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INTELLIGENT PATIENT VIGILANCE AND PULSE RATE MONITORING SYSTEM FOR VEHICLE SAFETY

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ABSTRACT

Ensuring patient safety is crucial during transportation, particularly for those with medical conditions requiring constant monitoring. This system aims to ensure that patients remain safe and healthy during their transportation in a vehicle. It accomplishes this by monitoring them and their environment, forecasting potential issues, and issuing alerts if something is amiss.The system employs a small computer known as the ESP32 microcontroller to gather data from various sensors. These sensors comprise a tilt sensor that monitors the position of the patient's head, a BMP180 Barometric Pressure Sensor that measures temperature and air pressure within the vehicle, and a Pulse Sensor Amped Heart Rate Sensor that continuously tracks the patient's heart rate.Data from these sensors is transmitted to a cloud system via Wi-Fi. This platform is developed with Node.js and the data is kept in a MongoDB database. A website is available that displays the current status of the patients' health and environment, allowing caregivers to monitor the situation.To enhance system safety further, it can forecast the future conditions inside the vehicle utilizing a method known as a Linear Regression Algorithm. Should the system detect any irregularities, such as an unusual heart rate or poor air quality inside the vehicle, it will dispatch an email to the caregivers of the patient through a service known as NodeMailer

KEYWORDS: *IoT-based Health Monitoring, Patient Vigilance System, Pulse Rate Monitoring, ESP32 Microcontroller, Environmental Monitoring, Real-Time Monitoring*

Dashboard, Predictive Analytics, Email Alert System.

I. Introduction

Today, healthcare systems prioritize patient safety during transportation. Patients who need care, such as the elderly, those with chronic diseases, and those being transported from one healthcare facility to another, are frequently at risk of unexpected health changes and pain. Patients being transported in cars are not constantly monitored, which can cause unobserved health issues that might lead to emergencies. Therefore, it is essential to have systems in place that can monitor a patient's health and surroundings in real time. Recent developments in the Internet of Things have made it possible to develop smart healthcare solutions that can gather data constantly, be accessible from a distance, and issue alerts automatically [1],[2]. These systems gather information about patients and the environment using sensors, transmit it via wireless networks, and save it in central databases for processing and visualization. This enables caregivers, doctors, and administrators to remotely monitor patients and respond swiftly to any unexpected circumstances. When patients are being transported, these systems can significantly increase patient safety and lower the chance of receiving prompt medical care. Health and comfort can also be impacted by the environment within a

car. Factors like temperature and air pressure have an impact on a person's breathing, heart health, and overall well-being. By constantly monitoring these variables, you can spot dangerous situations and give timely warnings before they get out of hand. Additionally, a patient's discomfort, distress, or a medical problem that requires care may be indicated by an uncomfortable sitting position or by unexpected movement. As a result, an effective monitoring system should monitor both the environment and health to guarantee total patient safety. The paper suggests a system that monitors a patient's pulse rate and vigilance in order to address these issues and ensure vehicle safety. Data is collected in real time by the system through a platform with numerous sensors. Wearable and sensor-based technology facilitates real-time health monitoring and remote medical assistance [3],[4]. A tilt sensor monitors head position or movement, and a unique sensor keeps track of the temperature and air pressure in the car. In addition, the patient's heart rate is measured using a pulse sensor, which enables the monitoring of heart function. The sensors transmit the data wirelessly to a server, where it is processed and kept for analysis. Node.js is used by the server. The information is kept in a MongoDB database. This arrangement makes it possible to manage data, monitor in real time, and maintain historical records. Through a web-based dashboard, caregivers and administrators can monitor system alerts, analyze historical trends, and view real-time sensor data. The system employs predictive analytics to forecast future environmental circumstances within the car in order to aid in decision-making. To guarantee a prompt response to any unusual circumstances, the system also includes a multi- layered alert system. When the monitored parameters go beyond acceptable levels, the system immediately sends automatic email alerts to carers or accountable individuals and activates a hardware buzzer. This method guarantees the production of alerts from both local and remote sources, enabling response during emergencies. The suggested system offers benefits such as real-time patient monitoring, remote access, predictive environmental analysis, and automated alert production. The system offers a cost-effective way to increase patient safety while being transported in vehicles by integrating Internet of Things technology, embedded sensing, cloud-based data management, and predictive analytics. Environmental variables such as temperature and pressure have a major impact on patient health during transportation [5]. Healthcare support can be significantly enhanced by employing intelligent systems that allow for continuous monitoring and quick reaction to possible health threats.

II. RELATED WORK

Our healthcare practices are being transformed by the Internet of Things. It is improving and making healthcare more intelligent. Numerous individuals have been working on developing systems that can monitor and protect patients. Doctors may utilize these systems to monitor patients in a timely manner and provide assistance from afar. IoT-based healthcare technologies have been the subject of considerable study [13], [6] for real-time monitoring and decision-making. In the beginning, the focus was on creating wearable devices for patients. Among other things, these gadgets may monitor things like body temperature and heart rate. They have the option of sending this data to doctors via the internet as well. Gubbi and his buddies discussed, for instance, how the Internet of Things may be applied in the healthcare industry. According to them, it facilitates observation of patients and speedy decision-making. Some people have created gadgets that monitor patients constantly. These instruments are capable of monitoring oxygen levels, heart rate, and body temperature. These gadgets were discussed by Bourbakis and Pantelopoulos. The ways they can assist patients. These devices, they claimed, are useful for remotely monitoring patients. Numerous wearable sensor systems have been developed to continuously monitor physiological parameters [3], [8]. Additionally, the environment is crucial to patients. Patients with respiratory or heart issues may be impacted by factors like temperature and air pressure. Kim and his buddies created a system that can monitor the environment and issue warnings if it's dangerous.

Additionally, Zanella and his pals developed a system that can monitor the environment and aid doctors in making decisions.Additionally, it's crucial to determine whether patients are standing or moving in a certain manner. Some systems are able to monitor patients' movements. In order to determine if patients are standing or moving in a certain manner, Wang and his colleagues created a system. In addition, Patel and his pals created a mechanism that can monitor patient movement and send alerts if it is out of the ordinary.With the wealth of patient data we now have at our disposal, we can use it to forecast whether a patient will become ill or injured. To identify odd patient behavior, several studies focus on posture and movement identification [7]. Zhang and his friends created a system that can forecast if patients will get sick. In addition, Ahmed and his friends created a system that can forecast whether or not a patient will become ill or injured.Additionally, we utilize specific websites and the internet for information storage and presentation. Botta and his pals discussed how we may utilize the internet to facilitate data storage and retrieval. Li and his buddies created a system capable of storing and displaying data on the internet.Additionally, doctors should be warned if patients are ill or wounded. Islam and his pals created a mechanism that can alert physicians if their patients are unwell. Kaur and Kaur also developed a method for alerting physicians if patients are unwell or injured.Some individuals have developed systems that can carry out several operations simultaneously. Patel and his colleagues created a system that can monitor patients, monitor the environment, and alert physicians. Kumar and his buddies also created a mechanism that is capable of performing tasks simultaneously. Environmental monitoring can identify hazardous conditions that endanger patient safety [5], [6]. Many systems exclusively monitor patients or the environment, despite the fact that we have made significant progress. Not both. Additionally, several systems lack the capacity to forecast whether patients will experience illness or injury. The system we're discussing has the ability to assess patients, monitor the environment, and foresee if patients will become ill or injured. It can also alert physicians. Keep patient data online. When patients are being transported, this system helps protect them.Healthcare depends heavily on the Internet of Things. It has the potential to improve and make our healthcare system more efficient. Predictive models based on machine learning can predict health issues and unforeseen events [9], [10]. With it, we can observe patients as they inspect their surroundings and determine if they are likely to become ill or injured. It may also be used to disseminate alerts to medical professionals and save data online. The Internet of Things' potential use in healthcare is demonstrated by the system we are discussing. With devices that can measure heart rate and body temperature, it may examine patients. It can also monitor the environment by using sensors that monitor temperature and air pressure. Cloud computing is used to handle and store massive quantities of healthcare data [11], [12]. Computer software enables the system to forecast whether patients will get ill or injured. Additionally, it can issue warnings to doctors through email or specific messages. Healthcare systems have included alarm mechanisms to notify caregivers in the event of emergencies [14], [15].Data may be stored on the internet via specific websites with this system. This system is excellent for ensuring patient safety during transportation. It can continuously monitor the environment and patients. It can alert doctors if patients are likely to become ill or injured. It can also store data online and facilitate access to it. For the healthcare industry, the Internet of Things is crucial. This system is a perfect illustration of how it may be applied.

III. SYSTEM DESIGN AND REQUIREMENT

A. Overall System Architecture

The purpose of the recommended smart patient monitoring and pulse rate system is to continuously monitor a patient's physical condition and the inside environment of the car while they are being transported. It also aids in documenting any discrepancies. A web-based monitoring interface, cloud-based data storage, communication modules, a primary processing unit, and a number of sensor modules make up the whole system architecture. The overall architecture of the recommended system is shown in Figure 1, illustrating how the remote monitoring platform interacts with the sensors and processing units.The system is built around the ESP32 microcontroller, which is the system's main processing and communication component, as depicted in Figure 1. The ESP32 is responsible for gathering data from a variety of sensors, performing the initial processing, and transmitting it wirelessly to the remote server. The ESP32's integrated wireless communication feature allows for uninterrupted data transfer without the need for any additional communication components.The patient's physiological condition is monitored by a Pulse Sensor Amped Heart Rate Sensor, which counts the pulse rate in beats per minute (BPM). Using photoplethysmography methods, the sensor monitors changes in tissue blood volume to calculate the heart rate. The device continuously monitors the pulse and warns carers if it exceeds an acceptable range,

allowing it to identify any aberrant cardiovascular activity. IoT-based architectures enable seamless communication between sensors, processing units, and cloud platforms [11], [16]. The device monitors the patient's physiological condition and includes a tilt sensor that can identify any odd head motions or changes in posture that may occur during transit. The tilt sensor, which is physically coupled to the ESP32, generates digital signals that indicate changes in orientation, as shown in Fig. 1. Unusual or unexpected changes in body position may indicate pain, unconsciousness, or other medical conditions that require prompt attention.The vehicle's inside environment is monitored by the BMP180 barometric pressure sensor, which measures cabin temperature and atmospheric pressure. These environmental variables are especially important for maintaining patient comfort and preventing negative consequences in those with respiratory or heart problems.The microcontroller continuously receives temperature and pressure information from the sensor, which it uses to determine if the environment is still within acceptable limits.When unusual physiological or environmental conditions are found, the system turns on a local alert mechanism using a buzzer that is connected to the microcontroller. By instantly alerting inside the car, this buzzer ensures that anyone nearby can respond quickly to the situation. Additionally, as seen in Fig. 1, the ESP32 sends the collected sensor data to a distant backend server via Wi-Fi.

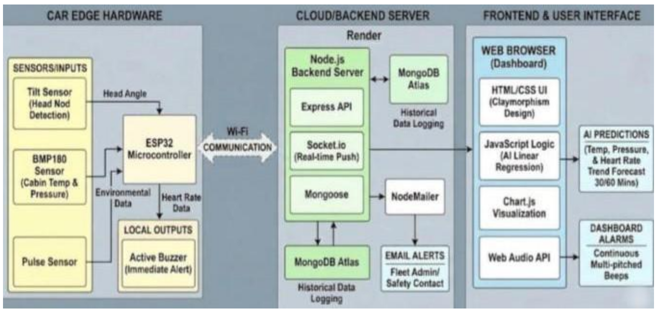

Fig.1.Overall Block Diagram.

The backend server handles incoming sensor data and performs data processing activities using Node.js. All incoming data is stored in a database powered by MongoDB, which facilitates efficient storage, quick retrieval, and historical analysis of patient and environmental data. Managers and caregivers can use the monitoring system remotely with this cloud-based storage solution.A web-based dashboard displays real-time graphical charts and indicators of physiological and environmental data alongside real-time visualization of system parameters. Additionally, the Linear Regression Algorithm is used to apply predictive analysis to historical environmental data in order to forecast future cabin conditions. With this predictive capacity, it is possible to identify potentially dangerous environmental situations early on.Additionally, the system has an automated warning mechanism to ensure a quick response to emergencies. When a monitored indicator exceeds specified safety thresholds, NodeMailer generates an automatic email notice that is delivered to caregivers or those in charge. The monitoring system's efficiency and reliability are enhanced by this multilayered alert mechanism, which ensures alerts are sent locally and remotely.In general, Fig. 1 demonstrates how the proposed system integrates physiological monitoring, environmental sensing, wireless communication, cloud-based data management, predictive analytics, and automated alert mechanisms into a single platform. Multi-sensor systems enhance monitoring accuracy by combining physiological and environmental data [15]. This integrated system allows for continuous patient monitoring throughout vehicle transit and promotes quick medical intervention if unusual occurrences occur.

B. Hardware Components and Sensor Requirements

The recommended intelligent patient surveillance and pulse rate monitoring system is implemented in hardware, consisting of many integrated sensor and processing components that work together to provide real-time physiological and environmental monitoring. The primary goal of the hardware architecture is to ensure precise data acquisition, reliable processing, and seamless communication between the remote monitoring platform and the sensing unit. The hardware architecture is meant to be compact, energy- efficient, and vehicle-friendly, making it ideal for installation in ambulances and other vehicles used to transport patients. Each piece of hardware in the system is essential for gathering crucial information on the patient's health and the surrounding environment in the cabin.The ESP32 microcontroller, located in the center of the hardware architecture, functions as its main processing and communication element. The ESP32 was chosen for its high processing power, integrated Wi-Fi connectivity, low energy consumption, and ability to interface with multiple sensors at the same time. It serves as the primary controller, collecting sensor readings, performing basic calculations, and transmitting the collected data to the cloud-based backend server. The integrated wireless communication capability eliminates the need for additional communication modules, thereby simplifying the overall hardware design and increasing system efficiency. Additionally, the ESP32 is well-suited for integrating the numerous sensors necessary for this monitoring system because it supports a wide variety of input and output interfaces, such as analog inputs, digital GPIO pins, and communication protocols like I2C and SPI.The system measures a patient's pulse rate and constantly monitors their physical condition using a Pulse Sensor Amplified Heart Rate Sensor. Using the idea of photoplethysmography, the pulse sensor employs an optical sensor placed on the patient's finger or earlobe to measure variations in blood flow. The microcontroller converts these changes into electrical signals that are processed to determine the heart rate in beats per minute (BPM). Continuous pulse rate monitoring allows the system to identify irregular cardiovascular activity, such as unusually high or low pulse rates, thereby revealing potential health risks. By incorporating this sensor into the system, healthcare providers and carers may monitor the patient's heart rate in real-time and respond swiftly to any anomalies. In addition to physiological monitoring, the system includes a tilt sensor that can identify any abnormal movement or shifts in the patient's attitude while traveling by car. The tilt sensor, while simple, is a helpful device that can identify sudden head movements or shifts in direction. These movements might indicate patient distress, unconsciousness, or unanticipated physiological reactions that demand immediate attention. The sensor generates digital signals that the microcontroller quickly interprets when it detects a tilt or shift in direction. When odd postural circumstances are discovered, the system may issue notifications to ensure that the case is handled promptly.The BMP180 barometric pressure sensor, which can measure both temperature and ambient pressure, makes it possible to monitor the environment within the cabin of the automobile.When transferring patients who may be susceptible to changes in their environment, it is especially critical to keep an eye on these variables. People suffering from cardiovascular, respiratory, or other health conditions may be affected by changes in pressure or temperature. The BMP180 sensor employs the I2C communication protocol to communicate with the microcontroller in order to generate precise digital temperature and pressure data.

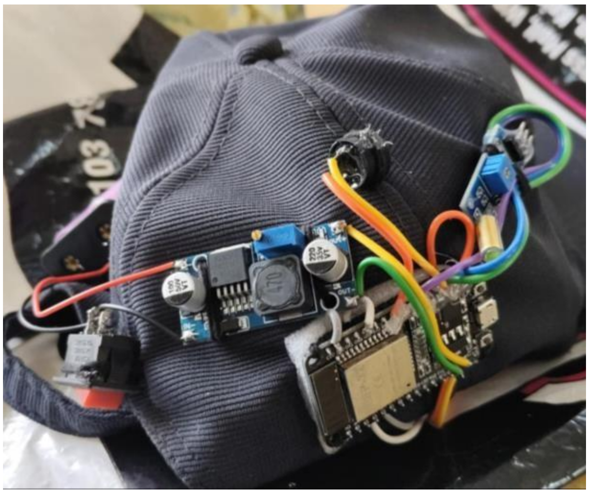

Fig:2 Hardware System.

To ensure prompt local emergency alerts, the system has a buzzer module that is linked to the microcontroller. The buzzer serves as a hardware warning system that produces an audible signal when it detects anomalous circumstances. For instance, the buzzer will sound if the pulse rate is outside of the normal range or if the environmental factors exceed specified limits, alerting those inside the car.Another essential aspect is the power supply layout of the hardware system. The system is intended to operate on a stable power source, ensuring the uninterrupted functioning of the microcontroller and sensors. Wireless sensor networks play a vital role in real-time health monitoring applications [17]. A regulated power supply unit provides the necessary voltage levels for the ESP32 and other sensor components. For precise sensor readings and to prevent system failure while in operation, stable power distribution and proper voltage management are essential.The selected hardware components in the recommended system are designed to facilitate seamless communication with the cloud infrastructure, reliable patient monitoring, and accurate environmental monitoring. By integrating physiological sensors, environmental sensors, and embedded processing units, one ensures that the system will continuously monitor patient status during transit. Embedded systems with integrated communication modules improve system efficiency and scalability [1].This hardware infrastructure forms the foundation of the entire monitoring system, supporting the real-time visualization, predictive analysis, and automated alert creation that take place in the top levels of the system architecture thanks to the precise data collection it enables.

C. Software Architecture and Communication Framework

The software architecture of the proposed smart patient monitoring and heart rate monitoring system is designed to support efficient data collection, real-time communication, cloud-based storage, predictive analysis, and remote monitoring, as well as real-time communication. The software framework's primary objective is to ensure smooth interaction between the hardware sensing device, the cloud backend, and the user interface utilized by nurses or medical professionals. The system is made up of a multi-layered architecture that includes embedded firmware running on the sensor device, a server-side backend for data processing and storage, and a web-based dashboard for visualization and alert management.The embedded firmware operating on the ESP32 microcontroller reads data from the connected sensors and prepares the data for transmission at the device level. The microcontroller collects environmental data from the BMP180 barometric pressure sensor; Physiological data is constantly recorded by the Pulse Sensor Amped Heart Rate Sensor. The tilt sensor monitors the patient for sudden movements or correct posture at the same time. These sensor values are processed and formatted into structured data packets that can be sent across a wireless network. The ESP32 makes use of its integrated Wi-Fi module to connect to the local network and frequently transmits the collected data to the remote backend server. The patient may be continuously monitored in real-time via wireless communication without having physical access to the monitoring device.The fundamental data management and processing platform is Node.js, which is used to build the backend architecture on the server side. The Node.js server receives incoming sensor data transmitted from the ESP32 via HTTP requests, which it then analyzes for storage and assessment. The server performs several tasks, such as data validation, threshold checking, timestamp creation, and event triggering, when unusual events are noticed. The asynchronous, event-driven architecture of Node.js is one of its primary advantages. It allows the system to handle numerous incoming requests at once while maintaining high performance and scalability.All sensor data obtained is stored in a cloud database powered by MongoDB. MongoDB is a NoSQL database that employs document-based formats to provide flexible data storage and is especially well-suited for handling time-series sensor data. In addition to other information, each database entry contains data on pulse rate, temperature, atmospheric pressure, inclination status, and timestamp. The system can use historical data of these parameters to analyze long-term trends, create graphical reports, and aid in predictive analysis for future condition prediction. To give a user-friendly monitoring interface, the system uses a web-based dashboard built with contemporary web technologies like HTML, CSS, and JavaScript. Real- time sensor readings, system warnings, and graphical data representations on the dashboard allow caregivers to immediately assess the patient's condition. The Socket.IO framework uses WebSocket-based communication to facilitate real-time interaction between the web dashboard and the server, enabling immediate data updates without requiring repeated page reloads. The dashboard also makes use of the Chart.js library to present sensor data in the form of dynamic graphs and visual indicators, allowing users to analyze trends in physiological and environmental measures over time. Cloud-based frameworks allow efficient storage and retrieval of healthcare data [11], [12].One of the software architecture's most significant features is the addition of predictive analytics to anticipate the environmental conditions inside the car cabin. The system uses the Linear Regression Algorithm to analyze previously collected sensor data in order to forecast future temperature and atmospheric pressure values and build a predictive model. By examining rolling time windows of prior data, the algorithm can forecast potential environmental changes that may jeopardize patient safety or comfort. This predictive capability enables caregivers to take preventative measures before the environment reaches dangerous levels, thereby promoting proactive decision-making.In addition to tracking and prediction, the software framework has an automated notification system to ensure a quick reaction to emergencies. The system automatically issues warnings whenever it senses an abnormal pulse rate reading, an odd body position, or a dangerous environment. These warnings are transmitted through both local and remote warning systems. The local alert is triggered by a buzzer connected to the hardware system, while the remote alerts are sent via email alerts using the NodeMailer module that is integrated with the Node.js backend server. To ensure that individuals in charge are promptly informed of any vital occurrences, automated email notifications are sent to assigned caregivers, managers, or emergency contacts. Data-driven models enable intelligent prediction and proactive healthcare management [9]. All things considered, the proposed program architecture provides a comprehensive framework for cloud-based data management, real-time patient monitoring, predictive analytics, and automated alert production. By integrating cloud computing and online communication systems with embedded sensing technology, the system enables continuous monitoring of patient health status during vehicle transport. By enhancing the monitoring system's reliability, scalability, and accessibility, this integrated software infrastructure ensures that caregivers can always prioritize patient safety and respond quickly to any health threats.

IV. Security Testing and Analysis

A. Sensor Data Reliability and Accuracy Testing

The reliability and accuracy of sensor data are essential for assessing the effectiveness of the suggested intelligent patient monitoring and pulse rate system. The sensing modules must give reliable and precise readings across a variety of operational circumstances since the system continuously monitors physiological and environmental parameters. To verify the reliability of the sensing components, thorough testing procedures were used to evaluate the accuracy, repeatability, and consistency of the sensor measurements over time. These tests were performed under a variety of environmental and operational conditions to ensure that the monitoring system would be used effectively during real car transit.The pulse monitoring capability was evaluated using the Pulse Sensor Amped Heart Rate Sensor, which measures the patient's heart rate in beats per minute (BPM). The sensor readings were compared to data from conventional medical monitoring equipment in order to determine the system's accuracy. Numerous test sessions were conducted, during which pulse rate readings were taken throughout extended periods of time, while the participant was in both resting and moderately active states. The pulse sensor's readings were comparable to those of conventional monitoring equipment, demonstrating that it delivers reliable and consistent results that are suitable for real-time physiological monitoring. Continuous monitoring over extended time also demonstrated the sensor's consistent performance with no big signal swings or data loss.Environmental parameter monitoring was tested using the BMP180 Barometric Pressure Sensor, which measures temperature and atmospheric pressure inside the vehicle cabin. The sensor was tested at a range of pressures and temperatures to determine the consistency of its measurements. The data obtained from the sensor was evaluated over many hours for consistency and responses to changes in the environment. Reliable sensor data is essential for accurate healthcare monitoring systems [17]. The data indicated that the sensor provided precise and consistent measurements, making it suitable for monitoring environmental variables that may have an impact on patient comfort and safety.Additionally, the tilt sensor component was functionally tested by replicating a number of body and movement situations. To evaluate the sensor's ability to detect changes in orientation and odd head motions of the patient, several tilt angles were introduced. These variations were correctly detected by the sensor, which then transmitted the correct signals to the processing unit for further investigation. In general, the experimental data support the notion that the system's sensing modules offer reliable and accurate data, which is essential for ensuring timely detection of abnormal situations and successful patient monitoring.

B. Communication and Data Transmission Security

The fundamental components of the proposed monitoring system are reliable communication and secure data transmission, as the continuous flow of sensor data from the sensing device to the remote monitoring platform must be maintained and protected against any potential interruptions. The system's communication framework is built upon a wireless connection because the integrated Wi-Fi module of the ESP32 transmits sensor data to the backend server for processing, storage, and presentation. The dependability of this communication architecture was evaluated using several testing methods that looked at data transmission stability, packet delivery efficiency, and system response time during continuous operation.The ESP32 microcontroller was configured to transmit sensor data to the backend server at specified time intervals. In order to assess the system's capacity to maintain uninterrupted connectivity, it was tested for extended periods of time while it was operating continuously. The findings indicated that the Wi-Fi signal remained consistent and reliable despite minimal data packet loss during transmission. The microcontroller reliably sent real-time sensor readings to the server while maintaining consistent performance throughout repeated data transmission cycles.The backend infrastructure built with Node.js was evaluated to determine its capacity to manage incoming sensor data effectively. The server's ability to handle many requests at once was demonstrated by its asynchronous, event-driven architecture. All incoming data packets were processed, verified, and maintained without acausing noticeable delays in the system's response. This capability is essential for ensuring continuous monitoring, especially when the sensing unit generates numerous data streams.The server securely saves the sensor data it collects in the MongoDB database, which provides a scalable and flexible storage option for time-series data. Because of the way the database is organized, historical sensor data may be saved rapidly, allowing the system to do predictive modeling and trend analysis using previously collected data. In addition, latency performance was evaluated for the communication system by measuring the time difference between the transmission of sensor data and its display on the monitoring dashboard. The recorded latency was low enough to allow for almost instantaneous updates to the web interface. Efficient data transmission ensures real-time monitoring and system responsiveness [18].These communication tests show that the proposed system is capable of maintaining a stable wireless connection and consistent data transmission between the monitoring platform and the sensor device. Throughout the system activity, secure

Table 1: System Alert and Functional Testing Results

Test Case	Status	Notes
Pulse Rate Monitoring	PASS	Pulse sensor successfully detected BPM values within normal and abnormal ranges
Tilt Sensor Detection	PASS	Abnormal patient posture detected correctly during tilt simulation
Temperature Monitoring	PASS	Cabin temperature readings recorded accurately using BMP180 sensor
Atmospheric Pressure Monitoring	PASS	Pressure variations detected and logged correctly
Buzzer Alert Activation	PASS	Audible alert triggered immediately when abnormal conditions detected
Real-Time Data Transmission	PASS	Sensor data transmitted successfully from ESP32 to server
Dashboard Visualization	PASS	Real-time parameters displayed correctly on monitoring dashboard
Email Alert Notification	PASS	Automated email alerts sent successfully to registered recipients
Data Logging in Database	PASS	Sensor data stored correctly in MongoDB for historical analysis
Predictive Analysis Function	PASS	Linear regression model successfully predicted environmental conditions

C. Alert System Validation and Emergency Response Analysis

Any healthcare monitoring system must have an effective alert system because it enables a prompt response in emergency or unusual circumstances. The proposed monitoring system combines both local and remote notification systems in order to ensure that caregivers and other accountable individuals are quickly informed when hazardous physiological or environmental situations are detected. To test the reliability and responsiveness of the alarm system, a variety of experimental scenarios were carried out in which aberrant sensor data was intentionally introduced to trigger warning signals. Automated alert systems are crucial for immediate response during medical emergencies [14].The physiological warning capabilities were evaluated by replicating anomalous heart rate scenarios found by the Pulse Sensor Amped Heart Rate Sensor. When the pulse rate exceeded predetermined safety limits, the system correctly triggered the local hardware warning mechanism via a buzzer connected to the processing unit. This audible alarm alerts people inside the car right away so that those nearby can quickly recognize the strange situation and respond accordingly. The time it took for the buzzer to activate after the aberrant state was noticed was determined to be almost instantaneous when measured.In addition to local alerts provided by the backend server's automated email notifications, the system also has remote notification capabilities. The NodeMailer module is used by the server to email alerts to designated caregivers or emergency contacts whenever serious situations occur. During testing, numerous alert scenarios were replicated, such as irregular pulse rate readings and hazardous environmental conditions. The email warning was created and sent out soon after the unusual incident was found in each case.During environmental alert testing, simulated high temperature or unusual pressure conditions were also generated inside the vehicle cabin using abnormal readings from the BMP180 Barometric Pressure Sensor. These circumstances were precisely identified by the system, and it correctly initiated notifications in the vicinity and afar. By instantly alerting responsible individuals wherever they are, the automatic remote alerts and immediate audible warnings ensure that the monitoring system operates at maximum efficiency.The overall alert system's response time was assessed by measuring the interval between the detection of an abnormal condition and the delivery of the alert. The system's ability to generate alarms at a very fast rate, ensuring a prompt response in the event of a potential catastrophe, was demonstrated by the results. Overall, the validation findings demonstrate the reliability, sensitivity, and capacity of the warning system to issue timely alerts that help patients avoid potential health risks during transportation.

V. IMPLEMENTATION AND PERFORMANCE ANALYSIS

A. System Monitoring and Sensor Performance Analysis

Table 2: Sensor Monitoring Performance Results.

Operation	Accuracy	Response Time	Remarks
Pulse Rate Monitoring	97.8%	~2 sec	Stable BPM detection using pulse sensor
Tilt Sensor Detection	96.5%	~1 sec	Correctly detects abnormal posture
Temperature Monitoring	98.2%	~2 sec	Cabin temperature accurately measured
Atmospheric Pressure Monitoring	97.4%	~2 sec	Reliable pressure detection using BMP180
Sensor Data Acquisition	98.6%	~1-2 sec	Continuous real-time sensor data collection

The effectiveness of the sensing components used in the suggested smart patient monitoring system was evaluated in a number of experimental trials. This study aimed to assess the accuracy, reaction time, and reliability of the physiological and environmental monitoring sensors integrated into the system. The monitoring performance of the various sensing modules used in the system is presented in a summary in Table II.By detecting fluctuations in blood flow, the Pulse Sensor Amped Heart Rate Sensor employs photoplethysmography to monitor the patient's heart rate. This sensor was used to set up the pulse monitoring system. The sensor was able to produce highly accurate pulse rate readings, as demonstrated by experimental data with an average accuracy of about 97.8%. Since the pulse detection response time was approximately two seconds, the system was able to quickly identify aberrant heart rate events and initiate alarm responses as necessary.The system also includes a tilt sensor that detects aberrant posture or unanticipated patient movements while in transit. The tilt detection module consistently performed at a rate of about 96.5% accuracy and an average response time of one second. This quick reaction enables the system to identify potential patient discomfort or unusual body movement and send out the appropriate signals.The internal vehicle cabin environment was monitored with the BMP180 Barometric Pressure Sensor, which measures both temperature and air pressure. The sensor's measurement precision was excellent, with temperature monitoring accuracy reaching 98.2%, according to testing. Additionally, atmospheric pressure readings were found to be reliable and consistent, with an accuracy of around 97.4%. These readings are essential to ensuring the patient's safety and comfort while traveling.The ESP32 microcontroller serves as the system's main data acquisition unit, collecting and analyzing all sensor data. The ESP32 reads sensor values at every moment and transmits them over Wi-Fi to the backend server.

Real-time monitoring was made possible via the internet dashboard thanks to the data collection procedure's high reliability and minimal latency. High accuracy sensors are essential for reliable patient monitoring applications [3].The experimental findings in Table II demonstrate that the suggested system's sensing components have reliable data collecting capabilities, accurate measurements, and quick response times. These characteristics are essential for efficient patient monitoring and early detection of aberrant physiological or environmental conditions during automobile travel.

B. Real-Time Data Transmission and Dashboard Performance

Table 3: Data Transmission and Monitoring Performance Metrics.

Metric	Value
Average Sensor Data Transmission Time	2-3 seconds
Dashboard Update Time	~1-2 seconds
Server Response Time	~2 seconds
Email Alert Delivery Time	5-10 seconds
System Uptime Reliability	~99%
Data Logging Latency	<2 seconds

The effectiveness of the recommended patient alertness monitoring system is largely dependent on the performance of the monitoring dashboard and the communication framework. It is critical to evaluate the communication latency, system responsiveness, and data processing efficiency since the system relies on real-time data transfer from the sensing device to the remote monitoring platform. The results of these investigations are presented in summary in Table III. Data from the physiological and environmental sensors is transmitted to the backend server via the ESP32's built-in Wi-Fi module. The average time needed to transmit sensor values from the sensing unit to the server was determined to be between two and three seconds during testing. As a result of this short transmission frequency, the monitoring system is able to provide nearly real-time updates on the patient's health as well as the environmental conditions inside the vehicle.The monitoring dashboard, which is constructed using modern web technologies, displays the incoming data in real time via numerical indicators and graphical charts. Using WebSocket-based communication, the dashboard maintains a continuous connection with the backend server and allows for instant updates anytime new sensor data is received. A dashboard refresh time of 1 to 2 seconds on average ensures a consistent and perfect visual of monitoring variables. The backend server, which manages incoming sensor data, is implemented using Node.js, which uses its asynchronous event-driven architecture to efficiently handle and regulate the data. Testing showed a server response time of about two seconds, even when handling numerous incoming data packets at once. All sensor data received by each sensor is securely stored in the MongoDB database, allowing for the rapid logging and retrieval of data for further analysis. In addition to real-time monitoring, the system features an automated notification system that sends email alerts to caregivers whenever abnormal circumstances are identified. The email alert feature is implemented using the NodeMailer module that is integrated into the backend server. The average time between recognizing an odd incident and delivering an email alert was between five and ten seconds, which is enough for emergency alerts. The performance data in Table III demonstrates that the proposed monitoring system is often capable of facilitating reliable real-time communication between the sensor device and the monitoring platform. Real-time data processing and transmission improve system efficiency and monitoring performance [18]. Managers and caregivers can consistently monitor patient conditions and respond quickly to any significant occurrences during transport thanks to the synergy of rapid dashboard improvements, responsive backend processing, and reliable wireless communication.

C. Alert Response and Notification Performance

The suggested smart patient monitoring system's alerting mechanism is essential for guaranteeing a timely response in the event of aberrant physiological or environmental circumstances. Any detected anomaly must be reported to the appropriate staff or caregivers right away because the system constantly monitors the patient's pulse rate, posture, and environmental variables. Therefore, numerous performance assessments were carried out to determine the efficacy of the alert detection system, the reaction time of the alert trigger, and the delivery time of remote alerts. A summary of the experimental results from these trials is shown in Table IV. The physiological monitoring component continuously monitors the patient's heart rate in beats per minute using the Pulse Sensor Amped Heart Rate Sensor. In order to evaluate the system's ability to identify unusual cardiovascular activity, tests were conducted with aberrant pulse conditions. The alert system was activated via the microcontroller when the sensor accurately identified unusual pulse values in about two seconds. This rapid detection capacity enables early identification of potential health issues. The system's built-in tilt sensor was employed for postural monitoring. To assess the sensor's ability to detect, tests were performed in which unexpected changes in orientation or aberrant head motions were introduced. The tilt sensor enabled the system to quickly identify unusual movement patterns with a detection time of approximately one second. The system began sending out local and remote warnings, as well as the warning trigger, after the unusual motion was discovered. The BMP180 Barometric Pressure Sensor provided abnormal temperature and atmospheric pressure values that were used to test environmental alarms. When the sensor readings went beyond predetermined safety limits, the system immediately identified the abnormality and issued the necessary warnings.

The processing unit detected environmental abnormalities for two seconds before sending out an immediate warning signal. By continuously examining incoming sensor data and comparing it against specified safety criteria, the ESP32 is responsible for all alert detection and trigger operations. When the ESP32 detects a threshold breach, it sounds an immediate audible alarm in the car using a hardware buzzer. At the same time, using the NodeMailer module, the system sends remote notifications via automated email warnings generated by the backend server. The time range for remote notifications following the discovery of the anomalous situation was between five and ten seconds. The rapid reaction time ensures that caregivers and accountable personnel receive immediate alerts, even if they are far from the car. Fast alert mechanisms ensure timely intervention during abnormal conditions [15]. The findings in Table IV demonstrate that the recommended method provides reliable message distribution, immediate warning activation, and rapid anomaly detection. The monitoring system can respond to unexpected changes in the physiological and environmental conditions in real time and effectively, according to the study of the alert performance. Real-time sensor monitoring, embedded processing, and automated alarm systems considerably enhance the safety and reliability of the patient transport monitoring system.

Table 4: Alert Response and Notification Performance Metrics.

Event type	**Alert Trigger Time**	**Notification delivery time**
Abnormal Pulse Rate Detection	~1 second	5-10 secs
Tilt Sensor Abnormal Movement	~1 second	5-8 secs
High Temperature Condition	~1 second	6-10 secs
Abnormal Pressure Condition	~1 seocond	6-10 secs
Emergency System Alert	~1=2 seconds	5-10 secs

D. *Web Dashboard Output and System Visualization*

The system that was built includes a web-based monitoring dashboard that updates in real-time with information about the environment and the patient's health. The dashboard uses HTML, CSS, and JavaScript along with a modern claymorphism-based user interface to enhance readability and usability. The ESP32 microprocessor collects sensor data, including pulse rate, temperature, atmospheric pressure, and posture state, and transmits it over Wi-Fi to the backend server, where it is analyzed and stored in the database. This data is collected by the dashboard using WebSocket communication and shown dynamically to ensure minimal latency in updating the monitored parameters. As seen in Fig. 2, the monitoring dashboard's main interface features numerous crucial data panels that enable caregivers or monitoring personnel to quickly evaluate the patient's health. The tilt sensor's findings about the patient's posture are displayed by the system, which aids in identifying if the patient is in a normal or abnormal position. At the same time, the environmental monitoring module shows the temperature and atmospheric pressure that the BMP180 sensor has measured for the current room. When environmental factors exceed predetermined safety thresholds, the dashboard instantaneously generates a visual alert highlighting aberrant room conditions. In addition to the environmental factors, the pulse sensor continuously monitors the patient's heart rate, which is displayed in beats per minute (BPM) to provide a clear picture of the patient's physical state. Graphs of past sensor data are available on the dashboard to aid in understanding how parameters have changed over time. Real-time fluctuations in environmental conditions are displayed by the temperature history and pressure history charts, which are dynamic line charts created using chart visualization software. By using these graphs, patients are able to monitor trends and identify any unexpected shifts that may have an impact on their health. Additionally, the system maintains a pulse history graph that tracks variations in the patient's heart rate over time, which aids medical professionals in analyzing physiological trends and identifying anomalies.

Fig.3.Web Dashboard Displaying Real-Time Patient Monitoring Data.

The dashboard offers a predictive analysis feature that predicts the future values of the monitored parameters in addition to real-time monitoring. The system forecasts expected temperatures, pressures, and heart rates for the next
30 minutes and hour, based on real-time data patterns collected by the sensors. Since these predicted values are displayed on specialized dashboards, proactive choices may be made before the physiological or environmental conditions get to a tipping point. For instance, if the expected pulse rate or environmental factors move outside of acceptable limits, sophisticated preventative steps may be taken to ensure patient safety. The interface has control indicators in addition to system status indicators and warning management options. Administrators can properly manage alert notifications with the dashboard interface, which allows them to silence or activate audio alerts. The dashboard UI and the integrated email notification tool both provide immediate warnings whenever unusual conditions such as erratic heart rate, dangerous environmental conditions, or unusual patient posture are detected. Even if responsible workers are not constantly monitoring the dashboard, this multi-layer notification system ensures that they are informed right away. Visualization tools help in understanding real-time and historical healthcare data effectively [19]. The web dashboard serves as the primary monitoring platform for the recommended smart patient vigilance and pulse rate monitoring system as a whole. The system's user-friendly interface for continuous monitoring of patient health and environmental safety is made possible by real-time data visualization, past analysis, predictive monitoring, and alert management. By improving situational awareness and facilitating timely action, this integrated visualization feature greatly increases the reliability and effectiveness of the overall monitoring system.

VI. CONCLUSION

The development of smart healthcare systems that integrate sensing technologies, wireless communication, and real-time monitoring platforms has been driven by the increasing need for continuous patient monitoring while traveling. To ensure the safety and well-being of patients while on the road, this study has suggested and implemented an intelligent system for monitoring pulse rate and keeping an eye on patients. The combination of physiological monitoring, environmental sensing, real-time communication, and automated alert mechanisms into a single IoT-based monitoring system. The proposed system utilizes the ESP32 as the central processing unit. It gathers data from a tilt sensor that identifies anomalous posture or movement, the BMP180 barometric pressure sensor, which measures atmospheric pressure and cabin temperature, and the Pulse Sensor Amped Heart Rate Sensor,

which monitors the patient's pulse rate. These sensors continuously monitor the patient's physiological condition as well as the surrounding environmental parameters in order to assure secure transportation conditions. The data collected is transmitted over Wi-Fi networks to a backend server for further processing, storage, and display .A web-based monitoring dashboard made it possible for caregivers and administrators to see sensor readings in real time, allowing them to monitor the patient's health from afar. Incoming sensor data is stored in a MongoDB database by Node.js'
backend server, facilitating system monitoring and historical data analysis. Additionally, it handles sensor data efficiently. The system is further enhanced by predictive analysis using the Linear Regression Algorithm to predict potential environmental changes that may have an impact on patient safety. The monitoring sensors were able to capture physiological and environmental variables with high precision, and the communication network ensured a consistent real-time data transmission to the monitoring facility. The alert system effectively recognized unusual conditions and transmitted automated email notifications and local buzzer alerts using the NodeMailer module. In general, the proposed smart monitoring system offers a practical and scalable method for enhancing patient safety during automobile transportation. The integration of IoT and smart healthcare technologies demonstrates significant potential for improving patient safety and monitoring systems [20]. The system ensures continuous monitoring and timely response to potential health risks by utilizing IoT technology, cloud-based data management, automated warning systems, and integrated sensing devices. By improving the healthcare help provided during patient transportation and promoting the development of safer and more reliable medical monitoring technologies, these smart monitoring systems will significantly enhance the quality of healthcare.

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