INTERNET OF THINGS BASED DUAL HEALTH MONITORING SYSTEM

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Abstract: Heart attack and malaria are the leading cause of death in Africa. Signs of heart problems are poor heartbeat, palpitation, chest pain etc. while symptoms of malaria are high body temperature and feverish condition. This work developed a dual health monitoring device for examining the heart pulse rate in beat per minute and for checking the body temperature. The system comprised power supply, voltage converter, microcontroller, and heartbeat and temperature sensors. The temperature readings and pulse rate were displayed on Liquid Crystal Display (LCD) screen and mobile phone for easy access. For the purpose of validating and testing the performance of the system, the temperature and heartbeat of four persons were taken and the readings were compared with those obtained using conventional method. Temperature readings of four patients obtained via the system developed were 36.6^{0}C, 37.1^{0}C, 36.1^{0}C and 37.1^{0}C, respectively which translated to an average error of $\pm 1\%$ when compared with 36^{0}C, 36.9^{0}C, 36.5^{0}C and 36.7^{0}C obtained respectively, through axillary thermometer. It was also seen that heartbeat rates measured compared favourably well with those released by American Heart Association for the given age bracket.

Keywords: blue-tooth module, heartbeat sensor, internet of things, microcontroller, temperature sensor, dual system

Introduction

Access to good health care is essential for maintaining a healthy life and for increasing life expectancy. Health care monitoring device is an essential component of health care system which every household is expected to have for constantly checking the essential health parameters. Body temperature, blood pressure, heart rate, body mass, height and body glucose level are significant parameters that must be observed regularly. Usually, on arrival at the hospital, a physician or nurse on duty checks the blood pressure, heart rate and body temperature before other tests are carried out on the patient. Heart rate refers to the number of times heart dilates in minutes and indicates how functional the heart is. Heart rate varies over a number of age groups. For those within the age bracket of 18 and above, the normal resting heart rate is between 60 to 120 Beats Per Minute (BPM), toddlers have higher rate usually around 130 BPM while children below 18 years have heart beat rate between 70 and 100 BPM (Dogo *et al*., 2013). Bradycardia is a condition when the heart rate is slow while Tachycardia occurs when the heart rate is faster than normal. Patients with poor heart beat rates exhibit the following symptoms which include, palpitation, high-headedness, fatigue, chest pain, dizziness and shortness of breath. (Alam et al., 2016). Temperature like heart rate varies from one person to the other and it depends on the condition of the body at a point in time. The normal body temperature varies from 36.1 to 37.8 degree Celsius (Ufoarah and Nnadkwe, 2021). The temperature of the body above this range is assumed to be high. High temperature may indicate fever and unstable heart rate may pointer to an underlying heart problem. Temperature readings can be taken in a variety of ways, worthy of mention is the axillary thermometer which is put under the armpit of the patient whose body temperature is to be taken. Researchers have also devised different approaches for checking the heartbeat of patients. Works in that regard include Singh et al. (2016) which develop a system for measuring the heartbeat of patient in remote areas. Dogo et al. (2013) construct a device that displays the result of heart pulse rate of patients on liquid crystal display and produce voice prompt of the results in Nigerian languages. Parihar et al. (2017) and Khamitkar and Rafi (2020) construct a device for real time measurement of the heartbeat. Anitha et al. (2018) present Wireless Fidelity (WiFi) heartbeat measuring device which is accessed via the internet for providing real time information to users. Ichwana et al. (2018) develop a system that measures heartbeat rate of sport men and intimates them of impending danger when heart rate is beyond allowable limit. A low cost heartbeat monitoring system using infra-red sensor is developed by Irekefe and Akingbade (2021) while Shirzadfar *et al*. (2018) utilize an optical sensor to measure the heartbeat. These devices could not perform dual role of measuring temperature and heartbeat at the same time. Though Sollu et al. (2018), Nookhao et al. (2020) and Hendryani et al. (2021) develop heartbeat and body temperature measuring device, the system cannot provide real time information to mobile phone users. This work develops heartbeat and human body temperature measuring device that displays results not only on LCD screen but also on the smart phone for easy access and convenience

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Materials and Methods

Overview of the System

Figure 1 illustrates the block diagram of dual health monitoring system consisting of the input unit, processing unit, power supply unit, connecting unit and the receiving or output unit.

Input Unit

The input unit comprises heartbeat sensor and temperature sensor. The heartbeat sensor works on the principle of photoplethysmography (Khan et al., 2020) where light is emitted to the index finger of the patient whose heartbeat is being measured. The light travels through the blood (cardiovascular) part of the body which is reflected and detected by photo detector. The pumping of the blood is influenced by the pulse rate of the heart, the photo detector therefore measures the change in blood volume through the index finger. The change in blood volume corresponds to the pulse train detected by photo detector which is counted by the microcontroller in minute.

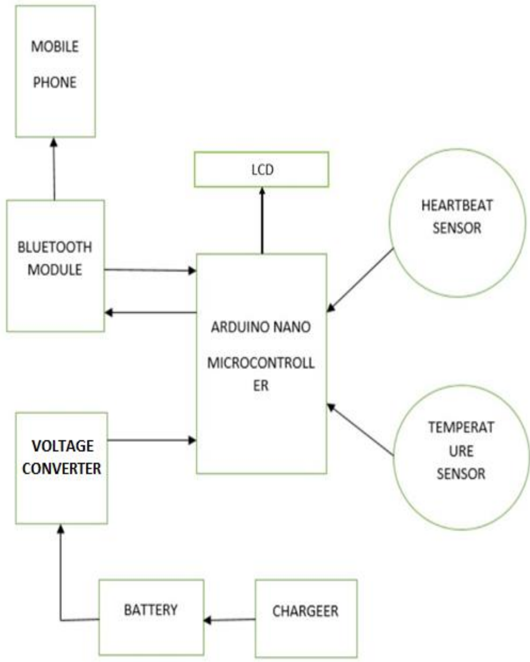


Figure 1: Block diagram of dual health monitoring system

The temperature sensor measures the temperature of the human body. LM35 is used in this work as the temperature sensor. It consists of three pins; the first pin is the input, the second pin is the output and the third pin is the ground. It is a cheap and small precession integrated circuit whose voltage changes depending on temperature around it. It responds to temperature between -55°C to 150°C. It can easily be interfaced with microcontroller that has analog to digital conversion function or development platform like arduino. LM35 is powered by regulated +5V voltage which is connected to the input pin (pin 1). Pin 3 connects LM35 to the ground of microcontroller while pin 2 is connected to the input pin of arduino microcontroller. If the temperature is 0°C, then the output voltage is also 0V. There is rise of 0.01V (10mV) for every degree Celsius rise in temperature.

Processing Unit

The processing unit is the main brain of heart beat and temperature measuring system. It accepts data or signal, processes it and gives output. Here, AT mega 328P microcontroller is utilized for coordinating the activity of the dual heath monitoring system. It consists of 32 pins; 13 digital input/output (I/O) pins, 8 analog I/O pins, 3 reset pins, 3 serial peripheral interface (SPI) pins, 5 power pins, and a mini USB port. The USB port is used for programming and serial monitoring. The microcontroller is powered by 9-12 D.C. voltage while the operational voltage is 5V. It has a flash Memory of 32 KB and clock speed 16 MHz. Figure 2 presents the pin configuration of AT mega 328P microcontroller.

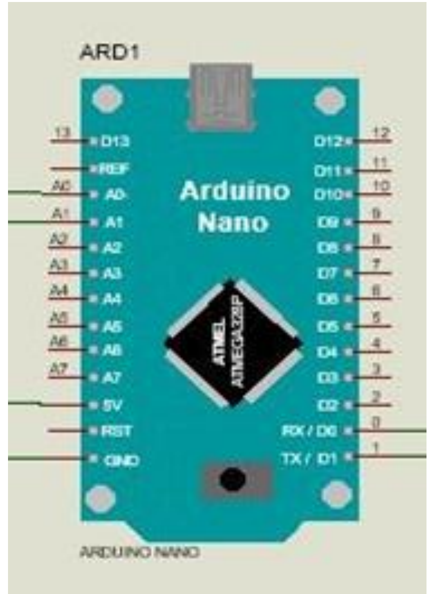


Figure 2: Configuration of AT Mega 328P microcontroller (Source: Datasheet).

It receives signal from the sensors through pins A0 and A1 (receiver input pins). The two pins act and process the signal and convert it into a form that D1 pin can accept. D1 transmits the processed signal to the receiver pin of Bluetooth module and at the same time transmits the same signal to LCD. The module is connected to the arduino through D0 and D1 pins while LCD is connected to the arduino through pin D2, D3, D4, D5, D6, and D7. The microcontroller is programmed via C-programming language.

Power Supply Unit

This is the unit that powers the system. The system requires 9VD.C. to power the arduino. This is taken from the output of voltage converter which steps down voltage values of three (3.7VDC) batteries connected in series to 9VDC, sufficient for powering the arduino.

Connecting Unit

This is the unit that serves as the intermediary between microcontroller and output unit (smart phone). The system makes use of HC05 Bluetooth module which links or connects the device to the smart phone.

Output Unit

The system makes use of smart phone and Liquid Crystal Display (LCD) as the receiver to display the data. The system therefore has two modes of displaying the result at the same time, either through mobile phone or through the LCD screen. The LCD that is used in this work is LM016L which consists of 16 pins and displays 16 characters per each line. There are two lines in LCD of the type utilized in this work. Figure 3 shows the pin configuration of LCD

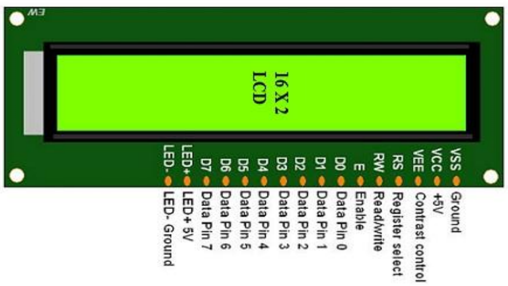


Figure 3: Pin configuration of 16X2 LCD (Source: Datasheet)

The circuit diagram of dual health monitoring system is displayed in Figure 4 which is combination of units in Figure 1.

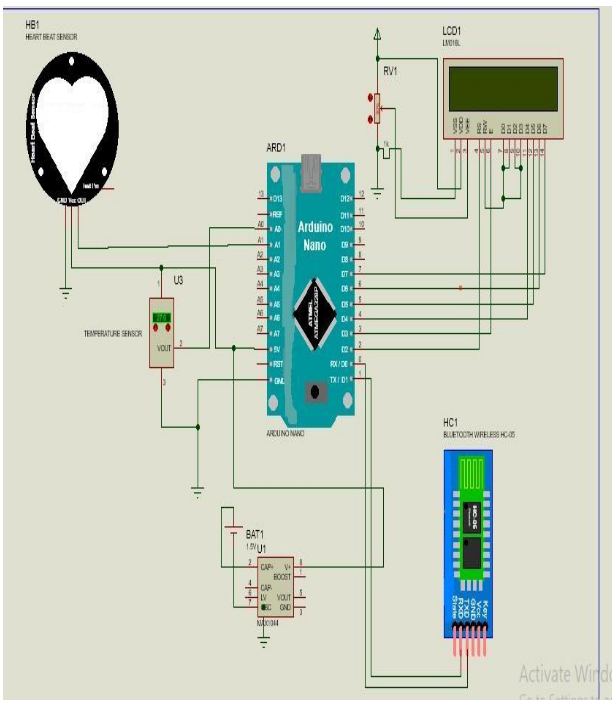


Figure 4: Circuit diagram of dual health monitoring system

Results and Discussion

System Developed

Figure 5 shows the internal features of the system, where all the components in different unit in Figure 1 are laid, linked and soldered to the Vero-board. The components are mounted on the Vero-board such that pins 8 & 9 of the arduino microcontroller are used as the transmitter (TXD) and the receiver (RXD) for communicating with the Bluetooth module. In that regard, the RXD and TXD of the arduino are connected to the TXD and RXD of the Bluetooth module. This type of connection is known as asynchronous data connection. This mode of connection is a multithreaded model that is mostly used in networking and communication and allows multiple activities to take place at the same time. It facilitates multiple related operations to run concurrently without waiting for other tasks to complete. The input of the Bluetooth module is connected to 5V of the arduino and the ground of the Bluetooth module is connected to the ground of the arduino. The arduino receives signal from temperature and pulse sensor via pin A0 and A1, respectively. The pin 1 of the LCD is connected to the ground of arduino while pin 3 and pin 2 of LCD are linked together and are connected to 5VD.C.of the arduino. However pin 4 of LCD is connected to D2 of arduino and pin 6 of LCD is connected to D3 of arduino while pin 5, data pins (D7, D8, D9 and D10) are linked together. In addition, pins (D11, D12, D13 and D14) of LCD are linked to corresponding pins (D4, D5, D6 and D7) of arduino microcontroller. Arduino is powered with 9VD.C. from the output of voltage converter. Figure 6 depicts the external part of the system consisting of the screen and sensor

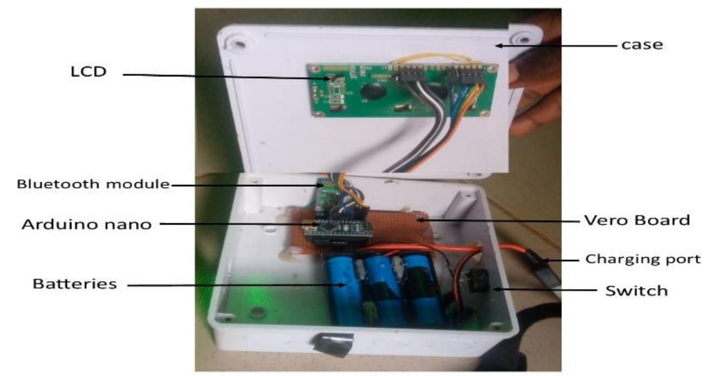


Figure 5: Internal component of dual heart monitoring system

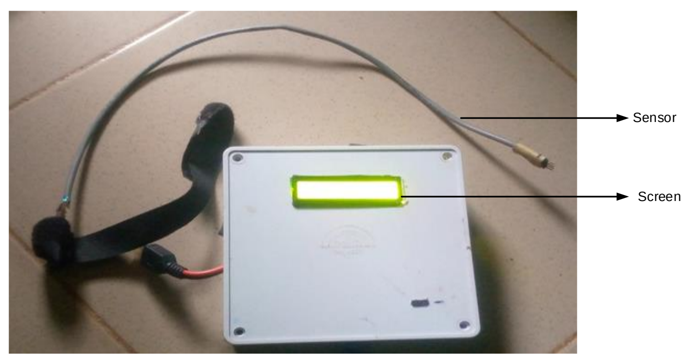


Figure 6: External features of dual health monitoring system

Performance Test

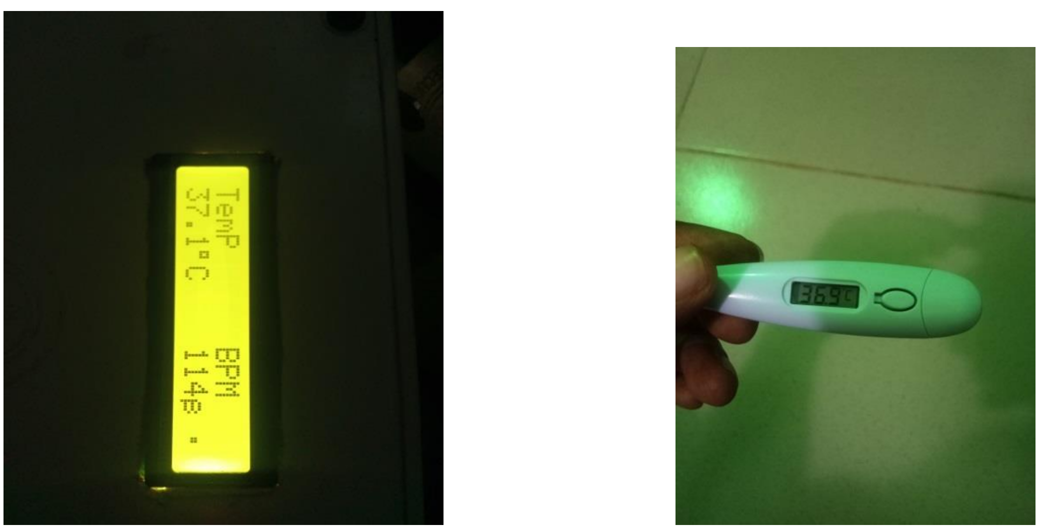
In order to test the performance of the system, four patients whose age ranges between 25 and 30 years are used as candidate and are subjected to testing by placing their index fingers on the sensor. Figure 7 is the snapshot of one of the patients under test with the smart phone being used to display the result of the measurements

Figure 7: Testing of the system with the first patient.

Figures 8-11 depict the results of the measurements for all the four patients using system developed in this work and conventional (axillary) thermometer

(a) (b)

Figure 8: Heartbeat and temperature measurements of patient 1 (a) LCD displaying temperature and heart beats of patient 1 using the developed system (b) temperature reading obtained for patient 1 using axillary thermometer



(a) (b)

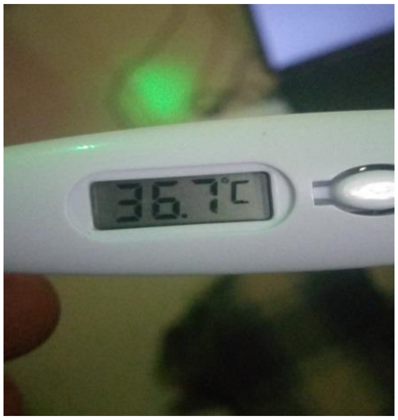
Figure 9: Heartbeat and temperature measurements of patient 2 (a) LCD displaying temperature and heart beats of patient 2 using the developed system (b) temperature reading obtained for patient 2 using axillary thermomet

(a)

(b)

Figure 10: Heartbeat and temperature measurements of patient 3 (a) LCD displaying temperature and heart beats of patient 3 using the developed system (b) temperature reading obtained for patient 1 using axillary thermometer

(a)



(b)

Figure 11: Heartbeat and temperature measurements of patient 4 (a) LCD displaying temperature and heart beats of patient 4 using the developed system (b) temperature reading obtained for patient 1 using axillary thermometer

Table I presents summary of the percentage error in the conventional temperature readings and those obtained via the system developed in this work.

Table I: Temperature readings obtained via developed system and axillary thermometer.

Patient	Age	Gender	Temperature reading via the developed device	Temperature readings via axillary thermometer	% error
1	29	Male	36.6	36.0	-1.667
2	27	Male	37.1	36.9	-0.54
3	24	Female	36.1	36.5	1.09
4	28	Male	37.1	36.7	-1.09

It is observed from table I that there is no significant difference between temperature readings of the developed system and those obtained via calibrated thermometer. It is seen that the average error in the two readings falls within $\pm1\%$. However table II presents the summary of heart rates for the four patients which compared well with heartbeat chart released by America Heart Association (www.heart.org/en/healty-living/fitness-basics/target-heart-rates) for the ages of the patients that were tested

Table II: Heartbeat rate measurements

Patient	Age	Gender	Heart beat measurement in beat per minute
1	29	Male	106
2	27	Male	114
3	24	Female	105
4	28	Male	104

Conclusions

Regular monitoring of heartbeat and body temperature play critical role in minimizing heart attack and preventing occurrence of malaria. This work developed a device that performed dual role of temperature and heart beat measurement at a time, in a bid to improving wellbeing of people. The device measured heart rate and temperature in analog form which were converted to digital format by the microcontroller. The device displayed the results on the phone and LCD screen. Tests carried out on the device using four patients as candidates produced temperature readings of 36.6^{0}C, 37.1^{0}C, 36.1^{0}C and 37.1^{0}C, respectively while those obtained via axillary thermometer were 36^{0}C, 36.9^{0}C, 36.5^{0}C and 36.7^{0}C, respectively. An average error of $\pm1\%$ was recorded when the two temperature readings were compared. The values of heartbeat in beat per minute agreed and fell within the range given by American Heart Association.

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