Penerbit Akademia Baru

Malaysian Journal on Composites Science and Manufacturing

Journal homepage:
https://www.akademiabaru.com/submit/index.php/mjcsm/
ISSN: 2716-6945

Design and Fabrication of a Quick Action Medicine Dispensary

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ARTICLE INFO

Article history:
Received 15 May 2024
Received in revised form 21 February 2025
Accepted 25 February 2025
Available online 30 March 2025

ABSTRACT

One of the major concerns in the medication process is ensuring that patients take the right medicine at the right time. This issue often necessitates additional assistance, especially for patients who need to take multiple medications multiple times a day, as it can be challenging to remember and manage all medications efficiently. Extensive research has been conducted on developing automated medicine dispensaries to aid patients in this process. However, most existing solutions are either theoretical design concepts or limited to dispensing medicines in batches only. This research aimed to design and fabricate an automated and universal medicine dispensary that addresses the challenges of accessibility and the complexities of scheduled medication intake. This dispensary also provides the capability to dispense medicines both in batches and as single units, according to user requirements. A comprehensive design concept was developed, incorporating essential features such as medicine storage, a user interface, a dispensing mechanism, and a timer system. The prototype was constructed using polyvinyl chloride (PVC) and polylactic acid (PLA), and its functionality was evaluated. The evaluation demonstrated that the automated dispensary could store multiple types of medicines. It featured a compact and user-friendly interface, an accurate alarm system for reminding patients of their scheduled medication times, and a precise dispensing mechanism capable of dispensing medicines discretely and in batches. This automated medicine dispensary, leveraging composite materials like PVC and PLA, has the potential to streamline medication intake processes, enhance healthcare services and revolutionize next-generation medicine.

Keywords:
Automated Medicine Dispensing, Medication Management, Next Generation Medicine, Poly Vinyl Chloride, Polylactic Acid

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https://doi.org/10.37934/mjcsm.16.1.4659

1. Introduction

In the field of healthcare, medicine management is as important as receiving medical consultancy. In today's world, where every aspect of life is becoming automated, automating medication management is a logical step. Managing a large number of medicines on multiple schedules can be a critical and challenging task. Due to these complexities, many individuals often require specialized assistance to manage their medications. This dependency can make the medication process problematic, as it is not always feasible to have a personal assistant for medication management. Moreover, even individuals who manage their medications independently can miss doses due to human error, especially when dealing with a large number of medications. This issue is particularly prevalent among elderly individuals, who may suffer from conditions like Alzheimer's disease and have a tendency to forget things. Consequently, there is a high probability that elderly patients may forget their prescribed medication schedules or the correct dosages [1].

Thus, there are two major complexities in managing medications: handling the amount and variety of medicines and ensuring they are taken at the scheduled times. Researchers have sought solutions to these issues, leading to the development of smart medicine systems [1-7]. The term "smart medicine system" implies the integration of automation and digitization in medicine management. Its aim is to make medication management less dependent on human intervention and more computer-based, thus relieving individuals from the burden of remembering schedules and types of medicines, making the process easier and more comfortable.

There have been many efforts in developing smart medicine systems. Initially, researchers focused on applying sensors and microcontrollers in smart medicine. They developed systems using Arduino microcontrollers to alert patients about medication times. To enhance the reminder system, features such as voice assistance, display units for better user experience, and motion capture sensors for individuals with upper-limb disabilities were added. Sensors were also introduced to ensure real-time monitoring of medicine management [2-7]. As the Internet of Things (IoT) gained popularity, researchers began integrating IoT into smart medicine systems, developing software to remind patients about their medication schedules. This led to the replacement of hardware-based reminder systems with applications for medication reminders [8-11]. Some researchers combined both software and hardware to fully implement IoT, leading to the development of smart medicine boxes that could be operated with third-party software, allowing users to receive reminders on their mobile devices and take their medicine accordingly [2, 11-12].

The integration of IoT not only digitized the medication process but also made it easier and more comfortable. However, it had limitations. Many software-based systems were complicated for users to operate without proper tutorials. Additionally, these systems focused only on reminders, not on the management and storage of medicines. Although the concept of medicine boxes for storing medicines existed, further complexities arose. One issue was the dispensing of medicines. Due to the irregular sizes and shapes of medicines, they were often dispensed in batches through small containers, limiting the user's ability to dispense a single medicine. To address this, researchers developed one-by-one dispensing mechanisms, allowing medicines to be dispensed in discrete amounts, enabling controlled dispensing and reducing patient confusion [3-4, 13-15]. However, information on the implementation of these mechanisms was vague, as they were not used in any physical smart boxes available. Another issue was the size of smart medicine boxes. Most were large and intended for commercial use, such as in pharmacies. This created a need for more personalized, portable smart medicine boxes. Researchers then developed smaller, portable smart medicine boxes that could be used anywhere, making them more relevant as household appliances [13, 15].

Based on these works, a few points are clear. Firstly, most research focused on developing effective reminder systems to alert patients to take medicines on time, with little work on medicine storage and dispensing mechanisms. Secondly, even though some research specified the storage and dispensing mechanisms of medicines through a medicine box, the implementation of these concepts was limited.

In most medicine boxes, the patient has to manually pick the medicine from the specified storage when the reminder provides a notification. In some cases, the user has to dispense a batch of medicines even though only one medicine is required. Based on these factors, it is clear that there is a significant gap between the implementation of smart medicine assistance and the ease of user interaction. To address this gap, this paper aims to create a solution that not only automates the medicine-dispensing process and functions as a reminder system but also serves as a personal assistant to aid individuals in their medication process. The ultimate objective is to develop a user-friendly smart medicine dispensary that can be easily placed in a residence. Users can set a schedule based on their medication prescription through a simple, user-friendly input interface. The system will assist in taking medicine in discrete amounts or batch quantities with the help of an audio and visual reminder interface.

The medicine dispensary will be a universal system, capable of both one-by-one dispensing of medicines through a novel quick-return mechanism proposed by the authors and batch dispensing using small pans. This quick-action medicine dispensary will not only be a significant addition to next-generation medication systems. Still, it will also simplify the medication process, reducing dependency on others to take medicines, especially for elderly individuals.

2. Methodology

To construct the medicine dispensary, the principle of operation of the dispensary was initially plotted. For this, an algorithm was built to define the step-by-step functionality of the dispensary.

Once the algorithm was developed, a program was scripted to operate the dispensary. Based on the program, the circuit of the dispensary was designed and simulated, and it was later constructed using all the necessary equipment. Following the circuit, the structure of the dispensary was initially plotted as a 3D model. Then, the essential parts of the structure were either processed or fabricated and assembled. Finally, the dispensary was operated to evaluate its performance and functionality. The entire process or the set steps of the methodology that the authors followed are streamlined in Figure 1. The following sections of the methodology are discussed to provide ideas related to the authors' work.

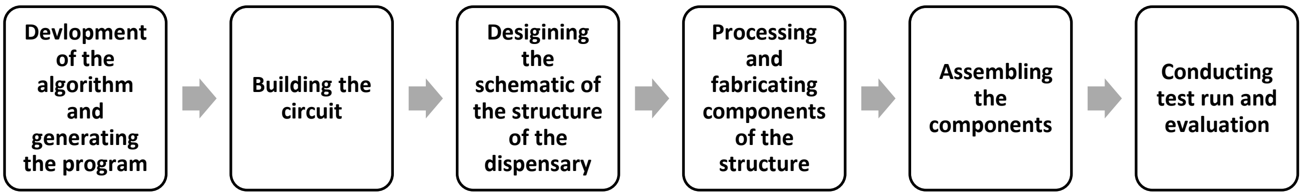


Fig. 1. The Methodology process flowchart

2.1. Development of the Algorithm and Generating the Program

The main function of the dispensary is to take user input related to the type of medicine and time for medicine. Thus, based on the input, set up a timer to provide a reminder to the user about the time to take medicine and thus dispense the selected medicine. Thus, to incorporate this basic principle into the system of the dispensary, a simple yet detailed algorithm was developed describing the step-by-step functioning of the dispensary. Once the algorithm was finalized, a code was generated based on the algorithm to allow the dispensary system to operate. The system used for the medicine dispensary was the Arduino. The code was generated using Arduino IDE, a C++ language-based platform to make programs and codes for the operating system of the Arduino microprocessor.

Figure 2 depicts the flowchart of the program developed for the system. The program operates three different sections of the medicine dispensary, each controlled by a distinct key on the keypad. Key 'A' represents the first section, key 'B' corresponds to the second section, and key 'C' controls the third section. Each section contains a pair of LEDs: a Green LED indicates the 'On' status, and a Red LED indicates the 'Off' status for each section of the dispensary. The servo motors in each section are labeled as servo '1', '2', and '3'. The motion of the servos is defined as outward and inward with respect to the front view of the dispensary. Further details related to the sections, such as servo motors and LEDs, are described in detail in later sections. To set an alarm, a separate process is programmed in the code, which is explained with another process flowchart shown in Figure 3. Once the time value is provided, specific keys allow the time to be set in seconds, minutes, or hours, thereby enabling the reminder to be set.

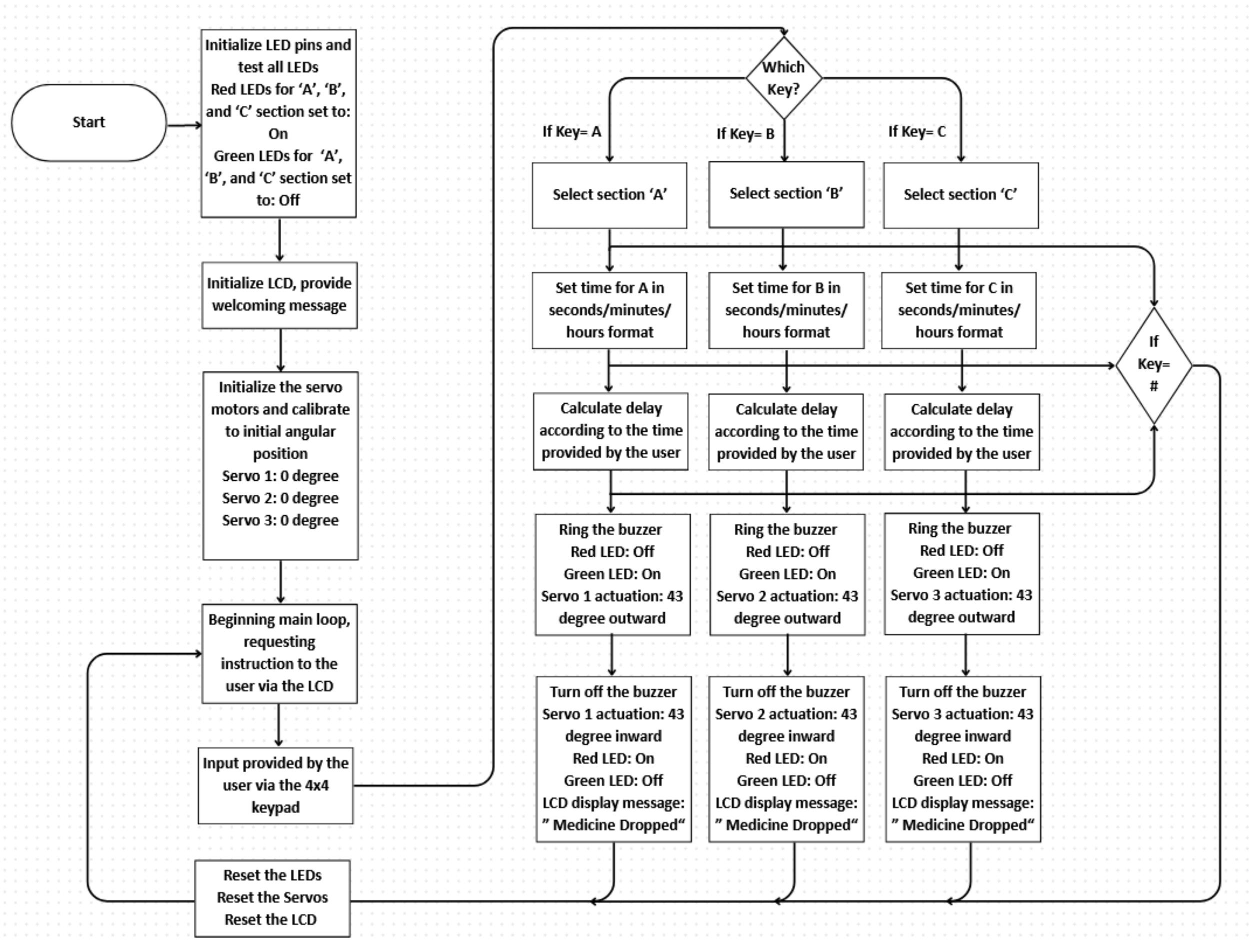


Fig. 2. The program flow chart of the dispenser system

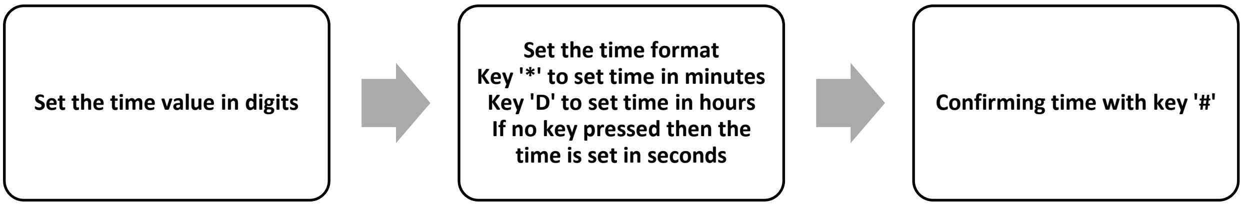


Fig. 3. Time setting and formatting process

2. 2. Building the Circuit

After the program was developed, a circuit was constructed to implement it. The circuit was a closed-loop system, designed so that the user could respond and change input based on feedback. Initially, the circuit was simulated using the circuit building and simulation software 'TinkerCAD'. Through the simulation, the circuit shown in Fig. 4 and its components were calibrated according to the developed code. Once the circuit was finalized and calibrated, the necessary components were assembled, and the circuit was physically built. The components used in the circuit are listed in Table 1.

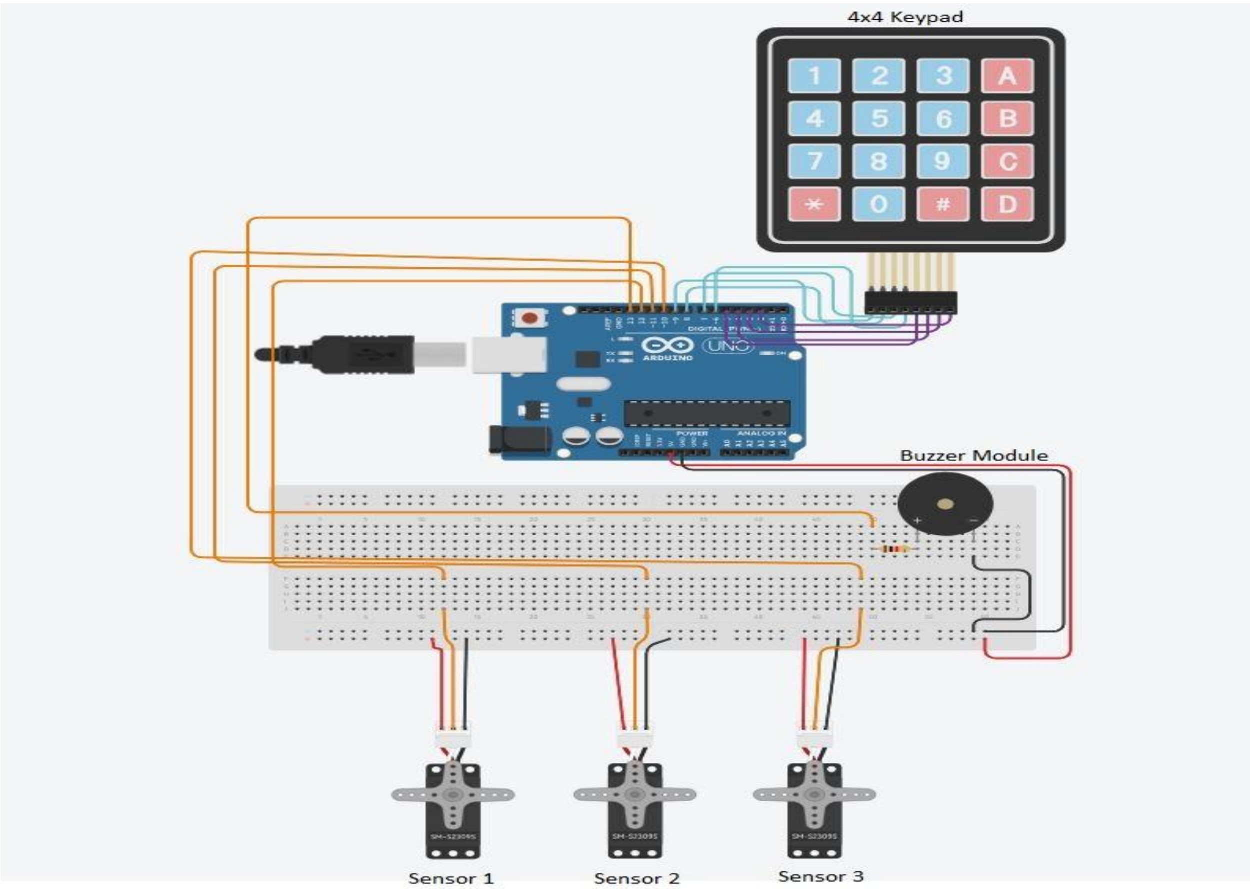


Fig. 4. The circuit of the system

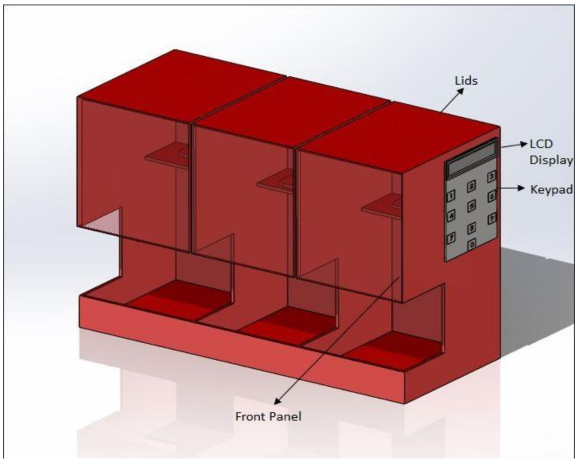
Table 1
The components of the circuit of the dispensary

Name of the Components	Function in the Circuit
16x2 LCD	Visual display unit
4x4 Keypad	Input unit
Arduino Mega 2560 and breadboard	The central processing unit (CPU)
LED	Backlit and indicator lighting system
Active buzzer module	Reminder system
Servo motor	To actuate the motion of the valves

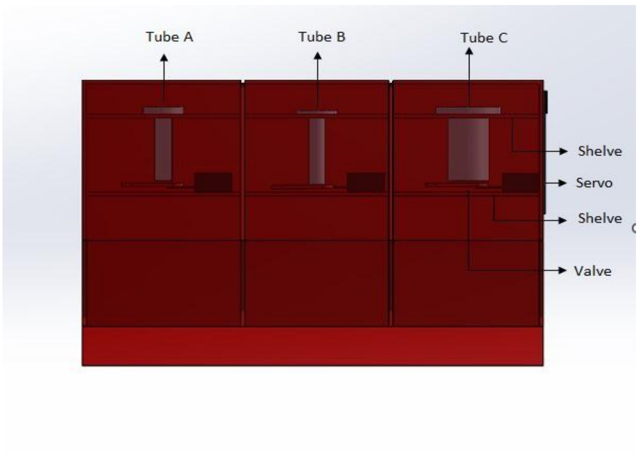
2. 3. Designing the Schematic of the Structure of the Dispensary

Once the circuit was ready, the schematic of the infrastructure was built. Initially, a 3D model of the structure of the dispensary was created using 'SolidWorks' to visualize the concept. Figure 5 shows the isometric view (a) and the front view (b) of the overall design of the quick-action medicine dispensary.

The schematic identified and specified the necessary components required to build the structure. Based on this, the components were processed and assembled. Some of the primary components that built the dispensary are described in the upcoming sections.



(a) Isometric view



(b) Front View

Fig. 5. The 3D model of the medicine dispensary

2. 3. 1. The Outer Structure

The overall structure of the dispensary is planned to be rectangular, with three sections designed to dispense three different categories of medicine. The sections are labeled as ‘A’, ‘B’, and ‘C’. In Figure 6, taken during the construction of the dispensary, these sections are labeled respectively from the left side. Each section of the dispensary consists of two shelves and a lid. There is an opening at the bottom of each section for dispensing the medicine, and all sections are covered at the front with a transparent acrylic slide. At the back of the QAMD, there is an extended tray to hold the necessary circuit-building components. All components are placed there, and the wiring is sorted and placed in the tray.

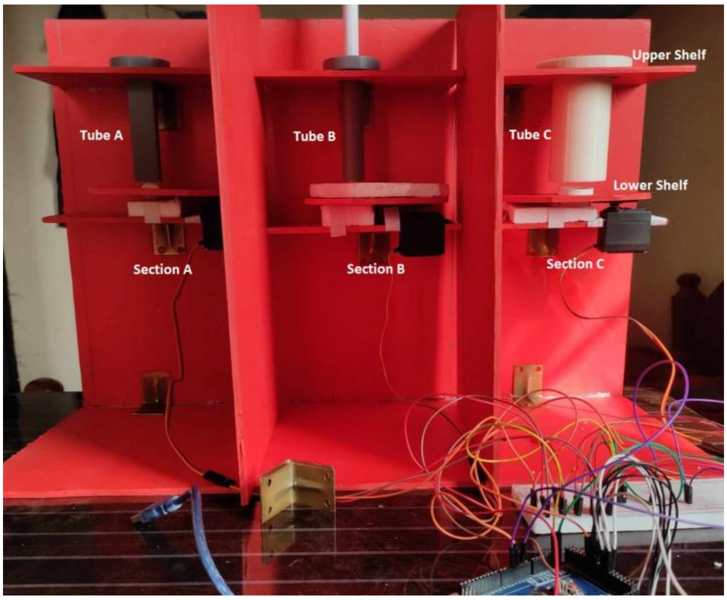


Fig. 6. The three sections of the dispensary

2. 3. 2. The Shelves

There are a total of six shelves, with two shelves in each section. One shelf holds the servo and places the valve, referred to as the lower shelf, and the other holds the tube, referred to as the upper shelf. These shelves provide support and serve as a base to hold the servos and tubes. Both types of shelves are cut with the necessary slots to hold the servo and the tube, and they are attached with angles to the casing. The two shelves in each section are labeled and can be seen in Figure 6.

2. 3. 3. The Lids

At the top of each section, there is a rectangular-shaped lid to cover the entrance of the slots. The lids are attached with hinges and supported with angles. They can be opened and closed as needed to load and unload the tubes with medicine.

2. 3. 4. The Tubes

The tubes are the containers for storing the medicine. There are three tubes with different specifications to store three different types of medicines: tube 'A', tube 'B', and tube 'C'. These tubes were planned to be manufactured using 3D printing, and a 3D model for each tube was developed initially.

2. 3. 5. The Valves

The valves are part of the primary dispensing mechanism of the automated dispensary. There are three valves in the dispensary, made of PVC boards and elliptical in shape. The valves contain a slot according to the dimensions of the medicine.

2. 4. Processing and Fabricating Components of the Structure and Assembling

Once the 3D model of the dispenser was developed and the structural components were specified, the construction of the dispenser commenced. Initially, the outer structure of the dispenser was built using Poly Vinyl Chloride (PVC) as the main material. PVC boards with a thickness of 5mm were cut using various cutting tools and then joined together with adhesives. Angles were placed at multiple joints of the dispensary for added support. After the structure was built, an extended tray slot was attached to the back of the dispenser to hold circuit components such as the breadboard and the Arduino microcontroller. Next, the shelves were added to the structure using angles and adhesives. Once the shelves were in place, the lids were connected to each of the three sections of the dispenser using door hinges, allowing them to be opened and closed like doors.

With the structure ready, the tubes for holding the medicines were fabricated using an additive manufacturing process. The tubes were 3D printed using Polylactic Acid (PLA) filaments and then inserted and placed on the upper shelf of each section of the dispensary. Finally, the assembly of the circuit components was carried out. The servos with attached valves were mounted on the lower shelves, and the LED indicator lights were placed in each section. The breadboard and the Arduino microcontroller were placed in the tray behind the dispenser. Ultimately, the dispensary was activated by providing power to the Arduino, resulting in the setup shown in Figure 7.

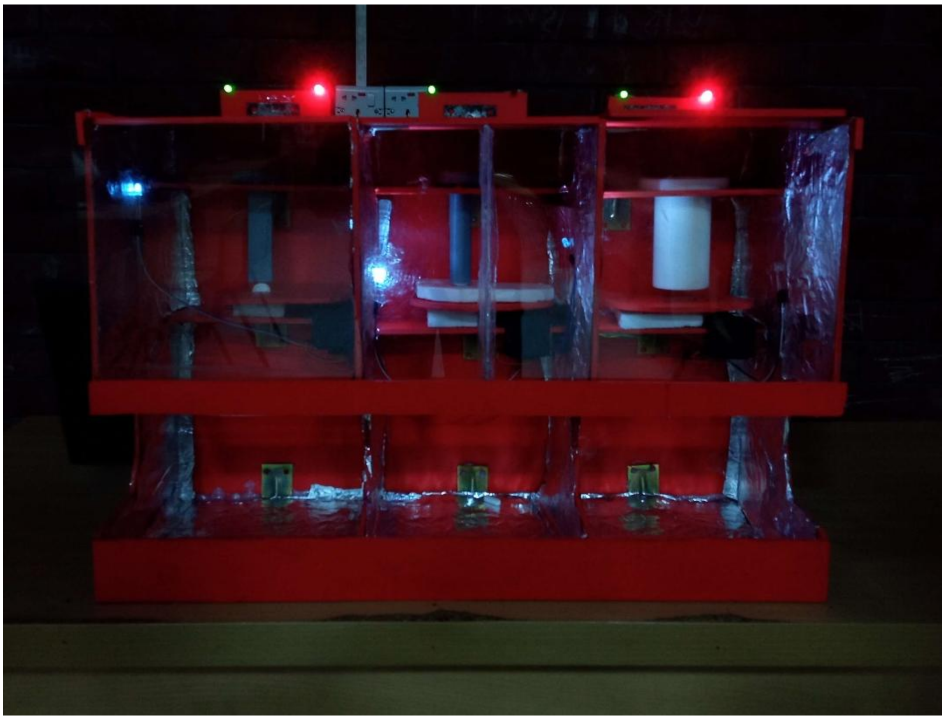


Fig. 7. The Quick Action Medicine Dispensary (QAMD)

3. Results and Discussion

The Fabricated Quick Action Medicine Dispensary (QAMD) was designed to automate the medicine intake process and improve the management of medication schedules and storage. After fabrication, the QAMD was provided to a group of users for trial tests. Based on user feedback, the performance of the dispensary was evaluated, yielding the following results.

3. 1. Quick Action and Rapid Dispensing of the Medicines with Minimum Processing Lag

This section explains how the QAMD ensures the unobstructed, fast dispensing of medicines through the application of a quick return mechanism. Inside each tube, medicines are placed in an order that allows them to be dispensed one by one. For this to work, the movement of the valves must be accurate and precise; otherwise, multiple medicines may drop or clog inside the tubes. The returning motion of the valve must be faster than the dropping velocity of the medicine to prevent additional medicines from dropping.

This precise and quick movement of the valves was achieved by setting specific parameters for the servo motor's movement. Each servo motor has two parameters: the angular displacement and the delay time between the forward and return motion of the valve. These parameters can be set and modified through coding. In the system's program, the maximum angular displacement of the servo was set to 43 degrees, and the time delay for the servo to return to its initial position was set to 1000 milliseconds. These values were obtained experimentally through a trial-and-error method, optimizing the angle and time for operation. As a result, as soon as one medicine was dropped, the tubes were closed by the valve, keeping the remaining medicines intact and properly stored. This quick return mechanism ensured the rapid and unobstructed dispensing of medicines.

Regarding the delivery time of the medicine, the dispensary is coded to dispense the required medicine within 5000 milliseconds of the alarm. Therefore, within 5 seconds of the timer running out, the buzzer will ring, and the medicine will be delivered to the user within 1000 milliseconds. Typically, each Arduino has a response delay of 1000 milliseconds to mitigate time loss due to system lag at the microcontroller. However, in the dispensary's program, the authors included an additional waiting period of 5000 milliseconds and removed the extra input lag from the system. Consequently, the system worked without any input lag and was able to deliver medicine just 1000 milliseconds after the alarm rang. Therefore, the dispensary is termed the quick action medicine dispensary because it dispenses medicine within a second of the specified time.

3. 2. Robust Reminder and Flexible Scheduling System

This section describes how the scheduling of the medicine intake process can be set. The QAMD is programmed to receive time inputs in any of the following formats: seconds, minutes, and hours. The coded program of the QAMD uses the delay function to store time in milliseconds, allowing time scheduling for medicine intake to be set for up to 42 days. Thus, the dispensary provides a very flexible time period for scheduling medicine intake, allowing users to set schedules on an hourly, daily, weekly, or even monthly basis.

The QAMD is also equipped with an active buzzer module. Once the timer is set, the buzzer rings exactly after the set time interval at a frequency of 4000 kHz. This frequency was selected through a trial-and-error method to ensure the alarm is neither too loud nor too soft to hear. Feedback from user trials indicated that the reminder system effectively prompted users to take their medications on time, and most users were able to hear the alarm clearly. Instances of missed doses were infrequent and often attributable to user oversight rather than system failure.

3. 3. Simple and Friendly User Interface and System

The QAMD is equipped with a 4x4 keypad as an input device and a 16x2 LCD as an output device. Both devices serve as the user interface, allowing users to provide input according to their specifications. The user interface and its components were selected and designed to be user-friendly, simple, yet effective. The keypad prompts the user to provide the following set of instructions as shown in Table 2.

Table 2
The instruction prompt for the dispensary

Instruction sequence	Prompt	Input Key
01	Select Slot Number 01	A
02	Select Slot Number 02	B
03	Select Slot Number 03	C
04	Set Time	1,2,3,4,5,6,7,8,9
05	Set Time Format (Minutes)	*
06	Set Time Format (Hours)	D
07	Reset	#

As seen, most of the prompts are linear and have minimal variation, with only 16 keys to operate. Each prompt corresponds to a single, discrete key, making the interface simple to understand and reducing the likelihood of user confusion. Besides the keypad, the user interface also includes an LCD display unit. The LCD shows the instructions to be given to the QAMD, the required keys to press, and the options selected by the user for each instruction.

Fig. 8. The input output section of the dispensary

During trial usage, users found it clear and easy to understand which instructions to give and in what order. If participants made any mistakes in giving prompts, they could see and reset the prompt as desired. This made the user interface more responsive and flexible. Participants generally found the user interface intuitive and easy to navigate. The LCD display, with its illuminating feature, made it easy to use the dispensary even in dark places. Figure 8 shows the user interface of the dispensary, with the 4x4 keypad placed right below the LCD. Additionally, there are six indicator LEDs placed above each section, indicating which section of the dispensary is to dispense medicine. This way, even if the user is far from the dispensary or finds it difficult to view the LCD, they can still observe the LEDs and determine from which section the medicine will drop. Thus, the LEDs make the system more interactive and easier to operate.

3. 4. Universal Medicine Storage Facility

The QAMD is equipped with three types of tube containers to store medicines. The first tube, or the tube of slot 'A', is made for tablets, which are coin-shaped medicines. This tube is designed as a cylindrical tube on the outside with a rectangular through-hole on the inside. The middle tube, 'B', is made for capsules, which are shell-shaped medicines. This tube has a cylindrical structure with a cylindrical through-hole. Tube 'C' is a universal tube for storing any type of medicine. Since some medicines have irregular shapes and dimensions, making exact dimension tubes for them is not feasible both financially and technically. Thus, tube 'C' is designed with 'pans' inside which the medicines are placed. When slot 'C' is selected, the valve dispenses these 'pans' instead of the medicine. The 'pans' are designed to store medicines of various sizes and shapes. This way, the automated dispensary ensures one-by-one dispensing of medicines and enables dispensing a set of medicines for users. Therefore, if users need to take more than one medicine at a scheduled time, they can use the third section of the dispensary. The tubes are designed to store five medicines of each kind, allowing for a 5-day dosage period.

3. 5. Robust and Safe Materials for Fabrication

To build the outer infrastructure of the QAMD, its valves, shelves, and lids, 5mm thick PVC boards were used. PVC is well known for its moisture resistance, waterproof properties, and robust structure. Additionally, metallic angles were used to provide strong support at the joints of the structure. The combination of PVC boards and metallic angles gives the medicine dispensary a strong and durable structure that can withstand water and prevent the dispensary from breaking down due to the weight of the medicines and other components stored within it.

When it comes to storing medicines, a significant concern is preserving them, as medicines are prone to contamination. To protect the medicines from environmental hazards and contamination, aluminum foil sheets were used to cover the inner layer of each section of the dispensary as well as the inner surface of each tube. The layer of aluminum foil, shown in Figure 9, plays an important role in preserving the medicines from germs, moisture, and temperature. Its inert nature and established track record in pharmaceutical packaging further enhance the safety and integrity of the medication storage system, underscoring our dedication to providing a secure and reliable solution for elderly individuals managing their medications. Additionally, the tubes were fabricated using Polylactic Acid (PLA), a non-toxic and biodegradable material that poses minimal risk of contaminating the medicines. PLA's biocompatibility and absence of harmful additives prioritize the safe preservation of the medicines.

3. 6. Integration of 3D-Printing for Precise Fabrication

The tubes of the QAMD were fabricated using 3D printing technology. Through 3D printing, the accurate dimensions of the tubes were ensured, enabling the precise storage and dispensing of each type of medicine. Thus, all five medicines in each of the corresponding tubes fit perfectly and were dispensed properly through the slots of the valves. As shown in Figure 10, the tubes were fabricated and later placed inside the dispensary, with the medicines subsequently stored within them.

Fig. 9. The layer of Aluminium foil inside the dispensary

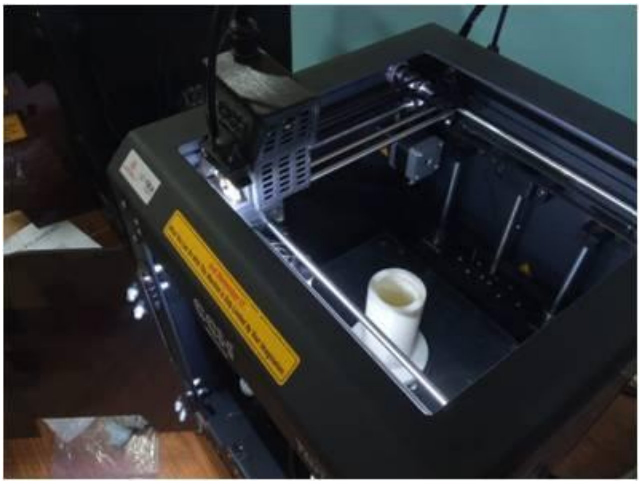


Fig. 10. 3D printing of the tubes

4. Conclusion

The development of a medicine dispensing machine such as the QAMD is a promising endeavor with notable implications for next-generation medicine. The project aimed to enhance medication management by automating the medication process, ensuring precise timing, and enabling the multipurpose dispensing of pill-type medicines like capsules and tablets. Although the dispensary is primarily focused on pills rather than liquid medicines, it is designed as a universal pill dispensary, capable of dispensing pills of any shape, size, and quantity. This leaves room for future activities to incorporate the dispensing of liquid medicines.

Through a user-centric approach, the authors addressed technological familiarity issues, incorporated personalized medication plans, and provided features such as reminder notifications. Users can easily set timers for any period and receive audible reminders for their medication. The system's interface was kept simple and linear to make it more engaging for users. While acknowledging the limitations, the authors followed an experimental trial-and-error method to determine the specifications of the dispensary machine, such as the servo’s angular displacement and delay time before dispensing. This approach allowed for the optimization of these parameters based on practical implications rather than theoretical calculations.

However, there was a slight delay due to the response time of the components. The implications of these findings extend beyond mere technological innovation, emphasizing the importance of bridging the gap between healthcare and technology to cater to the unique needs of older individuals at home, thereby fostering increased independence, safety, and overall well-being in this demographic.

Some recommendations for future work on this project include:

i. Enhancing the system's capabilities based on user-specific health conditions and response patterns. Introducing the Internet of Things (IoT) to the current automated system of the dispensary could ensure virtual interaction.
ii. Setting up a voice activator as a significant upgrade. Adding artificial intelligence to the current system could improve the medicine dispensing process.
iii. Implementing more medicine slots and incorporating liquid medicines. Considering temperature and pressure factors for storing and dispensing liquid medicines could be a new field of exploration.

Acknowledgment
The authors would like to thank the Department of Mechanical and Production Engineering, Islamic University of Technology (IUT), for the expertise, raw materials and facilities used to conduct the experimental work.

References

[1] Kalovrektis, Konstantinos, Apostolos Xenakis, Dimitra Sofianou, Gavriil Simatos, Georgios Papadopoulo and George Stamoulis, "A Low Cost IoT TestBed System for Alzheimer's Early Stages Diagnosis in Health 4.0 Application," *2022 7th South-East Europe Design Automation, Computer Engineering, Computer Networks and Social Media Conference (SEEDA-CECNSM),* 2022: 1–5.
https://doi.org/10.1109/seeda-cecnsm57760.2022.9932974

[2] Deepthi, Alisyam Sai and G. A. E Satish Kumar, "Smart Pill Notification Device Using Arduino," *2022 IEEE International Conference on Distributed Computing and Electrical Circuits and Electronics (ICDCECE)*, 2022: 1–5. IEEE. https://doi.org/10.1109/ICDCECE53908.2022.9792842

[3] Antoun, Wissam, Ali Abdo, Suleiman Al-Yaman, Abdallah Kassem, Mustapha Hamad and Chady El-Moucary, "Smart Medicine Dispenser (SMD)," *2018 IEEE 4th Middle East Conference on Biomedical Engineering (MECBME)*, 2018: 20–23.
https://doi.org/10.1109/MECBME.2018.8402399

[4] Gawali, Nikhil, Vaibhav Ingale, Vicky Sose, Raksha Raut, and Gajanan D. Mandavgade, "Automatic Pill Dispenser Machine," International Advanced Research Journal in Science, Engineering and Technology 10, no. 6 (2023): 174-180.
https://doi.org/10.17148/IARJSET.2023.10628

[5] Muguro, Joseph K., Pringgo Widyo Laksono, Wahyu Rahmaniar, Waweru Njeri, Yuta Sasatake, Muhammad Syaiful Amri bin Suhaimi, Kojiro Matsushita, Minoru Sasaki, Maciej Sulowicz and Wahyu Caesarendra, "Development of Surface EMG Game Control Interface for Persons with Upper Limb Functional Impairments," Signals 2, no. 4 (2021): 834–51.
https://doi.org/10.3390/signals2040048

[6] Bindu Sree, V., K.S. Indrani and G. Mary Swarna Latha, "Smart Medicine Pill Box Reminder with Voice and Display for Emergency Patients," *Materials Today: Proceedings* 33, (2020): 4876–4879. https://doi.org/10.1016/j.matpr.2020.08.400

[7] Khedkar, Shilpa, Sagarika Deshpande, Manasi Choudhari, Doreen Charles, and Sarish Shaikh, "A Smart Pill Box to Remind of Consumption Using IoT," International Journal of Computer Applications 182, no. 1 (July 16, 2018): 38–40. https://doi.org/10.5120/ijca2018917436

[8] Surjandy, None, None Meyliana, Andreas Raharto Condrobimo, Henry Antonius Eka Widjaja, Wiedjaja Atmadja, Rudy Susanto, and Bruno Sablan, "The Essential Factors and Trend Development of IoT Smart Box," Indonesian Journal of Information Systems 6, no. 1 (August 29, 2023): 88–97. https://doi.org/10.24002/ijis.v6i1.6794

[9] Chang, Juihung, Hoeyuan Ong, Tihao Wang and Hsiao-Hwa Chen, "A Fully Automated Intelligent Medicine Dispensary System Based on AioT," IEEE Internet of Things Journal 9, no. 23 (2022): 23954–23966. https://doi.org/10.1109/JIOT.2022.3188552

[10] Cha, ByungRae, HaGang Kim and JongWon Kim, "Prototype Design of Drug Usage Information Retrieval System." *International Conference on Information Science and Applications*, January 1, 2010: 1–6. https://doi.org/10.1109/icisa.2010.5480324

[11] Deepthi, Alisyam Sai and G. a. E Satish Kumar, "Smart Pill Notification Device Using Arduino," *2022 IEEE International Conference on Distributed Computing and Electrical Circuits and Electronics (ICDCECE)*, April 23, 2022: 1–5. https://doi.org/10.1109/icdcece53908.2022.9792842

[12] Al-Mahmud, Obaidulla, Kausar Khan, Rajdeep Roy and Fakir Mashuque Alamgir, "Internet of Things (IoT) Based Smart Health Care Medical Box for Elderly People," *2020 International Conference for Emerging Technology (INCET)*, June 1, 2020: 1–6. https://doi.org/10.1109/incet49848.2020.9153994

[13] Miao, Fengyi, Yu Zhang, Xincheng Wang and Xinhong Xiong, "Home-style Smart Medicine Box for the Elderly," Journal of Physics Conference Series 1748, no. 4 (January 1, 2021): 042024. https://doi.org/10.1088/1742-6596/1748/4/042024

[14] Minaam, Diaa Salama Abdul and Mohamed Abd-Elfattah, "Smart Drugs:Improving Healthcare Using Smart Pill Box for Medicine Reminder and Monitoring System," Future Computing and Informatics Journal 3, no. 2 (November 29, 2018): 443–56. https://doi.org/10.1016/j.fcij.2018.11.008.

[15] S. Samhitha and Srinath NK, "Design and Development of Portable Smart Medicine Dispenser," International Journal of Scientific Research in Computer Science Engineering and Information Technology, (May 1, 2019): 147–52. https://doi.org/10.32628/cseit195351