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A mobile application for ECG detection and feature extraction

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Abstract. This paper presents a system for early detection and alerting of the onset of a heart attack. The system consists of a wireless, easy wearable and mobile ECG biosensor, a cloud based data center, smartphone and web application. A significant part in the system is the 24h health monitoring and care provided by expert cardiac physicians. The system predicts potential heart attack and sends risk alerts to the medical experts for assessment. If a potential heart attack risk exists, ambulance is being called with the coordinates of the cardiac patient wearing the sensor. The timely reaction can prevent serious tissue damage or even death to the users of the system.

Keywords: electrocardiogram, sensors, cloud, Internet of things, medical application, heart monitoring

1. Introduction

It is scientifically proved that certain types of heart attacks can be detected up to two hours before the heart attack takes place [1]. Traditional ECG tests are done in a special medical institution with the proper equipment and with professional medical personnel who will read the results and look for patterns and problems with the activity of the patient’s heart. Recently, with the advent of new advanced portable and wireless technologies, the medical institution need not be the only place where ECG tests are conducted [2]. With the advancements these technologies, we are able to detect the risk of heart attack occurrence, and with a timely medical attention potentially reduce the number of heart attacks and their impact to the patients at a global level.

This paper presents a proof-of-concept system for analysis of heart operation and heart attack detection using ECG (Electrocardiogram) sensor.

The wireless ECG sensors that are used in the presented system architecture are easy to wear on the human body, they do not cause any discomfort and can be worn at all times, wherever the patient goes.

The organization of the paper is as follows. The background is presented in Section 2. Section 3 describes the system architecture. Related work is discussed in Section 4 and finally, the conclusions are given in Section 5.

2. Background work

Traditionally heart operation analysis is performed in the hospital or clinic where the patient is lying and sophisticated immobile medical equipment is being used for a Electrocardiography scan. This limits the ability for obtaining ECG data since the patient must be physically present in a medical institution.

Several improvements for this problem are provided. Some of them are data recorders such as Holter[1] or Cardionet[2]. These improvements use a lot of loose cables that are attached to the body in order to connect the device to multiple ECG electrodes.

In the research communities, IoT (Internet of Things) has been defined from various different perspectives and hence numerous definitions for IoT exist. The system that is presented in this paper is based on the IoT paradigm and presents a significant improvement of those problems since it uses only two electrodes for ECG scanning and utilizes cloud technology for real-time online analysis and diagnosis.

The main reason for the vagueness of the IoT term is the fact that it is composed of two distinct terms – Internet and things. Those two terms are distinct as the first one refers to the network oriented vision of the IoT and the second one tends to focus on different objects in our surrounding that should operate together in a common framework [3]. Recent publications shows that IoT is moving towards cloud of things [4], which is why we decided to build a cloud based system.

3. System architecture

This system consists of two parts: a mobile application and a web application in the cloud.

The mobile application aims to:

- communicate with the ECG sensor worn on a patient's body,
- monitor the patient's ECG scans,
- alert on abnormal heart function.

The cloud web application is used to:

- manage the information for all patients,
- analyze the received signals,
- alert on abnormal heart function,
- monitor the ECGs.

The mobile application communicates with the ECG sensor via Bluetooth (eventually Ultrasound or other communication technology). It will also communicate to the accelerator, GPS sensor or other data stored on the mobile phone. Further on, it communicates via WiFi or 3G/4G mobile operator network to the cloud server. As an alternative the mobile phone can communicate to the local computer (laptop or desktop computer) connected by an appropriate cable.

Since this is a data-centric product it will need somewhere to store the data. Both the mobile application and cloud web application will communicate with the database, however in slightly different ways. All of the database communication will go over the Internet.

Data is stored in the mobile phone in a limited capacity dependent on the available phone's memory. Data files are also stored in the cloud server and can be a subject for various analyses.

The patient can monitor and access the data on the phone received directly from the sensor. Another user role that can monitor the ECG of a patient and receive alerts for abnormal heart functions the caregiver. The caregiver can access the cloud and retrieve data files representing the patient's ECGs. The doctor can use a web application to retrieve patient's ECGs.

Whenever detected, the alerts are sent to the patient and the caregiver. When the doctor receives an alert, he/she is able to make a proper diagnosis and specify an EHR (Electronic Health Record), which can be overviewed by the patient or the caregiver.

The workflow starts with the cardiac patient that attaches the ECG sensor to the chest. The sensor sends information to a smartphone using low energy Bluetooth 4.0 technology and specific data transfer protocols. Afterwards authorized users can log in into the web application for status reports and history of the patients. Authorized users consist of medical personnel (this personnel can give diagnosis based on an ECG and monitor alerts for their validity) and caregivers (this users could only view the ECG history and diagnosis given from the medical personnel for a particular patient). This process is shown on Figure 1.

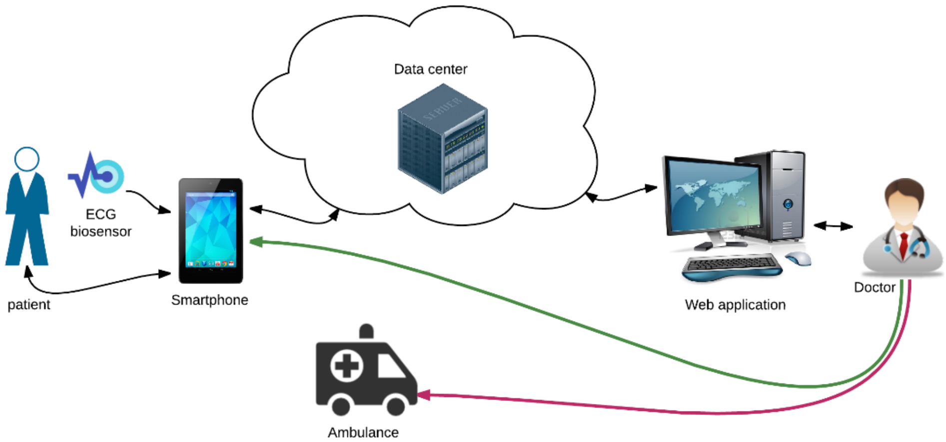

Fig. 1. Workflow of the ECGalert system

3.1. Sensors

The ECG biosensor used in our proof of concept is Savvy. It is fixed on two standard ECG electrodes that are waterproof and can be easy attached/detached to the body of the users. The sensor is small and lightweight with dimensions of 7x2cm and weight of only 3 grams. On Figure 2, the Savvy ECG biosensor is shown along with a two-euro coin for size compartment.

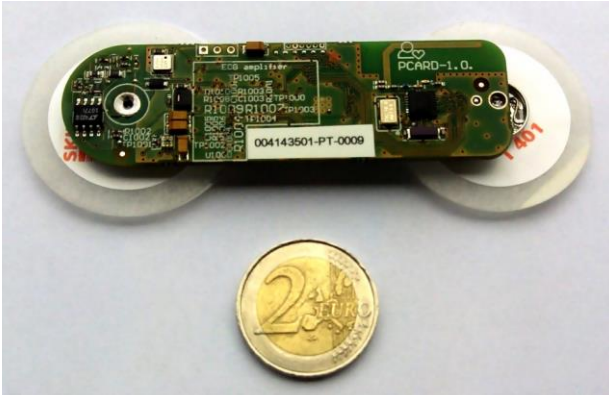

Fig. 2. Savvy Ecg BioSensor

3.2. Web application

The cloud based web application helps users to detect the onset of a heart attack, using sophisticated, intelligent algorithms that analyze ECG data. The ECG data sent to the cloud servers is analyzed and stored on the server, where registered doctors have permission to check it. If potential risk of a heart attack is detected, the patient, doctor and caregivers are alerted. Data is received, analyzed and processed prior to storing. The main database keeps information about all users and realizes authentication, authorization and alerting.

The main function of the web application is to enable heart condition monitoring by analyzing ECG data. This function is authorized to doctors, patients and their caregivers. They can monitor and access the cloud and retrieve data files representing the patient's ECGs. If the doctor receives an alert for abnormal heart operation, he/she is able to make a proper diagnosis and specify an EHR (Electronic Health Record), which can be overviewed by the patient or the caregiver on the web application.

A sample patient ECG scan on the web application interface is shown in Figure 3, when a doctor is the authenticated user, according to [5]. The diagnosis of the current scan is provided on the current display of the web application, under the actual ECG visualization. The doctor can also view all the patients in this application, view the history of ECG scans and diagnosis for a specific patient using the electronic health record.

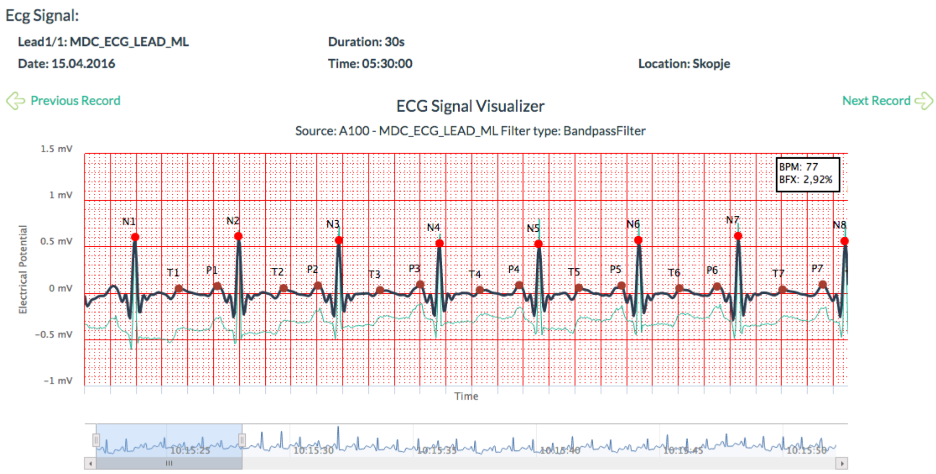

Fig. 3. Web application interface

3.3. Mobile application

The mobile application receives streaming data from the sensor, which is captured and saved as files 30 sec. Those files are stored locally on the device for history view and sent to the server for analysis. The Bluetooth connection to the sensor provides 126 samples per second, and each sample is 10 bits. A sample file of 5130 bytes is packed for a 30 sec ECG recording. If abnormal function detected, an alert file is saved for the detected problem. A listing of alert files is always updated on the mobile phone. Each alert file should be accompanied by an EHR (Electronic Health Record). A doctor forms an EHR after examination of the alert ECG file. Additionally, the doctor sets diagnosis and eventually modifies the therapy or recommends a more thorough examination.

In case of a persistent Internet connection, each ECG file is sent to the cloud. However, the patient user can set an Internet saver mode. In Internet saver mode, the system sends only files on a given period, for example, 1 file per 1, 5, 10 or 60 minutes. Alert files are always sent! If there is no Internet connection, then files are sent when Internet connection is possible. Alert files are sent first, then one file per hour is sent from the normal heart function files. Files can be kept in the mobile hone's memory up to 2 months, depending on available memory capacity. In case of keeping the files for last 60 days, the required phone memory is 1.6GB.

Figure 4 presents two screens of the mobile application. The first screen shows the current ECG measurement along with the information for the connected sensor and the connected cloud network for ECG analysis. The second screen shows the screen for examination of a particular ECG in the phone history. The ECG scan contains the average bpm and hrv, the diagnosis and anamnesis for that scan, the prescribed therapy if it exists and some additional notes that can be added from the medical personnel or the user.

Fig. 4. Mobile ECG application

The history part of the mobile application enables to view recorded ECG files with alert info and corresponding note. Filters for daily, monthly and yearly view are provided and the alert files are first on the list. The mobile application sends a compressed ECG file to the file server (streaming unit) in order to keep the data transfer as low as possible. Each ECG file represents samples within a 30 second interval.

4. Related work

A medical cloud is a cloud that offers health care oriented services to the customers and mainly is working with EHRs. Tasic et al. [6] present a design of a cloud. For the purpose of this project, we have adapted this idea for the use of ECG signals.

Prior to storing, data is processed via band pass filters to eliminate the noise from electricity (50Hz) or the noise initiated by a physical movement or breathing. An example of an efficient implementation of an algorithm using a wavelet transformation is presented by Milchevski and Gusev [7]. A way to speedup the flitering processing is also demonstrated by a Maxeler dataflow engine [8].

Recently, few researchers work towards a wearable wireless, mobile, and remote ECG biosensor that is going to monitor heart rate and display. All of them differ to our work in few crucial aspects.

For instance, the sensor Shimmer3 ECG [9] provides a continuous recording of vital signs, but does not analyze the data and has no mechanisms for early warning.

Similarly, NeuroSky [10] provides a recording of vital signs but is more intended for conducting stress tests in hospitals.

QardioCore [11] is a multi-sensor platform that besides ECG, measures body temperature, the level of activity, and other vital signs, and thus presents a more complete picture of the patient's health. Nonetheless, the data is only presented, and not processed at all.

Philips health applications [12] also introduced a sensor in the form of a replaceable patch where the battery lasts for up to 14 days and sends data to clinical software, where medical professionals set a diagnosis and therapy. While this is a good starting point, no warning in case of emergencies is offered.

One such comprehensive study [13] examined 120 different ECG biosensors from several aspects. The authors conclude that this area is a hot research topic, and that innovative, applicative solutions may seize a unique market chance.

Worldwide, there is no published work that organizes a 24h remote medical care based on remote sensing and early alerting. Usually, they function by telephone or by physical presence. The end-user benefit is the reduced mortality rate due to early alerting of potential heart attack, and prolonged patient life. The benefit of the medical experts that will actively participate is in the possibility to react faster and be more successful in the treatment of the patients. Also, potentially large data knowledge databases are going to be generated from the everyday system operating and the diagnosis that can help doctors in their process of diagnosis using similar scenarios.

5. Conclusion

This paper presents a proof-of-the-concept of a system for early alerting of a heart attack. The prototype built is being tested and the EU is testing the sensor for a certification.

The main diference to other similar systems is in the intended use. While the others think about replacing the existing Holter procedures and system with a lot of wires attached to a human body, our system is moving a step forward, with several benefits:

- It is intended for a constant 24h monitoring of a patient.
- The sensor is easy to wear, as a sticker with two electrodes attached to a human body.
- An alert is generated whenever an abnormal heart function is detected, so a medical expert can provide a medical healthcare and prevent serious consequences.

Although a prototype is built, still this is a kind of a work in progress, since it allows a lot of research opportunities to estimate the current heath condition, or to evaluate the influence of other factors on heart function.

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