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AIoMT-Based Multi-Model Soft Computing Techniques for the Prediction of Heart Disease

GopiKrishna Pasam*, Subhash Gupta, Srinivas G, Mr. Hameed Shaik
Senior Lecturer, Engineering department, College of Engineering and Technology,University of Technology and Applied Sciences, Ibra, Sultanate of, Oman

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Abstract
The high rate of occurrence of heart disease these days needs immediate advancements implementation of predictive methodologies for early diagnosis with high precision to improve the disease treatment and reduce the mortality rate. This paper proposes an efficient prediction and alarming system that integrates the multi-model deep learning techniques, such as Radial Basis Function Neural Network (RBFNN), Support Vector Machines (SVM), Adaptive Neuro-Fuzzy Inference System (ANFIS), and Backpropagation Neural Network (BPNN with the Artificial Intelligence of Medical Things (AIoMT) to enhance the ability of prediction of heart disease in the real-time environment. The proposed model offers a comprehensive solution that produces data-driven insights for accurate prediction and timely heart disease alerts. This study reveals the potential of AIoMT in transforming the healthcare sector by providing a forward-looking view into the control and management of cardiac health conditions of patients on a large scale. The results presented in this paper is evident to the effective impact of AIoMT technology on healthcare towards cardiac health management and preventive strategies.

Keywords: Artificial Intelligence of Medical Things (AIoMT), Deep Learning Techniques, Artificial Neural Networks (ANN), Support Vector Machine (SVM) and Heart Disease Prediction Techniques.

1. Introduction

The combination of the Internet of Medical Things (IoMT) and Machine learning (ML) is a revolutionary development in the healthcare sector, particularly in diagnosing early cardiovascular disease, a leading cause of global mortality. The World Health Organization reports disclose that heart diseases are the main cause for 17.9 million deaths per year, often linked to risk factors, such as high cholesterol and high blood pressure [1]. Smart healthcare systems, an amalgamation of the Internet of Things (IoT) and Artificial Intelligence (AI), are becoming crucial in disease screening and diagnosis. This IoMT especially is the main key for disease diagnosis through its intelligent sensors and smart devices, enabling easy remote patient monitoring and chronic disease management [2]. Machine learning, a core part of AI, is instrumental in healthcare for analyzing extensive datasets to draw useful insights vital for early disease prediction. The functionality of ML in healthcare is evident in generating accurate and comprehensive datasets, largely contributed by IoMT devices [3].

Given the alarming rate of heart disease incidence, this paper addresses the question: How can integrating AIoMT with multi-model soft computing techniques optimize heart disease

*Email: gopi.pasam@utas.edu.om

prediction? We hypothesize that AIoMT-based systems, enhanced with multi-model soft computing techniques, will markedly enhance the prediction accuracy and efficiency for the diagnosis of heart disease compared to existing methods.

In this paper, the main development objective is to develop an advanced predictive model for heart disease using AIoMT combined with multi-model soft computing techniques. After that, a detailed comparative analysis will be conducted to evaluate the performance of this model against traditional heart disease prediction systems, and at the end, the implementation results will illustrate the practical implementation and effectiveness of the proposed model in real-world clinical settings.

The significance of this research is profound. It aims to contribute substantially to the early and precise detection of heart disease, potentially reducing the global mortality rate associated with it. Additionally, this study seeks to pioneer a novel approach in medical informatics, integrating AIoMT with soft computing and setting a new standard for predictive accuracy in healthcare.

Incorporating computer technologies in patient identification and disease diagnosis applications has become more efficient due to the accessibility to substantial amounts of research data and patient cases. Different machine learning and deep learning models proved to be efficient tools for disease classification and prognosis applications [4]. The effectiveness has been documented about the usage of various ML models in classifying and diagnosing heart diseases, including techniques like CART automatic classifiers and deep neural networks for feature selection [5].

The enormous volume of patient data collection in digital healthcare systems necessitate efficient management systems. The IoT and IoMT provide the infrastructure for collecting and handling this vast data. The initial disease prediction, including heart disease, becomes effective by utilizing machine algorithms to apply ML methods for initial disease prediction, including heart disease [6]. In medical imaging, deep learning techniques manage large datasets collected via IoT, addressing challenges such as energy depletion and packet loss ratio, which are crucial for remote cardiac imaging and the overall effectiveness of IoMT platforms [7].

Optimal feature selection for medical data classification is a pivotal application of IoMT, enhancing early detection of critical illnesses. Techniques like the opposition-based crow search methodology have been suggested to boost the efficiency of deep learning classifiers in the analysis of medical [8].

This introduction sets the stage for presenting an AIoMT-based system that utilizes multiple soft computing techniques to advance heart disease prediction. The subsequent sections will detail the specific AI methodologies employed and the implementation framework using IoMT devices, aiming to demonstrate how this integrated system could offer more accurate and timely predictions, thereby transforming healthcare, particularly in managing and preventing heart disease.

2. Related Work

The literature pertinent to the applications of AI and IoMT in cardiovascular disease prediction highlights a burgeoning field with transformative potential. Here's a synthesized narrative combining the insights from various studies.

AI, particularly deep learning, has become a significant methodology in heart disease predictions, showing a rapid increase in adoption over the past five years, with substantial applications in diagnostics and predictions [9]. IoT and IoMT technologies have been effectively paired with machine learning techniques to forecast cardiovascular diseases in real time, although progress is hindered by the lack of accessible public datasets [10].
Research indicates that neural networks and combined techniques, such as random forest and XGBoost, have achieved high predictive accuracy. However, there is a notable gap in integrating AI fully into clinical decision-making [11]. Deep learning models have reached up to 96% accuracy in predictions, demonstrating the critical role of substantial data from medical institutions in furthering AI applications in cardiovascular health [12].
AI has shown its capacity for disease photomapping, developing early warning systems, enhancing risk prediction, and automating the processing and interpretation of imaging to increase operational efficiency within cardiovascular medicine [13]. The ability of prediction by machine learning algorithms in medical applications like prediction of heart diseases is remarkable. With SVM and boosting algorithms having shown effective results in disease prediction, as indicated by the pooled area under the curve metrics from multiple studies [14]. The latest review from "Hypertension Research" emphasized the limitation of the abilities such as artificial intelligence full-scale incorporation into medical decision-making is pending. The importance of aligning technological progress with medical ethics is also highlighted and stressed on the essential for methodical reviews personalized to each cardiovascular subspecialty [15]. This limitation, as emphasized leads to the importance of usage of integration of AI and IoMT in progressing cardiovascular health care, with a focus on the challenges of data availability, selection of prediction machine learning models with high accuracy, and the ethical considerations of clinical integration and management.

3 Methodology

The proposed system's working operation is illustrated in the block diagram as shown in Figure 1. It describes a comprehensive methodology for heart disease prediction and alerting system developed using the (AIoMT) Artificial Intelligence of Medical Things. Sequential steps of data collection from various medical sensors, preprocessing like the cleaning of data, advanced model selection, rigorous training and validation phases, and completing in the evaluation of model performance through key metrics.

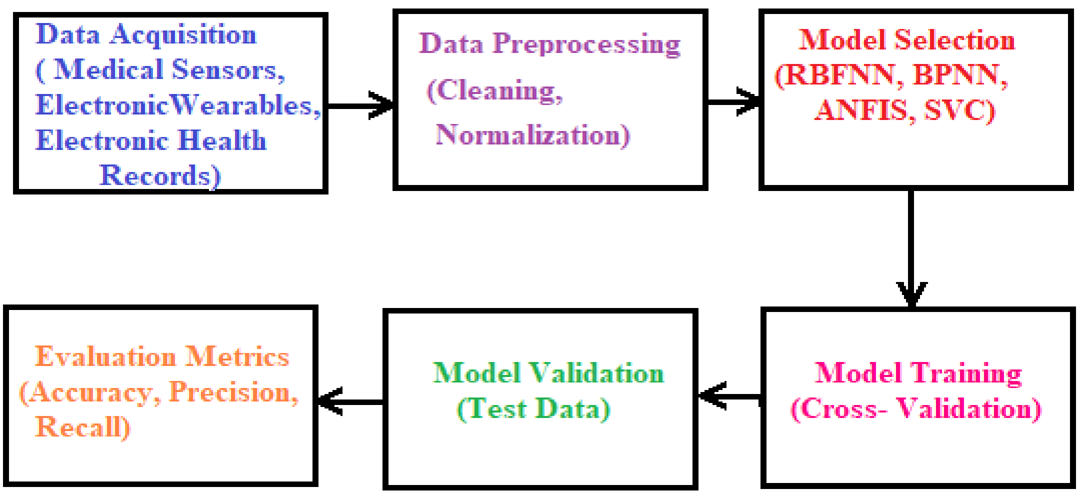

Figure 1: Proposed Block Diagram for AIoMT-Based Heart Disease Prediction Workflow.

i. Data Acquisition:

The process begins with collecting data from various medical sensors, wearable devices, and electronic health records (EHRs) of patients, ensuring a comprehensive dataset that includes real-time physiological parameters and historical medical data [16].

ii. Data Pre-processing:

This data is related to the pre-processing stage of data cleaning, generally used for cleaning data to remove any irregularities or inappropriate data and normalization to regulate the range of data values.

iii. Model Selection:

In this stage, the cleaned data after data preprocessing is used to select appropriate predictive models. The predictive models RBFNN, BPNN, ANFIS, and Support Vector Machine (SVM) are chosen as they are effective in their capability to manage difficult and nonlinear data patterns [17].

iv. Model Training:

In this stage, with the chosen models, the system proceeds to train them using cross-validation techniques, which help in optimizing the models by dividing the available data into training data, and validation data is used to train the deep learning models and to evaluate its performance respectively [18].

v. Model Validation:

In this stage, after completing the training of models, their performance is validated by using separate checking data to test their predictive accuracies and to ensure they fit well with new data [19].

vi. Evaluation Metrics:

In this stage, the effectiveness of the suggested models is measured through evaluation parameters such as accuracy, recall, and precision. These parameters provide a perception of the performance of the models in terms of their ability to precisely identify patients with heart disease and their reliability in decreasing fallacious predictions [20].

4. Proposed IoMT Test System

The proposed IoMT Heart disease prediction test system, shown in Figure 2, is used to test real time data of various patients. The implementation of the proposed IoMT Heart disease prediction test system is described in the following algorithm steps:

1. *Data Acquisition*: The system begins with collecting patient data through IoMT-enabled devices and smart electronic wearables. This also includes comprehensive electronic health records incorporating significant indications, medical history, and other appropriate health parameters.
2. *Data Pre-processing:* The collected raw data is then processed, which involves cleaning and normalization to process through the proposed method.
3. *Model Training:* Four different machine learning models, such as RBFNN, BPNN, ANFIS, and SVM, are trained using the pre-processed data . This training phase involves adapting the models to identify pattern recognition within the data input and output that are representative of heart disease risk.
4. *Risk Stratification:* Each trained model outputs a prediction risk score for heart disease. Based on these risk scores, patients are categorized into three risk levels, High Risk (scores > 0.5), Medium Risk (scores in the range of 0.3 to 0.5), and Low Risk (scores < 0.3).
5. *Alert System:* Depending on the risk level, the system triggers corresponding alerts. High-risk alerts are sent online through IoMT platforms, ensuring immediate attention from healthcare providers. Intermediate-risk cases obtain a regular notification, while minimal risk instants may be communicated through hospital health care division personnel in offline channels, such as follow-up customer care interactions.

This organized method permits for appropriate and effective patient management and exploring the capabilities of IoMT and AI to improve the prediction and continuous monitoring of disease of heart.

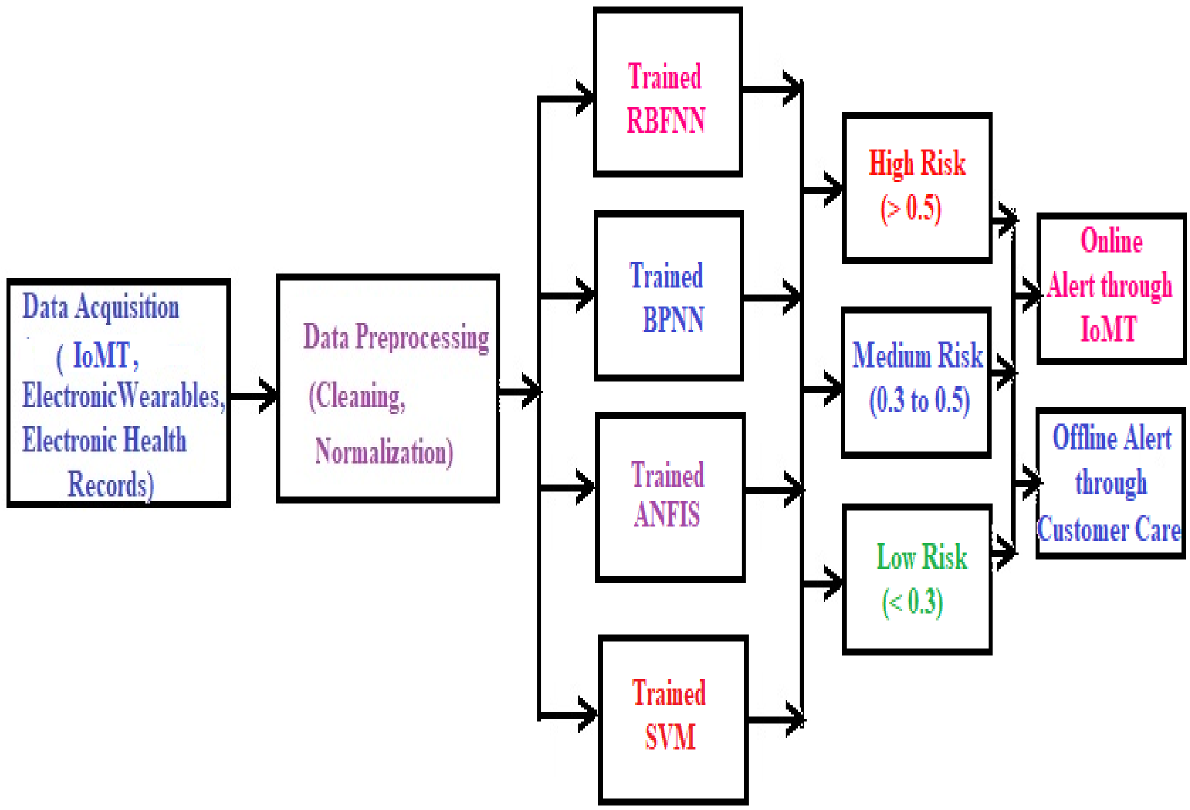

Figure 2: Proposed IoMT Test System for the prediction heart disease

5. Results and Discussion

5.1 Collection of Data

In the effort to implement our proposed IoMT test system as described in section 4, large data samples of 4,240 patients were collected through a wide-ranging electronic health record (EHR) dataset from a various patient data sheet to assess the AIoMT-based predictive system. The dataset, collected from one of the known Hospitals, included a wide range of cardiac related systems of measurement, such as patient details like age, education, diabetes, smoker, blood pressure readings, cholesterol levels, heart rate variability, and historical cardiovascular events can be found in the sample data screenshot as shown Table-2.

Each patient data experienced rigorous data pre-processing to ensure accuracy and consistency, which line up with the proposed system's requirement for high-quality input data. This rich dataset formed the basis of our test system, enabling a robust evaluation of the predictive models' performance in identifying potential heart disease cases. The results, characterized by precision, recall, and AUC metrics, demonstrated the system's efficacy in early detection and risk stratification, marking a significant advancement in AIoMT-facilitated diagnosis.

Table 2: Sample Data of Collected Patient Data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	male	age	education	currentSmoker	cigsPerDay	BPMeds	prevalentStroke	prevalentHyp	diabetes	totChol	sysBP	diaBP	BMI	heartRate	glucose	TenYearCHD
2	1	39	4	0	0	0	0	0	0	195	106	70	26.97	80	77	0
3	0	46	2	0	0	0	0	0	0	250	121	81	28.73	95	76	0
4	1	48	1	1	20	0	0	0	0	245	127.5	80	25.34	75	70	0
5	0	61	3	1	30	0	0	1	0	225	150	95	28.58	65	103	1
6	0	46	3	1	23	0	0	0	0	285	130	84	23.1	85	85	0
7	0	43	2	0	0	0	0	1	0	228	180	110	30.3	77	99	0
8	0	63	1	0	0	0	0	0	0	205	138	71	33.11	60	85	1
9	0	45	2	1	20	0	0	0	0	313	100	71	21.68	79	78	0
10	1	52	1	0	0	0	0	1	0	260	141.5	89	26.36	76	79	0
11	1	43	1	1	30	0	0	1	0	225	162	107	23.61	93	88	0
12	0	50	1	0	0	0	0	0	0	254	133	76	22.91	75	76	0
13	0	43	2	0	0	0	0	0	0	247	131	88	27.64	72	61	0
14	1	46	1	1	15	0	0	1	0	294	142	94	26.31	98	64	0
15	0	41	3	0	0	1	0	1	0	332	124	88	31.31	65	84	0
16	0	39	2	1	9	0	0	0	0	226	114	64	22.35	85	NA	0
17	0	38	2	1	20	0	0	1	0	221	140	90	21.35	95	70	1
18	1	48	3	1	10	0	0	1	0	232	138	90	22.37	64	72	0
19	0	46	2	1	20	0	0	0	0	291	112	78	23.38	80	89	1
20	0	38	2	1	5	0	0	0	0	195	122	84.5	23.24	75	78	0

5.2 Results and Discussion

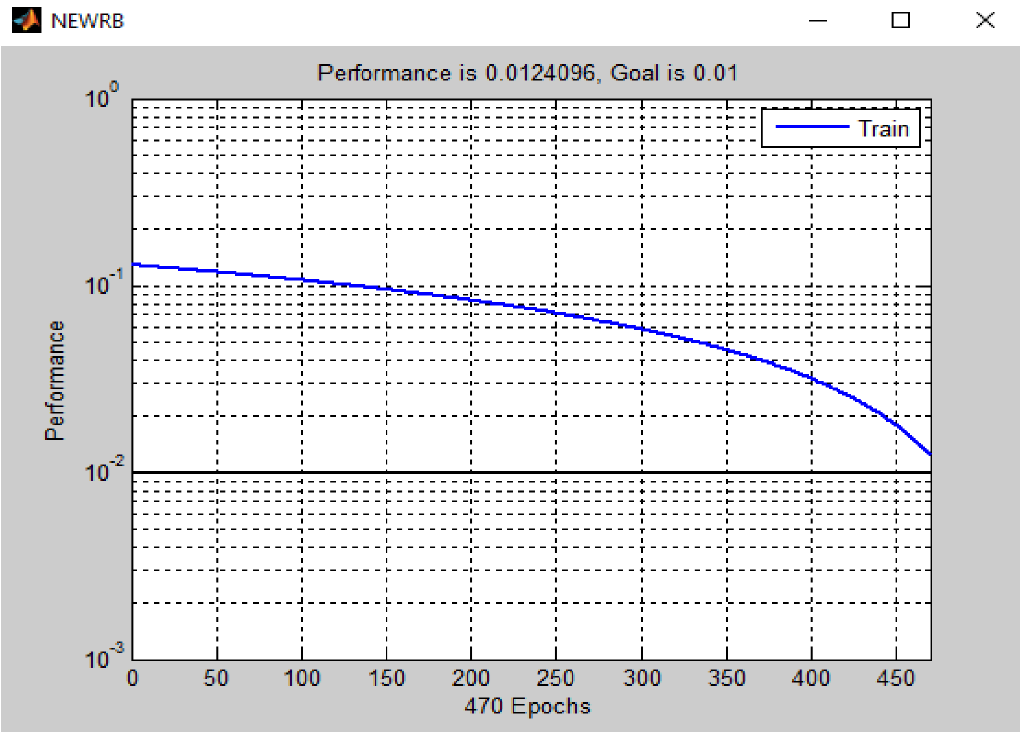

Figure 4: RBFNN Training Performance on Heart Diseases data

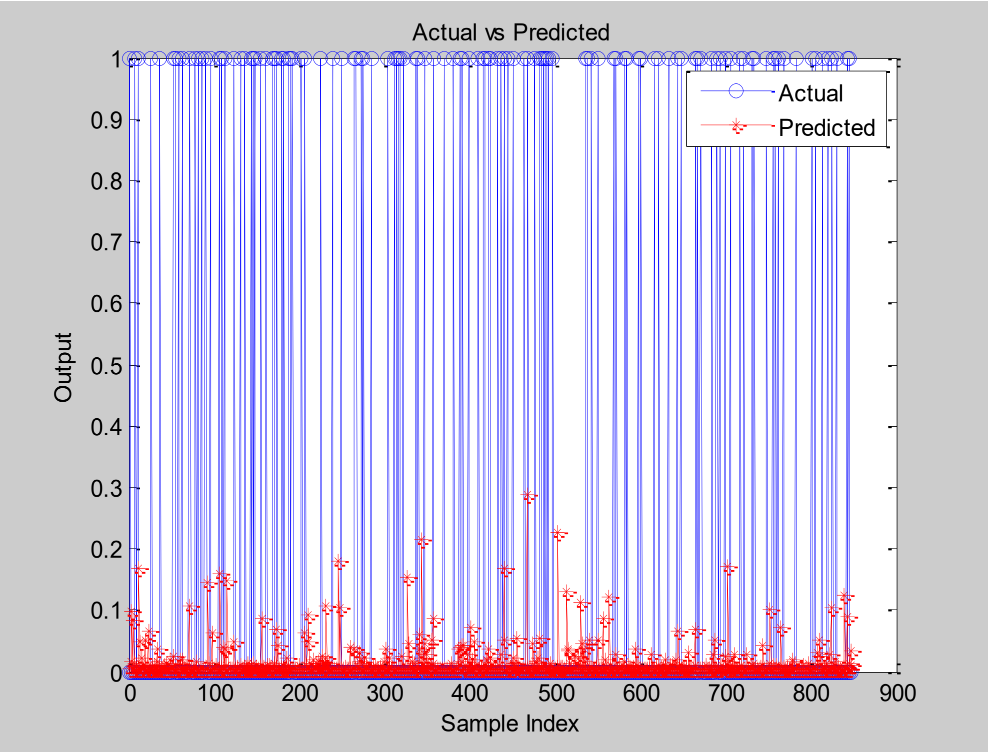

Figure 5: Comparative Result of RBFNN with Actual and Predicted

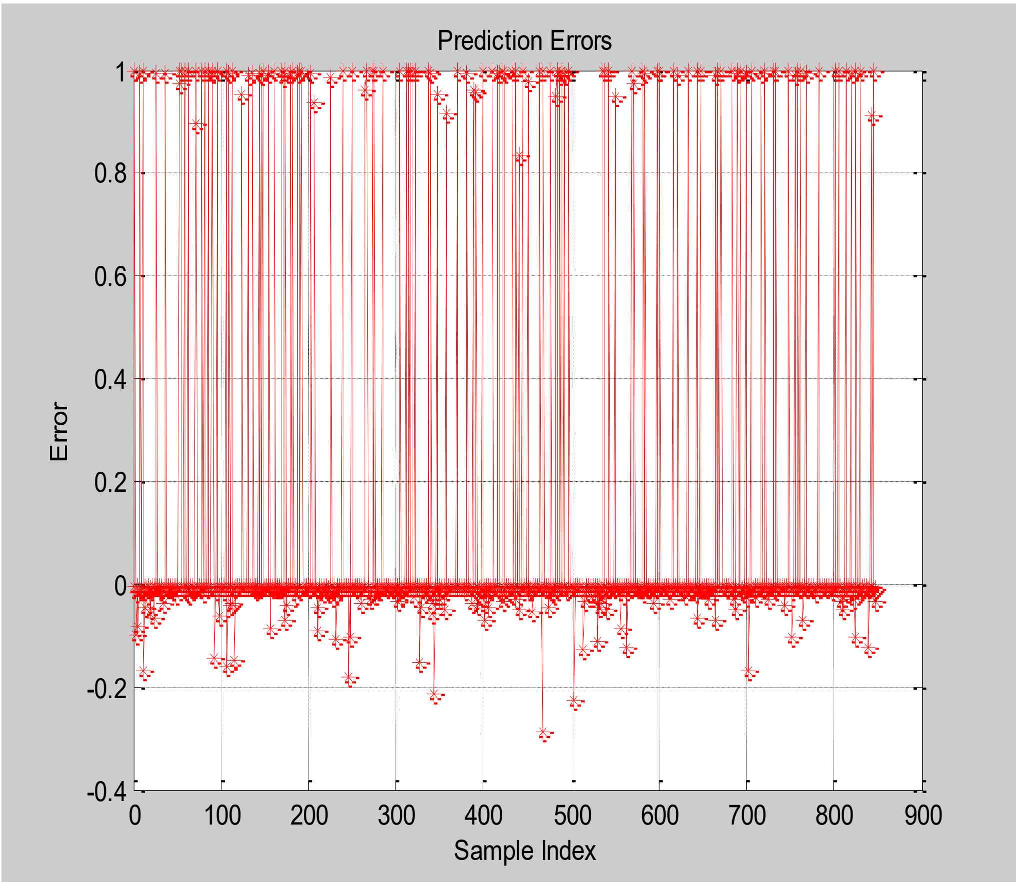

Figure 6: RBFNN Error plot between actual and predicted

Table 3: Comparative Results of ANN with Proposed Relay Selection

Soft Computing AI Model	% Accuracy
RBFNN	85.85
BPNN	83.50
ANFIS	87.75
SVM	84.55

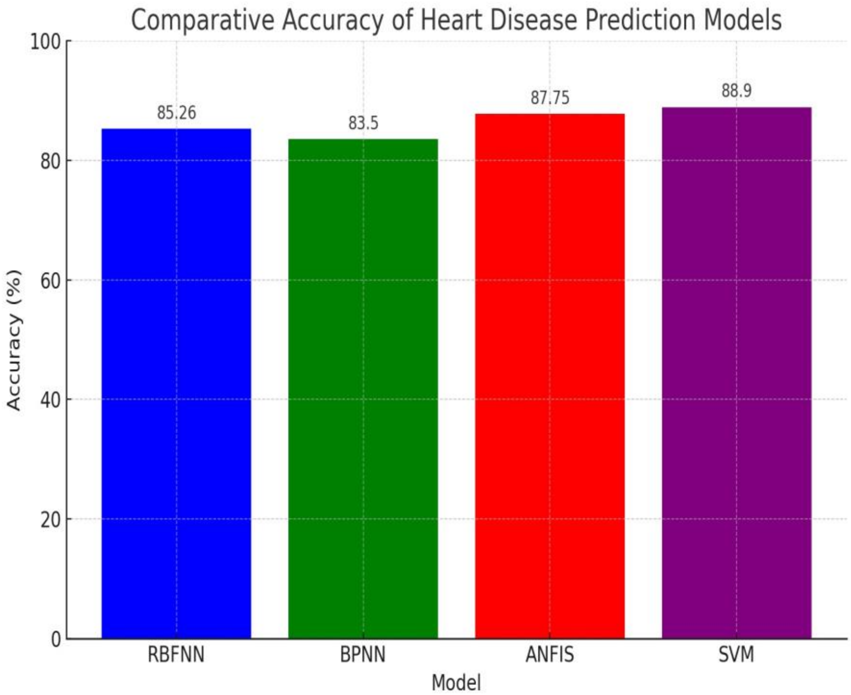

Figure 7: Comparative prediction accuracy of multi model AI based soft computing techniques

The obtained results, as shown in Figure 4 to Figure 7 and Table 2 indicate the implementation and predictable capabilities of heart disease through the proposed Intelligent of Medical Things (IoMT).

5.3 Online Platform and Approach of Data Connection for Heart Disease Prediction System

The proposed heart disease prediction system in this paper utilizes an online IoMT approach, employing a heartbeat sensor connected to an ESP32 microcontroller. This setup represents a practical example of the Internet of Medical Things in action. The ESP32, known for its versatility and connectivity features, is crucial in data acquisition and transmission.

Stage-1: Data Acquisition and Transmission

- The heartbeat sensor, interfaced with the ESP32, continuously monitors the patient's heart rate.
- This sensor is designed to detect fluctuations in heart rate, which are pivotal markers for potential heart issues.
- Upon recording the heart rate data, the ESP32 microcontroller transmits this information to our dedicated channel on ThingSpeak.

Stage-2: Connecting with ThingSpeak

- As an IoMT analytics platform is incorporated using ThingSpeak, which allows the accumulation, visualization, and analysis of live heartbeat sensor data streams in the cloud as a simple implementation of IoMT.
- Our harware system uses ThingSpeak as the essential source for the heart rate data collected by the latest Arduino based ESP32 module.
- Our channel continuously records the heartbeat sensor data on ThingSpeak, and from this it is efficiently stored and used for further analysis.

Stage-3: Data Processing and AI Application

- The heart rate data stored on ThingSpeak is accessed using our specific channel ID.
- We utilize MATLAB, hosted on matlab.mathworks.com, to run our proposed algorithms of AI on the saved data.
- MATLAB, with its Neural Network toolboxes and capabilities for handling big data and machine learning, is employed to analyze the heart rate data and to apply our predictive models based on AI.

Stage-4: Triggering of Alerts

- The proposed AI algorithms of RBFNN, BPNN, and ANFIS in MATLAB are designed to detect irregularities or patterns related to the risk of heart disease or heart attacks.
- When such patterns are identified, the system triggers an alert mechanism.
- The alert system is integrated to notify healthcare providers or patients directly, ensuring instant attention to any possible risk of heart disease.
- This alert approach will play a vital role in timely involvement and can be personalized to specific needs, such as sending notifications via email, SMS, or directly phone calls through a healthcare provider using updated patient management system.

Overall, the proposed online platform for predicting heart disease risk and related responses is obtained through the combination of the IoMT hardware ESP32 with the ThingSpeak and MATLAB, demonstrating a real application of AIoMT for heart disease estimate. It proves the practicality and effectiveness of using live data streams, processed through AI algorithms, for early and precise heart disease detection. The amalgamation of these technologies facilitates a practical approach to health care, possibly renovating how heart diseases are predicted and managed.

6. Conclusions

The proposed AIoMT methods discussed in this paper present significant development in the area of heart disease prediction through innovative application of the Artificial Intelligence of Medical Things (AIoMT). By exploring a multi-model soft computing framework that integrates RBFNN, BPNN, ANFIS, and SVM, this research demonstrates a systematic approach to data gathering, pre-processing, model training, validation, testing, and estimation. The proposed system, implemented in MATLAB and tested with real-world EHR data obtained useful results, mainly with the RBFNN model, which achieved accuracy of 85.26%. This suggests that such AIoMT systems have the capability to enhance the accuracy and timeliness of heart disease prediction in an online environment like open source IoT systems of Thingspeak, enabling us to lead to better patient outcomes and more efficient healthcare services. These approaches and findings emphasize the significance of AIoMT in revolutionizing cardiac healthcare, providing a path for future advancements in the timely advice and reaction of giving precision medicine and patient care.

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