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Smart IoT Mobile Medication Dispenser

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Abstract: The increase in the population of senior citizens created a new challenge of the shortage of healthcare workers to take care of the elderly. The elderly with multiple chronic conditions face problems in managing their daily medication intake. This has inspired us to design a low-cost Smart Internet of Things (IoT) Mobile Medication Dispenser (SMMD) to take care of the daily medication intake of the elderly. SMMD consists of hardware (medication dispenser) and software (an app for the user to control the SMMD and program the time to dispense the medication). The NodeMCU is used to control the stepper motor, organic light-emitting diode (OLED), and motor driver. The OLED displays the current time and the time set by the caregiver/elderly to take the medicine. The SMMD with three wheels enables it to move and dispense medication to the elderly. The NodeMCU is connected to the Firebase database to access the time required to dispense the medicine. The total cost of SMMD is USD50 and is affordable for the elderly from the lower-income group and making the process of taking medicine not a hassle for the elderly. The price of SMMD can be much lower when it is mass-produced.

Keywords: *Medication dispenser, Smart Internet of Thing*

1. Introduction

The ageing population has increased recently with the estimation of people aged more than 65 years, which will exceed 10 million by 2030 [1]. The percentage of people age 65 years and older from 2000 to 2020 for Japan was 54%, Canada was 43%, Australia was 39%, New Zealand was 34%, United States was 33%, Germany was 32%, France was 26%, United Kingdom was 24% and Malaysia was 5% [2], [3]. A new challenge is the shortage of healthcare workers to take care of the elderly. The E-Healthcare System proposed can be used to monitor the health condition of the elderly [22]. However, most of the elderly could maintain their health if they took their medication at the correct dosage punctually. The highest percentage of errors reported in consuming the wrong medication was 41.9% when the elderly self-managed their medication [4]. The elderly were classified into four groups, i.e. 1) middle-aged group (45 to 60 years), 2) young old group (60 to 70), 3) middle old (70 to 80) and oldest group (> 80) [5]. The middle old and oldest groups have proven to have trouble taking their medication. They have a short memory and attention span. So, they tend to forget that they even need to take medicine. They had a hard time managing their medication. The economic factor might lead to non-adherence to medication. They might have a tight budget to buy the medication needed [7].

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This has motivated us to design a smart low-cost SMMD for the elderly. This project also supports Sustainable Development Goal number 3 which is to ensure the healthy lives of the elderly [6]. By using the current technology such as IoT, medication dispensers were proposed to tackle this problem [9], [11]-[13], [15]. SMMD will dispense the medicine automatically. With pre-filled medication in the slot, the caregiver can just give the medication to the elderly without any hassle of remembering the dosage.

A study in 2005 was conducted to measure the trust and reliance on medication among older adults and younger adults. In this study, both older adults and younger adults were required to perform a task that simulates how they manage their medication. However, they were provided with computer aid to make the decision. Participants were free to rely on the aid or make their own decision. The results indicate that the older adults group relied on the aid more than the younger adults [8].

The first automated dispensing device was created in 1980 with the hope to reduce medication errors, increase the efficiency of pharmacies, and improve pharmacy inventory and billing function. It was intended for hospital and pharmaceutical use only [9]. A survey in 1999 was conducted and it was found that medication error within hospitals occurred in 2% to 17% of doses for the patient in general. One huge study found that 0.05% errors for drugs resulted in 5.3 errors per 100 orders and pharmacy dispensing caused 11% of the error while nursing administration caused 38% of the error. This error is caused by manual dispensing by staff workers. This shows that human mistake is not negligible and cause a huge percentage of error [10]. Therefore, a solution is needed to address this issue.

The medication dispenser proposed in [11] was designed to be located beside the patient bed in the hospital attached with a magnetic card for security purposes and a computer. The medication dispenser is equipped with a lock system and the slot is filled with medicine. At the pre-set time, the dispensing device will unlock for the nurse to take the medicine. Medication that can fit in this machine is tablets, capsules, small and pre-filled syringes [11].

The next dispensing device is the Baxter ATC-212 which used a microcomputer to automatically classify and pack the medication. When the medication is ordered, the order will be sent to the microcomputer, the particular canister will dispense the tablet. This type of medication dispenser is usually installed at the pharmacy only [12]. Other medication dispensers include Pyxis Medstation and Medstation Rx. The Medstation interface with a pharmacy computer. The Medstation will show the patient profiles and the nurses who were provided with a password will verify the order. Bills for the pills are incurred automatically and medication will be dispensed by the dispensing system [13].

Nowadays the medication dispensing system is also used at home by the caregiver which is a family member or nurse. The medicines are filled beforehand into individual cups and load it into the devices. Then, the time is set for when the medicine will be dispensed. During the pre-set times, an alarm will ring to invite the patient to take their medication that had already been dispensed. The caregiver will be contacted by the system if the patient missed their dose. However, the design is bulky and expensive as it requires monthly fees [14].

The smaller size medication dispenser developed by e-pill is called MedTime XL. After the pill is filled in this medication dispenser, it will automatically be locked. It is equipped with 28 slots and daily alarms with sound and visual notifications. The duration of the alarm is selectable between five minutes to one hour which is silenced upon dispensing. The downside of this system is its high price considering its small size. The price is approximately USD 375 [15].

The 3D-model pill dispenser was designed by Sopak in 2016. It consists of seven different parts which are the front panel, wheel top, wheel body, wheel bottom, wheel knob, wheel carriers, and motor gear. It consists of 20 slots to be filled with pills and medicine [16]. This design was used to construct the medication dispenser.

A low-cost medicine dispenser that consists of 4 containers to store the medicine, an alert system and a messaging system was proposed [17]. This system can store up to 4 different types of medicine and the elderly will be alerted to take the medication on time. However, the elderly need to get the medication that is dispensed from the containers and the elderly may fail to collect all the medicine dispensed from different containers. Furthermore, this is a static dispenser and it may be a challenge for some elderly to access the dispenser.

An automated medication IoT dispenser was proposed to minimize physical contact during the Covid-19 pandemic [18]. The QR code will be given to the patient through the mobile app and the dispenser will dispense the medicine after scanning the QR code. The elderly are required to use the mobile app that is installed on a smartphone which most of the elderly may face some difficulty with this.

A simple medicine dispenser kit was proposed to alert the elderly to take the medicine [19]. An alert was generated through the LED light from one of the pillboxes in the dispenser during the preset time to take medicine. Sensors are used to detect whether the elderly has taken out the medicine from the pillbox or not. A similar medicine dispenser was proposed to store the medicine and notify the elderly to take medicine on time [20]. However, a mobile app is needed for the caregiver to access the status of the dispenser remotely.

A pulse meter sensor is added to the medical dispenser that consists of 6 containers to store the medicine was proposed [21]. This system alerts the elderly using sound and light to indicate the correct medicine to be taken from different containers. The caregiver can monitor the status through an app. Enhancement can be made by adding a movement system to the dispenser to enable it to reach the elderly easier.

The paper is organized as follows. Section 2 discussed the methodology to design the SMMD. The results and discussion are illustrated in section 3. Finally, a conclusion is drawn at the end of the paper.

2. Methodology

SMMD consists of two major parts, i.e., hardware and software. The hardware consists of the medication dispenser and the 3 wheels chassis. The 3 wheels chassis provide mobility to the medication dispenser and this enables the elderly to reach the medication dispenser much easier. The software consists of three parts which are Arduino, Firebase, and a mobile app. NodeMCU microcontroller is used with the other electronic components such as stepper motor, organic light-emitting diode (OLED), motor driver, power supply and reset button. The body of the medication dispenser is 3D printed and the 3D model design was proposed by Sopak [16]. Arduino Integrated Development Environment (IDE) is used to program the NodeMCU to communicate with the hardware attached to it. The motor is used to rotate the Medication Dispenser to dispense the medicine. OLED is programmed to display two pieces of information, i.e., the current time and the time set by the user to take their medicine.

Firebase is used as the bridge between the NodeMCU and mobile app. The user inputs the time to dispense the medicine through the mobile app. The updated time will be forwarded to the Firebase database. NodeMCU will get the updated information from the Firebase. SMMD will dispense the medicine according to the time programmed by the user through the mobile app. The operation flow of the SMMD is shown in Figure 1.

Fig. 1. The operation flow of the SMMD

2.1. Hardware

The block diagram of the SMMD system is shown in Figure 2. The user can choose to activate the moving features so that the medication dispenser can move around or as a stationary system. Figure 3 shows the circuit diagram of the SMMD system. SMMD is powered by a 9V alkaline battery through the external voltage and ground pin.

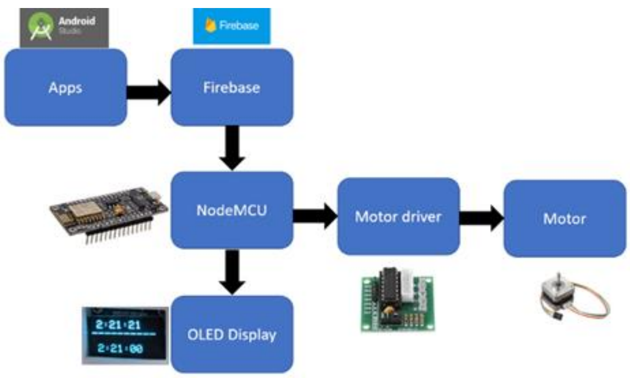

Fig. 2. Block diagram of the SMMD system

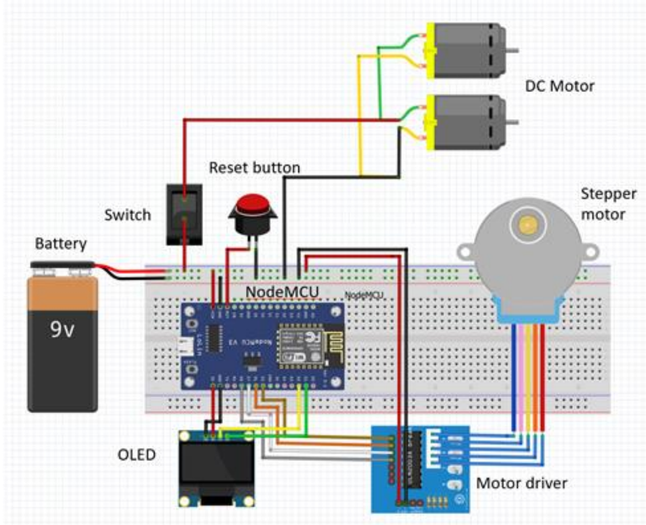

Fig. 3. Circuit diagram of the SMMD system

Fig. 4. 3-wheel car chassis for SMMD system

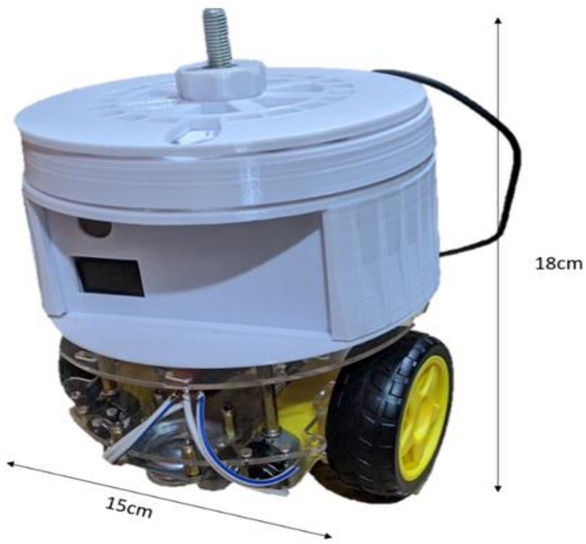

Fig. 5. The final prototype of the SMMD System

Polylactic acid (PLA) type of 3D printing filament is used to print the body of SMMD. It has a lower printing temperature and high heat resistance. The diameter of filament used is 1.75mm which is a standard and most commonly used for 3D printing applications. SMMD is equipped with a 3-wheels car chassis shown in Figure 4. It consists of two bigger black wheels for movement and a smaller white wheel to control the direction of the car. Two DC motors are used to rotate both side wheels. SMMD can move in a straight line whenever the switch is on. Therefore, it could help the elderly to reach the SMMD easier. Figure 5 shows the final prototype of the SMMD proposed.

2.2. Software

Arduino Integrated Development Environment (IDE) is used to program the NodeMCU and Android Studio which is used to develop the mobile app. C programming language is used to program the NodeMCU. Various libraries are used as follows, 1) NTP (Network Time Protocol) Client is used to provide the current time, 2) Firebase Arduino is used to connect the SMMD with Firebase database, 3) ESP8266 NodeMCU microcontroller is used to control the SMMD, 4) WifiUDP is used to configure the WiFi connectivity, 5) Adafruit GFX graphics library is used to configure the syntax of the content display on the Organic Light Emitting Diodes (OLED) display, 6) Adafruit SSD1306 is used to configure the OLED for display, 7) Wire is used to connect the SMMD with OLED, 8) SPI (Serial Peripheral Interface) is used to communicate with the microcontroller, 9) Time library is used to define the time format, 10) Stepper library is used to configure and control the stepper motor.

The specification of the components, WiFi ID and password and the firebase connectivity are configured in the C programming language. WiFiUDP will be initialized to ntpUDP (network time protocol User Datagram Protocol). NTP client will fetch the time client using the argument given from “pool.ntp.org” to display Malaysia’s time.

Figure 6 shows the loop function of the SMMD program. The instruction in this function will be repeated infinitely until the power supply is discarded from NodeMCU. Six different variables are declared and assigned to fetch six different integers. The first part will capture the data (Hour, Minute, and Status) from the real-time Firebase database and the data are stored in the NodeMCU.

An app is developed in Android Studio through the graphical approach. The graphical approach is a good option for beginners compared to the coding approach because it is easier and the result can be seen instantly. However, the graphical approach can only be used to create the layout or front end of the app. This includes buttons and switches which can be seen when opening the app. The back end of the app needs to be programmed by the developer. This includes the behavior of the said button and switches.

Two major components are developed with the android studio which are the time picker and switch. User can easily pick their time with this time picker shown in Figure 7. The Time picker enables the user to easily configure the time for SMMD to dispense the medication. It will send the data in the format of the hour and minutes to Firebase after the user picks the time. The other is an animated switch that enables the user to turn the SMMD system on or off. It is user friendly and easy to program. The app developed in the android studio is easily connected to the Firebase database with assistance from the android studio. Figure 8 shows the flowchart of the SMMD system proposed.

```
void loop() {
  //fetching data from firebase
  int Hour =Firebase.getInt("Data/Hour");
  int Minute =Firebase.getInt("Data/Minute");
  int Status =Firebase.getInt("Data/Status");

  int hour=timeClient.getHours();
  int minute=timeClient.getMinutes();
  int second=timeClient.getSeconds();
```

Fig. 6. Loop function

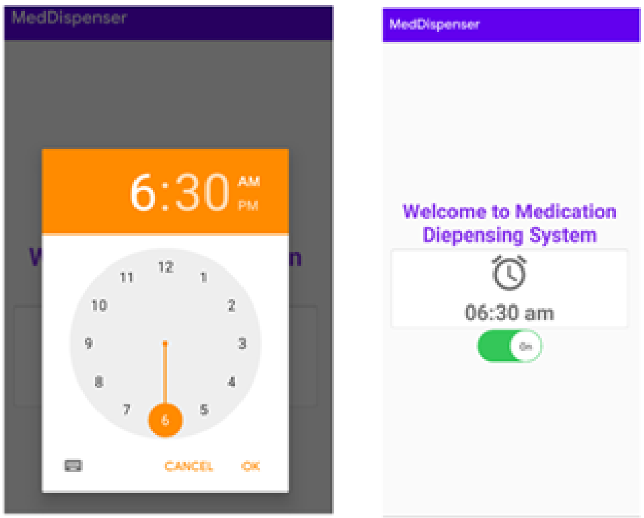

Fig. 7. The interface of the SMMD MedDispenser app

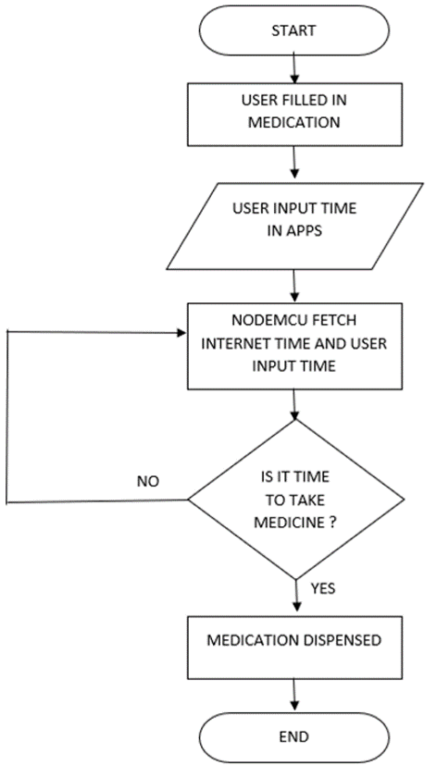

Fig. 8. The flow chart of the SMMD system

3. Results and Discussion

3.1. Peak Throughput

An extensive experimental test is carried out to evaluate the performance of the SMMD system. The Stepper motor is tested at a different speed and steps per revolution which results in the number of rotations and the time to complete the rotation in seconds. The data are tabulated in Table 1. As shown in Table 1, the SMMD works the best on 360 steps at 60 rpm (round per minute). The rotation speed is moderate and is suitable for SMMD to operate with minimum maintenance. One complete rotation of the stepper motor does not mean it moves from one slot to another. Since the gear has eight teeth and the rack has 64 spaces. Therefore, eight full rotations of the motor will completely rotate the dispenser. Since the dispenser has 20 slots and one empty slot, moving one slot to another would take approximately 1/3 of the rotation of the gear. One slot could accommodate two regular-sized pills or three small size pills.

Table 1. Rotation Speed Analyses of the SMMD

Steps per revolution	Speed (rpm)	Time to complete one rotation (s)	Time to dispense the medicine (s)
360	30	9	3
	60	6	2
	90	3	1
720	30	6	2
	60	3	1
	90	Not working	-
1080	30	3	1
	60	1	1/3
	90	Not working	-

3.2. Evaluation of the SMMD Meddispenser App

The SMMD MedDispenser app is evaluated from the user's perspective. The evaluation is based on the test function, aspect, and expected results of the execution task as shown in Table 2. The SMMD MedDispenser app is working as intended in the aspect of responsiveness, effectiveness, and animation.

Table 2. Evaluation of the SMMD MedDispenser App

Test function	Aspect	Expected Result	Result
Time picker	Responsiveness	Able to respond to user touch	Working
	Effectiveness	Able to pick all hours	Working
		Able to pick all minutes	Working
	Animation	Able to animate the process of picking	Working
Switch	Responsiveness	Able to respond to user touch	Working
	Effectiveness	Able to switch on and off	Working
	Animation	Able to animate the process of switching	Working

3.3. Figures and Tables

Firebase is used as a connector that connects the app and SMMD. It might create a delay in updating the time set by the user from the app when the network connection is slow. Many tests had been conducted to test the communication between the SMMD and the app. Table 3 shows a summary of the testing.

Table 3. Analysis of Firebase and Write Data

Aspect	Expected Result	Results
Hour	8	Working

Minute	30	Working
Status	On	Working

4. Conclusion

A low-cost SMMD is proposed for the elderly to dispense medication at the right time. It consists of two parts, i.e., hardware and software. NodeMCU is used to control the rotation of the stepper motor and OLED display. A mobile app is designed with the Android Studio that allows the user to set the time of the SMMD to dispense the medicine. NodeMCU gets the updated time to dispense the medicine from the app through the Firebase database. A low-cost SMMD prototype is developed with a total cost of USD 50. The price is affordable for the elderly from the lower-income group.

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Author contributions

Wai Leong Pang: Conceptualization, Methodology, Software, Writing-Reviewing and Editing **Kah Yoong Chan:** Data curation, Writing-Original draft preparation **Gwo Chin Chung:** Software, Validation **It Ee Lee:** Visualization, Writing-Reviewing and Editing **Haziq Muqri:** Field study, Visualization, Investigation

Conflicts of interest

The authors declare no conflicts of interest.

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