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Vending Machine for Enhancing Healthcare Access

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| Article Info	Abstract
	This project addresses challenges in pharmacy access and feedback mechanisms for vending machine utilization by developing an advanced healthcare vending system. The system integrates RFID technology and an Arduino Mega microcontroller to enable secure dispensing and a conceptual RFID-based payment system. Additionally, an MIT App was developed to provide customer assistance. The methodology involved designing and assembling the vending machine's mechanical and electrical components, programming the Arduino Mega, and testing the system. Results demonstrated robust RFID tag detection at 100% within 1.0 cm, declining accuracy at greater distances, and product vending accuracy ranging from 70% to 90% across slots. These findings highlight the potential of the system to enhance healthcare accessibility through reliable dispensing technology. Future improvements include IoT-based real-time inventory tracking for stock and expiration monitoring and implementing a Telegram bot for intelligent inventory management.

1. Introduction

The evolution of vending machines, initially designed for dispensing snacks and beverages, has showcased the potential for automation and convenience across industries [1]. While widely successful in the food and beverage sector, their application in healthcare, specifically for medical supplies, remains underexplored [2]. This study addresses the challenges associated with traditional healthcare distribution channels, emphasizing the need for timely and accessible means to obtain Over-the-Counter medicines and first aid products [3]. Despite advancements in vending machine technologies, significant challenges persist in ensuring continuous access to essential healthcare products. Many vending machines lack real-time inventory monitoring and advanced payment options, limiting their usability for healthcare applications [4]. Additionally, the absence of user-owner communication mechanisms for feedback further restricts the optimization of these systems for medical purposes. This paper proposes a comprehensive system to tackle the challenges of providing continuous access to essential medications. The system leverages advanced technology, including servo motors and Arduino Mega boards, to create an efficient dispensing mechanism. Additionally, the integration of RFID and NFC scanning for payment processing ensures a seamless and contactless purchasing experience. To further enhance user convenience, an MIT application and Google Sheet will be developed for managing transactions and assisting users. The proposed system not only aims to improve the availability of healthcare essentials but also seeks to optimize user satisfaction and reliability. By addressing the limitations of current vending machine systems and providing a robust solution, this research endeavors to make a significant contribution to the healthcare sector, ensuring that individuals have access to the medical essentials they need, whenever and wherever they need them.

2. System Block Diagram

The vending machine system comprises three key components: hardware circuitry, microcontroller programming (Arduino IDE software), and mobile application development (MIT Application). The vending machine operates through three essential systems, each playing a crucial role in ensuring its smooth functioning. The primary system, consisting of servo motors and an Arduino Mega, is dedicated to vending operation. The second system is the locking mechanism, comprising RFID technology and a 12V solenoid lock. Lastly, the smart lighting system involves a 12V LED strip and an ultrasonic sensor.
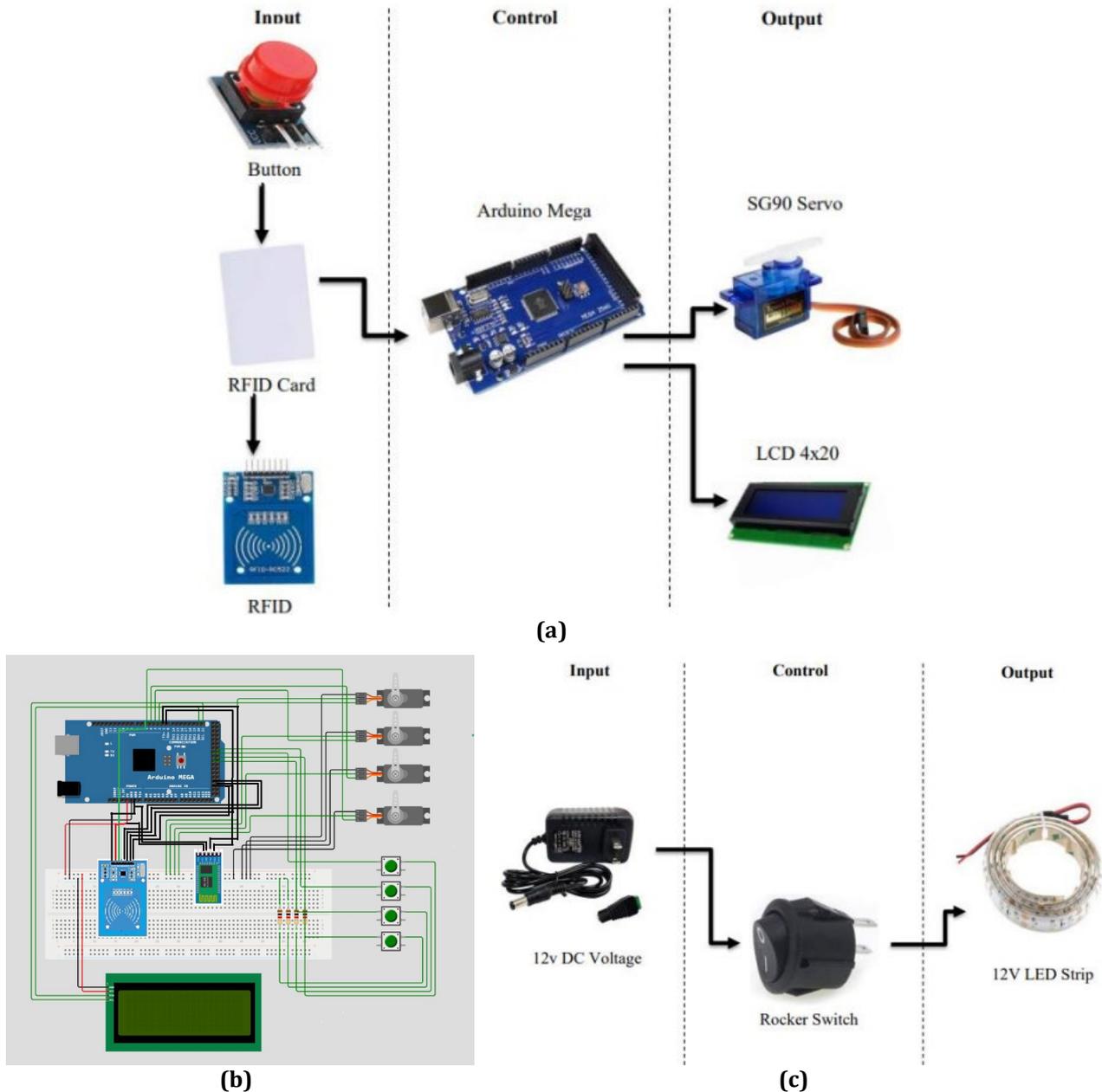
Fig. 1 *The block diagrams of vending machine for enhancing healthcare access: (a) Block diagram of Arduino based RFID vending system; (b) Circuitry; (c) Block diagram of lighting system*

Integration of these three systems is key to achieving efficient and effective project operation. The block diagram in Fig. 1 (a) illustrates an Arduino-based vending system, thoughtfully organized into three distinct sections for clarity. In the input section, there are buttons, an RFID card, and an RFID reader. The control section features an Arduino Mega microprocessor board. The output section incorporates a servo motor. The block diagram's sequence initiates with a button press. Subsequently, the LCD prompts the user to make a payment by tapping the RFID card. Upon presenting the RFID card, the servo motor rotates for a specified duration, facilitating

the delivery of the selected product to the customer. Following the successful transaction, the LCD displays a gratitude message before looping the system for the next purchase. Its circuitry connection is shown in Fig. 1(b). On the other hand, Fig. 1 (c) outlines a 12v Dc lighting system. The input section incorporates 12v DC Adapter. The control section features a rocker switch, while the output section includes a 12V LED strip. The block diagram's operation initiates with the button. If the button switched on, the 12V LED strip activates and remains on until the button turned off. This approach serves to illuminate the vending machine, potentially placing it in hibernation mode.

The Arduino Integrated Development Environment (IDE) was utilized to program the microcontroller, enabling precise control over the vending machine's motor functions. By writing and uploading custom code through the Arduino IDE, the microcontroller was configured to regulate motor movements essential for dispensing products. This programming ensures accurate coordination between user inputs and mechanical actions, allowing the motor to operate efficiently and deliver items to the user in a controlled manner. The simplicity and versatility of the Arduino IDE make it an ideal platform for developing and refining the motor control algorithms required for the vending process.

On the other hand, the MIT App Inventor platform was employed to develop a mobile application that enhances user interaction with the vending machine. The application provides a user-friendly interface to display transaction options and facilitates wireless connectivity with the vending machine. Additionally, the app includes a feature for lodging improvement reports, allowing users to submit feedback directly. These reports are seamlessly integrated into a Google Sheets database, enabling the vending machine owner to review and address user suggestions efficiently. This integration ensures continuous system improvement and a more satisfying user experience while maintaining streamlined communication between users and the vending machine operator.

3. Result and Discussion

This section discusses the final product output, and the four types of tests conducted on the vending machine. The performance of the servo motors was analyzed using a digital oscilloscope, revealing consistent and reliable operation for accurate product delivery. Push button continuity analysis confirmed that all buttons functioned correctly, ensuring reliable user input. The LM7812 voltage regulator performance analysis indicated a stable power supply, enhancing overall system reliability. RFID card detection accuracy was high, ensuring secure and efficient cashless transactions. Additionally, product vending accuracy in each slot was tested, confirming the system's reliability in consistently delivering the correct items. These tests collectively demonstrate the vending machine's robustness and effectiveness in providing secure, accurate, and reliable access to essential healthcare products

3.1 Final Product

Fig.2 presents the final product of this project: a fully integrated vending machine with servos, lights, and an MIT system. Image (a) shows the front view, Image (b) shows the left side view, and Image (c) shows the right1side view. The front door features an LCD display, four buttons, and an RFID tag reader. Users select the desired item and tap their RFID tag as a method of payment, after which the servo motors dispense the selected item to the customer. The MIT app allows users to scan and download the MIT APK for providing feedback and complaints to the vending machine owner, facilitating further improvements.

(a)　　　　　　　　　**(b)**　　　　　　　　　**(c)**

Fig. 2 *Final product (a) Front view; (b) Left-side view; (c) Right-side view*

3.2 MIT Application Interface

The MIT application interface consists of five screen pages. Fig. 3(a) displays the initial welcome screen of the app, which automatically transitions to the next page shown in Fig. 3(b). Here, the user is presented with three options: Product Details, Feedback and Complaints, and Hotline. The Product Details screen, depicted in Fig. 3(c), provides a comprehensive description of the products available in the vending machine. The Feedback and Complaints option allows users to send feedback to the owner by inputting their email address and message, then clicking the send button. The Hotline option leads to the screen shown in Fig. 3(e), where users can view the creator's details and contact information for further assistance.

(a)   **(b)**   **(c)**

(d)   **(e)**

Fig. 3 *MIT application interface (a) User authentication page; (b) Administration page; (c) Product description; (d) Feedback and report page; (e) Creator information*

3.3 Push Button Continuity Analysis

Table 1 outlines the process for conducting button continuity tests, which are crucial for ensuring the functionality and reliability of buttons in electronic devices. During this test, specific pass/fail criteria are employed to determine if a button is operating correctly or if there are potential defects in the button mechanism or associated circuitry. Using a multimeter in continuity mode, the test involves setting the multimeter to measure continuity, where it emits a beep or indicates a complete electrical connection between two points. Each button or switch is

activated, and the multimeter's probes are placed across the terminals or contacts of the button. If the multimeter indicates continuity, it confirms that the button or switch is making a proper electrical connection, verifying that the device functions as intended when the button is pressed. This process is fundamental in validating the functionality and reliability of buttons within electronic systems.

Table 1 *Continuity detection analysis*

Button	Continuity Detection	Result
1	Sound	Functional
2	Sound	Functional
3	Sound	Functional
4	Sound	Functional

3.4 Servo Motor Analysis

Fig. 4 displays the wave difference between input and Arduino mega signal to the servo motor. In Fig. 4 (a), Pulse with Modulation signal with a consistent peak-to peak voltage of approximately 5V and uniform delays between pulses, indicating a stable and fixed command aimed at maintaining the servo motor in a constant position captured with a time division of 10 ms/div and a voltage scale of 5 V/div. This difference in pulse width could signify a variation in the control signal or a response characteristic of the servo motor circuitry. Such distinctions in pulse width can impact 47 the servo motor's behavior, influencing factors like position or speed, depending on the specific pulse width modulation (PWM) control scheme implemented. The pulse width difference can affect the servo motor's performance, such as its position or speed, depending on the pulse width modulation (PWM) control scheme used. This analysis helps in understanding the precise timing and voltage characteristics of the signals involved, which is crucial for debugging and optimizing the performance of the servo motor system in your project.

(a)

(b)

Fig. 4 *Wave difference analysis (a) Servo motor's Input signal wave; (b) Servo motor signal wave during operation*

3.5 LM7812 Voltage Regulator Performance Analysis

Table 2 details the performance efficiency percentage for LM7812 voltage regulators. The primary objective is to verify that each of the four regulators provides the correct voltage drop, thereby safeguarding the servo motors from potential damage. The LM7812 is specifically chosen for its ability to maintain a constant 12V output, making it ideal for applications requiring a stable voltage supply. This setup ensures the safety and reliability of the servo motors by delivering a regulated and stable 49 voltage, eliminating the risk of overvoltage-related issues. In essence, this analysis underscores the importance of LM7812 voltage regulators in maintaining proper functionality and safety for servo motors through regulated voltage supply.

Table 2 *Voltage regulator performance analysis*

Voltage Regulator	Input Voltage (V)	Output Voltage (V)	Performance Efficiency
Regulator 1	12.10	5.10	100%
Regulator 2	11.91	5.17	100%
Regulator 3	12.16	5.11	100%
Regulator 4	11.94	5.10	100%

3.6 RFID Card Detection Accuracy

Table 3 shows the data collected during RFID card detection accuracy testing. The RFID detection accuracy test was conducted to determine the effective range of the RFID detector. The results, as summarized in Table 3, indicate that the detection reliability diminishes with increasing distance between the RFID card and the detector. At a close range of 0.5 cm and 1.0 cm, the RFID card was successfully detected in all five trials, achieving a 100% detection rate. However, as the distance increased to 1.5 cm, the detection rate dropped to 60%, with the card being detected in only three out of five trials. Further increases in distance to 2.0 cm resulted in a detection rate of 40%, with the card detected only once out of five trials. Beyond this range, at distances of 2.5 cm and 3.0 cm, the RFID card was not detected at all, resulting in a 0% detection rate. These findings highlight the critical impact of proximity on RFID detection accuracy, underscoring the need for close placement of RFID cards to the detector for reliable operation.

Table 3 *RFID detection analysis*

Distance of RFID card from Detector (cm)	Trial					Successful Detection Percentage (%)
	1st	2nd	3rd	4th	5th	
0.5	Detect	Detect	Detect	Detect	Detect	100
1.0	Detect	Detect	Detect	Detect	Detect	100
1.5	Not Detect	Detect	Detect	Detect	Not Detect	60
2.0	Detect	Not Detect	Not Detect	Detect	Not Detect	40
2.5	Not Detect	Not Detect	Not Detect	Not Detect	Not Detect	0
3.0	Not Detect	Not Detect	Not Detect	Not Detect	Not Detect	0

3.7 Product Vending Accuracy in Each Slot

The product vending accuracy test for various medical items revealed varying levels of reliability in the vending machine's performance. As shown in Table 4, Hurix's Inhaler had a successful vending rate of 70%, with 7 out of 10 successful attempts. Both Hansaplast and Neobun Medicated Plaster had a successful vending rate of 80%, each with 8 out of 10 successful attempts. Salonpas Pain Reliever exhibited the highest accuracy, with a 90% success rate, successfully vending 9 out of 10 times. These results highlight that while the vending machine generally performs well, there is room for improvement, particularly for items like Hurix's Inhaler. This analysis underscores the importance of optimizing the vending mechanism to ensure consistent and reliable dispensing of all products.

Table 4 *Product vending accuracy in each slot*

Medical Items	10 times Vending Trial		Accuracy Percentage (%)
	Successful Vending	Unsuccessful Vending	
Hurix's Inhaler	7	3	70
Hansaplast	8	2	80
Neobun Medicated Palster	8	2	80
Salonpas Pain Reliever	9	1	90

A comparative analysis of existing medical vending machines reveals key limitations and areas for improvement that the proposed system addresses. Earlier designs, such as the system by Brolin *et al.* [5], relied on manual inventory updates and debit/credit card payments, while Singh [6] introduced token or coin-based payment with barcode scanning but lacked real-time connectivity. Similarly, Bhande *et al.* [7] implemented an open-source payment gateway but omitted inventory tracking capabilities, and Anusha *et al.* [8] focused solely on storing common medications without advanced dispensing mechanisms. Unlike these systems, the proposed healthcare essentials vending machine integrates RFID technology for seamless and secure transactions, coupled with a servo motor mechanism to enhance the efficiency and reliability of the dispensing process. Additionally, the implementation of a lighting system ensures better visibility during item retrieval. By incorporating IoT for real-time inventory tracking and a mobile application for user feedback and system management, this work significantly advances the capabilities of healthcare vending machines, bridging critical gaps in accessibility, usability, and system intelligence

4. Conclusion

In summary, the successful design and development of the Essential Healthcare Medical Vending Machine project was achieved through the integration of RFID technology, servo motors, and an Arduino Mega. This initiative involved the identification and testing of various electronic components before their integration into a cohesive system. After the planning and design phases, the Arduino code was developed and uploaded to each control unit. Rigorous testing was conducted to evaluate the system's performance in real-world scenarios, and the analysis results were documented. This cashless vending machine operates without the need for physical currency, allowing users to make transactions using electronic payment methods such as RFID and NFC. Detection reliability was found to diminish with increasing distance between the RFID card and the detector. At close ranges of 0.5 cm and 1.0 cm, the RFID card was successfully detected in all five trials, achieving a 100% detection rate. However, at 1.5 cm, the detection rate dropped to 60%. The MIT application interface for the vending machine consists of five screen pages, including the initial welcome screen, product details, feedback and complaints, and hotline access.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** *Satheesh Anantha Rao, Yee See Khee;* **data collection:** *Satheesh Anantha Rao;* **analysis and interpretation of results:** *Satheesh Anantha Rao, Yee See Khe;* **draft manuscript preparation:** *Satheesh Anantha Rao, Yee See Khe. All authors reviewed the results and approved the final version of the manuscript.*

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