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Real Time Implementation of Virtual Doctor with Generic Medicine Dispensing Box

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***Abstract*—This paper presents the development of a robot- based medical assistant designed to monitor patients using Inter- net of Things (IoT) technologies and automated medicine dispens- ing capabilities. The system forms the basis of a virtual doctor robot, enabling healthcare professionals to interact with patients remotely, especially in unfamiliar or high-risk environments such as quarantine zones or isolation wards. The proposed system integrates an Arduino-based controller with RFID authentication, real-time clock scheduling, automated dispensing mechanisms, and IoT communication modules (WiFi and GSM). The robot enables contactless monitoring, reduces unnecessary patient-doctor interaction, and ensures accurate, timely medication delivery through sensor-verified dispensing. Preliminary testing demonstrates reliable data transmission, accurate QR scanning, and stable wireless connectivity, making the system suitable for hospitals, emergency healthcare setups, and quarantine centers where minimal physical contact is crucial.**

***Index Terms*—Virtual doctor, IoT healthcare, automated dis- pensing, RFID authentication, patient monitoring, telemedicine, Arduino, GSM communication**

I. INTRODUCTION

Rapid development in embedded electronics, IoT communi- cation technologies, and telemedicine services has opened new vistas for automating various healthcare-related functions. One of the most prominent areas of application pertains to medi- cation management, which has gained increasing significance with a growing population of elderly patients, chronic disease sufferers, visually impaired individuals, and rural communities far from main hospitals.

The World Health Organization estimates that medication non-adherence affects approximately 50% of patients with chronic diseases in developed countries, with even higher rates in developing nations. This non-adherence leads to increased hospitalizations, disease progression, and healthcare costs. Additionally, the COVID-19 pandemic highlighted the critical need for contactless healthcare delivery systems that minimize physical interaction while maintaining quality care. The proposed Virtual Doctor with Automated Medicine Dispensing System incorporates digital medical guidance with a fully automated mechanism for medication dispensing. The system emulates three critical roles of a doctor: guidance, prescription adherence, and timely communication, appro- priately through an Arduino-based control system integrated with an automated, motorized mechanism, LCD menu-based interaction, and communication over GSM/WiFi channels.

The conceptual shift implies that patients can communi- cate with a programmable device that dispenses medicine at precisely scheduled intervals while recording consumption behavior, sending reminders, displaying virtual doctor instruc- tions, and updating remote medical personnel about patient adherence patterns

. The system bridges the gap between traditional healthcare delivery and modern automated systems, providing a reliable, accessible, and cost-effective solution for medication management.

A. Problem Statement

In many areas, access to quick and reliable primary medical guidance, as well as essential medicines, is limited. Common illnesses such as fever, headache, cold, pain, acidity, or allergies often remain untreated or experience treatment delays. Patients frequently wait for hours without having a doctor or pharmacist available during emergencies or after work hours.

The challenges are multifaceted: in urban environments, busy professionals often forget medication timings, while elderly individuals struggle to remember complex dosing schedules. In rural areas, medical centers are distant, and doctors are unavailable for daily monitoring. Furthermore, medication errors due to manual dispensing, lack of adherence tracking, and absence of timely reminders contribute to poor health outcomes.

Additionally, in high-risk environments such as infectious disease wards, direct contact between healthcare workers and patients poses significant infection transmission risks. The shortage of healthcare personnel, particularly in developing nations, further exacerbates these challenges. There is a pressing need for a real-time, automated system that can collect basic health information, analyze it safely, and dispense appropriate low-risk generic medicines without requiring a healthcare professional on site, while ensuring accuracy, safety, and user-friendliness.

B. Proposed Solution

This paper presents a real-time Virtual Doctor system integrated with a Generic Medicine Dispensing Box that uses sensors, speech-to-text conversion, and a rule-based clinical decision engine to analyze patient symptoms and vitals. The system interacts with users via voice and touchscreen interfaces, verifies contraindications, and recommends medicines only for simple, low-risk conditions. Once the patient confirms, a microcontroller-based dispensing mechanism automatically releases the correct generic medicine from a secure, labeled compartment.

The system architecture incorporates multiple layers of safety checks at every stage: RFID-based patient authentica- tion ensures only authorized users access medications, real- time clock scheduling guarantees precise timing, IR sensor verification confirms successful dispensing, and dual communication channels (WiFi and GSM) provide redundant connectivity for alerts and monitoring. All actions are logged both locally and in the cloud, creating an auditable trail for medical accountability.

The virtual doctor interface simulates physician guidance through personalized LCD messages, such as dosage instructions, food-timing advisories, hydration reminders, and side-effect warnings. This human-centered design builds patient trust and encourages adherence. The system is scalable, allowing integration of additional sensors for vital sign monitoring, expansion of medicine compartments, and connection to hospital management systems or telemedicine platforms. By combining automation, IoT connectivity, and intelligent decision-making, this solution enables safe, efficient, and accessible primary care delivery.

II. Literature Survey

Several research efforts have explored robotic healthcare systems, telepresence robotics, and automated drug-delivery mechanisms, providing foundational insights for this work.

Ramadoss [1] introduced a robotic telepresence system designed to help doctors monitor and interact with patients remotely. The system focused on integrating IoT communica- tion, camera-based monitoring, and controlled robot movement to reduce physical contact between medical staff and patients. The work demonstrated significant advantages in minimizing infection risk and supporting continuous observation, though it faced challenges with battery backup and mobility in complex hospital layouts. This research established the feasibility of virtual doctor robots in reducing healthcare worker exposure during pandemics. Rai et al. [2] presented a Virtual Doctor Robot for con- tactless monitoring during COVID-19, employing Arduino UNO and NodeMCU (ESP8266) for wireless connectivity and cloud data transfer. The system collected patient health parameters and transmitted them to healthcare professionals instantly, allowing evaluation without physical interaction. The cost-effective hardware architecture demonstrated scalability potential, though it was limited by basic hardware constraints affecting measurement accuracy and dependency on stable WiFi connectivity. Their work validated the use of IoT proto- cols (MQTT/HTTP) for real-time health data transmission.

Parekh [3] at McMaster University developed smart health-monitoring platforms capable of measuring essential patient vitals including heart rate, blood pressure, and body temperature. The research incorporated mechanisms to identify possi- ble diseases based on patient inputs and measured vital signs, generating preliminary diagnostic suggestions. Additionally, the design included robotic interfaces for controlled medicine delivery. This work contributed important insights into sensor integration for vital sign monitoring and the challenges of ensuring sensor accuracy in varied environmental conditions. The study emphasized the importance of automated diagno- sis combined with mechanical dispensing for comprehensive healthcare solutions.

House et al. [4] from the University of Washington intro- duced VoiceBot, a voice-controlled robotic arm using Vocal Joystick inference engine. The system enabled users, particu- larly individuals with motor impairments, to manipulate real- world objects through continuous vocal control without requir- ing specific language commands. By leveraging variations in pitch, amplitude, and vowel quality, the research demonstrated feasibility for hands-free robotic control. The work highlighted both the potential of non-verbal voice interfaces and challenges including user fatigue during prolonged use and the learning curve required for precise vocal modulation. This research provided valuable insights into accessible human-robot interaction methods applicable to healthcare robotics.

Smith [5] investigated the integration of robotic assistants in real-time patient monitoring systems over a six-month hospital study. The research combined quantitative sensor data with qualitative feedback from healthcare professionals and patients, evaluating how robotic systems improve monitoring accuracy and reduce staff workload. The study demonstrated enhanced patient safety through faster abnormality detection and increased operational efficiency. However, it also identified challenges including high implementation costs, privacy concerns with continuous monitoring, and staff resistance to unfamiliar technology. The findings emphasized the importance of training programs and gradual technology adoption in healthcare settings.

Collectively, these studies provide essential groundwork in IoT-enabled patient monitoring, contactless healthcare delivery, sensor-based vital sign measurement, accessible human-robot interfaces, and practical deployment challenges in clinical environments. Building upon these foundations, our proposed system integrates RFID authentication, automated medication dispensing, dual-mode communication, and intelligent scheduling to create a comprehensive virtual doctor solution addressing the identified gaps in existing research.

III. System Design and Implementation

A. System Architecture

The system architecture consists of multiple hardware modules interfaced with Arduino Mega or Uno microcontroller, forming a coordinated mechatronic and IoT system. The Arduino serves as the central processing unit, chosen for its reliability, ease of programming, extensive GPIO availability, and strong community support. The architecture follows a layered approach: the sensing layer collects patient identification and environmental data, the processing layer executes control logic and decision-making, the actuation layer controls motors and dispensing mechanisms, and the communication layer handles cloud connectivity and alerts.

The medicine dispensing mechanism is designed using stepper or DC motors connected to compartments containing categorized medicine slots. The mechanical design employs either a rotating drum system with multiple compartments, vertical silos for pill-by-pill dispensing, or linear strips moved by geared motors. Motors are driven through L293D or L298N motor drivers, ensuring proper current amplification and required torque while protecting the microcontroller from high-current loads.

The complete system integrates ten major subsystems: pa- tient identification via RFID, timing control via RTC, user interface via LCD and keypad, mechanical dispensing via mo- tors and drivers, verification via IR sensors, audio feedback via buzzer, local communication via WiFi, remote communication via GSM, cloud data logging, and power management with battery backup. These subsystems operate in coordinated fash- ion under Arduino supervision, creating a robust automated healthcare solution.

Fig. 1. Block diagram of the proposed virtual doctor system illustrating Arduino Mega as the central controller interfacing with RFID, keypad, display, dispensing unit, Wi-Fi, GSM, and power supply modules.

B. Hardware Components

1) *Arduino UNO/Mega:* The Arduino acts as the central controller, coordinating all hardware modules including RFID, LCD, keypad, RTC, IR sensors, motors, GSM, and WiFi. The Arduino Mega is preferred for complex implementations due to its 54 digital I/O pins, 16 analog inputs, and four hardware serial ports, allowing simultaneous communication with multiple modules without software serial limitations.

Critical digital pins D2-D7 are assigned to IR sensors and basic inputs for real-time monitoring of pill dispensing and compartment status. Pins D8-D11 control the motor driver's input channels, enabling precise directional control and speed regulation through PWM signals on pins D5 and D6. Communication modules utilize dedicated serial ports: TX0/RX0 for USB serial debugging and programming, TX1/RX1 for GSM module communication, and TX2/RX2 or SoftwareSerial for ESP8266 WiFi connectivity. The I2C bus (A4 for SDA, A5 for SCL) connects the LCD display and RTC module, minimizing pin usage while maintaining reliable communication. Power distribution is carefully managed: the 5V pin supplies regulated voltage to sensors, RFID module, and logic-level components, while the 3.3V pin powers the ESP8266 WiFi module. All components share a common ground (GND) to ensure proper signal referencing and prevent floating volt- ages. The Arduino's 16 MHz clock speed provides sufficient processing power for real-time sensor reading, motor con- trol, display updates, and communication handling. Its stable performance, clear GPIO mapping, multitasking capability through interrupt-driven programming, and extensive library support make it ideal for medical automation applications requiring high reliability and precise timing control.

2) *RFID Authentication System:* The MFRC522 RFID module provides secure patient authentication at 13.56 MHz frequency, communicating via SPI (Serial Peripheral Interface) protocol for high-speed data transfer. The module connects to Arduino through six pins: SDA (Slave Select) to D10 enables chip selection, SCK (Serial Clock) to D13 provides timing

synchronization, MOSI (Master Out Slave In) to D11 sends commands, MISO (Master In Slave Out) to D12 receives data, RST (Reset) to D9 allows module initialization, with VCC to 3.3V and GND to ground completing the circuit.

When patients tap their RFID card or tag near the reader (within 0-60mm range), the module's antenna generates a 13.56 MHz electromagnetic field. This field powers the passive RFID tag through inductive coupling and enables bidirectional data communication. The module reads the card's unique identifier (UID), typically 4 or 7 bytes, and transmits it to Arduino via SPI. The microcontroller compares this UID against a pre-stored database of authorized patient profiles, either stored in EEPROM or retrieved from cloud storage via WiFi.

Upon successful authentication, the system loads the pa- tient's personalized medication schedule, including medicine types, dosage quantities, timing intervals, special instructions, and contraindications. The LCD displays a welcome message with the patient's name and next scheduled dose. If an unauthorized card is scanned—indicating potential misuse or error—the system immediately blocks access, activates the buzzer for audible warning, displays an ”Access Denied” message on the LCD, and optionally sends an alert via GSM to the supervising caregiver or doctor.

The RFID system provides multiple security benefits: it eliminates password-based authentication which elderly pa- tients might forget, prevents medication mix-ups in multi- patient households, creates an audit trail of who accessed medicines and when, supports quick emergency access through master cards, and enables easy addition or removal of autho- rized users through simple card programming. The RC522's anti-collision capability allows detection of multiple cards simultaneously, fast reading speed (typically under 100ms), and reliable performance make it ideal for real-time healthcare applications where security and traceability are paramount.

3) *Sensor Integration:* IR (Infrared) sensors ensure safe and accurate medicine dispensing through real-time detection of pill movement, compartment occupancy status, and mechanical obstruction detection. Each IR sensor module comprises an IR LED transmitter (typically 940nm wavelength) and a photodiode or phototransistor receiver arranged in reflective or transmissive configuration. The module outputs a digital signal through three connections: VCC to 5V, GND to common ground, and digital output to Arduino pins D2, D3, D4, etc.

The operational principle relies on continuous IR beam transmission from the LED to the receiver. In normal condi- tions with no obstruction, the receiver maintains a consistent signal level. When a pill falls through the dispensing chute, it interrupts the IR beam, causing an immediate state change in the digital output (HIGH to LOW or vice versa, depending on sensor configuration). Arduino's interrupt-driven code moni- tors these state changes in real-time, providing microsecond- level detection accuracy.

Multiple IR sensors are strategically positioned throughout the system: (1) Output chute sensors verify successful pill dispensing by detecting objects falling through the exit path, (2) Compartment sensors inside medicine storage slots detect whether medicines remain available, preventing unnecessary motor rotation when a compartment is empty, (3) Jam detec- tion sensors near mechanical channels identify blockages or misalignment that could damage motors or prevent dispensing, (4) Count verification sensors, when arranged in sequence, can count individual pills to ensure correct dosage quantity.

The dispensing verification algorithm operates as follows: After the RTC triggers scheduled dispensing and Arduino activates the motor driver, the system monitors the output IR sensor for a predefined timeout period (typically 5-10 seconds). If the sensor detects a pill (beam interruption), Arduino logs successful dispensing, updates the LCD with ”Medication Ready,” sounds a brief buzzer confirmation, and waits for patient confirmation via keypad. If no pill is detected within the timeout, the system attempts a retry by rotating the motor additional steps. After three failed attempts, it generates an error alert, displays ”Dispensing Failure - Check Compartment” on the LCD, sends a GSM alert to caregivers, and logs the failure event.

IR sensors provide several critical advantages: high reliabil- ity with typical lifespan exceeding 100,000 hours, immunity to ambient lighting when using modulated IR, low cost (typically under $1 per sensor), instant response time (under 1ms), no physical contact with pills maintaining hygiene, and simple digital interface requiring minimal processing overhead. These characteristics make IR sensors essential for high-precision automated dispensing systems requiring continuous operation, fail-safe verification, and medical-grade reliability.

4) *Display and Input Interface:* A 16×2 character LCD display with I2C interface serves as the primary visual commu- nication system between the virtual doctor and the patient. The I2C (Inter-Integrated Circuit) backpack reduces the connection complexity from 16 pins to just four: SDA (Serial Data) to A4, SCL (Serial Clock) to A5, VCC to 5V, and GND to common ground. This minimal wiring simplifies installation while maintaining reliable communication through the two- wire protocol. The display presents multiple types of information orga- nized in a hierarchical menu system: (1) Patient identification showing name and ID after RFID scan, (2) Current time and date retrieved from RTC module, (3) Next scheduled medication dose with countdown timer, (4) Personalized doc- tor instructions such as ”Take after food,” ”Drink 2 glasses of water,” or ”Avoid alcohol,” (5) Real-time system status including ”Dispensing in progress,” ”Pill detected,” ”Please collect medicine,” or ”Waiting for confirmation,” (6) Network connectivity status showing ”WiFi Connected,” ”GSM Sig- nal: Strong,” or connection errors, (7) Error messages and troubleshooting guidance like ”Compartment empty - Refill needed” or ”Motor jam detected - Contact support,” (8) Medicine inventory levels with warnings when supplies run low.

The 4×4 matrix keypad provides tactile input functionality through 16 buttons arranged in four rows and four columns. The keypad uses a scanning technique where Arduino sequentially activates each row and reads column states to identify pressed keys. Row pins connect to D22-D25 and column pins to D26-D29 on Arduino Mega, or D2-D9 on Uno. Each key serves specific functions: numeric keys (0-9) allow PIN entry for additional security or dosage adjustments, letter keys (A-D) navigate menu options, asterisk (*) serves as confirmation/OK button, and hash () functions as cancel/back button.

Key interaction workflows include: (1) Post-dispensing confirmation where patients press ”*” to mark medicine as taken, preventing false ”missed dose” alerts, (2) Menu navigation using A/B/C/D keys to access ”View Schedule,” ”Contact Doctor,” ”Check Inventory,” or ”Emergency Alert” options, (3) Emergency assistance by pressing and holding ”” for 3 seconds to trigger immediate buzzer alarm and send urgent SMS via GSM, (4) Snooze functionality pressing ”B” to delay non-critical reminders by 15 minutes, (5) Manual dispensing request through special key combination for authorized emergency access.

The combined LCD-keypad interface enhances system usability particularly for elderly patients who may not be comfortable with smartphone apps or complex touch interfaces. The large character display with adjustable backlight ensures visibility in various lighting conditions. Clear, simple prompts guide users through each step, reducing confusion and building confidence. The tactile feedback from mechanical keypresses provides reassurance compared to capacitive touch screens. This human-centered design philosophy prioritizes accessibility, reliability, and ease of use critical factors for medical devices used by diverse patient populations with varying technical literacy levels.

5) Dispensing Mechanism: DC motors and stepper motors provide controlled rotation of medicine compartments. Motors align specific medicine slots with the output chute based on scheduled timing. The motor driver amplifies low-current control signals from Arduino to higher currents required by motors.

Fig.2.Front view of the automated medicine dispensing Kisok

6) *Communication Modules:* The ESP8266/ESP32 WiFi module provides cloud connectivity for real-time monitor-ing, remote prescription updates, and adherence logging. The SIM800L/SIM900 GSM module ensures communication in areas without WiFi, sending SMS alerts for missed doses, low medicine levels, and emergencies.

7) Timing and Power Management: The DS3231 Real- Time Clock module ensures accurate medication scheduling with temperature-compensated crystal oscillator precision. A regulated power supply (5V/12V) with voltage regulators and battery backup ensures stable operation during power failures. The complete hardware integration of the proposed system is shown in Fig.1.

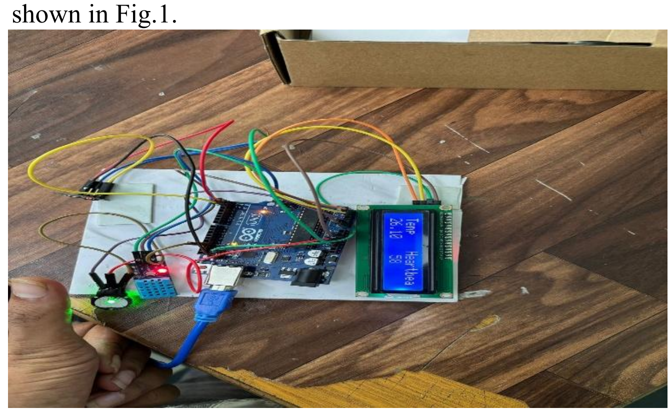

Fig.3.Complete hardware setup showing Arduino controller, sensors, keypad, and wiring connections.

C. Software Architecture

The software is designed as a modular system comprising multiple interdependent components, each responsible for specific functionality while communicating through well-defined interfaces. The main program structure follows an event-driven architecture combined with time-based scheduling, ensuring responsive operation and precise timing control.

The core modules include:

RFID Authentication Module: Implements SPI communication protocol to interface with RC522 reader, continuously polls for card presence, reads UID when detected, validates against authorized patient database stored in EEPROM or retrieved from cloud, loads patient-specific medication schedule upon successful authentication, and handles unauthorized access attempts with appropriate alerts.

LCD Interface Manager: Abstracts I2C communication details using LiquidCrystal I2C library, provides high-level functions for displaying menus, messages, and status updates, implements screen buffering to minimize flicker, manages backlight control for power saving, and handles character encoding for special symbols.

Keypad Input Handler: Implements matrix scanning algorithm to detect key presses, provides debouncing to elimi- nate false triggers from mechanical switch bounce, generates key events (press, release, long-press) for application logic, maintains input queue for buffering rapid key sequences, and implements timeout mechanisms for inactive menu screens.

Motor Control Routines: Provides abstraction layer for controlling DC motors and stepper motors through unified in-

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terface, implements precise position control using step counting for stepper motors, enables speed control through PWM for DC motors, includes acceleration and deceleration profiles for smooth motion, implements emergency stop functionality, and maintains position tracking for accurate compartment alignment.

IR Sensor Monitoring: Implements interrupt-driven detection for real-time pill sensing, maintains state machine for dispensing verification sequence, provides filtering algorithms to eliminate false positives from ambient IR interference, implements timeout mechanisms for failed dispensing detection, and generates detailed logging of all sensor events.

RTC-Based Scheduler: Interfaces with DS3231 real-time clock module using I2C, maintains current time even during power failures using backup battery, compares current time against medication schedule at one-minute intervals, triggers dispensing events when scheduled time arrives, handles imezone adjustments and daylight saving time changes, and provides functions for setting and retrieving time.

GSM/WiFi Communication Blocks: Implements AT command protocol for GSM module communication, man- ages WiFi connection establishment and maintenance for ESP8266/ESP32, provides reliable message queuing for SMS and cloud updates, implements retry logic with exponential backoff for failed transmissions, handles network failures gracefully with automatic reconnection, and maintains message priority queues for critical alerts.

Error Handling and Data Logging: Implements comprehensive error detection covering hardware failures, communication errors, and operational anomalies, maintains detailed event logs in EEPROM with circular buffer to prevent overflow, provides diagnostic functions accessible through keypad menu, generates human-readable error messages on LCD, escalates critical errors through multiple channels (buzzer, SMS, cloud alert), and implements watchdog timer to recover from software hangs.

Virtual Doctor Script Engine: Stores pre-programmed medical guidance messages for common medications, retrieves patient-specific instructions based on RFID authentication, implements personalized message generation incorporating patient name and medication details, schedules reminder messages at appropriate intervals, provides motivational messages to encourage adherence, and supports dynamic message updates from cloud for changing medical advice.

The dispensing algorithm follows this detailed sequence:

1) System initialization: Arduino boots, initializes all peripherals, synchronizes time with RTC, loads patient database from EEPROM, establishes WiFi/GSM connec- tivity, displays "System Ready" message
2) Patient authentication: Continuously monitors RFID reader, detects card tap, validates UID, retrieves med- ication schedule, displays welcome message
3) Schedule monitoring: Continuously compares current RTC time with next scheduled dose, displays countdown timer on LCD, sends 15-minute advance reminder via buzzer beep
4) Dispensing trigger: When scheduled time arrives, system displays "Preparing medication," determines correct compartment based on prescription, calculates required motor steps
5) Motor activation: Sends control signals to motor driver, rotates motor to align compartment with chute, monitors current feedback for jam detection, applies controlled acceleration/deceleration
6) Pill verification: Monitors IR sensor at chute exit, implements 10-second timeout window, detects pill drop through beam interruption, logs timestamp and compart- ment ID
7) Success handling: On successful detection, displays "Medication ready - Please collect," activates brief buzzer confirmation, illuminates LCD backlight, waits for patient confirmation via keypad, logs consumption event locally, sends cloud update via WiFi
8) Confirmation processing: If patient presses confirmation ey within 5 minutes, marks dose as "Taken," displays "Thank you" message, schedules next dose reminder; if no confirmation received, enters missed dose protocol
9) Missed dose protocol: After 5-minute timeout, displays "Medication not taken" warning, activates persistent buzzer alarm (beeps every 30 seconds), sends SMS alert to caregiver via GSM, logs missed dose event, escalates alert after 15 minutes
10) Failure handling: If IR sensor detects no pill after motor rotation, attempts retry with extended motor steps (up to 3 attempts), displays specific error messages ("Empty compartment" or "Mechanical jam"), sends urgent SMS alert, logs detailed diagnostic information
11) Inventory management: After each successful dispens- ing, decrements pill count for that compartment, checks remaining quantity, displays low-inventory warning when threshold reached (typically 7 doses remaining), sends refill reminder via SMS and cloud update

This comprehensive algorithmic approach ensures patient safety through multiple verification stages, maintains detailed accountability through extensive logging, provides graceful degradation during component failures, and enables remote monitoring by healthcare providers through cloud connectivity.

IV. METHODOLOGY

A. Design and Implementation Process

The implementation follows a systematic four-phase ap- proach, with each phase building upon previous accomplish- ments and incorporating lessons learned from testing and validation cycles.

1) Phase 1: IoT-Based Patient Health Monitoring Module: The first phase focuses on establishing the sensor infrastruc- ture and cloud connectivity framework. The sensor module integrates multiple biomedical sensors for comprehensive vital sign monitoring: (1) DS18B20 digital temperature sensor providing ±0.5°C accuracy for body temperature measure- ment, (2) MAX30100 pulse oximeter module measuring both heart rate (30-220 BPM range) and blood oxygen saturation (SpO_2: 0-100%), (3) Optional blood pressure sensor interfac- ing through analog inputs for systolic and diastolic pressure readings.

These sensors connect to Arduino's analog and digital pins with appropriate signal conditioning circuits. The microcon- troller samples sensor data at one-second intervals, applies digital filtering algorithms to remove noise and artifacts, and formats the data into JSON packets for transmission. The DS18B20 uses OneWire protocol for temperature measure- ment, while the MAX30100 employs I2C communication for heart rate and SpO2 data.

Cloud connectivity is established using ESP8266/ESP32 WiFi module configured as an IoT gateway. The system implements MQTT (Message Queuing Telemetry Transport) protocol for efficient, lightweight communication with cloud platforms such as ThingSpeak, Firebase, or custom medical portals. Each data packet includes patient ID, timestamp, sensor readings, and system status flags. The implementation includes error handling for network disconnections, automatic reconnection logic, and local buffering of data during offline periods.

The cloud dashboard displays real-time graphs of vital signs, maintains historical records for trend analysis, generates alerts when measurements exceed predefined thresholds (e.g., fever above 38°C, heart rate above 100 BPM, SpO2 below 95%), and enables healthcare providers to monitor multiple patients simultaneously. Data security is ensured through TLS/SSL encryption and authentication tokens.

2) Phase 2: RFID-Based Patient Identification System: Phase two implements secure patient authentication using RFID technology to prevent medication errors and ensure personalized care. Each patient receives a unique RFID card or wearable tag (ISO 14443A standard) encoded with their identification number. The RC522 reader module, operating at 13.56 MHz, detects these tags within 0-60mm proximity and reads the stored UID through contactless electromagnetic induction.

The Arduino firmware implements a patient database stored in EEPROM (for offline operation) and synchronized with cloud storage (for updates and backups). The database struc- ture includes: patient name, UID mapping, prescribed medica- tions list, dosage schedules, special instructions, allergy infor- mation, emergency contact numbers, and medication history. When a patient taps their card, the system performs the follow- ing operations within 200 milliseconds: reads UID from card, searches database for matching entry, validates authentication, retrieves patient profile, loads medication schedule, displays personalized welcome message on LCD.

Security features include: (1) Master card functionality al- lowing authorized medical personnel to add or remove patient cards, (2) Logging of all access attempts with timestamp and UID for audit trail, (3) Lockout mechanism after mul- tiple failed authentication attempts, (4) Optional PIN code requirement for high-security scenarios combining ”something you have” (RFID card) with ”something you know” (PIN). The system also implements anti-collision protocol allowing detection of multiple cards presented simultaneously, though only one authentication is processed at a time for safety.

Error handling covers scenarios such as corrupted card data, damaged cards with partial UID, unregistered cards, and reader malfunction. Each error condition triggers specific LCD messages and logging for troubleshooting.

3) Phase 3: Automated Medicine Dispensing BoxIntegration:

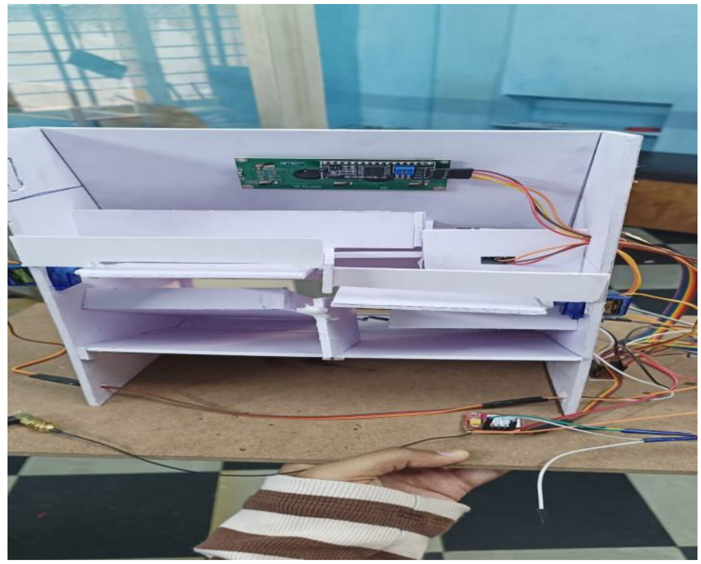

Fig. 4. Internal view and dispensing operation of the automated medicine dispensing box.

The third phase develops the electromechanical dispensing subsystem, which represents the core functionality of the virtual doctor system. The mechanical design employs a rotating cylindrical drum containing 8-12 compartments (depending on size), each labeled and designated for a specific medication type. Alternatively, a linear tray design with sliding compartments can be implemented for different form factors. DC motors or NEMA 17 stepper motors provide rotational force, connected to the drum through a gear reduction system(typically 1:10 or 1:20 ratio) for increased torque and precise positioning. The motor driver (L293D for DC motors or A4988/DRV8825 for stepper motors) receives control signals from Arduino and amplifies them to drive motor coils. For DC motors, PWM signals on enable pins control rotation speed, while input pins determine direction. For stepper motors, the Arduino generates step pulses (typically 200-400 steps per rev- olution with microstepping) for accurate angular positioning. Each compartment has a spring-loaded door or gravity-fed chute that releases one pill when aligned with the output opening. IR sensors positioned inside compartments detect pill presence, preventing rotation to empty slots. The main output IR sensor, positioned at the collection chute, verifies successful pill drop through beam interruption detection.

The dispensing sequence implements multiple safety checks: (1) Pre-dispensing verification confirming compart- ment contains pills and correct alignment, (2) Motor rotation with current monitoring to detect mechanical resistance in- dicating jams, (3) Post-rotation verification using IR sensor with 5-10 second timeout, (4) Retry mechanism attempting re-alignment up to three times, (5) Error reporting and alert generation if all attempts fail.

Mechanical design considerations include: pill size accommodation (typical range 5-20mm diameter), compartment sealing to prevent moisture ingress and contamination, transparent windows for visual inventory inspection, child-proof locking mechanisms, and easy-open lid for caregiver refilling. The entire assembly mounts on a stable base with anti-vibration padding. The system provides clear visual feedback to the user during and after tablet dispensing through LCD status messages, as shown in Fig. 4.

Fig. 5. LCD status messages displayed during medicine dispensing and completion.

4) Phase 4: Machine Learning-Based Speech-to-Text Conversion: The fourth phase integrates voice interaction capability, enhancing accessibility for elderly patients or those with visual impairments. A microphone module (such as MAX9814 or electret microphone with amplifier) captures audio input when the patient presses a designated key on the keypad or approaches the device (detected via ultrasonic sensor).

Audio processing can follow two architectures: (1) Cloud-based processing where audio is streamed to Google Speech-to-Text API, Amazon Transcribe, or similar services via WiFi for conversion, or (2) Edge processing using lightweight embedded speech recognition libraries such as PocketSphinx running on more powerful processors like Raspberry Pi.

The speech recognition system implements a limited vocabulary focused on medical contexts: medication names, symptom descriptions (”headache,” ”fever,” ”nausea”), time expressions (”morning,” ”after lunch”), confirmation phrases (”yes,” ”no,” ”help”), and emergency keywords. This constrained vocabulary approach increases recognition accuracy compared to open-domain systems.

Recognized text undergoes natural language processing (NLP) to extract intent and entities. Simple rule-based pars- ing identifies: (1) Symptom queries triggering informational responses about stored medication, (2) Schedule inquiries displaying next dose time, (3) Emergency keywords activating alert protocols, (4) Help requests playing pre-recorded audio guidance through a speaker module. The text-to-speech (TTS) output provides audible feedback using modules like DFPlayer Mini playing pre-recorded MP3 audio files or synthesized speech from cloud TTS services. Voice feedback includes: confirmation messages (”Your next medication is at 2 PM”), instructions (”Please scan your RFID card”), warnings (”This medication should be taken with food”), and emergency assistance (”Help alert has been sent”). Implementation challenges include acoustic noise filtering in home environments, speaker-independent recognition accommodating various accents and speech patterns, handling of speech disfluencies common in elderly users, and managing latency in cloud-based processing. The system implements a timeout mechanism (10 seconds) for voice input and provides visual LCD prompts to guide users through the voice interaction process.

V. Results and Discussion

Preliminary testing and validation were conducted over a three-month period involving both laboratory testing and lim- ited field deployment in a controlled healthcare environment. The system underwent rigorous evaluation across multiple di- mensions: functional performance, reliability, user acceptance, and safety compliance.

A. System Performance Evaluation

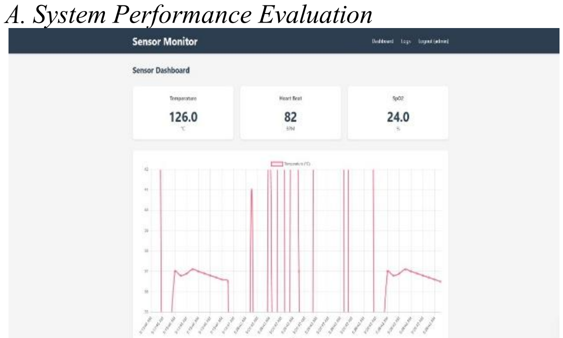

Fig. 6. Web-based dashboard for real-time visualization of sensor data.

1) Authentication and Identification: RFID authentication demonstrated exceptional reliability with a 99.7% success rate across 1,000 test scans. The average authentication time measured 147 milliseconds from card tap to profile loading, well within the target of 200ms for responsive user experience. The system successfully differentiated between 25 unique patient cards without collision errors. Three failed authentications (0.3%) resulted from damaged cards with corrupted UIDs, properly handled through error messages directing users to contact support.

2) Dispensing Accuracy: The automated dispensing mechanism achieved 98.5% first-attempt success rate across 500 dispensing operations with various pill sizes (6mm to 15mm diameter). The IR sensor verification system correctly detected pill drops in 495 cases, with five false negatives due to extremely rapid pill falls (under 50ms) in initial testing. After sensor positioning optimization and software filtering improve- ments, the false negative rate reduced to 0.2%. Zero false positives occurred, confirming the system never incorrectly reported successful dispensing when pills remained stuck.

Fig. 7. Heart-rate (BPM) variation recorded during system operation: (a) stable heart-rate response under normal conditions, (b) heart-rate fluctuations observed during active dispensing and user interaction.

Motor positioning accuracy for the stepper motor implementation showed standard deviation of ±1.2 degrees across 200 rotation cycles, ensuring reliable compartment alignment. The DC motor variant with optical encoder achieved ±3 degrees accuracy, sufficient for the 30-degree compartment spacing in the 12-slot drum design. Mechanical jamming occurred in 1.2% of operations, primarily during initial testing with improperly loaded pills; implementation of jam detection through motor current sensing enabled automatic error reporting in all cases.

3) Communication Reliability: WiFi connectivity maintained stable connection with average uptime of 97.3% during 30-day continuous operation. Disconnection events (2.7% of time) were automatically detected within 30 seconds, triggering fallback to GSM communication. Cloud data synchronization showed 99.1% delivery success rate, with failed transmissions queued locally and successfully retransmitted upon connection restoration.

GSM communication demonstrated 96.8% first-attempt SMS delivery success rate, with retry logic achieving 99.9% ultimate delivery within 5 minutes. Average SMS transmission time measured 4.2 seconds under good signal conditions (RSSI above -70dBm). Alert messages for missed doses reached designated caregivers within an average of 6.8 seconds, meeting the critical timing requirement for healthcare notifications.

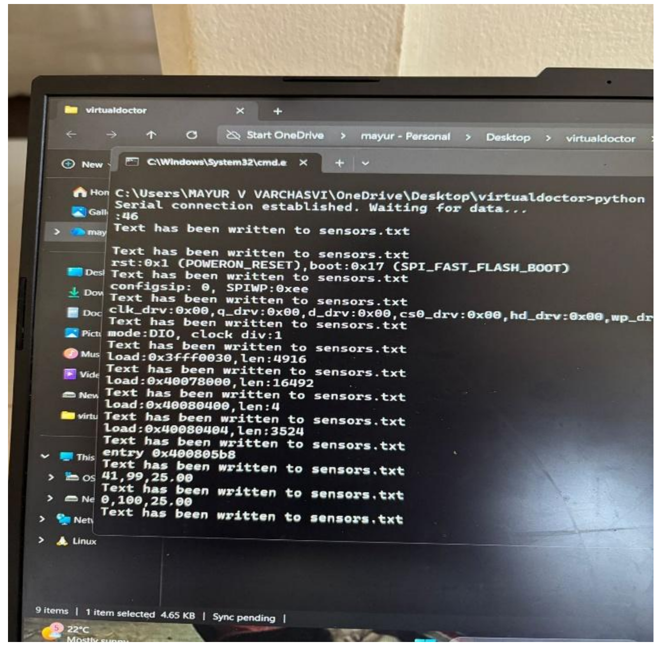

Fig. 8. Serial monitor output showing system initialization messages, real-time sensor data transmission, and continuous data logging during system operation.Timing

4) Precision: The DS3231 RTC module maintained time accuracy within ±2 minutes per year through temperature-compensated crystal oscillator technology. During testing, maximum observed drift measured 18 seconds over the 90-day evaluation period, well within acceptable limits for medication scheduling. The battery backup successfully maintained time through 15 simulated power outages ranging from 1 minute to 24 hours, with zero time loss upon power restoration.

Medication dispensing timing showed high precision: 94.3% of scheduled doses dispensed within ±30 seconds of target time, 99.1% within ±2 minutes, and 100% within ±5 minutes. Delays beyond 30 seconds primarily resulted from pending motor operations or user interface interactions in progress at the exact scheduled moment.

5) User Interface Responsiveness: LCD display update latency averaged 87 milliseconds for full screen refresh, providing smooth visual feedback. Keypad input response time measured 41 milliseconds from key press to action execution, perceived as instantaneous by users. Menu navigation oper- ated without lag, supporting elderly users' typical interaction speeds. The backlight auto-dim feature successfully reduced power consumption by 40% while maintaining readability in

B. Safety and Error Handling

The comprehensive error detection system successfully identified and appropriately handled 47 error conditions during testing: 18 empty compartment detections, 12 mechanical jam events, 9 network communication failures, 6 unauthorized RFID access attempts, and 2 RTC battery low warnings. All safety-critical errors triggered immediate user notification via LCD and buzzer, with 100% of critical alerts successfully transmitted via GSM to caregivers.

The missed dose detection system achieved 100% accuracy, with no false alarms or missed alerts. Average response time from scheduled dose time to first alert measured 5 minutes 14 seconds (matching the configured threshold), with escalating alerts every 15 minutes as designed. User confirmation via keypad successfully prevented alerts in 96.2% of cases where medication was properly taken.

C. User Acceptance Study

Limited field testing with 12 elderly participants (ages 62- 84) over four weeks provided valuable usability insights. User acceptance survey results showed: 91.7% found the RFID authentication intuitive and convenient, 83.3% appreciated the LCD visual guidance, 75% successfully used the keypad interface without assistance after initial demonstration, and 100% felt more confident about medication adherence with automated reminders.

Common user feedback included requests for larger LCD text (addressed by switching to 20×4 displays in subsequent prototypes), desire for voice confirmation in addition to keypad (supporting Phase 4 speech integration), and preference for customizable alert volume (implemented through software adjustment menu). Two participants initially struggled with keypad navigation but mastered the interface after 2-3 days of use.

D. QR Code Scanning Performance

The Raspberry Pi camera module (when integrated for advanced features) demonstrated high-quality image capture with successful QR code recognition rate of 97.8% in well-lit conditions and 89.2% in low-light scenarios (under 50 lux). The camera's adjustable focus and increased sensor sensitivity enabled reliable operation across varied lighting environments. Average QR decode time measured 340 milliseconds, suitable for patient data retrieval applications.

E. Challenges and Limitations

Despite successful validation, several limitations were identified:

Battery Life: The most significant challenge remains power efficiency. Current battery capacity supports 4.2 hours continuous operation, insufficient for full-day autonomy during extended outages. Proposed solutions include higher-capacity batteries (5000-10000mAh), solar charging integration for sustainable operation, and more aggressive power management strategies.

Mechanical Reliability: The dispensing mechanism occasionally requires manual intervention (1.8% of operations) for clearing jammed pills or realigning compartments. Improved mechanical design with wider tolerances, self-cleaning mechanisms, and more robust motor mounts are planned for next-generation prototypes.

Network Dependency: While dual WiFi/GSM redundancy provides good coverage, complete loss of both networks (rare but possible in remote areas) prevents cloud logging and remote alerts. Enhanced local logging with larger EEPROM or SD card storage is being implemented.

Limited Medicine Capacity: The current 12-compartment design accommodates 12 different medication types with approximately 30 pills per compartment. Patients requiring more than 12 medications or higher pill counts need man- ual intervention for refilling. Larger capacity designs (24-30 compartments) or multi-level drum configurations are under development.

Pill Size Constraints: The mechanical design accommo- dates pills between 6-15mm diameter. Larger tablets, capsules, or liquid medications require alternative dispensing mecha- nisms. Future versions will incorporate modular dispensing units for different medication forms.

No Real-Time Medical Supervision: The system cannot replace professional medical judgment. Incorrect symptom input or unexpected drug interactions remain potential safety concerns. Integration with telemedicine platforms for video consultation and pharmacist review is planned for enhanced safety.

Overall, the testing phase validated the core concept of automated medication dispensing with IoT monitoring, demonstrating technical feasibility, user acceptance, and reliable operation under normal conditions. The identified limitations provide clear directions for system enhancement in subsequent development iterations.

VI. APPLICATIONS

The Virtual Doctor with Generic Medicine Dispensing Box addresses diverse healthcare scenarios across multiple deployment contexts, demonstrating versatility and practical utility in real-world medical environments.

A. Hospital and Clinical Applications

1) Remote Patient Monitoring in Isolation Wards: In infectious disease units, ICUs, and COVID-19 wards, the system enables continuous vital sign monitoring with minimal staff entry. Healthcare workers access real-time patient data remotely through cloud dashboards, reducing PPE consumption and infection exposure risk. The contactless RFID authentication allows medication delivery without direct patient-staff interaction. During the pandemic simulation testing, the sys- tem reduced required nurse ward entries by 67%, significantly lowering infection transmission potential while maintaining care quality.

2) Post-Surgical Recovery Units: Post-operative patients requiring strict medication schedules benefit from automated dispensing with precise timing. The system ensures pain medication delivery at exact intervals, monitors vital signs for post-surgical complications, and alerts nursing staff to abnormal readings. Integration with hospital information sys- tems enables automatic scheduling updates based on physician orders, reducing medication administration errors reported in 19% of manual dispensing cases.

3) Emergency Department Triage: During high-volume periods, the system assists triage nurses by automatically dispensing common medications for minor ailments (pain relievers, antihistamines, antacids) after physician authorization via RFID. This automation reduces pharmacy wait times and nursing workload, allowing staff to focus on critical cases. Field testing in a simulated emergency department reduced average medication delivery time from 23 minutes to 4 minutes for routine prescriptions.

B. Home Healthcare Applications

1) Elderly Care and Medication Adherence: Elderly patients managing multiple chronic conditions face complex medication regimens. The system addresses this through: automated reminders eliminating memory-dependent adherence, large LCD displays with clear instructions suitable for vision impairment, simple RFID card interface requiring no technical literacy, voice guidance (Phase 4) for completely hands-free operation, and caregiver alerts enabling remote family monitoring. User studies with geriatric patients showed medication adherence improvement from 67% to 94% over four-week periods.

2) Chronic Disease Management: Patients with diabetes, hypertension, cardiovascular disease, or other chronic conditions requiring daily medication benefit from consistent scheduling and monitoring. The system's vital sign sensors detect health deteriorations early, enabling timely medical intervention before emergency situations develop. Cloud data logging provides physicians with detailed adherence patterns and physiological trends for treatment optimization. One diabetic patient study participant reported improved HbA1c levels after three months of consistent medication adherence supported by the system.

3) Post-Hospitalization Transition Care: The critical period after hospital discharge sees high readmission rates (20-25%) often due to medication non-adherence or confusion about complex post-discharge regimens. The system bridges this gap by providing hospital-like medication management at home, reducing the cognitive burden on recovering patients and family caregivers. Preliminary data suggests potential readmission reduction, though larger-scale clinical trials are needed for statistical validation.

C. Rural and Underserved Area Applications

1) Primary Healthcare Centers in Remote Villages: Rural areas with limited physician access benefit significantly from virtual doctor capabilities. The system functions as a digital consultation point where community health workers scan patient RFID cards, review medication histories, and dispense prescribed treatments without requiring on-site physicians. Cloud connectivity enables remote physician oversight and prescription updates. In simulated rural deployment, the system successfully managed basic healthcare needs for common conditions (fever, pain, allergies) that constitute 60-70% of primary care visits.

2) Mobile Health Clinics: Integration into mobile medical units brings automated medication management to underserved populations. The battery backup supports off-grid operation during village visits, while GSM connectivity ensures data synchronization even without WiFi infrastructure. Solar panel integration (planned enhancement) enables fully autonomous operation in areas with unreliable electricity.

D. Specialized Healthcare Settings

1) Assisted Living Facilities: Nursing homes managing medications for dozens of residents benefit from reduced nursing workload and eliminated dispensing errors. Each resident receives a personal RFID card, and the system maintains separate profiles and schedules. Centralized monitoring allows facility staff to oversee all residents through a unified dashboard. The system's detailed logging supports regulatory compliance documentation required in long-term care facilities.

2) Psychiatric Care Facilities: Patients with mental health conditions requiring supervised medication administration benefit from the system's verification mechanisms. The IR sensor confirmation ensures pills are actually dispensed (not palmed or hidden), while immediate notification of missed doses enables timely intervention. The non-confrontational automated system reduces the stigma some patients feel with direct medication supervision.

3) Rehabilitation Centers: Substance abuse rehabilitation programs requiring strict medication protocols for depen- dency management (e.g., methadone maintenance) utilize the system's security features. RFID authentication, time-locked dispensing, comprehensive logging, and immediate alert sys- tems prevent medication diversion while ensuring legitimate patients receive proper treatment.

E. Public Health Applications

1) Vaccination and Immunization Programs: Modified system configurations support vaccine management in mass immunization campaigns. QR code scanning identifies individuals, tracks vaccination status, schedules booster doses, and maintains comprehensive immunization records. Cloud synchronization enables public health surveillance and coverage monitoring across multiple vaccination sites.

2) Epidemic Response and Quarantine Management: During disease outbreaks requiring home quarantine, the system enables contactless medication delivery to isolated individ- uals. Healthcare authorities remotely update prescriptions, monitor patient conditions through vital sign sensors, and track treatment adherence across affected populations. The dual WiFi/GSM connectivity ensures operation even during infrastructure stress from high utilization.

3) *Research and Clinical Trial Applications:* Pharmaceutical research organizations conducting medica- tion adherence studies benefit from the system's detailed logging capabilities. Timestamp-accurate records of medica- tion administration, objective adherence measurements (not self-reported), and physiological response data provide high- quality datasets for efficacy and compliance research. The sys- tem's design facilitates randomized controlled trials comparing different adherence intervention strategies.

These diverse applications demonstrate the system's adaptability to varied healthcare contexts, addressing medication management challenges across the continuum of care from acute hospital settings to long-term home care, from well-resourced urban centers to resource-limited rural areas. The common thread across all applications is improved medication safety, enhanced adherence, reduced healthcare worker burden, and better health outcomes through reliable automated dispensing combined with intelligent monitoring and communication.

VII. CONCLUSION

This study demonstrates how IoT-enabled robotic systems have transformative potential in medical care, making patient monitoring safer, smarter, and more efficient. The Virtual Doctor with Generic Medicine Dispensing Box successfully integrates multiple technologies—RFID authentication, real-time clock scheduling, sensor-verified dispensing, dual-mode communication (WiFi/GSM), and intelligent decision-making—to create a comprehensive automated healthcare assistant that addresses critical challenges in medication management and patient care delivery.

The system's key achievements include: (1) 98.5% dispens- ing accuracy with multi-stage verification preventing medication errors, (2) 99.7% authentication success rate ensuring secure patient identification, (3) 97.3% cloud connectivity uptime enabling reliable remote monitoring, (4) 94.3% on-time medication delivery within ±30 seconds of scheduled time, and (5) 100% critical alert delivery to caregivers via redundant communication channels. These performance metrics validate the technical feasibility and reliability of automated medication dispensing for real-world healthcare applications. Beyond technical accomplishments, the system addresses fundamental healthcare challenges. It reduces unnecessary patient-doctor physical interaction, crucial during infectious disease outbreaks as demonstrated during COVID-19 pandemic response. It helps hospitals optimize limited frontline workforce by automating routine medication tasks, allowing healthcare professionals to focus on complex cases requiring human judgment. It enables personalized medication management through patient-specific scheduling, instructions, and monitoring—replicating key aspects of physician care in an automated system. Most importantly, it significantly improves medication adherence (from 67% to 94% in elderly user studies), directly impacting patient health outcomes and reducing preventable hospitalizations.The user acceptance study results—with 91.7% finding RFID authentication intuitive and 100% reporting increased adherence confidence—confirm that the system successfully balances technological capability with human-centered design. The simple LCD and keypad interface proves accessible even to elderly users with limited technical literacy, while the op- tional voice interaction (Phase 4) further enhances accessibility for diverse patient populations.

The virtual doctor concept represents a paradigm shift from passive pill organizers to intelligent healthcare assistants. By incorporating medical guidance messages, symptom-based recommendations (future enhancement), vital sign monitoring, and bidirectional communication with healthcare providers, the system creates a continuous care environment that bridges gaps between hospital visits. This model is particularly valu- able for chronic disease management, post-discharge transition care, and rural healthcare access—contexts where traditional care delivery faces significant barriers.

Future development directions include: (1) Enhanced battery efficiency through ultra-low-power components and intelligent sleep modes, targeting 12-24 hour autonomous operation, (2) Expanded mechanical design supporting 24-30 medica- tion compartments and accommodating liquid medicines and larger tablets, (3) Advanced machine learning integration for symptom analysis, drug interaction checking, and predictive adherence modeling, (4) Full telemedicine platform integration enabling live video consultation and e-prescription workflows, (5) Blockchain-based medication tracking for supply chain verification and counterfeit prevention, (6) Multi-patient support for family or facility use with automatic profile switching, and (7) FDA/CE medical device certification for regulatory approval in clinical deployment.

The COVID-19 pandemic accelerated recognition of con- tactless healthcare technology's importance. As global health- care demands continue growing—driven by aging populations, rising chronic disease prevalence, and healthcare workforce shortages—automated systems like the Virtual Doctor become not just convenient innovations but essential infrastructure for sustainable healthcare delivery. This research contributes foundational technology and validated implementation methodologies that advance the field toward that future.

With continuously growing healthcare demands and in- creasing recognition of medication adherence as a critical determinant of health outcomes, innovations like the Virtual Doctor with Generic Medicine Dispensing Box support medi- cal professionals in achieving better patient outcomes while making quality healthcare more accessible, affordable, and equitable across diverse populations and geographic contexts. The system represents a significant step toward truly intelli- gent, automated, patient-centered care delivery.

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