Journal of Computing & Biomedical Informatics
ISSN: 2710 - 1606

SICAIET
2024

Research Article
Collection: Artificial Intelligence and Emerging Technologies

An IoT- Assisted Patient Monitoring and Alert System

Hina Afreen[1], Ayesha Amir[1], and Umar Farooq[2*]

[1]Department of Computer Science, The Islamia University of Bahawalpur, Bahawalnagar Campus, 62300, Pakistan.
[2]Department of Education, The Islamia University of Bahawalpur, Bahawalnagar Campus 62300, Punjab, Pakistan.
[*] Corresponding Author: Umar Farooq. Email: umerfarooq@iub.edu.pk

Academic Editor: Salman Qadri **Published:** February 01, 2024

Abstract: In today's fast-growing technology world, efforts are being made to bring innovation in various areas to make human life easier. One important focus is improving medical services for people who don't have easy access to health care, especially in remote areas. According to the World Health Organization (WHO), forty-one million people die across the globe annually due to chronic diseases which is equivalent to 74% of deaths worldwide. It is a critical issue that needs to be addressed across the globe by providing easy-to-access and cost-effective real-time healthcare solutions. The Internet of Things (IoT) has become an emerging trend to provide effective and smart healthcare services to patients. The goal of this study is to develop an IoT-assisted Patient Monitoring and Alert System (PMAS) to remotely monitor the patient's health and intimate the caregiver about their health status. The novelty of the proposed approach is to gauge vital parameters such as heart rate, body temperature, and oxygen level of a patient remotely and keep their caregivers informed in case of emergency. Therefore, it becomes possible for caregivers to make necessary decisions according to the patient's health status. The proposed study has two main parts, in the first part, sensors are used to measure important information about a patient's health, and in the second part, transmitting gauged data to a doctor or caregiver who can monitor a patient's health progress even from far away, outside of hospitals. After collecting data, analysis of data is per-formed in Python using Machine Learning (ML) algorithms for the classification of health status. The patient's health status is classified into three classes based on collected data i.e., Good, Satisfactory, and Alarming. Moreover, on alarming status, an email alert is sent to the doctor or caretaker to take appropriate action. Henceforth, the presented study aims to develop a cost-effective and efficient solution to monitor a patient's health remotely and inform the caregiver accordingly so that timely necessary action will be taken by the caregiver or doctor for the life safety of a patient ultimately contributing to reducing the annual death rate.

Keywords: IoT; RQ; RO; WHO; BP; BT; HR; AT; AH; SPO2; IDE; SVM; DT; RF.

1. Introduction

With every technological advancement that the human race makes, health is always a top priority [1]. According to the World Health Organization (WHO), Noncommunicable Diseases (NCDs) account for 41 million annual deaths worldwide, or 74% of all deaths. The majority of NCD deaths approximately 17.9 million annually are caused by cardiovascular illnesses, which are followed by mortality by cancer (9.3 million), chronic respiratory diseases (4.1 million), and diabetes (2.0 million including deaths from renal disease induced by diabetes). More than 80% of all early NCD deaths are caused by these four categories of diseases__. Four major NCDs diabetes, cancer, chronic lung diseases, and cardiovascular disease account for three out of every five deaths worldwide[2]. NCDs are acknowledged as a significant obstacle to sustainable development in the 2030 Agenda for Sustainable Development. Heads of state and government pledged in the Agenda to create aggressive national plans by 2030 in order to reduce premature death from NCDs by one-third via prevention and treatment (SDG goal 3.4). Target 3.4 of the Sustainable Development Goals is to be achieved, and the coordination and promotion of the worldwide battle against NCDs is largely under the direction of WHO [2], [3]. Henceforth, it is a global objective to reduce the death rate caused by NCDs in the world. The Internet of Things (IoT) [4], is becoming a popular trend for giving patients smart and efficient healthcare services. Therefore, it is need of time to use state-of-art IoT technology for remote health monitoring of patients in order to predict their health status without the need for a caregiver's physical presence at that place. The purpose of the proposed study is to create a Patient Monitoring and Alert System (PMAS) that uses the Internet of Things to help monitor a patient's health remotely and notify a caregiver of the patient's condition. The innovative aspect of the presented study is its ability to remotely monitor a patient's vital signs, including heart rate, body temperature, and oxygen saturation, and to notify their caregivers in the event of an emergency. As a result, caregivers are able to make the necessary judgments based on the patient's condition.

The use of sensor-based systems in medical care to monitor patient conditions and alert medical staff in case of emergencies. Currently, sensors are hardwired to a laptop, and doctors and nurses need to visit the patients regularly to check their condition. The proposed system uses Wi-Fi and unique patient identities to enable continuous monitoring of the patient's condition, with greater accuracy, security, and contentment, and at a lower cost. The system allows patients to carry out their daily activities without interference from hardwired sensors, and physiological monitoring hardware can be easily implemented with simple connections between a microcontroller and sensors, which could result in the development of low-cost devices for healthcare monitoring [5]. The use of human-computer interaction and IoT wearables in healthcare monitoring. The proposed method is effective in monitoring the physical characteristics of patients and notifying relevant authorities when certain variables exceed critical levels. IoT wearables can collect necessary data and send it for processing and storage to track user history. When connected to external devices and services, preventive and emergency actions can be taken [6]. Chronic illnesses are becoming more prevalent in low-income countries due to various risk factors, and healthcare monitoring can improve people's quality of life. The healthcare industry is increasingly using patient monitoring and healthcare, which can help prevent patient mortality due to lack of monitoring and treatment [7]. IoT technology is now being used to develop health-tracking systems that require sensors and communication equipment. IoT has greatly facilitated healthcare applications and has played a crucial role in improving healthcare during the global pandemic. Remote monitoring equipment is used to monitor patients' vital signs, allowing accurate health assessments while they are at home, which has resulted in smart healthcare for all ages and reduced patient mobility during COVID-19 [6], [8]. IoT technology is used to establish a link between patients and physicians to monitor vital health variables such as bodily movement and position analysis. The data collected is analyzed to identify any medical emergency. The technology can assist with diagnosis and finding nearby clinics or hospitals. Patient data is transmitted to the portal through various web-based apps, medical sensor devices, and patient information to provide medical support [9] Smartphones can be used as a hub to gather, transfer, and present health data, which is flexible, simple, and beneficial for people of all ages, especially the elderly, by avoiding direct contact and limiting the transmission of viruses and illnesses. Wearable real-time health tracking gadgets are beneficial for senior citizens through continuous monitoring and fast action in the event of an emergency. IoT-based systems for smart health monitoring are presented, along with their advantages, disadvantages, and benefits [10]. The objective is to continuously monitor remotely treated patients to reduce hospital running expenses, and communication costs, and raise the standard of healthcare. Remote patient health tracking to determine one's health situation of the patients. Providing medical treatment and support to patients who are confined to beds at vital factors with superior clinical facilities has end up one of the essential issues in the present-day in world [11]. A quick-acting, cost-effective alert system is unavoidable in hospitals [12].

The article discusses remote health monitoring systems that allow for the continuous monitoring of patients' vital signs, particularly the elderly [13]. Advancements in technology have led to the development of small, efficient, and cost-effective sensors and microcontrollers. However, challenges exist such as the cost of these systems, internet connectivity, and accommodating the minimum conditions in developing countries. There are two types of monitoring systems, single-factor and multi-parameter. The multi-parameter system is preferred as it monitors several parameters at once, providing a more accurate assessment of a patient's condition [14].

The article also highlights the Esp32, a programmable device that can be used to integrate IoT into patient monitoring systems in healthcare. This also discusses a remote fitness tracking method that allows for monitoring physical activity and gathering physiological information at home, which is useful for elderly or ill individuals who wish to avoid extended hospital stays. The method involves a CPU analyzing sensor indicators obtained and sent via wireless sensors. The platform aims to collect data from various sensors, including heartbeat and body temperature sensors, and then utilize specific parameter monitoring systems for remote detection [15]. Future medical applications must integrate with existing technology and practice trends, support elderly and chronic patients, and have wearable and long-lasting battery features that are easy to use. The focus of healthcare monitoring and alert systems should be on the parameters or factors that cause health issues due to the lack of reliable or cost-effective alert systems. This raises important research questions that need to be addressed [16].

RQ1: How to remotely monitor the health of a patient?

RQ2: How to inform the doctors or caretakers about the patient's health status?

RQ3: How can identify the effect of factors on health monitoring?

Remotely monitoring of patients for the assistance of patients and generating alerts according to the status of their health and intimate the caretakers or doctors or guardians are necessary for achieving the best goals in remote healthcare monitoring or IoT in healthcare.

To deal with above mentioned research questions there are possible research objectives are

Given below that helps to improve remote monitoring in healthcare sectors.

RO1: By developing an IoT system for remotely monitoring the health of a patient.

RO2: By generating alerts to intimate the doctors or caretakers about patient Health status.

RO3: By measuring major parameters can identify the effect of factors on health monitoring.

Continuous monitoring of patients and generating alerts based on their vital signs can improve remote monitoring systems and technology in healthcare. This can reduce the risk and burden on patients by avoiding unnecessary trips to hospitals during emergencies. It also helps in managing time and resources efficiently [17].

The article discusses the development of a remote healthcare system using easily accessible components to create a blood oxygen saturation detection mechanism, heartbeat recognition, body temperature recognition system, and room temperature and humidity recognition system. This system allows for remote monitoring of patients' health metrics, reducing the need for hospital stays and visits. The data is stored in the cloud, making it more secure than storing it on paper or electronic devices. In cases of emergency, notifications are sent to the doctor. There are certain modules that collect data from sensors and work is done on certain modules for healthcare monitoring—chronic Health Patient Monitoring System Using IoT [18].

The Raspberry Pi a module that takes up the sensor data and uses Wi-Fi gives real-time monitoring of the health parameters for physicians. Home Monitoring and Device Control Using the Internet of Things Controlling human-useable instruments with Esp32 allows industrialized machines to produce consumer goods [19].

In present days, IoT-enabled devices are making the possibility of developing novel solutions to many real-life problems. In particular, COVID-19 peoples, diabetes patients, high blood pressure patients, etc. around the globe has to suffer a lot even with no monitoring of such health issues. Buying instruments as an individual costs very much everyone can not afford it [20].

Continuous observations of remote monitoring of IoT-Based devices are essential for improving health care and its cost. But it is also important to store health monitoring data cloud-based for managing previous health records and real-time record keeping. After data storing it undergoes processing and visualization for making further decisions [21].

A cold storage observation and alerting system that is based on an intelligent, IoT-enabled system [22]. Shortly to give better service to clients and maximize the benefits of such technology for their health. Examples include adding more sensors to devices and using monitoring services [23]. To avoid capability issues in future technologies, only academics are working to continuously improve the veracity and legitimacy of vibrant version tracking and support systems [24]. Another research stressed the necessity of considering the mobility power of medical sensors amongst various types of smart e-health gateways [25]. One study validated the finding that scientific charity asserts IoT provides great amenities [26] Examples of continuity of contact include Wi-Fi, a mobile phone, NFC, GPS, etc. [27].

Methods of systematic and qualified testing should be used. Rotariu and Manta emphasized developing this network for heartbeat [28] etc. It is demonstrated supporting medical emergency services by illustrating how IoT data may be gathered and integrated for compatibility. [29] examined the specifics of the software needed and requirements for the healthcare industry and presented an architecture for healthcare and IoT. He measured things like his temperature, blood oxygen level, respiration, and ECG [30]. After the installation of physical sensors, discern between "health data" in a doctor's analysis and diagnosis. Reducing maintenance costs is the IoT in healthcare's key advantage. IoT is already available as the main stage for monitoring Neurons. IoT-based smart healthcare monitoring systems. Monitoring techniques have been gathered with the help of the sensors to keep a continual flow of materials by the patients who have been referred there for caretakers [31].

Table 1. State Of Art Features and Limitations

Year	Purpose	Features					
		BT	HR	SPO2	AT	AH	ESP32
2023	IoT-Based remote Patient Monitoring	×	×	×	✓	✓	✓
2022	IoT-Based Health Monitoring	✓	✓	✓	×	×	×
2021	Remote monitoring of patient	×	✓	×	×	×	✓
2020	IoT Based Patient Monitoring	✓	×	×	×	×	×
2020	An IoT-based Patient Monitoring	×	✓	×	✓	✓	×
2020	Smart Health Care Monitoring	✓	✓	×	×	✓	×
2020	Remote patient monitoring	✓	×	✓	×	×	×
2020	Progressed IoT Based	✓	✓	×	×	×	×
2019	IoT-Based Smart Monitoring	✓	✓	×	×	×	×
2018	IoT Patient Health Monitoring	✓	✓	×	×	×	×
2018	Advanced IoT-based Monitoring	✓	✓	×	×	×	×
2018	Health Monitoring by Android	✓	×	✓	×	×	×
2018	Health Monitoring using IoT	×	✓	×	×	×	×
2017	Design of E-Health Monitoring	×	✓	×	×	×	×
2017	Health Monitoring Lora WAN	✓	×	×	×	×	×
2017	An IoT based Health Monitoring	✓	✓	×	×	×	×
2016	IoT& Android based Monitoring	✓	×	×	×	×	×
Purposed Study	An IoT- Assisted Patient Monitoring and Alert System	✓	✓	✓	✓	✓	✓

Remarks: BT Stands for Body Temperature, HR Stands for Heart Rate, SPO2 Stands for Oxygen Saturation Level, AH Stands for Air Humidity, and AT Stands for Air Temperature.

By employing a single ECG parameter that can track the patient's health. alert generated through clouding and app [32] remote health system uses the Arduino Uno microcontroller to assess blood pressure, body temperature, and heart rate, to send the data it collects by clouding [33].

A microprocessor instead of a microcontroller on WI-Module in faraway web-based ECG monitoring. In an IoT-based patient monitoring system that uses sensors for identifying, and analyzing, besides observing dual fundamental dynamic factors, the severe respiratory parameter may also be identified. They anticipate health-related matters and treat them, detecting it inside and outside of hospitals [21]. The idea of linked IoT medical services devices and smart IoT devices offers tremendous possibilities for hospitals as well as for people's awareness of their preferences. Other sensors, including humidity sensors, RFID sensors, and biochemical detecting sensors, such as glucometers, body position sensors, respiration sensors [34], and CO2 sensors, are also employed in certain health monitoring systems [35].

The most prevalent and widely used components in global health monitoring systems are microcontrollers. MCUs are excellent for processing raw sensor data quickly [36].

Using Bluetooth, the digital data are sent to a smartphone. The system made use of a Bluetooth module, which has a limited range. We created a mobile health solution for diabetics. It's a system for the home environment. With the use of this gadget, a diabetic patient may keep tabs on their health, exercise, nutrition, insulin dosage, and medical consultations. Nevertheless, there is no clinical validation for the designed technology [37].

The range restriction could be bypassed by using the Wi-Fi or IR modules. There are several available commercial gadgets for personal healthcare monitoring, but they are difficult for biological sensors to self-attach and use. The IoT Telemedicine system is based largely on heart rate monitoring, blood drift tracking, and blood pressure monitoring [38] and is made available on a mobile phone. A key factor in the unexpected and sudden mortality rate associated with the current, stressful lifestyle that people lead. The sensors are attached to the patient's frames. Using the readily available sensors, this PMS shows important physiological indicators such as body temperature, Electrocardiogram, HR, Along with BP. The essential PMS is now supplied with digitalized data from a few microcontrollers. Every sensor is connected to a microcontroller through identification. Each module wirelessly feeds data to the gateway connected to the primary PMS's computer. IoT offers enormous potential to speed up and improve the delivery of healthcare. Decision-makers at all levels of government are using technology-assisted healthcare delivery techniques in response to the unique COVID-19 crisis [39].

A customized medical chair has been created utilizing IoT to solve this problem. This chair keeps track of who sits in it and for how long, as well as the person's posture while seated. Liquid Crystal Display (LCD) warnings are also audibly signaled by alarms when they are present. The data is sent to the web via a Wi-Fi module so that it may be recorded. The technology can monitor a person's sitting time and posture [40]. Using the Smart Belt, researchers devised a method for identifying incorrect postures that could contribute to problems with abdominal weight [41].

One of the most beneficial assets around the globe is the smartphone. A smartphone typically has 14 different types of sensors, and many more will be included in the future [42].

Android-based cellphones were utilized by the majority of the systems under study. Compared to other exclusive operating systems, Android offers simple access to smartphone sensor data, which is necessary for the quick creation of smartphone-based health monitoring systems. More than 2.5 billion Android smartphones are now in use [42], [43].

2. The Materials and Methods

2.1 *Architecture of Proposed PMAS*

Data gathering is the initial stage of data collecting using sensors. Each interval's data is gathered by data processing, and the results are then saved as a dataset. In order to achieve the best results, we employed a decision tree classifier to analyses the data. The system will then generate a projected result for the target user after matching the output or results achieved to the anticipated outcomes for validation. In the above figure 1 patient data is collected through different sensors. Collection of data include the values of Air Temperature & Humidity through DHT11 Sensor used for measuring Room Temperature and Humidity. Body Temperature through LM35 Sensor, Oxygen Saturation level which is termed as SPO2 and Heart Rate through MAX30102 Sensor used for measuring of Heart Rate and Oxygen level.

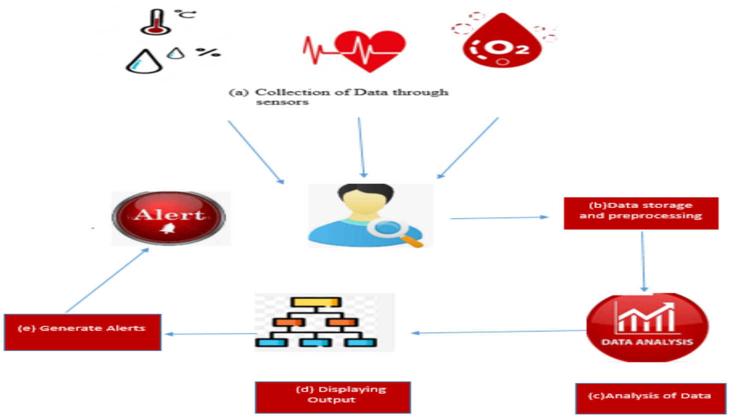

Figure 1. Architecture of Proposed PMAS.

MAX30102 Sensor used for measuring Heart Rate and Oxygen level. After the collection of data, preprocessing and storage of that data is done. After that Analysis of data is done and classification is applied to that data. On the base of that classification output results are displayed and alerts are generated according to those results.

2.2 Used Classifier for IoT-based Approach

The process of classification involves identifying and grouping of objects and concepts into specific categories. In machine learning, pre-categorized education datasets are used to train classifier models that can then classify future datasets into relevant categories. By using input education data, these models can estimate the likelihood that new data will fall into one of the established categories.

Email service providers use categorization to identify and filter spam emails through pattern recognition. Usability of Machine learning techniques [18] such as sentiment analysis and decision tree classifiers are used to classify data points and identify similarities between them. A random forest classifier is an application of decision tree classifiers that averages data to link to the closest tree based on the data scale. Classification and regression are popular supervised machine learning methods that use algorithms to categorize and train information. The confusion matrix is used to evaluate the model's overall performance. Accuracy and recall are used to determine the model's ability to correctly categorize and anticipate high-quality values. Applications of categorization algorithms include drug detection, spam email filtering, cancer detection, and biometric authentication.

2.2.1 Decision Tree Classifier

A decision tree is a supervised learning technique that may be used to classification and regression problems, however it is most typically used to tackle classification problems. It is a tree-structured classifier, where each leaf node represents the classification outcome and inside nodes represent the features of a dataset [44].

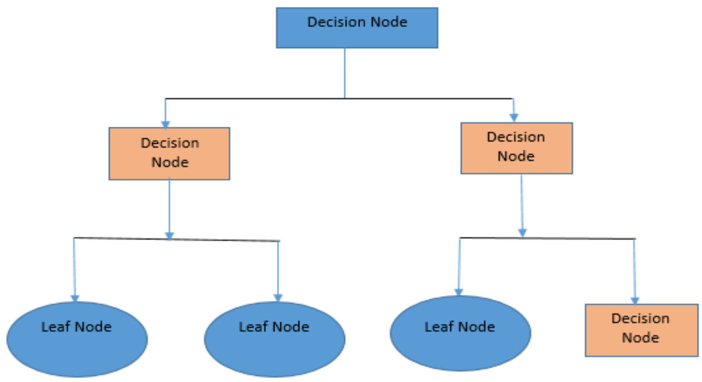

Figure 2. Decision Tree Classifier

A decision tree consists of decision nodes and leaf nodes that use features of a dataset to make decisions and indicate outcomes. It is a graphical representation for finding solutions to problems based on predefined parameters, commonly used for classification problems. Nodes in the network represent dataset characteristics, branches represent the decision-making process, and leaf nodes indicate the classification result.

2.2.2 Logistic Regression Classifier Model

A well-known machine learning algorithm that falls within the category of supervised learning is logistic regression also known as logistic function. It provides binary outcomes limited to 0/1, true/false, or yes/no works as an extension of linear regression model. Mostly, accomplish binary classification tasks by making predictions or observations. It never output probabilities to create the predictions, an algorithm was applied to a labeled dataset. Classification issues are resolved using logistic regression classifier [45].

2.2.3 Random Forest Classifier Model

Random Forest is a machine learning algorithm that falls within category of supervised learning also known as meta estimator that mostly fits on subsets. It uses multiple decision trees on different subsets of data and averages the results for higher accuracy, instead of relying on a single decision tree. It provides single result by combining multiple decision tree classifiers output. The more trees in the forest, the greater the accuracy. It combines and handles both regression and classification problems. It is very flexible and easily adaptable for achieving highest accuracy by combining classification and regression [46].

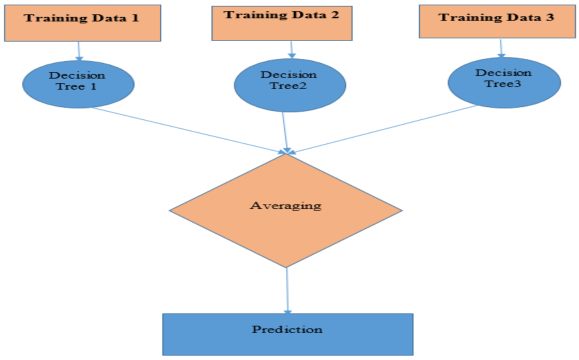

Figure 3. Random Forest Classifier

2.2.4 Support Vector Machine Algorithm

In order to quickly categories new data points in the future, the SVM algorithm aims to identify the best line or target variable that can split n-dimensional space into classes. The name for this ideal decision boundary is a hyper plane. In order to help create the hyper plane, SVM chooses the extreme vectors and points [47].

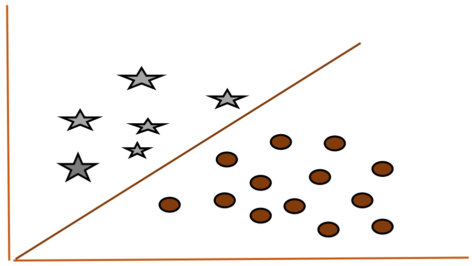

Figure 4. SVM Classifier.

3. Experiments

IoT systems use sensors to measure real-time data, and the ESP32 is a cost-effective and efficient hardware option for connecting sensors and actuators. ESP32 has integrated features such as antenna switches, filters, and power management modules, and can connect with other Wi-Fi and Bluetooth devices. The proposed system consists of multiple modules.

Table 2. Hardware Components

Hardware	Description
Esp32	Microcontroller
LM35	Body Temperature Sensor
DHT11	Air Temperature & Air Humidity
MAX30102	Heart Rate & Oxygen Saturation level

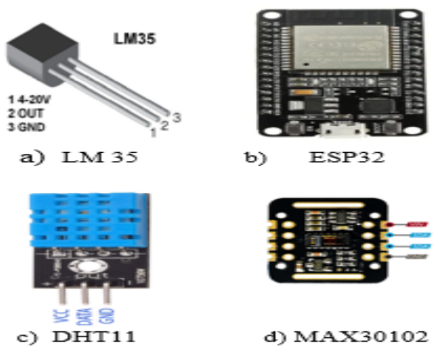

Figure 5. Hardware Components for PMAS

A sensor-based system was created using a microcontroller-based circuit to gather data on SpO2, heart rate, ambient temperature, and humidity, which can be used to monitor a patient's status and condition.

3.1 Measuring Body Temperature

Temperature is a crucial component in patient monitoring and can indicate changes in the patient's condition. Measuring body temperature is important for routine monitoring of symptoms and signs of illness. Temperature is especially important for those who cannot communicate their discomfort, such as infants. An increase in body temperature is the first sign of an illness and can help in the early diagnosis of disease. Normal body temperature ranges between 36.1 and 37.2°C and represents the equilibrium between heat production and loss.

Table 3. Standard Range of body temperature

Temperature	Temperature °F	Status
36.5-37°C	97.7-99.°F	Good
37.5°C	99.5°F	Satisfactory
>37.5	99.5-100.9°F	Alarming

3.2 Measuring Room Temperature

High ambient temperatures cause perspiration, leading to moisture loss from the skin and changes in the body's temperature equilibrium, which can be harmful. Room temperature affects diabetes management, respiratory health, schizophrenia, and dementia symptoms. A safe and appropriate room temperature is crucial for maintaining patient health as it affects the body's metabolism.

Table 4. Standard Range of room temperature

Temperature	Status
16.5 °C - 23.5 °C	Good
23.5 °C-25°C	Satisfactory
<16.5 °C->25 °C	Alarming

3.3 Measuring Room Humidity

Humidity levels in indoor spaces affect how a room feels and can impact health. A comfortable range for relative humidity is between 30 and 60 percent, with levels between 30 and 50 percent being ideal. Low humidity increases the risk of airborne viruses and dry skin. High humidity can lead to the growth of dust mites, mold, fungus, and bacteria, which can trigger allergies and asthma. High humidity can also cause lethargy and reduced energy levels.

Table 5. Standard Range of room humidity

Humidity	Status
30% - 50%	Good
60%	Satisfactory
<30% - >50%	Alarming

3.4 Measuring Oxygenation

Oxygenation refers to the level of oxygen in the blood, which is essential for the proper functioning of the body. Low blood oxygen levels can lead to serious health consequences, and the body carefully regulates oxygen saturation levels to avoid organ damage. Hypoxemia is low blood oxygen levels, cause problems in body tissues as oxygen levels fall.

Table 6. Standard Range of SPO2

SPO2	Status
95% - 100%	Good (Normal)
80%- 100%	Satisfactory
<95% - >100%	Alarming

3.5 Measuring Heart Rate

The heart rate is an important indicator of health, with a normal range of 60 to 100 beats per minute. Lower resting heart rates typically indicate better cardiovascular health. Heart rate monitors are a useful tool for tracking heart activity and improving overall health. The cardiovascular system circulates blood throughout the body to deliver oxygen and nutrients to active muscles.

Table 7. Standard Range of Heart Rate.

SPO2	Status
60 – 100	Good (Normal)
80- 100	Satisfactory
>100	Alarming

Body Temp	Air Temp	ir Humidit	Pulse Rate	Oxygen level	Patient Status
36	28.9	68.6	88	88	Good
36	28.9	68.6	136	92	Good
36	28.9	68.6	166	94	Good
40.1	28.9	68.6	78	87	Alarming
36	28.8	68.5	88	88	Good
40.1	28.8	68.5	166	94	Alarming
36	28.8	68.5	115	90	Good
36	28.8	68.5	93	88	Good
40.1	28.9	68.6	93	88	Alarming
36	28.9	68.6	187	96	Good
36	28.9	68.6	150	93	Good
36	28.9	68.6	100	89	Good
36	28.9	68.5	187	96	Good
36	28.9	68.5	100	89	Good
36	28.9	68.5	125	91	Good
36	28.9	68.5	125	91	Good
36	28.8	68.5	39	83	Good
36	28.8	68.5	0	0	Good
39.79	28.8	68.5	0	0	Satisfactory
40.1	28.8	68.5	166	94	Alarming
36	28.9	68.6	166	94	Good
36	28.9	68.6	88	88	Good
36	28.9	68.6	75	87	Good
36.16	28.9	68.6	100	89	Good
36	28.9	68.5	107	89	Good
40.1	28.9	68.5	115	90	Alarming
36	28.9	68.5	115	90	Good
36	28.9	68.5	100	89	Good
40.1	28.9	68.6	34	83	Alarming
36	28.9	68.6	83	87	Good

Figure 6. Working rules for PMAS

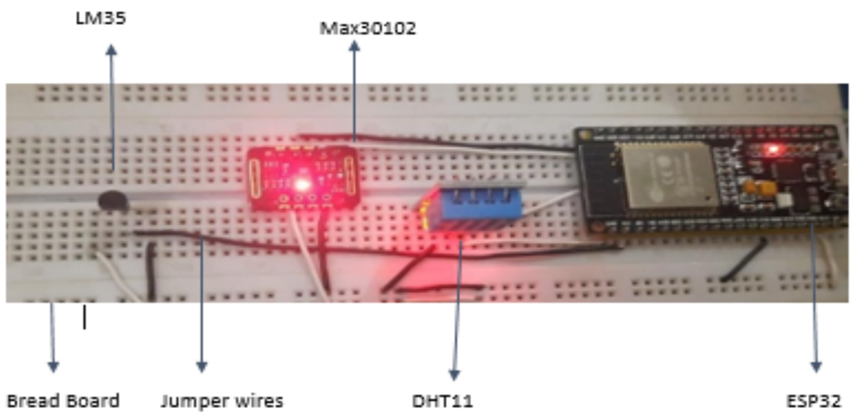

Figure 7. Experimental Setup

3.6 Visualization of Data

The interdisciplinary subject of information and data visualization focuses on the graphic representation of data and information. It works really well for engaging with massive volumes of data or information, like a time series. Above or below of optimized value it considered as alarming. For good or normal it is represented by 0, for satisfactory it represented as 1, while after crossing optimized or standard it is represented by -1.

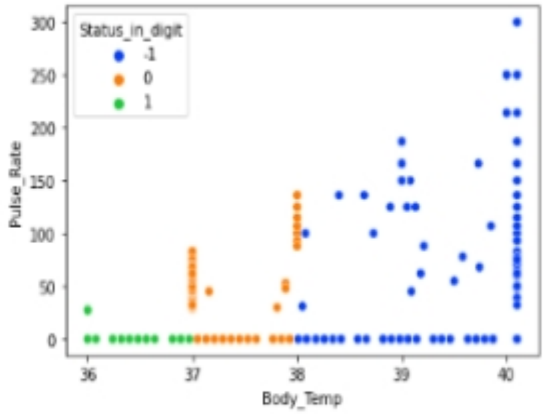

Figure 8. Visualization of Pulse Rate

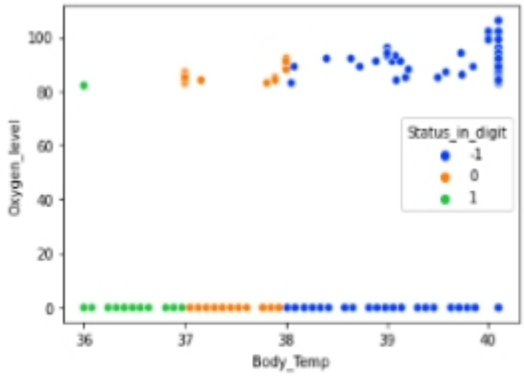

Figure 9. Visualization of Oxygen Level

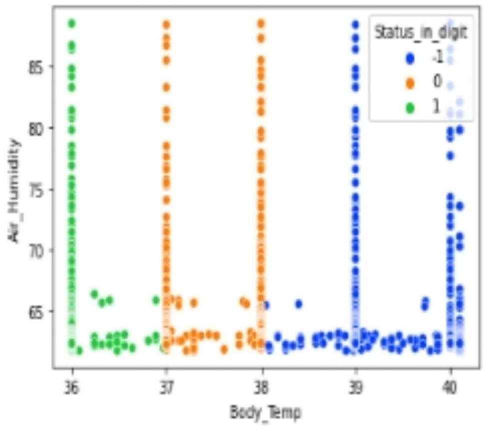

Figure 10. Visualization of Air Humidity

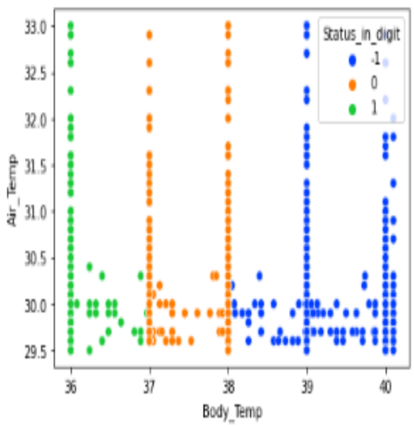

Figure 11. Visualization of Air Temperature

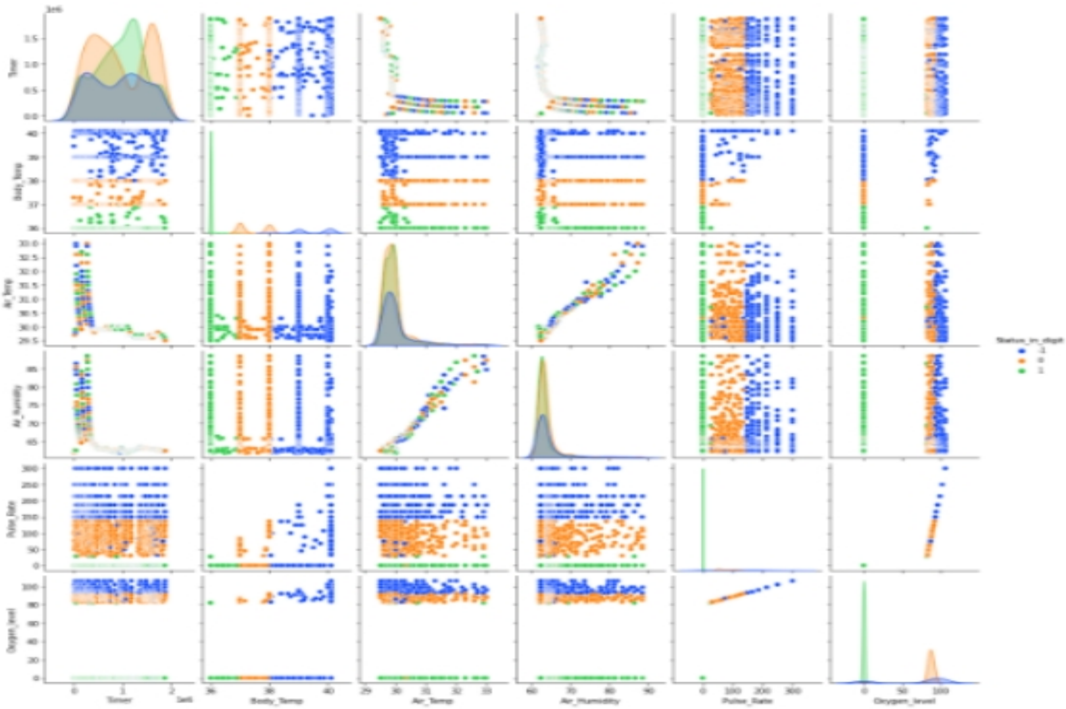

Figure 12. Visualization of different parameters

4. Results

To evaluate the effectiveness of the training classifier, we have employed two statistical measures: Recall, Precision, and Accuracy [48], [49], [50]. By measuring the proportion of true predictions out of all the predictions and plotting it [51]. The proposed study uses these two evaluation measures for all classifiers used in this study and is described in the above section. To assess the decision tree classifier correctness, Equation (1)'s formula was utilized to calculate the suggested system's precision:[48].

$$\text{Precision} = \frac{\text{TP}}{\text{TP+Wp}} \tag{1}$$

Where WP = Incorrectly predicted instances and TP = Correctly predicted instances [49].

$$Recall = \frac{TP}{TP+NP} \tag{2}$$

Where Np = Not Predicted Instances and T = Really Predicted Instances [52].

$$\text{Accuracy} = \frac{\text{TP+TN}}{\text{TP+FP+TN+FN}} \tag{3}$$

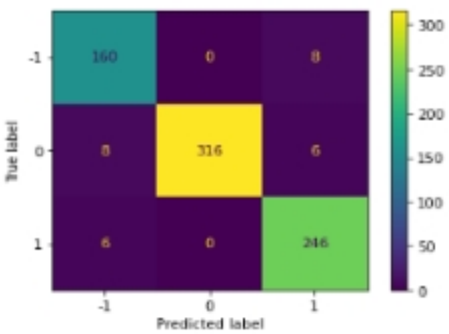

Figure 13. Confusion Matrix of DT classifier

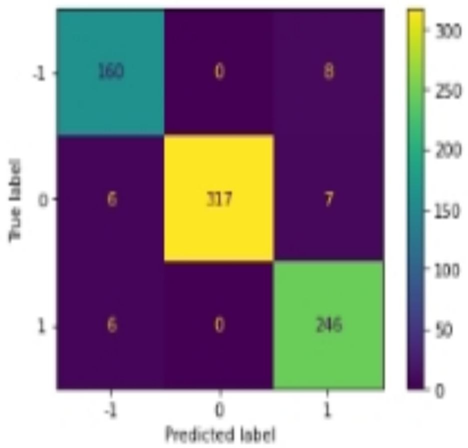

Figure 14. Confusion Matrix of RF classifier

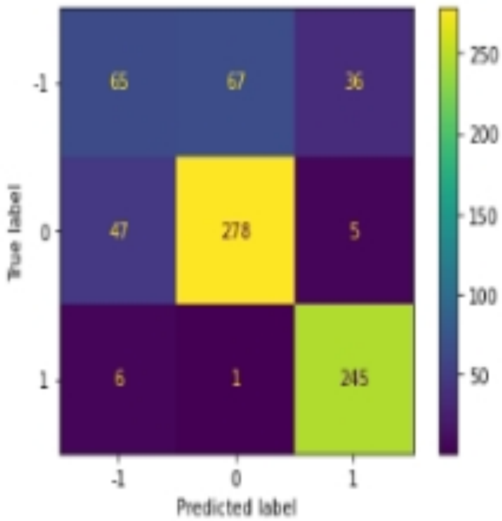

Figure 15. Confusion Matrix of SVM classifier

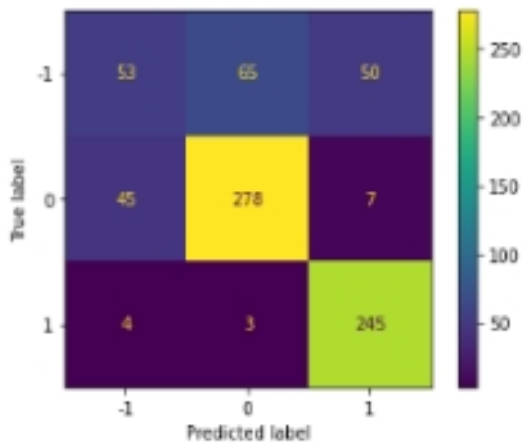

Figure 16. Confusion Matrix of LR classifier

Table 7. Evaluation Measures of different classification models

Classification Model	Precision	Recall	Accuracy
Decision Tree	0.96	0.9598	0.962
Random Forest	0.96	0.9534	0.964
SVM	0.65	0.4876	0.784
Logistic Regression	0.7419	0.4724	0.7613

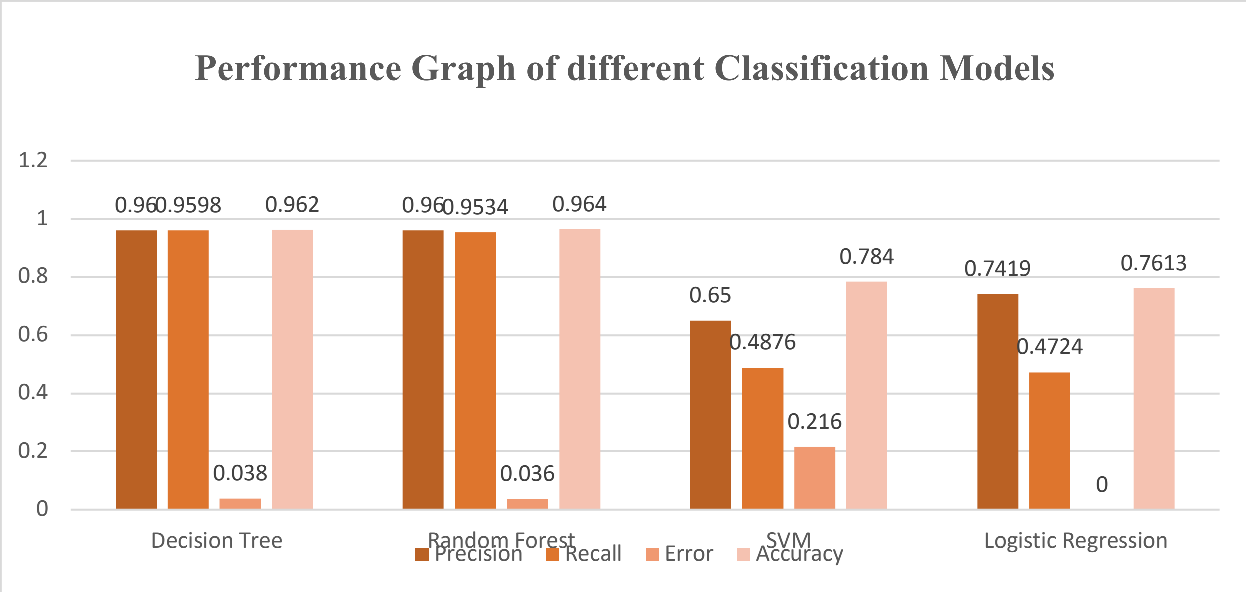

Figure 17. Data Analysis results of different classification models

5. Conclusions

Health care services are crucial component for our society, and automating these services eases the stress on individuals and the measurement process. Patients are more likely to trust this method because of its transparency. Our system may be enhanced much further to improve its performance and more easily customization, for as by using more sophisticated sensors. The doctor's personal computer or mobile device will get health-related data thanks to wireless data transmission through the internet. Hence, it is necessary to visit the hospital frequently, and sending a doctor a message will result in an expedient resolution to the health issue.

IoT sparked technological progression in health industry that is opening up new opportunities for game-changing and life-improving services globally. By highly developed and enhanced service delivery and customization, the IoT has the ability to benefit people, patients, government sectors, and enterprises in both the economic and social spheres. Remote patient health monitoring is made possible, and there are other advantages for hospital administration as well. IoT gadgets are essential to the medical industry. We've shown a few applications here for health surveillance.

ECG, glucose monitoring, bodily activity, air quality, and other metrics are among them. These variables not only have an impact on the health of the patient but also exhibit relationships with other traits. It is essential to pay attention to these elements as well for an effective wound monitoring system. In our recent research, we suggested a sensor-based monitoring system. Our suggested solution is made up of two modules. The first module is an ESP32-based circuit that we utilized to monitor parameters utilizing sensors for body temperature, oxygen saturation levels, heart rate, room temperature, and room humidity, respectively, using LM35, MAX30102, and DHT11.

In the second module, we employed classification-based algorithms to quickly determine the patient's state or condition. Various classification classifier, such as DT classifiers, RF classifiers, SVM, LR classifiers, divide categorized input into three evaluation groups depending on their values, namely good, satisfactory, and frightening. The best classification results are produced by the random forest method, which has an accuracy gain of 96.4%, a precision rate of 96%, and a recall rate of 95%.

6. Future Works

Also, there are a variety of other elements that might be incorporated into the currently proposed system for healthcare monitoring in the future, such as body mobility. The system could get more features to make it more functional, such as links between ambulance services, top physicians and their specializations, hospitals and their unique amenities, etc.

Via the smartphone app, doctors may raise public knowledge of illnesses and associated symptoms. The system is better for patients as a consequence of assessment and analysis's findings, and doctors can now evaluate their patients' health more effectively.

References

1. Almotiri, S.H., M.A. Khan, and M.A. Alghamdi. Mobile health (m-health) system in the context of IoT. in 2016 IEEE 4th international conference on future internet of things and cloud workshops (FiCloudW). 2016. IEEE.
2. Murray, C.J., The global burden of disease study at 30 years. Nature medicine, 2022. 28(10): p. 2019-2026.
3. Hajat, C. and E. Stein, The global burden of multiple chronic conditions: a narrative review. Preventive medicine reports, 2018. 12: p. 284-293.
4. Afreen, H., et al., IoT-based smart surveillance system for high-security areas. Applied Sciences, 2023. 13(15): p. 8936.
5. Ruman, M.R., et al. IoT based emergency health monitoring system. in 2020 International Conference on Industry 4.0 Technology (I4Tech). 2020. IEEE.
6. Singh, R.P., et al., Internet of things (IoT) applications to fight against COVID-19 pandemic. Diabetes & Metabolic Syndrome: Clinical Research & Reviews, 2020. 14(4): p. 521-524.
7. Akkaş, M.A., R. Sokullu, and H.E. Çetin, Healthcare and patient monitoring using IoT. Internet of Things, 2020. 11: p. 100173.
8. Pronovost, P.J., M.D. Cole, and R.M. Hughes, Remote patient monitoring during COVID-19: an unexpected patient safety benefit. Jama, 2022. 327(12): p. 1125-1126.
9. Swaroop, K.N., et al., A health monitoring system for vital signs using IoT. Internet of Things, 2019. 5: p. 116-129.
10. Malasinghe, L.P., N. Ramzan, and K. Dahal, Remote patient monitoring: a comprehensive study. Journal of Ambient Intelligence and Humanized Computing, 2019. 10: p. 57-76.
11. Al-Khafajiy, M., et al., Remote health monitoring of elderly through wearable sensors. Multimedia Tools and Applications, 2019. 78(17): p. 24681-24706.
12. Youssef Ali Amer, A., et al., Vital signs prediction and early warning score calculation based on continuous monitoring of hospitalised patients using wearable technology. Sensors, 2020. 20(22): p. 6593.
13. da Silva, D.B., et al., DeepSigns: A predictive model based on Deep Learning for the early detection of patient health deterioration. Expert Systems with Applications, 2021. 165: p. 113905.
14. Pravallika, K., et al. Sensor based controlling system for monitoring Home automation using IOT. in IOP Conference Series: Materials Science and Engineering. 2020. IOP Publishing.
15. Hayes, C.J., et al., Utilization of remote patient monitoring within the United States health care system: A scoping review. Telemedicine and e-Health, 2023. 29(3): p. 384-394.
16. Ashraf, S., S.P. Khattak, and M.T. Iqbal, Design and Implementation of an Open-Source and Internet-of-Things-Based Health Monitoring System. Journal of Low Power Electronics and Applications, 2023. 13(4): p. 57.
17. Afreen, H. and I.S. Bajwa, An IoT-based real-time intelligent monitoring and notification system of cold storage. IEEE Access, 2021. 9: p. 38236-38253.
18. Pasha, S., ThingSpeak based sensing and monitoring system for IoT with Matlab Analysis. International Journal of New Technology and Research (IJNTR), 2016. 2(6): p. 19-23.
19. Bharathi, A., et al., Internet of things technologies, in Internet of Things in Biomedical Engineering. 2019, Elsevier. p. 291-322.
20. Balakrishnan, S., et al., IoT for health monitoring system based on machine learning algorithm. Wireless Personal Communications, 2022: p. 1-17.
21. Waleed, M., et al., Unlocking insights in iot-based patient monitoring: Methods for encompassing large-data challenges. Sensors, 2023. 23(15): p. 6760.
22. Butpheng, C., K.-H. Yeh, and H. Xiong, Security and privacy in IoT-cloud-based e-health systems—A comprehensive review. Symmetry, 2020. 12(7): p. 1191.
23. Asghar, M., et al., A Genetic Algorithm-Based Support Vector Machine Approach for Intelligent Usability Assessment of m-Learning Applications. Mobile Information Systems, 2022. 2022.

24. Song, Y.-Y. and L. Ying, Decision tree methods: applications for classification and prediction. Shanghai archives of psychiatry, 2015. 27(2): p. 130.

25. Dreiseitl, S. and L. Ohno-Machado, Logistic regression and artificial neural network classification models: a methodology review. Journal of biomedical informatics, 2002. 35(5-6): p. 352-359.

26. Orozco-Arias, S., et al., Measuring performance metrics of machine learning algorithms for detecting and classifying transposable elements. Processes, 2020. 8(6): p. 638.

27. Abba, S. and A.M. Garba. An IoT-based smart framework for a human heartbeat rate monitoring and control system. in Proceedings. 2019. MDPI.

28. Michaud, E.J., Z. Liu, and M. Tegmark, Precision machine learning. Entropy, 2023. 25(1): p. 175.

29. Ani, R., et al. Iot based patient monitoring and diagnostic prediction tool using ensemble classifier. in 2017 International conference on advances in computing, communications and informatics (ICACCI). 2017. IEEE.

30. Singh, P. and A. Jasuja. IoT based low-cost distant patient ECG monitoring system. in 2017 international conference on computing, communication and automation (ICCCA). 2017. IEEE.

31. Gómez, J., B. Oviedo, and E. Zhuma, Patient monitoring system based on internet of things. Procedia Computer Science, 2016. 83: p. 90-97.

32. Hao, Y. and R. Foster, Wireless body sensor networks for health-monitoring applications. Physiological measurement, 2008. 29(11): p. R27.

33. Khamitkar, S.S. and M. Rafi, IoT based System for Heart Rate Monitoring. International Journal of Engineering Research & Technology (IJERT), 2020. 9(07): p. 2278-0181.

34. Fernandez-Salmeron, J., et al., HF RFID tag as humidity sensor: Two different approaches. IEEE Sensors Journal, 2015. 15(10): p. 5726-5733.

35. Marques, G., C.R. Ferreira, and R. Pitarma, Indoor air quality assessment using a CO 2 monitoring system based on internet of things. Journal of medical systems, 2019. 43: p. 1-10.

36. Perumal, B., et al. Real Time Transformer Health Monitoring System Using IoT in R. in 2022 International Conference on Computer Communication and Informatics (ICCCI). 2022. IEEE.

37. Chaari Fourati, L. and S. Said. Remote health monitoring systems based on bluetooth low energy (BLE) communication systems. in The Impact of Digital Technologies on Public Health in Developed and Developing Countries: 18th International Conference, ICOST 2020, Hammamet, Tunisia, June 24–26, 2020, Proceedings 18. 2020. Springer.

38. Ahmed, A., et al., RETRACTED ARTICLE: IoT-based real-time patients vital physiological parameters monitoring system using smart wearable sensors. Neural computing & applications, 2022. 35(7): p. 5595-5595.

39. Narine, L. and C. Meier, Responding in a time of crisis: Assessing extension efforts during COVID-19. Advancements in Agricultural Development, 2020. 1(2): p. 12-23.

40. Karanth, G., et al. IoT based smart posture detector. in Proceedings of the Global AI Congress 2019. 2020. Springer.

41. Tariq, M., et al., Accurate detection of sitting posture activities in a secure IoT based assisted living environment. Future Generation Computer Systems, 2019. 92: p. 745-757.

42. Majumder, S. and M.J. Deen, Smartphone sensors for health monitoring and diagnosis. Sensors, 2019. 19(9): p. 2164.

43. Bari, M.A., S. Ahamad, and M.R. Ali, Smartphone Security and Protection Practices. International Journal of Engineering and Applied Computer Science (IJEACS), 2021. 3(01).

44. James, G., et al., Tree-based methods, in An Introduction to Statistical Learning: with Applications in Python. 2023, Springer. p. 331-366.

45. Misra, P.K., et al., Heart disease prediction using logistic regression and random forest classifier, in Data-Centric AI Solutions and Emerging Technologies in the Healthcare Ecosystem. 2023, CRC Press. p. 83-112.

46. Borup, D., et al., Targeting predictors in random forest regression. International Journal of Forecasting, 2023. 39(2): p. 841-868.

47. Kurani, A., et al., A comprehensive comparative study of artificial neural network (ANN) and support vector machines (SVM) on stock forecasting. Annals of Data Science, 2023. 10(1): p. 183-208.
48. Shang, H., et al. Precision/Recall on Imbalanced Test Data. in International Conference on Artificial Intelligence and Statistics. 2023. PMLR.
49. Yang, X., et al., An automatic classifier for monitoring applied behaviors of cage-free laying hens with deep learning. Engineering Applications of Artificial Intelligence, 2023. 123: p. 106377.
50. Bryll, R., R. Gutierrez-Osuna, and F. Quek, Attribute bagging: improving accuracy of classifier ensembles by using random feature subsets. Pattern recognition, 2003. 36(6): p. 1291-1302.
51. Valero-Carreras, D., J. Alcaraz, and M. Landete, Comparing two SVM models through different metrics based on the confusion matrix. Computers & Operations Research, 2023. 152: p. 106131.
52. Colliard-Granero, A., et al., Deep learning for the automation of particle analysis in catalyst layers for polymer electrolyte fuel cells. Nanoscale, 2022. 14(1): p. 10-18.