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Long Term and Remote Health Monitoring with Smartphone

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Abstract: The basic aim of our work is to provide solutions with monitoring the heart beat rates of disabled or old people. And also we expect to help the people who have specific heart diseases like potential cardiac arrests and cardiac pacemaker carriers. Besides in case of emergency situations, our system will produce an immediate alarm to provide urgent help for the patients. In the system, emergency situations depend on the heart beat rates. If the heart beat rates of a person decreases at lower rates compared with normal heart beat rates or if the heart beat rates of a person increases at higher rates compared with normal heart beat rates or if big heart beat rate changes occur during the predetermined time period then these situations will be evaluated as emergency situations and these situations should be announced to considered people and places like hospitals, patient's doctor and patient's family members. The proposed system collaborates with smartphone and includes sensors to collect data from the patient. Also the system is used to process and compare data with predefined normal heart beat rates by patient's doctor and to notice if there is an emergency situation. Besides, in case of an emergency situation, the system sends messages including the patient data and location to the hospital and patient's doctor to inform them. But if there is not an emergency situation exists, then the system stores the collected data and sends them as daily and weekly graphics to the patient's doctor. These graphics are collected as a result of definite daily activities like sleeping, sitting, standing, walking and jogging. The results are compared with the doctor's determined normal heart beat rate intervals for every activity period.

Keywords: *Remote health monitoring, GPS, wireless sensor network, sensors.*

1. Introduction

Due to the developments in the technological areas of wireless communication and embedded computing, recently remote health monitoring and mobile health attract more attention. Therefore, low cost and portable health monitoring devices become more feasible. Today, diagnosing and patient caring with wireless technology presents convenience and contentment for patients. Wireless technology ensures requirements of each patient individually together with considering their life standards. The main aim of remote health monitoring is monitoring patients at anywhere and anytime. Thus, the patient's life standard will not be affected and the patient will lead a carefree life [1].

With the remarkable developments at wireless sensor network technology, monitoring daily activities of patients [2] at indoor [3] or at hospital [4] become easier with the wearable sensors [5-7]. A pulse oximeter prototype is developed with using a IEEE 802.11 (Wi-fi) including PDA by WiiSARD [8]. In US army, at the psychological state monitoring project, heart beat rates, metabolic energy loss rates of a walking person, body temperature, location information and movements are monitored [9] .

In the paper, heart beat rate data are acquired with an embedded system. Then collected data are sent to a mobile phone used as a gateway with IEEE 802.15.1 Bluetooth wireless communication standard. The data can be analyzed and stored and results can be displayed on the mobile phone screen. If an emergency situation occurs, the mobile phone sends the information to the central server using Wi-Fi or GSM/GPRS wireless technology. In this way, real time remotely monitoring can be achieved. Thus, people can be monitored at the outside of the hospital and also an early treatment may be possible. Furthermore, location data which is obtained from GPS receiver is shown on the digital map and individual patient location related units, like hospital, patient's doctor and relatives are informed. The system is used by twenty patients for testing. Because of the system's user friendly interface and simple sensor structure, the patients found the system easy to use and useful for everyday usage. Developed portable monitoring system may remind you about drug taking hour, meal eating hour and exercise making hour etc. in the future. Thus the proposed system makes daily life easier for the patients, pregnant women, firemen, and soldiers. The system provides health monitoring outside the hospital. Besides, the system can be used as a long term and portable data storing unit in arrhythmia diagnosis and stress monitoring.

The rest of the paper is organized as follows. The proposed system description is given in Section II. Implementations and user interfaces are explained in Section III. Eventually, concluding remarks are proposed in Section IV.

2. Proposed Architecture and Components of the Proposed System

In the system, heart beat rates are gathered and transmitted by the pulse sensor from the patient as in figure 1. The hardware part includes an embedded system which is composed of a microcontroller, Bluetooth and a sensor. The utilized softwares

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are Arduino, C and Java over the hardware part. Furthermore, the software part includes mobile application software, web service software, a data base design and windows form software.

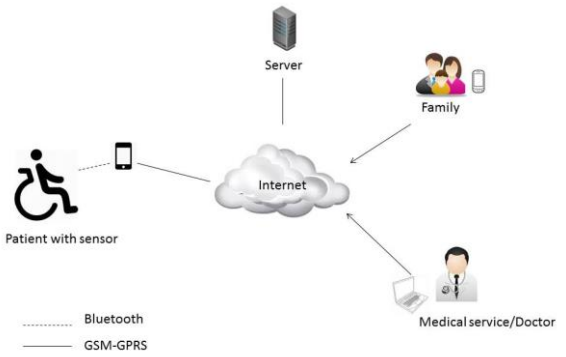


Figure 1. Basic architecture of the system

A microcontroller can work by itself, communicate with other electronic circuits and perform the needed functions for the application with owning definite amount of memory units and input/output ends. They may be used for collecting and processing information that are received from the sensors because of including analog-digital converters. They are small sized, low power consuming, low cost but high performance owning devices, thus they are mostly preferred in electronic technology especially in embedded systems. In our work, we used Arduino Uno R3 as a microcontroller. Arduino owns a simple I/O card and uses a processing/wiring programming language. It is an open source physical interaction platform. At each of the sender and receiver sides, a microcontroller and a software for microcontroller which is developed at processing/wiring programming language and compiled at Arduino IDE are used. Processing IDE is also used for displaying the received data at the computer. As a Bluetooth module, Arduino Bluetooth shield is used for providing the transmission of the coming data from the pulse sensor to the smart phone over microcontroller. In the proposed system heart beat rates are collected from patients by the pulse sensor which is presented in figure 2.



Figure 2. Pulse sensor utilized in the proposed system [11]

In general, in pulse oximetry method the SpO_2 measurement is performed with HbO_2 (oxyhaemoglobin) and Hb (hemoglobin) molecules' different sorption characteristics which are at the red and infrared spectrum [5,10]. The pulse oximetry system has an optical converter, two LED diodes that spread infrared and red light and also a photodetector which is sensitive at both of the lights' wavelengths. The light data gained at the photodetector end is converted to the voltage by the current-voltage converter. The output of the circuit is processed at an amplificator layer to be able to end the high frequency noise. Gained light data is converted to an 8 byte signal with an analog numerical converter and transmitted to a microprocessor owning system. And the data is transmitted to the microcontroller which is Arduino Uno R3 over the serial port [5,10].

At the Bluetooth module, we make loading with the Arduino coding. To be able to examine the loaded data we utilized from Bluetooth test application to monitor the sending and receiving phases of the data.

Another application which is used in the system is mobile application software. It works on the monitored patient's smartphone. The embedded system sends the medical parameters that are measured at the patient to the patient's smartphone periodically with Bluetooth technology. In the system, serial port profile (SPP) service is used as Bluetooth service. At the emergency situations, collected medical data are sent to considered people and places by the mobile application. Flowchart of the system with basic steps is given in figure 3.

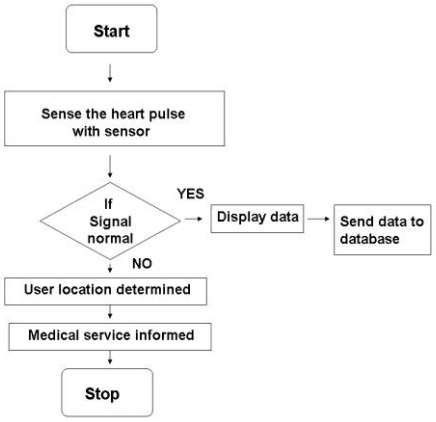


Figure 3. Basic flow of the system

Also in the system, informing the patient about her own situation is also considered. The interpreting of the collected data is a vital factor in monitoring systems because presenting the raw data to the patient may not help him/her. Because we should not expect the end user to have an idea about the medical parameter values or rate meanings, thus, brief explanations about the collected values should be given in the system. While presenting the heart beat rate value as for example 65, it will be better to give the meaning of the measured rate as normal, low or high for his/her age. For this reason in our work, we presented the data received from the sensor together with the interpretation of it with our data interpretation part.

3. Proposed System for Health Monitoring

For using our system, the user enters the system with his/her email and password which is the serial number of the device as given in figure 4. At the first entrance to the system, the user should enter his/her personal information like name, surname, age, height, weight, blood type, telephone number and address for keeping as a record as illustrated in figure 5.



Figure 4. Interface of login part

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Afterwards, the patient mounts the sensor on his/her finger or ear lobe to collect the pulses. The pulses are collected with the system and compared with the intervals in table 1 then presented to the user by the application interface with the interpretation of the pulse rates. The cardiac outputs are influenced by many factors. At sleeping state, there will not be a change. But while eating there will be 30 % increase and while exercising there will be nearly 700 % increase occur at the outputs. Also, at anxiety state, the increase may be between 50 and 100 %. At sitting or standing positions from lying there will be decrease between 20 and 30 %. Besides, special situations of patients may also affect the outputs like pregnancy. Pregnancy condition increases the outputs [12]. Therefore, we considered many of these factors as lie state, stand state, jog state, and run state together with the gender factors with male and female options in our system as given in figure 6.



Figure 5. Interfaces of registration part

At the mobile application design part, we used visual studio as an application development editor with windows phone application design 7.1 SDK and we utilized from Dev Express for designing the interface.

The communication infrastructure which is the vital part of the system is constructed with the Windows communication foundation (WCF). It is a framework API that is used for developing distributed applications. Many important functions are provided by this part of the system. These functions are:

- Record Emergency Situation: Previously occurred emergency situations are managed and recorded at the center.
- User Data: User data providing method.
- Personal data: Personal data providing method.
- User Data Add: User data recording method.
- User Detail Add: Detailed user data recording method.
- User Login: Controls the email and password of the user while entering the system.
- Personal Login: Controls the email and password of the personal while entering the system.

SQLite and SQL Server is used as database in the system. Medical service part of the system is designed as windows form application. It is used as displaying interface of the data which is sent from the telephone to the medical service as in figure 7.

Table 1. Cardiac function changes [12]

Work (kg-m/min)	Pulse Rate (per min)	Cardiac Output (L/min)
Resting	64	6.4
288	104	13.1
540	122	15.2
900	161	17.8



Figure 6. Heart beat rate measuring state determination interface and pulse rates of patients



Figure 7. Hospital automation interface

In figure 7, at the left side of the interface page, user account entrance is shown with user name, user surname and user password text boxes. Here, user enters his/her name, surname and password to be able to enter the system. And at the right side of the page, system entrance, help and about buttons are placed for the users.

In critical emergency situations, the system immediately determines the location of the patient with GPS on the map and inform medical services as in figure 8. The emergency situation can be ended with entering an explanation over this interface or with the help of the location information an ambulance request can be sent to the nearest hospital [13].

Also, to prevent critical emergency situations, for less important discomforted situations the system can present and show some advises that are determined in advance for the patient by his/her doctor. By this means, the doctor can define the critical value intervals and some personal advises that should be applied by the patient at definite situations for every one of his/her patient by the system.



Figure 8. Location information interface

In the system, the emergency situations are listed in detail. Also, these emergency situations can be sorted according to the critical value levels, the date, etc. The details of an emergency situation can be seen together with a link on the page providing the latest health parameters of the patient.

4. Conclusion

The main aim of our work can be summarized as providing real time medical monitoring with mobile applications, informing considered people and places like doctors, relatives and hospitals at the emergency situations and providing early intervention for the probable illnesses for ill and old people. Also, with the proposed system, the obligation of staying at hospital for medical controls will be decreased. The medical maintenance and monitoring of patients out of the hospital will be cheap and easy. With the low power consuming, low cost, wearable and portable systems, the movements and daily activities of the patients will not be affected or restricted thus the patients will be as free as in their normal life which was before their illnesses so the life quality of the patients will be improved. Also, the collected data will be analyzed immediately and the doctor and the patients will be informed instantly about patients' health situations.

In the future, we will focus on body temperature and respiration rates of patients for helping anxiety and physiological problems. During the whole day collecting body temperature and respiration rates together with heart beat rates of patients will help doctors to learn which factors affect the patients' mental state. The behaviors of the patients' at crowded, noisy, silent environments can be examined, also when they are alone, their reactions to people, animals or environmental changes around them can be examined. With collecting these data, many mental illnesses can be examined, understood, and new solutions can be improved.

Besides, remote health monitoring can be examined together with smart homes. The positions of the old and ill people may need 24 hours monitoring in their home. If they fall, faint or do not move for a definite time period, then an emergency situation emerges. The determination of such an emergency situation can be easily performed by smart home and remote health monitoring systems. And then an ambulance is called and relatives are informed. Furthermore, until the arrival of an ambulance, the environment around patient the can be designed according to the patient with adjusting the temperature of the room, opening/closing windows, closing television, closing stove and opening lights by the smart home systems.

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