

IoT-based Smart Liquid Medicine Dispenser for Dysphagia Symptom Patients

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Abstract

Since the onset of COVID-19 pandemic in Malaysia from 2020, a shortage of medical staff has been revealed due to the rising number of patients. Especially when Movement Control Order (MCO) finished, the critical ill patients returned back to emergency departments causing overcrowded crisis in emergency departments. Additionally, the issue of shortage of nurses in Malaysia had always been the major problem. With the rising of patients, workload of existing nurses in Malaysia increased and hence directly immense pressure on them. In order to the insufficient of medical staffs, smart pill box had been invented in the market nowadays. However, it does not benefit to some groups of patients for example, elderly, children and the patients with dysphagia symptom, as they had difficulty in swallowing solid medication such as pills and tablets. Therefore, this paper presents the invention of smart liquid medicine dispenser with Internet of Things (IoT) by using the components of ESP32 microcontroller, peristaltic liquid pump for transferring liquid medicine, L298N DC motor driver module for controlling the speed and time taken for the peristaltic liquid pump to spin, HC-SR04 ultrasonic sensor for switching properties of the prototype, and a passive buzzer for notification. Besides, Arduino Cloud IoT Remote application is utilized as the platform of IoT. As a result, the smart liquid medicine dispenser with IoT able to dispense liquid medicine with the accuracy of 98% to 100%.

1. Introduction

Since the Covid-19 pandemic started in Malaysia from 2020 till now, the issue of insufficient medical staffs in medical employment had been discovered with the rise of patients. According to Boo Su-Lyn (29 December 2022) from Hospital Code Blue, she recapped that emergency department overcrowding crisis was worse than pre-pandemic days and it is categorized in top 10 Malaysia health issues in 2022 [1]. After the interruption of two years Covid-19 lockdown, most of the seriously sick patients such as heart disease, kidney failure, stroke and diabetes came back to the emergency department causing the medical staffs are overwhelmed and the patients forced to wait one and a half day for a bed in a ward [1].

Besides, insufficient of medical staffs in Malaysia is also caused by the issue of contract doctor has not been fully addressed in 2023 [2]. According to Dr Milton Lum (5 January 2023), there are about 30 of its best and brightest junior doctors lost to Singapore annually due to the financial unsustainability and reducing demand in Malaysia [3]. Other than the problem of contract doctor, the shortage of nurse is still a major problem in Malaysia although the growth of registered nursing workforce is continuation upward [4]. As the significant nursing shortage and decreases of doctors in Malaysia not solved, increased workload will directly immense pressure on existing nurses and soon will affect the quality of patient care [4].

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In order to solve the problem of insufficient medical staffs and low quality of treatment and health care in Malaysia, smart pill box dispenser had been invented in marketing nowadays. The features of smart pill box dispenser are very simple. It includes separate sub-boxes that contain different types of pills and tablets. The 2 function of smart pill box is to remind patients to take the corresponding pills via application [5]. With this function, patients able to take their pills correctly on time with the aid of nurses. However, smart pill box does not contain liquid medicine such as elixirs, solutions, suspensions, syrups and others. Hence, the disadvantage of smart pill box is unfriendly for who have difficulties swallowing tablets and capsules such as children, elderly and patients who had dysphagia symptom. In medical term, dysphagia means for difficulty swallowing or swallowing problems [6]. The symptoms of dysphagia included choking or coughing, shortness of breath or change in breathing pattern and vomit when trying to swallow tablets and capsules [6]. Therefore, this project is carried out to design a smart liquid medicine dispenser with IoT that replaced tablets and capsules to liquid medicine.

1.2 Related Works

Singh et. al., proposed an IoT based smart medical box system to make user work simple for patients, mostly for elderly, to take their prescribed daily medications on time [7]. In this project, the microcontroller used is NodeMCU ESP8266 in which it is connected with Blynk application via WiFi. In order to detect the conditions of the patients, temperature sensor and heart rate monitor sensor is also included in this project. Buzzer and LED is also used in the system that functioning as notification for the user to take medicine. Through Blynk application, the information of patients such as the air quality surrounding the patients, the body temperature, heart rate, and the humidity over the past few days can be monitored in the dashboard.

Arun et. al., introduced a smart medicine box that includes several features in the medicine box such as monitoring the patient heart rate and temperature, emergency alert to the patient, and SMS alert to the caretaker and doctors [8]. This project included the IoT application in which the patient's heart rate and temperature will upload to the cloud and the doctor able to review via WiFi. The main advantage of this design is that patients are able to know their growing health condition since the system will store the patient's information in the cloud. In this project, the authors use Arduino Mega as the microcontroller while GSM module and IoT module for communication control and networking of the system. Besides, cloud, SMS and Gmail is used in this project instead of using mobile application. Doctors and patients are able to review the health condition via cloud while Gmail is used to receive all the data such as notification of taking medicine and alert message. Red LED and buzzer are also included in the hardware implement in which they act as alarm system. If the patient is not yet taking the medicine at scheduled time, red LED will start blinking and buzzer will be triggered. At the same time, GSM module will send SMS to the caretaker.

Sabit et. al., suggested an IoT-based smart pillbox to overcome the problem of untimely and improper intake of medicines [9]. Besides, this project also aimed to ease the life of patients and maintain the well-being of patient's health. The microcontroller used in the pillbox implementation is ESP32 as the pillbox needs to stay connected to the internet to upload the patient's health data to the cloud. The mobile application used in this project is REST API android app in which it is connected to the ESP32 via Bluetooth. REST API android app will collect all the data from the server and can update the latest data for the user. Besides, REST API android app will also notify the patient to take their medicine in time. Buzzer is used in this project to act as alarm for reminder while GSM module is used for alerting the remaining pills in the pillbox.

Afiqah et. al., proposed a smart pill dispenser by using the NodeMCU ESP8266 microcontroller [10]. The controller is used to connect the smartphone for notification via WiFi. Stepper motor is used in this project to rotate the compartment slot to the lip cap and dispensing the pill through the lid cap. Blynk application is also used to allow user setup the medication timing. There will be included a push button in the hardware in which it is for reset the system. About the notification system of this project, Blynk application will send notification to the user via smartphone followed up by turning on of LED and buzzer. The main issue of this project is that the stepper motor is unable to move to the appropriate angle.

With this information, this project is designed by using the ESP32 microcontroller and Arduino Cloud IoT Remote application as the platform for IoT. Besides, a variety of components, such as peristaltic liquid pump, motor driver, buzzer, and ultrasonic sensor, are utilized for various functions.

2. Methodology

In this section, the theoretical analysis of the method in completing the project will be discussed for example, block diagram, flowchart, and the connections of all components.

2.1 System Block Diagram

Figure 1 shows the block diagram of the proposed smart liquid medicine dispenser with IoT. In this system, the components include ESP-WROOM-32S 38 PINS development board as the programmable WiFi module that

enables to connect application via WiFi. Besides, it also acts as the microcontroller and brain to control the peristaltic liquid pump. The ESP-WROOM-32S 38 PINS development board receives power from L298N DC motor driver module and gives power to all components in the system. Next, for the input, ultrasonic sensor will detect the presence of liquid medicine cup and functioning as switching properties of the peristaltic liquid pump to keep it in hygiene. For example, if it detects that the medicine cup does not presence, the peristaltic liquid pump will not operate although the user selects the required amount of liquid medicine.

After that, in the output, L298N DC motor driver module will control the speed of rotation of the DC motor that attached together in the peristaltic liquid pump. With that, it able to control the amount of liquid medicine to be dispensed. A 12V power adapter is connected to L298N DC motor driver for supplying power supply to microcontroller and two peristaltic liquid pumps. Besides, two peristaltic liquid pumps will be used to pump two different types of liquid medicines in the unit of millilitre (mL). After the dispensing system is done, the passive buzzer will play the tone set in the program to inform patients or nurses about that. Lastly, Arduino Cloud IoT Remote application will be used to control the amount of liquid medicine to be pumped by the user over long distance via WiFi. Besides, the user also can make a schedule through the scheduler inside Arduino Cloud IoT Remote for the dispensing system to operate automatically after reaching a certain time. A messenger is also included in Arduino Cloud IoT Remote to show the status of dispensing system and if patients forget to take the medicine, it will notify the nurse through messenger as well.

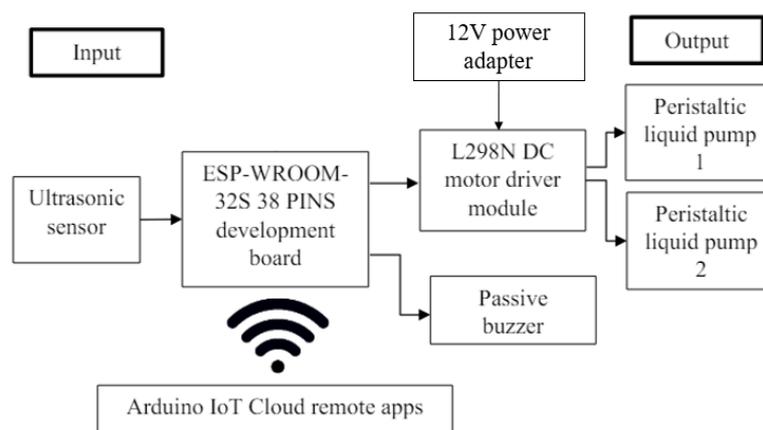


Fig. 1 Block diagram of the project

2.2 System flowchart

This hardware is designed with two conditions which is user friendly for the users. The first condition is the manual operation, in which the nurses can turn on the system manually with the switch in the IoT Remote application for medicine dispensing. Meanwhile, the second condition is the automatic operation, in which the users are able to set up a schedule for a certain date and certain time with the scheduler in IoT Remote application. The details of both conditions are shown in the flowcharts below.

Figure 2 shows the flowchart of the smart liquid medicine dispenser with IoT for manual operation condition. Firstly, the user needs to connect the Arduino Cloud IoT Remote application to ESP32 development board via WiFi. Through the Arduino Cloud IoT Remote application, the user will be able to select the amount of liquid medicine to be dispensed and switch on the system manually. Next, as ESP32 development board received the signal from the Arduino Cloud IoT Remote application, it will request for the ultrasonic sensor to detect the presence of medicine cup. If there is no medicine cup, ESP32 development board will not trigger the L298N DC motor driver module. Otherwise, ultrasonic sensor will give response to ESP32 development board and let it triggers the L298N DC motor driver module.

After that, the L298N DC motor driver module will control the time taken of dispensing system operation with maximum speed of DC motor that is attached in the peristaltic liquid pump according to the amount of liquid medicine selected by the user. The time taken for the dispensing system is calibrated and calculated in the program. As the amount of liquid medicine dispensed is same as the amount of user request, ESP32 development board will turn on the passive buzzer to inform the user and start to detect the distance again via ultrasonic sensor. If the distance detected is still near to it for certain time, it indicates the patient has not taken the medicine yet, thus notifies the nurse via messenger in Arduino Cloud IoT Remote to inform or remind the patient to take the medicine. Then, it continues to detect the presence of medicine cup. After the patient took the medicine, no medicine cup was detected by ultrasonic sensor. The system will send a message that the patient has already taken the medicine. Then, the system will loop back to the idle mode and wait for another task to be implemented.

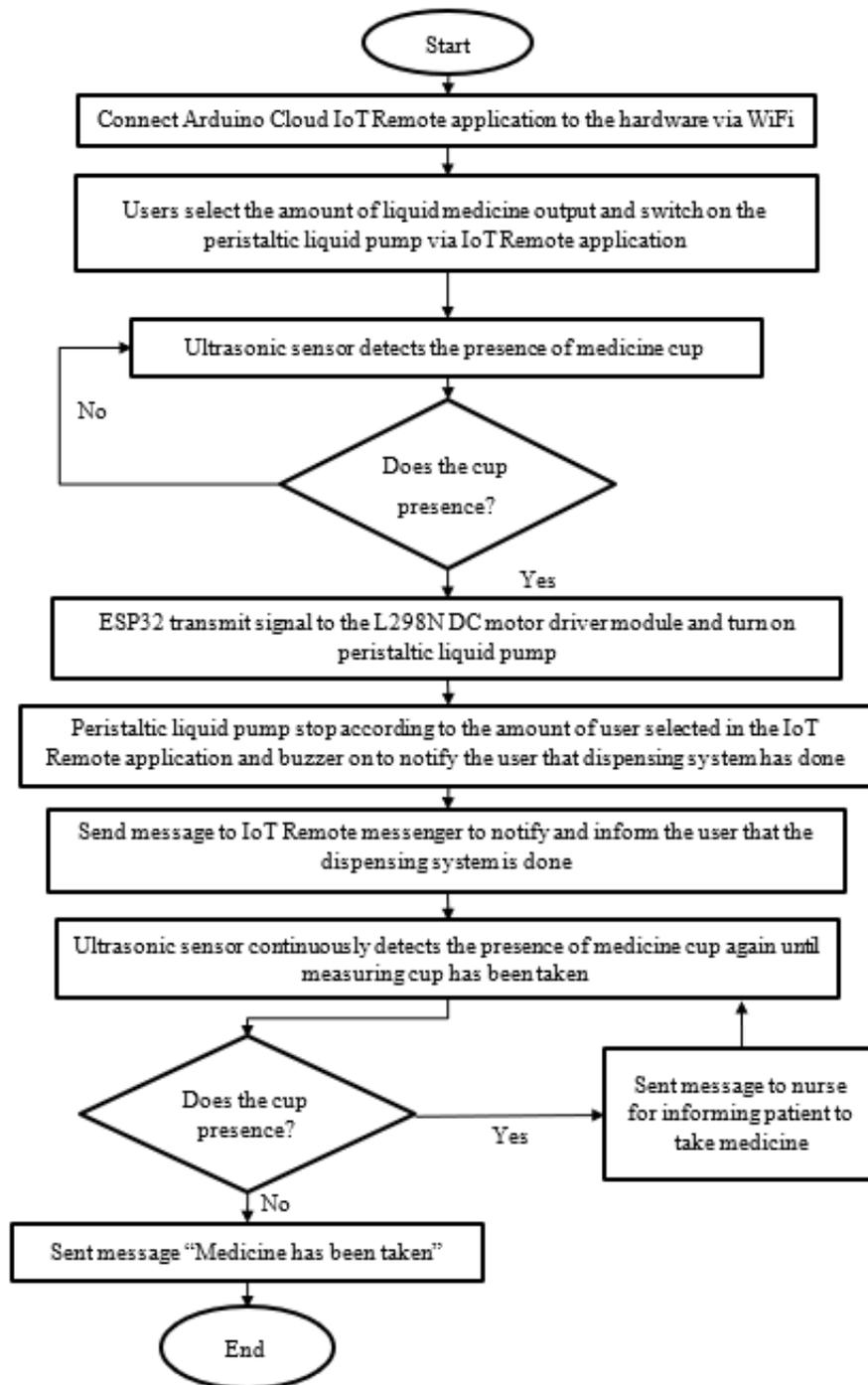


Fig. 2 Flowchart of the proposed smart liquid medicine dispenser with IoT for manual operation condition

Figure 3 shows the flowchart of the smart liquid dispenser with IoT for automatic operation condition. The flow of automatic operation condition is quite similar to manual operation condition. The difference is just the presence of scheduler in Arduino Cloud IoT Remote application. Through scheduler, the user can set up date and time in the application. Then, the system will start to detect whether the real time is same as what has been set up in scheduler. If yes, then the scheduler will transmit signal and turn on the peristaltic liquid pump for dispensing system. If not, then it will continue to detect real time. After the dispensing is done, the system will undergo the notification part which is similar to normal condition.

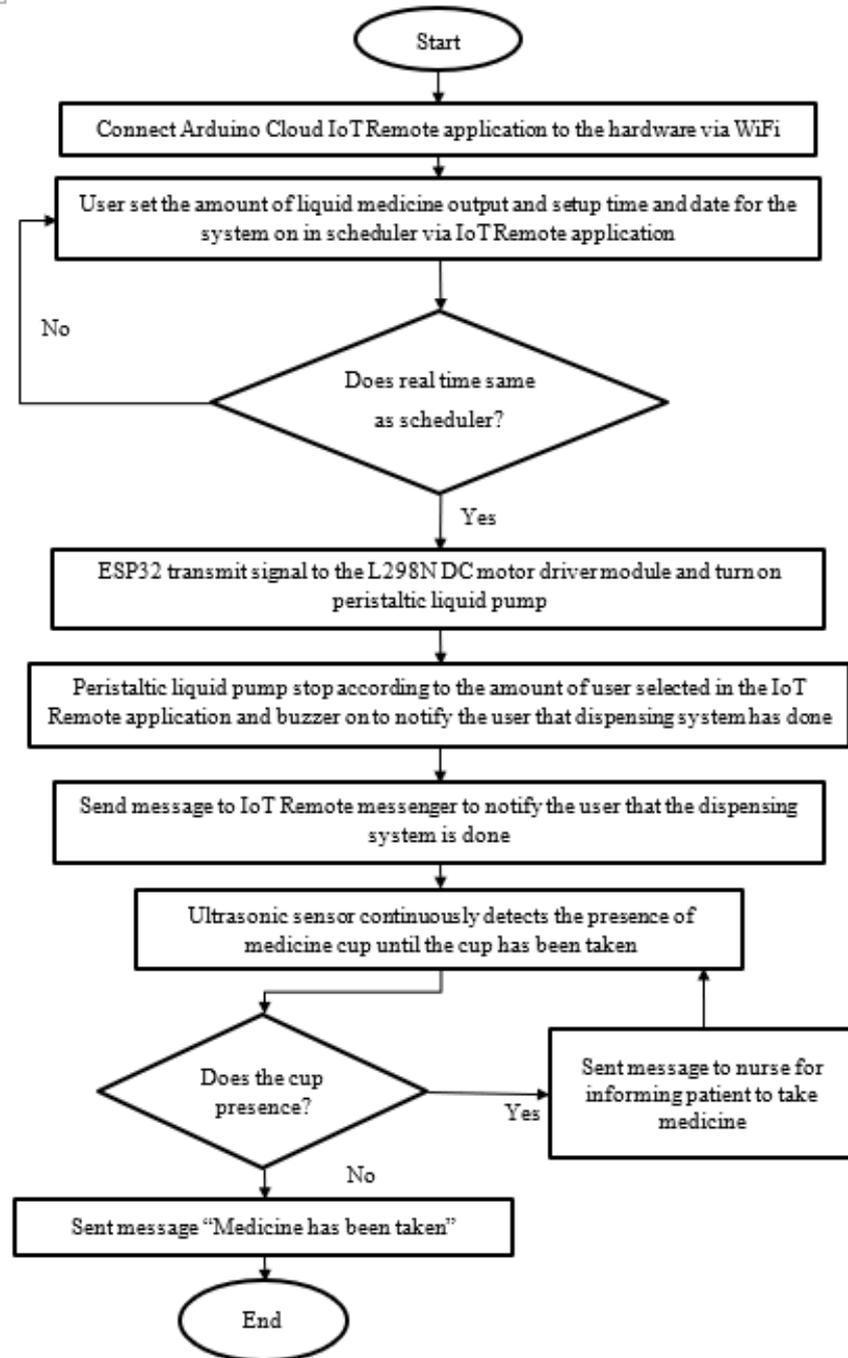


Fig. 3 Flowchart of the proposed smart liquid medicine dispenser with IoT for automatic operation condition

2.3 Connection of Components in The Hardware

Figure 4 and Figure 5 show the connection of all related components in the hardware and the connection of peristaltic liquid pumps in this hardware, respectively. Besides, Table 1 and Table 2 show the pin assignment of I/O ports of ESP32 and the pin assignment of peristaltic liquid pumps, respectively.

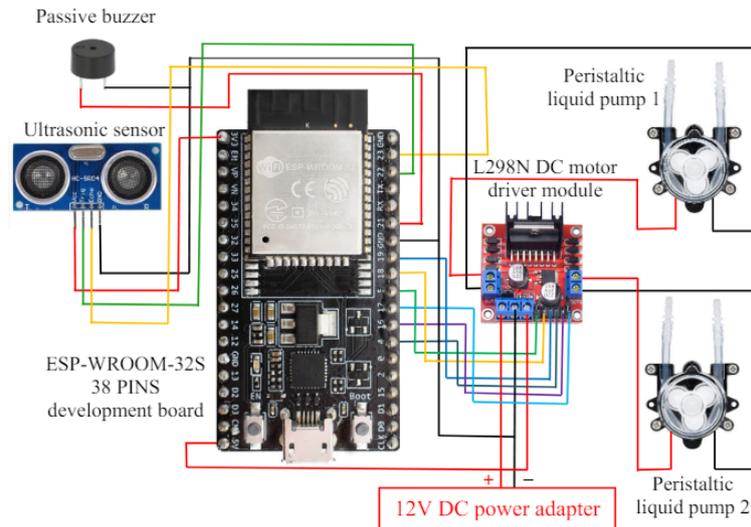


Fig. 4 Connections of all components in the hardware

Table 1 Pin assignment of I/O ports of ESP32

ESP32 Pinout	Peripheral	Peripheral PIN Name
	Passive buzzer	GND
GND	L298N DC motor driver module	GND
	Power adapter	Negative port
5V	L298N DC motor driver module	5V PIN
3V3	HC-SR04 ultrasonic sensor	VCC
GPIO4		IN3
GPIO5		ENA
GPIO16	L298N DC motor driver module	IN4
GPIO17		ENB
GPIO18		IN1
GPIO19		IN2
GPIO21	Passive buzzer	Positive Pin
GPIO22	HC-SR04 ultrasonic sensor	Trig
GPIO23	HC-SR04 ultrasonic sensor	Echo

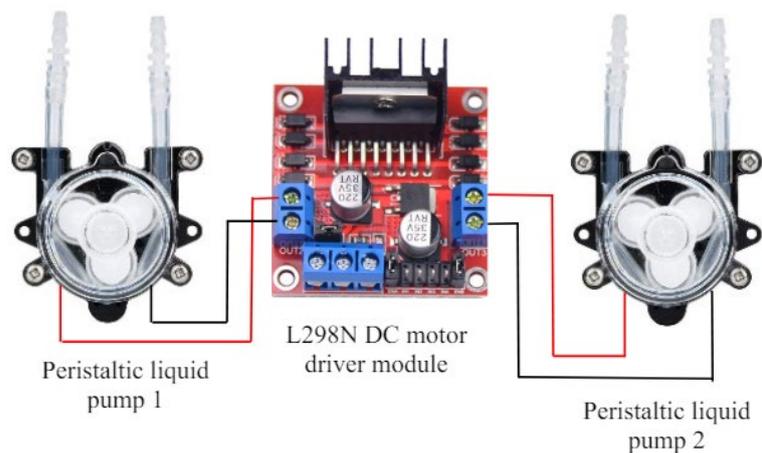


Fig. 5 Connections of peristaltic liquid pumps

Table 2 Pin assignment of peristaltic liquid pumps

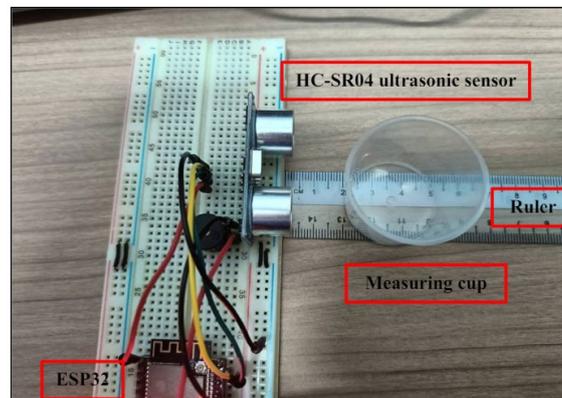
Peristaltic Liquid Pump	Peristaltic Liquid Pumps Pin Name	Peripheral	Peripheral PIN Name
1	VCC	L298N DC motor driver module	OUT1
	GND		OUT2
2	VCC		OUT4
	GND		OUT3

3. Results and Discussions

In this section, the results from the completed hardware in this project is presented for example, the hardware realization, calibration of ultrasonic sensor, calibration of peristaltic liquid pumps, and the flow of system in Arduino Cloud IoT Remote.

3.1 Calibration of HC-SR04 Ultrasonic Sensor

Theoretically, the working principle of an ultrasonic sensor is transmitting original wave from transmitter and receiving reflected wave from the object in front by the receiver. Therefore, the calibration can be done by putting a measuring cup on a ruler in front of ultrasonic sensor. During testing, measuring cup position is adjusted to get the closest distance detected with the actual range. The set up of testing ultrasonic sensor is shown in Figure 6 while the result of testing is shown in Table 3. Besides, Figure 7 shows the graph of percentage error versus the actual distance.

**Fig. 6** HC-SR04 ultrasonic sensor function testing and calibration**Table 3** Result of testing and calibration

Actual Distance of Measuring Cup (cm)	Distance Detected By Ultrasonic Sensor (cm)	Measurement Error (cm)	Percentage Error (%)
1.0	No consistent value	NA	NA
1.5	2.06	+0.5	33.33
2.0	2.06	+0.06	3
2.5	2.69	+0.19	7.6
3.0	3.0	0	0
3.5	3.33	-0.17	4.86
4.0	3.96	-0.04	1
4.5	4.29	-0.21	4.67
5.0	2.92	-0.08	1.6
5.5	5.25	-0.25	4.54

6.0	5.25	-0.75	12.67
6.5	6.21	-0.29	4.46

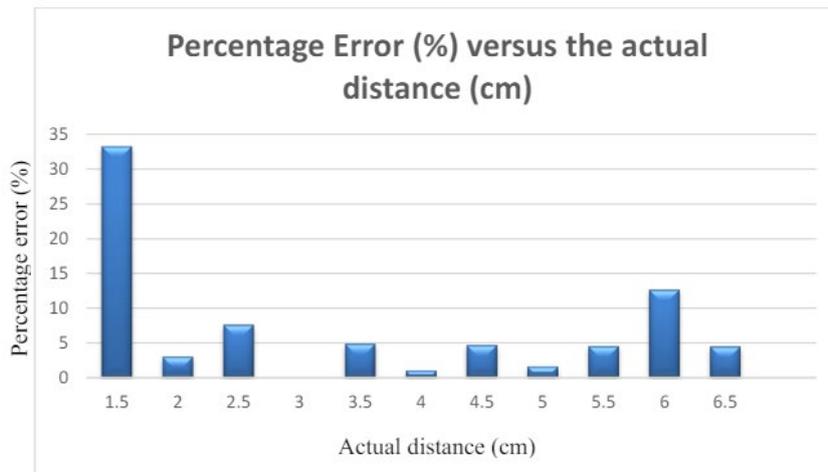


Fig. 7 Graph of percentage error (%) versus the actual distance (cm)

According to Table 3 and Figure 7 above, when the measuring cup is positioned 1cm away from the ultrasonic sensor, the result shows no consistent value. During this distance, the ultrasonic cannot detect the presence of the measuring cup although it is just in front of the ultrasonic sensor. Besides, when the distance is added to 1.5cm away from the ultrasonic sensor, it gives the result of 2.06cm which is not accurate compared to actual distance. Therefore, this can be finalized as the measuring cup should not be placed less than 2cm away from the ultrasonic sensor. Besides, when the measuring cup is placed 5.5cm away from the ultrasonic sensor, the value of measurement error is getting larger. Thus, this can be finalized as the measuring cup should not be placed more than 5cm away from the ultrasonic sensor. Next, when the measuring cup is placed in within the range of 2cm to 5cm away from the ultrasonic sensor, the ultrasonic sensor will give the most accurate results which is approximately ±0.21cm accuracy and less than 7.6% percentage error. Hence, it is finalized that the measuring cup should be placed within 2cm to 5cm away from the ultrasonic sensor. Lastly, the position of measuring cup should not be too high or too low, in which it will directly affecting the distance calculated by the ultrasonic sensor.

3.2 Calibration of Peristaltic Liquid Pumps

In this prototype, two peristaltic liquid pumps are used to dispense liquid medicine from the bottle to the measuring cup. As they are related to the accuracy of the overall system, they play a very important role. Thus, calibration of two peristaltic liquid pumps is carried out to make sure the system can dispense liquid medicine accurately and same as the amount of liquid medicine that user required in Arduino Cloud IoT Remote. The calibration is done by doing some simple mathematics and adjusting the time taken to dispense each millilitre. The rotation speed of 12V DC motor that attached to the peristaltic liquid pump will be fixed with the speed of 255 in digital output. An equation is created as shown in (Eq. 1) in below to relate between millilitre (mL) and the time taken for the DC motor to spin. By referring to Eq. 1 below, control is representing the amount of liquid medicine that is set up by the user in IoT Remote while actual is representing the actual amount of liquid medicine dispensed by the system. Besides, *t* is represents the time taken for peristaltic liquid pump to dispense one millilitre of liquid medicine.

$$control (mL) \times t(ms) = actual (mL) \tag{1}$$

Initially, the time taken to dispense one millilitre is set to 500ms which is also equivalent to 0.5s. Then, the liquid medicine is set up with a certain amount of millilitre in IoT Remote and the dispensing system is switched on to dispense liquid medicine into the measuring cup. After dispensing system is done, the actual amount of liquid medicine can be determined by referring to the measuring cup. For the first peristaltic liquid pump, when control is equal to 12mL, the actual value I got is equal to 10mL. Therefore, we can find out the perfect time taken by doing some manually calculation. The calculation is shown in below:

$$\begin{aligned}
 control (mL) \times t(ms) &= actual (mL) \\
 12mL \times 500ms &= 10mL \\
 \text{Therefore, } 6s &\approx 10mL
 \end{aligned}$$

To dispense 10mL of liquid medicine in actual result, the time taken for the first peristaltic liquid pump to on is equal to 6s. Thus, to make it accurate with the amount in IoT Remote:

$$\begin{aligned}
 6s &= 10mL \\
 10mL \times (new\ t_1) &= 10mL \\
 10mL \times (new\ t_1) &= 6s \\
 new\ t_1 &= \frac{6}{10} = 0.6s \approx 600ms
 \end{aligned}$$

In the final result calculation, the new time taken for the first peristaltic liquid pump to dispense one millilitre should be equal to 600ms. After that, the time taken for first peristaltic liquid pump to turn on in the program is changed to 600ms and a testing is carried out to test the final accuracy of the first peristaltic liquid pump. Table 4 below shows the testing results of the amount of liquid medicine that has been set up in IoT Remote and the actual amount of liquid medicine dispensed by the first peristaltic liquid pump.

Table 4 Testing result of the amount of liquid medicine that has been set up in IoT Remote and the actual amount dispensed by the first peristaltic liquid pump

Amount of Liquid Medicine In IoT Remote (mL)	Actual Amount of Liquid Medicine Dispensed By The First Peristaltic Liquid Pump (mL)			Average (mL)	Accuracy (%)
	First Try	Second Try	Third Try		
	5.0	5.1	5.0		
10.0	10.0	10.0	10.0	10.0	100
15.0	15.0	15.0	15.0	15.0	100
20.0	19.5	19.8	19.5	19.6	98

Next, the steps for calibration of the first peristaltic liquid pump is repeated to calibrate the second peristaltic liquid pump. Initially, the time taken for the second peristaltic liquid pump to dispense one millilitre of liquid medicine is equal to 600ms, 59 which is also equivalent to 0.6s. Then, by dispensing any amount of liquid medicine, calculation can be done.

$$\begin{aligned}
 control\ (mL) \times t_2\ (ms) &= actual\ (mL) \\
 14mL \times 600ms &= 15mL \\
 \text{Therefore, } 8.4s &\approx 10mL
 \end{aligned}$$

To dispense 15mL of liquid medicine in actual result, the time taken for the second peristaltic liquid pump to switch on is equal to 8.4s. Thus, to make it accurate with the amount in IoT Remote:

$$\begin{aligned}
 8.4s &= 15mL \\
 15mL \times (new\ t_2) &= 15mL \\
 15mL \times (new\ t_2) &= 8.4s \\
 new\ t_2 &= \frac{8.4}{15} = 0.56s \approx 560ms
 \end{aligned}$$

In the final result calculated, the new time taken for the second peristaltic liquid pump to dispense one millilitre should be equal to 560ms. Table 5 below shows the testing results of the amount of liquid medicine that has been set up in IoT Remote and the actual amount of liquid medicine dispensed by the second peristaltic liquid pump. Besides, Figure 8 below shows the components set up during the calibration of peristaltic liquid pumps.

Table 5 Testing result of the amount of liquid medicine that has been set up in IoT Remote and the actual amount dispensed by the second peristaltic liquid pump

Amount of Liquid Medicine In IoT Remote (mL)	Actual Amount of Liquid Medicine Dispensed By The First Peristaltic Liquid Pump (mL)			Average (mL)	Accuracy (%)
	First Try	Second Try	Third Try		
	5.0	5.0	5.0		
10.0	10.0	10.0	10.0	10.0	100
15.0	15.0	14.9	15.0	14.96	99.78
20.0	19.9	20.0	20.0	19.97	99.83

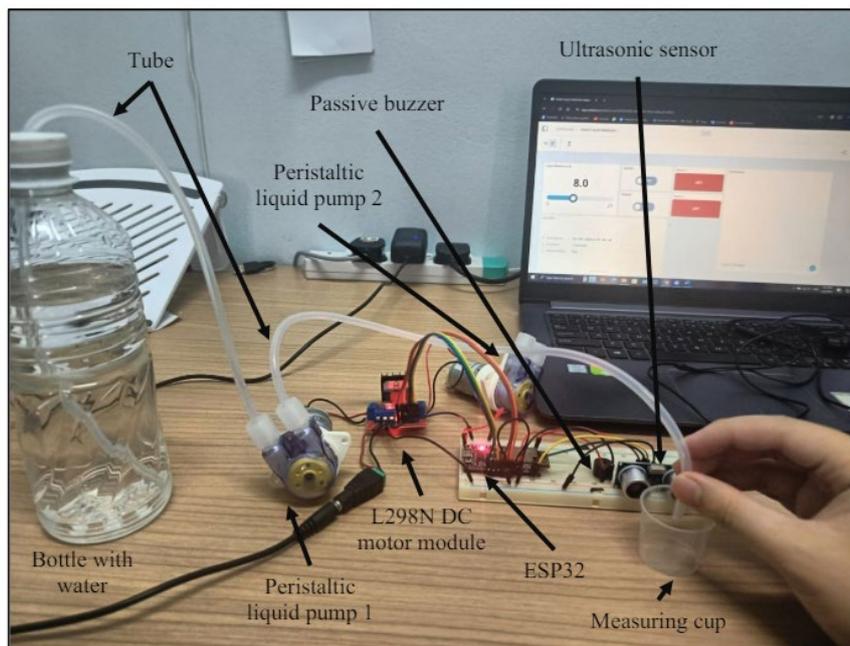


Fig. 8 Calibration of peristaltic liquid pumps

According to the testing results of the first peristaltic liquid pump in Table 4, it does dispense water accurately especially when dispensing 10mL and 15mL of water with the accuracy of 100%. Besides, it has the accuracy of 99.4% when dispensing 5mL of water. Other than that, it has the accuracy of 98% when dispensing 20mL of water.

Based on the testing results of the second peristaltic liquid pump in Table 5, it has the most accurate results with the accuracy of 100% when dispensing 10mL of water. Besides, it has 99.33% of accuracy when dispensing 5mL of water and 99.78% of accuracy when dispensing 15mL of water. Other than that, it has the accuracy of 99.83% when dispensing 20mL of water.

With the observation above, the first peristaltic liquid pumps has achieved the accuracy in the range from 99.4% to 100% while the second peristaltic liquid pumps has achieved the accuracy in the range from 99.33% to 100%. The accuracy may can improve as the measuring cup used in this testing may has no standardized measurement. When the measuring cup is changed to another type during this testing, the accuracy decreased. Therefore, it is important to make sure only one type of measuring cup is used for this prototype. Otherwise, the dispensing system for both peristaltic liquid pumps need to be calibrated again.

3.3 Hardware Realisation

Figure 9, Figure 10 and Figure 11 below show the top view, side view and back view of the prototype, respectively. This prototype will be cased and constructed by using four acrylic sheets with A4 size. With an acrylic cutter, straight line cutting and some small box cutting able to be performed. Besides, an electric drill is used to drill small holes on the acrylics. The small holes are to make sure that wires can passing through from one layer to another layer as there will be two layers in the prototype at the end of prototype to separate the donut board and medicine bottles. Before bonding the acrylic sheets together into a box, the connection in the breadboard will be moved to a donut board by soldering before bonding the acrylic. Figure 12 below shows the connection of all

components in the donut board. The acrylics are then bonded together by using epoxy. The epoxy used has two types of power glues, in which these two power glues need to be mixed together, then only can start to bond the acrylic sheets together.

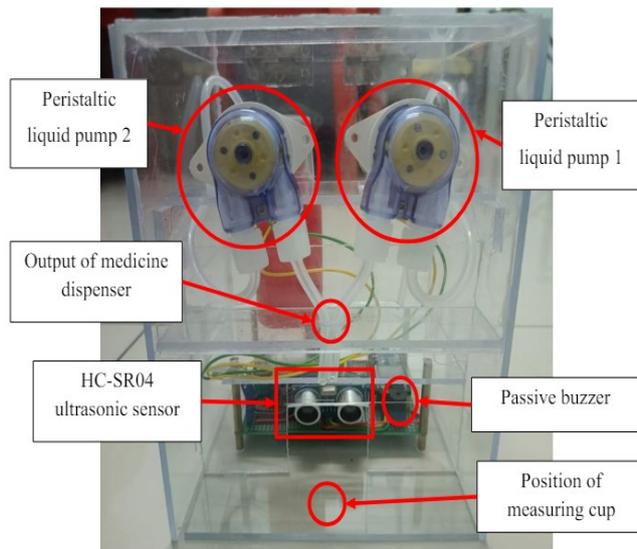


Fig. 9 Front view of the prototype

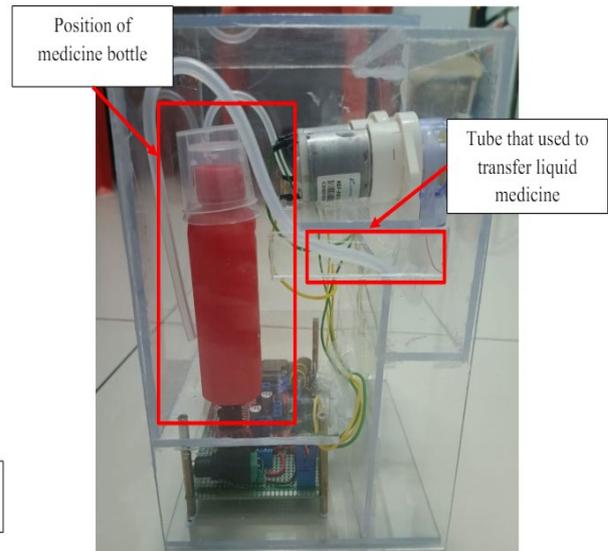


Fig. 10 Side view of the prototype

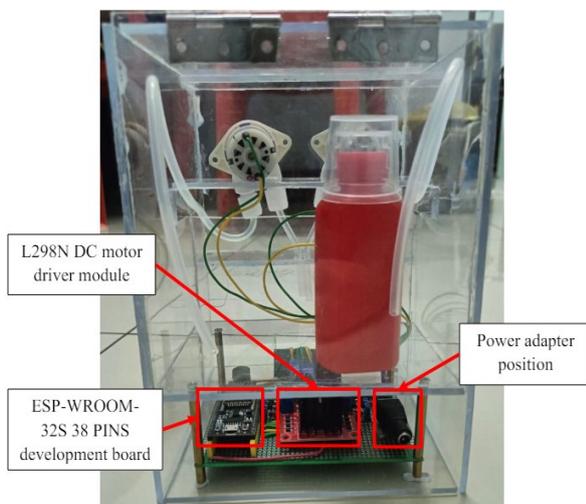


Fig. 11 Back view of the prototype

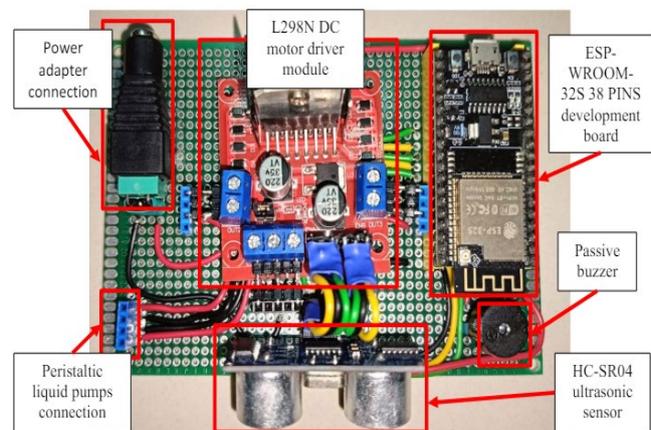


Fig. 12 Connection of components in donut board

3.4 Operation of Liquid Medicine Dispensing System By Using Arduino Cloud IoT Remote

In this project, Arduino Cloud IoT Remote is used as the platform for different IoT interface functions such as a slider that the user can select the amount of liquid medicine required by sliding the slider, two switches for the user to switch on peristaltic liquid pump 1 and peristaltic liquid pump 2, two status to display the status of both peristaltic liquid pumps, a scheduler for the user to modify and interface the dispensing system by according to their preferences, and a messenger that act as long distance notification to the user if the medicine is not taken by the patients. The operation principle of Arduino Cloud IoT Remote is also very easy to use, once the prototype and the handphone has connected to the WiFi, the user can use the system. Figure 13 (a) shows the dashboard designed with relevant functions in the Arduino Cloud IoT Remote.

Besides, this prototype is designed as dispensing liquid medicine system in which the user can select the amount of liquid medicine that suit their preferences. In order to implement this system, a tool that called as slider is added in the dashboard of Arduino Cloud IoT Remote. The range of this slider is set in between 0mL to 20mL, in which the minimum amount of liquid medicine can be dispensed is 0mL while maximum amount of liquid medicine can be dispensed is 20mL. Through this slider, the user can slide the slider to select the amount of liquid medicine to be dispensed in the range of 0mL to 20mL. Figure 13 (b) below shows the photo of slider in Arduino Cloud IoT Remote.

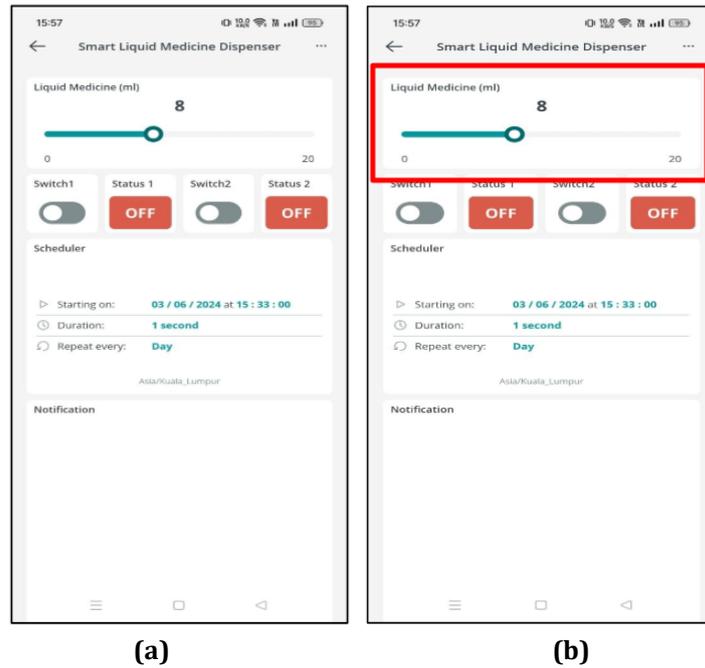


Fig. 13 (a) Dashboard designed with relevant functions in the Arduino Cloud IoT Remote; (b) Slider in the dashboard in Arduino Cloud IoT Remote

Other than that, in this prototype, two peristaltic liquid pumps are used to dispense two same or different types of liquid medicine. Therefore, two toggle switches are added to act as the switching properties for both peristaltic liquid pumps. Switch 1 will interface the switching properties of the first peristaltic liquid pump while switch 2 will interface the switching properties of the second peristaltic liquid pump. After the user has selected the amount of liquid medicine to dispense through the slider, the user can select which type of liquid medicine that they needed. For example, if the user has to take medication 1, they can turn on switch 1 to dispense the medicine 1 by sliding the quantity indicated in the bottle's instructions. Besides, the system will go into standby mode if the switches are toggled and the measurement cup is not present. Unless the measuring cup is positioned in front of the ultrasonic sensor, the peristaltic liquid pump will not operate during standby operation, even while the switch is on. Figure 14 shows the condition when the system is in standby operation.

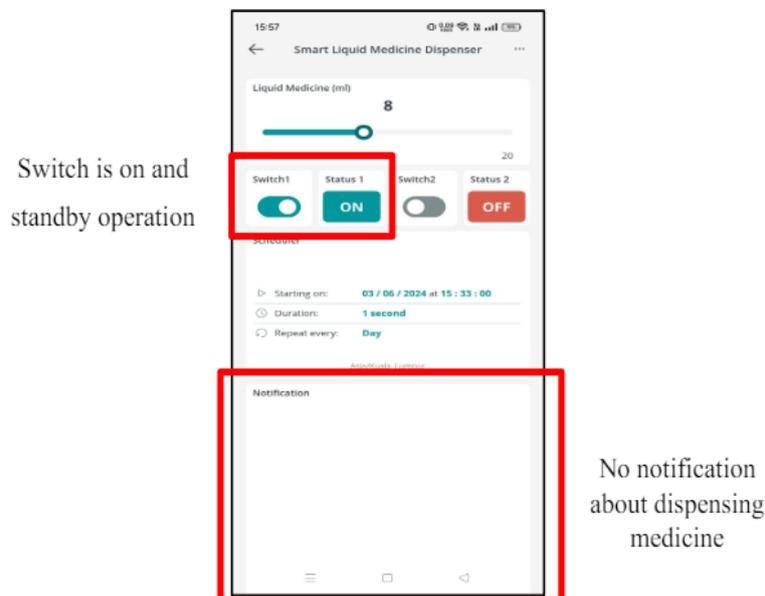


Fig. 14 The condition when the system is in standby operation

To prevent the prototype from executing multiple tasks concurrently and ensure proper task management, two status bars are added for displaying the condition of both peristaltic liquid pumps. The status will display the switching properties for both peristaltic liquid pumps. For example, if switch 1 is switched on and the first peristaltic liquid pump is operating, the status will display on. At the same time, if the users need to use the system, they can know in advance whether the system is using. If the system is operating, the user can wait for their turn to use the system. Figure 15 below show the status bar 1 that is synchronous with the switching properties of the first peristaltic liquid pump and status bar 2 that is asynchronous with the switching properties of the second peristaltic liquid pump respectively.

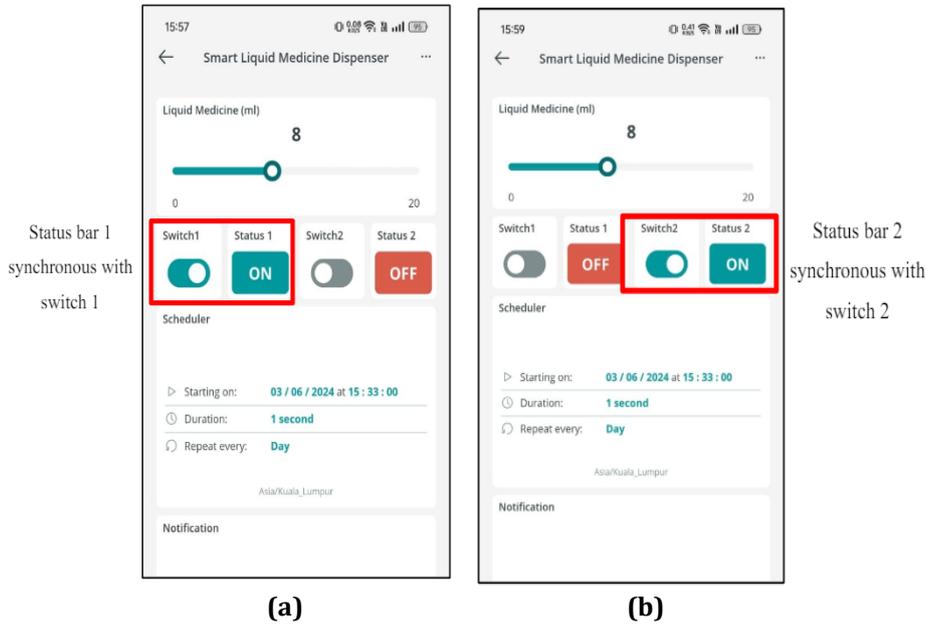


Fig. 15 (a) Status bar 1 synchronized with the switching properties of the first peristaltic liquid pump; (b) Status bar 2 synchronized with the switching properties of the second peristaltic liquid pump

Besides the manual operation by the user, scheduler is added in this system for automatically switching properties. If the users need to use the system for a certain time only, they can create a schedule for the system to turn on the system when the real time is same as the time setup in the schedule. In the scheduler, the users can set up the date and time to start the system. Besides, the users also can set up the duration for the signal to be activated. If duration is set up to 1 second, the scheduler will only activate for 1 second. Next, the users also can choose whether the schedule will repeat in every minute, hour, day, week, month, year or does not repeat. Lastly, the users can choose when to end the recurrence. Figure 16 below show the available options during setting a schedule and the options for repeating the schedule or not, respectively.

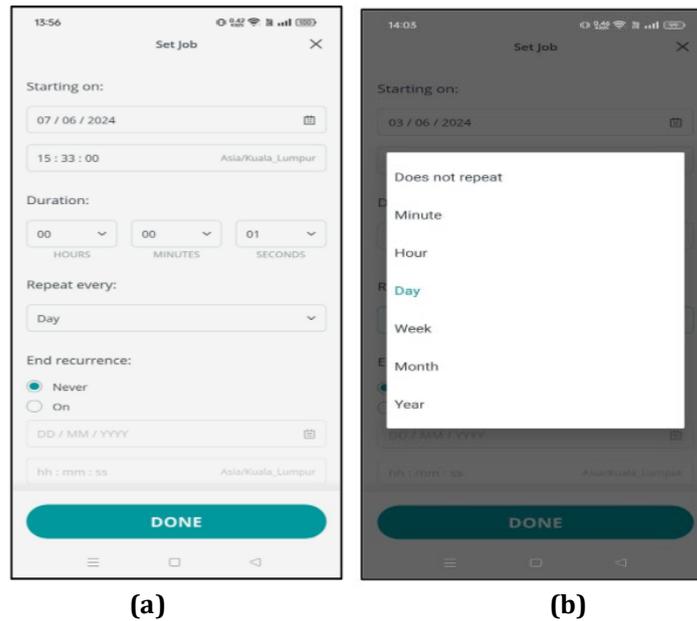


Fig. 16 (a) Option during set up a schedule; (b) Options for repetition schedule

In this prototype, a messenger is added in Arduino Cloud IoT Remote to act as the notification system. If the first peristaltic liquid pump is operating and dispensing the liquid medicine, a message of “Dispensing medicine 1...” will be shown in the notification and a message of “The liquid medicine 1 has been dispensed.” will be shown when the dispensing system for medicine 1 is done. In opposite, a message of “Dispensing medicine 2...” will be shown in the notification if second peristaltic liquid pump is operating and a message of “The liquid medicine 2 has been dispensed” will be shown for the completed dispensing process.

Besides, if scheduler is active and switching on the first peristaltic liquid pump, a message of “Scheduler is active. Dispensing medicine...” will be shown in the notification. After the dispensing system is done, the system will trigger ultrasonic sensor to detect the presence of measuring cup again. If the measuring cup is still presence after one minute, a message of “Liquid medicine has not been taken yet, please inform the patient.” will be shown to inform the users or nurses about the patients have not taken the medicine yet. During this state, the system will not operate and change into standby operation until the patients take away the measuring cup. In opposite, a message of “Liquid medicine has been taken.” will be shown when the patients had already took the medicine and ultrasonic sensor detected the absence of measuring cup.

Figure 17 below shows the summary of all responses for the notification system. Condition 1 is when the system is dispensing medicine 1 and the patients had taken the medicine on time. Condition 2 is when the system is dispensing medicine 1 and the patients have not taken the medicine on time. Condition 3 is when the system is dispensing medicine 2 and the patients had taken the medicine on time. Condition 4 is when the system is dispensing medicine 2 and the patients have not taken the medicine on time. Condition 5 is when the scheduler is activated and detecting whether the patient has taken the medicine or not on time.

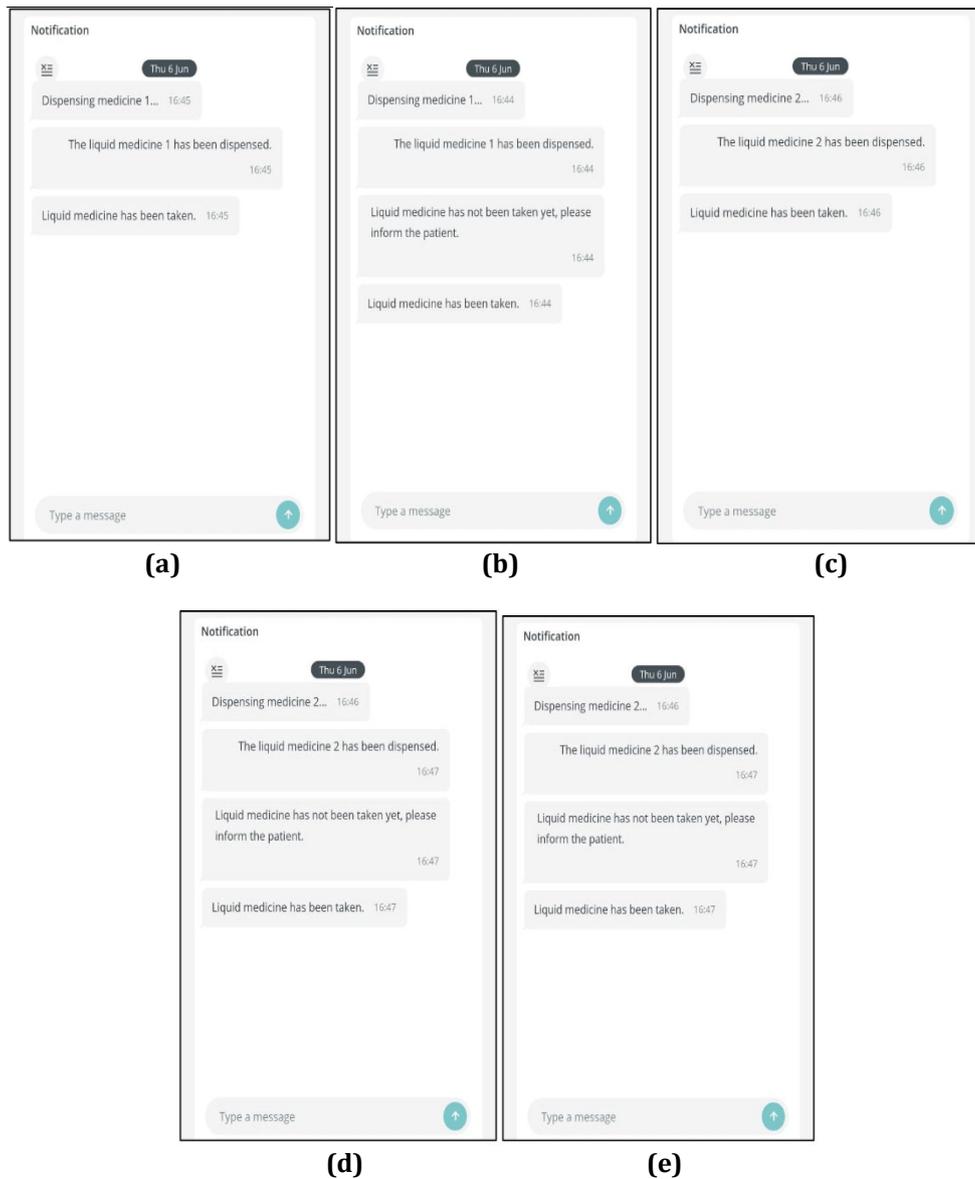


Fig. 17 Summary of all responses for the notification system (a) Condition 1; (b) Condition 2; (c) Condition 3; (d) Condition 4; and (e) Condition 5

4. Conclusion

In the nutshell, the project's goals and objectives have been effectively achieved through the design and development of the prototype. First, the prototype for an Internet of Things (IoT)-based smart liquid medicine dispenser was developed to automatically and precisely distribute liquid medication, doing away with the need for manual labour or outside aid. Additionally, the Arduino Cloud IoT Remote application was incorporated into the prototype to provide remote control, improving user comfort and operational flexibility. Not to mention, thorough testing of the prototype demonstrated accurate dispensing and quick operation, confirming its functional reliability. This creative approach represents a significant leap in medical technology and has the potential to improve patient care and liquid medication adherence.

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