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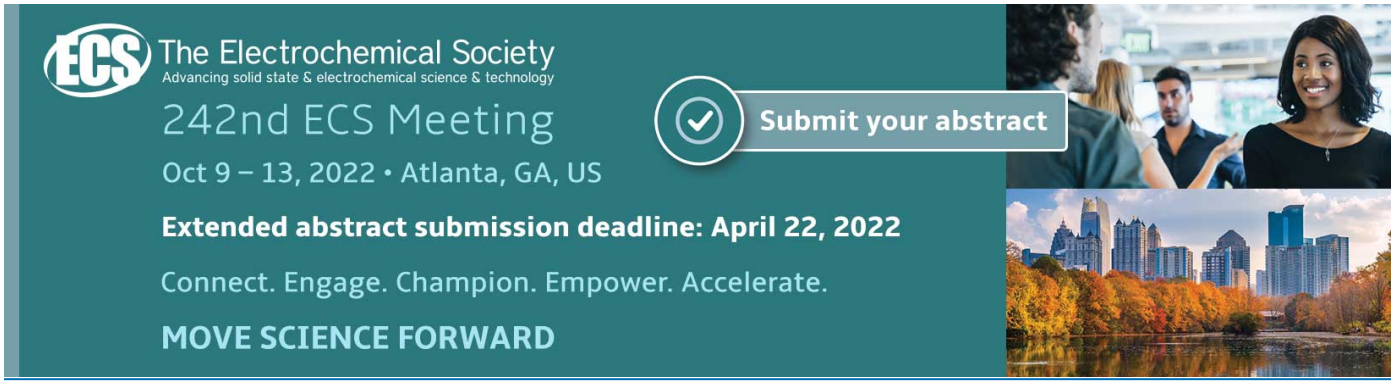

Design and construction of remote patient monitoring device

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Abstract. Health care services are important part of the society, automating these services lessen the burden on humans and eases the measuring/monitoring process. The construction of local remote patient monitoring system (RPMS) was done using the Arduino Uno connected to the global system for mobile (GSM) module SIM 800a, heart pulse sensor and body temperature sensors. It worked with 5 V power supply and the output is read on the liquid crystal display (LCD). The constructed device was tested by measuring the body temperature, heart pulse and electrocardiogram (ECG). The testing was conducted on 5 willing students and the values measured were within the normal body temperature between 36.1 to 37.2 ^{o}C. The device also sent message to alert the doctor when the value went below the prescribed value. The response time of the the device to send and receive short message service (SMS) is between 6 s to 13 s. The RPMS worked as intended and when improved upon by neater coupling and packaging, it will be a sellable low-cost product to the country locals as health care monitoring device.
Keywords: remote monitoring system, heart pulse, body temperature, GSM module

1. Introduction

Remote patient monitoring system (RPMS) is a technology used for monitoring patients outside of conventional clinical settings- for example, in the home settings, which may lead to increase in the care of patient and decrease in the healthcare delivery cost [1]. By using this technology, we can reduce the number of emergency cases at the hospital and patient duration of hospital stays, since patient vitals can be monitored by their caregivers with integrated GSM device to RPMS. The patient monitoring technology which exist like single parameter monitoring system and multi parameter monitoring system are systems which the patients who use it have to remain stationary for a while for the result signal to be sent to integrated GSM device. With RPMS doctors can monitor outdoor patient's vital signs without physical contact with patients all the time. This practice is new in Nigeria and if adopted over time, the construction of remote patient monitoring system (RPMS) becomes key to help physicians keep their patient's vital signs from afar off. Doctors appointment days can be booked from the recorded vital sign where required. Nowadays, health and engineering researchers drive is to design products that are easy-to-wear and used at low-cost [2-5]. In developing countries, product importation is one reason for high cost and completed used product, since the product is not primarily design with the country's locals in mind. RPMS which measure the body parameters in real time by using noninvasive methods can actually be locally constructed to meet patient monitoring needs for ease of care-giving. This is the emphasis of the current study. The parameters that RPMS can read are body temperature, pulse (heart rate) and ECG. These parameters are vital signs of a stable patient. The 'Remote' in RPMS is a very important part in patient the vitals transmission. There are several technologies which can transfer these data and present it in a LCD screen in a remote location. The technology has been making great advances since the 1960s,

with new challenges to surmount. The lack of broadband infrastructure has proven challenging for the advancement of many forms of telemedicine, specifically high demand video and store-and-forward services, which require expansive health networks [6]. The main benefit of remote patient monitoring system is that it allows a patient to use a mobile medical device to perform routine tests and send test results to a doctor in real-time without the necessity of visiting a medical institution. Remote patient monitoring enables easy and quick communication between physicians and patients suffering from sleep disorder, mental, cardiovascular, respiratory and other diseases. Doctors can counsel sick people online with no need to wait for the appointment date. Remote patient monitoring system improves patients' lifestyle. Incorporating Remote patient monitoring system (RPMS) in chronic disease management can significantly improve a person's quality of life. With remote patient monitoring system (RPMS) chronically ill people can spend more time at home with their families rather than at hospitals. A monitoring device is also able to inform patients about critical deterioration of health when they need to apply for emergency help as soon as possible [7]. The current study aimed at constructing remote patient monitoring (RPM) device fabricated locally to be made available to end users at low cost and readily available. This is done to measure vital signs of patients and transmit the data to a remote device. Send messages during emergency situations when the value is below the prescribed level.

1.1 Health Parameters

Heart pulse rate this is the rate or pace at which a heart beats per minute. The pulse rate or number of times a heart beats in one minute is low when the body is at rest examples are when the body is sleeping, watching TV, and other activities in seemly inert position. The pulse rate or number of times a heart beats in one minute is high when the body is in motion and other postures in which the body is not at rest such as exercise. The standard pulse rate for a young person is 70 beats per minute to 100 beats per minute and the standard pulse rate for older person are between 60 beats per minute to a 100 beats per minute [6].

Electrocardiogram commonly known as ECG is a medical examination done on a person to find out the electrical occurrences of the heart to make sure it is functioning at its normal efficiency. The ECG output is displayed on a screen or in a segmented paper. A licensed physician can interpret the displayed reading, the physician would be able to explain what the spike and fall in the graph means. An electrocardiogram can be a valuable method to see if hypertension has done any harm to the person's heart or veins. It is important for any person who is feeling stressed in the heart to get an ECG. These are some of the disease or illness the ECG can detect cholesterol obstructing the heart flow of blood, heart attacks from pervious times, enlargement of parts of the heart and irregular heart beating.

The body temperature of a person is the level of heat of the body. The body is a very fragile system which as to maintain a regular temperature and this temperature is different in both male and female gender other parameters which affects the body temperature are external temperature, menstrual cycle, the hour of the day. The average body temperature is between 36.4 degrees Celsius to 37.3 degrees Celsius for a mature human body. The appropriate device used for calculating the body temperature is a thermometer. There are different types of thermometer which are glass or mercury thermometer, pacifier thermometer, forehead thermometer, plastic strip thermometer, digital thermometer, electronic car thermometer.

2. Materials and Method

The components used for the construction of remote patient monitoring device are: ECG sensor, Arduino UNO R3, GPS (Sim 800L), Breadboard, GSM Module (Sim800L), Potentiometer, Connecting wires, LCD 16x2 and Sim card.

2.1. Design

The construction of the device is divided into two stages as follows: power supply stage and Arduino connection stage. The power supply for this system is 5 V DC. According to the power needed for the

components of the device, supply of +5 V regarding GND is created. The total hardware worked with TTL (Transistor-Transistor Logic) rationale dimension of 0 V to 5 V. Applying a higher voltage to the system will not provide any more power to the Arduino and its peripherals/shields. Instead, the excess power is dissipated in the regulator as heat. The Arduino Uno R3 is the brain of the device. The connection starts by putting the entire component to the vero board, using connecting wires. The liquid crystal display (LCD) 16 X 2 was connected to the Arduino Uno pin 4, The GPS module used in this project is the GPSNEO6M [8]. It has 22 tracking/ 66 acquisition-channels [9]. GPS module (GPSNEO6M) was connected to the Arduino Uno VCC. The SIM 800L RX GSM/GPRS module was used in this project. It is the component responsible for sending the SMS containing the GPS coordinates and other essential information to a pre-programmed number [10]. It is connected to Arduino Uno pin 12, The ECG, heart pulse and body temperature sensors were connected to the Arduino as shown in Figure 1. Finally, the coupled components are connected to computer and power supply. Calibration of Arduino sensors was done by taking each sensor reading for five minutes during startup of coupled device, the highest and the lowest reading obtained are the sensor reading range.

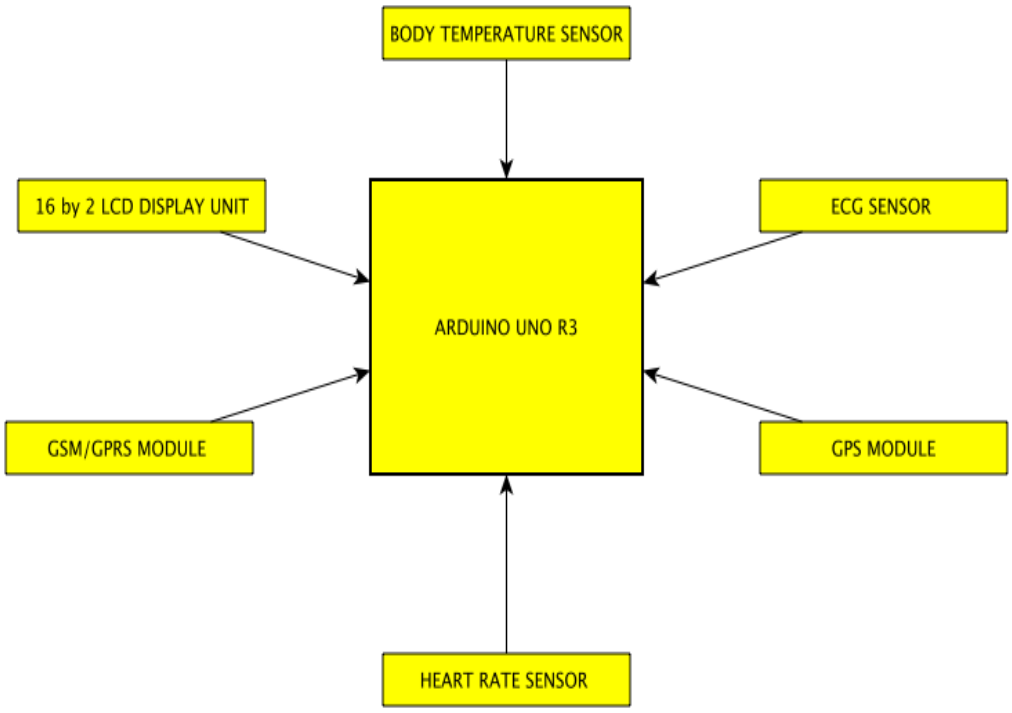

Figure 1: Block diagram of the constructed system

3. Result and Discussion

According to the proposed plan and design platform, the study was implemented by integrating Arduino Uno R3 processor, sensors, GPS module, and GSM module. The complete system helps to takes care of daily health checkup and emergency condition as well as helps to create communication between patient and doctor. When the power is switched on, the system initialized and starts monitoring the parameters which will be displayed on the LCD. A sensor was connected to patient's body this in turn senses the body parameters including ECG, temperature, heart rate and gives analog output to the microcontroller. The processor consists of in built analog to digital converter thereby converting the analog values into digital values using analog to digital convertor. When threshold value is reached digital values was displayed on the LCD screen and a text message is sent through the GSM module.

Table 1 presents the measurement taken from different people just to check whether the constructed device is working properly and can measure vital parameters within the normal. Other reading taken to test the sensors, this reading was captured on the Arduino IDE. The mean value for the patients ranged between 36.1 to 37.2 ºC, 662 to 686 mm/s and 62 to 90 beat/s for body temperature, ECG and heart pulse respectively. The measured values are within normal level for range for the heart pulse, body temperature and ECG. The temperature and heart pulse of the same set of person were measured using conventional device and compared with the measurements taken with this device the deviation is within ±0.05 which is considered insignificant deviation. An emergency situation is simulated in order to check whether the device will send message to the appropriate doctor in case the values go beyond the prescribed level. This situation was tested using water in a bottle. The mean temperature for the water was found to be 19 ºC because the simulated body temperature is below the threshold value (normal body temperature is between 36.5 to 37.5 ºC) intended. Since the temperature of water read was below the threshold value, a text message was sent to the phone number which was assign as the doctor or emergency number. Short message service (SMS) message sent from the constructed device for the emergency is displayed in Figure 2 and Figure 3 showing the average ECG waveform obtained from a patient. The response time that is the time to send information and receive feedback on the device is between 6 and 13 seconds. This is expected due to mobile network seasonal variations.

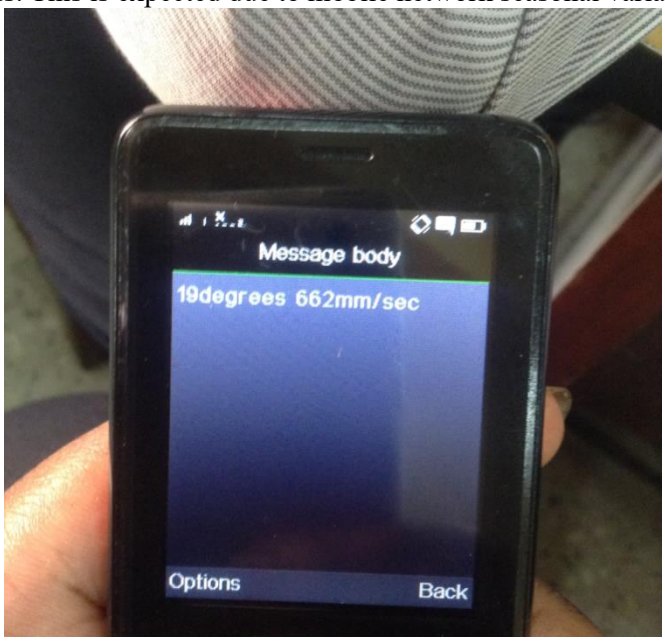

Figure 2: SMS message sample from constructed device

Figure 3: ECG result

Table 1: Constructed Device Test Result

Test ID.	Temperature Degrees Celsius (^oC)	Electrocardiogram (mm/sec)	Beat Per Minute (BMP)	Response Time (Seconds-for SMS)
T1	37.00	662.00	62.0	11.00
T2	36.70	667.00	70.0	10.00
T3	37.20	667.00	88.0	6.00
T4	36.10	686.00	67.0	13.00
T5	36.7	686.00	90.0	9.00

4. Conclusion

Remote patient monitoring system (RPMS) had been constructed using available components. The highest device response time was 13 seconds and the least were 6 seconds. This is expected due to mobile network seasonal variation. Test results shows that the constructed RPMS worked as intended and when improved upon by neater coupling and packaging, it will be a sellable low-cost product to the country locals as health care monitoring device. Government and health agencies should give incentive for mass production of medical devices for easy access of patients for monitoring of vitals at low-cost.

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M. R. Usikalu conceptualized, supervised and edited the manuscript, T. Ogunnubi carried out the experimental work using appropriate methodology, C. A. Onumejor wrote the draft manuscript and J. A. Achuka collected and analyzed the data and revised the draft manuscript.

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