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Original Article

Automatic Pill Dispenser for Pharmacy

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Abstract *- Medication plays an essential role in people's daily lives. Individuals often experience headaches, pains, upset stomach, fever, and common colds, among other ailments. Factors such as long working hours, limited relaxation, extreme weather changes, and irregular sleeping and eating patterns can contribute to illness and disease. Medications are necessary to alleviate symptoms or even prevent them. Additionally, many people take vitamins and mineral supplements to meet their nutritional needs when their diets fall short. Typically, over-the-counter (OTC) medicines and vitamin supplements can be readily purchased at pharmacies without needing a doctor's prescription. Automatic Pill Dispensers for Pharmacies have been designed and built specifically to streamline the process of dispensing these OTC medications and supplements. Pharmacies often face long queues, and automatic pill dispensers offer a time-saving solution by quickly dispensing medicines and supplements, much like a typical vending machine. The prototype hardware was designed using cost-effective materials and components, with a particular focus on the dispensing mechanism. Control is facilitated through an Arduino Mega microcontroller, and payment can be made through a coin validator/acceptor, simplifying the purchasing process for both pharmacists and customers. A notable advantage of this system is its modular design, allowing for the replacement of custom-designed dispensing discs to accommodate different types of pills. Experimental results were obtained by conducting tests on various aspects, including servo motor performance, dispensing accuracy, serial vs. parallel processing, and the comparison between manual dispensing and an automatic dispensing system. The automatic pill dispenser not only extends the service hours of the pharmacy by serving as a self-access kiosk but also achieves performance comparable to existing research in the field.*

Keywords *- Pill dispenser, Pharmacy, Over-the-counter medicines, Dispensing accuracy, Parallel processing.*

1. Introduction

Medication has undoubtedly been a part of treatment for people with common illnesses or diseases. Pharmacies provide people access to medicines, and pharmacists play an important role in primary medical consultations and delivering the correct medications at the right doses, especially for prescribed medicine.

With the advancement of technology, manual and repetitive pharmacy tasks can be done/operated by automated systems/devices so that pharmacists can focus on critical tasks. Automation minimizes costs, increases efficiency, and streamlines business processes.

While there has been a significant amount of research on automatic pill dispensers, most of these studies have focused on automatic pill organizers or devices that can remind and dispense pills for scheduled medication to patients, especially elderly or disabled individuals. However, automatic pill dispensers designed specifically for hospitals and private pharmacies/drug stores have been relatively scarce. While some commercially available automatic pill dispensers exist, they tend to be expensive and may not be practical for small pharmacy owners.

The initial step of this research was developing an automatic pill dispenser machine for pharmacies that can sell medicines, essential supplements, and vitamins. The machine will operate on the vending machine principle, allowing pharmacists to reduce the time spent selling common over-the-counter (OTC) medications. This will also make it easy and convenient for people to buy medication and dietary supplements. OTC medications refer to a set of drugs used to alleviate or prevent minor illnesses such as upset stomach, headaches, sore throat and fever.

Individuals can use them to treat themselves or their loved ones without needing a doctor's prescription. Dietary supplements are nutrients the body needs in addition to the main meal and help maintain good health. Both OTC medications and dietary supplements can be found in typical pharmacies where pharmacists can distribute them without a doctor's prescription.

Mostly, medicines are in three types: solid-type (pill), powder-based, and liquid-type medicine (syrup). Most patients prefer solid-type medicines due to their tastelessness and easiness of swallowing [1]. In this research, solid-type (pill) is selected to use for the dispenser and six types of pills are chosen for the experiment. The work can be divided into two parts: hardware and software. The hardware part will involve designing and making the pill dispenser for pharmacies. The software part will control the coin receiver and the dispenser's operation through an Arduino microcontroller program.

Experiments for servo motor performance, dispensing accuracy, manual vs parallel processing, and pharmacist vs automatic dispensing system were conducted using an automatic pill dispenser, and data were collected. The system's performance is evaluated through data analysis, and the functions of the dispenser and future works are also discussed.

2. Literature Review

Nowadays, numerous solutions are available in the market to manage medication, including pill organizers and dispensers. These solutions aim to remind patients about their medication through smartphone alerts or dispenser machines, helping them keep track of their medication stock. The consequences of inaccurate medication can be severe, leading to delayed recovery, worsening of the disease, or even fatalities. The medicine dispenser offers a viable solution to address such challenges by providing timely reminders to patients to take their medications correctly and accurately. Furthermore, the medicine dispenser facilitates instant communication between caregivers and patients. It promptly rings an alarm signal when the patient's medication is due, ensuring that doses are not missed and that the patient's health is well-monitored and supported. This feature enhances patient adherence to prescribed treatment plans and promotes better health outcomes [2-4].

It is found that many research works were done under different names: electronic pill dispenser [5], automatic pill dispenser [6], autonomous pill dispenser [7], automatic medicine dispenser [8], smart pill dispenser [9-10], Smart medication dispenser [11], Smart Medicine Dispenser [12], Smart tablet dispenser [13], Robotic Medicine Dispenser [14], and pill dispensing device [15], Smart Medical Box [16] etc.

Pill organizers, sorters and dispensers are built using automation and intelligence as a smart system. Other than working as a simple pill organizer, the devices are designed to have automated functionalities by using AI and IoT [8]. The pills can be dispensed from different types of packaging: vials, blisters, and other containers [2,5-7]. These systems are used by patients or medical staff at home, hospitals, pharmacies and nursing homes based on their needs.

In [6], an automatic pill dispenser was designed to help healthcare professionals provide medication to patients prescribed by the physician correctly and completely. The system can dispense the correct drug according to the programmed date, time, and number of intervals and notify the user to take medicine by displaying a message on the LCD screen and generating a sound with a buzzer. Adding internet connectivity to the system and embedding an IoT-enabled wireless controller allows caregivers to remotely manage the pill dispenser and monitor the status of taking medication correctly and timely. The purpose is to provide hospitals with a solution to administer prescriptions without needing regular physical visits to the hospital ward, particularly during a pandemic. This approach effectively minimizes the exposure time to a virus for both patients and healthcare personnel [17].

Meghla et al. [2] developed an Internet of Things (IoT) - based Smart Medication Dispenser (SMD) connected to an integrated web application for patient diagnosis. Their system intended to help the patients, mainly the elderly, by dispensing medication and alerting them when they forget. The activity of taking medication is passed to the doctor or staff as input via an IoT system that enables monitoring of the status to take the drug on time and help reduce overdose or underdose to patient. With an IoT dashboard and the database of common health conditions of patients, SMD can prescribe generic medications for ailments such as the common cold, fever, asthma, etc.

Smartphones are ubiquitous and the best communication device today and can also be applied to monitor/control remotely to other user devices. By using a smartphone app, pill schedules and usage data can be remotely managed and controlled [12]. The patients can receive specific information and alerts to take medication according to the scheduled time, and the caretaker will receive an alert almost instantly via SMS in case the patient forgets to take his/her pill. In [18], a pillbox prototype was built for a medicine reminder and monitoring system that allows medical caretakers or clients to program the pill name and amount and set the timing to take medication. The device illuminates or makes a buzzing sound to remind clients or patients about medication time. The Android application developed enables the users to program, monitor and control the pill box remotely via mobile phone.

Robotic devices have been developed and used in various areas of the healthcare industry, for example, in medical/hospital operations, medicine dispensing and assisting elderly people. In [19], the current state and perspectives of pharmacy robots and medicine dispensing technology highlighted the growing need for robotic-assisted pharmacies, as these robots can significantly enhance the overall functionality and operation of pharmacies. They manage medication and patient data effectively to deliver more efficient and reliable pharmacy services. Compared to human operators, they can handle increasing workloads,

reduce errors, increase revenue, improve counting efficiency and safety, and avoid delays to improve performance. The use of AI in combination with identification and localization technologies can enhance the operation of pharmacy robots to interact with different users: physicians, pharmacists, assistants, and patients. Robots or machines play a prominent role in advancing hospital pharmacy systems; however, they cannot replace human duties entirely, as they still need human interventions to correct errors.

Takase et al. [20] presented a large-scale robot dispensing system designed for hospitals featuring automatic dispensing robots for both conventional medications and powdered medicine. Additionally, they introduced a bar-coded medication dispensing support system using a PDA (Personal Digital Assistant). Their study highlights that integrating a robotic dispensing system, in collaboration with pharmacists and pharmacy support staff, can significantly reduce prevented and unprevented dispensing errors. Moreover, the dispensing time of pharmacists during manual processes was notably decreased. Implementing automated dispensing robots not only improved the quality and safety of medication but also enabled pharmacists to dedicate more time to providing clinical care to patients, thereby enhancing overall patient outcomes.

Using a mobile robot as an automatic medicine dispenser for patients/elderly people who are living independently is found in some research work. Mobile robots can navigate to find the patient/elderly people by following lines or using infrared and ultrasonic sensors to dispense the right medicine dosage and/or other supplies at the right time [21-23]. Also, a self-mapping robot combined with a pill dispenser can help to take appropriate medication [15].

In summary, most research has focused on developing robots or automated devices that remind patients, especially the elderly or disabled, about medication schedules and dispensing prescribed medicines. These automatic medicine dispensers significantly contribute to patients adhering to their medication regimens. Medical caregivers and pharmacists in hospitals and nursing homes can use them to administer, monitor, and control the medication process. However, there is still a research gap concerning pill dispensers crucial for pharmaceutical supply in retail pharmacies. Emerging technologies such as AI, IoT, robotics, and mobile technologies can enhance the current healthcare system to achieve better connectivity and intelligent functionalities. The research of using medicine-dispensing mobile robots is still in the early stage of development and needs further improvement and investigation.

3. Materials and Methods

3.1. Hardware and Software

The device components that build up the pill dispensing machine are shown in the following Figure 1. The main components include the Arduino Mega 2560 microcontroller the main controller board for the pill dispenser. This board was chosen because it has a bigger size, more memory space and I/O pins than other boards.

Six servo motors are used to do the task of opening/closing the six dispensing channels. Servo motors can control the degree of rotation of the dispensing discs to dispense the pills into the collecting containers. The TFT touch screen receives touch signals and outputs data to the Arduino Mega microcontroller, which then sends signals to control the operation of servo motors. Coin validator/acceptor can accept coins of various sizes up to 6 types of coins with a value of 1 baht, 2 baht, 5 baht, and 10 baht. The device will send a different pulse signal according to each coin to the Arduino Mega microcontroller (Fig. 1).

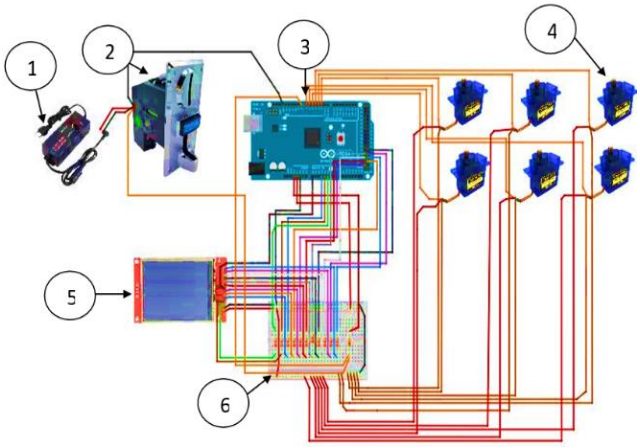

Fig. 1 Circuit diagram schematic

1. AC to DC Adapter
2. Coin Validator SG-1
3. Arduino Mega Microcontroller
4. Servo Motor (s)
5. TFT Display Touch Screen Module ILI9341
6. Protoboard

Arduino IDE (Arduino Integrated Development Environment) is used for operational controls of automatic pill dispensers for pharmacies. Arduino is a platform that will help developers to gain enhanced speed and accuracy in applications. The program code is uploaded to the Arduino Mega microcontroller to control the TFT Display touch screen, Coin Validator and Servo Motors.

3.2. Pill Dispenser Design

An automatic pill dispenser is designed considering the functions needed for the buyers and pharmacists. The machine is housed in a 30cm*40cm acrylic container. The exterior design of the system showed that it includes an input touch screen, 2 pill collector/drawer boxes and a coins acceptor for payment (Fig. 2).

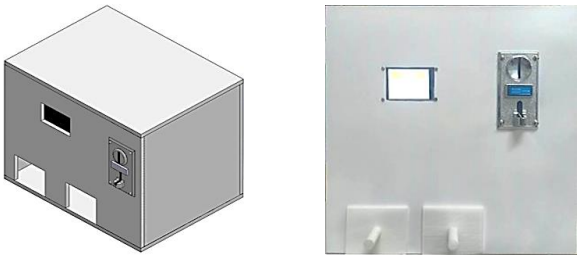

Fig. 2 Exterior design of the pill dispensing system

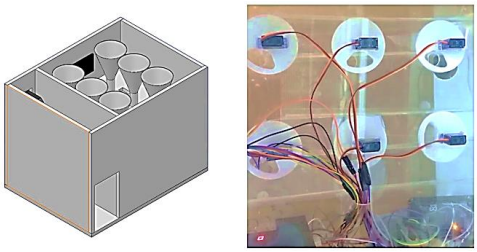

Fig. 3 Interior structure of the pill dispensing system

Fig. 4 Cone-shaped Funnel (pill/vial container)

Fig. 5 A dispenser disc used for dispensing pills

The housing of the device includes a dispenser area and a microcontroller area. The dispenser area has six cone-shaped funnels that act as vial containers and two pill collector/drawer boxes. The dispensing operation is divided into two channels; each channel consists of 3 servo motor dispensers and one pill collector/drawer box. The next area is filled with a microcontroller and coin validator (Fig. 3).

A 3D printer was used to create internal components of the pill dispenser. The pill/vial container is built in the shape of a funnel for the smooth leaving of pills to the dispensing disc area (Fig. 4).

The dispenser disc plays an important role/part of the dispensing system. Each disc is connected to the servo motor to do the dispensing task. The discs are designed and built using a 3D printer according to the size and shape of the pill (Fig. 5).

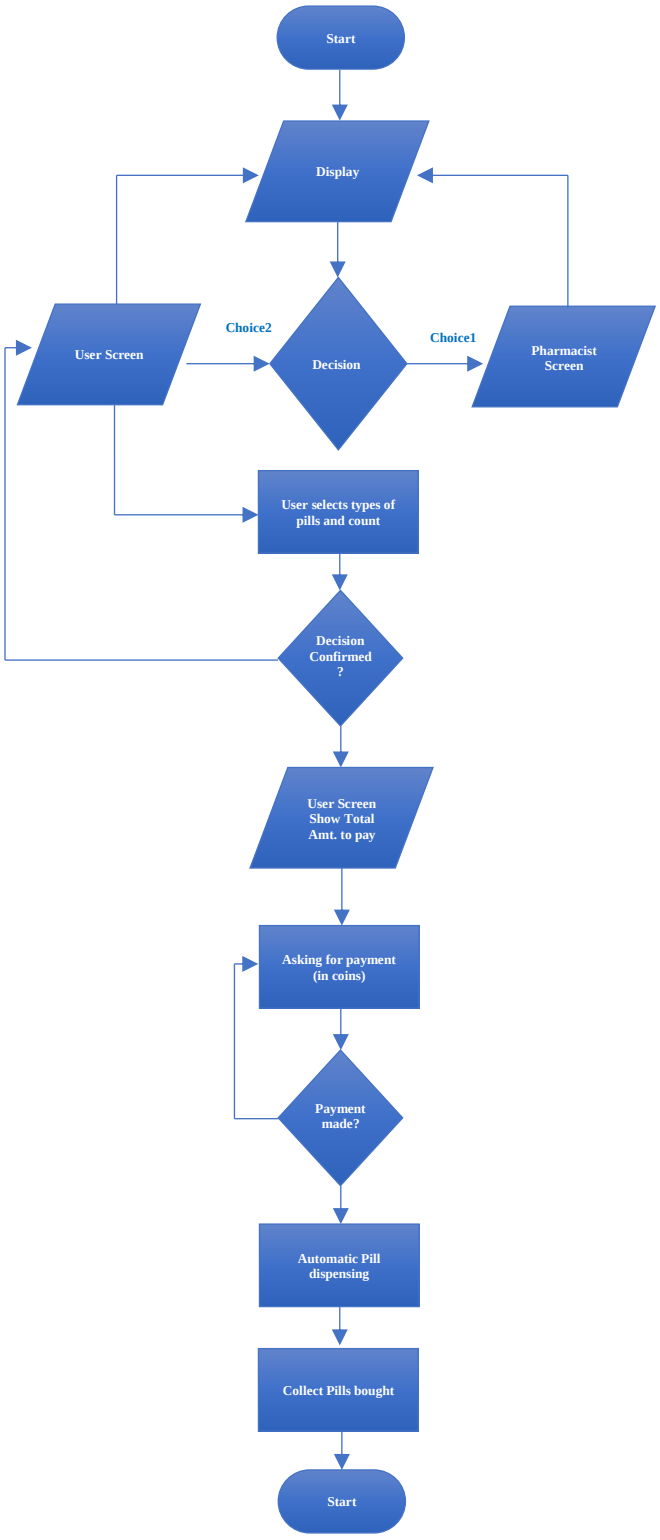

Fig. 6 Control flow diagram

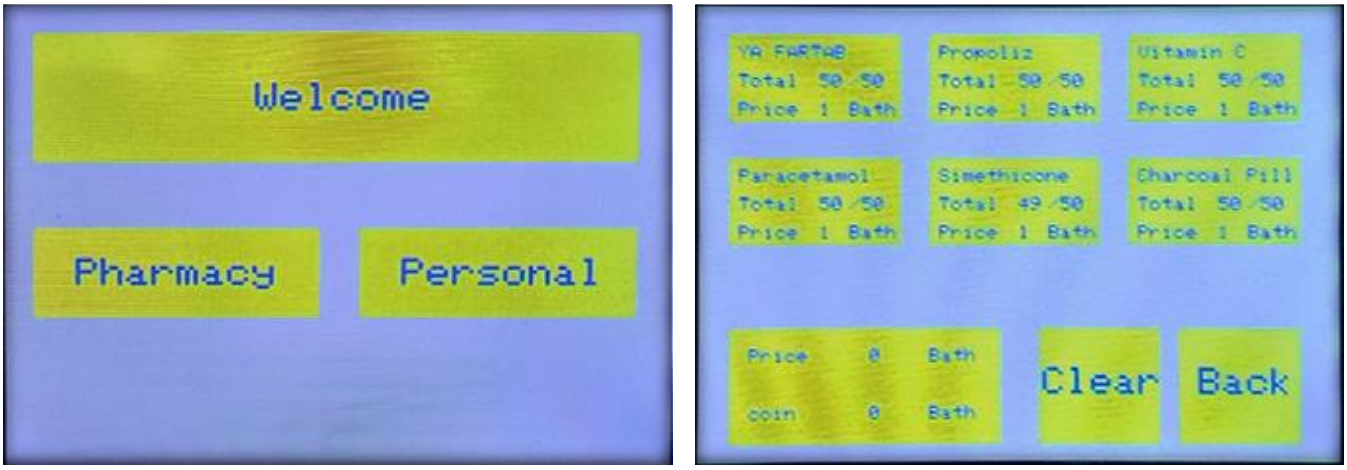

Fig. 7 User interface of automatic pill dispenser

3.3. System Workflow

The automatic pill dispenser starts with the buying decision of the pills. The system's touchscreen display provides two menu options: for the pharmacy and the buyer (personal). The pharmacist can check the current sale amount for a day through the pharmacy menu, and the buyer can choose a personal menu to access the user's screen for buying the pills. There are 6 types of pills available to buy, and the buyer can select the types and count of the pills to buy. After confirmation, the system will proceed to the payment step. The user screen will show the total amount for payment, and the payment can be made using a coins validator. Then, the automatic pill dispenser will dispense the pills that the buyer selected into pill collection drawer boxes. The control workflow and user interface of the automatic pill dispenser are shown in the following Fig. 6 and 7.

4. Results and Discussion

Experiments were conducted to evaluate the pill dispenser's functional operations and performance.

4.1. Server Motors Performance

There are six servo motors used in the machine for dispensing tasks. After filling 6 types of pills (Ya Fartab, Propoliz, Vitamin C, Paracetamol, Simethicone, Charcoal Pill) to each Pill container (cone cylinder) in the order of servo motors (S1-S6), the operation time of each servo motor was recorded for 10 rounds.

After testing, the results of the operational performance (dispensing time in seconds) of each servo motor were collected. In 10 rounds of testing, the initial test rounds have higher SD and Variance values compared to later rounds that gain more stable performance results, as shown in Figure 8.

Figure 9 compares each servo motor's performance. The data collected stated that the Charcoal pill has the highest SD and Var value in comparison with others, probably due to its capsule shape and hardness of the pill.

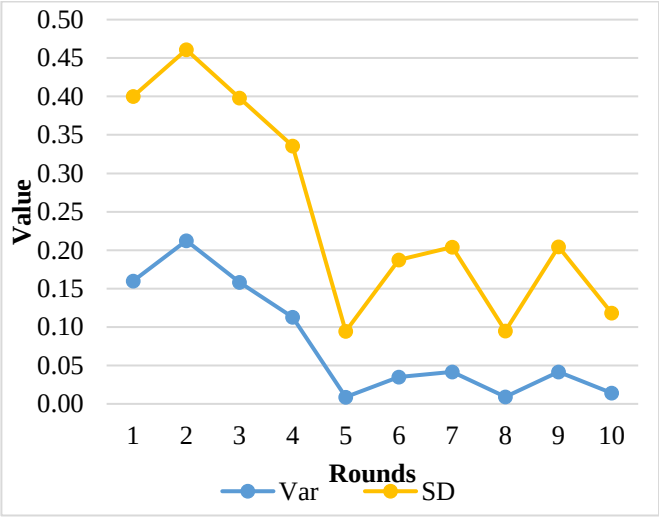

Fig. 8 Overall servo motor performance

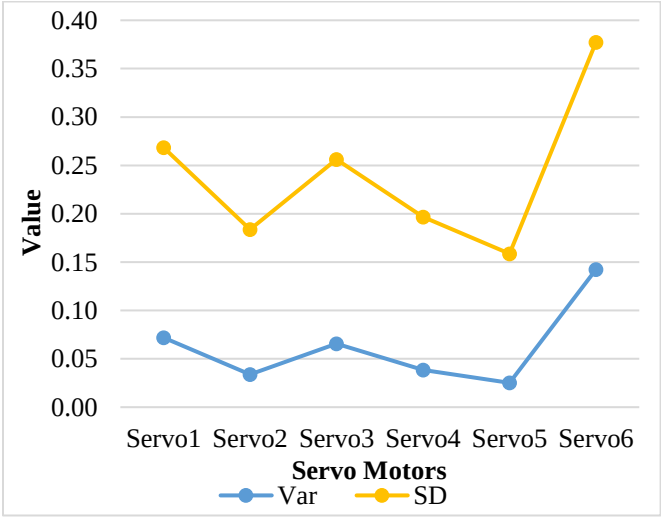

Fig. 9 Each servo motor performance

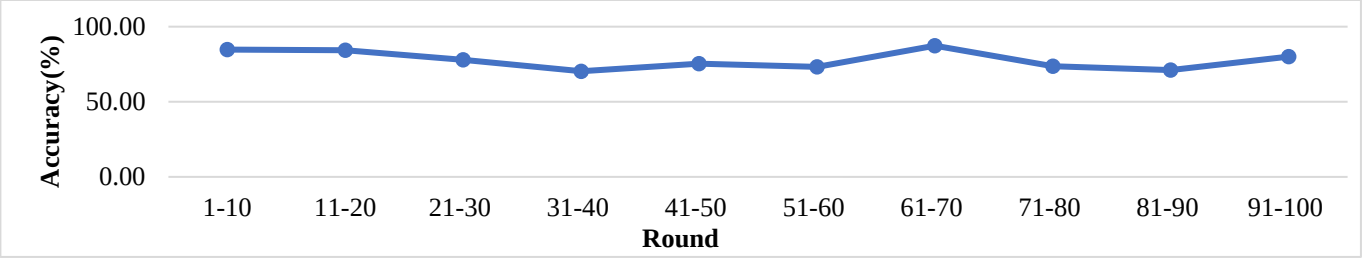

Fig. 10 Dispensing accuracy

4.2. Dispensing Accuracy

Dispensing was tested for 100 rounds after filling 5 pills of different types for each servo dispenser (a total of 30 pills per round). Figure 10 shows the 100 test rounds conducted and the average accuracy calculated for every 10 tests. Accuracy was determined by the number of successful dispensing rounds out of total rounds. The system had a problem getting high accuracy for dispensing, which put the system's performance below expectations. Accuracy is somewhat unstable in each round and gets highest in 61-70 rounds. The impacting factors regarding accuracy might be servo quality and speed, dispenser disc design and the hardness and shape of the pills. However, the dispenser's average accuracy is better than the one presented in [3] [77.8% vs 71%].

4.3. Serial vs Parallel Processing

The automatic pill dispenser system was tested in two processing modes: serial and parallel. The serial processing is quite simple, to do one task after another sequentially so a servo rotates the dispenser disc one after another. For parallel processing, we tried to run six servo motors in parallel; however, the workload is quite heavy to run all servo motors at the same time parallelly. Therefore, we set up a pair of servo motors to work in parallel in our experiment. A total of 12 pills of different types were used for the experiment and tested. The results (Table 1) showed that the parallel system saves the dispensing time by 4.16 seconds over serial dispensing, which took 9.18 seconds to complete the task (45.32% gain).

4.4. Pharmacist vs Automatic Dispensing System

Automatic pill dispensing can be used as a kiosk not only by buyers but also by pharmacists. Table 2 compares the dispensing time (in seconds) between the manual dispensing of the pharmacist and the automatic dispensing machine. The pharmacist's working area is assumed to be within 1.5 meters of delivering the requested order. The test is conducted after changes in pill count that will give the same type of pills and different types of pills. According to the result shown in Table 2, there is an increase in processing time if the pill count increases for both the pharmacist and the automatic dispenser machine. There is a little difference in time between the two for the same type of pills, and the pharmacist is faster in some cases. However, the automatic pill dispenser performs better to process the different types of pills than the pharmacist.

Table 1. Serial vs Parallel processing

Pills Name	Pills Count	Sequential Dispensing (s)	Parallel Dispensing (s)
Ya Fartab	2	9.18	5.02
Propoliz	1		
Vitamin C	3		
Paracetamol	3		
Simethicone	1		
Charcoal Pill	2		
Total	12		
Dispensing Time Difference (s)		4.16	
Time Gained (%)		45.32	

Table 2. Pharmacist vs automatic dispensing

	Pills (Tablets) Count	Same types of Pills (s)	Different types of Pills (s)
Pharmacist	3	13.48	15.42
	6	20.57	18.11
	9	25.43	41.27
	12	29.56	45.38
Automatic Dispensing Machine for Pharmacy	3	12.61	13.42
	6	17.08	16.1
	9	29.71	34.91
	12	30.35	38.95

Table 3. Comparison of pill dispensers

	Automatic pill dispenser for pharmacy	Robotic medicine dispenser [14]	Kerby Lester KL 60
Dispensing Performance	~92 RX/Hr	~60 RX/Hr	~160 RX/Hr
Number of cells	6	4	60
Cell holding capacity (500 mg)	600	150-200	900
Price tag	<US$ 200	~US$ 2000	~US$ 80000

4.5. Functions and Performance of Dispenser

There are few comparable research studies about automatic pharmacy pill dispensers, especially for selling pills in retail/hospital pharmacies. This prototyped model has some useful functions over typical dispensers, such as parallel dispensing, touch screen display, coin payment system, current stock status, daily sale amount display and multi-user support.

A comparison table of automatic pill dispensers for pharmacy and other two dispensers: 1) a low-cost robotic medicine dispenser and 2) a commercial dispenser Kirby Lester KL 60, which were presented in [14], can be seen in Table 3 regarding dispensing performance, capacity and cost.

The custom-designed servo-based cells demonstrate an impressive dispensing accuracy of nearly 80%. These cells were rigorously tested with six different types of tablets and capsules, each varying in size and shape.

While the results indicate a need for improvement in accuracy, the proposed device model excels in other critical aspects, offering a higher dispensing rate of 92 prescriptions per hour, increased holding capacity, and cost-effectiveness, which are comparable features to other models in the market.

Performance gain in this work was achieved due to parallel processing in the dispensing mechanism. This machine is particularly well-suited for small pharmacies and drug and convenience stores selling over-the-counter medicines.

5. Conclusion and Future Works

Medication dispensing is a tiresome job for pharmacists, especially in busy times. The pharmacist must pay attention to administering the correct pills for the patients. The automatic pill dispenser can help to administer common/over-the-counter medicines that do not need a prescription from doctors; the pharmacist can save his/her time and concentrate on the prescribed medicines.

The novelty of this machine is that it works as a self-access kiosk for users and can be used even after the closing hours of the pharmacy. The system is portable due to utilizing low-cost materials and components. The system is built as a modular system, as the custom-designed dispensing discs could be built and replaced for chosen types of pills.

However, the dispenser was initially designed for experiments; therefore, there are some limitations regarding record keeping, a fully functional payment system, reminders and alerts, and remote control by pharmacists or supporting staff. Regarding dispenser performance, further research is necessary to get full accuracy after considering the impacting factors. Adding database functions and communication channels through the IoT module will enhance the automatic pill dispenser's connectivity, usability and interactivity.

Acknowledgments

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