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IoT and Machine Learning Non-Invasive Blood Pressure Monitoring System with Early Prediction of Diseases

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ABSTRACT

The project aims to develop a non-invasive, real-time blood pressure monitoring system using the MAX32664 module, IoT, and machine learning. Traditional BP monitoring can be uncomfortable and costly, so this system offers a convenient alternative by continuously collecting patient vitals through wearable sensors. An ML model analyzes real-time and historical data to predict blood pressure accurately and detect early signs of heart disease or hypertension. By enabling early intervention, this technology can reduce healthcare costs and improve patient outcomes, making cardiovascular health monitoring more accessible and efficient.

Keywords: Non-invasive blood pressure monitoring, Machine learning (ML), Internet of Things (IoT), MAX32664 sensor module, Photoplethysmography (PPG), Electrocardiography (ECG), Real-time health monitoring, Early disease prediction, Cardiovascular health, Wearable technology.

INTRODUCTION

Monitoring blood pressure and cardiovascular health is crucial, yet conventional techniques can be uncomfortable and not ideal for long-term application. This initiative presents an innovative, non-invasive solution that utilizes IoT technology and machine learning to track blood pressure and identify potential health complications in real-time.
The essential component of this system is the MAX32664 sensor, which precisely measures oxygen levels, heart rate, and blood pressure. The information gathered is transmitted wirelessly through an ESP8266 module to the ThingsBoard cloud, facilitating uninterrupted real-time tracking. Moreover, the data is safely stored in Google Sheets, making it readily available for additional examination.To enhance precision and extract significant health insights, machine learning algorithms process the data within Google Colab. These consist of an autoencoder for spotting irregularities, XGBoost for forecasting, and a rule chain algorithm to discern trends and possible dangers. In combination, these resources offer timely alerts and critical insights, empowering users to adopt proactive measures for improved heart health and the prevention of illnesses.

LITERATURE SURVEY

Over the years, advancements in wearable technology and machine learning has revolutionized non-invasive cardiovascular monitoring. Early research focused on improving the accuracy and reliability of wearable sensors, such as reducing motion artifacts in PPG signals (Sun et al., 2019) and analyzing blood pressure waveforms for early cardiac issue detection (Abreu et al., 2020). Studies also highlighted the impact of medication timing on blood pressure control (Hermida et al., 2021). Charlton et al. (2022) emphasized the potential of PPG sensors for real- time tracking, while Byfield et al. investigated pulse wave velocity as a blood pressure estimation method. In 2024, AI- based approaches gained momentum—autoencoders and RNNs were applied for anomaly detection (Singh et al., Zhao et al.), while XGBoost and transformer models were used to predict hypertension risks and cardiac irregularities (Miller et al., Li et al.). Wearable technologies and artificial intelligence (AI) can improve early disease identification and real-time health monitoring.

OBJECTIVES

1. Create an IoT-based, non-invasive blood pressure monitoring system.
2. Make real-time data storage and transfer possible.
3. For precise health analysis, use machine learning models.
4. Find irregularities and issue warnings in advance.

5. Make it easier to utilize for both clinical and personal purposes.

LAYOUT OF THE PROJECT

Listing the components to be used in the circuit. Drawing a block diagram of the circuit to be used. Stating the methodology and processes to be followed. Writing the detailed processes and working on them. Obtaining the results and trying to make more improvements. Taking note of the improvements in the subject and scope for future work.

INTEGRANT

A. *Hardware Requirements*

1.1 ESP8266 Wi-Fi Module

1.2 MAX32664 Sensor

1.1 *ESP8266*

The ESP8266, a tiny but potent microcontroller with integrated Wi-Fi, is essential to our idea since it makes wireless data transfer seamless. Vital indicators, including blood pressure (BP), heart rate (HR), and oxygen saturation (SpO_2) may be tracked in real-time with this device, and the data is sent straight to ThingsBoard for remote monitoring.

By serving as a link between the sensor module and the cloud, it guarantees dependable data transfer, increasing the effectiveness of health monitoring. The ESP8266 is ideal for Internet of Things-based healthcare solutions because of its rapid information processing speed and reliable connectivity.

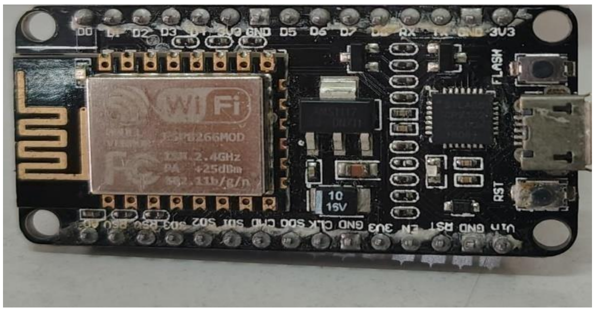

Fig 1.1: ESP8266

One of its greatest features is its low power consumption, which makes it perfect for continuous health monitoring without rapidly depleting the battery. For portable and wearable medical equipment that must operate for extended periods, this is particularly crucial. Its internet connectivity allows consumers and medical professionals to receive real-time health insights at any time and from any location. By incorporating the ESP8266 into our system, we're improving the dependability and accessibility of health data, enabling individuals to stay informed and take proactive measures to improve their health.

1.2 ***MAX32664 Sensor*****:**

The MAX32664 is an advanced biometric sensor designed for precise and non-invasive health monitoring. It uses advanced methods like pulse transit time (PTT) and photoplethysmography (PPG) to assess vital health factors like heart rate, blood pressure, and oxygen saturation (SpO_2). One of its standout features is its ability to filter out noise and motion artifacts, ensuring accurate readings even when the user is in motion. This makes it an excellent choice for wearable medical devices, where consistent and reliable monitoring is crucial.

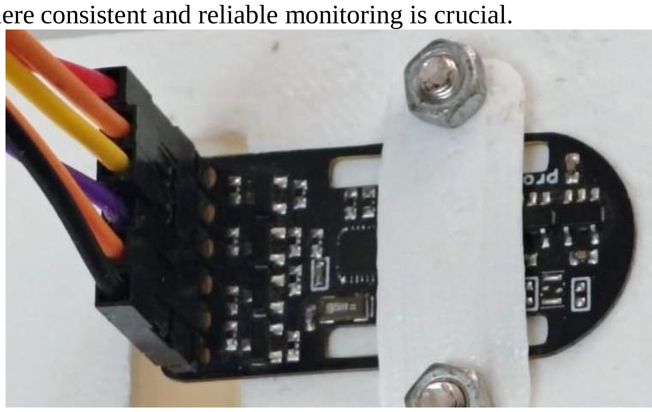

Fig 1.2 MAX32664 sensor

In addition to being accurate, the MAX32664 is small and energy-efficient, which makes it ideal for portable medical applications. It enables real-time health tracking by swiftly processing health data and sending it to the ESP8266 for a seamless cloud connection. Through ongoing monitoring, users may keep up to date on their health, identify possible problems early, and take the appropriate safety measures. This sensor gives people the confidence to take control of their health by making health insights conveniently available

B. Software Requirements

The project combines IoT and machine learning to provide non- invasive real-time health monitoring by employing biosensors to assess heart rate, skin temperature, and blood pressure. Microcontroller programming is done by the Arduino IDE, and sensor data is transmitted over ESP8266 Wi-Fi. Google Colab uses scikit-learn for anomaly detection and TensorFlow to build machine learning models, while ThingsBoard allows for remote visualization and monitoring. Preprocessing methods for data, such as outlier detection and normalization, increase accuracy. Through the integration of cloud computing, artificial intelligence, and the Internet of Things, the system improves healthcare monitoring, gives doctors fast notifications, and facilitates proactive health management and early disease identification.

ACCOMPLISHMENT

To provide real-time tracking, early threat identification, and seamless data transmission, the health monitoring system incorporates IoT and machine learning technology. The MAX32664 biometric sensor, which is the main component of this system, measures blood pressure (BP), oxygen saturation (SpO_2), and heart rate, among other critical health indicators. The sensor employs Pulse Transit Time (PTT) and Photoplethysmography (PPG) to ensure accurate readings while minimizing movement- related errors. As a result, wearable health devices can make extensive use of it, allowing users to conveniently monitor their vital signs throughout the day.

To allow wireless connectivity, the NodeMCU ESP8266 microcontroller collects health data from the sensor and transmits it to ThingSpeak Cloud. By securely storing the data and offering real-time visualization, this cloud-based solution enables users and medical professionals to remotely monitor health trends. By routinely updating and analyzing the incoming data, the platform ensures that any deviations from standard health markers may be detected early on.

A. Block Diagram

This block diagram represents a Smart Health Monitoring A system integrates IoT and Machine Learning to track vital health parameters and provide predictive insights. It begins with a MAX32664 sensor, measuring blood pressure (BP), oxygen saturation (SpO2), and heart rate. The collected data is transmitted wirelessly via NodeMCU ESP8266 using WiFi. Subsequently, the data is sent to Google Colab for analysis and ThingSpeak Cloud for storage and visualization. This ensures that real-time health information is available for further processing.

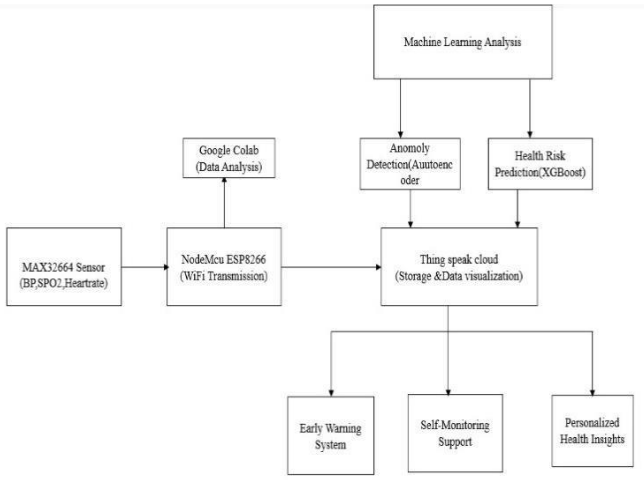

Fig IV: Block Diagram of the Project

To enhance decision-making, the system incorporates Machine Learning Analysis for advanced health insights. It employs Anomaly Detection using Autoencoders to identify unusual patterns and Health Risk Prediction using XGBoost to assess potential risks based on past trends. The processed data is then visualized in ThingSpeak Cloud, enabling features such as an Early Warning System for critical alerts and Self-Monitoring Support for continuous monitoring. tracking, and Personalized Health Insights for customized recommendations. This system provides a proactive approach to health monitoring, helping individuals and healthcare professionals make timely and informed decisions.

B. ***Flow chart***

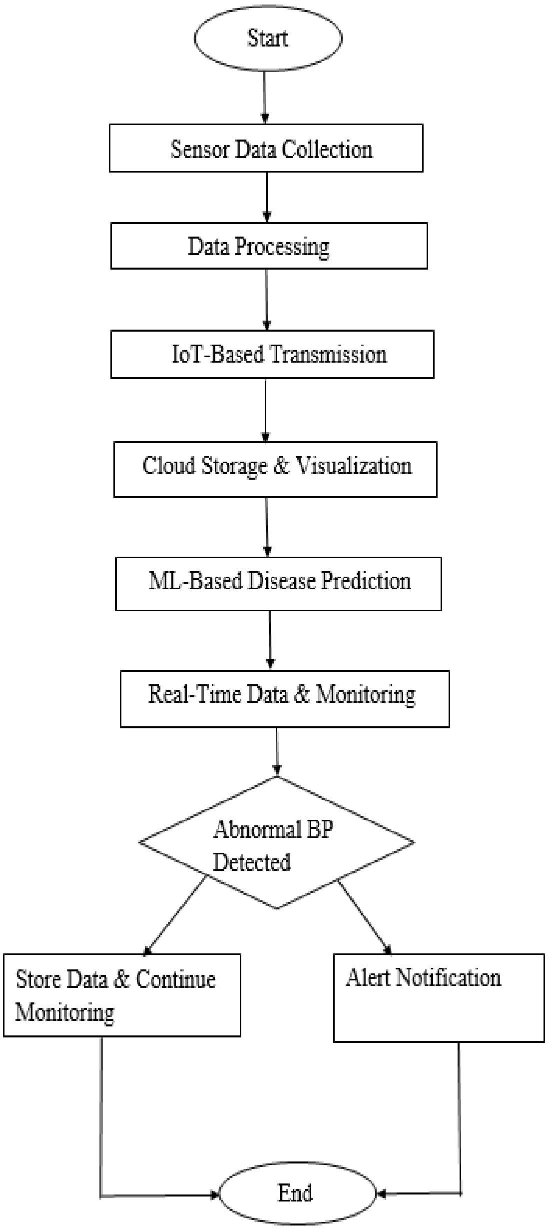

Fig IV: Block Diagram of the Project

For further in-depth research, the system uses Google Colab's machine-learning algorithms to decipher health trends and forecast possible hazards. To find anomalies, an autoencoder model is used to recognize any abrupt or odd changes in vital signs. Furthermore, a prediction model based on XGBoost evaluates long-term health patterns, assisting in the early detection of potential health issues. The precision and dependability of health monitoring are improved by these AI- driven insights, which also provide important assistance with early diagnosis and prevention.

The Arduino IDE is essential to the development and programming of our project. Because of this easy-to-use platform, which allows us to create, upload, and test code for microcontrollers like the ESP8266, our health monitoring system functions flawlessly. Using the Arduino IDE, we configure the MAX32664 sensor to collect blood pressure (BP), heart rate (HR), and oxygen saturation (SpO_2) data in real-time. The IDE provides a simple coding environment that ensures reliable data processing while facilitating the integration of several hardware components. Its open-source nature and active community enable us to diagnose and enhance our system more efficiently. They also assist us in adjusting the sensor data for increased accuracy.

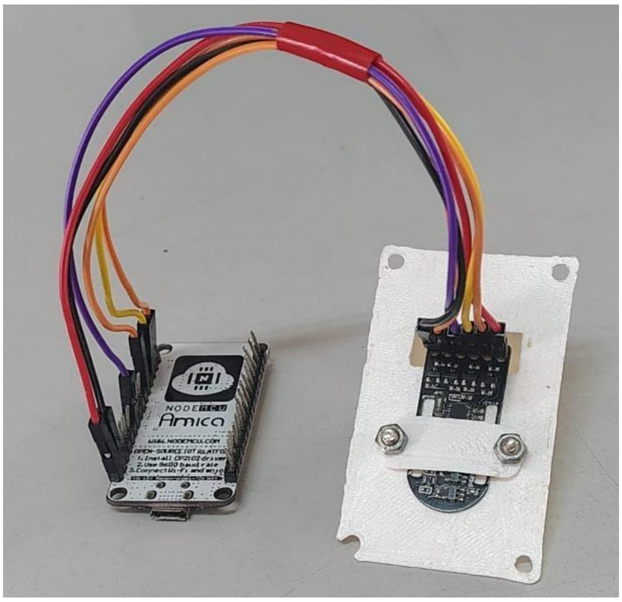

Fig V: Circuit connections

AFFILIATION

1. The MAX32664 sensor, which detects vital indicators including blood pressure (BP), heart rate (HR), and oxygen saturation (SpO_2), provides real-time data to the NodeMCU ESP8266 microprocessor in this health monitoring system. Remote health monitoring is
2. made feasible by the ESP8266's ability to wirelessly transmit this data to ThingSpeak Cloud via its integrated WiFi.
3. ThingSpeak stores and visualizes the data in real time, assisting physicians and patients in identifying any odd health trends early on. The technology alerts users to any abrupt changes in vital signs so that prompt action may be taken. Healthcare is now more proactive and accessible because of this cloud-based strategy.
4. Google Colab's machine learning models examine the data one step further. Whereas an XGBoost model forecasts long-term health hazards, an autoencoder model finds abrupt abnormalities. Over time, the system becomes smarter and more dependable thanks to these AI-powered insights that aid in early diagnosis and prevention.
5. The foundation of the development process is the Arduino IDE, which makes programming the ESP8266 simple. The IDE is always being optimized and improved due to its open-source nature.

RESULT

This health monitoring system is collecting and showing real- time health data quite well thanks to ThingsBoard. Staying on top of health trends is made easy by the dashboard's clear display of vital signs including body temperature, oxygen levels, blood pressure, and heart rate. Users and healthcare professionals may promptly identify any changes with this configuration and take appropriate action. Notably, the heart rate is a little elevated at 135 bpm, which may be the result of physical activity, stress, or an issue that requires attention. At the same time, the blood pressure is within the usual range, which is encouraging, and the oxygen levels are healthy at 98%, which indicates that the body is receiving adequate oxygen, which is always comforting.

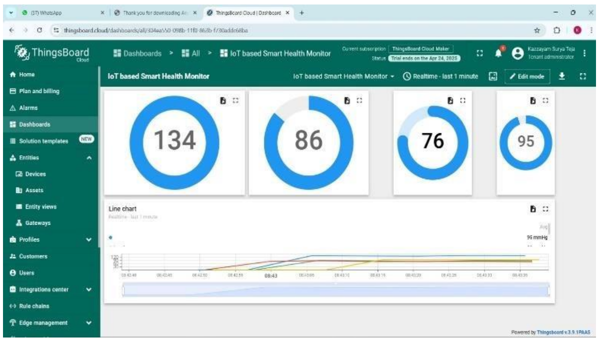

Fig VI(a) Measured P.Nageshwara Rao(Age 65) oxygen saturation, systolic blood pressure, body temperature, diastolic blood pressure, and heart rate fluctuation.

Systolic blood pressure fluctuations may be tracked over time with a line graph, which makes it simpler to see odd spikes or declines. The body temperature is 39°C, though, which is a little high. This may be a sign of a low-grade fever or a sensor calibration problem that must be checked. In any case, it serves as a helpful reminder to confirm the veracity of readings.

This solution goes beyond basic data collecting by combining cloud computing, IoT, and AI-powered analytics to improve accuracy and dependability in health monitoring.

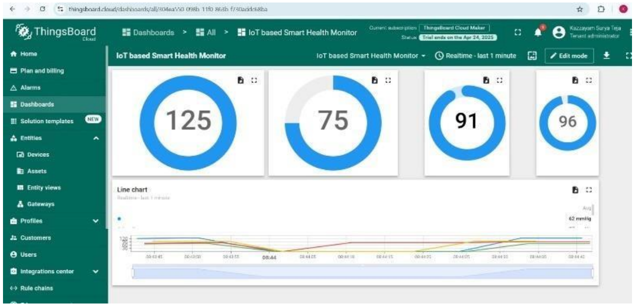

Fig VI(b) Measured K.Adhi Lakshmi(Age 42) oxygen saturation, systolic blood pressure, body temperature, diastolic blood pressure, and heart rate fluctuation.

integration with IoT and AI guarantees that consumers obtain precise, quick, and actionable health information whether they are utilized in telemedicine, home care, or hospitals. Thistype of innovation is a step toward improving the efficiency, data- drivenness, and patient-centricity of healthcare.

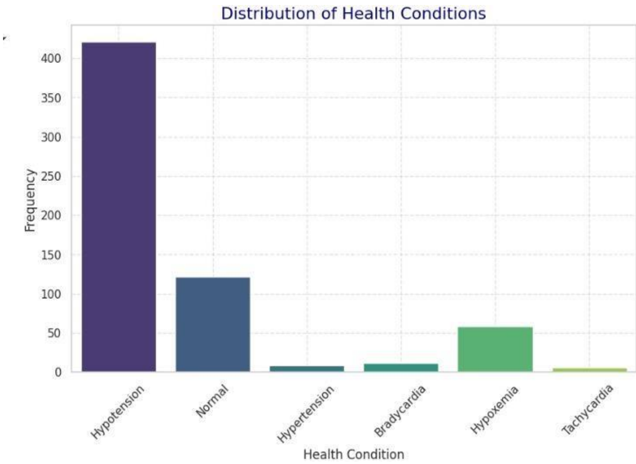

Fig VI(c) Distribution of Health Conditions

Heart rate, SpO2, BP Sys, and BP Dia distributions are displayed in the histograms. About 40–45% of blood pressure values seem to be missing or inaccurate, although 30–40% are within normal limits. 20% of patients have a risk of hypertension. Ten percent are extreme outliers, while seventy percent have typical heart rates (less than 100 bpm). Sensor problems are probably the cause of the inconsistent SpO2 measurements, with 60% displaying lower values and some above 100%. In general, outliers and missing values must be addressed through data cleaning to provide accurate health monitoring.

With its real-time tracking, early warning systems, and remote accessibility, this health monitoring system is an all-around effective tool for preventative healthcare. It's smooth integration with IoT and AI guarantees that consumers obtain precise, quick, and actionable health information whether they are utilized in telemedicine, home care, or hospitals. This type of innovation is a step toward improving the efficiency, data- drivenness, and patient-centricity of healthcare.

CONCLUSION AND FUTURE SCOPE

An innovative development in healthcare, the non-invasive blood pressure (BP) monitoring system provides a more pleasant and effective substitute for conventional BP testing techniques. It continually measures blood pressure, heart rate, and SpO_2 without the discomfort of traditional cuff-based methods thanks to sophisticated non-invasive sensors. By integrating with IoT platforms like ThingsBoard, the system facilitates remote health monitoring and real-time data collecting, giving people and medical professionals access to the most recent health information from any location.
Lowering the need for frequent clinic visits and encouraging early diagnosis and prompt interventions, enhances

healthcare accessibility, especially for patients with chronic diseases like hypertension and heart disease.
In the future, wearable technologies and AI-driven advancements will drive the system's evolution. CNNs and RNNs are examples of advanced machine learning models that will improve the accuracy of blood pressure predictions and facilitate the early diagnosis of illness. Smooth, real-time health tracking will be possible with the incorporation of blood pressure monitoring into smartwatches, exercise bands, and other wearable technology. Cloud-based solutions will provide safe and effective data exchange by connecting the system to telemedicine platforms and electronic health records (EHRs). Furthermore, expanding into underdeveloped and isolated areas would increase access to healthcare globally, and blockchain technology will protect patient data. Globally, these developments will increase the effectiveness and accessibility of proactive, individualized healthcare.

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REFERENCES

[1] Mant, J.; Marozas, V.; Chowienczyk, P.; Alastruey, J.; Charlton, P.H.; Kyriacou, P.A.; Wearable photoplethysmography for cardiovascular monitoring. IEEE Institute of Electron Engineering, Proc. 2022.

[2] Jeong, J.S.; Yun, J.S.; Kwon, H.S.; Baek, K.H.; Song, K.H.; Ahn, Y.B.; Ko, S.H.; Kim, M.K.; Jeong, J.S.; Yun, J.S. A 10-year longitudinal cohort research found that the hemoglobin glycation index predicts cardiovascular risk in individuals with type 2 diabetes mellitus. J. Complicated Diabetes. 2018

[3] Sun, B., Wang, C., Chen, X., Zhang, Y., and Shao, H. Feature estimation-based approach for correcting motion artifacts in PPG signals. Optik in 2019.

[4] Abreu, P.; Carneiro, F.; Restivo, M.T. Non-invasive blood pressure waveform identification as a screening method for cardiac issues. Data 2020.

[5] A systematic review and meta-analysis of published human trials was conducted by Hermida, R.C.; Mojón, A.; Hermida- Ayala, R.G.; Smolensky, M.H.; Fernández, J.R. To what extent hypertension drugs reduce blood pressure while you sleep depends on when you take them. 2021; Sleep Med. Rev.

[6] Mant, J.; Marozas, V.; Chowienczyk, P.; Alastruey, J.; Charlton, P.H.; Kyriacou, P.A.; Wearable photoplethysmography for cardiovascular monitoring. IEEE Inst. Electr. Electron. Eng. 2022 Proceedings

[7] Byfield, R.; Miles, J.; Guidoboni, G.; Miller, M.; Lin, J. Moving toward reliable blood pressure estimation using photoplethysmography sensors to monitor pulse wave velocity. IEEE Sens. J. 2022.

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