Android-based real-time healthcare system

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Abstract: The human health becomes obsession for most people around the world, the heart diseases is one of many factors that threatens human lives, the objective of this paper is to provide medical intervention anywhere at any time using GSM and GPS technologies. This paper presents the design and implementation of a remote patient monitoring (RPM) system by utilising the cellular GSM technology in order to send short message service (SMS) to the responsible person typically the doctor in charge of following the patient health. The earlier mention technologies are indeed as easy practical, inexpensive and very effective way for transmitting vital information to the healthcare providers. The novelty of this paper appears by using an android-based application which is a user friendly application running either on smart phone or tablets. The android application records the received SMS and keep these messages in the database.

Keywords: smart healthcare; sensors; smart city; embedded systems.

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1 Introduction

Hypertensive heart disease was estimated to be responsible for 1.0 million deaths worldwide (Kearney et al., 2005). Rather than the hypertension heart diseases, the high blood can be a factor and attribute to cause many other disorders, such as stroke aneurysms, ischemic heart, and kidney disease. Hypertension increases the risk of heart failure by two or three-fold (Chobanian, 2003) and probably accounts for about 25% of all cases of heart failure (Kannel and Cobb, 1992). In addition, hypertension precedes heart failure in 90% of cases (Mathers et al., 2008), and the majority of heart failure in the elderly may be attributable to hypertension. Hypertension was ranked 13th in the leading global causes of death for all ages (Mathers et al., 2008). Statistics for the numbers of heart diseases were not available due to the bad condition of many countries of the Middle East region, so this project may encourage relevant institutions to collect such statistics.

In an era of laziness and lack of physical exercises, fat, sugar, meats, smoking, obesity and the lack of eating fruit and vegetables. Under the shade of difficult economic situation, physical fatigue, stress and to having dignified life the blood pressure disease has been the famous one in the last century due to poor eating habits. These neurological conditions are chief of this kind of illness, in many countries. Not only medical intervention is required to detract the effects but Smart and Innovative solutions should be adopted to increase the responsive actions quality in both time and level; and since Singh (2014) has identified eight key aspects that define a smart city concept namely the smart city concepts are: smart governance; smart building; smart infrastructure; smart energy, smart technology; smart citizen; smart mobility; and smart healthcare. In this paper we propose system architecture for smart healthcare based on GSM and GPS technologies.

Based on visiting hospitals, it was approved of the effectiveness of this project and its ability to facilitate communication between the patient and his doctor. Utilising the available services of GSM and GPS technologies to build a smart health monitoring system can improve and enhance the real time monitoring, where: GSM services are used for global communications any time and anywhere, GPS technology is applied for outdoor positioning.

Figure 1 System flow-chart (see online version for colours)

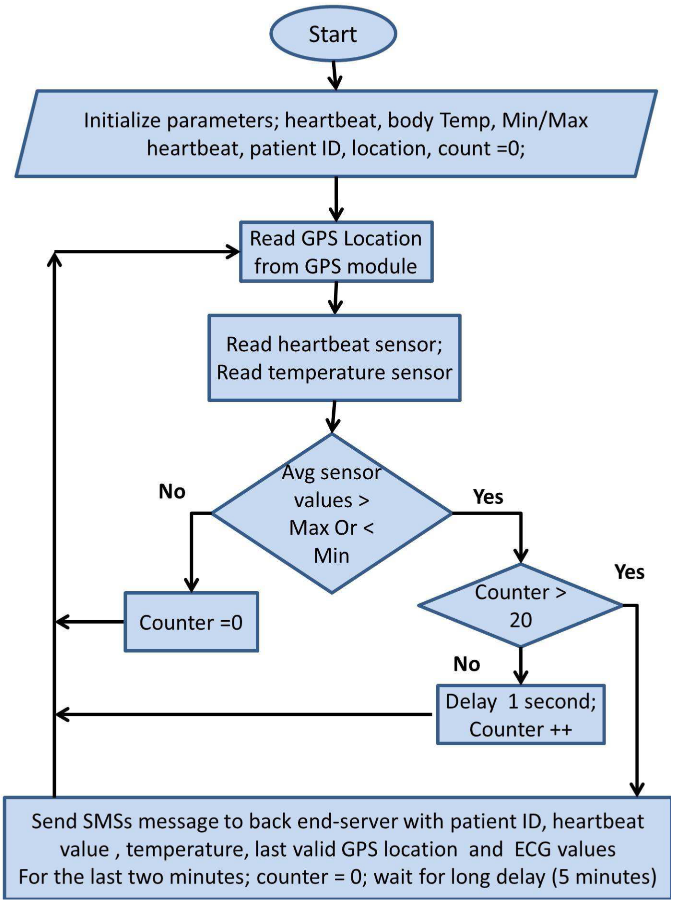


Figure 1 describes the flow chart of the suggested system, starting with reading the heart rate and body temperature by using specific sensors: pulse sensor and temperature sensor; the captured data will be compared via microcontroller i.e., Arduino with a given threshold. The Arduino also keep checking the position 20 times using the GPS module. The readings will be compared with the maximum and minimum stored values in the microcontroller, in the case that the measured values where out of the allowed threshold range a SMS will be sent immediately to the relevant person contains: the patient name, heart rate, body temperature, the patient's location and the corresponding UTC time-stamp. Electrocardiogram (ECG) could be drawn by sending the reading to a specialised processor.

The paper is organised as the following: Section 1 introduces the importance of the Smart Health system. Section 2 states the different emerging engineering issues. Section 3 provides a brief summary of similar research projects and papers. Section 4 presents insights structure of the proposed system and explain the main building blocks and the interconnection relationships among the system blocks. Preliminary results and their discussion are collected using the implemented parts of the proposed system are shown in Section 5. Finally, Section 6 concludes the paper and presents the future plans to enhance the proposed system.

2 Ethical, social and engineering issues

In the era of globalisation, the proposed system model could be implemented in different countries with different cultures and big diversity of legal and political enforcement and although the paper is focusing on the technical and engineering issues from ICT perspectives, we cannot overlook the issues created by its global possible implementations such as:

- *Social and political issues:* the system would create notable social impact by questioning the new relation between the patient and the doctor, and its effect on the medical work life style since the doctor will be always aware of the patient's current health condition by monitoring his vital readings through the proposed model any time, and any where. Moreover, the legal responsibilities should be defined in cases of system down, or misbehaviour, by ratification new regulations and laws to control and manage such cases.
- *Ethical issues:* the privacy dilemma for both patient's location and vital readings should be discussed with those who will be objects for the implementation and using the system, with different culture which may not accept such system functions in term of surveillance. Real time health monitoring systems, however, are only the foundation tool. Doctors, patients and any other potential system beneficiary must be educated about real time health monitoring in order to ensure that all of them perceive the privacy issues posed by such system. Moreover, doctors and patients need to be educated to understand how the proposed system and related technologies works, to be able to spot the system capabilities as well as limitations.
- *Security issues:* the digital immunity of the system relies on basic security mechanism such as authorisation and authentication provided, moreover the GSM technology is a secure and licensed technology by its standards. Deep inspection and security procedures must be carried out to ensure the system equipped with advanced and high security standards.
- *Sustainability issues:* although, the system is composed of low maintenance set of electronics, it cannot last functioning for ever due to its physical nature, so the system needs to consider periodic tests and inspections for realise system high sustainability, moreover, ICT system administrations is required to guarantee the system reliability. Notwithstanding, the system components should take into consideration low energy consumption.

- *Development issues:* healthcare sector needs both new applications using already existing components and development of new electronic components or software which enable a wider range of application possibilities in the healthcare monitoring systems.
- *Manufacturing issues:* enhancement in healthcare systems needs the suggested and proposed new systems to be manufactured and implemented in real life, even by impeding these technologies in smart phones and wearable devices.

3 Related work

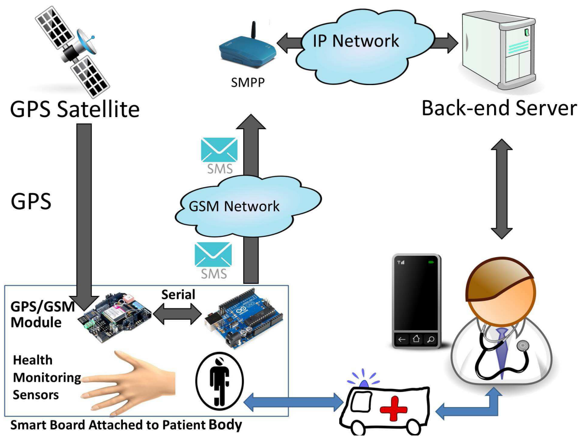
St-Denis, designed *LifeLine* project that can monitor heart rate, blood sugar levels, human's body temperature, and by using a wireless communication technologies to synchronise and display these information into a smart mobile phone or a standard computer. Such device gathers data from user and display some related graphs in order to encourage users to remain aware of their health conditions by providing a week to week feedback (St-Denis, 2015).

Eric Hariton, designed Gluco (M) wristband which monitors the blood glucose levels (Behance, 2015). Angle (2011) created a platform for tracking human biomechanics, starting with a unique sensor-based solution for posture and back pain. This solution is comprised of a discreet biomechanics-monitoring sensor, an engaging mobile app, and intelligent algorithms for a personalised user experience. Patent-pending solution harnesses the power of human movement data to provide real-time actionable feedback and to enable healthy behaviours (Angle, 2015). Thepu (2015) founded a Mobisante for ultrasound imaging that will be displayed. Healthcare workers in remote locations can check pregnant women, monitor a baby's health, examine patients for heart and lung problems, and triage other problems. Their phone can then transmit the images to a hospital for consultation (Thepu, 2015). In this paper, a tracking system will be designed and implemented for monitoring heart rate and body temperature. Early findings of the study can be found on Aziz et al. (2016) and Tarapiah et al. (2016).

4 Architecture and implementations

This section provides insights structure of the proposed system and explains the main building blocks and the interconnection relationships among the system blocks. Mainly, the proposed system aims to cover an end-to-end smart health application that can be build up from two functional building blocks. However the main function of the first building block is to gather all sensory data that are related to the monitored persons, whereas the second block functions are to store, process and present the resulted information of this stage to the doctors and nursery staff that are fallowing the case of the monitored person.

Figure 2 Proposed system model (see online version for colours)



As depicted in Figure 2, which illustrates the overall model when the patient's heartbeat rate changes badly, the Arduino which recorded pulse and LilyPad temperature sensors readings, orders GSM shield to send an SMS message containing these readings, patient ID and the location of the patient which has been taken via GPS shield, to his doctor's mobile phone, who – by his turn – send an ambulance to the patient's location.

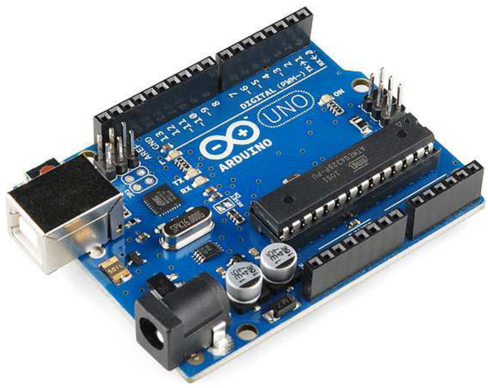
4.1 Smart embedded board (SEB)

This sub-section provides the hardware components details used to compose a smart board attached to the human body. Periodically, the Smart board senses the human health conditions using several dedicated sensor devices and then the broad conveys the raw sensed data to the back-end server application using GSM SMS.

4.1.1 Microcontroller

It is the core part of the SEB design; the microcontroller acts as the brain of the smart board that is holding the main board flow chart logic. However, there are many microcontrollers available in market and can perform well the main board logic such as PIC, Beagle-Bone, and Arduino. For the sake of demonstration proposes the choice falls on Arduino Uno according to its specifications and simplicity of use. Arduino Uno as depicted in Figure 3 this board is based on AT mega 32 microcontroller which has a set of 14 input/output digital pins, where six out of 14 can be used as a PWM output pins, also, the microcontroller board has six analogue inputs, a ceramic resonant of 16 MHz, an USB interface, a DC power jack, a reset button, and ICSP header. The USB interface, simplifies the connection of the microcontroller with the computer, also the USB can be a power supplier for the microcontroller board (Arduino Uno, 2015).

Figure 3 Arduino microcontroller (see online version for colours)



4.1.2 GPS/GPRS/GSM MODULE V3.0

This is a GPS/GPRS/GSM shield from DFRobot as depicted in Figure 4 is a quad-band GSM/GPRS engine that works on frequencies EGSM 900 MHz/DCS 1,800 MHz and GSM850 MHz/PCS 1,900 MHz. It is also Supports GPS technology for satellite navigation. Sending messages via GSM network controlled via AT commands (GSM07.07, 7:05 and SIMCOM enhanced AT Commands). The design of the shield allows driving the GSM and GPS function directly with any computer and Arduino board. GPS/GPRS/GSM shield includes a high-gain SMD antenna for GPS and GSM. The consumption expenditure of SIM548C is an embedded chip from SIMCom (DFRobot, 2015).

Figure 4 DFRobot GPS/GPRS/GSMMODULE V3.0 (see online version for colours)

4.1.3 Heart beat pulse sensor

Figure 5 shows the heart beat pulse rate sensor, whereas the pulse measurement is not an easy task; pulse sensor measures the heart rate optically, amplifies the signal and eliminate the noise by connecting the sensor directly to Arduino or any other controller with working voltages from 3 to 5 V. Simply plug the sensor on the ear or finger sensor and consider that the maximum wire length of about 60 cm (4project, 2015).

Figure 5 Heart beat pulse sensor (see online version for colours)

4.1.4 Human body temperature sensor

In order to measure the human body temperature we have used YSI 400 rectal patient monitor temperature sensor probe, as stated in Figure 6. The program of YSI 400 series compatible medical temperature probes and YSI 400 series compatible medical thermistor sensors for patient monitoring are designed for use with integrated patient monitoring systems and individual temperature monitors. The intensive care temperature probes are divided into groups related to their measuring points of body temperature and the categories of patients.

Figure 6 YSI temperature sensor (see online version for colours)

The program of YSI 400 series compatible temperature probes is based on exclusive use of PVC free materials like medical grade silicone and stainless steel and plastic materials. It consists of YSI 400 series compatible intensive care temperature probes which are designed exclusively for rectal body temperature monitoring with a design that lock the temperature probe in the correct position, which in particular is important under body temperature measurement and febrile patient monitoring (medicalthermometry, 2015).

4.2 Online-web-based monitoring application

Doctors and nurses are provided with a simple web-based application to track and monitoring the patient's health conditions. The implemented web application is accessible through a standard web browser, smart phone and tablets devices. The REST (RESTful) software architectural style has been adapted to insure the resulted web application is scalable and flexible. Moreover, communication among the web application modules uses JSON data representation. Furthermore, the implemented system leveraging on the well known three-tier architecture (Eckerson, 1995):

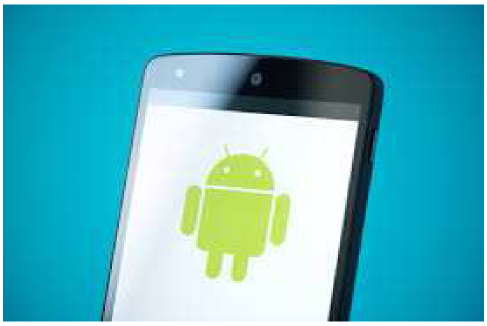
1. The front-end represents the web-page which is accessible by the doctors and nurses. This part uses several web technologies such as hypertext transfer markup language version 5 (HTML5), cascading style sheet (CSS), the open source JQuery software library and Javascript client side programming language. However, a bidirectional data communication channel is maintained between this tire and the middle tire through the Asynchronous JavaScript AJAX technology. The final web-page is responsive and is running on smart phones, tablet devices and standard PCs.
2. The middle tire which hosts the main server logic has been developed using PHP programming language and this logic has been deployed on an Apache web server. This tire uses RESTful style to expose its internal functionality towards the client side web-page as well as this software tire leverage on the MySQL native driver for PHP in order to store and retrieve data.
3. The back-end tire which hosts the MySQL database server and this database is used to store all the patient data, system users (doctors, patients and nurses, patients' medical profiles and their corresponding alerts. This design of this module is based on a relational database structure. However, health data records and patients' positioning information are time stamped using the standard UTC reference time.

In a RESTful software architectural style every thing is a resource and for each resource there is a URI (Universal Resource Identifier) that represents the corresponding resource unique address. Moreover, there are four verbs that are usable to transfer and manipulate any resource representation. Finally, the word CRUD refers to these four verbs and the C letter is coming from create, R from read, U from update and D from delete.

4.3 Mobile application, android application

World is contracting with the growth of mobile phone technology. As the number of users is increasing day by day, facilities are also increasing. Starting with simple regular handsets which were used just for making phone calls, mobiles have changed our lives and have become part of it. Now they are not used just for making calls but they have innumerable uses and can be used as a camera, music player, tablet PC, TV, web browser, etc., and with the new technologies, new software and operating systems are required. Android operating (logo 7) have developed a lot in last 15 years. Starting from black and white phones to recent smart phones or mini computers, mobile OS has come far away. Especially for smart phones, mobile OS has greatly evolved from palm OS in 1996 to Windows pocket PC in 2000 then to Blackberry OS and android (Android, 2015).

Figure 7 Android application (see online version for colours)



5 Results and discussion

A well functioning system prototype was build composed of the following hardware components: LilyPad temperature sensor, pulse sensor, GPS/GPRS/GSM MODULE V3.0 and the Arduino integrated together to perform a healthy system as shown in Figure 8.

Figure 8 System hardware model (see online version for colours)

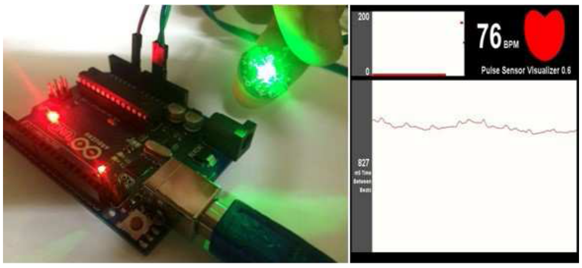


Figure 9 Temperature sensor interfacing circuit (see online version for colours)

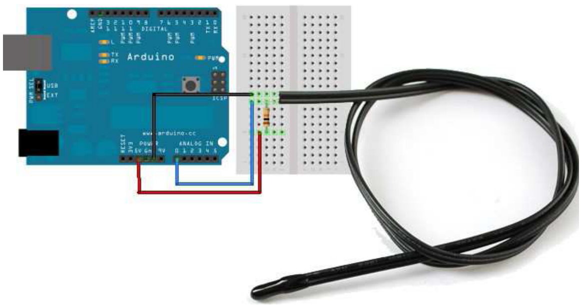


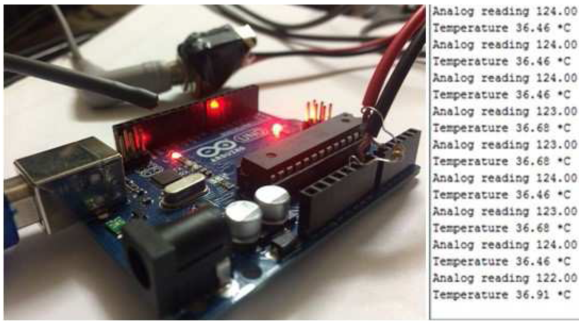
Figure 9 shows the interfacing circuit between the temperature sensor and Arduino microcontroller. For achieving an accurate and precise patient's temperature readings the system developers work with Steinhart equation which models the resistance of semiconductor (temperature sensor) at different temperatures. For simplicity and prototype purposes the computed temperature values are based on beta factor method instead Steinhart equation (Steinhart and Hart, 1968).

Table 1 Error percentage: system readings vs. in site standard device readings

Heartbeat/temperature	*System reading*	*Standard device reading*	*Error percentage*
HeartBeat	*86*	*84*	*2.3*
HeartBeat	78	77	1.2
Temperature	36.91	37.2	0.78
Temperature	36.46	36.1	0.83

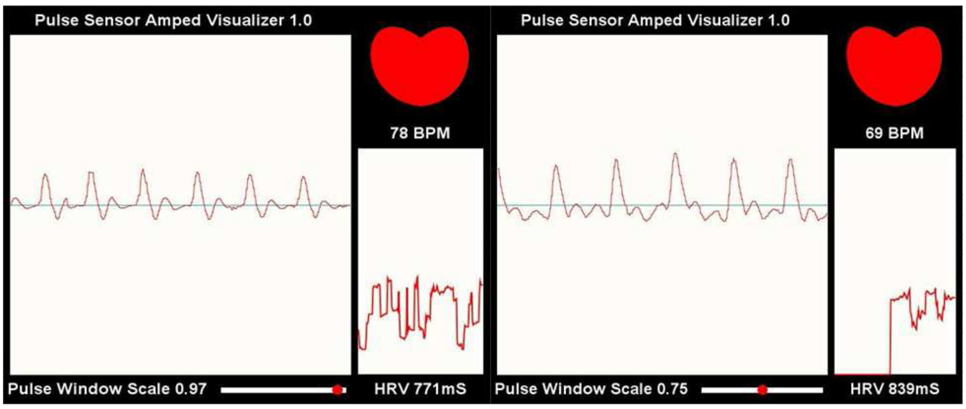
Table 1 illustrates results of in site experiments on both the prototype and traditional sensors – heartbeat and temperature – used by doctors in real life to diagnostic patients' health conditions. For both sensors – heartbeat and temperature – used in the prototype the observed readings are similar to the corresponding sensor reading used by in site doctors with a minor error percentage that is tolerated for both cases, Heartbeat and Temperature readings.

Figure 10 Temperature sensor readings (see online version for colours)



The connected temperature sensor shown in Figure 10 gives us the variable resistance translated to the temperature by Steinhart equation.

Figure 11 Normal ECG (see online version for colours)

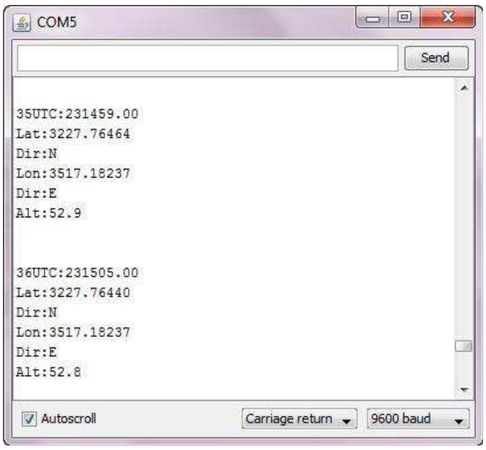


In order to analyse, test and validate the system demonstrator several experiments has been performed and the results presented in Figure 11 shows the ECG – which had been drawn using simulation software – for a healthy normal persons. It is clear that the normal heart rate is in the range of 60–90.

Figure 12 Unconnected pulse sensor ECG (see online version for colours)

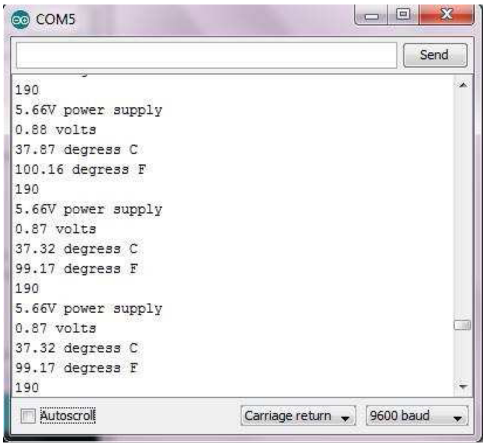
While Figure 12 shows the ECG when the sensor was unconnected to the human body.

Figure 13 The position took by GPS module (see online version for colours)



In the other hand Figure 13 demonstrate the position (geographical position longitude and latitude) which was collected using GPS/GPRS/GSM module.

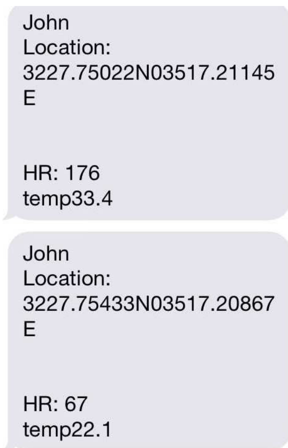
Figure 14 LilyPad temperature sensor readings (see online version for colours)



While the LilyPad temperature sensor readings are illustrated in Figure 14 in terms of corresponding voltage level and temperature degrees both in Celsius degree and Fahrenheit degree. Finally, all these results are displayed on the serial monitor.

The sent SMS including PatientsâĽ™ name, heart rate, body temperature, longitude and latitude of the position are exhibited on Figure 15.

Figure 15 The SMS exchanged by the system (see online version for colours)



And by using GoogleMap the location of the patient could be determined, and appeared in the SMS shown in Figure 16.

An android application has been developed to build a user interface that contains three components which are the login activity and the patient information and database contains the whole data. The login activity gives the interface to the doctor in order to control the patients data and it has the ability to access the database based on authentication authorisation accounting (AAA), AAA authentication can be used to authenticate users for administrative access or it can be used to authenticate users for remote resources, After users are successfully authenticated against the selected AAA data source, they are then authorised for specific network resources, while the AAA accounting collects and reports usage data. This data can be used for such purposes as auditing or billing. After the doctor insert his username and password the program open the next activity which is allow the user to control more options which are add patient, show the list of patients in addition to editing and modifying on the database as shown in Figure 17.

Figure 16 Google maps patient location (see online version for colours)

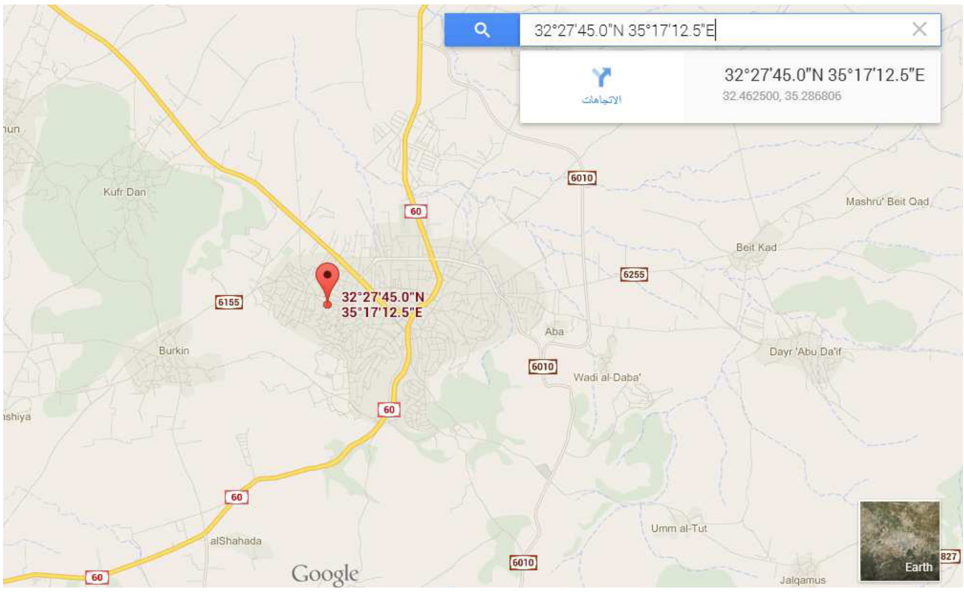
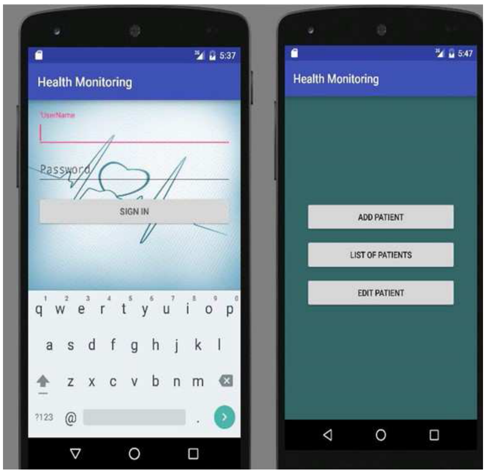


Figure 17 Layout for authentication of android application (see online version for colours)



Where, the patient activity contains important information about the patient himself which are his name, gender, phone number, ID, birthday, blood type, etc. as shown in Figure 18.

Figure 18 Layout for patient medical record (see online version for colours)

6 Conclusions

This paper stated the design and implementation of a well-functioning and reliable system for healthcare monitoring in real-time by following the human vital readings such as heart pulse rate and human body temperature. This design depends on using mainly GSM, GPS, Arduino microcontroller, heart beat sensor, and body temperature sensor in addition to use an android application as an end graphical user interface (GUI). The merit of this project relies on its future development targeted in two factors; first one: its multi-uses and services by making some modifications on the software, so many diseases and illnesses like Alzheimer, mental and motion patients could be benefited from this system; second factor: wireless technologies cloud be used to avoid wired connections which somehow may limit the patient mobility.

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