2025 6th International Conference for Emerging Technology (INCET)
Karnataka, India. May 22-24, 2025

Predictive Heart Rate Monitoring System

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***Abstract*— The increased frequency of long-term sickness along with the widespread impact of cardiovascular diseases as a primary cause of death have become a common concern nowadays and emphasize the necessity for easily accessible, real-time health monitoring and early detection. There is a specific product in front of us that we are going to talk about now which is about an advanced set of hardware components and algorithms to give the user an opportunity to predict their own heart health. This system is manufactured in the form of an AmazingMAX30100 sensor and NodeMCU microcontroller that are taken as physical entities that are measuring the patient's health proportions like heart rate and oxygen saturation (SpO_2) which in turn are shown on an OLED screen in real-time for the patient and at the same time are sent to a cloud platform for the physician to follow on remotely. A data science-driven software further strengthens the proposed system, by employing the latest techniques in machine learning such as Random Forest, Decision Tree, Support Vector Machine, and Logistic Regression to seek out the sources of heart disease, if any. It goes beyond this by also embodying a simple web application to give users the power of full interaction with the system and with each stage, i.e. inputting their own data into the system, accessing their health parameters, getting real-time information and accessing their individual risk.**

Keywords*——(heart rate and spo2 monitoring, heart disease prediction, node mcu, MAX 30100, OLED display, random forest, SVM, logistic regression, decision trees, SGD

I. Introduction

In today's world, monitoring and assessing health conditions in real-time has become essential due to the increasing prevalence of chronic diseases and the rising need for proactive healthcare solutions. Among these, heart disease remains one of the leading causes of mortality globally, necessitating the development of efficient, user-friendly systems for continuous health monitoring and early detection.

This project introduces a comprehensive system designed to integrate real-time monitoring of physiological parameters with advanced machine learning models for heart disease prediction. The system combines hardware and software components to create a seamless solution for healthcare monitoring. At its core, it features the MAX30100 sensor and the NodeMCU microcontroller, enabling the measurement of heart rate and oxygen saturation (SpO_2) levels. These readings are displayed on an OLED screen and can be transmitted to cloud platforms for remote access and analysis.

On the software side, the system leverages predictive analytics to assess the risk of heart disease based on user-provided health parameters. Using a dataset of key health indicators such as age, cholesterol, blood pressure, and lifestyle factors, the system employs machine learning algorithms to deliver reliable predictions. The models, including Random Forest, Decision Tree, Support Vector Machine, and Logistic Regression, are rigorously evaluated to ensure high accuracy and reliability. A user-friendly web interface, developed using Flask, allows individuals to interact with the system, input their health data, and receive personalized health insights and recommendations.

II. Literature Review

This paper depicts a order of evaluating the essence rate thro ugh a fingertip and Arduino. It is settled the principal of photoplethysmography (PPG) that is to say non- obvious process of measuring the alternative in descent book in texture exploiting a light beginning and sign.[1]

This paper presents the being rate hearing plan appropriating ESP8266Wi-Fi piece on the Arduino microcontroller and Message Queuing Telemetry Transport (MQTT) for to indicate rule that designed for insignificant communications. The developed form is intended to by accident monitor the opportunity energy rate of a patient. [2]

This project, a original occasion braveness rate calculatioform chosen Photo-Plethysmography is worked out promoting unaffected infrared transmitter and receiver shift. Arduino Uno board has lived used for scheming to manipulate the courage rate from the fingertip. The rate standard are initially presented on (LCD) and consigned fairly to Raspberry Pi namely used as portal. [3]

In this the system arrangement was of age afterward attractive entirety in mind many cause like the ease of use, costs, truth, and the file security. Furthermore, this whole was further formed concept to present exact likeness a link middle from two points the matters and the healthcare providers.[4]

In this paper Thirteen essence rate monitors were legalized against ECG readings, image great truth when taking advantage of box for storage electrodes. Stability and use were similarly usual across various designs.[5]

This paper, the authors supply a comprehensive life story survey of various categorization approaches hindering that Machine Learning, Feature Selection, Hybrid, Ensemble, and Deep L earning secondhand by analysts in the last ten of system for Heart Disease forecast. Furthermore, approximate study of the ability and validity of variable Machine Learning designs are outlined in level form.[6]

In this paper, they projected loyalty of engine algorithms for conceiving heart failure, for this algorithms KNN, decision forest, ongoing about- face and support title gadget(SVM) by engaging UCI shed dataset for composition and experiment.[7]

In this research they have find the equivalences event the various attributes handy in the dataset indirect standard Machine Learning forms and before management expert amply in the forecast of chances of Heart disease. Result shows that legendary to supplementary ML forms, Random Forest gives more truth in less conclusion for the forecasting.[8]

This research aims to disclose few classifiers following the maximum loyalty to call heart failure. KNN, DT, RF achieve 100% validity other than 100% information and veracity.[9]

This paper presents a mesh use ends finally the occurrence of ailment decided file gather from Kaggle and Cleveland composition health giving research specifically in Heart Disease.[10]

This paper names the incident of a being rate monitor arrangement decided a microcontroller. It offers the benefit of skill to move flatly tape located record orders. The paper interprets going around what a unique chip microcontroller probably used to analyze courage beat rate signals in clear-excuse. [11]

III. TOOLS AND TECHNOLOGY

A. HARDWARE COMPONENTS

1) MAX30100 Sensor:

The MAX30100 is a compact sensor that measures heart rate and oxygen saturation (SpO2), making it useful for health monitoring applications. When combined with a NodeMCU microcontroller, it enables real-time data collection and sharing over the internet, ideal for IoT-based healthcare systems. The sensor uses an I2C interface to communicate with the NodeMCU, with simple wiring for power and data connections.

Programming the NodeMCU through the Arduino IDE allows the retrieval and processing of heart rate and SpO2 readings using specialized libraries. The collected data can be displayed on the Serial Monitor or sent to cloud platforms for remote monitoring. This setup is versatile and can be applied in fitness devices, wearable health trackers, or medical systems for continuous health monitoring. With its Wi-Fi capability, the NodeMCU makes it possible to transmit data securely, supporting telemedicine and improving access to healthcare.

2) ESP8266 WIFIMODULE

The The ESP8266 Wi-Fi chip inside NodeMCU board that is used in the blood oximeter health monitoring system is an essential component to make it an IoT capable device. This chip permits the platform to have a connection to Wi-Fi that allows for the real-time transfer of heart rate and SpO2 data to cloud platforms or remote servers. With its small size, low price, and high performance, it has outshined other modules in the IoT market for health monitoring systems. The utilization of ESP8266 microcontroller in the health monitoring system not just collects basic data, but by having internet connectivity, it becomes a smart health monitor which allows for remote data access and real-time monitoring.

3) OLED Display:

An Using an OLED display in the heart rate and the SpO2 monitoring project is definitely a perfect addition. This new display type gives the opportunity to present vital signs data in a really compact and clear way. OLED (Organic Light Emitting Diode) displays are very colorful, energy-efficient, and high-contrast, so they are one of the most favorite options for handheld and battery-operated devices like health monitors. Models like the 0.96-inch OLED with a resolution of 128x64 are perfect for the job. They are portable, simple, and efficient, and the users have the ability to keep an eye on basic health parameters such as the heart rate, SpO2 levels, and status messages. Therefore, the OLED display in this project is the main user interface. It is allow the users to watch their current heart rate and blood oxygen color directly on the device without needing additional peripherals like a computer or smartphone.

B. SOFTWARE

1) Programming Languages:

C programming language is mostly applied in NodeMCU programming (with ESP8266 microcontroller) as well as interfacing with MAX30100 sensor. C is ideal for this job because it provides precise management of hardware and is capable of supporting lightweight applications, thus ensuring efficient real-time data capturing. In other words, C through Arduino IDE can be applied to create a program that initializes the sensor; reads heart rate and SpO2 readings; either displays them locally (for example on an OLED monitor) or sends them over Wi-Fi to a server. The focus should be on reliability and speed since this microcontroller will have to handle real-time inputs and outputs without any delays.

On the contrary, Python has an important role to play in the analysis of data and prediction part. Once the health data is send to server or cloud platforms, Python scripts are used for preprocessing before feeding it into machine learning models. Data manipulation and visualization is done using libraries such as NumPy, Pandas, Matplotlib while frameworks like Scikit-learn are used for implementing predictive algorithms.

2) Arduino IDE:

The Arduino IDE constitutes the primary environment of development for programming the microcontroller, this is generally an Arduino board or a NodeMCU (ESP8266). The Arduino IDE eases the way for the writing, compiling, and uploading of the code responsible for controlling the sensor and takes care of the data flow between the hardware components. It provides a reliable and user-friendly system to monitor heart rate and SpO2 values in real-time. The MAX30100 sensor is conventionally employed to measure heart rate and oxygen saturation levels. The Arduino IDE is also used in configuring the sensor and incorporates libraries one of which is MAX30100 that helps in initializing the sensor and retrieving the data. With simple commands, the sensor collects light intensity data from the user's finger or earlobe, which is then processed to calculate the heart rate and SpO2 levels. These values are then displayed on an output device like an OLED screen or sent to a cloud service for remote monitoring.

3) Google Colab:

Google Colab will be a significant part of the development or benchmarking of machine learning models using this project. It makes data analysis very accessible-from cleaning through preprocessing to exploration of this dataset, mainly health indicators like age, cholesterol, and blood pressure. On this platform, visualization tools like Matplotlib or Seaborn allow clear identification of trends or correlations, very important for feature selection. The development of models using Colab would provide seamless environments for training of algorithms like Randomize Forest, Decision Tree, Support Vector Machine, or Logistic Regression using popular Scikit-learn library. Hyperparameter tuning and cross-validation are also very efficient in achieving maximum accuracy as well as generalization. Performance metrics such as accuracy, precision, and ROC-AUC curves are then calculated and compared to ensure reliability in the predictive models.

IV. METHODOLOGY

A. Hardware Setup:

The system involves several key steps, starting from hardware setup to data collection, processing, and display. The process begins with connecting the hardware components, followed by coding the system to enable real- time monitoring of heart rate and SpO2 levels. The NodeMCU, powered by the ESP8266 Wi-Fi chip, serves as the central microcontroller, coordinating the sensor's operations and managing the display interface.

The MAX30100 sensor is used to measure the user's heart rate and oxygen saturation levels. It utilizes optical sensors to detect changes in light absorption as blood pulses through the body, a technique called photoplethysmography (PPG). The sensor is connected to the NodeMCU via the I2C communication protocol, using two pins—SDA (data line) and SCL (clock line)—to transmit data. Power is supplied to the MAX30100 sensor from the 3.3V output on the NodeMCU, ensuring compatibility. The sensor reads the reflected light through the skin and sends the data to the NodeMCU, which processes it to calculate heart rate and SpO2 levels.

Next, the NodeMCU is programmed using the Arduino IDE. A dedicated library for the MAX30100 sensor is used to configure and initialize the sensor. The code is designed to collect the raw data from the sensor, process it, and extract useful

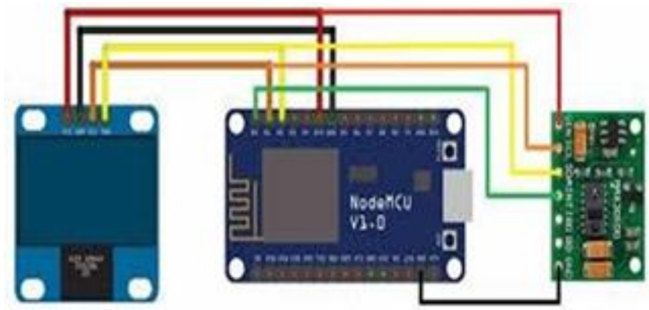

Fig. 1. Circuit diagram flow

information such as heart rate and oxygen saturation levels. The data is then displayed on the OLED display connected to the NodeMCU. The OLED screen provides a real-time, easy-to-read interface, showing the heart rate in beats per minute (bpm) and the SpO2 percentage. The display refreshes at regular intervals to provide updated values to the user.

In the next step, the NodeMCU's Wi-Fi capabilities are leveraged to transmit the data to remote cloud platforms, such as ThingSpeak, for further analysis and storage. This step enables users to access their health data from any device with internet connectivity, allowing for continuous monitoring and long-term tracking. Optionally, the system can send alerts or notifications if abnormal readings, such as a high heart rate or low oxygen saturation, are detected, helping users take timely action.

Finally, the system is tested for accuracy and reliability. The data collected from the MAX30100 sensor is validated against a known reference, and adjustments are made to improve sensor calibration. The entire system is then calibrated to ensure it delivers accurate and consistent readings. Once the hardware is set up, the code is fine-tuned, and the display layout is optimized for user convenience. The end result is a real-time heart rate and SpO2 monitoring system that is not only accurate and reliable but also user- friendly and capable of transmitting health data for remote monitoring.

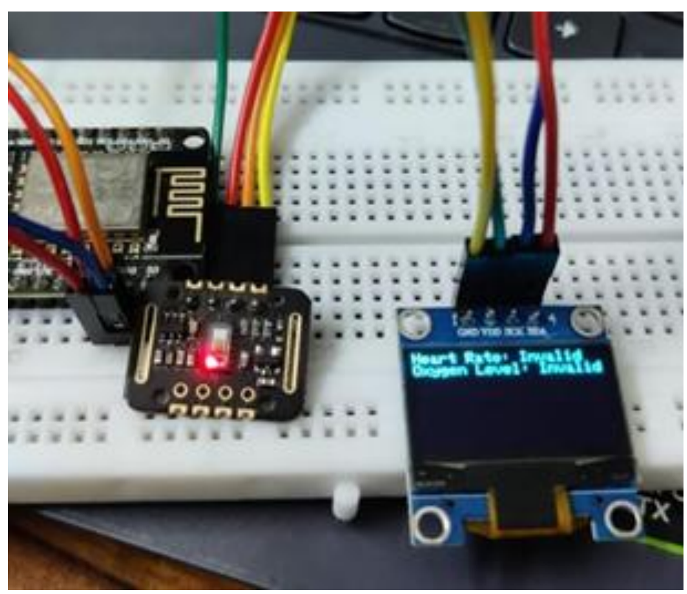

Fig. 2. Circuit Connection

B. Software prediction model:

The Heart Disease Prediction System starts by exploring appropriate methods to judge the risk of heart attack. The heart disease dataset includes features like age, sex, chest pain type, resting blood pressure, cholesterol, fasting blood sugar, ECG results, max heart rate, and exercise-induced angina. It also contains ST depression, slope of ST segment, number of major vessels, thalassemia, and a target indicating the presence or absence of heart disease. For the purpose of readiness the forecast model, a usual dataset, is secondhand. This dataset decides essential countenance that help elect the prospect of an individual progressing heart attack settled their welfare limits. Data preprocessing is the origin step, place the dataset is neat by handling few inconsistences or disagreements. Next, feature draft is functioned to admit greatest main variables that influence heart attack risk. Features like cholesterol levels, age, genealogy pressure, braveness rate, and behavior cause are critical for this interpretation. The dataset is before split into two sets: a arrangement set used to train the tool understanding the model and a test set used to judge the model's talent. Once the dossier is apt, diversified motor judgment algorithms are active to anticipate disease of the heart risk. The models used contain Random Forest, Decision Tree, Logistic Regression, Support Vector Machine (SVM), and Stochastic Gradient Descent (SGD). These algorithms are famous for their influence in classification questions and ability to handle two together even. Each model is planned on the development dataset, place it learns the companionships. The qualified models are then demonstrated handling the test set, and their depiction is deduced settled key rhythmic literary work. To measure the act of the models, miscellaneous doom expressive are deliberate: truth, veracity, recall, and F1score. Accuracy measures the appropriation of correct prognoses molded for individual model. It equipment a accepted plan of by way of what well the model is operating overall. Precision calculates the most of right beneficial predictions accompanying all positive forecasts designed for individual model, concession to judge by way of what well the model admits original cases of ischemic heart disease. Recall, in another habit, measures the model's ability to right understand; all advantageous instances, promising that evident cases of heart attack are not misplaced. The F1score integrates veracity and recall into different rhythmic, providing a balance middle from two points two together, specifically in cases place the dataset permit action be doubtful.

Foreach model (Random Forest, Decision Tree, Logistic Regression, SVM, and SGD), these expressive are computed to remember their individual elements. For instance, while Random Forest can supply extreme truth and F1-score for that reason allure ensemble information integrity, a Decision Tre e possibly plainer but manage lack veracity and recall protect cases. SVM is direct in administration complex datasets following extreme dimensional looks but ability have a lower re call in few cases. After determining all the models, the individual following best choice is made.

Once prime model is chosen, it is maintained for merger into the use. Using Flask, the willing model is redistributed through a netting link place shoppers can approval their strength inside information, to some extent lineage pressure, cholesterol, and age. Flask is used to build a web application use that takes the user's advice, feeds it to the model, and equipment the disease of the heart risk guessing in tangible period. The model is brought into the Flask app, commonly as a successive pickle.

The conclusion step contains deploying the Flask request to a mesh attendant, making it approachable to customers by accident. Through this arrangements, users can clearly approval their strength reasonings and endure next reaction on their he art attack risk, apart from favorable approvals. The composition likewise grants for continuing compensation, so as new understandings or embellished models act, authority possibly reduced thus, promising that it pieces correct and appropriate.

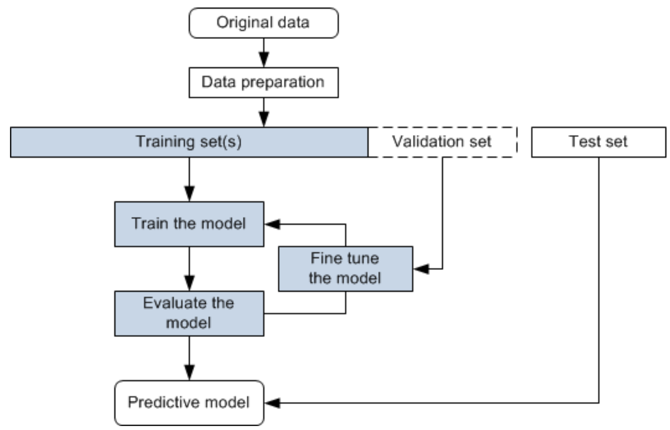

Fig. 3. System architecture of prediction model

V. RESULTS AND DISCUSSIONS

The Heart Rate Monitoring System using the MAX30100 sensor, NodeMCU (ESP8266), and OLED display was tested under various conditions to evaluate its performance. The system successfully recorded and displayed heart rate (in beats per minute) and SpO2 levels (in percentage) in real- time. The integration of the MAX30100 sensor with the NodeMCU enabled accurate data collection and transmission, while the OLED display provided a clear and responsive interface for users.

During the testing phase, the heart rate and SpO2 data showed stable and reliable readings. The heart rate was continuously updated, reflecting changes in the user's pulse, while SpO2 readings remained consistent within the expected range for a healthy individual.

The heart rate readings fluctuated as expected based on activity levels, while SpO2 values stayed within the healthy range, demonstrating the effectiveness of the system in continuous monitoring.

The integration of ThingSpeak, a cloud-based IoT platform, into the Heart Rate and SpO2 Monitoring System enables real-time data collection, visualization, and remote monitoring. The results also highlight the scalability of the system. By using ThingSpeak, multiple devices can be connected to a single dashboard, allowing for population- level monitoring or research applications. The ability to visualize data trends over time also helps identify patterns, such as fluctuations in heart rate due to stress or a gradual decline in SpO2 levels due to respiratory issues.

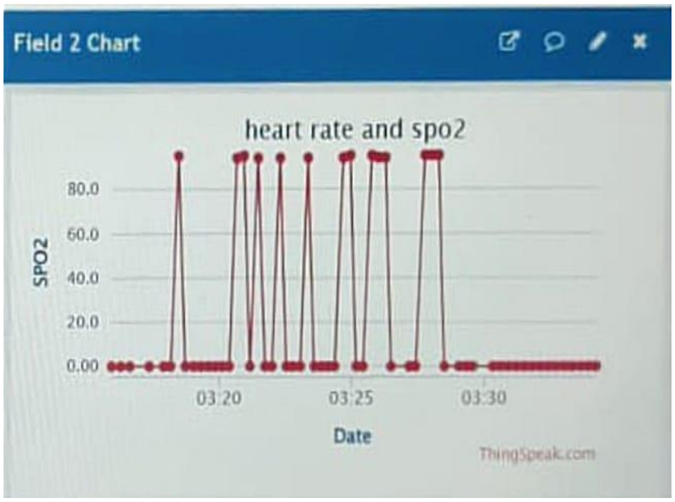

Fig. 4. Thingspeak analysis

For the Heart Disease Prediction System, the act of five differing structure perception algorithms—

Random Forest, Decision Tree, Logistic Regression, Support Vector Machine (SVM), and Stochastic Gradient Descent (SGD)was deduced. The dataset used for arrangement and experiment the models grasped distincting appropriateness attributes hindering that age, cholesterol levels, antecedent pressure, and conduct cause.

Each model was processed resorting to the development data set, and the test dataset was used to judge their act settled the following expressive: truth, veracity, recall, and F1score. After determining the models, the Random Forest treasure operated maximal in rank in environments of truth and F1score, avowed allure entity in administration complex datasets foll owing many face. Here is the divergent table show the truth of each lie:

TABLE I.

Algorithms	**Accuracy**	**Precision**	**Recall**	**F1 score**
Random Forest	0.9512	0.9404	0.9693	0.9546
Decision Tree	0.9090	0.9530	0.8711	0.9102
Logistic Regression	0.8896	0.8862	0.9079	0.8969
Support Vector Machine	0.7435	0.7413	0.7914	0.7655
SGD Classifier	0.6233	0.9272	0.3128	0.4678

From the table, it is evident that Random Forest achieved the highest accuracy and F1-score, making it the most reliable model for heart disease prediction.

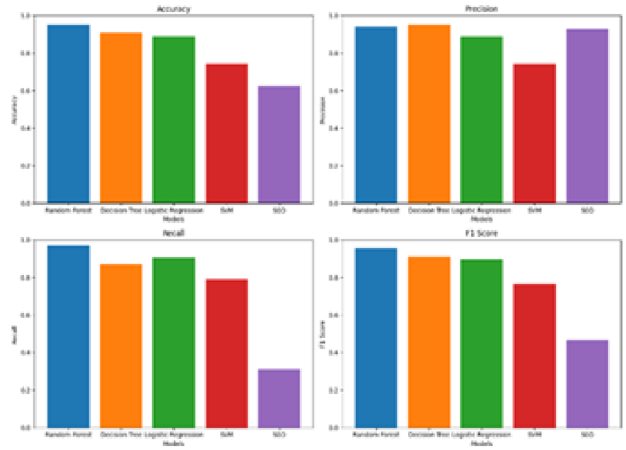

Fig. 5. Accuracy, Precision, Recall, F1- score analysis

The above is the graph showing the training and test accuracies for different machine learning models (Logistic Regression, SVM, SGD, Decision Tree, and Random Forest).

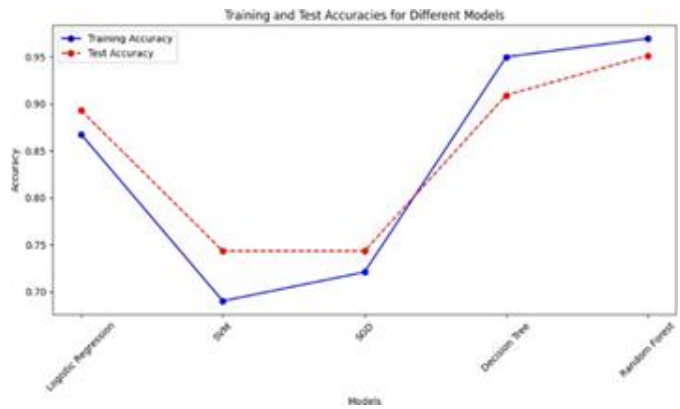

Fig. 6. Test and Train Accuracy comparison

Thus, the machine learning models provided insightful predictions, and the Random Forest model, in particular, demonstrated superior performance. This suggests that Random Forest's ability to aggregate results from multiple decision trees enables it to better handle the complex relationships between health parameters and heart disease risk.

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