Research Article

World Journal of Sensors Network Research

Development of an Automatic Pill Dispensing and Health Vitals Measuring System for Hypertensive Patients

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Submitted: 25 November 2024 **Accepted:** 02 December 2024 **Published:** 09 January 2025

Citation: *Ismail, N., Anafi, F. O., & Sabur, A., A. (2025). Development of an automatic pill dispensing and health vitals measuring system for hypertensive patients. Wor Jour of Sens Net Res, 2(1), 01-09.*

Abstract

Medication non-adherence is a significant issue for patients who require regular medication, especially those with complex schedules or multiple daily doses. This problem is particularly severe in hospitals where doctors are scarce, and monitoring hypertensive patients can be challenging. To address this problem, a proposed system has been developed that integrates automatic pill dispensers and health monitoring systems to help patients manage their condition effectively and reduce the need for constant doctor checkups. The system uses an ESP32 microcontroller and MYSQL database for data storage. DC and servo motors are utilized for dispense medication mechanism, and the real-time clock ensures that it only dispensing when required. The health monitoring system can measure temperature and blood pressure and has shown promising results when compared to other devices. The system has been tested with ten different people, and the overall reading error is within the acceptable range, with blood pressure reading error of < 10mmHg and temperature of <3.2°C indicating that it is an effective tool for managing medication adherence and monitoring health vitals. The system was able to transmit all the measured data, and the web can display the recorded data correctly.

Keywords: ESP32 Microcontroller, DC Motor, Health Vitals, HTML, MCU, MYSQL, PHP

Introduction

Hypertension is the most common chronic health condition, affecting 1.4 billion (31%) adults globally [1]. With long-term manifestations including cardiovascular, cerebrovascular and chronic kidney disease and stroke, hypertension has been identified by WHO (World Health Organization) as a leading risk factor for morbidity and mortality, responsible for the death of one in six adults annually [2]. Despite the availability of effective antihypertensive medications and lifestyle interventions, hypertension remains poorly controlled in many patients. One of the primary reasons for this is the lack of continuous monitoring and medication management. Despite significant evidence demonstrating the benefits of antihypertensive treatment, hypertension remains underdiagnosed and undertreated, with an estimated 11 million hypertensive adults unaware of their disease and, of those aware, half surpassing guideline-recommended blood pressure targets [3].

In recent years, there has been an increasing demand for innovative healthcare technologies that can help improve the quality of life for patients [4]. It significantly impacted various aspects of healthcare, and the integration of health monitoring and medication management systems holds tremendous potential to improve patient outcomes and enhance healthcare management. This system has the potential to revolutionize the way patients manage their medication by automating the dispensing process and providing real-time monitoring of their health vitals [5].

Managing multiple medications can be particularly challenging, especially when patients are taking several different drugs that need to be taken at different times of the day. In addition, coordinating medication refills to ensure that patients never run out of their prescribed medications can be time-consuming and requires careful planning. Proper medication management is crucial for hypertensive patients, and caregivers play a vital role in ensuring that patients receive their prescribed medications as directed. To achieve this, caregivers must not only administer medications on time but also oversee a range of other tasks, including coordinating refills, managing side effects, and adjusting medication dosages as needed [6].

The responsibilities of caregivers can often be overwhelming, leaving them with limited time and resources to adequately monitor patients who have been admitted to hospital. This can be particularly challenging for patients requiring intensive and frequent check-ups, as inadequate monitoring can lead to serious health complications.

The advancement of technology has the potential to transform medication ma0nagement and enhance health outcomes for patients with hypertension. This innovation could aid in reducing medication errors, enhancing medication adherence, and providing monitoring of a patient's health parameters. It can be particularly advantageous for patients with chronic diseases such as hypertension, elderly patients, and disabled patients, who require long-term medication management and monitoring. It can also diminish the workload of healthcare professionals, enabling them to concentrate on providing more personalized care to their patients. The proposed system tends to develop an automatic pill dispenser that stores and dispense antihypertensive and related medications integrating it with health vitals measuring system capable of measuring patient's blood pressure, temperature and heart rate. Also, the proposed system proposed a web application that caregivers will use to access the patient's information and schedule medication to patients.

Existing work

Have developed a system that uses a line-following robot and obstacle avoidance to deliver medication to patients in their respective hospital rooms. To ensure only authorized patients receive their medication, the patient is required to scan their finger for authentication. Additionally, the system notifies the caregiver via text message if the patient has taken or has not taken their medication. The system was built using an Arduino Mega and a GSM module [7, 8]. Developed a smart healthcare and monitoring system that uses Arduino and ESP8266 microcontrollers to improve the medication process. The system comes with an Android app which connects to the system via Wi-Fi, allowing users to schedule medication dispense time and view their previous medication history. The system can automatically sort and dispense medication according to the pre-set schedule. Have designed a portable pill dispenser that can hold up to 7 different medications. The dispenser is scheduled to release the medication at the appropriate times [9]. The system is built using NodeMCU, which is connected to the internet to send data to the Firebase database that records the patient's intake status as either taken or missed. To configure the device and view the saved records online, an Android app was developed that allows the user to connect to the device. Developed a patient monitoring system that uses the Internet of Things to measure a patient's body temperature and heart rate [10]. The system was created using Arduino Uno and ESP8266 microcontrollers to process the raw data from the sensors and convert it into user-readable values. The ESP8266 was utilized to connect the system to the internet, enabling data transfer from the system to cloud storage. Users can access the readings on the ThingSpeak platform over the internet. Developed a health monitoring system for patients using IoT [11].

The system uses a NodeMCU and MCP3008 microcontroller to measure the patient's pulse rate, body temperature, and ECG using sensors. Since it is difficult to monitor patients round the clock, the system uses the ThingSpeak cloud platform to receive the collected data and save it. Caregivers can access this data throughout the day, enabling them to keep track of the patient's condition.

Theoretical Analysis

Designing an automatic pill dispensing and vital measuring system for hypertensive patients is a complex task that requires careful component selection. The dispensing mechanism includes a medication compartment operated by a DC and servo motor, a good microcontroller with better processing power and memory is required which process and control each and every component in the system.

The equations and theories adopted in this study are given on the table 1 below:

Table 1: Parts calculations

SN	Item	Equation	Parameters
1	Compartment	$v = \pi r^2 h$	h = 4.5 cm, r = 3.15cm, v = 140 cm^3
2	Pill	$v = w * h * b$	h = 2.5cm, b = 1.2cm, w = 1.0 cm volume = 3.0 cm^3
3	DC motor torque	$\tau = F * r$	τ = 0.023Nm, F = 7.848N, r = 0.029m
4	DC motor power	$P = \tau \, x \, \omega$	P = 0.23 watt, τ = 0.023Nm, ω = 10 rpm
5	Power consumption	Power = V * I	v = 5.0 V, I = 1,882.505mA, P = 16,328.5025mW
6	Battery rating	$Time\ in\ hours = \frac{battery\ rating\ (Ah)}{total\ current\ drawn\ by\ the\ system\ (Amp}$	T = 3 hrs., battery rating (Ah) = 5,565mAh

The blood pressure monitor was developed using a non-inversive method as shown in the figure below

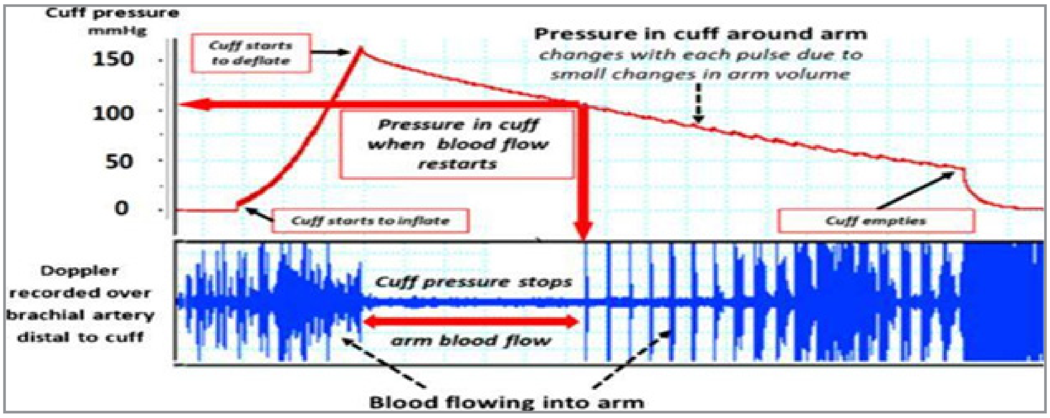

Figure 1: The relationship between the pressure in an automated machine cuff and the flow of blood into the underlying arm [12].

Materials and Methods

Designing an automatic pill dispensing and health vital measuring system for hypertensive patients is a complex process that requires the integration of both software and hardware components. These components include microcontrollers, sensors, actuators, and display units, among others. For the software part, it involves developing web-based applications and firmware source code for the microcontroller.

Body Temperature Sensor

The DS18B20 is a highly reliable temperature sensor that can precisely measure human body temperature within the range of -55°C to +125°C with an accuracy of ±5°C. It can be placed on various parts of the body such as the forehead, under the arms, and even under the tongue as it is waterproof. This temperature sensor has three wires, namely VCC, GND, and DATA, all connected to a single wire. It is connected to the Nodemcu and since every DS18B20 has a unique silicon serial number, multiple DS18B20s can be connected to the same wire. This sensor is ideal for use in thermostat control systems, industries for temperature measurement, and as a thermometer.

Figure 2: Temperature sensor

Microcontroller

The ESP32 microcontroller is a popular and versatile microcontroller module developed by Espressif Systems. It is based on the Xtensa LX6 dual-core processor architecture and is designed specifically for IoT (Internet of Things) applications [13]. The ESP32 offers a wide range of features and capabilities, making it a popular choice for various projects [14]. The ESP32 microcontroller is widely used in IoT projects, home automation, wearable devices, robotics, industrial applications, and many other domains. Its combination of processing power, wireless connectivity, and rich set of peripherals makes it a versatile platform for developing a wide range of applications [15].

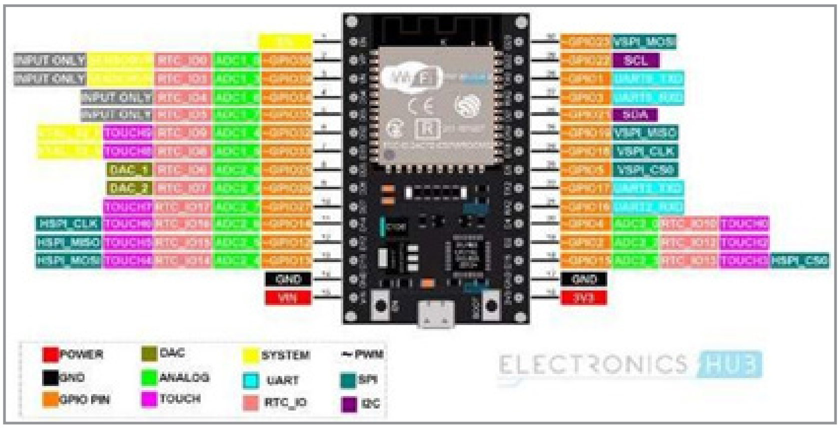

Figure 3: ESP32 microcontroller

Pressure Sensor

A pressure sensor, also known as a pressure transducer or pressure transmitter, is a device used to measure the pressure of gases or liquids. It converts the applied pressure into an electrical signal that can be measured and analyzed [16].

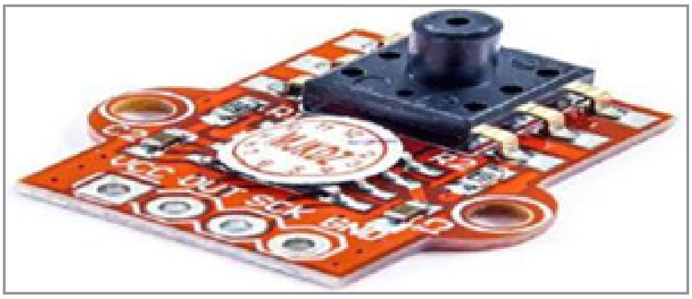

Figure 4: Pressure sensor

Stepper motor

A stepper motor is a type of electric motor that converts digital pulses into precise mechanical movements. It is designed to move in discrete steps or increments, hence the name "stepper" motor. Stepper motors are commonly used in various applications that require precise position control, such as robotics, 3D printers, CNC machines, disk drives, and more [17].

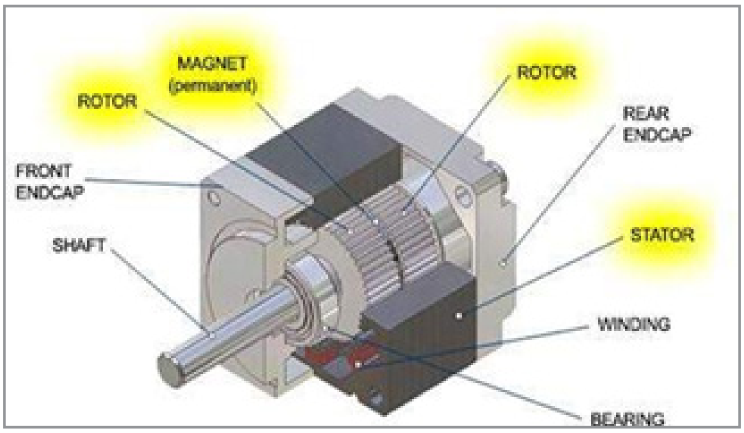

Figure 5: Stepper Motor

Methodology

The system development methodology refers to the structured approach used to design, develop, test, and deploy the automatic pill dispensing and health vitals measuring system for hypertensive patients [18, 19]. The development of the system would have the following steps as described in Fig 6 below.

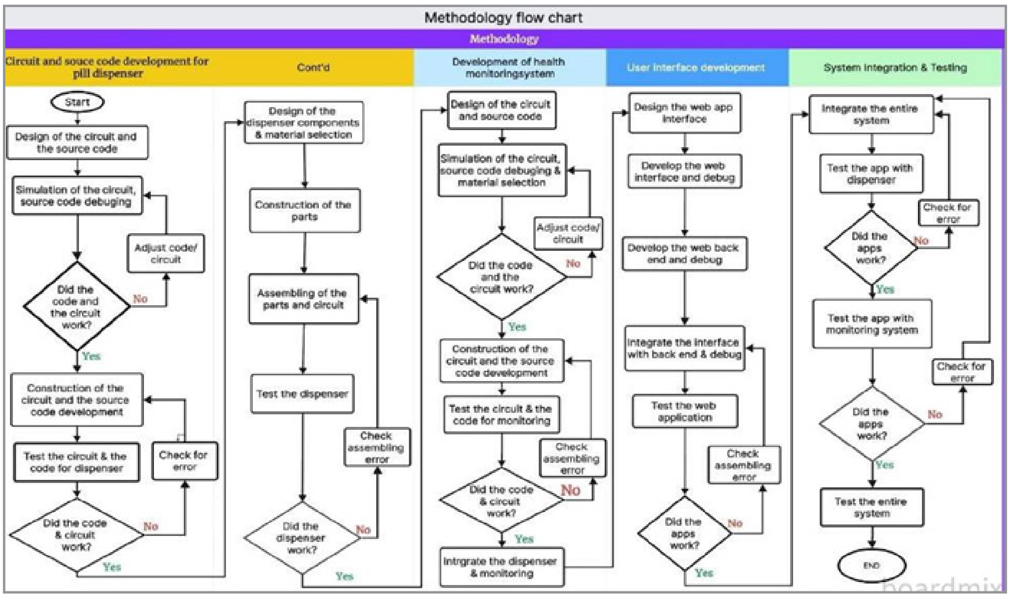

Figure 6: System development methodology flowchart

The system development process followed the steps outlined in Fig 6. An online tool was used to create the circuit design and source code, which the code was simulated and debugged to check and fix any errors. The system uses a web application as user interface for the doctors to interact with system. The web application allows them to prescribe medications to patients, view their vitals readings and lot more. The application was developed using HTML (Hypertext Markup Language) and PHP (Hypertext Preprocessor) was used as the back-end script. After that, construction of the circuit and assembling the necessary components were done. The design of the pill dispenser was carefully done and materials with best optimal performance were selected. The parts were assembled and enclosed them in a plastic case to protect the mechanism. The final construction is shown in Fig 7 below.

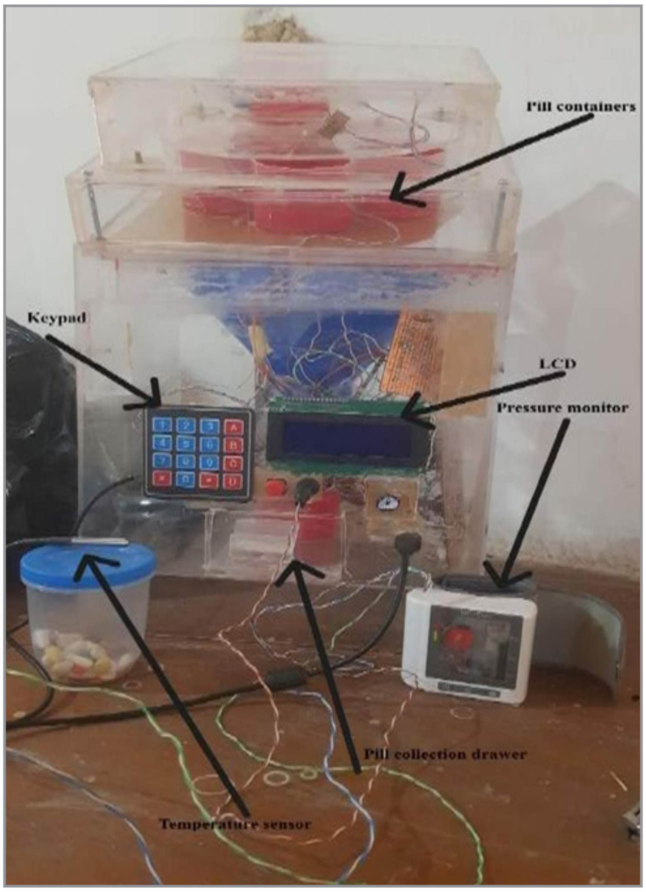

Figure 7: Developed System

Results and Discussion

The developed system went through several and intensive test to ensure reliability on the system which reveal a good positive result. Below are different tests result carried out on each part of the system.

Web Application Test

In order to access the dashboard of the web application, the user must input their login credentials to check if they are a registered user or not. Authenticated users can access patient data through the web application, which also enables doctors to prescribe medication and view vitals. See the figures below for the web app pages.

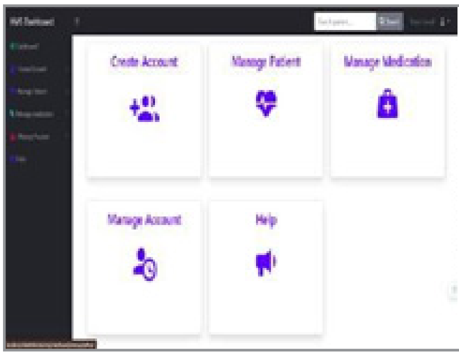

Figure 8: Dashboard

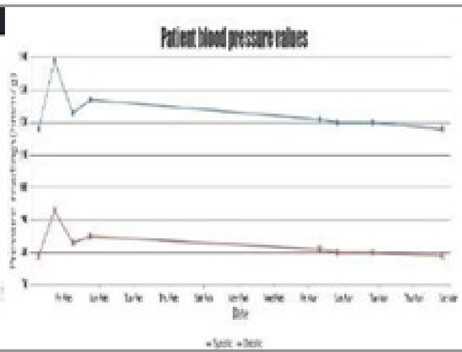

Figure 9: Blood pressure readings

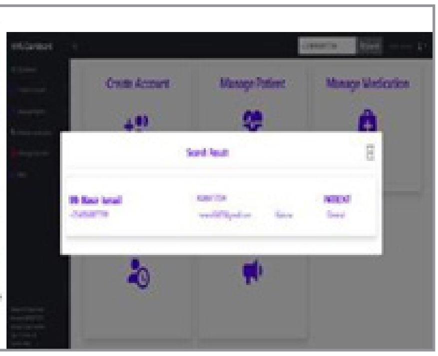

Figure 10: patients search result

Health Vital Measuring Test

The health vitals measuring system consists of a blood pressure and temperature monitor. The blood pressure monitors measure patient's blood pressure and send the reading direct to his account on database. Fig 11 shows the image captured during measurement.

Figure 11: Pressure readings

Table 2: Blood pressure readings between developed and Motech blood pressure monitoring device.

SN	Systolic pressure		Error (mmHg)	% Error	Diastolic pressure		Error (mmHg)	% Error
	Measured value (mmHg)	Actual value (mmHg)			Measured value (mmHg)	Actual value (mmHg)		
1	129	121	8	6.20%	86	79	7	8.14%
2	121	125	4	3.31%	81	84	3	3.71%
3	139	136	2	1.44%	93	87	6	6.45%
4	127	122	5	3.94%	85	82	2	2.35%
5	130	127	3	2.31%	87	84	3	3.45%
6	139	136	2	1.44%	93	86	7	6.45%
7	105	110	5	4.80%	72	69	3	4.20%
8	118	111	7	5.93%	71	69	2	2.82%
9	115	110	5	4.35%	75	71	4	5.33%

Table 2 above shows the readings obtained from the newly developed blood pressure measuring device in comparison to those obtained from the motech blood pressure monitor. The readings obtained from the developed device were found to be close to those obtained from the motech, with percentage errors ranging from 1.44% to 6.20% (2 - 8 mmHg) in systolic readingsand 2.35% to 8.14% (2 - 7 mmHg) in diastolic readings. These errors are within the acceptable range of ≤10 mmHg as per the current ANSI/AAMI/ISO requirements (Stergiou, et al., 2018).

Temperature Monitor Test

The temperature measurement device was tested multiple times, and the system was found to be working correctly, delivering accurate readings as required, as depicted in table 3. The system was also compared to an infrared laser thermometer, and the results showed a negligible percentage error, ranging from 1.3% to 8.86%.

Table 3: Temperature measuring device test

SN	Developed temperature monitor (°C)	Infrared thermometer (°C)	Error	%Error
1	38.0	37.0	1.0	2.70%
2	36.0	35.6	0.4	1.12%
3	38.0	37.5	0.5	1.33%
4	37.0	36.2	0.8	2.21%
5	37.0	36.5	0.5	1.37%
6	36.0	35.0	1.0	2.86%
7	38.0	38.5	0.5	1.3%
8	37.0	38.0	1.0	2.63%
9	31.9	35.0	3.1	8.86%
10	34.1	36.7	2.6	7.08%

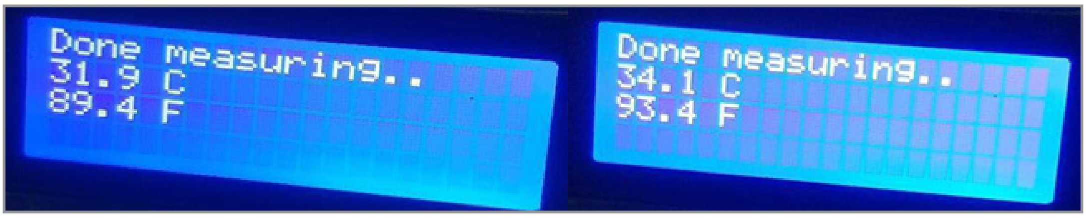

Figure 12: Temperature Reading

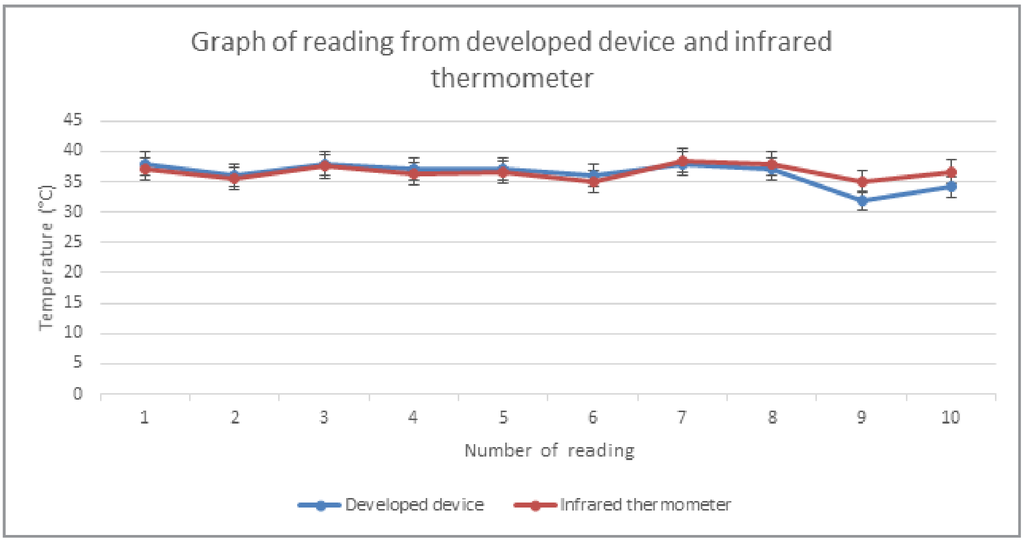

Figure 13: Temperature reading against developed and infrared thermometer

The graph provided above depicts the readings obtained from the temperature-measuring device and the infrared thermometer. As per the graph, the readings indicate a negligible variation and a high level of accuracy, with a percentage error ranging from 1.3% to 8.86%. The results obtained from the device seem to be satisfactory and reliable.

Pill Dispenser Test

The main central unit of the system responsible for dispensing medication to patients as per the doctor's prescription on the web app is the pill dispenser. It comes with a keypad that accepts user input and responds accordingly. The figure below illustrates the functionality of the dispenser that was tested.

Figure 14: Home and menu screen

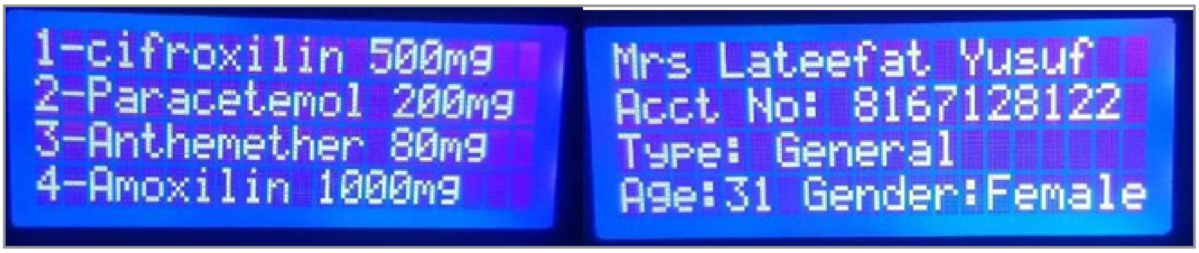

Figure 15: Home and menu screen

Table 4: Pill dispenser test

Test	Container	Morning dosage				Afternoon dosage				Evening dosage				Night dosage			
		Expected dose	Dose dispensed	Error	Pill detection	Expected dose	Dose dispensed	Error	Pill detection	Expected dose	Dose dispensed	Error	Pill detection	Expected dose	Dose dispensed	Error	Pill detection
Day one	One	1	1	0	⍰	0	0	0	⍰	0	0	0	⍰	0	0	0	⍰
	Two	2	2	0	⍰	2	2	0	⍰	2	2	0	⍰	0	0	0	⍰
	Three	1	1	0	⍰	1	1	0	⍰	1	1	0	⍰	0	0	0	⍰
	Four	3	3	0	⍰	3	3	0	⍰	3	3	0	⍰	0	0	0	⍰
Day two	One	1	1	0	⍰	0	0	0	⍰	0	0	0	⍰	0	0	0	⍰
	Two	2	2	0	⍰	2	2	0	⍰	2	2	0	⍰	0	0	0	⍰
	Three	1	1	0	⍰	1	1	0	⍰	1	1	0	⍰	0	0	0	⍰
	Four	3	3	0	⍰	3	3	0	⍰	3	3	0	⍰	0	0	0	⍰
Day three	One	1	1	0	⍰	0	0	0	⍰	0	0	0	⍰	0	0	0	⍰
	Two	2	2	0	⍰	2	2	0	⍰	2	2	0	⍰	0	0	0	⍰
	Three	1	1	0	⍰	1	1	0	⍰	1	1	0	⍰	0	0	0	⍰
	Four	3	3	0	⍰	3	3	0	⍰	3	3	0	⍰	0	0	0	⍰
Day four	One	1	1	0	⍰	0	0	0	⍰	0	0	0	⍰	0	0	0	⍰
	Two	2	2	0	⍰	2	2	0	⍰	2	2	0	⍰	0	0	0	⍰
	Three	1	1	0	⍰	1	1	0	⍰	1	1	0	⍰	0	0	0	⍰
	Four	3	3	0	⍰	3	3	0	⍰	3	3	0	⍰	0	0	0	⍰
Day five	One	1	1	0	⍰	0	0	0	⍰	0	0	0	⍰	0	0	0	⍰
	Two	2	2	0	⍰	2	2	0	⍰	2	2	0	⍰	0	0	0	⍰
	Three	1	1	0	⍰	1	1	0	⍰	1	1	0	⍰	0	0	0	⍰
	Four	3	3	0	⍰	3	3	0	⍰	3	3	0	⍰	0	0	0	⍰

The table labelled as Table 4 displays the results obtained from the pill dispenser test that was conducted over a period of five days with different prescriptions as mentioned in the table. The pill dispenser is an incredibly efficient device that ensures the accurate dispensation of prescribed medication at the scheduled time and in the exact dosage. This is made possible by the pill detection mechanism, which eliminates the possibility of any dosage errors by ensuring that the pills are dispensed and accurately counted, thereby eliminating any possibility of dosage errors.

Conclusion

The system that automatically dispenses pills and measures health vitals for hypertensive patients is a great example of how the internet of Things technology can be integrated into healthcare services. This system helps doctors and nurses manage patients remotely, making it easier and more convenient for everyone involved. With this technology, healthcare professionals no longer need to go from bed to bed to perform check-ups or administer medication. It's a practical solution that solves an existing problem in hospitals.

A new health vital measuring system has been developed and tested. It consists of sensors that measure blood pressure and temperature accurately. The readings are within the range stated by ANSI/AAMI/ISO requirements of <10mmHg. The measured readings are transmitted to the database for record-keeping purposes. The device has been developed to help regulate the health condition of individuals by keeping track of their vitals and improving medication adherence. Additionally, it assists in connecting the individual to their doctor and reducing the workload on caregivers. The web application, as an interface capable of displaying the information to doctors, was tested and found to be functioning correctly, displaying the right information on each page.

Acknoledgement

I would like to express my sincere gratitude to Professor F.O. Anafi, Dr. Alim A. Sabur, Dr. Y.S. Danbatta, PTDF, Ahmadu Bello University Zaria, and my family and friends for their invaluable guidance, support, funding, resources, and encouragement throughout my research work.

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