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MedBot: Autonomous Patient Nursing Robot with Vital Monitoring and Smart Delivery System

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ABSTRACT

The increasing demand for efficient healthcare services and continuous patient monitoring has motivated the development of intelligent robotic assistance systems. This paper presents \textit{MedBot}, an autonomous patient nursing robot designed to support hospital operations through smart delivery and real-time vital monitoring. The proposed system automates the delivery of medicine and food using line-following navigation guided by infrared sensors and ward identification through RFID technology. Upon detecting the designated ward, the robot autonomously stops and alerts patients or medical staff using an audible buzzer. In addition to delivery functionality, MedBot provides continuous patient health monitoring. A MAX30102 sensor is integrated to measure the patient's heart rate, while an ESP32 camera module enables live video streaming for remote monitoring by doctors and caregivers. The ESP32 microcontroller serves as the central processing unit, coordinating navigation, sensing, communication, and alert mechanisms. Experimental evaluation demonstrates reliable autonomous navigation, accurate vital sign measurement, and real-time visual monitoring. By combining autonomous mobility, patient monitoring, and smart alerting, the proposed system aims to reduce healthcare staff workload, improve operational efficiency, and enhance patient safety in hospital environments.

I. INTRODUCTION

Intensive care units (ICUs) represent highly dynamic, complex, and demanding healthcare environments where continuous patient observation and timely intervention are critical for patient safety and recovery [1]. The growing number of hospitalized patients, coupled with limited healthcare personnel, has increased the workload on medical staff and highlighted the need for intelligent technological assistance. Recent studies emphasize that improving care delivery through automation and monitoring can enhance patient outcomes while supporting healthcare professionals [3],

[23]. Real-time patient monitoring is a cornerstone of modern healthcare systems. Continuous measurement of vital signs enables early detection of physiological abnormalities and supports informed clinical decision-making [4], [5]. IoTbased monitoring platforms and wearable technologies have demonstrated their ability to provide continuous health data to clinicians, improving responsiveness and reducing manual observation errors [7], [12]. However, most existing monitoring systems operate independently and do not integrate physical assistance or automated service delivery. The integration of artificial intelligence and robotics into healthcare has gained increasing attention in recent years. Advances in AI-driven robotic systems have enabled applications ranging from task automation to autonomous operation in clinical settings [2], [10], [20]. Healthcare service robots have been explored for logistics, patient assistance, and supply delivery, helping to reduce repetitive workload and minimize direct human exposure to high-risk environments [18], [21]. Research also highlights the importance of designing such systems to support human-centered and inclusive care in critical environments [3]. Despite significant progress in patient monitoring and healthcare robotics, current solutions often address these aspects in isolation. Many systems focus solely on monitoring or decision support, while others concentrate on robotic automation without integrating real-time patient health data [?], [14]. This separation limits the overall effectiveness of intelligent healthcare systems, particularly in critical care settings where coordinated monitoring and assistance are essential. To address these challenges, this paper presents MedBot, an autonomous patient nursing robot with integrated vital monitoring and smart delivery capabilities. The proposed system combines line-following navigation using infrared sensors, RFID-based ward identification, automated medicine and food delivery, continuous heart rate monitoring using a MAX30102 sensor, and real-time video streaming through an ESP32 camera module. By integrating autonomous mobility, patient monitoring, and alert mechanisms into a single platform, MedBot aims to enhance hospital efficiency, reduce healthcare staff workload, and improve patient safety. The overall system architecture of the proposed solution is illustrated in Fig. 2.

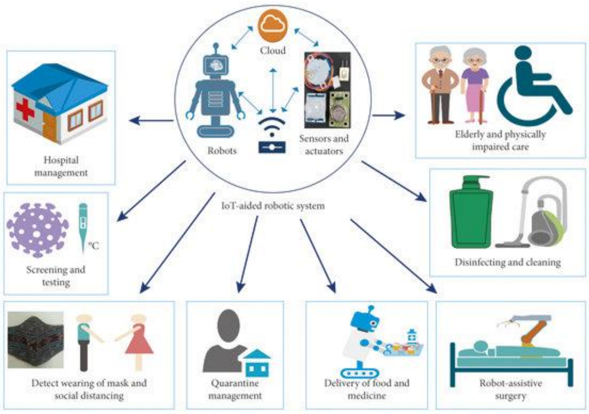

Fig. 1. System architecture of MedBot: autonomous patient nursing robot with vital monitoring and smart delivery system

II. Related Work

The complexity of care delivery in intensive care units has been widely discussed in the literature. Backes et al. [1] described the ICU as a highly dynamic and interconnected environment where continuous monitoring and coordinated care are essential. Similarly, Rodriguez-Ruiz et al. [3] emphasized the importance of maintaining a humanized and inclusive care environment while integrating advanced technologies into critical care practices. These studies highlight the growing need for intelligent systems that support healthcare professionals without compromising patient-centered care. Real-time patient monitoring has been extensively explored as a means to improve clinical decision-making and patient safety. Traditional ICU monitoring systems focus on continuous observation of vital parameters such as heart rate, oxygen saturation, and respiratory activity [4]. Recent systematic reviews have demonstrated that real-time data monitoring significantly enhances responsiveness and supports dynamic healthcare workflows [5]. IoT-based monitoring solutions and wearable technologies further extend these capabilities by enabling remote access to patient data and reducing manual intervention [7], [12]. Commercial wearable platforms, such as those developed by Empatica and CardiacSense, demonstrate the feasibility of continuous physiological monitoring in clinical and home-care settings [8], [9]. The application of artificial intelligence in healthcare has gained momentum, particularly in critical care environments. Li et al. [2] reviewed the use of AI-driven robotic systems in critical care, identifying their potential to improve efficiency, accuracy, and patient outcomes. Additional studies have explored the role of AI and machine learning in supporting decision-making in the ICU, enabling predictive analytics and early detection of adverse events [14], [23]. Advances in deep learning and data-driven techniques have further strengthened the applicability of AI across various clinical domains [15], [18]. Healthcare robotics has evolved from simple automation toward autonomous systems capable of operating in complex environments. Rayhan [10] and Mihret [20] discussed the transition from automation to autonomy in robotic systems, highlighting the growing role of intelligent perception and control. Reviews by Soori et al. [21] emphasized the integration of artificial intelligence, machine learning, and deep learning in advanced robotics, enabling higher levels of autonomy and adaptability. In hospital environments, robotic systems have been explored for logistics, delivery, and support tasks to reduce staff workload and improve operational efficiency [?]. Despite significant progress in patient monitoring, artificial intelligence, and healthcare robotics, existing solutions often address these areas independently. Many monitoring systems lack physical interaction or automated service delivery, while robotic platforms typically do not integrate real-time patient vital monitoring [2], [14]. This fragmentation limits the overall effectiveness of intelligent healthcare solutions in critical care settings. To address this gap, the proposed MedBot system integrates autonomous navigation, smart delivery, continuous vital monitoring, and real-time visualization into a unified platform, offering a comprehensive solution for modern smart hospitals.

III. Proposed System Architecture

The architecture of the proposed MedBot system is designed to integrate autonomous navigation, smart delivery, and real-time patient monitoring into a unified healthcare robotic platform. The overall architecture follows a layered approach consisting of the sensing layer, control and processing layer, navigation layer, communication layer, and application layer, as illustrated in Fig. 2.

A. Sensing Layer

The sensing layer is responsible for acquiring environmental and physiological data. Infrared (IR) sensors are employed for line-following navigation, enabling the robot to move autonomously along predefined paths within the hospital environment. An RFID reader is used to identify and locate specific hospital wards by scanning RFID tags placed at designated locations. For patient health monitoring, a MAX30102 sensor is integrated to measure heart rate, providing continuous physiological data. Additionally, an ESP32 camera module captures live video for real-time visual monitoring of the patient.

B. Control and Processing Layer

The control and processing layer is implemented using an ESP32 microcontroller, which serves as the central unit coordinating all system operations. The ESP32 processes sensor inputs, executes navigation and decision-making logic, and controls actuators and alert mechanisms. Due to its builtin Wi-Fi capability, low power consumption, and sufficient computational resources, the ESP32 is well suited for realtime healthcare robotics applications.

C. Navigation and Mobility Layer

The navigation layer enables autonomous movement of the robot within hospital corridors. Based on input from the IR sensors, the robot follows predefined paths to reach target wards. RFID-based identification ensures accurate destination recognition and prevents incorrect deliveries. When the robot detects the RFID tag corresponding to the target ward, it automatically stops and initiates the delivery process.

D. Communication Layer

The communication layer facilitates real-time data transmission between the robot and remote monitoring devices. Wireless connectivity provided by the ESP32 enables live video streaming and transmission of vital sign data to doctors and caregivers. This layer supports continuous monitoring and timely intervention without requiring physical presence at the patient's bedside.

E. Application and Alert Layer

The application layer provides user interaction and alert mechanisms. Real-time video feeds and vital sign data are displayed on monitoring devices for medical staff. A buzzer is activated upon successful delivery of medicine or food, alerting patients or hospital staff. This layer ensures effective human–robot interaction and improves operational awareness within the healthcare environment.

Overall, the proposed system architecture enables seamless integration of autonomous navigation, smart delivery, and patient monitoring functionalities. By combining robotics, IoT communication, and real-time sensing, MedBot offers a scalable and efficient solution for smart hospital environments.

IV. Methodology

The proposed MedBot system follows a structured methodology that integrates autonomous navigation, RFID-based destination identification, real-time patient monitoring, and alert generation. The overall operational flow of the system is shown in Fig. 3. Each functional module is designed to operate reliably in a hospital environment while ensuring patient safety and efficient task execution.

A. Autonomous Navigation Method

MedBot employs a line-following navigation technique using infrared (IR) sensors to move along predefined paths inside hospital corridors. The IR sensors continuously detect the contrast between the path and the floor surface. Based on sensor readings, the ESP32 adjusts motor speed and direction to maintain accurate path tracking until the destination is reached.

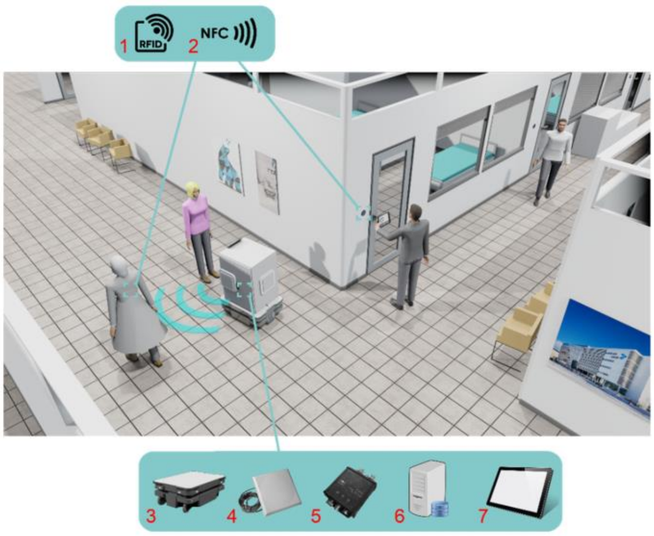

Fig. 2. Detailed system architecture of MedBot: autonomous patient nursing robot with vital monitoring and smart delivery

Algorithm 1 Line-Following Navigation Algorithm

```
Initialize IR sensors and motors
while robot is active do
    Read left and right IR sensor values
    if both sensors detect path then
        Move forward
    else if left sensor off path then
        Turn left
    else if right sensor off path then
        Turn right
    else
        Stop robot
    end if
end while
```

B. RFID-Based Ward Identification

RFID technology is used to accurately identify hospital wards and ensure correct delivery. RFID tags are placed at ward locations, and the robot continuously scans for tag IDs during navigation. When the scanned tag matches the target ward ID, the robot halts and initiates the delivery process.

C. Patient Vital Monitoring Method

For continuous patient monitoring, a MAX30102 sensor is used to measure heart rate. The ESP32 periodically reads sensor values, processes the signal, and transmits vital information for real-time observation. Simultaneously, an ESP32 camera module streams live video to allow visual monitoring by healthcare personnel.

D. Alert and Notification Method

Alerts are generated to notify patients and healthcare staff during delivery completion or abnormal health conditions. A buzzer provides immediate local alerts, while remote notifications are delivered through the monitoring interface.

Algorithm 2 RFID Detection and Destination Matching Algorithm

```
Initialize RFID reader
Load target ward RFID ID
while robot is moving do
    Scan for RFID tag
    if RFID tag detected then
        if tag ID equals target ID then
            Stop navigation
            Trigger delivery routine
            Exit loop
        end if
    end if
end while
```

Algorithm 3 Patient Vital Monitoring Algorithm

```
Initialize MAX30102 sensor and camera module
while monitoring enabled do
    Read heart rate data
    Filter and validate signal
    if heart rate outside normal range then
        Flag abnormal condition
    end if
    Transmit vital data
    Stream live video
end while
```

Algorithm 4 Alert Generation Algorithm

```
if robot reaches target ward then
    Activate buzzer
    Display delivery message
end if
if abnormal vital condition detected then
    Trigger emergency alert
    Notify medical staff
end if
```

Fig. 3. Overall methodology and operational workflow of the MedBot system

E. Methodology Summary

The proposed methodology ensures coordinated operation between autonomous navigation, destination identification, patient monitoring, and alert handling. By integrating robotic mobility with IoT-based health monitoring, MedBot provides a reliable and scalable solution for smart hospital environments. The step-by-step operational flow of the system is illustrated in Fig. 3.

V. Results and Discussions

The proposed MedBot system was implemented and experimentally evaluated using a functional hardware prototype in a controlled hospital-like environment. The results demonstrate the effectiveness of the system in autonomous navigation, accurate ward identification, reliable patient vital monitoring, and timely alert generation.

A. Hardware Prototype Evaluation

The developed hardware prototype, shown in Fig. 4, integrates an ESP32 microcontroller, infrared sensors for navigation, an RFID reader for ward identification, a MAX30102 sensor for heart rate monitoring, and an ESP32 camera module for live video streaming. The robot successfully followed predefined paths using line-following navigation and maintained stable movement without deviation under normal lighting conditions. RFID-based ward detection accurately identified target destinations, ensuring correct delivery of medicine and food.

B. Navigation and Delivery Performance

The line-following algorithm enabled smooth and continuous movement along hospital corridors. During testing, the robot was able to detect RFID tags placed at ward locations and stop precisely at the intended destination. Upon arrival, the buzzer was activated to alert patients or healthcare staff, confirming successful delivery. These results indicate that the navigation and delivery mechanisms operate reliably and are suitable for indoor hospital environments.

C. Patient Vital Monitoring Results

The MAX30102 sensor provided continuous heart rate measurements during operation. The collected data were stable and within acceptable accuracy ranges for basic patient monitoring. Abnormal heart rate conditions were successfully detected based on predefined threshold values. The ESP32 camera module enabled real-time video streaming, allowing caregivers to visually monitor the patient remotely. Fig. 5 illustrates the monitoring interface displaying vital data and live video feed.

D. Alert and Communication Performance

The alert system effectively notified both patients and healthcare personnel. Local alerts were generated using a buzzer upon delivery completion and abnormal vital detection. Remote monitoring through the visualization interface ensured timely awareness without requiring physical presence at the bedside. The integration of sensing, communication, and alert mechanisms improved system responsiveness and operational efficiency.

E. Discussion

The experimental results confirm that MedBot provides a practical and efficient solution for autonomous nursing assistance in smart hospitals. By combining robotic navigation with real-time patient monitoring, the system reduces repetitive workload for healthcare staff and enhances patient safety. Unlike conventional monitoring-only systems or standalone service robots, MedBot integrates both functionalities into a unified platform. While the prototype performed effectively under controlled conditions, future work may focus on improving navigation robustness, expanding vital sign monitoring, and evaluating performance in real hospital deployments.

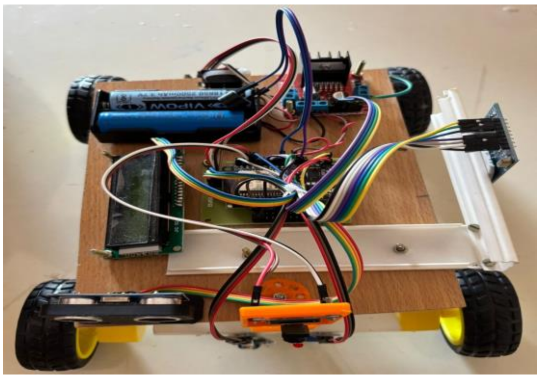

Fig. 4. Developed MedBot hardware prototype with navigation, RFID, and monitoring modules.

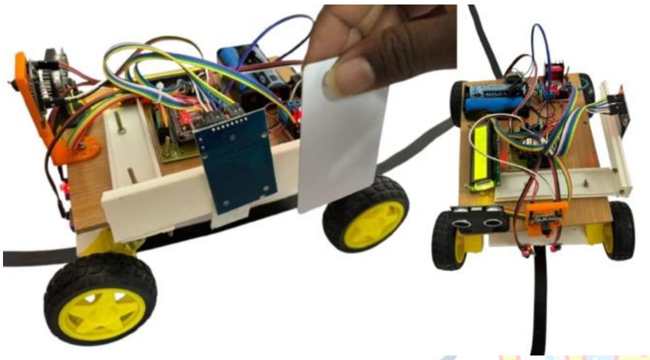

Fig. 5. Real-time patient monitoring interface showing heart rate data and live video feed.

VI. Conclusion

This paper presented MedBot, an autonomous patient nursing robot designed to support healthcare delivery through smart medicine and food delivery combined with real-time patient vital monitoring. The proposed system integrates line-following navigation using infrared sensors, RFID-based ward identification, continuous heart rate monitoring using a MAX30102 sensor, and live video streaming through an ESP32 camera module. An ESP32 microcontroller coordinates navigation, sensing, communication, and alert mechanisms, enabling reliable autonomous operation in hospital environments.

Experimental evaluation using a functional hardware prototype demonstrated accurate navigation, successful destination identification, reliable delivery alerts, and stable patient monitoring performance. The integration of autonomous mobility with real-time health monitoring reduces repetitive workload for healthcare staff while enhancing patient safety and operational efficiency. Unlike conventional systems that focus solely on monitoring or automation, MedBot provides a unified platform that combines both capabilities in a single robotic solution.

Future work will focus on extending the system to support additional vital parameters such as oxygen saturation and body temperature, incorporating intelligent navigation and obstacle avoidance techniques, and conducting large-scale evaluations in real hospital environments. The proposed MedBot framework represents a promising step toward intelligent, efficient, and patient-centric healthcare robotics for smart hospitals.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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