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A REVIEW ON PREDICTION OF CARDIOVASCULAR DISEASE USING IOT & MACHINE LEARNING TECHNIQUES

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Abstract— Cardiovascular Disease is major health hazard that causes most of death worldwide. The introduction to Internet of things (IoT) and advancement in machine learning algorithms enables early prediction of heart disease. Making diagnosis decisions become easier for healthcare professionals such as doctors, cardiologist. Many researchers have proposed different types of machine learning algorithms to predict and diagnose cardiovascular disease. In this paper, we have done exhaustive study on existing methods and discussed relevant for heart disease. The aim of this study is to help researcher for selecting the appropriate machine learning algorithm for predicting heart disease.

Keywords—Cardio Vascular Disease (CVD) Internet of Thing (IoT), Wearable IoT devices, Machine learning, Classification algorithms.

I. INTRODUCTION

Cardiovascular disease refers to the disease of heart failure and veins or blood vessels disorder. Two keywords are there in which cardio means heart and vascular means blood vessels. American Heart Association (AHA) and World Health Organization (WHO) reported that CVD's are the number cause of death due to heart disease [2, 4, 5, and 17]. Cardiovascular disease increases worldwide in developed as well as in undeveloped countries. In CVD heart fails to supply a sufficient blood to other parts of the body to accomplish their normal functionalities. Early diagnosing of heart problem is very essential for preventing patients from more damage and saving their lives. Physical body weakness, shortness of breath, feet swollen, and weariness with associated signs are the most common symptoms of cardiovascular disease. The risk of heart disease may be increased by the lifestyle of a person like smoking, unhealthy diet, high cholesterol level, high blood pressure, deficiency of exercise and fitness. In tradition system only one well known technique was there for diagnosing heart problem and that was angiography [26]. Conventional invasive-based methods used for the diagnosis of heart disease which were based on the medical history of a patient, physical test results, and investigation of related symptoms by the doctors. Among the conventional methods, angiography is considered one of the most precise techniques for the identification of heart problems [26]. Conversely,

angiography has some drawbacks like high cost, various side effects, and strong technological knowledge. Conventional methods often lead to imprecise diagnoses and more time due to human mistakes. Several clinical analyses (such as measuring blood pressure, blood glucose level, SpO2, level, Pulse rate and so, on) can be performed at home without the help of a healthcare professional [23]. Now a day's wearable sensor devices used in IoT health monitoring system generates large amount of data continuously [10]. This data gives information to the daily routine and physical examination. The medical industry also generates large electronic patient data. The timely, accurate and reliable analysis of this data will save cost and help practitioners in making correct diagnostic decision. Machine learning techniques have proven importance in disease diagnosis to predict the presence of disease [2]. World Health Organization (WHO) estimated that 76% of the death would be due to CVD by 2030[2]. Therefore there is a need to identify strategies, processes and technologies that have the potential to automatically identify patients at risk of CVD. So identification and prevention of CVD should reduce this growing death rate.

Health monitoring system continuously observes the individual's health condition such as respiratory rate, heart rate, body temperature, Oxygen level, ECG, blood pressure, activity level. Recent advancement of Bluetooth technology enabled wireless data collection devices allows efficient data collection in home self care patients. The existing approaches use only traditional databases and tools to process the large data generated from IoT devices. So it's required to build a scalable approach that stores as well as analyze the large volume of clinical data. Again due to lack of expert and the number of case incorrectly diagnosed. An efficient automated detection system is required. It uses to store the large volume of data in the cloud. Machine learning techniques have proven importance in disease diagnosis to predict the presence of disease. This will help to an increasing population of home monitored, remote and financially challenged patients. The predicted results can be used to prevent diseases and thus reduce cost for surgical treatment and other expenses.

WHO defines CVD as a group of disorder of the heart and blood vessels, including following diseases [5].

- Coronary Heart Disease (Supplying the heart muscle)
- Cerebrovascular Disease (supplying the brain)
- Peripheral arterial Disease (Arms and legs)
- Congenital heart Disease (malformation of heart existing at birth)
- Deep vein thrombosis pulmonary embolism (blood clots).

Some risk factors are uncontrollable like age, sex, racial group, hereditary and some are controllable like blood pressure, blood cholesterol, smoking, physical activity, obesity, diabetes, stress and anger. In IoT ECG, Respiration rate sensor, Pulse rate sensor, Activity level sensor, Oxygen level sensor and temperature sensor, Galvic sensor are available to collect patient data frequently. If it observed clinically abnormal then it sends an alert message with clinical value to the doctor. So, early notification is provided if any value is above threshold and parallel data stored in cloud either normal clinical value or abnormal. Machine learning algorithm will predict whether the individual affected with CVD or not. The benefits of this are no blood test or lab based data collection needed. It saves diagnostic cost and time and enhances the accuracy of the treatment process. If the disease is detective at early Stage and prevention assessment is taken as quickly as possible; the mortality rate can be drastically

controlled. Different existing datasets are also available like UCI ML repository, Cleveland datasets, Switzerland, Long Beach VA, Hungarian Institute of cardiovascular, UKC-JSI dataset, Physionet dataset and National Heart Lung and Blood Institute dataset.

The convergence of IoT and Machine Learning transformed the conventional healthcare into smart healthcare [23, 25]. Convergence is resulted in decreased healthcare cost and also strained the healthcare facility at rural and remote locations. Some IoT applications [23] in healthcare are, ambient assisted living which help to elderly people to live independently at home, Adverse drug reaction, ECG monitoring, glucose level monitoring, temperature monitoring, blood pressure monitoring, oxygen level monitoring, ashthma monitoring, stress level detection and many more.

In IoT some issues are also there that provide further scope for research [23].

Power Problem as IoT gadgets run on battery. When a sensor is put on, the substitution of the battery isn't simple. Thus, a powerful battery was utilized to power such a framework. One solution may be the integration of the IoT devices with renewable energy systems.

Security and privacy of data is also one issue. Due to cloud computing storing data becomes very easy but this has made healthcare networks more vulnerable to cyberattacks.

New Disease Investigation - countless portable applications are accessible for medical care applications, the sorts of sicknesses for which these applications were planned are as yet restricted. Thus, there is a need to incorporate more infections that were all things considered disregarded or got lacking thought before.

Machine learning is used to diagnose disease and predict therapeutic responses [24]. ML Save diagnostic cost and time and enhance the accuracy of treatment process. There are different machine learning techniques available for prediction. In existing method logistic regression, ANN, Decision Tree, KNN, Random forest, SVM, LDA and Naïve Bayes algorithms used to predict the heart disease but hybrid approach achieves good result [8].

II. RELATED WORK

Already, a range of studies have been suggested for prediction of cardiovascular disease. Association rules are developed to classify the risk of CVD. This study suggests the premium for health insurance should be based on the result of association rule [1]. The source of data used in this study is the Hungarian Institute of cardiology. Randomly 155 patient's data selected. The techniques namely Decision tree classifier, K-Means and Logistic Regression has been proposed to derive the association rule. Six classifier namely artificial neural network, Support vector machine, decision tree, nearest neighbor, Linear discriminate analysis, random forest apply on three CVD dataset and compare which classifier have better performance[2]. Random Forest (RF), Decision Tree (DT) and Artificial Neural Network (ANN) give higher accuracy (88%) then K-Nearest Neighbor (KNN), Support Vector Machine (SVM) and logistic regression. In [3] Martin and Anton proposed a heart prediction system on the basis of heart sound using phonocardiography. UKC-JSI dataset and PhysioNet dataset is used with recording based classifier. Recording based classifier gives higher accuracy (92%) then LogReg and Random Forest. In [4] Chunyan Guo and Zhang proposed Recursion Enhanced Random Forest with improved linear model for heart disease detection on IoMT platform. RERF-ILM method is utilized merging the feature of the linear model and random forest and achieved 96% accuracy. In [5] Chatterjee and Yan Li proposed machine learning model to predict CVD without blood test. Source data is used from National Heart Lung and Blood

Institute dataset. 5099 patient records are extracted from the original dataset of 5804 records. The proposed model is specifically built using NHLBI datasets. It was hard to generalize the model for all other datasets. In [6] Rajkumar Buyya and Tuli proposed a HealthFog model which is an IoT based fog-enabled cloud computing model for healthcare, which can manage the data of heart patients effectively. In [8] Mohan proposed the prediction model for heart disease with the hybrid random forest with a linear model and increased the accuracy (88.7%). It is still desirable to direct the investigation to real world dataset. In [10] Priyan proposed a three tier architecture to store and process huge volume of sensor data. Priyan used Apache Hbase for storing large volume data. This paper proposes a scalable IoT based three-tier architecture to process the sensor data and identify the most significant clinical parameters to get heart disease. The most significant clinical parameters that indicate impending heart disease are identified with the help of Receiver operating characteristic Curve (ROC) analysis. Blood Sugar (BS)-Fasting and Blood Sugar (BS)-Post Meal are found to have positive correlation with heart disease. However, Respiratory Rate (RP), Heart rate (HR), Blood Pressure (BP): Systolic Range (SR), Blood Pressure (BP): Diastolic Range (DR) and Body Temperature (BT) are found to be negatively correlated with heart disease. The experimental results prove that Respiratory Rate (RP) at around 50 and 12 is highly significant in the indication of the heart disease. Heart rate 160 is also indication of heart disease. Similarly, Blood Pressure (BP): Systolic Range and Body Temperature (BT) at 140 and 37 are also considered as a highly significant variable for heart problem indication. In[23] The current audit examined various parts of the HIoT framework. Exhaustive information about the engineering of a Healthcare IoT (HIoT) framework, their part, and the correspondence among these segments has been examined. By utilizing these ideas, the IoT innovation has helped medical services experts to screen and analyse a few medical problems, measure numerous wellbeing boundaries, and give analytic offices at far off areas. This has changed the medical services industry from an emergency clinic driven to a more patient driven framework. In [28] the remote care framework can compensate for the deficiency of clinical assets. This article plans a distant consideration help terminal framework dependent on ARM V7 with physiological boundary observing, remote video checking, and different capacities. The framework gives distant clinical checking and clinical intuitive administrations for patients, mostly for algorithmic handling of ECG, and circulatory strain information gathered in the observing framework and clinical staff can distantly direct related nursing work. In[24] Recognizing the danger of coronary illness with sensibly high precision might actually profoundly affect the drawn out death pace of people, paying little heed to social and social foundation. Early conclusion is a critical advance in accomplishing that objective. A few examinations have effectively endeavoured to foresee coronary illness with the assistance of AI. This examination takes comparative course, yet with an improved and novel strategy and with a bigger dataset for preparing the model. This exploration shows that the Relief (feature selection technique) highlight determination calculation can give a firmly connected list of capabilities which then, at that point can be utilized with a few AI calculations. The investigation has likewise distinguished that Random Forest with Bagging Method (RFBM) functions admirably with the high effect highlights and delivers accuracy, considerably higher than K-nearest neighbour with banging method (KNNBM), Decision Tree with Bagging Method (DTBM), Ada Boost Boosting Method (ABBM) and Gradient Boosting Boosting Method (GBBM). In [25] this

paper AI and IoT based disease diagnosis model has been developed. IoT gadgets, for example, wearables and sensors gather the information while AI procedures use the information to perform illness analysis. Then, at that point, iForest method is executed to dispose of anomalies that exist in the patient information. Followed by, the Crow Search Optimization- Cascaded long Short Term Memory (CSO-CLSTM) model is utilized to arrange the information if the infection exists. What's more, CSO is applied to advance the loads and inclination boundaries of the CLSTM model. The usage of CSO aids the improvement of analytic result of CLSTM model. The presentation of CSO-LSTM model was approved utilizing medical services information. During the experimentation, the CSO-LSTM model achieved a greatest accuracy of 96.16% on coronary illness. In [26] they analysed Coronary illness is quite possibly the most decimating and deadly ongoing infections that quickly expansion in both financially created and lacking nations and causes demise. This harm can be decreased impressively if the patient is analysed in the beginning phases and appropriate treatment is given to patient. In this paper, researcher fostered an insightful prescient framework dependent on contemporary AI calculations for the forecast and conclusion of coronary illness. The created framework was kept an eye on two datasets for example Cleveland (S1) and Hungarian (S2) coronary illness datasets. The created framework was prepared and tried on full highlights and ideal highlights also. Then classification calculations including, KNN, DT, RF, Naïve Bayes (NB), SVM, AdaBoost (AB), Extra Tree Classifier (ETC), Gradient boosting (GB), Logistic Regression (LR) , and ANN, and four element choice calculations, for example, Fast Correlation-Based Filter Solution (FCBF) , Minimum redundancy maximum relevance (mRMR), Least absolute shrinkage and selection operator (LASSO), and Relief are utilized. They include choice calculation chooses the most significant highlights from the component space, which diminishes the classification blunders as well as therapist the element space. To survey the presentation of classification calculations different execution assessment measurements were utilized like accuracy, sensitivity, specificity, Area under Curve (AUC), F1-score, Matthews correlation coefficient (MCC), and ROC bend. The classifcation exactnesses of the main two classifcation calculations for example ET and GB on full highlights were 92.09% and 91.34% separately. Afer applying highlight choice calculations, the classifcation exactness of ET with the alleviation include determination calculation increments from 92.09 to 94.41%. The exactness of GB increments from 91.34 to 93.36% with the FCBF highlights choice calculation. Thus, the ET classifier with the alleviation highlight choice calculation performs incredibly. In [27] the proposed model they tried on two notable Coronary Artery Disease (CAD) datasets: the Z-Alizadeh Sani and Cleveland information from the UCI vault. This model is a piece of the Nested Ensemble (NE) approach. It depends on various customary AI calculations. In this examination, the nu-SVC calculation, including direct, polynomial, RBF and sigmoid portions, was chosen as the base calculation of our NE-nu-SVC model. At the first level, the nu-SVC, SGD and random forest algorithms were combined using the stacking and bagging techniques. At the second level, the voting technique, and at the third level, the SMO and Naïve Bayes calculations, were utilized. nu-SVC gave the accuracy of 94.66% to the Z-Alizadeh Sani information and of 98.60% for the adjusted Cleveland information.

Year/Title	**Key Features**	**Dataset**	**Algorithms**	**Evaluation Metrics**	**Future Scope**
2022 [31] IoT Based Smart Monitoring of Patients' with Acute Heart Failure (sensors) MDPI	A smart healthcare framework is proposed that integrates IoT and cloud technologies for heart failure patients' real-time monitoring.	UCI repository known as Heart Failure Clinical Records	MLP, CNN, RNN and LSTM (92.89)	Accuracy, Precision, Recall	Collect large-sized datasets to improve the performance of the models for practical use. more deep learning models will be explored for better results.
2022 [32] Internet of things based electrocardiogram monitoring system using machine learning algorithm	Used Arduino and ECG and linear regression for prediction	2000 volunteers ECG signals	Linear regression 91%	Accuracy	Add some parameter in future like RR,PR,QRS complex,QT and checked in ML algorithm
[25] 2021 Artificial Intelligence and Internet of Things Enabled Disease Diagnosis Model	Design disease diagnosis model for heart disease and diabetes using AI and IoT convergence techniques	IoT devices data is used	CSO-CLSTM Model - 96.16% for heart disease diagnosis and **97.2 6%** for diabetes.	Accuracy, Sensitivity, Specificity	Dimensionality reduction with different feature selection techniques can reduce computational complexity.
[24] 2021 Prediction of Cardiovascular Disease Using Machine Learning Algorithms With Relief and LASSO	Proposed a model that incorporates different methods to achieve effective prediction of heart disease.	Cleveland, Hungary, Switzerland, and VA Long Beach and Statlog, Total - 1190	DTBM- ,**RFBM - 99%** ,KNNBM, ABBM, GBBM , Relief and LASSO	Accuracy, Precision, Recall, F1 Score, Error rate	Generalize the model for other feature selection algorithms
2020 [26] Early and accurate detection and diagnosis of heart disease using intelligent computational model	Various machine learning classification algorithms are investigated.	Cleveland, Hungary, Total -1329	LR, DT, NB, RF, KNN, SVM, AB, GB, **ETC -94.41** and ANN, FCBF, mRMR, LASSO and Relief	Accuracy, Sensitivity, Specificity, Precision, AUC, F1 Score, MCC	Use more optimization techniques, feature selection algorithms, and classification algorithms to improve the performance.

2020 [30] Ambient assisted living predictive model for cardiovascular disease prediction using supervised learning	Propose a framework for prediction of heart disease using major risk factors	Cleveland database, Statlog heart disease dataset	KNN, Naïve Bayes, **SVM - 92%**, Lasso and ridge regression	Accuracy, Precision, F-measure, f1-score	Need to investigate the time complexity of the diagnostic system in clinical application
2020 [3] Machine learning and end-to-end deep learning for the detection of chronic heart failure from heart sounds	Used phonocardiography audio recording to detect CHF	PhysioNet (3153), UKC-JSI	Logistic Regression, Random forest, Recording **based classifier (92.9%)**	Accuracy, Sensitivity, Specificity, f1-score	One could employ transfer learning tech to utilize data from other similar dataset, conduct and feature selection study to find optimal feature
2020 [4] Recursion Enhanced Random Forest With an Improved Linear Model for Heart Disease Detection on the IoMT Platform.	Used Recursion Enhanced random forest with Linear model (merged features of LM & RF)	UCI ML Repository	Random Forest with Linear model **(96.06%)**	Accuracy	Merged features can be used to improve accuracy
2019 [8] Effective heart disease prediction using hybrid machine learning techniques. IEEE Access	Used hybrid random forest	Cleveland dataset	Random Forest with linear model (**88.7%**)	Accuracy, Sensitivity, Specificity, Precision,	Desirable to direct the investigation to real world dataset

2019 [27] Nested Ensemble Clinical Decision Support System for Effective Diagnosis of Coronary Artery Disease	Proposes NE-nu-SVC model which combines traditional machine learning methods and ensemble learning techniques	Z-Alizadeh Sani and Cleveland, Total -606	NE-nu-SVC model - 94.66% in Z-Alizadeh Sani and **98.60%** in Cleveland datasets	Accuracy, Precision, Recall, F-measure, False Positive rate (FPR)	Proposed model can be implemented for other disease.
2019 [29] IoT based efficient hybrid recommender system for cardiovascular disease	IoT based recommender system that diagnoses cardiac disease and its type	Cleveland, Hungarian, long-beach-va, Switzerland and arrhythmia datase	SVM, Naïve Bayes, RF, and Multi-layer perceptron **98%**	Accuracy, Precision, Recall, Mean absolute error (MAE)	Eight available cardiovascular classes can be implemented using other algorithms.

III. MACHINE LEARNING METHODS FOR CARDIOVASCULAR DISEASE PREDICTION

From literature review we found that all existing method uses the different machine learning methods to predict cardiovascular disease. In Table 2, the features used in state of art techniques for predicting cardiovascular disease has been listed.

No.	Attributes	Data Types	Description	Value Range
1	age	Integer	Age in years	29 to 79
2	sex	Integer	Gender instance	0 and 1
3	cp	Integer	Chest pain type	1, 2, 3, and 4
4	trestbps	Integer	Resting blood pressure in mm Hg	94 to 200
5	chol	Integer	Serum cholesterol in mg/dl[	126 to 564
6	fbs	Integer	Fasting blood sugar > 120 mg/dl	0, 1
7	restecg	Integer	Resting ECG results	0, 1, and 2
8	thalach	Integer	Maximum heart rate achieved	71 to 202
9	exang	Integer	Exercise induced angina	0, 1
10	oldpeak	Real	ST depression induced by exercise relative to rest	1 to 3
11	slope	Integer	Slope of the peak exercise ST segment	1,2, 3
12	ca	Integer	Number of major vessels colored by fluoroscopy	0 to 3
13	Thal	Integer	Defect types	3,6,7
14	num	Integer	Diagnosis of heart disease	0, 1, 2, 3, and 4

Machine Learning provides numerous approaches to discover the hidden patterns or similarities present in the data. Cardiovascular diseases are very complicated, so care must be taken while treating them. Classification using machine learning is used for the detection of cardiovascular diseases.

A. Decision Tree

Decision Tree (DT) is one of most commonly used techniques, used to classify heart disease [24]. This algorithm uses tree having the root node which determine best split from the set of

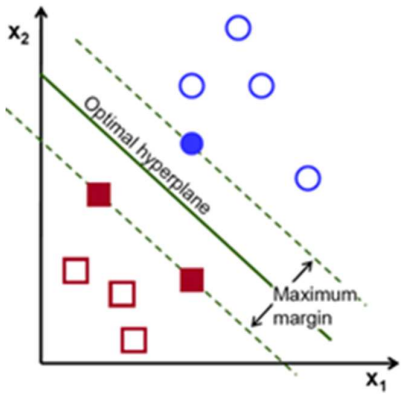
available features. Entropy based metrics such as information gain, gini index and gain ratio are used to find out best feature. In [24] decision tree is combined with bagging method to reduce the variance of classifier.

B. Random Forest

The Random Forest (RF) method is an ensemble algorithm that consists of several DT algorithms. Ensemble learning methods uses multiple learning algorithms to generate an optimal classifier. RF has a higher accuracy as it uses more features in comparison to DT, but may increase the computational overhead. RF can be combined with bagging method…

C. Support Vector Machine

Among several employed methods, the results from SVM prove to be useful in enhancing accuracy in the prediction of disease [29]. Support vector machine algorithm finds a hyper plane in an N-dimensional space to classify given data points. N represents the number of features that distinctly classifies the data points. As shown in figure 1 maximizing margin, turns to minimizing miss classification.



D. K-Nearest Neighbors

K-Nearest Neighbors (KNN) techniques is another most commonly used classification technique in healthcare [24].

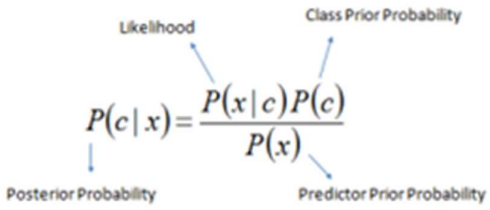
KNN considers the equivalence of the new data and the existing data and places the new data in the class, which is nearest to the existing classes. KNN is used for regression problems as well as for recognition problems. It is also known as the lazy learner algorithm.

E. Naïve Bayes

It is a classification technique based on Bayes' Theorem with an assumption of independence among predictors. In simple terms, a Naive Bayes classifier assumes that the presence of a particular feature in a class is unrelated to the presence of any other feature.

Naive Bayes model is easy to build and particularly useful for very large data sets. Along with simplicity, Naive Bayes is known to outperform even highly sophisticated classification methods.

Bayes theorem provides a way of calculating posterior probability P(c|x) from P(c), P(x) and P(x|c). Look at the equation below:



$$P(c|X) = P(x_1|c)\times P(x_2|c)\times\cdots\times P(x_n|c)\times P(c)$$

Datasets like UCI ML repository, Cleveland datasets, Switzerland, Long Beach VA, Hungarian Institute of cardiovascular, UKC-JSI dataset, Physionet dataset and National Heart Lung and Blood Institute dataset. No one used real dataset. So, the problem is that first individual need to contact doctor and then after clinical examination data were collected and after that using any machine learning algorithms CVD was detected. But we fill that now a day's it required a system which continuously monitor patient and immediately notify if anything is wrong like heart rate, respiration rate, activity level, blood pressure, temperature etc; Now this data is stored also in cloud environment and by hybrid machine learning approach CVD will be detected. The main goal is to save time and cost of treatment of financially challenged people. We used ECG, Oxygen level sensor, Heart rate sensor, respiratory rate sensor, temperature sensor to collect data. If any clinical value is abnormal then immediately notification will be send to individual with clinical value and in parallel data will be stored in cloud and then using hybrid machine learning algorithm it will be predicted whether the individual have CVD or not.

IV. CONCLUSION AND FUTURE DIRECTIONS

In this study, different mechanisms for detection of cardiovascular disease have been studied. Early detection of heart disease helps in saving human life as well as cost of treatment. This study helps researcher to select best classifier for analytical study to achieve higher model accuracy and improve overall system performance. The higher accuracy of model enables doctors to trust in automated system based on IoT and machine learning. IoT wearable device are especially useful to continuously monitor the patient remotely by collecting their data. It has been observed that ensemble machine learning algorithms give better accuracy in comparison to traditional machine learning techniques. Among all Random Forest with Bagging Method gives higher accuracy with Relief feature selection technique. Feature selection techniques such as lasso, relief play an important role in identifying important features.

In future more intelligent ensemble model can be deployed for further improving the accuracy, precision, recall and decreasing the error rate. New feature selection method can be developed to get a broader perception to increase performance of heart disease prediction which create the trust for medical practitioner. Integration of IoT devices is another important aspect to collect patient data efficiently. IoT device integration also helps in reducing the cost of healthcare.

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