

Smart Hospital Bed Occupancy and Patient Monitoring System Using IoT

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Abstract: Patient safety and continuous monitoring are essential in modern healthcare systems, especially for elderly and bedridden patients who require constant supervision. Traditional monitoring methods rely on manual observation by healthcare staff, which may lead to delayed response in emergency situations such as patient falls or prolonged immobility. This paper presents a Smart Hospital Bed Occupancy and Patient Monitoring System using IoT that enhances patient safety through automated monitoring. The proposed system integrates load cell sensors for detecting bed occupancy, motion sensors for monitoring patient movement, and physiological sensors for measuring basic health parameters such as temperature and pulse rate. An ESP32 microcontroller processes sensor data and transmits it to a cloud platform using IoT technology for real-time remote monitoring. When abnormal conditions such as sudden bed exit or prolonged inactivity are detected, the system generates alerts through buzzer notifications and IoT updates.

Keywords: IoT Healthcare, Smart Hospital Bed, Patient Monitoring System, Bed Occupancy Detection, ESP32, Embedded Systems, Real-Time Healthcare Monitoring, Load Cell Sensor, Remote Patient Monitoring.

I. INTRODUCTION

Healthcare monitoring systems play a critical role in ensuring patient safety and improving treatment outcomes. Patients who are elderly, disabled, or recovering from surgery often require continuous supervision to prevent accidents such as falling from hospital beds or remaining immobile for long periods. These situations may lead to severe injuries and delayed medical attention. Traditional hospital monitoring systems rely on nurses and caregivers to manually observe patients. However, continuous manual monitoring is difficult in busy hospital environments where a single nurse may be responsible for multiple patients. Recent advancements in embedded systems and Internet of Things (IoT) technology have enabled the development of smart healthcare monitoring systems. These systems use sensors and microcontrollers to continuously monitor patient conditions and provide alerts when abnormal situations occur. With the advancement of sensor technologies, researchers introduced pressure-based and load-based monitoring systems to detect bed occupancy in hospitals. Smart hospital beds equipped with sensing technologies can provide valuable information about patient presence, movement, and basic health parameters. These systems help healthcare professionals monitor patients remotely and respond quickly in case of emergencies. In addition, automated monitoring systems can reduce the workload of healthcare staff while improving patient safety and care quality. The system also generates alerts when abnormal conditions such as sudden bed exit, prolonged immobility, or abnormal sensor readings are detected. Healthcare professionals can monitor the patient's condition remotely through an IoT dashboard, enabling faster response and improved patient care

II. LITERATURE REVIEW

[1] Early healthcare monitoring systems mainly focused on measuring basic physiological parameters such as body temperature, heart rate, and blood pressure. These systems were commonly used in hospitals and intensive care units to observe patient health conditions. However, these traditional monitoring systems required manual observation by healthcare staff and lacked automated alert mechanisms. As a result, situations such as sudden patient movement, bed exit, or prolonged inactivity could not be detected automatically, which sometimes led to delayed medical response and increased risk for patients. [2] With the advancement of sensor technologies, researchers introduced pressure-based and load-based monitoring systems to detect bed occupancy in hospitals.

These systems used sensors such as pressure mats and load cells placed under hospital beds to identify whether a patient was present on the bed. Such systems helped in detecting patient presence and absence, thereby assisting healthcare staff in monitoring bedridden patients. However, these systems were limited in functionality because they only detected bed occupancy and did not provide information about patient health conditions or movement patterns.[3] In recent years, the development of the Internet of Things (IoT) has significantly improved healthcare monitoring systems. IoT technology allows sensors, microcontrollers, and communication devices to connect through the internet and share data in real time. Researchers have developed IoT-based patient monitoring systems that continuously collect physiological data such as temperature, heart rate, and oxygen levels and transmit the information to Cloud platforms. [4] Several studies have also explored motion detection systems to monitor patient activity and detect abnormal situations such as falls or prolonged inactivity. Motion sensors such as PIR sensors and accelerometers have been widely used in healthcare monitoring systems to detect patient movements. These sensors help identify whether a patient is moving normally or experiencing unusual inactivity, which may indicate a potential health issue.[5] Recent research efforts have attempted to combine multiple monitoring techniques into integrated healthcare systems. These systems use a combination of sensors, microcontrollers, and IoT communication modules to monitor different aspects of patient health and safety. For example, some systems integrate temperature sensors, pulse sensors, and pressure sensors to monitor both patient health parameters and bed occupancy status.[6] Despite these advancements, many existing healthcare monitoring systems remain expensive, complex, or difficult to implement in small hospitals and home healthcare environments. High equipment costs, complicated installation procedures, and high-power consumption are some of the major limitations of current systems. Therefore, there is a need for a cost-effective, reliable, and easy-to-implement healthcare monitoring system that can monitor patient presence, movement, and basic health parameters simultaneously. The proposed Smart Hospital Bed Occupancy and Patient Monitoring System using IoT addresses these limitations by integrating load cell sensors, motion sensors, and physiological sensors with an ESP32 microcontroller. The system uses IoT technology to transmit real-time data to a cloud platform, enabling remote monitoring and quick response from healthcare professionals. [7] wearable sensor-based healthcare monitoring systems have become an important technology for continuous health observation. Their research presents a comprehensive survey of wearable sensor systems used for monitoring physiological parameters such as heart rate, body temperature, and physical activity. These systems use wireless communication technologies to collect health data from patients and transmit it to monitoring devices or healthcare servers.[8] proposed a secure healthcare monitoring framework called BSN-Care, which is based on Internet of Things (IoT) technology and body sensor networks. Their system uses multiple biomedical sensors connected through wireless communication networks to monitor patient health parameters continuously. The collected health data is transmitted to healthcare servers where doctors can analyze patient conditions remotely. The authors also focused on improving the security of medical data transmission to protect sensitive patient information from unauthorized access. Their research demonstrates that IoT-based healthcare monitoring systems can improve remote patient monitoring and healthcare management. However, the system mainly focuses on physiological parameter monitoring and does not address hospital bed occupancy detection or patient movement monitoring in healthcare environments.[9] the Internet of Things (IoT) has emerged as a promising technology for improving healthcare monitoring systems. Their research presents a comprehensive survey on IoT-based healthcare applications and explains how interconnected devices, sensors, and communication networks can be used to continuously monitor patient health conditions. IoT technology allows medical devices to collect physiological data such as heart rate, temperature, and other health parameters and transmit the information to cloud platforms for remote monitoring. [10] discussed wearable and implantable wireless sensor network solutions for healthcare monitoring. Their research focuses on the use of wireless sensor networks (WSNs) for collecting and transmitting patient health data in real time.

III. BLOCK DIAGRAM



Fig: 3.1 Block Diagram

These systems consist of multiple sensors that are attached to or implanted in the human body to monitor vital parameters continuously. The collected data is transmitted through wireless communication networks to healthcare monitoring systems where doctors can analyze patient conditions. The study demonstrates that wireless sensor networks provide an effective solution for continuous patient monitoring and early detection of health problems.

III. METHODOLOGY

The methodology of the proposed Smart Hospital Bed Occupancy and Patient Monitoring System using IoT focuses on developing an intelligent monitoring solution that improves patient safety in hospitals. The system integrates sensor-based monitoring, embedded processing, and IoT communication to detect patient presence, monitor movement, and measure basic physiological parameters.

A. System Design and Architecture

The proposed system is designed as a smart healthcare monitoring system that helps healthcare professionals monitor patients more efficiently. The architecture consists of three main modules: sensing module, processing module, and communication module. The processing module consists of the ESP32 microcontroller, which receives sensor data and performs necessary processing. The microcontroller analyzes sensors readings and compares them with predefined threshold values to determine whether the patient is in a normal or abnormal condition. Hardware Components. The communication module is responsible for transmitting the processed data to an IoT cloud platform through Wi-Fi connectivity. This enables remote monitoring through mobile devices or web dashboards. If abnormal situations occur, the system generates alerts through buzzer signals and IoT notifications. The processing unit performs data analysis and machine learning inference. A compact and energy-efficient processor is used to ensure portability and long battery life. The GPS module supports outdoor navigation by providing location and route information. Vibration motors and audio devices deliver alerts and instructions to the user.

B. Data Acquisition and Preprocessing

The system continuously collects data from the sensors to monitor patient activity and health parameters. Sensor readings are transmitted to the ESP32 microcontroller where the data is analysed and processed. The load cell sensor measures the weight applied on the hospital bed to determine whether the patient is present or has left the bed. The motion sensor detects movement patterns to determine whether the patient is active or inactive for an extended period. Before analysis, the collected sensor data undergoes preprocessing to remove noise and improve measurement accuracy. Filtering techniques are applied to ensure reliable sensor readings and reduce false alarms. The processed data is then transmitted to the IoT platform through wireless communication. Healthcare professionals can access the data through an IoT dashboard and monitor the patient's condition remotely. If abnormal conditions such as sudden bed exit or prolonged inactivity are detected, the system generates alerts through both local alarm systems and remote notifications.

C. Sensor-Based Patient Monitoring

The proposed system uses sensor-based monitoring to detect patient presence, movement, and basic physiological parameters in real time. Instead of camera-based vision systems, the system relies on embedded sensors that provide reliable and cost-effective monitoring within the hospital bed environment. A load cell sensor is placed under the hospital bed to detect bed occupancy by measuring weight changes. This allows the system to determine whether the patient is present on the bed or left unexpectedly.

D. Communication System

The Internet of Things (IoT) plays a significant role in enabling real-time healthcare monitoring. The proposed system uses the ESP32 microcontroller with built-in Wi-Fi capability to transmit sensor data to an IoT cloud platform. This allows healthcare professionals to monitor patient conditions remotely through mobile devices or web dashboards. The system continuously sends information such as bed occupancy status, body temperature, pulse rate, and patient movement data to the IoT platform. These parameters are displayed on a dashboard interface where doctors and nurses can easily observe patient conditions in real time. When abnormal conditions such as sudden bed exit, unusual movement patterns, or abnormal physiological readings are detected, the system immediately sends notifications through the IoT platform.

E. Patient Monitoring and Decision Making

The patient monitoring module analyses sensor data to determine the condition of the patient. The system receives data from multiple sensors such as load cell sensors, motion sensors, temperature sensors, and pulse sensors. When the load cell sensor detects a sudden decrease in weight on the hospital bed, the system identifies that the patient has left the bed unexpectedly. Similarly, if the motion sensor detects prolonged inactivity, it may indicate that the patient requires medical attention. The system uses predefined threshold values to analyze sensor data and determine whether the patient's condition is normal or abnormal. Based on the analysis, the system triggers alerts or notifications to healthcare staff.

F. Alert and Notification Mechanism

The proposed system includes an alert and notification mechanism to ensure that abnormal conditions are detected and communicated effectively. The alert system consists of both local alerts and remote IoT notifications. Local alerts are generated through a buzzer and LED indicators connected to the ESP32 microcontroller. When abnormal conditions such as bed exit or prolonged inactivity are detected, the buzzer produces an audible alert, and the LED provides visual indication.

G. Testing and Evaluation

The system is tested in different ways to evaluate its performance and reliability. Various test scenarios are conducted to observe the behavior of the monitoring system under different conditions. Testing includes verifying the accuracy of bed occupancy detection using the load cell sensor, monitoring patient movement using motion sensors, and measuring physiological parameters such as body temperature and pulse rate.

Expected Outcome

The proposed system is expected to improve patient safety and healthcare monitoring in hospitals and medical care facilities. By integrating sensors, embedded systems, and IoT communication, the system provides continuous monitoring of patient activity and health parameters.

The system helps healthcare professionals detect abnormal conditions such as sudden bed exit, prolonged immobility, and abnormal health readings. This enables faster medical response and reduces the risk of patient accidents.

IV. RESULT

The proposed smart hospital bed monitoring system was developed and tested to evaluate its performance in monitoring patient activity and health conditions. The system successfully detected bed occupancy using the load cell sensor and monitored patient movement using motion sensors. The temperature and pulse sensors provided real-time physiological data, which was transmitted to the IoT platform through the ESP32 microcontroller.

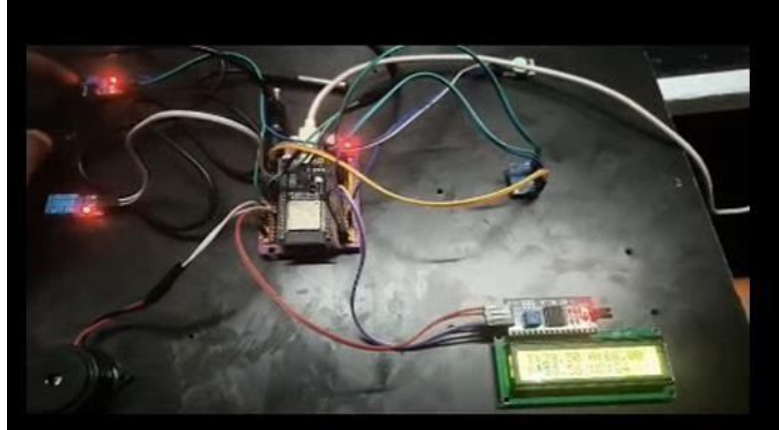


Fig:4.1 Output

During testing, the system achieved reliable detection of bed occupancy and patient movement. Alerts were generated quickly when abnormal situations such as bed exit or prolonged inactivity were detected. Experimental results demonstrate that the proposed system improves patient safety, reduces the workload of health care staff, and provides efficient real-time monitoring in healthcare environments. The experimental results demonstrate that the proposed monitoring system provides an efficient and reliable solution for patient safety in hospital environments. By integrating sensor technology, embedded systems, and IoT communication, the system improves patient monitoring, reduces the workload of healthcare staff, and enhances overall healthcare efficiency.

V. CONCLUSION AND FUTURE SCOPE

The proposed Smart Hospital Bed Occupancy and Patient Monitoring System using IoT presents an effective and reliable solution for improving patient safety and healthcare monitoring in hospital environments. The system integrates multiple sensors, embedded processing, and IoT communication to continuously monitor patient presence, movement, and basic physiological parameters. By using sensors such as load cell sensors, motion sensors, temperature sensors, and pulse sensors, the system can detect important patient conditions including bed occupancy, patient movement, and health status. The ESP32 microcontroller processes sensor data and transmits the information to an IoT platform through Wi-Fi communication. This enables healthcare professionals to monitor patient conditions remotely in real time. The system also includes an alert mechanism that generates notifications when abnormal conditions such as sudden bed exit, prolonged inactivity, or unusual health readings are detected. These alerts help medical staff respond quickly and provide timely assistance to patients, thereby reducing the risk of accidents and improving patient care.

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