Progress in Engineering Application and Technology Vol. 3 No. 1 (2022) 559-570

PEAT

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 2773-5303

Smart Medication Adherence System using IoT for Elderly Patient

Fahmi Sharmila Mat Nasir[1], **Omar Abu Hassan**[1]*, **Muhammad Rusydi Muhammad Razif**[1]

[1]Department of Electrical Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/peat.2022.03.01.056
Received 17 January 2022; Accepted 11 April 2022; Available online 25 June 2022

Abstract: The availability of electronic monitoring has developed a huge possibility in increasing elders' adherence towards medication. With the help of IoT platform, the system can be connected to the medical practitioner, care giver, and even the patients' mobile devices. The medication adherence monitoring system consists of electronic components such as sensors that can validate patients' medication intake and sent the data collected to those in charge of taking care of the patients. The Smart Medication Adherence system using IoT for elderly patient is seeking an improvement towards the classic way of taking medicine among elderly patient who lives away from their caregiver. With the help from IoT (Internet of Things), caregiver can monitor their patients' medication intake without having to be with them all the time. This project presents an IoT-based medication monitoring and reminder system that allow communication with the caregiver through phone call using a platform called IFTTT. In order to validate patient's consumption, magnetic switch sensor that were attached to the pillbox will detect whether patient open or close the pill-box cap. In addition, the Force Sensitive Resistor (FSR) sensor were used to detect the differences in force or pressure of the pills during consumption. The system is programmable that enables the caregiver or patients to determine the schedule of their prescription. Using NodeMcu, this device will be connected to Wi-Fi and enable the transmission of information to the IoT platform.

Keywords: IFTTT, IoT, Force Sensitive Resistor (FSR), NodeMcu

1. Introduction of IoT Monitoring System

The number of elderly people living alone appears to rise as they get older. Their mental and physical health may deteriorate over time without the presence of any family members. The elderly who lives alone have significantly worse physical and emotional health than those who live with family members. To improve medication adherence among the elderly, it is important to recognize the related

*Corresponding author: omar@uthm.edu.my

factors. Although pharmacologic therapy is one of the most important components in treating chronic diseases, about 50.00 % of chronic disease patients do not take their medication as prescribed [1].

Monitoring patients' medication intake is divided into two methods: physical monitoring and electronic monitoring. Physical monitoring includes self-report by the patients themselves, pill counts, and pharmacy records. Meanwhile, for electronic monitoring, devices are used to provide information on daily adherence, such as dosing patterns, and send the collected data to inform the medical practitioner [2]. The challenge of electronic monitoring is getting an accurate measurement to indicate patients' adherence. The methods of measurement are varied according to the components used in the electronic devices, such as the type of sensors, actuators, and microcontrollers. ScanAlert is a project developed by Sanchez V. et al. in 2019 to approach patients' medication adherence through an electronic medication monitor [3]. This system requires users to scan an RFID tag that is attached underneath the cap of the appropriate pill bottle to validate consumption whenever the buzzer is activated at the scheduled time. If the users do not comply within the one-hour window, an e-mail will be sent to the caretaker, physician, or a physician database that records nonadherence rates. However, short notifications such as e-mail or SMS are not enough to attract the attention of caregivers to notice that the patients do not take medications as prescribed.

As in medical field, IoT has played a big role in patient monitoring and management systems. Early detection of emergency cases such as heart attacks can be done through the alert mechanism that can be developed using IoT [4]. This paper aims to implement IoT to assist in the monitoring of the patient's adherence at a distance. Data collected from the sensor will trigger an alarm system to notify the care giver. The IoT platform is integrated with a service which is the VoIP as it enables the components such as NodeMCU to interact with the mobile application IFTTT through a phone call service.

2. Device Construction and Methodology

A block diagram is used to represent the layout and the structure of the system that involved. The design of the project will be described. Figure 1 illustrates the block diagram for the project.

This system can be divided into several parts, which are the validation system and the alerting system. The validation system consists of two sensors, which are magnetic switch sensor and force sensitive resistor. The RTC module is used as TIME and DATE remembering system to track medication time. The force sensitive resistor (FSR) sensor will be connected to the analog pin on the NodeMCU while the magnetic switch sensor will be connected to the digital pin. The alerting system consists of indicators such as buzzer and LED to alert the patient whenever the scheduled time arrives. There are two ways of communication between the NodeMCU and the alert function, including the phone call feature that will be executed using the VoIP service through the IFTTT application.

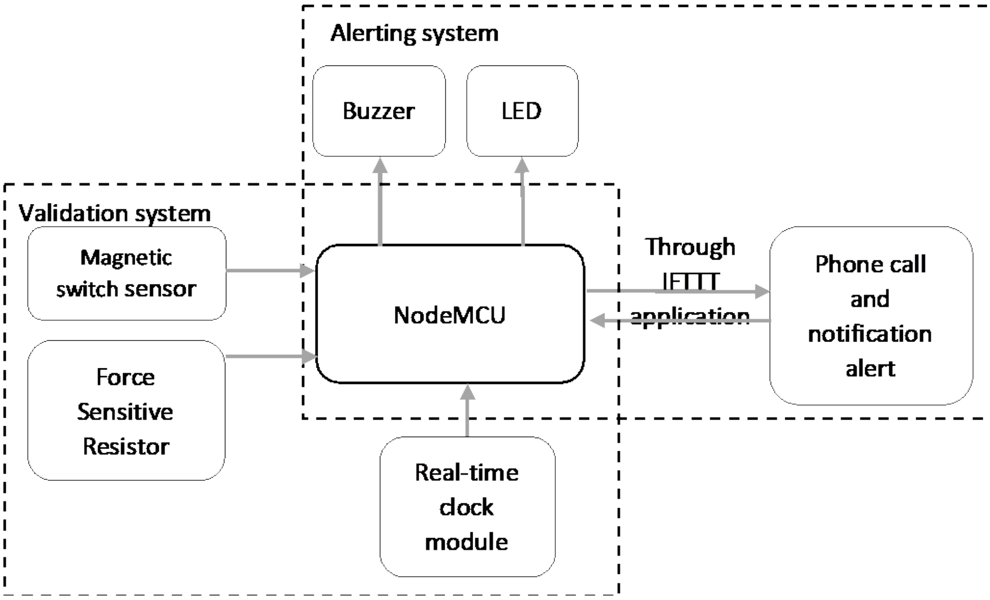

Figure 1: The block diagram of the project

2.1 System Operation Flowchart

- Medication timing:

The flowchart of the system of this project starts off by reading the input details of medications including the medication timing to be compared to the input time of medication. When medication time arrived, indicators including the LED and buzzer will be activated to alert the patient. The flow chart in Figure 2 shows the operation for medication timing.

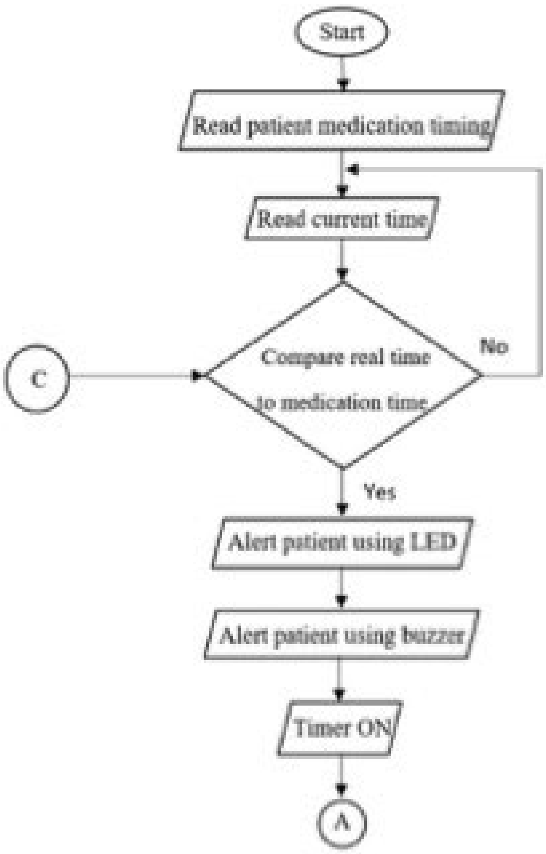

Figure 2: Flow chart for Medication Timing

- Adherence verification and alarm function:

To avoid declaring false statements about patients' adherence, a timer that has been set to 60 minutes will turn on when the patient is required to take their medication during that given period. During the 60-minute period, the magnetic switch sensor starts reading values to detect whether the patient has opened the pillbox cap. The buzzer and LED will turn off only when the reading of the magnetic switch sensor is high. The flow chart in Figure 3 shows the operations for adherence verification and alarm function.

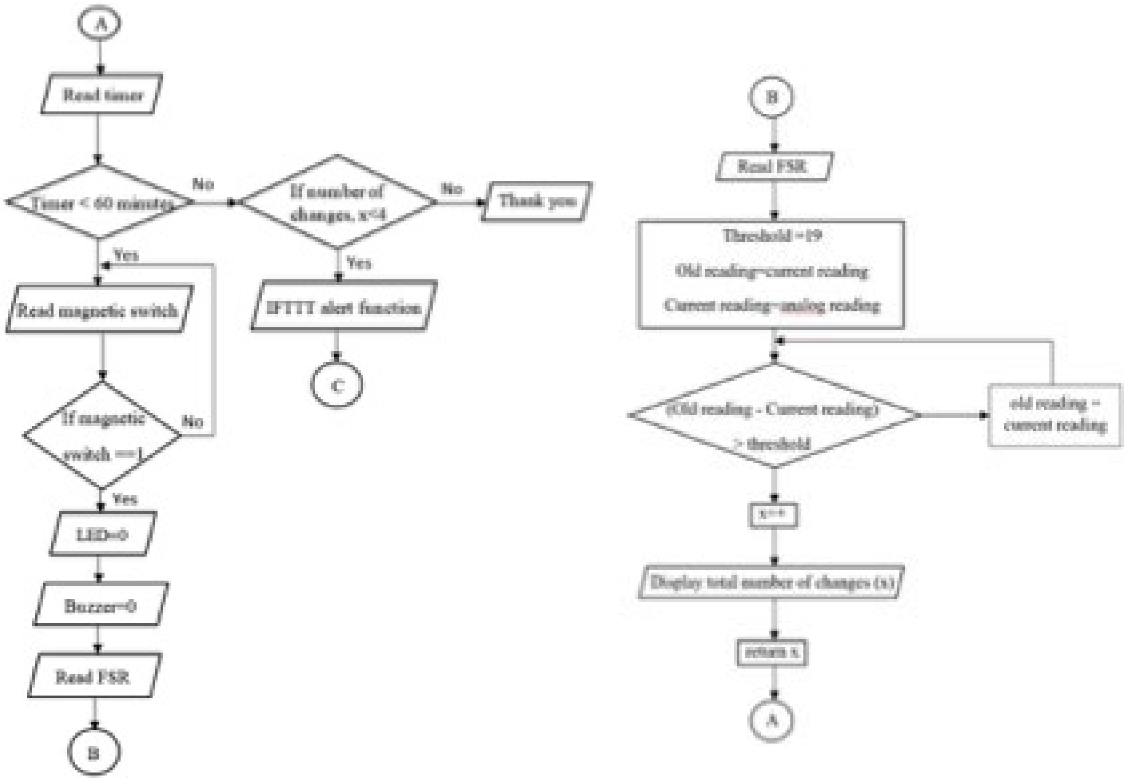

Figure 3: Flow chart for Adherence verification and alarm function

2.2 Hardware Development

This system uses two sensors and NodeMCU as the control system. LED and Piezo Buzzer acts as alerting function on the prototype meanwhile the 10 K pull-down resistor is connected to the FSR sensor. The RTC Module come with coin cell battery meaning it can be used without external power supply. Table 1 shows the list of the component for the prototype.

Table 1: List of components

Item	Parameter Name	Description
1	NodeMCU	ESP12E
2	RTC Module	DS1302
3	Magnetic Switch Sensor	MC-38
4	FSR Sensor	FSR-402
5	Resistor	10k Ω
6	LED	10mm, White
7	Piezo Buzzer	Operating voltage: 5V DC

2.2.1 Circuit Diagram

The magnetic switch is the first component that detects interaction between the patient and the system. The data will be sent to NodeMCU, which serves as the main microcontroller in the system that will be connected to the power supply. The reading from the real-time clock (RTC) module DS1302 will be compared to the input time of medication. When the inserted time is equal to the reading on the RTC, indicators, including the LED and buzzer, will be activated to alert the patient. Figure 4 illustrates the circuit diagram of the project.

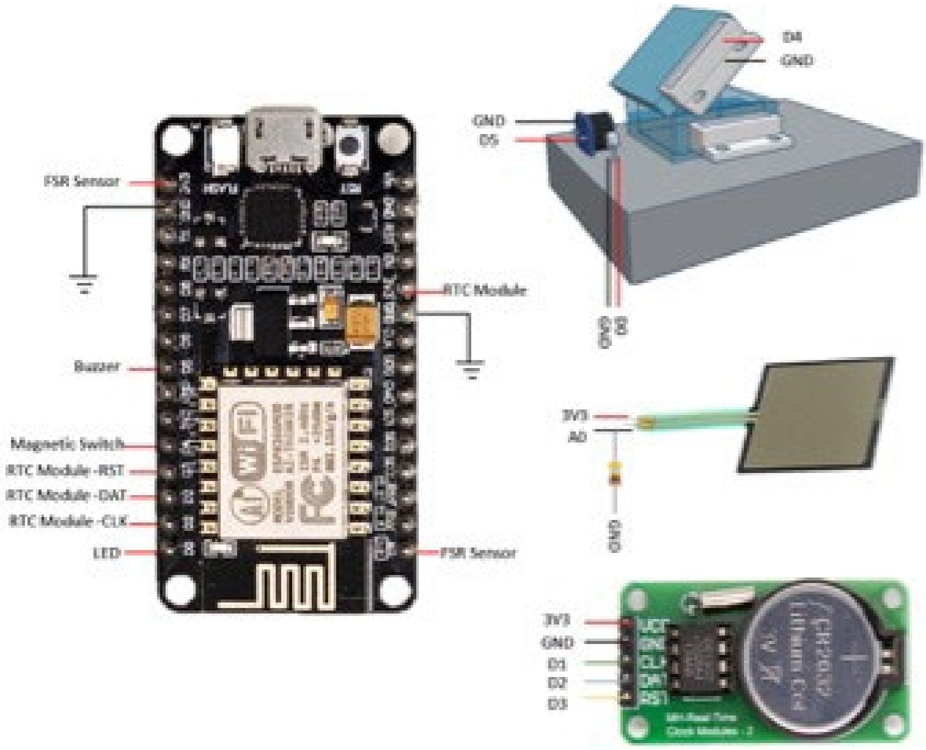

Figure 4: The illustration circuit of the project

Next, the FSR sensor is connected to the analog pin of the NodeMCU to convert the analog reading into a digital output that indicate whether patients follow their prescription. One end of the FSR pin is connected to 3.3 V power of the NodeMCU and the other pin is connected to a 10 K ohm pull-down resistor to the ground. Mathematical equations were used in the coding to obtain the value of resistance and voltage across the FSR sensor. The NodeMCU has an inbuild voltage regulator which keep the voltage level at 3.3 V. Therefore, for the Eq. 1 below, the input voltage for the FSR sensor is 3.3 V while the value for resistor is 10k Ohm.

$$FSR\ Voltage = V_{in}\left(\frac{R}{R + FSR\ reading}\right) \qquad Eq. 1$$

2.3 Software Development

The software development is required to be a part of monitoring and collecting data for this project. The software used to construct the programming code for the microcontroller is the Arduino IDE software. Proteus was used to design the circuit and simulate the project. For the alarm system, the IFTTT application is used to make a phone call to the caregiver to inform them about the patient's non-adherence.

By downloading the IFTTT mobile application available for Android and Apple's iOS, creators can make their own small applications or so-called programmes that connect two devices, applications, or services that are called *applets* [6]. Webhooks under IFTTT are a service that enables applications to communicate with each other to share data and information. In the mobile application, Webhooks act as the trigger that turns on every time a web request is received, indicating that a specified event has occurred [7]. This service can be used as an alert system by programming notifications or messages as the actions after the web request is received [7]. In this project, the VoIP calls applet service is triggered to make a phone call on the user's mobile phone when the Webhooks received a web request from NodeMcu. Figure 5 shows the logo of the IFTTT application.

Figure 5: IFTTT logo [5]

3. Functionality Testing and Result Analysis

The prototype was tested in a situation where the patient took their medication on time. Figure 6 shows that at 8 a.m., the LED and buzzer will be activated until the patient opens the pillbox. Figure 7 shows the LED and buzzer are OFF after the pillbox is opened. At this time, the FSR will start reading the force applied to the sensing area.

Figure 6: LED and buzzer at 8 a.m.

If the patient opens the pillbox and applies pressure while taking the pills, the LED will light up every time a change of force is detected. By having the LED as an indication, this might help the patient to confirm their medication intake. This is more practical for the system compared to using a button to indicate a patient's intake, as some patients might forget to push on the button whenever they take the pills. If no pressure is applied to the sensor, the system will consider the patient has not taken their medication and the alarm function will be activated.

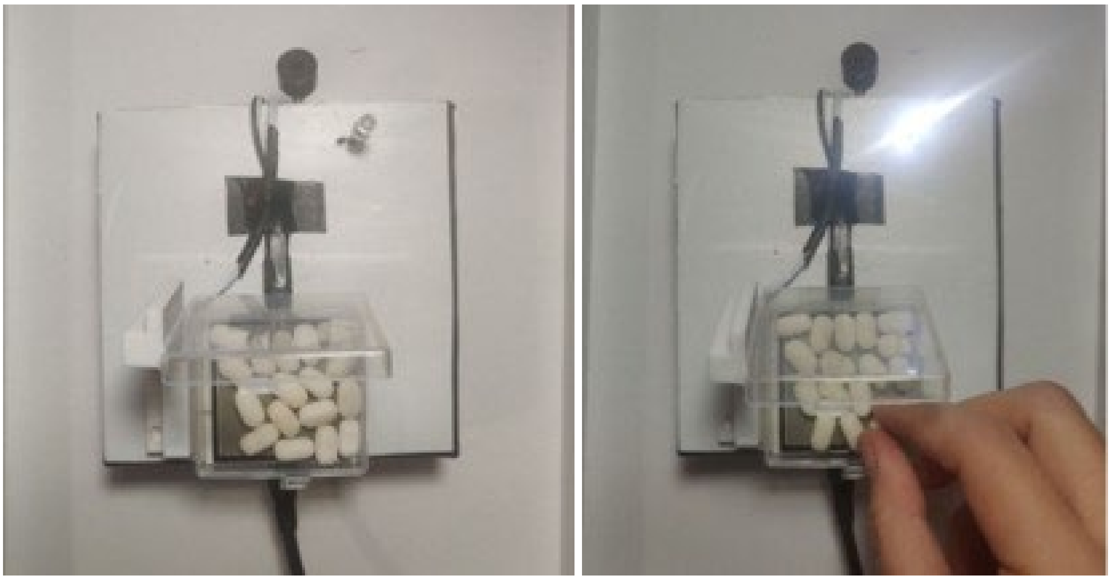

Figure 7: LED and buzzer on different condition

In the second situation, the patient did not open the pillbox in the duration of one hour after the medication time started, which is from 8 a.m. until 8.59 a.m. In this case, the LED and buzzer will keep on activating. Then, after the one-hour duration has ended, the system will terminate the alarm function. Figure 8 shows the serial monitor terminating the alarm function.

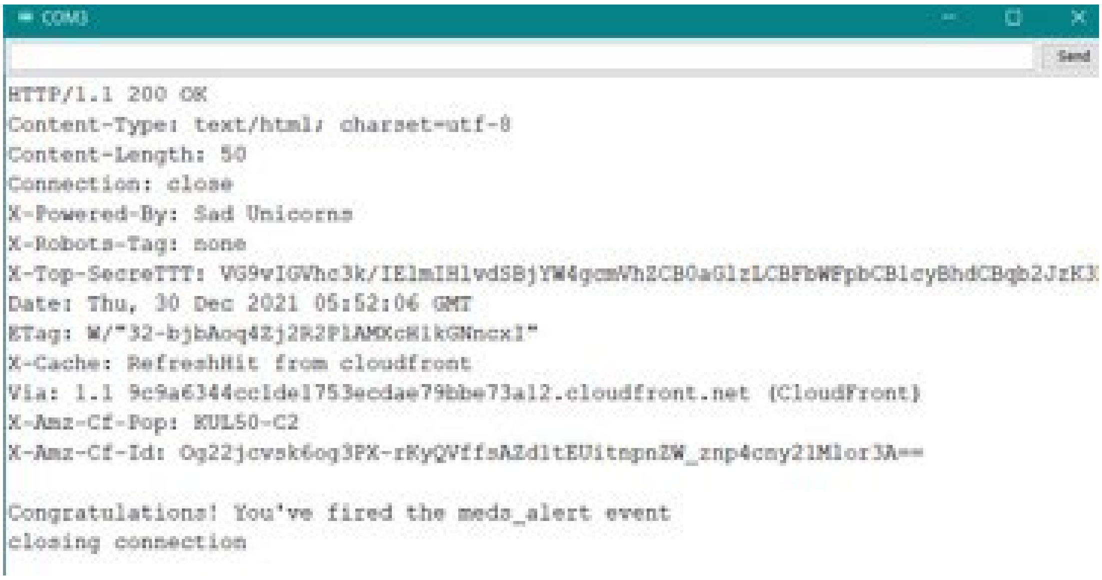

Figure 8: Serial monitor shows alarm function is terminated

3.1 Sensor Characteristic Reading of the System

When the magnetic switch is closed and the FSR sensor reading is below the threshold, the IFTTT alarm will be fired. The same result will happen when the magnetic switch is open and the FSR reading is still below the threshold. If the FSR sensor reading is above the threshold but the magnetic switch is closed, the system will not trigger the IFTTT alarm. The system will not activate the alarm function if both the magnetic switch and the FSR sensor readings are HIGH.

For the LED, it is set to HIGH if the magnetic switch has not been opened during the medication time. Besides, it will also blink whenever the FSR sensor detects any changes in forces. The buzzer will be HIGH when the medication arrives, then set to LOW after the magnetic switch is open. Figure 9 shows the sensor characteristic reading of the system.

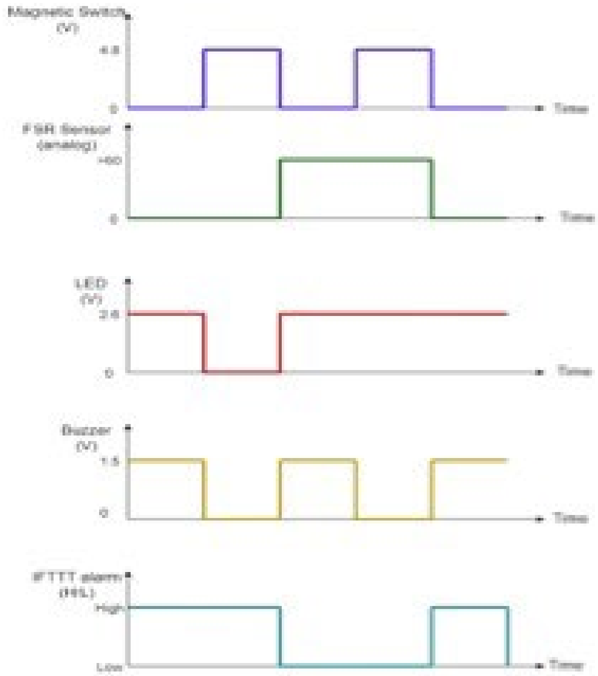

Figure 9: Sensor Characteristic Reading of the System

3.2 FSR Sensor readings

The FSR sensor is tested when the pill box is empty, and the force is only applied using the fingertip. This test was conducted three times to analyze the pattern of the analog reading. Figure 10 below shows the analog reading of FSR Sensor when pressure is applied slowly increases over time. The results show that the analog reading starts at a constant value, gradually increases, then decreases until the reading stays constant again when no force is detected. After testing, it has been found that the maximum analog reading for the FSR sensor is 956, while the minimum reading is 30, which were both recorded during Test 1. The marker labelled t1, t2, and t3 shows where the forces are no longer applied on the three tests.

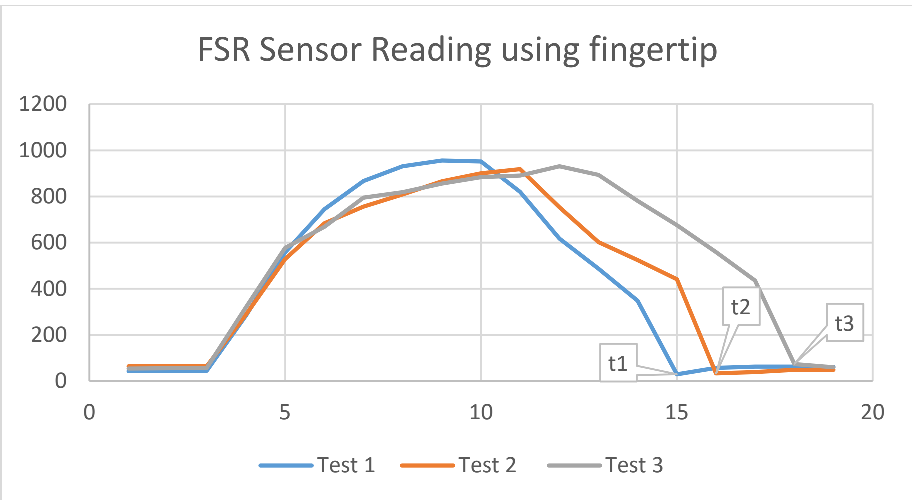

Figure 10: Graph of FSR sensor analog reading using fingertip

Figure 11 shows the result when the pillbox is filled with pills and forces are applied. This test was also conducted three times. Compared to the graph where the pillbox is empty, the graph below shows higher analog readings. Without any force applied at the beginning, the FSR sensor already reads the pressure coming from the pills. The initial readings start at around 100 meanwhile for Figure 10, the average for the initial reading is 54. The results show fluctuations occur during the time where forces are applied to the pills. For all the tests, the reading dropped after no pressure was applied to the FSR sensor.

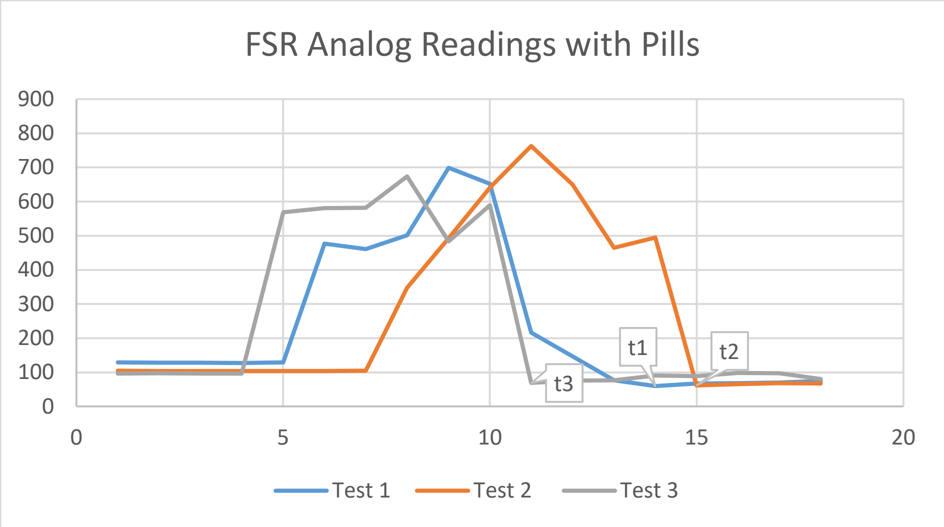

Figure 11: Graph of FSR sensor analog reading with pills

As shown in the graph in Figure 12, as force is applied to the FSR sensor, the resistance and voltage value inverse with each other. As maximum force was applied to the sensor, the resistance across the circuit reaches minimum value of -9 ohm as shown in Table 2. Meanwhile, the voltage reaches a maximum reading of 3.3 V because the output voltage from the NodeMCU pin connected to the FSR circuit is 3.3 V.

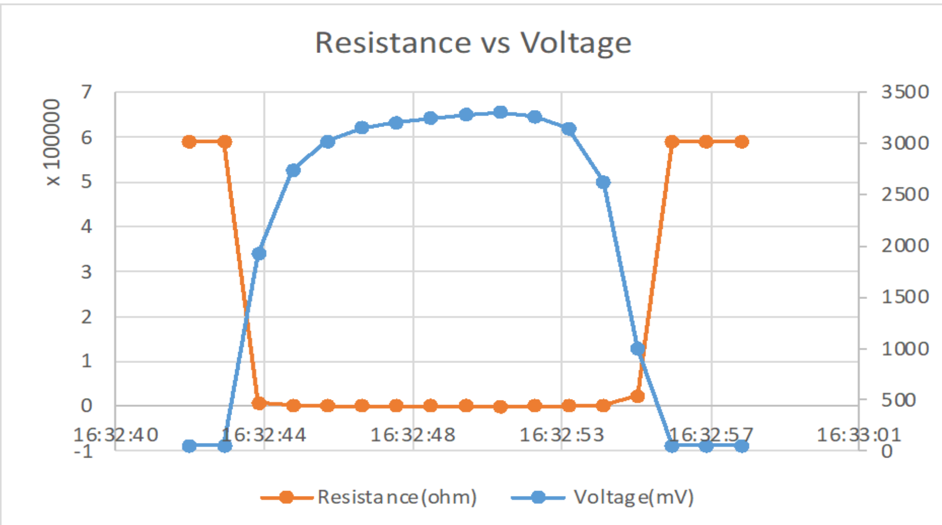

Figure 12: Graph of resistance and voltage

Table 2 below shows the distribution of three different parameters which is analog reading, voltage and resistance.

Table 2: FSR Sensor readings

Time	Analog	Voltage(mV)	Resistance(Ω)
16:32:43	67	216	142777
16:32:44	597	1926	7133
16:32:45	850	2742	2035
16:32:46	936	3019	930
16:32:47	977	3152	469
16:32:48	994	3206	293
16:32:49	1005	3242	178
16:32:50	1017	3281	57
16:32:51	1024	3303	-9
16:32:52	1011	3261	119
16:32:53	975	3145	492
16:32:54	813	2623	2581
16:32:55	308	994	23199
16:32:56	99	319	93448

3.3 IFTTT Application result

The phone call and notification in the IFTTT application will be executed in two situations where the patient did not open the pillbox and when the FSR sensor did not detect any force applied to the pillbox. The figure below shows the incoming phone call on the caregiver's smartphone to notify them of the situation. When the caregiver answers the phone call, a voice message that says "Alert! Patients did not take medicine on time!" was activated as shown in Figure 13.

Figure 13: A phone call received when patient did not take medication

Within a few seconds after the phone call, the system also sent a notification to the caregiver's smartphone about the situation in case the caregiver missed the phone call. The notification is shown in Figure 14. Besides the caretaker, this application can also be used by the patient itself where patients who uses smartphones can also install the application. However, it is better to have a caretaker who can monitor the patient's adherence through the application.

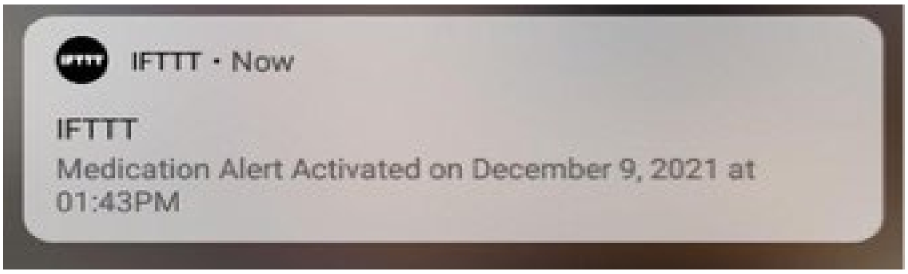

Figure 14: Notification from IFTTT

4. Conclusion

In conclusion, the Smart Medication Adherence System Using IoT for Elderly Patient project has been successfully developed. This project was developed by using a magnetic switch sensor and an FSR sensor as the main components to verify a patient's medication adherence. Other components involved help to make the project more practical for its users.

During this era, it is common to see many elderly people who live away from their children, struggling to be independent while living alone in their houses. With the help of this system, the care giver does not have to worry about the elderly's medication intake as the components that were used in this project are reliable for its functions.

The implementation of VoIP service in the IoT platform helps to introduce new types of alarming systems that were usually used in the development of monitoring systems. It also helps to improve the quality of caregiving for elderly patients.

Acknowledgement

The authors would like to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] H. Park, S. Seo, H. Yoo, K. L.-P. preference and, and undefined 2018, "Medication adherence and beliefs about medication in elderly patients living alone with chronic diseases," *ncbi.nlm.nih.gov*, Accessed: Jun. 09, 2021. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5790098/

[2] S. Sutton *et al.*, "Does Electronic Monitoring Influence Adherence to Medication? Randomized Controlled Trial of Measurement Reactivity," *Annals of Behavioral Medicine*, vol. 48, no. 3, pp. 293–299, Dec. 2014, doi: 10.1007/s12160-014-9595-x.

[3] V. Sanchez *et al.*, "ScanAlert: Electronic medication monitor and reminder to improve medical adherence," in *2019 IEEE 9th Annual Computing and Communication Workshop and Conference, CCWC 2019*, Mar. 2019, pp. 537–543. doi: 10.1109/CCWC.2019.8666581.

[4] Y. Liu, B. Dong, B. Guo, J. Yang, and W. Peng, "Combination of Cloud Computing and Internet of Things (IOT) in Medical Monitoring Systems," *International Journal of Hybrid Information Technology*, vol. 8, no. 12, pp. 367–376, 2015, doi: 10.14257/ijhit.2015.8.12.28.

[5] "Ifttt Your Free Personal Assistant - Ifttt Logo Transparent Transparent PNG - 1080x500 - Free Download on NicePNG." https://www.nicepng.com/ourpic/u2e6q8i1o0t4w7o0_ifttt-your-free-personal-assistant-ifttt-logo-transparent/ (accessed Jun. 13, 2021).

[6] "What is IFTTT? How to use If This, Then That services | Computerworld." https://www.computerworld.com/article/3239304/what-is-ifttt-how-to-use-if-this-then-that-services.html (accessed Jun. 13, 2021).

[7] "Linking IFTTT & Processing with Webhooks | by Violet Whitney | Measuring the Great Indoors | Medium." https://medium.com/measuring-the-great-indoors/linking-ifttt-processing-with-webhooks-6b20c6ed722d (accessed Jun. 13, 2021).