Computationally Intensive Medical Application Using Mobile Device and Raspberry PI

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***Abstract*— Paper deals with the problematics of the use of mobile devices (smartphones, tablets) in computationally intensive medical applications using specialized hardware and software solutions for collection, processing, evaluation and presentation of medical data which are acquired in real-time from patient body. Design of the application, compatible with two mobile platforms, that receives electrocardiogram (ECG) data from auxiliary device Raspberry Pi, processes and evaluates them, is described in the second part of the paper along with the results of the testing of designed application.**

***Index Terms* — medical systems, mobile application, Android, Windows Phone, Xamarin, electrocardiogram, ECG**

I. Introduction

The proliferation of mobile devices such as mobile phones and tablets reached a dimension in past decades where in developed countries is accounted more than one smartphone for a single user and significant is also the use of tablets. Even in less developed countries, the expansion of smartphones is large and even larger than it is in the case of personal computers or laptops. Mobile phones are in many cases the only way to connect to internet, read e-mails and use instant messaging applications in those countries.

Mobile devices such a smartphones or tablets dispose with high computational power, when they contain microprocessors with 4 cores and more and operating memory is up to 4 GB. Graphic accelerators are included and display technology offers resolution that is in highest models on the level of 4K. They are comparable with desktop and laptop computers in their parameters. Mobile devices dispose with some disadvantages, such as high consumption of energy which allows to run the device only for one day in average. Small dimensions can be considered as the disadvantage because of the small screen diameter, although the resolution is high and if it is needed to input some textual information, part of the display is used as the virtual keyboard, with the limited size of keys and only the part of the display can be used for effective viewing of information. Advantages of these devices are in the use of the touchscreen as the input interface, low weight and small dimensions, which allow users to carry their devices always with them. Another advantage is in incorporation of many sensors like accelerometers, gyroscopes, electronic compasses, pressure sensors, cameras or biometric sensors. Most important for many mobile applications is possibility to use GPS functionality. Mobile devices, that combine high computing capabilities and communication capabilities with small size of the devices and reach number of sensors, therefore can be used not only for communication through the mobile telephone network and internet but also can be used for many telematics applications such as Global Positioning System (GPS) navigations, Geographical Information Systems (GIS), mobile banking applications, different kinds of measurement applications and others.

A wide range of fitness and healthcare applications is also available. But many of them are not sophisticated enough to use full range of capabilities of mobile devices and to become applications that can be used for professional diagnostic purpose and medical care.

II. Related works

Innovations of digital technologies such as cloud services and variety of sensors and auxiliary devices, offers possibilities of the use of mobile devices in medicine, for example to monitor the health of the patient, including recording of blood pressure, blood sugar, heart rate, number of burned calories, warning patient to lack of exercise or fluid intake. They also may notify the patient to take the medicine or sending the collected data to doctor [1].

As an example may be mentioned an application iWander, designed for mobile platform Android, which aim is to provide safety precautions for people suffering by Alzheimer's disease. The application tracks the patient through the GPS in mobile device [2]. In the beginning the patient personal information and also the GPS coordinates of his house are entered to the application. In case it detects that the patient is too far from his own house for a long time or in the middle of the night, the algorithm of application evaluates that the patient may be confused and immediately calls emergency or helps patient navigate home [3].

Another example of the use of mobile devices is in rehabilitation. If the patient is unable to participate in rehabilitation in facilities intended for that purpose, there are possibilities to conduct exercises from comfort of his home by connecting ECG monitoring sensors to his body that communicates with a smartphone via Bluetooth and allows doctors to monitor the heart activities in real time while the patient performs exercises [4].

Principle of another application that uses the potential of a smartphone is to monitor the patient. Shoes equipped with sensors, which communicate with the phone may be used to monitor the level of physical patient activity which recently surpassed stroke [5].

Through the accelerometer that is located in almost all mobile devices it is possible to interpret the movement and balance of patient [6, 7].

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The electrocardiogram sensors attached to mobile device can diagnose and monitor treatment advances of sleep apnea, meanwhile offers an alternative to costly and labor intensive polysomnography [8].

The Diabeo application can facilitate the daily battle with the disease to patients with diabetes. This mobile application collects information about glucose, number of incoming carbohydrates and planed physical activity before it recommends insulin dosing [9].

Using of mobile devices in medicine could not only facilitate the work of doctors, but also provides greater comfort to patients. Considering that in present almost every person owns at least one mobile device this idea is becoming more viable. Smartphones or tablets could work as a kind of guardian for example for patients with cardiovascular diseases while would sent information about cardiac activity to the doctors database server at time intervals, so the doctor could supervised on patient. The patient would have available the application which would monitor his health condition and would not limit in his daily activities and its using could decrease frequency of ECG examinations. The application could contain a multitude of functionalities that would in life threatening condition save patients life. This application could completely replace pressure Holter, a device used for measuring blood pressure that is applied to the patient for monitoring of the heart activity for 24 hours. Disadvantage of the Holter is that unlike the above described applications it cannot signal the risk of heart failure and subsequently call emergency for help.

The following paragraph offers a description of medical applications that are primarily aimed at patients with cardiovascular diseases.

First application named Healthy Heart 2 is developed for iOS platform and is free for all Apple devices. Healthy Heart 2 offers ability to record the measurements of blood pressure, heart rate, cholesterol, blood glucose, potassium and drug ingestion information. Those data are backuped at Ringful online server, where it is possible to analyze them and share with the doctors and family members. The application offers detailed overview of the measured values over several days not even for patient, but also for the doctor. The disadvantage of Healthy Heart 2 application is the necessity of auxiliary equipment which does not communicate with the application and all of the measured data must be entered manually by the user.

The next example is AliveECG application that is the product of AliveCor Inc., which is focused on developing of medical applications and is available for the iOS and Android platforms. This application provides the analysis, storage and sending result of measured heart activity data using extern device named AliveCor Heart Monitor that is ECG recorder with smartphone dimensions. To measure ECG of patient is necessary to put down two fingers of both hands on AliveCore Heart Monitor device. The ECG data are wirelessly transmitted to AliveECG application installed on mobile device. Two clinical studies suggest that AliveCore Heart Monitor device and AliveECG application have a sensitivity over 85% and specificity over 90% in identifying paroxysmal atrial fibrillation. The advantage of this application is in the accuracy of measurement thanks to which it is clinically proved and approved by the Food and Drug Administration (FDA). Another benefit is the auxiliary device, which independently communicates with the application in mobile device. Despite the fact that the application is available on Apple Store and Google Play for free, the user is forced to buy an additional device AliveCor Health Monitor in case he wants to use it. It is also necessary to mention that the auxiliary device is available to buy only in USA, Australia, India, Ireland, New Zealand and in the Great Britain.

The last example is eMotion ECG device from Mega Electronics Ltd and it is the application for mobile devices designed to monitor and analyze patients' blood pressure. For proper functioning of the application it is necessary to own auxiliary device, which contains three sensors attached to device by the wires and it is necessary to establish communication with the device running application by the Bluetooth.

The functionality of this application offers to the patient possibility to display received data from auxiliary device, real-time blood pressure measurement, sending measured data to database server, track position and notify the patient if the unordinary data are measured. This application was approved by FDA. In spite of many benefits of eMotion ECG there are still some disadvantages for example the missing support for mobile platforms such iOS and Windows Phone because the application is available only for Android operating system.

III. Developed Application

This paper describes implementation of mobile application that is outcome of the research in above described field. Mobile application communicates with auxiliary device Raspberry Pi to which ECG sensors are attached. The acquisition of data containing patients' heart rate information and the algorithm design for evaluation is the subject of the other paper.

At first, it was considered that after the start of the application the registration or logon is required as it was assumed that the two types of users will use this application, namely patients and physicians. After choosing the role of patient, the application would require registration and the user is to give the name, surname, personal identification number and password. In case that the patient already has an account, will choose the second option and signs in using personal identification number and password.

After finished registration respectively sign in, the patient has an access to available paired Bluetooth devices and the application offers him a choice of which device he wants to join. It is expected that the patient should choose a Raspberry Pi device, to communicate with is the application primarily designed.

Finally it was decided that a mobile application will not have a registration and login database. It will not be needed to add an option for login physician, because all the necessary information about patients will be saved on a Raspberry Pi, which will contains the configuration software to store patients' information. Consideration was also given the fact that the application will be used exclusively by one user whereas each person holds at least one mobile phone in the present.

When the mobile device establishes a connection with the Raspberry Pi, application continually receives data that are subsequently displayed on the screen in the form of ECG graph (Fig. 1). The application is not only receiving ECG information but also the value that is signaling emergency situation of patient. If the auxiliary device detects ECG deviations from normal values, the application receives a warning signal, which is an incentive for conducting additional functionality that will be designed to ensure quicker patient medical treatment. In the case of emergency, application dials the number for emergency medical assistance what the patient with stroke could not be able to follow. Additional functionality of application might be sending SMS messages containing GPS coordinates of patient and the text that the patient is in danger. Patient will chose phone numbers for emergency information sending in the application settings.

At the time of the application software designing it was necessary to choose the programming language and mobile platform to which will be application designed for. As the best option has proved the programming language C# and Microsoft Visual Studio with Xamarin framework as a development environment. This framework allows the development of cross-platform applications using one programming language which led to the development of application for two mobile platforms namely Android and Windows Phone.

Given that the functionality of entire application depends on receiving data, it was necessary to decide what communication technology will be used. There were two options: communication will be implemented using WiFi Direct services or Bluetooth.

Fig. 1 Screenshot of the application with displayed ECG data received from connected Raspberry Pi device.

The first option is a relatively new technology that can connect two devices without need to connect to the access point unlike classic WiFi. This process is called ad hoc WiFi transmission. WiFi Direct technology became very popular not even in gaming industry (Nintendo DS, PlayStation Portable) but also in digital cameras, smart TVs and more other devices of consumer electronics. The advantage of this form of communication is more stable connection and faster data transfer between devices, but on the other hand, the implementation on raspberry Pi would be difficult and costly compared to Bluetooth.

The disadvantage is in the lack of support of application programming interfaces. The second option is Bluetooth. This form of communication establishes a short range connection between two devices. It uses the same frequency band (2,4 GHz like WiFi), but different technology. The Bluetooth network uses the client-server model to control when and where can data be sent. The most of devices use Bluetooth 4.0 version at present. The advantage of this communication protocol is the wide availability of application programming interfaces, low cost of Bluetooth adapter and mainly lower power consumption than WiFi.

Analysis of those two communication protocols showed that the Bluetooth technology will be used for developing application mainly due the low energy consumption. The energy consumption is a decisive fact because it is assumed that the patient will have a monitoring device connected throughout the day and counts with the possibility of missing the source for charging the mobile device. After successfully established connection between the application and the auxiliary device, the information about medical history of patient in json format is sent to the application. As soon as these received data are displayed on application screen, data are sent to physician web server. Subsequently, the data containing two values, the first ECG value of the patient and second, the information about the state of the patient, that could be 0 or 1 (in case patient is in critical state), are continuously received from the Raspberry Pi and drawn on the screen of the application, as the ECG graph, using OxyPlot library that supports cross-platform development.

Fig. 2 Screenshot of the application with emergency call displayed, that is activated in case of patients abnormal function of heart.

This data is also sent to physician web server every second where they are associated with a particular patients data based on his personal identification number.

If the application detects the specific count of critical values the alert message appears on the screen with the 10 seconds countdown and two buttons are rendered. With the first button, the patient can decline the critical state and the application will continue in normal work and continues with evaluation of incoming data, or with the use of the second button user can confirm the need of the call of emergency immediately. If the patient will not touch any button, the emergency will be called after 10 seconds (Fig. 2). Before the call is made, the SMS message with the GPS coordinates is sent to numbers that the patient stored in application settings.

The database that was used to store server address and phone numbers in application, was SQLite that is the most widely used database at present because of its simplicity. SQLite database is not based on the principle of client-server model, where the database server is running as a separate process. It is a library which is linked to the application.

The last state of developing the application is usually to test its functionality and the proper functioning. Application was tested by users on various mobile devices with Android and Windows Phone operating systems. The results of tests were positive and the application was working on Windows Phone 8.0 and upper versions and on Android 4.2.0 and upper versions.

IV. Conclusion

The development of application for monitoring the patients ECG was realized by cross-platform framework and the application is in a state of functioning prototype. The application could be extended by a new functionality like displaying first aid manual when the critical state is detected or by connecting application with on-board computer to brake a car in case of critical data detection. Another extension could be creating web server for physicians where would be data sent and the doctors could browse by them using various filters. Given that the application was developed using cross-platform framework Xamarin, application could be port to iOS platform thanks to the sharing of code, which this framework provides.

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