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Application of IoT and Machine Learning Techniques for Heart Disease Prediction and Diagnosis: A Comprehensive Review

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ABSTRACT

Heart diseases and related disorders have emerged as the most dangerous and leading cause of global deaths affecting mostly the elderly people who suffer from these diseases without realizing or knowing about it. Due to the fact that it's very hard to notice the signs of the sickness at an early stage, mostly the signs will be shown once the heart problem has reached the peak level. This paper therefore presents a detailed review of how to monitor and predict heart disease using machine learning and the IoT. With the help of IoT, patients and doctors will monitor cardiovascular diseases early enough. A comparative analysis of different IoT technologies, most of which employed machine learning approaches for predicting and diagnosing cardiovascular disease, is conducted, different methodologies are compared and the results analysis is conducted and the performance tabulated. The Internet of Things (IoT) is transforming embedded systems into networked smart gadgets with sensors. The primary drawback of employing smart devices was their limited storage and processing capability, which cloud computing addressed by providing high-level processing and storage capacities. The Internet of Things (IoT) is transforming embedded systems into networked smart gadgets with sensors. The most significant disadvantage of using smart devices was their low cost. The problem of limited storage capacity and processing power was solved by cloud computing.

Key Words: Internet of Things, cardiovascular disease, machine learning, Neural Networks.

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1. INTRODUCTION

Smart healthcare monitoring refers to a combination of remote smart computing and health monitoring with Internet of Things [1]. Body sensor nodes are composed of various sensors, including an implantable cardiac defibrillator, and heart monitor, that sense and track users' breathing rates, arterial pressure, pulse rate, and temperature [2]. According to studies on patients with heart failure, approximately 30% of them were admitted again in a space of 3 months. The recurrences have risen to 0.54 from 0.25 in a 3 to 6 months period [3].

In [4], a monitoring technique for cardiovascular patients is proposed, which utilizes an IoT-based DLMN (Deep Learning Modified Neural Network) to diagnose heart disease and administration of medicine. This approach is carried out in three distinct steps: starting with authentication using SHA-512 and substitution cipher followed by encryption using PDH-AES and finally classification is performed using DLMNN classifier.

K. BinSalman et al devised and created a system that allows patients to use wearable sensors to predict and alert them about their heart disease symptoms in [5]. When the solution is integrated with accurate diagnosis, informed decisions are easily made together with sending of emergency alerts more quickly, potentially saving lives. The suggested system is made up of three parts: a sensor, a desktop-based application, and a web-based system. Sensor data is collected from a patient and sent to the client desktop-based application. Data sampling is carried out and the data is stored in the system's database, which may be accessed remotely at any time.

The suggested study's goal in the research conducted in [6] is to use machine learning techniques to determine the important aspects in predicting of cardiovascular disease. An IoMT system to detect cardiovascular disorders combining ANFIS (adaptive neuro-fuzzy inference system) and MSSO (modified salp swarm optimization) is developed. MSSO-ANFIS classifies the data

from the sensor to determine the heart state. MSSO-ANFIS is demonstrated to be effective in disease prediction through simulation and analysis. The simulation results prove the MSSO-ANFIS prediction model outperforms existing approaches based on accuracy.

Another IoT disease detection approach based on cloud is suggested in [7] to track, detect, and detect cardiovascular disease. A system for predicting persons with heart-related illness is developed. In addition, classification techniques are applied to classify a patient's sensor data for prediction of heart disease.

Basheer S et al. in [8] explains an approach to heart disease prediction. Heart rate sensors, respiration rate sensors, and haemoglobin range sensors are put on the body of a patient to detect illness; heart rate sensors, breathing rate sensors, and haemoglobin range sensors are used for prediction. The subset contains characteristics having the highest connection with the classification variable and are retrieved by the maximum relevance–minimum redundancy technique using R Feature selection. Despite the fact that the traits are distinct, they are combined in this technique due to their substantial association. A hybrid fuzzy decision tree technique for classification. As a result, creating an algorithm requires combining one or more approaches to create a hybrid methodology. The decision tree algorithm is utilized to create this suggested approach for using rule sets and options. Deep learning is a strategy for studying and dealing with randomized data that combines extreme learning with supervised machine learning.

Deep learning algorithms are also studied by M. Umer et al for identifying a patient with heart failure as living or dead [9]. The system gathers data from Internet of Things (IoT) sensors and transfers it to a cloud web server for processing. Deep learning algorithms take this data and analyse it further to determine the health of patients. The dataset utilized in this investigation has 13 characteristics and was obtained from the Heart Failure Clinical Records repository at UC Irvine. With a 0.9289 accuracy rating, the CNN model outperformed other deep learning and machine learning models in the experiments.

2. PROBLEM STATEMENT

Data for the World Health Organization indicates that heart related complications and illnesses are the leading death causes worldwide. 17.9 million people are estimated to have died as a result of heart diseases in 2019 contributing 32% of the global deaths [10]. According to the Centers for Disease Control, a patient dies from heart-related complications every 36 seconds in the United States amounting to a total of about 659000 deaths annually [11]. There is therefore a subsequent need to develop a system based on the Internet of Things for cardiovascular disease monitoring, prediction and diagnosis. This would help in early disease prediction and diagnosis which in a long run will reduce the fatalities as a result of cardiovascular disease.

3. RELATED WORK

Valliappan.S et al. in [12], concentrated on implementing a low-cost system to remotely monitor health of elderly cardiac patients and trigger alarms. In their research, they employed Arduino UNO and Arduino Nano. The pulse, temperature, and GSR sensors are all included with the Arduino Nano. The Arduino UNO's RF module is used to send and receive wireless signals between two devices. To alert family and doctors, the GSM module was utilized in conjunction with an Arduino UNO. To assist people to cope with stress, the study adds a novel feature: an Arduino-based music player.

Xiang Pei et al. present a widespread healthcare IoT-based system for heart disease monitoring. This system continuously analyzes [13] vital indications like blood pressure as well as critical environmental variables, and it offers four data transmission options for balancing healthcare needs for communication and processing requirements. They developed a prototype to demonstrate how the system functions at a high level.

Muhammad Umer et al. in [14] demonstrated an intelligent IoT-based system for monitoring patients using real-time data and delivers heart failure patients with quick, reliable, and high-quality healthcare. In this approach for identifying heart failure patients as alive or dead, deep learning algorithms are also studied. The framework gathers data from IoT sensors and transfers it to a cloud web server for analysis. Deep learning algorithms take these data and process it further to investigate the patients' health.

The system in [15] suggests the creation of a low-cost heart rate monitoring gadget based on Bluetooth technology that may be utilized at the fingertips in this study. A heart rate module, an Android application, and a Bluetooth module are among the system's many components. The Heart Rate (HR) module obtains a heart rate signal from the subject (patients) using non-invasive technology (Photoplethysmography) and transmits it wirelessly to a computer or an Android application through Bluetooth. This system can be taken and combined as a telemedicine component. The data collected by the heart rate module can be saved and used for medical needs in the future.

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The study in [16] monitored the patient's heartbeat from the hardware system's output that includes Node MCU with a pulse sensor. A warning system was included that gets activated whenever the heartbeat falls below or exceeds the algorithm's authorized level. An alert notification is delivered to the medical personnel via a mobile app. Medical personnel on duty can check the patient's heart rate in the serial monitor using a real-time monitoring system. Because it is a more secure platform to keep data on, Adafruit is utilized for real-time monitoring.

Nehal Patel et al. developed a system in [17] based on the internet of things that can detect heart attacks by monitoring heart rate. In this project, they used IoT to create a method for monitoring heart rate and detecting heart attacks. The patient will be outfitted with sensors and an Android application, among other things. Users will be able to monitor their heartbeats and send them over the internet using the heartbeat sensor. The user has control over the high and low levels of the heartbeat. Once these parameters are set, the system can begin monitoring the patient's heartbeat, and if the readings go above or below the user-defined limit, a warning will be sent.

Researchers in [18] exhibited a medical device utilizing the Internet of Things for gathering patient heart status data before and after cardiac illness. The input was evaluated using a higher-level Boltzmann deep belief neural network after it is continuously sent to the HC center. The preceding heart disease elements are learnt using the deep learning technique, that resulted in the effective interpretation of complex data. These factors (specificity, loss function, sensitivity, and receiver operating characteristics) were used to calculate the system's performance.

3.1 Table of Analysis

Table 1: Table of Analysis

Author	Methodology	Contribution	Objective	Limitation
Sarmah [4]	DLMNN (Deep Learning Modified Neural Network)	Combine Deep Learning with IoT to aid with heart disease diagnosis and medicine administration.	To develop an effective health tracking and Heart Disease Prediction model based on IoT Using Deep Neural Networks	Issues of IoT security were not addressed
Khan et al. [6]	ANFIS (adaptive neuro-fuzzy inference system) and MSSO (Modified salp swarm optimization)	Develop a heart illness prediction system based on Internet of Medical Things	To implement health surveillance cloud-based system for heart disease prediction	Increasing the efficacy of predictive classifiers by combining wearable technologies with existing feature selection and optimization methods.
BinSalman et al. [5]	Sensor-based Desktop-based Application and Web System	Effective mobile and web-based remote monitoring system for patients	To develop a mobile and web-based system for monitoring heart disease	Incorporating data analytics processes such as cognitive analysis, that could provide a unique approach on data analytics.
Ganesan et al. [7]	Machine Learning and IoT	It evaluates different IoT-based machine learning techniques for prediction of heart disease	To design a cardiovascular disease machine learning and IoT based diagnostic	Issues of IoT security were not addressed
Al-Makhadmeh et al. rder [19]	DBNN (deep belief neural network) and HOB	Develop a smart IoT system that gathers patient data and predicts with machine	To design optimal machine learning model to predict heart disease	Did not employ Framework feature selection

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	(Boltzmann)	learning		
Ali et al. [20]	Optimal configured DNN and $x2$ - statistical model	A predictive cardiovascular disease diagnostic system with no overfitting and underfitting of training data	To develop an intelligent hybrid system that accurately detects heart disease	The research did not analyze the system's time complexity
Nourmohammadi-Khiarak et al. [21]	ICA with meta-heuristic	Uses the meta-heuristic technique with imperialist competitive model for optimal heart disease feature selection	To develop an optimal hybridized heart disease diagnosis method	Did not employ the feature selection approach to data that is incomplete or missing
MadhuSudana et al.[22]	Multi-objective optimization with evolutionary parameters	Develop a hybrid disease detection system based on support vector machine and multi-layer perceptron classifiers	To develop a hybridized system that diagnoses and predicts different diseases based on optimal classification parameters	Processing a dataset with a very high dimensionality and primary feature selection phases with evolution of classification parameters
Mohan, S. et al.[23]	Linear model based on hybridized random forest	Accurate prediction of cardiovascular disease using machine learning and IoT	To increase heart disease prediction performance accuracy	Did not utilize novel feature extraction techniques to gain a wider perspective of the crucial features for disease prediction
Shakila Basheer et al. [8]	Hybridized fuzzy decision tree algorithm	Combination of the hybridized based fuzzy decision tree means classification makes it simple to forecast heart disease. depending on user input	To model a hybridized fuzzy decision tree method for early disclosure of heart disease by continuously and remotely monitoring the patient	-
Umer et al. [9]	-	Provides easy, low-cost, and reliable monitoring, as well as a higher probability of survival for crucial patients	To design a smart IOT cloud-based healthcare framework to enhance the survival prediction of heart failure patients without relying on manual feature engineering	More datasets needed iso as to improve model performance of for practical use
Maryam Yahyaie et al [24]	-	-	To design a model based on electrocardiogram (ECG) data, making decision-making easier for predicting heart attack	More study on ECG monitoring is needed for reliable sickness diagnosis and accuracy based on ECG signals
Gupta et al. [25]	-	Developed a system that observes body temperature, physical movements heart rate, and blood pressure for	To design an IoT system to acquire real-time medical information about a patient	-

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		a patient on an ongoing basis		
Shahzad et al. [26]	Ontology based engineering	Developed an IoT-based cohesive healthcare system	To develop an ontological representation of a smart health system analysis	-
Chao Lia et al. [12]	-	Providing healthcare services based on the physical situation of patients rather than their emotions. A remote monitoring system is required to implement the pervasive healthcare service. they presented an ubiquitous system in this study.	They presented an ubiquitous monitoring system in this study that can convey real-time physical indicators from patients to remote medical applications.	Did not integrate a technology for data stream management to enhance functionality
Muhammad et al. [13]	Deep Leaning Models, Multilayer Perceptron Neural Network, CNN, RNN, LSTM	Patients with heart failure are monitored using a smart IoT-based framework that uses real-time data to provide timely, effective, and high-quality healthcare services.	The smart IoT-based framework monitors patients based on real-time data and provides heart failure patients with timely, effective, and high-quality healthcare services. Deep learning algorithms are also investigated in the suggested approach for categorizing heart failure patients as alive or dead.	-
S.Sandhiya[14]	Deep Belief Network	They monitor the disease level in this proposed heart disease monitoring system based on the inputs given to the IoT devices. Furthermore, it categorizes patient information based on the categories of cardiac disease and the severity of the disease.	This study presents a novel heart disease monitoring system for patients that incorporates the Internet of Things and Deep Learning techniques.	They monitor the disease level in this proposed heart disease monitoring system based on the inputs given to the IoT devices. Furthermore, it categorizes patient information based on the categories of cardiac disease and the severity of the disease.
Sahana S Khamitkar[15]	-	IoT is highly valuable because it replaces traditional monitoring systems with a more efficient method by giving important information about the patient's status to the doctor.	This study presents an IoT-based heart rate detection system.	The processing program currently displays the near-real-time PPG heart rate but does not record anything. There is a great deal of space for improvement in this area. Keeping track of heart rate and PPG samples, as well as the time-stamp information provided by the PC. If your heart rate is below or above the

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				threshold, you'll hear a beeping sound. The evolution of your heart rate over time, for example.
Sethuraman et al. [16]	ECG Waveform	Using IoT, this study presents a method for monitoring heart rate and detecting abnormalities.	In this study, an IoT-based system was developed that can monitor the heartbeat using the output of a hardware system that includes a NodeMCU and a pulse sensor.	-
Nehal Patel [17]	pulse sensor, Arduino board and a Wi-Fi module.	The heartbeat sensor will allow you to check your heart rate and send it over the internet.	Develop an intelligent hybrid system to increase heart disease diagnosis categorization accuracy.	-
Zafer et al. [18]	HOBDBNN	The HOBDBNN approach and IoT-based analysis accurately detect heart disease with 99.03 percent accuracy and minimal time complexity (8.5 seconds), effectively lowering heart disease mortality by reducing the diagnostic complexity	The suggested method employs a set of hidden layers to successfully retrieve new heart disease-related features from the past.	In the future, they will use the proposed long short-term memory recurrent neural networks as a strategy and aim to reduce the amount of local ECG data used to obtain acceptable accuracy levels.

4. REVIEW OF METHODOLOGIES

The methodology in [5] is applied in six stages namely; "definition of the problem and motivation, definition of objectives, design and development, demonstration, evaluation, and communication" [5]. The problem is then defined after conducting a literature review, and values are expressed more explicitly. A monitoring and control system is required, which necessitated the use of modern technology. Patients put on a sensor and activate it which will then begin recording vital data and storing it in a database. The data can be downloaded using the SDK that is part of the sensor package. The downloaded data includes various characteristics as well as vital sign analysis. Patients must first register with the system before they may use it. As a result, this system has two data sources. The first stems from manually entering patient information during patient registration. The used sensors are the second source of data.

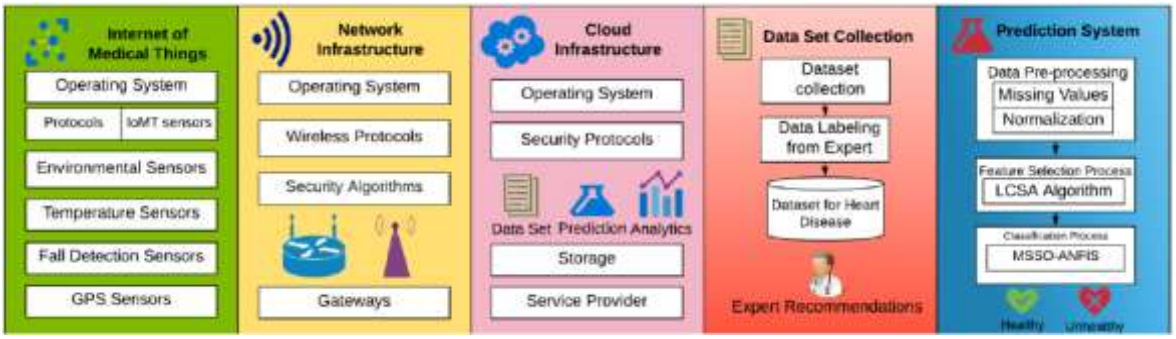

***Figure 1: Framework Proposed in* [6]**

The study conducted in [6] proposes an IoMT-based paradigm for better cardiac disease prediction. Before and after the beginning of cardiac illness, the IoMT device captures data on the heart of the patient. Sensor data obtained is sent to the hospital

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administration so as to determine the state of the patient. These data values were trained using the UCI data repository [27], followed by pre-processing, feature extraction and then MSSO-ANFIS classification. Patient's cardiac condition is classified as abnormal or normal depending on the final classification. The doctor takes the appropriate measures based on these results. The suggested framework's architecture is showed in Figure 1.

The proposed method in [4] is divided into three phases: authentication, encryption, and classification. There are 'three' steps in the authentication stage; registration, login, and verification. The patient uses his or her unique username and password to log onto the hospital website or app after registering their information. This patient information is stored on cloud as well as the health center's database. After registration, a cipher-based hash code is generated, which is used to verify the patient. At verification, the server uses the code generated during registration to confirm if the patient is authenticated or not. Access is provided if the patient is the correct person.

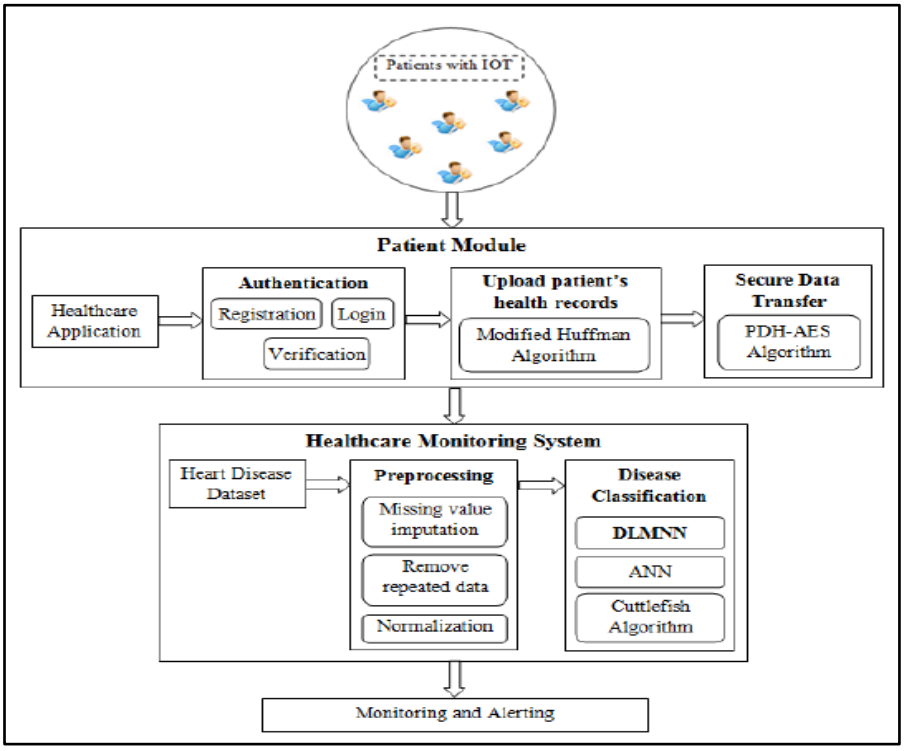

Figure 2: Framework Proposed in [4]

Figure 3 depicts the suggested system framework in [7] that works in three stages. The data is collected in the first step using IoT wearable devices and is stored on a cloud platform. Prediction finally takes place which involves classification that begins with training, which uses the dataset to perform classification to determine whether or not there is heart disease present. The trained classifier can then test new patient information to determine if the patient diagnosis is positive. The user can then access the test report that is generated.

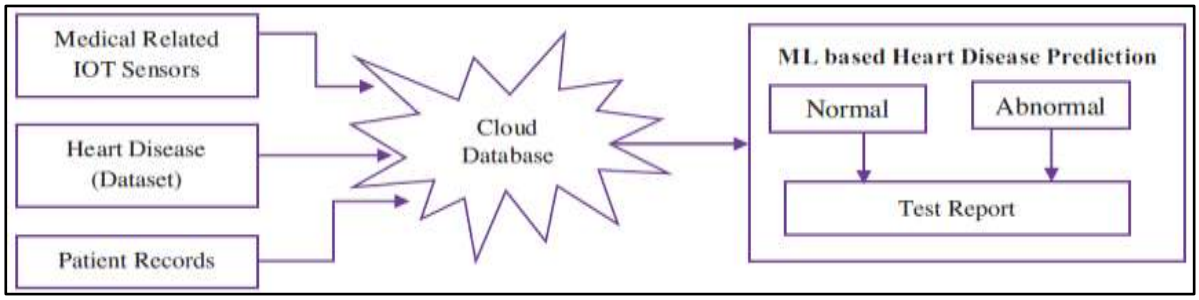

***Figure 3: Framework Proposed in* [7]**

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5. RESULTS ANALYSIS

This section compares the performance of different frameworks to assess their capacity in predicting heart disease. Different techniques such as MSSO-ANFIS, HOBDBNN, HRFLM, x2-DNN, ICA with meta-heuristic and hybrid intelligent systems are compared and the results are as tabulated below.

Table 2: Results Analysis

Author	Method	Evaluation Metrics (%)					
		Sensitivity	Precision	Accuracy	F1-Score	Specificity	Error
Sarmah [4]	Deep Learning Modified Neural Network DLMNN	93.75		96.8	98.2532	92.5	
Ganesan et al. [7]	Machine Learning	-	91.50	91.48	91.50	-	-
Mohan, S. et al.[23]	HRFLM	92.8	90.1	88.4	90	82.6	11.6
Khan et al. [6]	MSSO-ANFIS	97.89	96.54	99.45	98.79	97.88	0.55
Al-Makhadmeh et al. rder [19]	HOBDBNN	96.43	95.89	99.03	98.495	97.76	0.97
MadhuSudana et al.[22]	hybrid intelligent systems	93.49	94.07	94.05	94.05	94.77	5.95
Ali et al. [20]	x2- DNN	85.36	-	93.33	-	100	6.67
Nourmohammadi-Khiarak et al. [21]	ICA with meta-heuristic	96.27	-	94.03	-	90.36	5.97

Timely detection of different health concerns assists patients in taking the appropriate preventive steps, thereby saving their life. IoT devices can carry out real-time patient monitoring and trigger an alarm in case of irregularities. However, the framework should include encryption and security features to enhance the patient's data security as it is sensitive. Tiny sensors are used to enable easy integration with various systems and a combination of these with different machine learning techniques improves the robustness and accuracy of the system.

6. CONCLUSION

This paper has introduced, reviewed and summarized different IoT based technologies employed in the monitoring of cardiovascular diseases. Healthcare monitoring and prediction frameworks have proved essential in saving human lives, especially in cases where the sick are in rural areas. IoT-based healthcare systems for prediction and prevention of heart disease are reviewed in this paper. Precision, recall, F1-score, accuracy, and classification error are all measured and compared between the methodologies. Based on these findings, we may conclude that the various systems are capable of accurately detecting and continually monitoring patients' heart conditions. If necessary, the doctor can provide prompt treatment based on the cardiac issue discovered.

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