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Construction and Implementation of Internet of Things Based Patient Health Monitoring Device

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Abstract: *Due to population growth, the health management system has reached a standstill globally, resulting in subpar healthcare services and a shortage of medical personnel at crucial moments. With a population of roughly 223,804,632, or 223 million people, Nigeria is one of the most populous countries in the world. The country's population is expected to grow by 2.41 percent per year. The majority of Nigeria's healthcare facilities are insufficient to meet the needs of the nation's healthcare system. The majority of Nigerian hospitals also lack sufficient medical infrastructure for tracking patients' vital signs. Furthermore, during the entire working day, the doctors are unable to remotely monitor their patients in some emergency situations. However, because of needless communication and data access barriers that increase the risk of operational errors, diagnosis results are recorded incorrectly on paper. Given this, the primary focus of this study was an essential architecture solution that created an online real-time patient health monitoring system. The health sector will have a better future with the usage internet of things (IOT) in the healthcare system, which will enable patient to be track and monitor via simple inexpensive device. The patient health monitoring system (PHMS) and its cutting-edge technology will be regarded as major advancements in the medical field on a global scale. By decreasing the rate of operational errors in vital sign monitoring, the study used IoT to accelerate improvements in the healthcare services. The ATMEGA328 microcontroller (MCU) and "internet of things" (IoT) were used in the construction and implementation, along with an ESP12E Wi-Fi module. Four distinct factors, such as temperature, blood pressure, pulse-oximeter, and glucose level sensors, are incorporated into this system. This work is one of the few projects that incorporate the glucose sensor into clinical sessions' real-time monitoring. Using the web address created for this system, the "WI-FI" module is utilize to transmit data into the cloud via the internet of things (IoT) for processing, storing, and diagnosis by health specialists. Ten subjects of varying ages were used for the system's validation and performance assessment.*

Keywords: *internet of things (IoT), Microcontroller (MCU)*

INTRODUCTION

The prevalence of various diseases is typically correlated with an increase in the human population, which drives up demand for medical personnel and other resources related to health care (Hou et al., 2005). With a population of 223,804,632, or 223 million people, Nigeria is one of the most populous countries in the world. This country population is increasing at a rate of 2.41 percent per year (Olajide & Khadijat, 2023).The majority of Nigeria's healthcare facilities are inadequate to meet the needs of the nation's healthcare system (Adeloye et al., 2017).Furthermore, there has been a call to address these issues, particularly with regard to the improvement of health facilities in Nigeria, as the cost of healthcare facilities has increased during the past ten years. In a similar vein, the majority of third-world medical facilities lack sufficient and effective health monitoring systems (Chijioke et al., 2015).When a person is admitted into a hospital, they are called patients. A patient's medical status is determined by the clinical outcome of their interactions with the healthcare system. On the other hand, a single vital sign measurement taken upon before admission in clinics or hospitals is more effective in determining a patient's status than during admission when the condition deteriorating mostly within 72 hours without taking their fundamental vital signs (Quinten et al., 2018). In order to create intelligent medical systems devoted to continual medical monitoring, numerous studies are currently being conducted in the field of computer networking in the health domain. The health sector will have a better future with the used of internet of things (IoT) in the healthcare system, which will enable patient to be tracking and monitor via the used of sensors (Paganelli et al., 2022). The ‘‘patient health monitoring system’’ (PHMS) and its cutting-edge technology will be regarded as major advancements in the medical field on a global scale. Vital signs like blood pressure, temperature, glucose level, and pulse rate are measured by the ‘‘patient health monitoring system’’(Teja & Rao, 2018; Tamilselvi et al., 2020).When it comes to giving medical professionals effective data in an emergency medical service and patient data access, the ‘‘Internet of Things technology’’ utilized in the ‘‘Patient Health Monitoring System’’ (PHMS) is promise technology. These days, the ‘‘Internet of Things’’ (IoT) is widely used across many industries, and its application has a big impact on our daily lives. Additionally, it is utilized as an E-health application system for a number of purposes, including medical emergencies and the early identification of certain medical problems. On the other hand it provides the medical professionals with effective data in an emergency medical service (Rahaman et al., 2019). The (IoT) can be used in the (PHMS) to aid the measurement of vital parameters of patients and propagate them to a distant location (Shaown et al., 2019; Islam, 2019). In addition, according to a study by Paganelli et al. (2022), an ‘‘Internet of Things’’ (IoT)-based technology system proves useful during the COVID-19 pandemic. It enhances healthcare services during emergency situations and helps ensure the safety of medical personnel. The device that used IoT will soon be the fast and least expensive ‘‘healthcare monitoring system’’ available for patients in an emergency situation. As a component of the contemporary healthcare system, PHMS will be used as a medical apparatus connected to smart-phones that will track the wellbeing of the patients in and out of the clinical sittings. One could argue that cost, efficacy, efficiency, and safety should be the justifications for innovation in the sciences, engineering, and health care system (Kale et al., 2015). As a result of this, the prototype system's design takes these four factors into account as prerequisites for the implementation PHMS's to operation with internet.

Statement of the problem

The global "health management system" is at a standstill due to population growth, which has resulted in subpar healthcare services and a shortage of medical personnel at crucial moments. The majority of Nigerian hospitals also lack sufficient medical infrastructure for tracking patients' vital signs. Furthermore, in many critical conditions, doctors are unable to remotely monitor their patients for the entirety of their working hours. However, because of needless communication and data access barriers that increase the risk of operational errors, diagnosis results are recorded incorrectly on papers. Given this, it is necessary to add a wireless device or system that will regularly check the vital signs of patients in the clinics or hospital.

Materials

The idea and goal of this work is to develop and set up a wireless "internet of things" (IoT) device for patient vital sign monitoring. Therefore, in addition to the computation of the basic components, table 3.1 lists the necessary components and their corresponding prices that make up the health monitoring system.

Table 1.1 the components of patient health monitoring system

S/N	Item Descriptions	Quantity
I	Atmega-328p Microcontroller	1
II	WIFI-Module Note MCU	1
III	Heartbeat sensor	1
VI	Blood pressure sensor	1
VII	Glucose sensor	1
VIII	Temperature sensor D11	1
V	Dc air blower machine	1
VI	12V DC (reachable)Battery	4
VII	Regulator: 7912, 7805	2
VIII	Capacitor 1000uf 25V, 100μf X 25V	4
XI	Transformer 239 V12	1
IX	Diode IN4007	1
X	Resistor 10Ʊ	1
XX	Crystal Oscillator 16MHz	1
XL	Power Switch	1
XIL	Vero Board	1
XIIL	LCD 16x2	1

Methodology

The ‘‘internet of things’’ (IoT) and the ‘‘ATMEGA328 microcontroller’’ (MCU) were used in the system's construction and implementation. At the implementation stage, a Varo board, bolts and nuts, and solder gum were used to assemble the hardware components that made up this system as in table 1.1

Typically, the Alternative Current (AC) source voltage ranges from 220-240V and the computation indicates that this voltage exceeds the circuit's capacity. Consequently, this 230 AC source was stepped down to a 12V AC source using a step down transformer 239V12. To convert the AC source into DC in the circuit, the 12V input AC is permitted to pass through a bridge rectifier (IN4007). A 95% drop in voltage and a 95% increase in current result from the voltage reduction from 230 to 12V. Nonetheless, the multimeter value of 4.5V indicates that the output of the DC source is less than the 12V AC, according to the results test. In addition, the rectifier's DC output is less than 12 volts; an unwanted voltage was filtered using a 1000uf capacitor. Based on the fundamental computation, a 12-volt battery was needed for the system. Consequently, a regulator (7912) was employed to control the output voltage to 12 volts Direct Current (DC), which is appropriate for the (rechargeable) battery. Furthermore, the battery's output was only 9 volts, and since the circuit's components need 5 volts of DC to operate, a 100uf 25 volt capacitor was utilized to increase and stabilize the power to 12 volts DC using a 7805 regulator. These maintain and increase the voltage to ensure that all of the circuit's components are powered consistently, and a 16MHz crystal oscillator pulses the Microcontroller (MCU) processor so that it can detect every component. However, to generate the necessary pressure for the cuff, a DC blower machine was utilized, which transforms electrical energy into mechanical energy. All other sensors that are connected to the microcontroller (MCU) with 5V are detected and initialized by the MCU. Figure 1.1 shows the block diagram of the system, which includes the mobile application and the serial monitor of the ATMEGA328 that display the temperature and blood pressure measurements.

Implementation

The hardware apparatus was assembled at this point of completion, and the system is realized through the array of hardware mechanism. This machine's sequential setup and workflow include reading sensor values, initializing the switch, and transporting measured data values to a cloud server for storage. The microcontroller processor captures the information and links it to the cloud for archiving and future access by the user (a medical professional) to assess patient data in real time. The developed machine's circuit diagram is shown in Fig 1.2, where the processor connects the physical pins of the WI-FI (ESP12E) module to the sensors. All of the sensors, the voltage common collector (Vcc), and ground (GND) are connected to the Vcc and GND pins of the WI-FI (ESP12E), which serves as a processing device for sending data to the cloud. The signal pins of the glucose and pulse rate sensors are connected to the D15 and D16 pins of the ESP12E, respectively. The D30 pin of the ‘‘microcontroller (ESP12E)’’ is mapped to the data pin of the LM35. Furthermore, the processor's D2 and D3 pins are linked to the temperature sensor D11 and the blood pressure sensor signal pin, respectively. Consequently, Figure

1.4 shows the device that was constructed during the implementation phase. These are the vital signs that need to be determined in the event that a patient is reported into a clinical sitting. The LCD 1602 pin is attached into D22 and D23 of the microcontroller data pin, and link with 10Ʊ variable resistor to regulate the contrast of the device. As soon as the system turns on, measurement data is displayed on an LCD, MCU processor records data, and an ESP12E (Wi-FI) module links the data to the cloud. The data is displayed via a mobile application that connects to Wi-Fi and uses a "Uniform Resource Locator" (URL) module that is generated for the system using a local host.

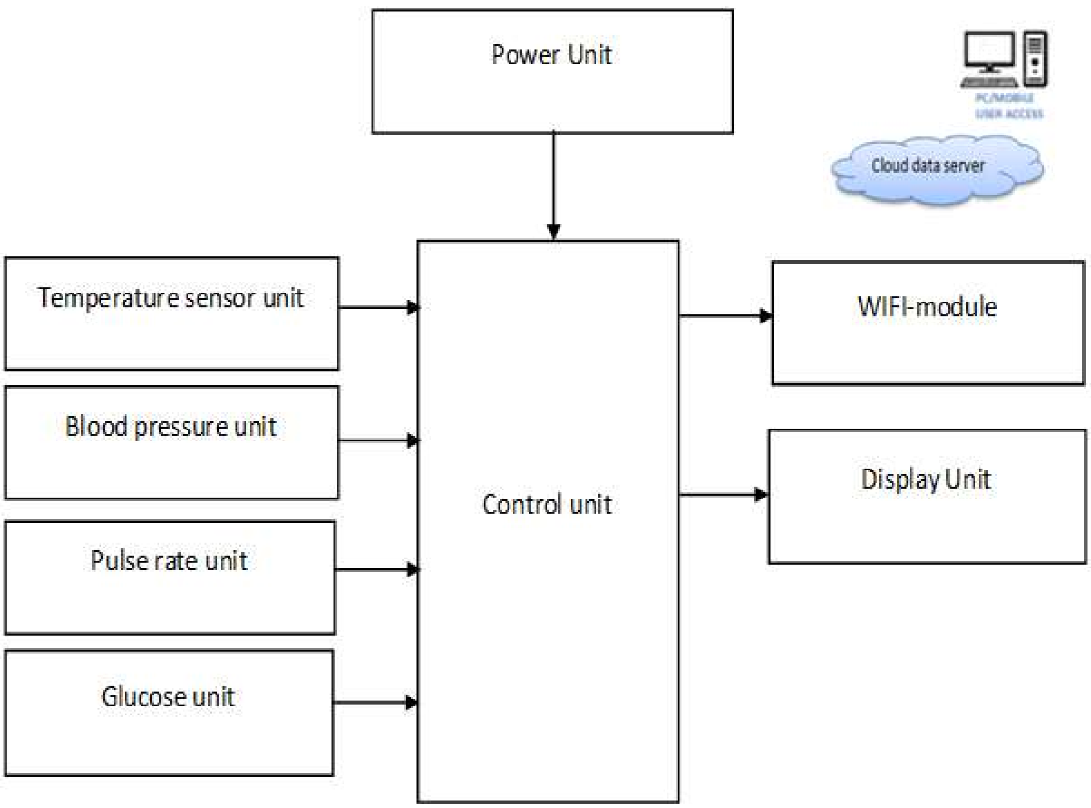

Figure 1.1 the built-in health monitoring device block diagram

The data parameter shows the information in digital form, and the heartbeat sensor's analog signal is transformed into a digital signal. Additionally analog sensors that were connected to the ATMEGA328's analog port were the body temperature and pulse rate sensors. As a result, the microcontroller increases the WI-FI module's signal to convert all analog data into digital sign (Kale et al., 2015). The circuit diagram for the proposed online health monitoring system prototype is shown in fig 1.2. Furthermore, the blood glucose sensor is an analog sensor that the microcontroller transformed into a digital signal. To assess the device's efficacy and dependability, a sample of ten subjects was chosen, and their ages were taken into consideration.

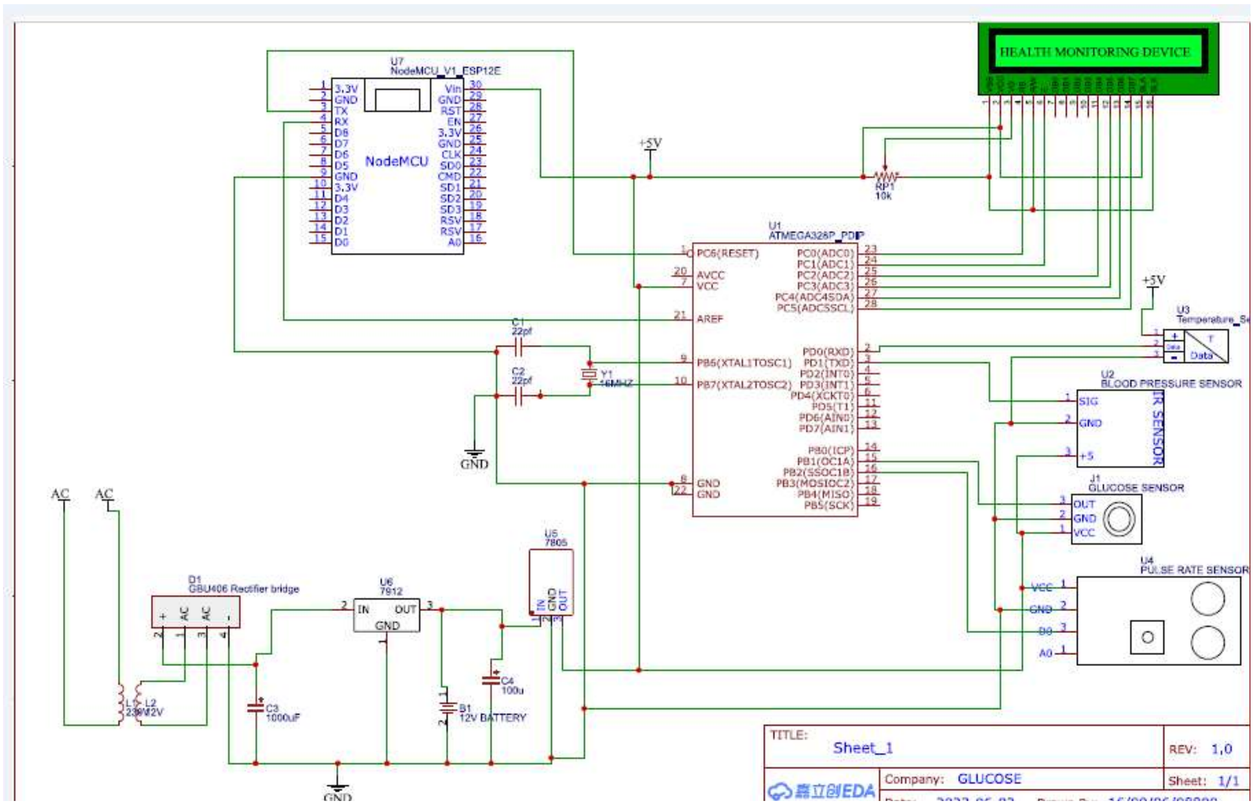

Figure 1.2 Circuit diagram of the constructed device

Results

Ten individuals of various ages were used to test with the developed prototype machine, in order to determine the machine's efficacy. The temperature, blood pressure, pulse rate, and glucose tests values were calculated manually. The first and second readings of the corresponding parameter's results were obtained, and a manual calculation of the mean value was made. Nonetheless, Tables 2.1, 2.2, 2.3, and 2.4 respectively present the first and second data's mean values for the sensors measuring blood pressure, body temperature, glucose, and pulse rate.

Table 2.1 Recorded temperature information (first reading), and (second reading)

Serial no	Age(years)	First ºC	Second ºC	Mean temperature
Sample 1	4	36.5	36.2	36.4
Sample 2	10	36.5	36.7	36.6
Sample 3	12	36.8	36.5	36.7
Sample 4	15	37.0	36.6	36.8
Sample 5	20	35.5	36.0	35.8
Sample 6	25	36.4	37.0	36.7
Sample 7	20	35.0	37.5	36.3
Sample 8	35	38.0	36.8	37.4
Sample 9	45	37.5	37.0	37.3
Sample 10	55	36.0	36.5	36.3

The findings of the body temperature measurements taken from the ten (10) subjects using the device that was built were displayed in Table 2.1. Similar to this, a normal body temperature is defined as falling between 36.0 and 37.5 degrees Celsius; any temperature that falls outside of this range is deemed high.

Table 2.2Recorded pulse rate level information (first reading) and (second reading)

Serial no	Age(years)	First (bpm)	Second (bpm)	Mean
Sample 1	4	106	110	108
Sample 2	10	80	79	80
Sample 3	12	90	86	88
Sample 4	15	68	74	71
Sample 5	20	60	73	66
Sample 6	25	90	87	88
Sample 7	30	74	80	77
Sample 8	38	80	86	83
Sample 9	50	96	98	97
Sample 10	61	89	90	89

Ten (10) subjects' real-time pulse rates, as determined by the health monitoring system built specifically for this research work, are shown in Table 4.2. Taking or measuring a patient's pulse rate during a clinical session usually serves as a starting point for additional diagnosis to identify any changes in the patient's condition. Since the pulse rate is commonly expressed in beats per minute (bpm), the subject's pulse rate was determined by taking a reading on their arm. This is because the human body can have multiple pulse points.

Table 2.3 Recorded BP information (first reading) and (second reading)

Serial no	Age(years)	First Systolic	Second Diastolic	First Systolic	Second Diastolic	Systolic Mean (mmHg)	Diastolic Mean (mm Hg)
Sample 1	4	105	45	104	45	104	45
Sample 2	10	97	56	97	54	97	55
Sample 3	12	94	57	96	57	95	57
Sample 4	15	100	65	100	66	100	66
Sample 5	20	105	60	105	62	105	61
Sample 6	25	109	66	106	62	107	64
Sample 7	30	141	95	138	87	140	91
Sample 8	35	123	80	125	80	124	80
Sample 9	45	130	85	130	80	130	82
Sample10	55	137	90	135	90	136	90

The blood pressure readings from the device, which was built using ten (10) subjects of varying ages, are shown in Table 2.3. Since blood pressure has no symptoms, it is regarded as one of the vital signs that should be measured and monitored during clinical sessions. Blood pressure is also known as one of the silent killers.

Table 2.4 Recorded glucose level information (first reading), and (second reading)

Serial no	**Age**(years)	**First** mg/dL	**Second** mg/dL	**Mean** mg/dL
Sample 1	4	80	82	81
Sample 2	10	90	87	88
Sample 3	12	78	78	78
Sample 4	15	98	106	102
Sample 5	20	95	100	97
Sample 6	25	90	95	93
Sample 7	20	130	136	133
Sample 8	35	100	138	199
Sample 9	45	89	100	95
Sample 10	55	164	140	152

The patient health monitoring system was used to measure the glucose levels of ten (10) subjects of varying ages in real time, and the results were displayed in Table 2.4. As part of a vital sign, the glucose level is monitored. Since some medications are not appropriate for people with diabetes, it has become standard practice in clinical settings to check the patient's glucose level before proceeding with any further treatment.

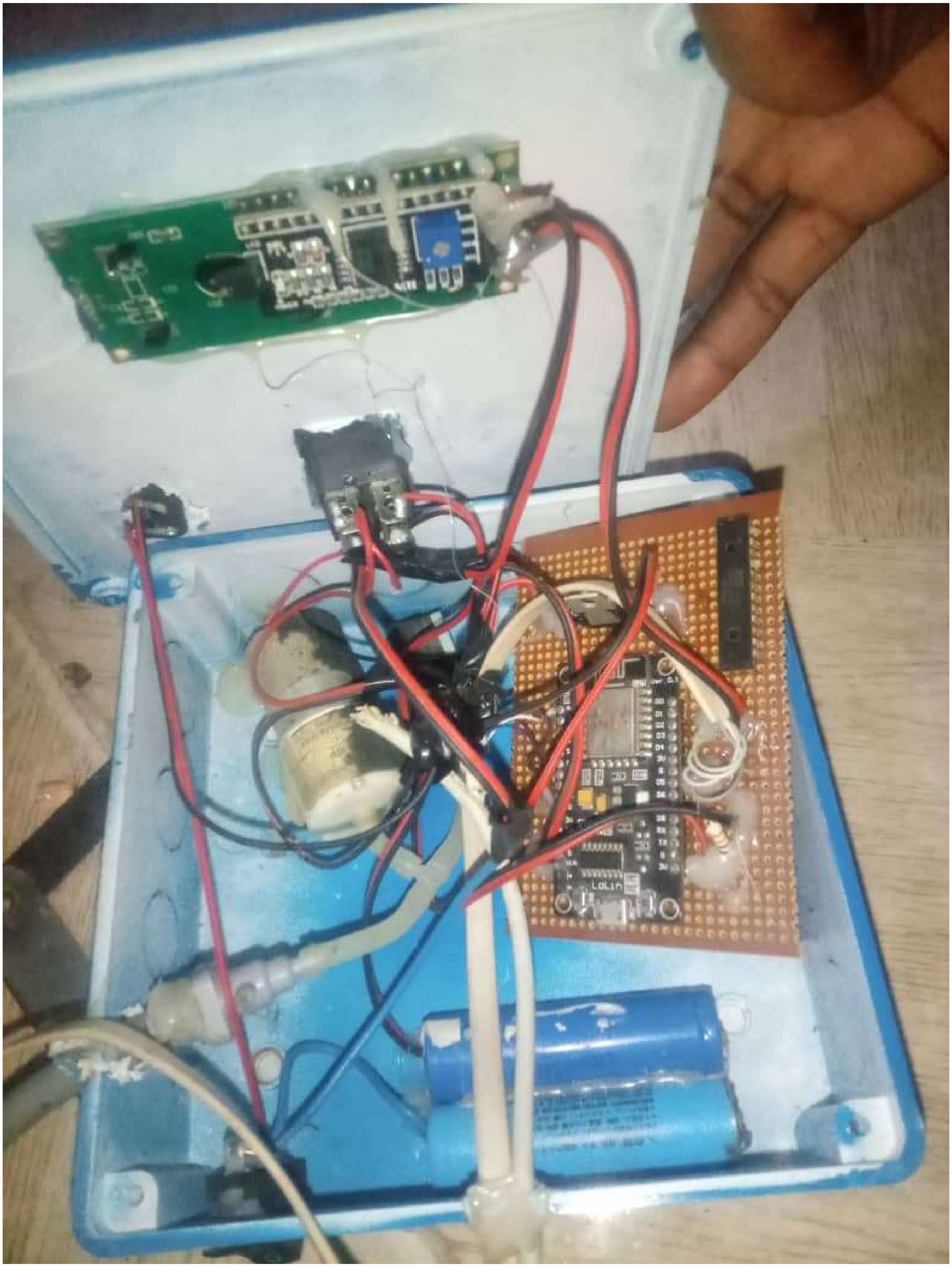

Figure 1.3 the inner portion of the device at the implementation phase
Furthermore, the device's motor will supply the necessary pressure for the microcontroller to measure blood pressure. The system prototype, shown in figure 1.4, was tested on ten subjects. Volunteer data, the reading are attached to the posture with one hand, and the data is displayed on the web server.

Figure 1.4.The picture of the prototype health monitoring system

Conclusion

This project concentrated on a crucial architectural solution that created a system for monitoring patients in real time. The doctors can easily access real-time patient condition information with the help of an online patient health monitoring system that tracks vital signs. Four distinct parameters, including temperature, blood pressure, pulse rate, and glucose level, are incorporated into the system. This study, however, is one of the few that incorporates a glucose sensor into the construction and implementation of a patient health monitoring system for real-time monitoring. The patient's data are displayed for the medical expert to monitor at home or at the office and is easily retrieved using the ‘‘Uniform Resource Locator’’ (UrL). The acquired data are real-time, so this system can be used for patient monitoring using ‘‘Internet of Things’’ health monitoring devices as well as contactless tracing. In a similar vein, the implementation of these system algorithms for patient ‘‘vital sign’’ monitoring will present chances to lessen the demand for medical-care services in areas where there is a deficiency of qualified medical personnel. In a similar vein, this system will work well with mobile devices used for e-health applications. The way the system is built and constructed will result in an efficient healthcare service that offers a lot of opportunities.

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