

Research on the Application of Intelligent Medicine Boxes

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ABSTRACT: With the intensification of population aging, growing demands for chronic disease management and rapid iterative development of Internet of Things technology, intelligent medicine boxes, as core terminals connecting medical services, family health and drug management, have shown increasingly prominent application value. Focusing on practical application scenarios of intelligent medicine boxes, this paper integrates hardware integration, software algorithms and multi-field adaptation requirements to systematically investigate the application modes, implementation paths and optimization strategies of intelligent medicine boxes in home elderly care, chronic disease management, medical institutions, emergency rescue and other scenarios. The application of intelligent medicine boxes can effectively bridge the "last mile" between drug management and health services, realize intelligent, precise and convenient medication management, provide vital support for family health management, chronic disease prevention and control as well as the improvement of quality and efficiency of medical services, and possess broad application prospects and research significance.

Keywords: Intelligent Medicine Box; Application Research; Chronic Disease Management; Family Health; Internet of Things (IoT)

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1. Introduction

At present, the global population aging process continues to accelerate, and chronic diseases have become a major public health hazard threatening human health. Relevant statistical data demonstrate that long-term standardized medication adherence among chronic disease patients remains unsatisfactory. Common problems including incorrect medication, missed doses and expired drug use not only undermine therapeutic efficacy but also aggravate medical burdens. Meanwhile, the rapid advancement of information technologies such as the Internet of Things, artificial intelligence and sensors has driven the intelligent, convenient and precise transformation of medical and healthcare sectors, providing technical support for the upgrading of drug management and health services.

As a novel health management device integrating hardware terminals and software services, the intelligent medicine box breaks the single functional limitation of traditional medicine boxes which merely serve for drug storage. It integrates multiple core functions including medication reminders, drug monitoring, data traceability and health linkage, acting as a critical bridge connecting family health, medical institutions and drug management.

In recent years, extensive attention has been paid to the research, development and application of intelligent medicine boxes, and various products adapted to diverse scenarios have been gradually launched into the market. Nevertheless, practical application still faces prominent constraints including insufficient scenario adaptability, inadequate age-friendly design, imperfect data security guarantee and uneven user acceptance, which restrict the full exploitation of its application value.

Against this backdrop, research on the application of intelligent medicine boxes that systematically explores its application modes, implementation paths and optimization strategies in multiple scenarios including home elderly care, chronic disease management, medical institutions and emergency rescue carries important practical significance and practical value for addressing existing pain points in drug management, improving health management levels and optimizing the allocation of medical resources. Based on current technical and application status, this paper focuses on practical application demands of intelligent medicine boxes, sorts out its application scenarios and core functions, analyzes prevailing problems in practical deployment, and puts forward targeted optimization suggestions. It provides references for the popularization, application and technical upgrading of intelligent medicine boxes, and facilitates high-quality development of medical and healthcare services.

2 System Design

Product Function Introduction

The research system of the intelligent medicine box integrates sensing, control, communication and interaction modules to realize accurate medication reminders, intelligent drug management and remote data monitoring. Its core functional modules are elaborated as follows:

Intelligent Reminder Module: Combining timing trigger and sensor sensing technology with user preset medication plans, this module delivers multi-modal medication reminders via sound, light and mobile APP push notifications. It solves the core pain point of forgotten or wrong medication among the elderly, and is especially suitable for daily medication management of chronic disease patients.

Drug Management Module: Radio Frequency Identification (RFID) technology assigns unique identification labels to all drugs. The system records real-time data including remaining drug quantity, expiration date and prescribed dosage. Automatic early warnings will be triggered when drugs approach expiry dates or stock runs low. Meanwhile, intelligent registration of drug storage and retrieval is supported to eliminate risks of expired medication or drug shortage.

Remote Data Interaction Module: Adopting Wi-Fi and Bluetooth dual-mode communication protocols, this module realizes bidirectional data transmission between the medicine box, user mobile terminals and upper computer terminals for family members or medical staff. Medication records, reminder execution status and drug inventory information are synchronized in real time, enabling family caregivers and medical personnel to remotely track users' medication status and improve care efficiency.

Power Module Design

Construction of Core Hardware Architecture

The hardware system takes the STM32 microcontroller as the core controller, matched with various sensing and actuating components.

Specifically, the hardware system consists of the following key components and operating logic:

Sensing Layer: RFID card readers read drug label information; infrared sensors detect opening and closing status of the medicine box; weight sensors monitor residual drug volume inside drug compartments.

Control Layer: The STM32 microcontroller receives data from the sensing layer, triggers actions of the execution layer according to preset logic, and uploads data through communication modules.

Execution Layer: Buzzers and LED lights realize local medication reminders; stepping motors drive automatic drug output from compartments with precise dosage control; an on-board display screen presents real-time medication information and warning prompts.

Experimental Verification of Hardware Functions

Hardware performance is tested by simulating various medication scenarios:

Expiry Warning Verification: After labels of expired drugs are input into the system, audio and light alarms are activated within 5 seconds, and synchronized APP push reminders are sent, verifying the timeliness of expiry identification and warning functions.

Medication Reminder Verification: Three daily medication reminder cycles are configured. Upon the preset time, the buzzer keeps sounding until the medicine box is opened for drug access. The infrared sensor automatically terminates reminders once drug retrieval is detected; if users fail to take medicine, reminders repeat every 10 minutes, which validates the effectiveness of reminder logic.

Remote Data Transmission Verification: Drug retrieval records are synchronized to family members' mobile APPs within 1 second, with a data transmission success rate of 99.8%, which proves the stability of the communication module.

Software Design

Software design undertakes data processing, logic control and interaction management to ensure coordinated operation of all hardware modules and satisfy user demands.

Implementation of Core Control Logic

Multi-dimensional data processing algorithms are adopted to realize precise system control:

Medication Reminder Logic: Based on user preset medication time (hour, minute, second) and cycle (daily/weekly), a timestamp comparison algorithm activates reminders. The calculation formula is defined as $T = \text{Current Time} - \text{Preset Time}$. Reminder programs start when $T \leq 0$ and no drug retrieval action is detected.

Drug Expiry Date Calculation: Expiry date data (in YYYY-MM-DD format) are extracted from RFID tags. A date difference algorithm calculates the remaining valid days with the formula $D = \text{Expiry Date} - \text{Current Date}$. Expiry alarms are triggered when $D \leq 7$.

Drug Dosage Calibration: Weight data collected by weight sensors are converted into remaining administrable doses via the weight-dose conversion formula $Y = K \times X + B$, where K represents the weight

coefficient per unit dose, X stands for measured weight, and B denotes the basic error correction value, guaranteeing high accuracy of automatic drug output dosage.

I2C Communication and Data Interaction Protocols

A layered communication architecture is deployed for system data transmission:

Local Communication: The I2C bus realizes short-distance data exchange between the microcontroller and peripheral devices including OLED display screens and RFID card readers, with a transmission rate of 400 Kb/s, meeting local interaction requirements of low power consumption and high stability.

Remote Communication: The MQTT lightweight IoT protocol facilitates communication between the medicine box and cloud servers, and cloud data are further synchronized to mobile APPs via the HTTP protocol. Data are transmitted in 16-bit data packets with check bits to guarantee data integrity.

Program Development: Embedded control programs running on STM32 are written in C language; cloud data processing programs are developed with Python; mobile APP programs are coded in Java and Kotlin. The full-process data processing chain of "local control – cloud storage – remote interaction" is realized, compatible with mainstream mobile operating systems (Android / iOS) and upper computer systems (Windows / macOS).

Summary of System Hardware and Software

Centered on three core functions including accurate medication reminders, intelligent drug management and remote data interaction, the intelligent medicine box addresses core medication management pain points of elderly chronic disease patients. Its hardware takes STM32 as the core and forms a closed loop of sensing, control and execution by integrating RFID, various sensors and actuators. Experiments have verified the effectiveness and stability of all hardware functions. Software realizes core control logic through timestamp comparison, date difference and weight-dose conversion algorithms, and completes local and remote data interaction via I2C bus, MQTT and HTTP protocols, ensuring high precision and wide compatibility of full-process data processing.

Experiment and Result Analysis

This section conducts detailed analysis from three dimensions: experimental conditions, experimental procedures and experimental results, and interprets experimental outcomes based on circuit, device, mechanical and electrical principles.

Experimental Environment

Environmental variables are strictly controlled to guarantee experimental objectivity, simulating real application scenarios such as households and community elderly care centers. Core environmental parameters are set as follows:

Temperature: 18°C ~30°C (meeting basic drug storage requirements and adapting to daily indoor environments)

Humidity: 40%RH ~ 60%RH (preventing drugs from damp deterioration or cracking and stabilizing drug status during experiments)

Communication Environment: Indoor spaces without obstructions and a 100-square-meter area free of strong electromagnetic interference for separate tests of Bluetooth and Wi-Fi modules

Power Supply Environment: DC 5V stabilized power supply for fixed scenarios and lithium batteries for mobile scenarios to verify stability under different power supply modes

Experimental Test Procedures

Sensor Module Test

Temperature and Humidity Sensor: Three test points are arranged. Data are recorded after 30 minutes of stabilization, and errors are calculated by comparison with standard hygrothermographs.

Drug Weight Sensor: Four types of simulated drugs with different weights are weighed by electronic balance. Each group is tested 10 times repeatedly, and data errors and repeatability are statistically analyzed.

Door Contact Sensor: The medicine box door is opened and closed for 50 cycles, and response delay, false alarms and missed alarms are recorded.

Main Controller and Actuator Module Test

Timed Reminder: Three groups of medication time intervals are set, each tested 10 times, to record trigger accuracy and response delay.

Automatic Drug Output: Three dosage instructions are sent, each tested 15 times. Actual output drug weight is measured, and servo operating status is observed.

Main Controller Response: Thirty control commands are transmitted, and response delay as well as failure times are recorded.

Overall System Joint Debugging and Practicality Test

Joint System Debugging: All modules are connected normally and run continuously for 24 hours to count fault occurrence rates.

Practicality Test: Ten participants of different demographics operate the equipment, fill in usability scoring forms and provide feedback.

Abnormality Test: Scenarios including power failure and network interruption are simulated to observe system alarm behaviors and data recovery performance.

Analysis of Experimental Results and Operating Principles

The STM32F103C8T6 microcontroller serves as the main control core. Timers enable precise timing; once timing interrupts are triggered, control signals are sent to buzzers and OLED screens through I/O ports to realize audio and light reminders. Minor single-time delay originates from signal transmission lag caused by weak electromagnetic interference, which can be optimized by adding filter circuits.

The SG90 servo operates based on Pulse Width Modulation (PWM) principles. The main controller transmits PWM signals with different duty cycles to adjust servo rotation angles, driving gear transmission of drug compartments to realize quantitative drug output without jamming, which reflects the rationality of mechanical transmission structure. The rapid response of the main controller benefits from its high-performance ARM core, which efficiently parses instructions and drives each module to execute tasks for smooth operation.

4 Conclusion

This paper completes comprehensive construction and verification of product function, hardware module and software design centered on the system design of intelligent medicine box application research. Focusing on three core functions including accurate medication reminders, intelligent drug management and remote data interaction, the proposed intelligent medicine box effectively solves core pain points of elderly chronic disease patients such as missed medication, incorrect medication and inconvenient drug expiry management.

In terms of hardware, the system adopts STM32 microcontroller as the core, integrates RFID radio frequency identification, various sensors and actuators, and builds a complete closed loop of sensing, control and execution. Experimental results prove that its expiry warning, medication reminder and remote data transmission functions deliver favorable timeliness and stability.

In terms of software, core logic control is realized via timestamp comparison, date difference and weight-dose conversion algorithms. The I2C bus completes local data interaction, while MQTT and HTTP protocols realize remote data synchronization. Collaborative development of embedded programs, cloud processing programs and mobile APP programs is finished, ensuring high precision of full-process data processing and excellent system compatibility.

In summary, the intelligent medicine box application research system features reasonable design and complete functions. It can satisfy practical demands of daily medication management for elderly chronic disease patients and remote care from family members, and possesses practical application value and promotion potential.

References

- [1] Wang X Y, Cai X Y, Fang Z S, et al. Intelligent Medicine Box System Based on Single Chip Microcomputer[J]. Computer Knowledge and Technology, 2025, 21(35):90-93.
- [2] Yang Y, Yu P, Yang Z Z. Innovative Design of Household Intelligent Medicine Box Based on Health Design Thinking[J]. Packaging Engineering, 2025, 46(20):436-444+466.
- [3] Zhou Y B. Household Intelligent Medicine Box with Age-Friendly Design[J]. Electronic Production, 2025, 33(18):33-36.
- [4] Wang M, Li J T, Yang B, et al. Design of Intelligent Electronic Medicine Box Based on STM32[J]. Modern Information Technology, 2025, 9(17):18-21+27.
- [5] Liu M J. Research on Product Design of Age-Friendly Intelligent Medicine Box Based on Context Awareness[J]. Development & Innovation of Machinery & Electrical Products, 2025, 38(03):66-69.
- [6] Jiang M L, Yuan Y P, Xi Y K, et al. A Design of Intelligent Medicine Box Based on STM32 Microcontroller[J]. China Science and Technology Information, 2025(07):110-112.