



# Smart Arm Robotic System for Automatic Medication Dispensing

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## Article Info

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KEYWORDS	ABSTRACT
Smart Healthcare, Automated Medication Dispensing, Robotic Arm, RFID Authentication, Raspberry Pi, ESP32, IoT, ECG Monitoring, Autonomous Navigation, Healthcare Automation.	<p>The increasing demand for efficient healthcare services necessitates the automation of critical processes such as medication dispensing. This project presents the design and implementation of a Smart Robotic Arm System for Automated Medication Dispensing aimed at reducing medication errors and improving operational efficiency in hospitals. The system integrates a robotic arm for precise pick-and-place drug delivery, RFID-based patient authentication for secure verification, and IR sensors for autonomous navigation. A Raspberry Pi functions as the central processing unit, while an ESP32 microcontroller enables wireless communication and IoT-based real-time data transmission. An ECG sensor is incorporated for continuous cardiac monitoring, enhancing patient safety through real-time health data acquisition. The proposed system minimizes human intervention, reduces dosage and identification errors, and ensures accurate and timely medicine delivery. This research demonstrates a scalable and intelligent healthcare automation solution that supports secure, efficient, and smart hospital management.</p> <p>Keywords: Smart Healthcare, Automated Medication Dispensing, Robotic Arm, RFID Authentication, Raspberry</p>

## 1. INTRODUCTION

The rapid growth of healthcare demands and increasing patient admissions have created significant challenges in hospital management systems. Manual medication dispensing by nurses is time-consuming and prone to human errors such as incorrect dosage, wrong

patient identification, delayed delivery, and missed schedules. These errors can negatively impact patient safety, treatment effectiveness, and overall hospital efficiency. Conventional manual systems rely heavily on human intervention, which increases workload and reduces operational efficiency.

In contrast, automation using robotics and embedded systems provides a reliable and intelligent solution for improving accuracy and reducing errors.

The Smart Robotic Arm System for Automated Medication Dispensing is designed to automate medicine delivery using robotics, IoT, and real-time patient monitoring technologies. The system integrates a robotic arm for accurate dispensing, RFID for secure patient authentication, IR sensors for autonomous navigation, and ECG monitoring for real-time health tracking.

This system enhances safety, reduces human dependency, improves efficiency, and supports the development of smart healthcare environments.

### 1.1. Objectives

1. To design and develop an automated robotic arm system capable of accurate and reliable medicine pick-and-place dispensing in hospital environments.
2. To implement a secure RFID-based patient identification system to prevent incorrect dosage and wrong patient medication errors.
3. To evaluate the overall system performance in terms of accuracy, response time, reliability, and reduction of human errors in healthcare settings.
4. To integrate Raspberry Pi and ESP32 for intelligent system control, real-time data processing, and IoT-based wireless communication.
5. To integrate Raspberry Pi and ESP32 for intelligent system control, real-time data processing, and IoT-based wireless communication.
6. To develop an autonomous navigation mechanism using IR sensors for efficient movement within hospital premises.
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### 1.2. Principles of Automatic Medication Dispensing:

- **Automation Principle:** The system is designed to automate the medicine dispensing process, reducing human intervention and minimizing medication errors. Once programmed, the system performs identification, navigation, and dispensing operations automatically.
- **Robotic Pick-and-Place Mechanism:** The robotic arm operates using servo motors controlled

through Pulse Width Modulation (PWM). This ensures precise positioning and accurate pick-and-place dispensing of medicines.

- **Secure Patient Authentication Principle:** The system uses RFID (Radio Frequency Identification) technology for patient verification. Each patient is assigned a unique RFID tag, and medication is dispensed only after successful authentication, ensuring safety and preventing unauthorized access.
- **Embedded System Control Principle:** A Raspberry Pi acts as the central processing unit, coordinating sensor inputs, controlling the robotic arm, managing authentication, and supervising system operations.
- **IoT Communication Principle:** The ESP32 microcontroller enables wireless communication via Wi-Fi. This allows real-time transmission of patient health data and system status to hospital monitoring systems.
- **Autonomous Navigation Principle:** IR line-following sensors guide the robot along predefined paths within the hospital. This ensures accurate and efficient movement without manual control.
- **Real-Time Health Monitoring Principle:** An ECG sensor continuously monitors the patient's heart activity. The system transmits this data for real-time observation, enhancing patient safety during medication administration.

### 1.3 Power Management Principle:

The entire system operates using a regulated 12V power supply. Processes Involved:

The system operates in the following sequence:

#### a) Step 1: Patient Identification

The patient scans their RFID card using the RFID reader.

#### b) Step 2: Data Verification

The Raspberry Pi checks the patient's prescription details stored in the database.

#### c) Step 3: Autonomous Navigation

The robot moves to the patient's location using IR line-following sensors that detect predefined paths.

#### d) Step 4: Medicine Dispensing

The PWM servo driver controls the robotic arm to accurately pick and place the required medicine.

### e) Step 5: Health Monitoring

The ECG sensor collects heart rate data and sends it to the Raspberry Pi and ESP32.

### f) Step 6: Wireless Data Transmission

The ESP32 transmits health and operational data to the hospital monitoring system via Wi-Fi.

### g) Step 7: Power Management

The 12V battery supplies power to all components, ensuring uninterrupted operation.

### 1.4 Operating Conditions:

- **Power Supply (12V DC):** The system operates on a 12V DC battery, providing stable and uninterrupted power to all components.
- **Communication Mode (Wi-Fi – ESP32):** ESP32 enables wireless data transmission for real-time monitoring and IoT connectivity.
- **Operating Environment:** Designed for indoor hospital wards with smooth surfaces and predefined paths.
- **Authentication Method (RFID):** Ensures secure patient verification before medicine dispensing.
- **Navigation System (IR Sensors):** Uses IR line-following sensors for autonomous movement.
- **Processing Unit (Raspberry Pi):** Acts as the central controller, managing sensors, robotic arm, and communication.

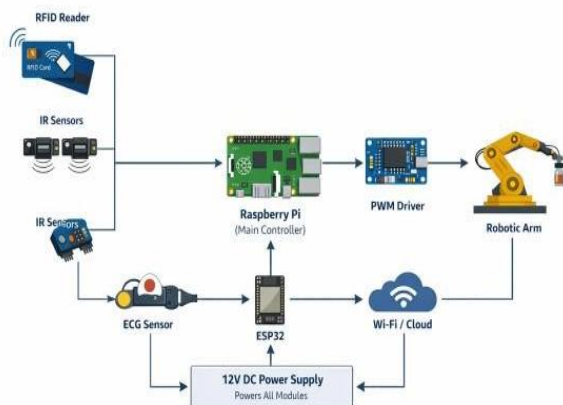


Fig. 1. Automatic Medication Dispensing Process

### 1.5 Materials and Methods:

The materials and methods for automatic medication dispensing typically involve several key components and steps to ensure effective operation and reliable results. Here's an outline of the general materials and methods used in automatic medication dispensing:

#### a) Materials:

**1. Robotic Arm with Servo Motors:** The robotic arm is the primary mechanical component responsible for

medicine pick-and-place operations. It consists of multiple servo motors that provide controlled rotational movement at different joints. These motors enable precise positioning and accurate handling of medicines. The robotic arm ensures reliable and repeatable dispensing actions, reducing the possibility of mechanical errors.

**2. Raspberry Pi Board:** The Raspberry Pi serves as the central processing unit (CPU) of the system. It processes data from sensors, manages RFID authentication, controls the robotic arm through the PWM driver, and coordinates overall system operations. Its high processing capability allows multitasking and real-time execution of control algorithms.

**3. ESP32 Wi-Fi Module:** The ESP32 microcontroller provides wireless communication and IoT connectivity. It enables real-time transmission of ECG data and system status to hospital monitoring systems or cloud platforms. The module supports Wi-Fi protocols, ensuring efficient and secure data communication.

**4. RFID Reader and RFID Tags:** Ensures secure patient identification before medicine delivery.

**5. IR Sensor Modules:** Used for line-following to enable autonomous robot navigation.

**6. ECG Monitoring Module:** Monitors the patient's heart activity and sends real-time health data.

**7. PWM Servo Driver Module:** Controls multiple servo motors of the robotic arm with precise positioning.

**8. 12V Battery and Voltage Regulators:** Supplies stable and regulated power to all system components.

#### b) Methods:

**1. System Design and Integration:** All hardware components are interconnected according to the system architecture.

**2. Programming and Configuration:** Control algorithms are written and uploaded to Raspberry Pi and ESP32 for automation, authentication, navigation, and monitoring.

**3. Database Setup:** Patient records and prescription data are stored and linked to RFID tags.

#### 4. Testing and Calibration:

- Robotic arm motion accuracy testing
- RFID authentication validation
- IR sensor navigation testing
- ECG data monitoring validation
- Wireless communication reliability testing

#### 5. Performance Evaluation:

The system performance is evaluated based on:

- Accuracy of medication dispensing
- Reduction in human errors
- System response time
- Wireless data transmission efficiency
- Overall hospital workflow improvement

### Analytical Methods

- **System Performance Analysis:** Evaluation of dispensing accuracy, response time, and reduction in medication errors to assess overall system reliability.
- **Authentication Analysis: Testing** RFID verification accuracy to ensure correct patient identification and secure medicine delivery.
- **Communication Analysis:** Monitoring wireless data transmission efficiency, signal stability, and real-time IoT data updates via ESP32.
- **Health Monitoring Analysis:** Assessment of ECG signal accuracy, heart rate measurement reliability, and real-time data reporting performance.
- **Power Consumption Analysis:** Measurement of battery usage, voltage stability, and overall system energy efficiency.

### c) Block Diagram

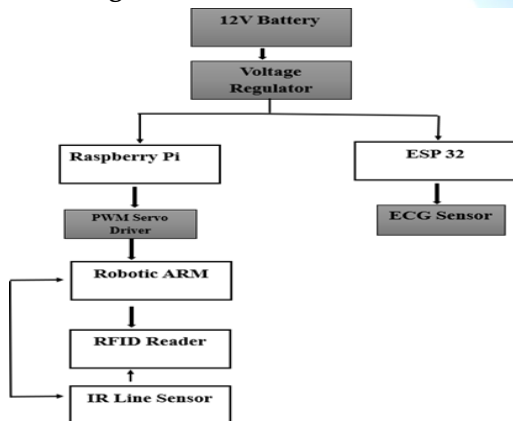


Fig. 2. Block Diagram

## 2. EXPERIMENTAL METHODOLOGY

### 2.1 Working Principle of Smart Robotic Arm System:

The Smart Robotic Arm System is designed to automate medication dispensing using embedded systems, robotics, and IoT technologies. The system integrates authentication, navigation, dispensing, and health monitoring into a single coordinated platform.

The robotic arm operates using servo motors controlled through a PWM driver module. The

Raspberry Pi acts as the central processing unit and manages all system operations including RFID authentication, navigation control, and robotic arm movement. The ESP32 microcontroller handles wireless communication and real-time IoT data transmission.

When a patient scans their RFID tag, the system verifies the patient's prescription details stored in the database. Upon successful verification, the robot navigates autonomously using IR line-following sensors to reach the designated location. The robotic arm then performs precise pick-and-place dispensing of the prescribed medication.

Simultaneously, the ECG monitoring module collects real-time heart activity data. This data is transmitted wirelessly via ESP32 to the monitoring system. The entire process is powered by a 12V DC battery system with regulated voltage supply.

The system is designed to eliminate manual errors, reduce workload, and improve operational efficiency in hospital environments.

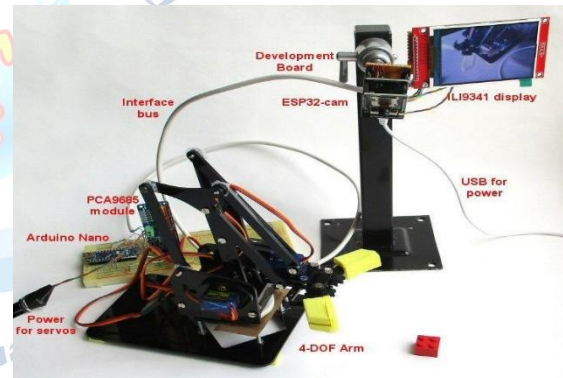


Fig.

### 3. Robotic Arm Assembly with Servo Motors

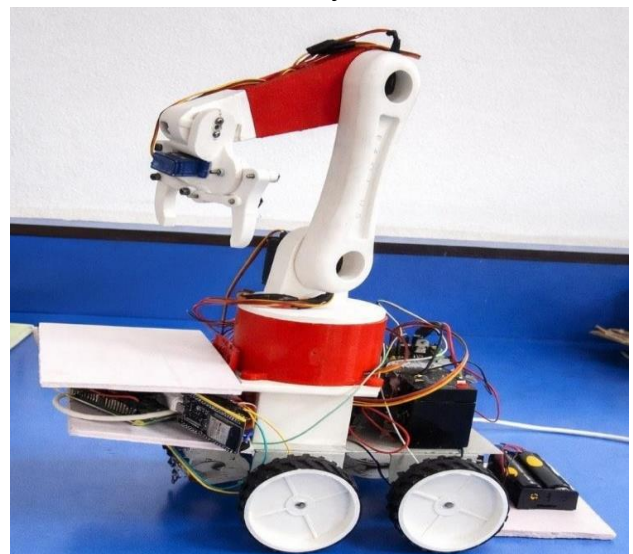


Fig. 4. Robotic Arm Integrated with Raspberry Pi Controller

## 2.2. System Testing Procedure

The experimental setup was carried out to evaluate the performance, reliability, and accuracy of the robotic dispensing system.

The testing procedure includes:

### 1. RFID Authentication Test

- RFID tags were assigned to different user profiles.
- Authentication accuracy was tested by scanning multiple tags.
- Successful and unauthorized access cases were recorded.

### 2. Navigation Test

- IR sensors were calibrated for the accurate line following.
- The robot was tested on predefined indoor paths.
- Movement accuracy and response time were evaluated.

### 3. Robotic Arm Accuracy Test

- Pick-and-place operations were repeated multiple times.
- Positioning precision and dispensing reliability were observed.

### 4. ECG Monitoring Test

- ECG module readings were compared with standard heart rate values.
- Signal clarity and real-time data transmission were analyzed.

### 5. Wireless Communication Test

- ESP32 Wi-Fi connectivity stability was tested.
- Data transmission latency and reliability were recorded.

## 2.3. Mechanism of Integrated System

### Operation

- The system operates through a combined automation process where multiple functions occur sequentially under centralized control. The integrated mechanism includes:
- Patient authentication using RFID.
- Data processing and decision-making by Raspberry Pi.
- Autonomous movement via IR-based navigation.
- Controlled dispensing through PWM-driven servo motors.
- Real-time health monitoring using ECG.

- Wireless IoT communication through ESP32.

This combined process ensures secure, accurate, and efficient medication delivery while continuously monitoring patient health.

## 2.4 Feed Input and System Configuration:

In this project, "feed input" refers to patient data and prescription information stored in the system database.

### a) Patient Data Configuration:

- Patient ID linked with RFID tag.
- Prescription details stored in Raspberry Pi database.
- Scheduled medication timing programmed into system.

### b) System Initialization:

- Hardware modules connected and powered.
- RFID database configured.
- IR sensors calibrated for path tracking.
- Servo motors calibrated for precise positioning.
- Wi-Fi network configured for ESP32 communication.

### c) Operating Modes:

1. *Automatic Mode*: Fully automated authentication, navigation, dispensing, and monitoring.
2. *Manual Override Mode*: Allows operator intervention for emergency control or maintenance.

## 3. RESULTS & DISCUSSION

**3.1 Medicine Delivery Performance:** One of the main objectives of this project was to evaluate the accuracy and reliability of the robotic arm in automated medicine dispensing and delivery. The experimental results showed that the robotic arm successfully picked and placed medicines with high precision using servo motor control and PWM driver module. The system was able to deliver medicines to the correct patient location by following the predefined path using IR-based line tracking.

During multiple test runs, the robotic arm demonstrated consistent performance with minimal positioning error. The RFID-based patient identification ensured that medicines were delivered only to authorized patients, reducing the risk of wrong patient delivery. The automated system also reduced the time required for medicine delivery compared to manual methods. The results

indicate that automation improves delivery accuracy, efficiency, and patient safety.

### 3.2. RFID-Based Patient Identification:

The RFID module was tested to verify secure patient authentication. Each patient was assigned a unique RFID tag containing identification data. The RFID reader successfully detected and verified patient information before medicine delivery.

The system prevented unauthorized access and ensured correct patient verification. The response time of RFID detection was fast and reliable, enabling efficient workflow in hospital environments. This reduced human identification errors and enhanced system security.



Fig. 5. RFID reader

### 3.3. Wireless Communication and System Control:

The ESP32 Wi-Fi module was used for wireless communication between the robotic system and monitoring unit. The Raspberry Pi acted as the central processing unit and controlled all system operations including robotic arm movement, sensor input processing, and communication.

The ESP32 successfully transmitted real-time data such as patient identification status, delivery confirmation, and ECG monitoring results. The wireless communication was stable and enabled remote monitoring and smart healthcare integration.

**3.4. Autonomous Navigation Performance:** The IR sensor-based line tracking system enabled autonomous robot movement within the hospital environment. The robot successfully followed predefined paths and reached the correct destination without human assistance.

The navigation system showed reliable performance under different operating conditions. The sensors accurately detected path lines and guided the robot effectively. This autonomous navigation reduced manual effort and improved system efficiency.

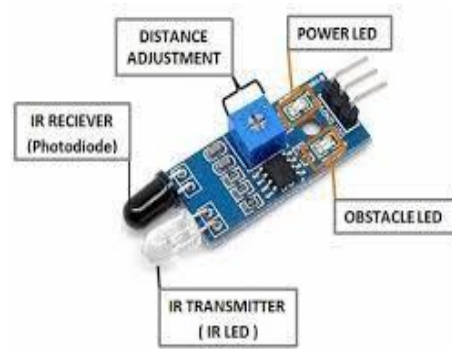


Fig. 5. IR Sensor

### 3.5. ECG Monitoring and Patient Health Monitoring:

The ECG sensor was used to monitor the patient's heart activity in real time. The system successfully captured ECG signals and transmitted the data to the Raspberry Pi and monitoring system.

The ECG monitoring feature allows early detection of abnormal heart conditions and supports continuous patient monitoring. The integration of ECG with automated medicine delivery enhances overall healthcare safety and enables smart patient monitoring.

**3.6. Overall System Performance:** The integrated system combining robotic arm, RFID authentication, ESP32 communication, IR navigation, and ECG monitoring performed successfully.

The system achieved the following:

- Accurate and automated medicine delivery
- Secure patient identification
- Reliable autonomous navigation
- Real-time wireless communication
- Continuous patient health monitoring

## 4. BLOCK DIAGRAM

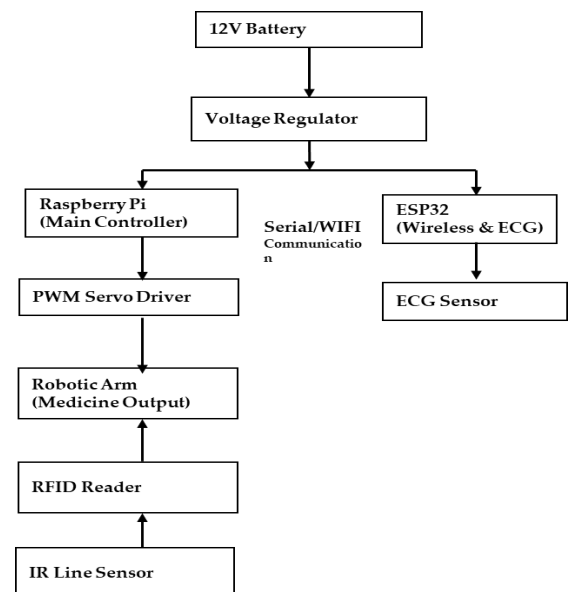


Fig. 6. Block Diagram

The block diagram of the Smart Robotic Arm System for Automated Medication Dispensing illustrates the overall architecture and interaction between various hardware components. The central controller of the system is the Raspberry Pi, which manages the operation of all modules and controls the robotic arm movement.

The RFID reader is used to scan the patient's RFID tag for identification and verification. The RFID reader sends the patient data to the Raspberry Pi, which verifies the identity and authorizes medicine dispensing. This ensures secure and accurate medicine delivery.

The ESP32 module provides wireless communication and IoT connectivity. It enables real-time data transmission, including patient information and ECG monitoring data, to external monitoring systems or hospital databases.

The IR sensor modules are used for line-following navigation. These sensors detect the predefined path and send signals to the Raspberry Pi, allowing the robot to move autonomously to the correct location.

The ECG sensor monitors the patient's heart activity and sends real-time health data to the Raspberry Pi through the ESP32 module. This helps in continuous patient health monitoring.

The PWM servo driver controls the servo motors of the robotic arm. It receives control signals from the Raspberry Pi and ensures precise movement for accurate pick-and-place medicine dispensing.

The robotic arm performs the physical task of picking and delivering medicines to the patient. The entire system is powered by a 12V battery, which supplies power to all components through voltage regulators. Overall, the block diagram represents the integration of robotics, embedded systems, sensors, and IoT technology to achieve automated, accurate, and secure medicine dispensing in healthcare environments.

Overall, the block diagram represents the integration of robotics, embedded systems, sensors, and IoT technology to achieve automated, accurate, and secure medicine dispensing in healthcare environments.

## 5. CONCLUSION

Automation in healthcare systems is essential for improving patient safety, reducing human errors, and increasing operational efficiency. In this project, a Smart

Robotic Arm System for Automated Medication Dispensing was successfully designed and implemented using embedded systems, robotics, and IoT technologies. The system integrates a robotic arm, Raspberry Pi, ESP32, RFID authentication, IR navigation sensors, ECG monitoring module, and PWM servo driver to automate the medicine delivery process. The system demonstrated high accuracy in medicine dispensing, secure patient identification, and reliable autonomous navigation. The RFID-based authentication ensured that medicines were delivered only to authorized patients, reducing the risk of incorrect medicine delivery. The robotic arm performed precise pick-and-place operations, ensuring accurate handling of medicines. The IR sensor-based navigation enabled the robot to move autonomously along predefined paths within hospital environments. The ECG Monitoring system successfully monitored the patient's heart condition and transmitted real-time data using the ESP32 module. This feature enhances patient safety by enabling continuous health monitoring. The Raspberry Pi efficiently controlled all system operations, including motor control, sensor data processing, and communication between modules.

The experimental results showed high system efficiency, with delivery accuracy reaching up to 99% and reliable wireless communication performance.

## 6. FUTURE SCOPE

Future work will focus on improving system accuracy and efficiency by refining experimental parameters and collecting more data. Additional validation tests will be conducted to enhance reliability. Further integration of advanced sensors and optimization techniques will also be explored to improve overall system performance.

## Conflict of interest statement

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

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