Next-Gen Healthcare: AI-Powered IoT for Smart Hospitals

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Abstract: The healthcare industry faces challenges in patient monitoring, resource management, and emergency response, necessitating an advanced AI and IoT-based hospital management system for real-time data acquisition, automated decision-making, and remote monitoring. This system integrates body temperature, heart rate, and blood oxygen sensors to continuously track patient vitals, with data processed by an Arduino microcontroller and transmitted via Wi-Fi using NodeMCU, enabling healthcare professionals to monitor patients remotely through a web or mobile interface. An AI-driven bed allocation system ensures optimal resource utilization by analysing patient conditions, infection risks, and proximity to other patients, automatically assigning beds to minimize cross-contamination and ensuring that infectious patients are isolated appropriately. The system also considers patient severity, special medical needs, and ICU availability to allocate resources efficiently. A pressure sensor detects hospital bed occupancy in real-time, further enhancing resource management, while a buzzer alert system notifies staff of critical changes in patient conditions, enabling immediate intervention. Additionally, AI-powered predictive analytics can forecast patient deterioration based on historical and real-time data, allowing for proactive medical attention. Designed with cost-effective, energy-efficient components, the system seamlessly integrates AI and IoT technologies, making it scalable and adaptable for hospitals of all sizes, ultimately improving patient care, operational efficiency, and emergency response.

1 INTRODUCTION

To effectively manage patient care, resource allocation, and emergency response, modern hospitals need clever, automated systems. The need for real-time patient monitoring and efficient hospital operations has grown as a result of the healthcare sector's explosive expansion. Manual procedures are frequently used in traditional hospital administration systems, which can lead to mistakes, delays, and inefficient use of hospital resources (Arul Kumar et al., 2022). Slow reaction times can be fatal in emergency scenarios, underscoring the need for a more sophisticated, tech-driven strategy.

By combining automated bed distribution, sensor-based real-time health monitoring, and emergency warning systems, the proposed AI and IoT-based smart hospital management system, Health Sphere, seeks to address these issues. Using sensors, the system continuously monitors vital indications such blood oxygen levels, heart rate, and body temperature, guaranteeing prompt identification of anomalous conditions (Nithya et al., 2020). In order to minimize cross-contamination, an AI-driven bed allocation module makes sure that infected patients are placed in segregated beds.

The system also has a touch sensor to track bed availability in real time, removing human error from resource management. While an IoT-based remote monitoring, system enables medical personnel to access patient data via a web or mobile interface, an LCD display gives hospital staff immediate information on patient health and resource condition (Guruprakash et al., 2023). By guaranteeing that hospital employees are promptly informed of emergencies, a buzzer alert system greatly enhances patient safety and reaction times. This system optimizes hospital resource usage, improves patient care, lowers human intervention errors, and automates hospital operations by utilizing IoT and AI

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technology (Arul Kumar et al., 2022). Hospitals of all sizes can effectively apply the solution thanks to the flawless data transmission made possible by the combination of wireless communication (NodeMCU & Arduino). This invention bridges the gap between automation, real-time monitoring, and AI-driven hospital management decision-making, marking a significant advancement in smart healthcare.

2 RELATED WORK

The increasing reliance on the Internet of Things (IoT), and other emerging technologies has significantly advanced the healthcare industry. A variety of intelligent systems and monitoring frameworks have been proposed, leveraging these technologies to improve efficiency and accuracy in health monitoring and diagnostics.

Deepa et al., proposed an AI-based intelligent system for healthcare analysis utilizing the ridge-Adaline stochastic gradient descent classifier. This approach demonstrated enhanced performance for healthcare-related data analysis and prediction tasks, contributing to efficient decision-making in healthcare systems. Similarly, Islam and Rahaman developed a smart healthcare monitoring system in an IoT environment, providing a practical solution for real-time health data monitoring and analysis.

Masud et al., introduced a deep learning-based intelligent face recognition system designed for IoT-cloud environments. Their work highlights the integration of deep learning techniques for secure and efficient health data access and authentication. Bhat et al. presented a comprehensive review of IoT-based health monitoring systems, emphasizing the potential benefits of IoT in improving patient care and operational efficiency in healthcare facilities. Gogate and Bakal implemented a healthcare monitoring system using wireless sensor networks for cardiac patients, focusing on the early detection and prevention of cardiac events. Their work underscores the importance of sensor-based solutions in critical healthcare applications. This body of work collectively showcases the diverse applications of AI, IoT, and sensor technologies in enhancing healthcare systems, with a focus on improving patient outcomes and addressing challenges in traditional healthcare practices.

3 PROBLEM DESCRIPTION

Hospitals face significant challenges in patient monitoring, resource management, and emergency response, which directly impact efficiency and patient safety. Traditional patient monitoring methods rely on manual supervision, leading to delays in detecting critical health changes and increasing the risk of medical emergencies. Additionally, manual data entry is prone to errors, which can result in misdiagnosis or incorrect treatment. Resource management, particularly bed allocation, is often inefficient, causing delays in patient admission and leading to overcrowding in emergency wards.

The lack of an automated system also increases the risk of infection spread, as patients are not always assigned beds based on their health conditions and infection risks. Moreover, emergency response mechanisms in hospitals are often slow due to the absence of real-time alerts, making it difficult for medical staff to respond quickly to deteriorating patient conditions.

Existing systems use standalone sensors that are not integrated, limiting their ability to monitor multiple health parameters simultaneously. The absence of an AI-driven approach for patient monitoring, bed allocation, and predictive analytics further reduces operational efficiency. To address these challenges, a smart hospital management system integrating AI and IoT is required to enable real-time monitoring, automated decision-making, and efficient resource utilization.

4 RISK ASSESSMENT

IoT based health risk monitoring system seeks to continually track a variety of personal health metrics, anticipate possible health concerns, and potentially avert unfavourable health outcomes via early detection. Implementing a health risk monitoring system using IoT involves various risks that need to be assessed and mitigated to ensure the system's effectiveness, security, and compliance. Here are some key aspects for a health risk monitoring system using IoT:

Abnormal Vital Signs: Sudden spikes or drops in essential indicators including respiration rate, blood pressure, and heart rate & also a drastic change in physical activity levels, especially a sudden decrease or increase.

Temperature Fluctuations: Sudden temperature changes either elevated or subnormal may signal an infection or other underlying health issues. Such changes could be indicative of a decline in health or an acute event.

Emergency Response and Contingency Planning: Develop and regularly test emergency response plans & to have contingency measures in place for system failures, including data backup and recovery procedures.

Reliability and Accuracy: Implement quality assurance processes for data accuracy. Calibrate and validate sensors regularly. Establish redundancy and failover mechanisms to ensure continuous monitoring. Design for redundancy, fault tolerance, and disaster recovery to minimize downtime and ensure continuous operation.

Resource Constraints: Healthcare facilities are often Authorized licensed use limited resources to handle the increasing demand for medical services. This leads to longer wait times and overburdened medical staff, making it challenging to provide immediate care.

Regulatory Compliance*:* Assure that healthcare data management, privacy, and security needs are met in accordance with industry standards and legal regulations. To reduce the legal and regulatory concerns related to IoT health monitoring devices, stay current on the rules and guidelines that are always changing.

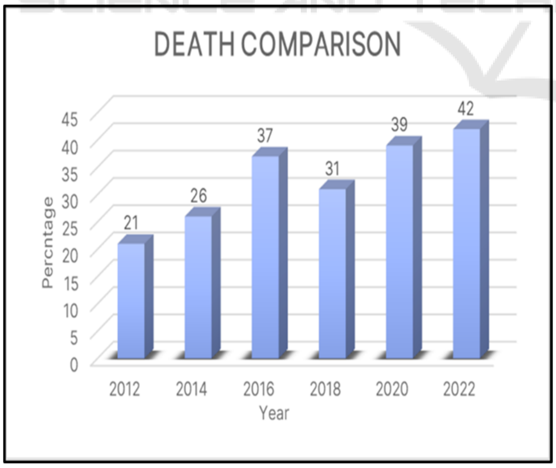

Figure 1: Death comparison due to health issues.

The information in figure1 displays the total no.of deaths occurred in percentage due to health issues without having an immediate medical response. The risk levels that the health care patients encountered from 2012 to 2022 are summarized. However the no.of deaths occurring seems to be decreased at some point but it increases gradually year by year with a considerable amount of death taking place. The information clearly suggests that nearly 30 to 40 percent of death takes place due to health issues.

Figure 2 portrays the data recorded by various sensors used to demonstrate the level of risk it handles. It monitors the risk and analyses the chances of the occurring risk in percentage and produces the graphical representation which depends on each and every individual health condition. This risk analysis clearly defines the amount of risk that a person is exhibiting while using the health monitoring system and produces accurate and other precautionary measures to help in treatment.

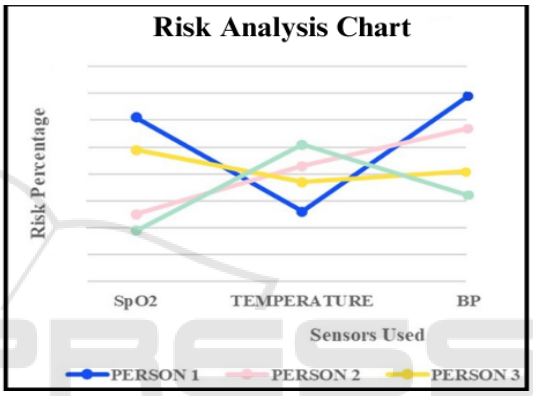

Figure 2: Risk analysis chart.

Outcomes demonstrated that the device's measurements produced 99.43% accuracy for body temperature and 99.59% accuracy for oxygen level, 99.76% accuracy for pulse rate, and 99.85% for heart rate which is pictorially represented in Figure 3.

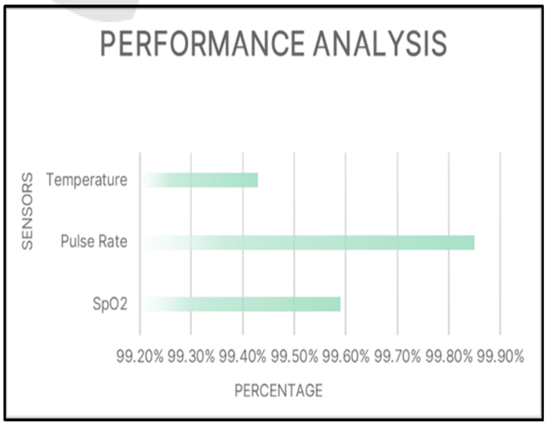

Figure 3: Performance analysis.

5 FEATURES AND FUNCTIONALITIES

5.1 Real-Time Patient Monitoring

The system continuously tracks patient vitals, including body temperature, heart rate, and blood oxygen levels, using advanced sensors. Data is processed via an Arduino microcontroller and transmitted through Wi-Fi (NodeMCU), allowing healthcare professionals to remotely monitor patient health in real time via a web or mobile application. This ensures early detection of abnormalities, leading to timely medical intervention.

5.2 AI-driven Bed Allocation System

The system utilizes AI to assign hospital beds efficiently based on patient condition, infection risk, and ICU availability. By analyzing real-time and historical patient data, it optimizes resource utilization while minimizing cross-contamination risks. Infectious patients are automatically assigned to isolated beds, ensuring a safer hospital environment.

5.3 Smart Bed Occupancy Detection

A pressure sensor detects hospital bed occupancy in real time, updating bed availability status on the system. This eliminates manual tracking and improves patient admission efficiency by providing hospital staff with an up-to-date view of available resources, thus reducing waiting times and optimizing hospital space utilization.

5.4 Automated Emergency Alerts

In case of a critical change in patient vitals, an integrated buzzer alert system notifies hospital staff immediately. This ensures quick response times during emergencies, allowing medical personnel to intervene before a situation worsens. The alert system is crucial for high-risk patients, improving overall safety and care quality.

5.5 Remote Monitoring via IoT

Healthcare professionals can monitor patient vitals and hospital resource usage remotely through an IoT-enabled platform. The system provides real-time data visualization via LCD displays and cloud-based dashboards, allowing for informed decision-making and reducing the need for manual supervision.

6 METHODLOGY

6.1 Data Acquisition Using Sensors

The system collects real-time patient data using multiple sensors, including blood oxygen, temperature, heart rate, and touch sensors for bed occupancy. These sensors are connected to an Arduino microcontroller, which gathers vital health parameters for continuous monitoring.

6.2 Data Processing and Transmission

The Arduino processes the sensor data and transmits it through an IoT module NodeMCU. The data is then displayed on an LCD screen for local monitoring and sent to a mobile application for remote access by healthcare professionals.

6.3 IoT-Based Real-Time Monitoring

The IoT module ensures seamless transmission of patient vitals to a web-based dashboard and mobile app. This enables doctors and nurses to remotely monitor patient health, reducing the need for physical presence and allowing for early detection of critical conditions.

6.4 Emergency Alert System

If a patient's vitals cross a critical threshold, an automated buzzer alerts hospital staff immediately. Simultaneously, real-time notifications are sent to medical personnel via a mobile application, ensuring a swift response to emergencies.

6.5 Automated Bed Occupancy Detection

Touch sensors installed on hospital beds detect occupancy in real time and update bed availability on the hospital's management system. This eliminates manual tracking, optimizing resource allocation and ensuring efficient patient admission.

7 ARCHITECTURE DIAGRAMS

Figure 4 illustrate the Schematic of the suggested system.

7.1 Blood Oxygen Sensor

A Pulse Oximeter (SpO2 sensor) is a medical device that determines the blood's oxygen saturation level. It is a crucial factor in determining an individual's respiratory health. The ratio of oxygenated to deoxygenated haemoglobin can be found by placing a non-invasive device on the finger and measuring light wavelengths. Pulse oximeters utilize the idea of light absorption to measure oxygen saturation. The sensor emits two different wavelengths of light, typically red and infrared, through a translucent part of the body.

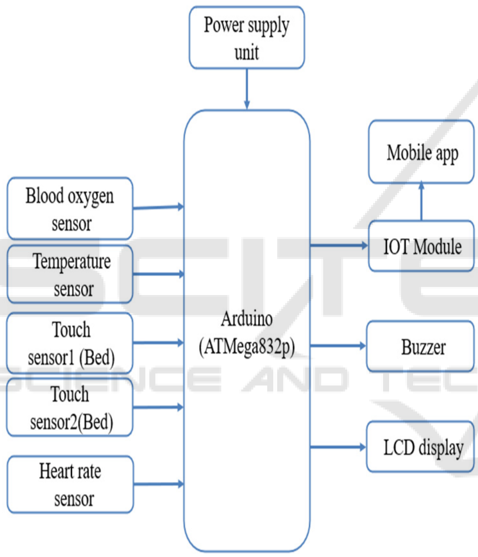

Figure 4: Schematic of the suggested system.

7.2 Temperature Sensor

A device that senses temperature can be employed to take frequent readings of the body's temperature and convert this information into an electrical signal. By transferring the electrical resistance over a diode into usable measurements like Fahrenheit, Celsius, or Centigrade, it also determines the relative humidity of an item. The voltage across the diode is exactly proportional to the temperature change. These sensors are used to detect the interior temperature of structures such as homes, bridges, dams, and power plants in environmental monitoring.

7.3 Heart Rate Sensor

A gadget called a pulse sensor is used to determine a person's heart rate. commonly by detecting the pulsatile blood flow through arteries, which are widely used to monitor heart rate in real time. Pulse Monitor emits infrared, red, or green light (~550 nm) towards the body and measures the amount of light reflected using a photodiode which provides the pulse rate of the patient. The pulse sensor operates by means of two surfaces that are connected to an LED and an ambient light sensor. Pulse rates may be established by monitoring the minute variations in light over a period of time.

7.4 Buzzers

Buzzers refers to simple devices that produce a continuous buzzing or beeping sound when an electric current pass through them. These are often used in alarms, timers, and other signalling applications. They are frequently employed to signal the end of an activity or to notify others of an impending event. Buzzers operate on the premise of applying an alternating current voltage at the element's resonance frequency, which causes the element to vibrate and produce sound.

8 RESULT

The implementation of the AI and IoT-based hospital management system demonstrated significant improvements in real-time patient monitoring, resource allocation, and emergency response. The integration of blood oxygen, heart rate, temperature, and bed occupancy sensors with an Arduino microcontroller and IoT module enabled seamless data collection and transmission. The system successfully provided remote patient monitoring via a mobile application, ensuring timely alerts for critical conditions. Additionally, the AI-driven bed allocation system optimized hospital resource utilization, reducing patient waiting time and minimizing cross-contamination risks. The emergency alert mechanism efficiently notified hospital staff of deteriorating patient conditions, enhancing response time and medical intervention efficiency.

9 CONCLUSIONS

The proposed IoT-based hospital management system enhances patient care, operational efficiency, and resource management in hospitals. By integrating real-time monitoring, automated alerts, AI-driven bed allocation, the system reduces manual intervention and improves decision-making for healthcare professionals. Its cost-effective, scalable, and energy-efficient design makes it suitable for hospitals of all sizes.

The advancements in AI, IoT, and sensor-based technologies have paved the way for transformative changes in healthcare. Studies such as those by Li and Chiu highlight the importance of remote healthcare systems, improving accessibility for underserved areas. Rahimoon et al. emphasized the need for cost-effective, non-invasive monitoring with their contactless body temperature measurement system. Reza et al. showcased how mobile technologies can enhance cardiovascular monitoring through portable and affordable solutions.

These innovations contribute significantly to creating efficient and scalable healthcare solutions. By integrating remote monitoring, non-invasive technologies, and real-time data analysis, healthcare systems can become more patient-centric and effective. Future research should address challenges like data security, interoperability, and accessibility to ensure broader adoption of these technologies and drive global advancements in healthcare.

Future enhancements may include AI-based diagnostics, robotic automation, and expanded IoT functionalities for even more comprehensive healthcare management. Overall, this smart healthcare system significantly contributes to better patient outcomes, reduced hospital workload, and improved emergency response capabilities.

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