Heart-rate monitorization system

Sensors, Actuators and IoT

Submitted by: Sara Cooper (H00304345)

Hanako Audry (H00310152)

Linda Estelle Mbongue Nguissi (H00309490)

Department: Engineering & Physical Sciences (EPS)

Supervisor: Dr. Mauro Dragone

Contents

List of Figures

List of Tables

1. Definition of aims and objectives

There are 3 main objectives:

1. Design a low-cost and miniaturized device that allows for pulse rate monitoring accurately by using a microcontroller that gathers information parameters and sends them through wireless technology.
2. Provide a user-friendly app and a remote monitoring system using the ThingSpeak IoT platform and Android studio, ensuring data privacy all the while
3. Implement an alarm system that is activated whenever pulse rate is abnormal

2. Motivation

Cardiovascular disease is one of the major causes of death worldwide, which can be brought about by a heart attack or stroke, for instance. Constant heart rate monitorization is especially important for these people, to detect possible abnormalities -such as arrhythmia or bradycardia - that may indicate a risk of suffering a heart rate.

However, in-hospital stays are expensive, as are the transport costs to the hospital that would be required for frequent check-ups. In addition, people in general prefer to stay at home. Home-care can be greatly improved by means of Internet of Things, that permits efficient connection between different devices and access to their data remotely. By designing a heart rate monitorization system that is based on IoT, it would be easy to collect heart rate from home, reduce cost, and give patients more freedom over their lives, while also enabling quick connection to professionals in the event of an emergency.

3. Literature analysis

Heat rate is the number of times the heart beats in a minute and is produced via depolarization at the sinoatrial and atrioventricular nodes in the heart. The most common areas to locate pulse is the wrist, neck , inside the elbow, behind the knee and ankle joint.

Heart rate can be measured manually, by using the radial method -the pulse is taken on the wrist - or the carotid method -taking it on the throat. However heart monitoring devices are more accurate than manual methods, as they give continuous readings. Some devices that display heartbeat readings digitally include pulse oximetry, electrocardiography (ECG) and blood pressure monitors. Out of these the ECG is the one that detects the heart beat signals and shows it graphically. However, there are many sensors and cables connections, fluctuations in the

signal and noise, not to mention that it may be uncomfortable for continuous motorization. That is why a simple photoplethysmograph (PPG) is better suited.

PPG measures the changes in blood volume by illuminating the skin with a LED, and then measuring the amount of light either transmitted or reflected to a photodiode.

Normal heart rate differs depending on the age and health condition of a person. For the average adult, this is of around 70 beats per minute (BPM) for males and 75 beats per minute for females. A person may be considered to be in the “normal” heart beat range if it between 60 and 100 BPM. A lower value is considered bradycardia, while a higher value tachycardia[1, 2].

Several works have been done so far regarding the design of pulse rate monitoring system, based on a microcontroller.

In many cases the beats per minute that are collected through an ARDUINO are visualized on a LCD screen[3]. While this can be a cheap solution, it doesn’t allow keeping track of the data as it doesn’t possess a database, and as is not possible to evaluate how the patient’s health is progressing. In addition, there is no interconnection with professionals that can be notified if the patient’s condition worsens.

Hoping to create a better user-interface, some works have addressed custom-designed Android apps interconnected with Arduino.

In [4] the pulse rate sensor data is received by an Android App via Bluetooth connection. However the app only serves to display current heart rate data and is not connected to an IoT platform to allow for remote access.

To enable remote data access, many cases use the ThingSpeak open-source IoT platform and API to store and retrieve data from things using the HTTP protocol over the Internet or via a Local Area Network[4,5,6].

It can monitor data and control the system over the internet. ThingSpeak ‘Collects’ the data from the sensors, ‘Analyze and Visualize’ the data and ‘Acts’ by triggering a reaction.

Thanks to the visibility of charts, it is also easy to evaluate the progress of the patient, which can be accessed by both patients and doctors alike. It also serves to store a database with all patient history and allow devices such as mobile phones to access the data as well.

Some other data visualization methods include freeboard.io, which is also connected to ThingSpeak [7].

Some works integrate the use of ThingsSpeak with Android Apps, to both allow storing and chart visualization on the laptop but also to provide a friendly user-interface through the phone.

An option is to use the application ThingsView, an app to visualize charts of ThingsSpeak. ThingSpeak. However, while this may be interesting to view how the heart rate of the patient has been changing in time, it would also be necessary to devise a way to only show the current beats-per-minute to facilitate real-time monitorisation [3] .

In [8] a rather exhaustively designed app is targeted at both the patient and the remote doctor. The app can listen and write data to ThingSpeak, which is the core of the system that contains patient history. The app’s interface is different for the patient -where he/she can

measure the heart rate or view the history - or for the doctor - which includes a list of patients under his/her care and access to their data.

An important part of a monitorization system is to reach for help when needed. In [8] for instance a buzzer is connected to the monitorisation system that sounds whenever BPM values are outside the normal range. In [3] the web server automatically sends an alert message to the doctors twitter account. Other ways of alerting the doctor would be by email or by SMS. In the present project the alert will be sent to the doctor's phone by SMS, as is most likely to obtain the highest response from the doctor.

Another important aspect when dealing with medical records on the cloud is data privacy[9].

Access should be restricted to the patient and doctors and/or nurses that are in charge of the patient. This can already be achieved by creating a private channel on ThingSpeak, which can be accessed by a 16-digit API key. This digit will be required to both read and write data to the channel.

Furthermore, to view data on the app, access can be restricted by requesting username and password when accessing the data from the app. In most cases, the patient will be given a medical ID, which the doctors will also need to introduce to view their status[8].

An important thing to take into account is that heart rate will also be different depending on the level of activity of the person. That is, in the works mentioned so far that include an alarm system, it is assumed that the person is resting at all times while the heart rate is being monitored. However, if a continuous monitorisation is desired, while also allowing the patients to do other activities, it would be beneficial to include a system that takes this factor into account.

An accelerometer enables the system to identify whether the patient is in resting state or having a vigorous activity.

According to [10] a person's heart rate is stable or not, depending on the conditions seen in table 3-1.

Table 3-1 Heart rate state depending on BPM and accelerometer data

BPM reading	Accelerometer reading	Diagnosis
Normal	Low	Patient is resting and heart rate is stable
Normal	High	Patient is having a light activity and heart rate is stable
High	High	Patient is having an excessive activity, heart rate is stable but needs precaution
High	Low	Heart rate is abnormal

The project will therefore also have to take into account the accelerometer data to determine when to send an alert to the doctor.

4. Technical requirements

The system must:

- Be portable and have low power-consumption
- Be easy to use
- Allow for remote monitorisation by connecting the ARDUINO with IoT platform ThingSpeak wirelessly
- Include a user-friendly Android application that reads data from ThingSpeak and displays the beats per minute -current and history.
- Ensure data privacy by having the app password protected and creating a private ThingSpeak channel
- Have a mechanism to send alerts to doctors (SMS) when heart rate is considered to be unstable

5. High-level architecture

The pulse rate sensor is attached to the patient's wrist, which will be fixed with a band. It will measure the change in volume of blood, which causes a change in the light intensity through that organ. At the same an accelerometer, located on the chest of the patient , will detect patient movement.

Both of these sensors will transmit their data to the ARDUINO UNO microcontroller. Through the Arduino IDE the heart beat is acquired, as well as whether the patient is in resting condition or not.

The ESP8266 wifi module communicates with Arduino to send the data to Thingspeak wirelessly. The data received on Thingspeak will be shown in the form of a chart, including the past readings as well as it will store patient data. These data will be accessible anywhere in the world, for instance, by the doctor. To ensure privacy a private channel which can be accessed by a 16-digit API key is created. This will allow a device to read and write from a private channel.

A custom-designed Android app is connected to the private ThingsSpeak channel, so that the patient can view the charts on the phone. In addition, the interface also includes the possibility of viewing only the current beats-per-minute.

In order to use the app, the patient first needs to register introducing their personal details, after which they are given a medical ID. They will also need to provide an emergency contact detail -preferably a doctor.

Depending on the BPM and acceleration values -whether the person is at rest or not- a SMS will be sent to the doctor's phone every 1 minute -a maximum of 5 times. It will indicate the condition of the patient.

The condition to send a SMS are the one seen in table 5-1. It is assumed that if a person is doing physical activity and the heart rate is also high, the condition will be stable. However, a low heart rate is considered abnormal (indicating bradycardia).

Table 5-1 Conditions for alarm activation

BPM reading	Accelerometer reading
>100	Low
<60	Low
<60	High

Lastly, the doctor will be able to track patient's progress as well through ThingSpeak.

The general architecture is seen in figure 5-1.

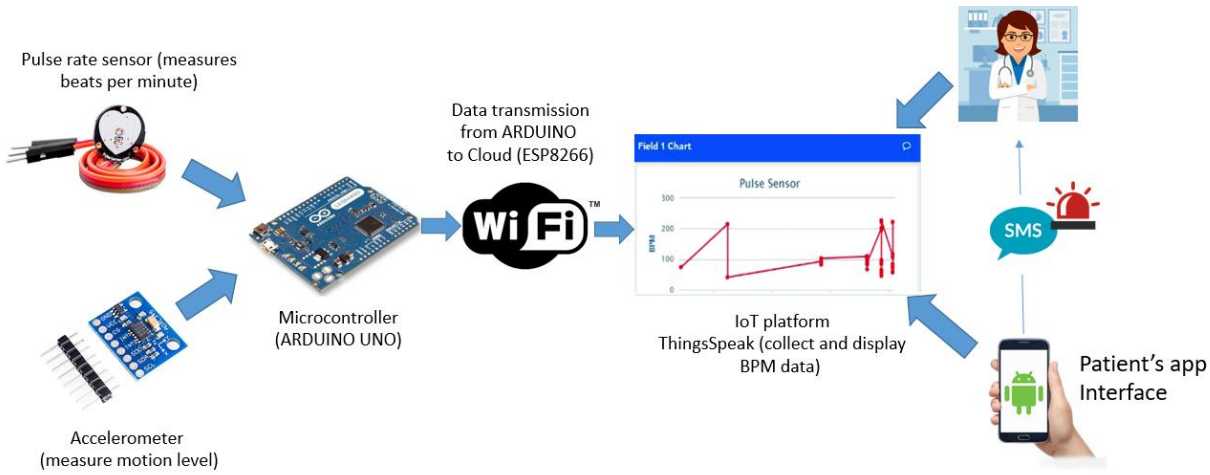

Figure 5-1 High-level system architecture

6. Risk analysis

As the people that the demo will be tested with are expected to be in healthy conditions, it is not expected that it will be possible to evaluate the SMS alert system in real conditions. Therefore, it is likely that the conditions to trigger the alert may have to be altered, by specifying a smaller range of "normal" beats-per-minutes -instead of 60-100 BPM - or by adjusting the "normal" accelerometer values. There is also little literature regarding when to determine a person is at rest given accelerometer data, therefore some assumptions will need to be taken.

Related to this, ideally the doctor should determine when he/she wants to receive an alert from a patient, as depending on whether they tend to do a lot of sports or not and other health-factors, they can be considered to be in a critical state or not. This work assumes that increase in heart when performing sports is considered to be normal, but that a heart rate below 60 if the person is not at rest is not normal.

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A. Appendix

A.1 Project Plan