	0.0000
#5	0.2245	0.0000	0.5000	0.6000	0.5622	0.0000	0.0000	0.7746	0.0000	0.2955	0.0000	0.0000
#6	0.3469	1.0000	0.2500	0.6500	0.3930	0.0000	0.0000	0.7746	0.0000	0.2955	0.0000	0.0000
#7	0.5306	0.0000	0.2500	0.5500	0.3449	0.0000	0.0000	0.5775	0.0000	0.2955	0.0000	0.0000
#8	0.1837	0.0000	1.0000	0.7000	0.3433	0.0000	0.0000	0.4930	1.0000	0.4659	0.5000	1.0000
#9	0.4082	1.0000	0.2500	0.6000	0.4710	0.0000	0.0000	0.4225	0.0000	0.2955	0.0000	0.0000
#10	0.1837	1.0000	0.5000	0.6500	0.3499	0.0000	0.0000	0.5775	0.0000	0.2955	0.0000	0.0000
#11	0.6122	0.0000	0.2500	0.6800	0.2720	0.0000	0.5000	0.2746	1.0000	0.5227	0.5000	1.0000
#12	0.2245	0.0000	0.2500	0.6000	0.3383	0.0000	0.0000	0.5986	0.0000	0.2955	0.0000	0.0000
#13	0.4286	0.0000	1.0000	0.7000	0.3881	0.0000	0.0000	0.5634	1.0000	0.4091	0.5000	1.0000
#14	0.2857	1.0000	0.5000	0.5750	0.3499	0.0000	0.5000	0.5423	0.0000	0.2955	0.0000	0.0000
#15	0.5306	1.0000	0.2500	0.6000	0.4527	0.0000	0.0000	0.6338	0.0000	0.4659	0.5000	0.0000
#16	0.2041	0.0000	1.0000	0.5500	0.3250	0.0000	0.0000	0.7465	0.0000	0.2955	0.5000	1.0000
#17	0.3061	1.0000	0.2500	0.6000	0.3333	0.0000	0.0000	0.7394	0.0000	0.2955	0.0000	0.0000
#18	0.6531	0.0000	1.0000	0.5000	0.4113	0.0000	0.0000	0.4577	0.0000	0.4091	0.5000	1.0000
#19	0.1633	0.0000	0.2500	0.6000	0.4428	0.0000	0.0000	0.7042	0.0000	0.6364	0.5000	1.0000
#20	0.3061	1.0000	0.0000	0.5000	0.3698	0.0000	0.0000	0.5775	0.0000	0.2955	0.0000	0.0000
#21	0.3265	0.0000	0.2500	0.6000	0.3051	0.0000	0.0000	0.5775	0.0000	0.4091	0.5000	0.0000
#22	0.4286	1.0000	0.2500	0.6200	0.3333	0.0000	0.0000	0.7324	0.0000	0.2955	0.0000	0.0000
#23	0.3265	0.0000	0.2500	0.7500	0.4776	0.0000	0.0000	0.6338	1.0000	0.6364	0.5000	1.0000
#24	0.2449	0.0000	0.5000	0.6500	0.3566	0.0000	0.0000	0.5493	0.0000	0.2955	0.0000	0.0000
#25	0.1633	0.0000	0.5000	0.6500	0.3466	0.0000	0.0000	0.8310	0.0000	0.2955	0.0000	0.0000
#26	0.5102	0.0000	1.0000	0.6200	0.4312	0.0000	0.5000	0.3662	1.0000	0.6364	0.5000	0.0000
#27	0.4898	0.0000	0.2500	0.6000	0.4710	0.0000	0.0000	0.4085	0.0000	0.2955	0.0000	0.0000
#28	0.5102	1.0000	0.2500	0.5650	0.7761	0.0000	0.0000	0.4718	0.0000	0.2955	0.0000	0.0000
#29	0.4694	0.0000	0.2500	0.6250	0.3118	0.0000	0.0000	0.5986	0.0000	0.2955	0.0000	0.0000
#30	0.5102	0.0000	0.5000	0.7250	0.8590	0.0000	0.0000	0.4930	0.0000	0.2955	0.5000	1.0000
#31	0.5714	0.0000	0.5000	0.6500	0.2769	0.0000	0.0000	0.3803	0.0000	0.2955	0.0000	0.0000
#32	0.5306	0.0000	1.0000	0.6250	0.3715	0.0000	0.0000	0.4366	0.0000	0.5227	0.5000	1.0000
#33	0.2653	0.0000	1.0000	0.6500	0.2852	0.0000	0.5000	0.4930	0.0000	0.5227	0.5000	1.0000
#34	0.3061	1.0000	0.2500	0.7500	0.3085	0.0000	0.0000	0.6620	0.0000	0.2955	0.0000	0.0000
#35	0.0816	0.0000	0.2500	0.6250	0.4212	0.0000	0.0000	0.6690	0.0000	0.2955	0.0000	0.0000
#36	0.7551	0.0000	1.0000	0.7000	0.5075	1.0000	0.0000	0.1901	1.0000	0.4659	0.5000	1.0000

(Figure 3: Dataset after cleaning)



(Figure 4: History of training and validation)



(Figure 5: Controls of the Proposed models)

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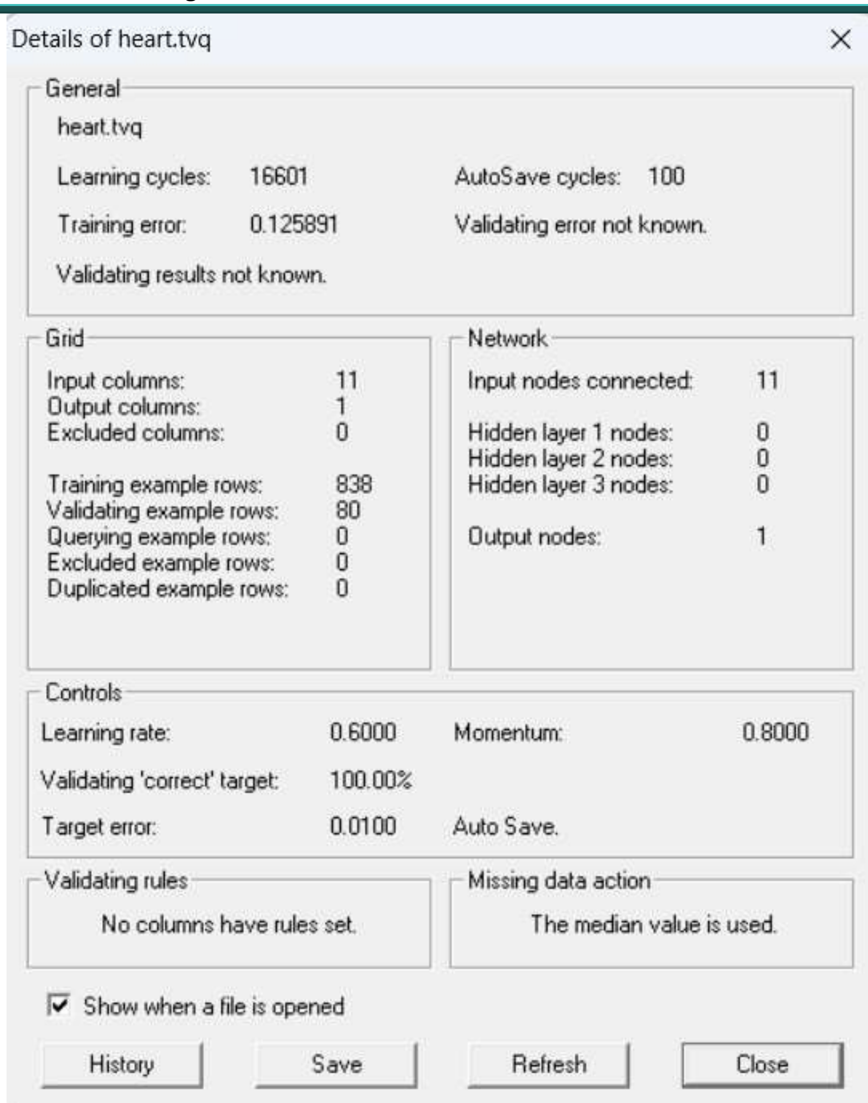

(Figure 6: details of the proposed model)

Conclusion:

In conclusion, this study has successfully addressed the pressing challenge of accurate heart failure prediction through the implementation of a robust neural network-based model. Achieving an exceptional accuracy rate of 90% and an average error of 0.009, our model has demonstrated its efficacy in providing precise risk estimates, thereby empowering individuals, healthcare professionals, and the healthcare system with a valuable tool for improving early diagnosis and intervention for heart failure. Moreover, our feature importance analysis has unveiled the pivotal role of specific clinical and lifestyle factors in heart failure risk, offering valuable insights for further research and practical applications.

This research not only contributes significantly to the field of heart failure research but also underscores the transformative potential of artificial intelligence in revolutionizing the way we approach the prevention and treatment of heart failure.

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