IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⁙ Peer-reviewed & Refereed journal ⁙ Vol. 14, Issue 12, December 2025

DOI: 10.17148/IJARCCE.2025.141248

AI-Driven Healthcare Robot For Medication Delivery And Personal Care Assistance

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Abstract: This project introduces an AI-based healthcare robot designed using an Arduino Mega to automate medication delivery and personal care in hospitals and homecare environments. The robot integrates MAX30102 (SPO2) and temperature sensors for real-time health monitoring, an ultrasonic sensor for safe navigation, and a webcam for continuous patient observation and visual feedback. Health data is shown on an LCD display and wirelessly transmitted through Bluetooth/Zigbee for remote monitoring. The APR voice module supports verbal communication, enhancing user interaction. Equipped with motors, a relay-pump mechanism, and smart control, it reduces human workload, promotes contactless healthcare, and provides a reliable, low-cost medical assistant.

Keywords: AI healthcare robot, Arduino Mega, Webcam monitoring, MAX30102 sensor, APR voice module, Wireless communication, Human-robot interaction, Contactless care, Smart healthcare system.

I. INTRODUCTION

In the wake of global health crises and increasing demand for automation in healthcare, the integration of robotics and artificial intelligence has become essential to ensure the safety of medical professionals and enhance operational efficiency. This project proposes a smart AI-powered personal care robotic assistant designed specifically for hospital environments. Its main goal is to reduce direct human involvement in routine yet critical tasks such as patient monitoring, medication delivery, sanitation, and real-time communication, particularly in scenarios involving infectious diseases.

The system incorporates multiple sensors and modules to achieve its objectives. A temperature sensor and SPO2 sensor (MAX30102) are used to continuously monitor patient vital signs such as body temperature, heart rate, and blood oxygen saturation levels. An ultrasonic sensor ensures safe navigation by detecting obstacles in the robot's path, making it suitable for mobility in hospital wards or patient rooms. Additionally, an ESP32-CAM module is used for real-time image capturing and facial recognition, enabling the robot to identify patients accurately before delivering medicines or providing assistance. This feature ensures safety and personalization in patient care.

The proposed system is designed to provide multiple benefits, including reduced dependency on healthcare workers for routine tasks, contactless monitoring during critical conditions such as pandemics, and assistance for elderly or disabled patents.

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II. METHODOLOGY

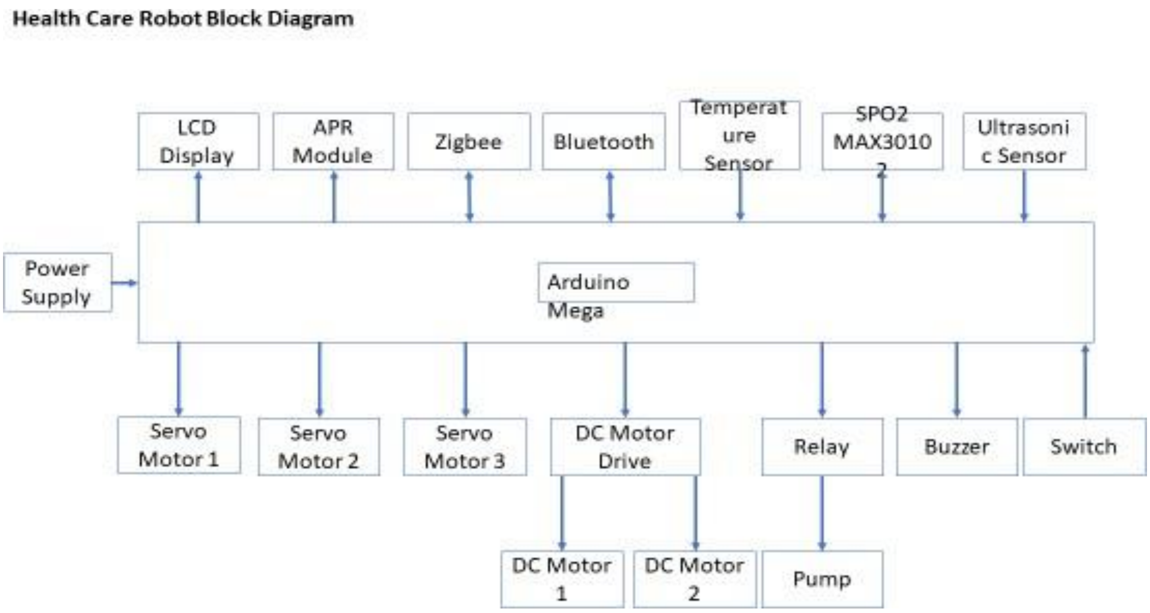

Fig 1: Block Diagram of Healthcare Robot

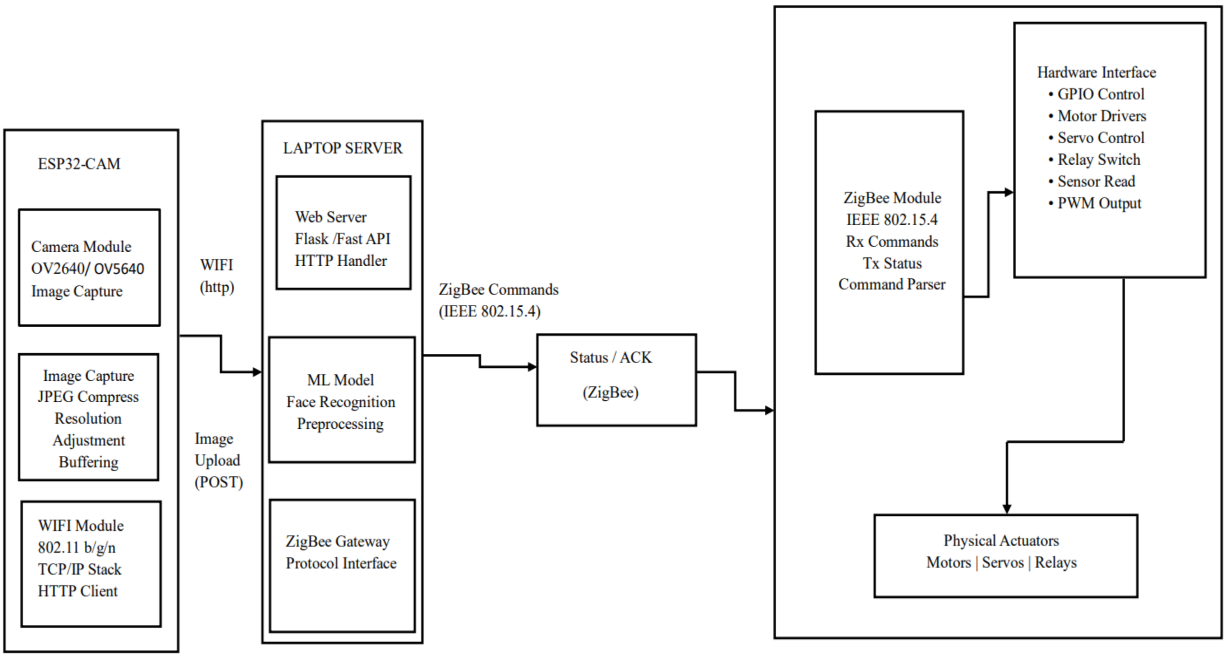

Fig 2: Image capturing through ESP32 Webcam and Face Recognition System

The methodology for developing the AI-Driven Healthcare Robot for Medication Delivery and Personal Care Assistance involves a systematic process covering system design, hardware integration, software implementation, communication setup, testing, and future enhancement. The goal is to create an intelligent, low-cost robotic system capable of monitoring patient health, delivering medicines, and supporting hospital automation.

III. METHODS AND MATERIALS

1. System Design:

The architecture of the robot is built around the Arduino Mega 2560 as the main controller, which coordinates all sensor inputs, motor operations, and wireless communication modules. The design integrates biomedical sensors such

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as the MAX30102 SPO2 sensor for heart rate and oxygen level detection, and an LM35 temperature sensor for body temperature measurement. An ultrasonic sensor provides obstacle avoidance for safe navigation.

For visual monitoring and identity verification, an ESP32-CAM module is used to capture images and perform face recognition through Wi-Fi connectivity. The robot also integrates Bluetooth and Zigbee modules for wireless communication with caregivers, and an APR voice module to enable simple voice-based interaction with patients.

2. Hardware Implementation:

All sensors and modules are interconnected through the Arduino controller. The L298N motor driver manages the movement of DC and servo motors, ensuring smooth navigation and controlled operation of the delivery tray. A relay-pump unit automates sanitizer or liquid dispensing, while the power supply unit provides stable voltage levels to each component. The robot's design ensures energy efficiency, reliability, and ease of maintenance.

3. Software Implementation:

Programming is carried out using the Arduino IDE for sensor control and robot operation, and Python with OpenCV for image processing and facial recognition. The ESP32-CAM streams real-time video over Wi-Fi, and Python scripts handle data processing and visualization. The system logic includes threshold detection for abnormal health readings, automatic alerts, and motion control, ensuring intelligent and responsive robot behaviour.

4. Communication and Control:

Wireless communication is achieved using Zigbee for short-range hospital networking and Bluetooth for direct connectivity with mobile devices. The ESP32-CAM extends connectivity through Wi-Fi, enabling remote video monitoring. An LCD display presents real-time readings of vital parameters, allowing quick review by healthcare staff and enhancing situational awareness.

5. ESP32 Face Recognition Operation:

The ESP32-CAM module captures a patient's facial image and compares it with pre-stored data using OpenCV algorithms. This ensures that each patient is correctly identified before receiving medication, preventing delivery errors and improving operational safety.

Materials

1. Hardware

- Microcontroller: Arduino Mega 2560 / Raspberry Pi.
- Motors: DC motors with motor driver (L298N).
- Sensors: o LM35/DS18B20 (Temperature) o MAX30102 (SpO_2 & Heart rate) o Ultrasonic sensors (obstacle avoidance).
- Camera: USB webcam or ESP32-CAM.
- LCD Display
- Zigbee Module
- Bluetooth Module (HC-05)
- APR Voice Module:
- Relay-controlled sanitizer spray mechanism.
- Push button /Buzzer for emergency stop.
- Switch
- Power Supply

2. Software

- Python + OpenCV (Face detection and recognition).
- Arduino IDE / Micro Python.

IV. IMPLEMENTATION

AI-driven healthcare robot for medication delivery and personal care assistance requires a multi-phased approach focusing on defining needs, development, validation, and integration into existing clinical workflows. This process must navigate significant technical, ethical, and regulatory challenges to be successful.

Implementation Steps:

1. **Assemble a Multidisciplinary Team**: Involve clinicians, patients, developers, engineers, ethicists, and legal experts in the design process to ensure a human-centred approach that addresses real-world needs and concerns.
2. **Data Collection and Preparation**: Gather high-quality, diverse medical data (EHRs, images, sensor data) to train the AI models. Ensure data is properly anonymized and securely stored to comply with privacy regulations like HIPAA and GDPR.

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3. **Hardware and Software Development**: Develop the robotic platform with necessary components, including navigation systems (sensors, cameras, mapping), manipulation capabilities (robotic arms for delivery), interaction modules (voice recognition, displays), and a power management system (auto-recharging).
4. **AI Model Training and Integration**: Train AI models for specific functions like facial recognition for accurate patient identification, natural language processing for communication, and predictive analytics for health monitoring. Integrate these AI systems seamlessly with the robot's hardware and existing hospital IT infrastructure (EHR/HIS systems).
5. **Testing and Validation**: Conduct rigorous testing in both simulated and real-world environments to ensure safety, reliability, and accuracy. This includes functional testing, security testing, and clinical validation to demonstrate effectiveness and safety in patient care.
6. **Address Regulatory and Ethical Considerations**: Ensure compliance with relevant health and safety standards and seek necessary certifications (e.g., FDA approval for medical devices). Establish clear ethical guidelines and legal frameworks, particularly regarding data privacy, accountability in case of errors, and the robot's role in human interaction.
7. **Pilot Program and Phased Rollout**: Begin with a controlled pilot program involving a selected group of users to gather feedback and identify potential issues. Use a phased approach for broader deployment based on the pilot's success.
8. **Training and Ongoing Support**: Provide comprehensive training for healthcare workers and patients on how to interact with and operate the robot effectively. Continuously monitor the system's performance, provide regular software updates, and offer ongoing support to address any emerging issues
9. **Define the Use Case and Goals**: Clearly define the specific problems the robot will solve (e.g., reducing medication errors, freeing up nursing time, providing companionship) and the target environment (e.g., hospital wards, assisted living facilities, private homes).
10. **Deployment and Maintenance:** Deploy the robot in healthcare settings, such as hospitals, nursing homes, or patient homes. Provide ongoing maintenance, updates, and training for healthcare staff.

V. RESULT

1. Mechanical Structure & Internal Electronics

Fig 1: Mechanical & System Output

a. External View
- The robot's outer structure houses sensors, LCD modules, and dispensing drawers.
- A clean visual indication system with LED markers was operational.

b. Internal Electronics
- Wiring includes Arduino, Raspberry Pi, motor drivers, HeartBeat sensors, temperature sensors, and servo mechanisms.
- The internal electronics were fully operational, with stable power distribution.
- Diagnostic LEDs (blue, red) confirmed active microcontroller processing and sensor communication.

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2. Vital Sign Monitoring Results

Fig 2: Vital Sign Monitoring Results

a. Heart Rate & SpO_2 Measurement

The MAX30100/MAX30102 sensor module was tested for real-time pulse and oxygen saturation measurement. Observed Output on LCD:

- Heart Rate (HR): 87 BPM
- SpO_2: 98%

These values show that the sensor is functioning and accurately reading vital signs.

b. Temperature Measurement

The temperature sensor (LM35/DS18B20) displayed:

- Temperature: 24.12°C

This validates the thermal monitoring system and its integration with the LCD.

The robot is equipped with biomedical sensors for measuring heart rate, blood oxygen saturation (SpO_2), and body temperature. A fingertip pulse sensor mounted on the upper section of the robot captures the user's physiological data, which is processed by the internal microcontroller and displayed on an integrated LCD screen.

3. Smart Medicine Dispensing System

Fig 3: Smart Medicine Dispensing System

The robot also incorporates an automated medication management system programmed to provide reminders and dispense tablets at predetermined times of day. The LCD screen displays notifications corresponding to each dosage schedule.

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The robot contains three compartments for delivering scheduled medication:

1. Morning Tablet
2. Afternoon Tablet
3. Night Tablet

LCD Results:

- "MORNING TABLET" was displayed when the morning slot was activated.
- "AFTERNOON TABLET" displayed when the afternoon slot opened.
- "NIGHT TABLET" confirmed the functioning of the night compartment.

Each compartment opened and dispensed tablets successfully during testing.

4. Patient Recognition Module

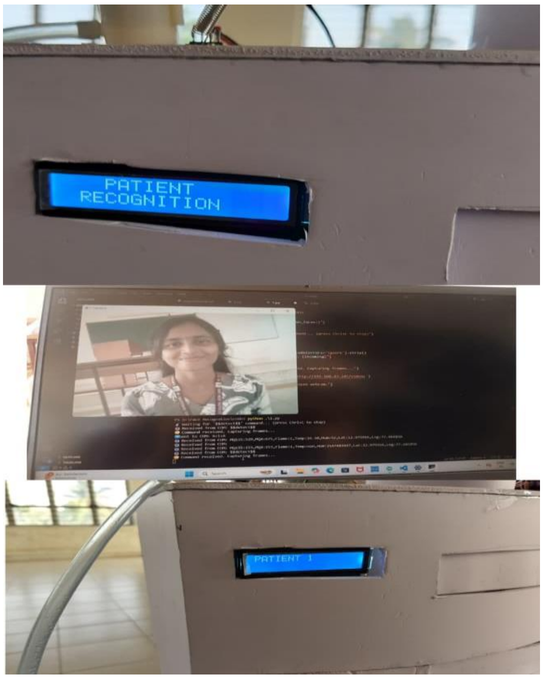

Fig 4: Patient Recognition Module

The robot uses a camera-based AI face recognition system to identify registered patients.
During testing:

- The LCD displayed "PATIENT RECOGNITION" when the module was activated.
- The camera successfully detected the patient's face and processed it using the recognition algorithm.
- Once identified, the robot displayed "PATIENT 1" on the LCD, confirming successful recognition.

This ensures correct patient-specific medication and health monitoring.

VI. CONCLUSION

The "AI-Driven Healthcare Robot for Medication Delivery and Personal Care Assistance" project successfully demonstrates how modern technologies—AI, robotics, and IoT—can be integrated to enhance healthcare efficiency, safety, and accessibility. By combining biomedical sensors, autonomous navigation, wireless communication, and facial recognition, the robot provides an effective solution for reducing the workload on healthcare professionals while ensuring continuous and accurate patient monitoring. Its modular design and use of cost-effective components make it highly suitable for hospitals, quarantine centres, elderly care homes, and rural medical facilities. The experimental results validate the system's functionality, accuracy, and usability, demonstrating that intelligent automation can significantly improve patient care and reduce human error. Overall, this project proves that AI-enabled healthcare robots can play a transformative role in future medical environments. With further enhancements—such as IoT cloud integration, predictive analytics, and advanced navigation—the system can evolve into a fully autonomous healthcare assistant capable of supporting smart hospitals and personalized home-care solutions.

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VII. ACKNOWLEDGMENT

I would like to express my sincere gratitude to everyone who supported and guided me throughout the development of this project. First, I extend my heartfelt thanks to my project guide and faculty members for their valuable suggestions, constant encouragement, and technical guidance. Their expertise played a crucial role in the successful completion of this AI-Driven Healthcare Robot.

I am also thankful to the technical staff and my peers who assisted in the hardware configuration, troubleshooting, and integration of various modules such as the Bluetooth interface, Patient Recognition and dispensing mechanisms. Their cooperation and insights greatly helped in overcoming challenges faced during experimentation and implementation.

A special note of appreciation goes to my family and friends for their continuous motivation, patience, and support, which kept me focused and determined throughout this journey. Lastly, I would like to acknowledge the resources, tools, and reference materials provided by the institution and online learning platforms, which significantly contributed to enhancing my knowledge and ensuring the project's success.

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