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Implementation of Remote Patient Monitoring System using GSM/GPS Technology

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ABSTRACT

Remote patient monitoring (RPM) is a technology that enables the continuous monitoring of patients from remote locations. This usually involves the monitoring of patient's vital signs (e.g., heart rate, blood pressure, temperature etc.) and other health information (e.g. disease signs and symptoms) from a remote location using RPM devices. This data is collected by monitoring devices, placed on the patient's body or in the patient's residence. This data is transferred electronically to a remote location where it is stored, and analyzed by care givers in order to detect early disease onset, improvements or deterioration in patient conditions. This work proposes an implementation of Remote Patient Monitoring System using GSM/GPS Technology. The system monitors heart rate and body temperature of patient and display information on an LCD Display. The measured data and GPS location coordinates is continuously uploaded to a remote database on a web server. An SMS alert is sent to a preregistered phone number when the measured values fall below or go above the set threshold. The system was tested and worked as expected.

Keywords: *GSM, GPS modules; Heart Rate, RPM; Temperature sensor*

1 INTRODUCTION

Remote patient monitoring (RPM) is a technology that enables the continuous monitoring of patients from remote locations. This usually involves the monitoring of patient's vital signs (e.g., heart rate, blood pressure, temperature etc.) and other health information (e.g. disease signs and symptoms) from a remote location using RPM devices. This data is collected by monitoring devices, placed on the patient's body or in the patient's residence. This data is transferred electronically to a remote location where it is stored, and analyzed by care givers in order to detect early disease onset, improvements or deterioration in patient conditions. Using remote monitoring allows the patient to send in vital signs on a regular basis to a health care manager without the need for hospital visitation. One of the most common uses of RPM is in chronic disease management. There is significant confirmation that RPM can enhance healthcare and wellbeing, and also reduce costs from emergency hospital visits, unnecessary hospital admissions and length of stays (Priyanka, Tripathi, & Kitipawang, 2015). The differing applications of RPM lead to different architectural designs of RPM devices. On the other hand, most RPM enabled devices take after a general architectural design that consists of four functional sub units.

- Biomedical sensors that measure patients' vital signs.
- Local storage systems at the patient's site that interfaces between sensors and the remote data storage systems.
- Remote data storage system, to store data sent from sensors and other relevant sources.
- Diagnostic software that trigger intervention alerts and develop treatment recommendations based on the analysis of the collected data.

Depending upon the ailment and the vital signs that are monitored, diverse blends of measuring devices and software may be deployed (Malasingle, Ramzan, & Dahal, 2017)

Patient vitals, for example, heart rate, temperature, and other patient health information are gathered by sensors on measuring devices. Some examples of these devices include: pulse oximeter, and glucometer etc. The data gathered by these measuring devices is transmitted to health care providers or other concerned third party by means of communication devices and networks. This information is assessed for potential issues by a health care professional or by means of clinical decision support systems, and care givers and other concerned parties are quickly alerted if a problem is detected (Saleem, Muhammad, & Martine-Emrique, 2010). The major goals of RPM are to improve access to health care and reduce health care delivery costs. These goals are facilitated by delivering health care straight to the home (Pantelopoulos & Bourbakis, 2010). Monitoring of patient vitals is one of the most precise methods for detecting early disease onset, improvements, and deterioration (Patil & Khadelwal, 2013). Currently, patient monitoring is carried out manually and can be a costly process when continuous monitoring is required. Therefore, the need to automate this process and enable continuous monitoring of patients cannot be overemphasized. In this work, we hope to tackle this problem by developing a system that will enable the continuous monitoring of patients' heart rate and body temperature from any location.

The developed system will be able to provide the following services:

- To continuously measure heart rate and body temperature of patients.
- To upload measured data to a remote database server.
- To enable device and patient location tracking by acquiring GPS coordinates and sending to remote server.
- To send SMS alerts to care giver's phone when an anomaly is detected in the measured data.

The scope of this work includes the design of an RPM system equipped with temperature and heart rate measuring devices, a GPS receiver, and a GSM/GPRS module. This work leveraged on the fact that substantial research and development has been done in the area of biomedical sensors design, GPS, and GSM/GPRS. Therefore, our main focus in this project was the integration of the component hardware modules and the development of the software required to implement the system functionality specified.

2 LITERATURE REVIEW

In order to gain sufficient understanding and information about RPM device design and development, and other related information relevant to this work, it is necessary to review existing projects, research papers and the base technologies that support or have a relationship with this subject area. There are several academic projects and research papers about Remote Patient Monitoring devices, but we have chosen to review the most notable literatures that have a direct relationship or are very similar to this project work.

Remote Patient Monitoring projects and papers are based on the one fundamental problem of "building a device that will efficiently and effectively enable remote and continuous monitoring of vital signs from patients". Therefore, these projects often include an extensive study of the problem domain and a system specification and design that is expected to serve as an optimal solution.

A Heart beat monitoring and alert system using GSM Technology was proposed in (Ufoaroah, Oranugo, & Uchechuku, 2015). The paper showed the development of a system that was able to measure heart rate and send SMS alerts to a medical expert only when a set heart rate threshold value was exceeded. The system was made up of the heart rate measuring device, an LCD display, Arduino Uno board for data processing and signal conditioning, and a Quectel GSM Modem for sending alerts via SMS. One of the limitations of this system was that the data measured was not stored either locally or remotely for record and trend analysis but only served as an alert system.

An Implementation of a GSM Based Heart rate and Temperature Monitoring system was proposed by (Subhani, Sateesh, Chaitanya, & Prakash, 2013). The major components of the system were a Heart rate monitor circuit, LM35 temperature sensor, an AT89S52 Microcontroller and a GSM Modem. The system was able to measure temperature and heart rate and send the data via SMS to a predefined phone number programmed in the system.

(Krishna, Rokibul, & Maruf, 2014) developed a portable GSM-Based Patient Monitoring System. The system was able to measure four vital signs from a patient and send the data to the health care manager's phone via SMS. Four vital signs measuring devices were used, and the system could measure heart rate, blood pressure, temperature, and blood glucose level. The system used an ARM7 Microcontroller for data processing, signal conditioning and storage, and a SIMCOM SIM300 GSM modem for sending the measured data via SMS. One of their main targets was to build a low cost system which, if adopted, would be able to improve access to health care especially for the deprived masses. However, the system does not have GPS tracking system and cannot provide World Wide Web service.

A GSM Based Patient Monitoring System using biomedical sensors was proposed by (Atiya & Madhuri, 2016). The main theme of the paper is to continuously monitor the patient health parameters.

2.1 GSM

GSM which stands for Global System for Mobile Communications is a digital mobile telephony system that was developed by the European Telecommunications Standards Institute (ETSI). It is the most widely mobile communications system in the world. GSM uses a variation of time division multiple access (TDMA) and cellular technology to provide high capacity and extensive coverage. GSM digitizes and compresses data, then sends it down a channel with two other streams of user data, each in its own time slot. GSM operates in the 900 MHz and 1800 MHz frequency band (Haq, Rahman, Ali, & Faisal, 2017). Some of the services offered by GSM include DTMF, Voicemail, Short Messaging Service (SMS) etc.

2.2 GPRS

The General Packet Radio Service (GPRS) packet based data communication system for mobile devices that enables data to be sent and received across a mobile telephone network. GPRS is a packet switching network that is deployed on the existing circuit switched GSM network infrastructure . It enables services such as internet access for mobile devices connected to the GSM network (Haq, Rahman, Ali, & Faisal, 2017) .

2.3 GPS

The Global Positioning System (GPS) is a space-based navigation system that provides location and time information anywhere on the Earth surface. The GPS system was developed by the United States Government for the Military, although access to the system has been made available to civilians also. GPS generates specially coded satellite signals that are processed in a GPS receiver, enabling the receiver to compute position, velocity and time. Signals from four GPS satellites are used to compute positions in three dimensions and the time offset in the receiver clock. The GPS system consists of three segments namely:

- The Space Segment: This consists of Satellite constellations.
- The Control Segment: Ground Stations that monitor and control the GPS satellites.
- The User Segment: This consists of GPS receivers and the users.

3 DESIGN AND METHODOLOGY

In this section, the design process and methodology adopted in other to achieve the set goals for this work are stated and explained in detail. The design processes carried out here were mainly influenced by the literature reviewed in the previous section. Some of the system improvement recommendations gotten from the literature review were also taken into consideration in the system design process.

In the development of this system, the Modular Design approach was adopted. Modular Design is a system design approach that breaks down a system into smaller self-contained parts called modules. The modules have well defined interfaces and are reusable.

3.1 SYSTEM SOFTWARE ARCHITECTURE

The system's software was developed using Object Oriented Analysis and Design (OOAD) techniques. Shown below is the software architecture model, showing the software classes and object relationships. The system software architecture is shown in figure 1.

3.2 HARDWARE REQUIREMENT

The following hardware modules were used to achieve the desired system functionality:

- Arduino Mega2560
- SIMCOM SIM900A GSM/GPRS Module
- U-BLOX Neo-5M GPS Module
- Photoplethysmograph (Pulse Sensor device)
  - LM35 Precision Centigrade Temperature Sensor

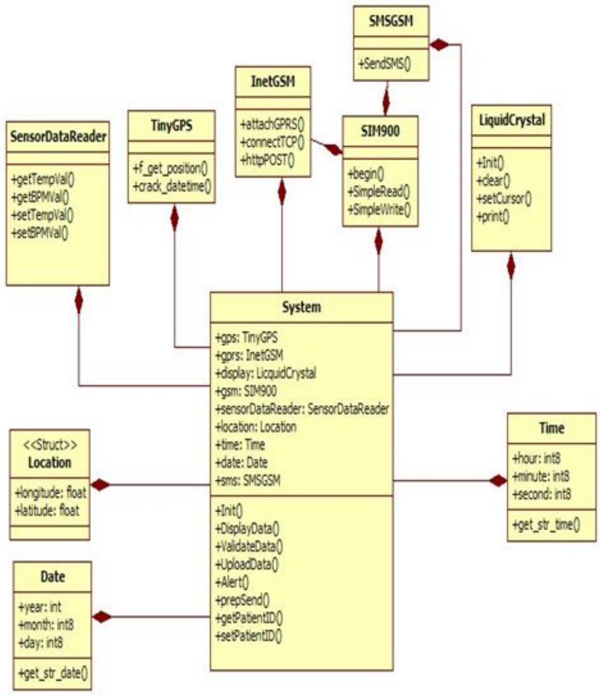

Figure 1: System Software Architecture

The Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller.

The Pulse Sensor Amped is a photoplethysmograph, which is a device the uses light to measure the changes in blood volume due to the heart movement. The signal produced by this device is used to determine heart rate.

The SIM900A is a complete Dual-band GSM/GPRS module which is designed specifically for small form factor and cost-effective solutions. Featuring an industry-standard interface, the SIM900A delivers GSM/GPRS 900/1800MHz performance for voice, SMS, Data, and Fax in a small form factor and with low power consumption. The LM35 temperature sensor is a precision integrated-circuit temperature device with an output voltage that is linearly-proportional to the Centigrade temperature. The LM35 sensor does not require any external calibration to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55°C to 150°C temperature range.

3.3 SYSTEM PROCESS FLOW

The system interfaces with the patients via the sensors, a sensor data reader object reads the data measured by the sensors and a sensor data analyzer object analyzes this data in order to validate the data and the data uploading system gets this data and uses the services provided by the

GPRS interface to upload this data to a remote server. The uploading system also acquires GPS coordinates from the GPS receiver device and uploads them to the server. The sensor data analyzer also calls an alert function whenever measured values go above or below some set thresholds. This alert functions sends an SMS message using the services provided by the GSM interface, to a preregistered phone number programmed in the system. The integrated system process flow is shown in the flowchart diagram of figure 2.

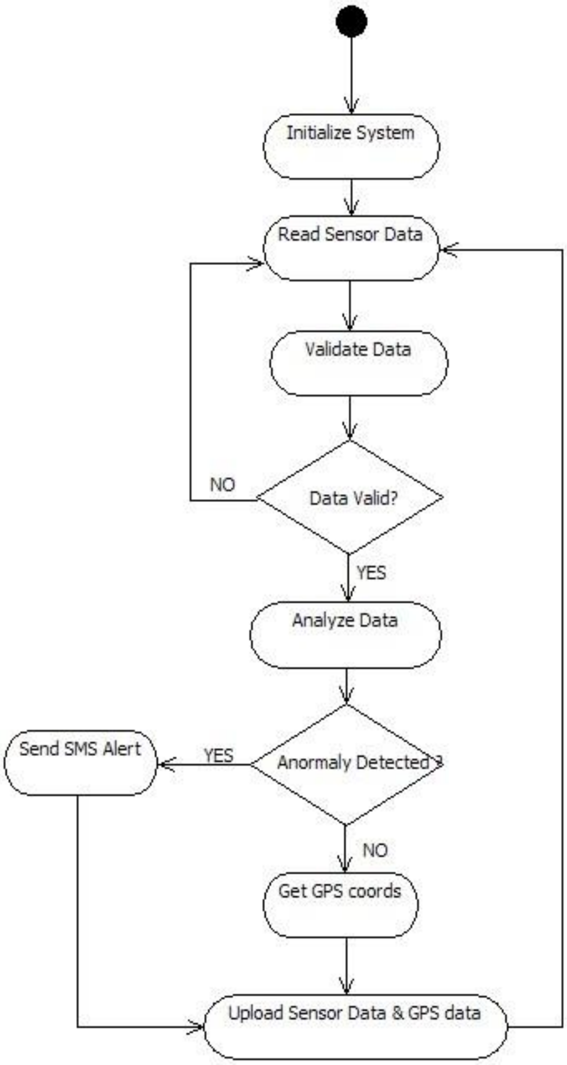

Figure 2: System Process Flow Chart

4 TEST AND RESULT DISCUSSION

This section shows the tests carried out and the respective results that were obtained. The developed system measures the heart rate and body temperature of a patient attached to it, and transmits this data to a remote server for storage in a database and for further processing. This measured data is also monitored so that it does not go above or below some clinical set values for normal conditions. Incase these measured values go above or below this set thresholds, an SMS alert is sent to a preregistered detail (phone contact) programmed in the system. The system also displays all these measured data on an LCD display. Also all the functional units used in this project to achieve the desired functionality were individually tested and their respective results recorded. A general system integration test was carried out and all the results were recorded.

4.1 PULSE SENSOR TEST AND RESULT

The pulse sensor used in this work uses optical signals to detect the variations in blood volume that occur during a heartbeat cycle. This data is converted into an analog electrical signal and processed with a microcontroller in order to determine the heart rate. We were able to accomplish that in this work, and the following results of heart rate measurements were captured at intervals of 1s for an observation period of 10 seconds. The result obtained for the measurement of the heart rate at an interval of 1 second is shown in table 1. It can be observed that the heart beat rate varies at different time.

TABLE 1: HEART RATE VALUES MEASURED BY THE SENSOR

Interval	Measured Heart Rate
1	120
2	92
3	90
4	87
5	81
6	76
7	78
8	80
9	75
10	70

4.2 LM35 TEMPERATURE SENSOR TEST & RESULTS

The LM35 is a precision centigrade grade (Celsius) temperature sensor with an accuracy of ±0.5 and linear scale of 10mV/oC rise in temperature. It was used in this project as the device for measuring body temperature. The test for this device was carried out in two stages. In stage one, the devices was left to measure the environmental temperature and the values were read at intervals of one (1) second for an observation period of 10s and the results were recorded in a table. In the second stage, we placed the device in the armpit area of the body the values were read for the same interval and observation period and the results were also recorded to produce the table 2.

TABLE 2: TABLE OF MEASURED TEMPERATURE VALUES

Interval	Measured Environmental Temperature	Measured Body Temperature
1	31.25	33.69
2	30.76	34.18
3	31.25	35.15
4	30.76	34.67
5	31.25	35.64
6	31.25	36.13
7	31.25	36.13
8	30.76	35.64
9	30.76	36.13
10	31.25	36.13

4.3 GSM Module Test & Results

The GSM/GPRS module is used in this system for connecting the system to the internet, and for sending SMS alerts to a phone number programmed in the system. The GSM/GPRS module is controlled using AT commands, and it was tested for registration to the GSM network, and for connecting to the GPRS network and acquiring an IP address. The module was connected to the ArduinoMega2560 board via the UART Serial1 interface, and the responses to the commands sent to the module were displayed on the Arduino IDE's Serial monitor interface as shown in the images in figure 3.

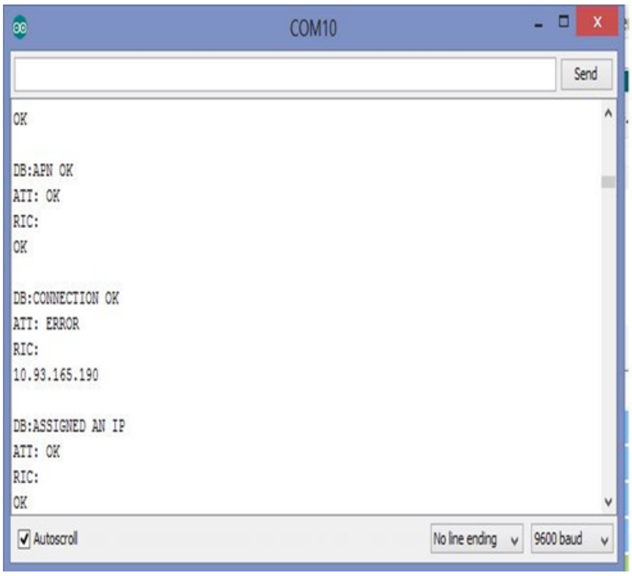

Figure 3: GSM/GSPRS Configuration Results via Serial Monitor

4.4 GPS MODULE TEST & RESULTS

The GPS module in this device is a GPS receiver that outputs GPS information from satellites in NMEA format. The output information from this module is processed with the microcontroller in order to extract location information, date, and time. The following image in figure4 is a capture of the data output by the GPS Module in NMEA format from the Arduino IDE's Serial monitor interface.

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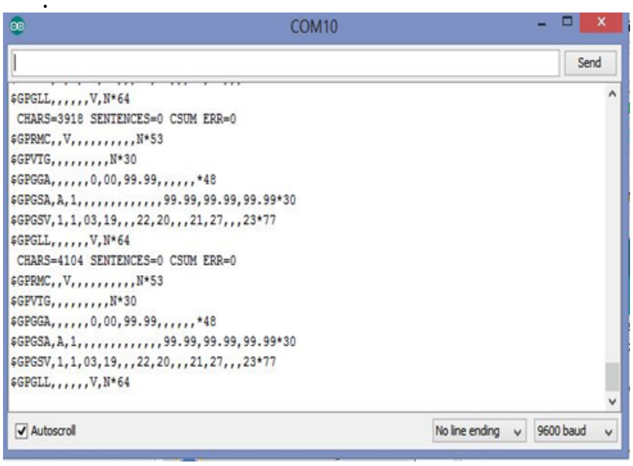

Figure 4: Received GPS information from module in NMEA format

4.5 System Integration Test & Results

The components mentioned in the sub-sections above are connected together in order to achieve some desired set functionalities. In the final general system integration test, test cases were generated for all the functions the system was expected to carry out. The system monitors heart rate and body temperature of patient and display information on an LCD Display. The measured data and GPS location coordinates is continuously uploaded to a remote database on a web server. An SMS alert is sent to a preregistered phone number when the measured values fall below or go above the set threshold.

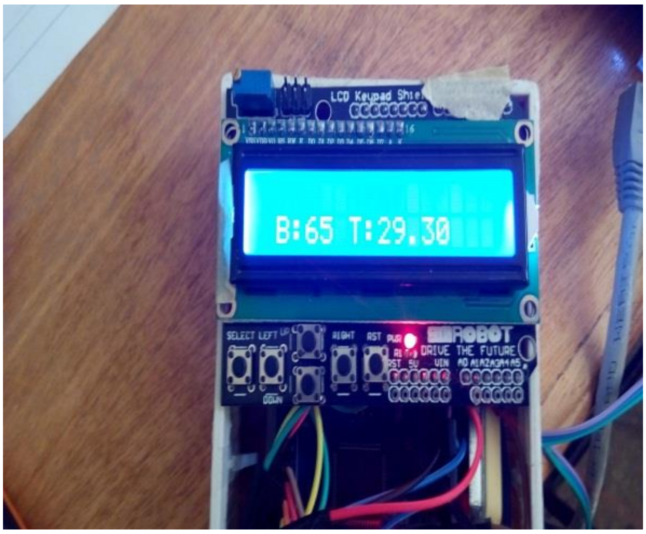

Figure 5: System Displaying Heart Rate and Environmental Temperature

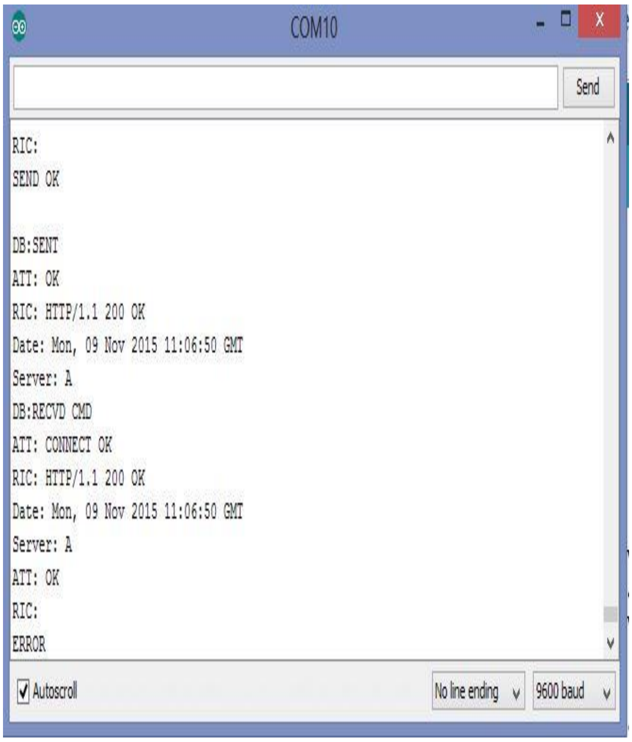

Figure 6: HTTP Response from server after data sent

+ Options

←T→				Date	Time	Heart_rate	Temperature	Latitude	Longitude
Edit	Inline Edit	Copy	Delete	2015-11-09	11:04:13	112	30.27	0	1000
Edit	Inline Edit	Copy	Delete	2015-11-09	11:04:34	82	30.27	0	1000
Edit	Inline Edit	Copy	Delete	2015-11-09	11:04:54	77	30.27	0	1000
Edit	Inline Edit	Copy	Delete	2015-11-09	11:05:08	103	29.79	0	1000
Edit	Inline Edit	Copy	Delete	2015-11-09	11:05:30	135	29.79	0	1000
Edit	Inline Edit	Copy	Delete	2015-11-09	11:05:54	88	29.79	0	1000
Edit	Inline Edit	Copy	Delete	2015-11-09	11:06:16	102	30.27	0	1000
Edit	Inline Edit	Copy	Delete	2015-11-09	11:06:50	177	30.27	0	1000

Figure 7: Snapshot of Data Received and Stored in database by Server

5 CONCLUSION

In this project we set out to develop a low cost remote patient monitoring system that could monitor the heart rate and body temperature of a patient. The results show that the system was able to monitor the body temperature and heart rate of a person. The result data was then uploaded to the server. The SMS Alert functionality also worked as expected. For future work, the system can be equipped with more sensors so that it can be able to monitor more vital signs. A web application can also be developed to display the plots of the data stored in the database for visualization and trend analysis. The GPS coordinates can also be connected to the Google Maps API and the location of the device & patient can be displayed on Google Maps.

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