SISTEM ZA ZDRAVSTVENO PRAĆENJE KORIŠĆENJEM MOBILNIH TELEFONA I NOSIVIH UREĐAJA
HEALTH MONITORING SYSTEM USING MOBILE PHONES AND WEARABLE DEVICES

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Sadržaj: *U radu su predstavljeni istraživanja i razvoj sistema za zdravstveno praćenje korištenjem mobilnih telefona, nosivih uređaja i web/cloud tehnologije. Najvažnije karakteristike sistema je 24-satni praćenje zdravstvenog stanja pacijenta. Osim toga, druge pogodnosti su brzo vrijeme odziva, povećavanje zdravstvena prevencija, mogućnost prijavljivanja pogoršanja zdravstvenog stanja pacijenta i snimanje izmjerene podataka (otkucaji srca). Ovo rezultira smanjenjem ukupnih troškova za pacijentima i bolnice, kao i poboljšanje zdravstvene zaštite. Sistem je implementiran na Android mobilnih telefona i web/cloud, a pritom smo koristili Eclipse, PHP i MySQL baza podataka.*

Abstract: *This paper presents research and development of a health monitoring system based on wearable devices, mobile phone and web/cloud application. The most important benefit of the system is 24-hour monitoring of the patient's condition. In addition, other benefits are rapid response time, improved medical prevention, reporting of worsening of the patient's condition in real-time and the recording of the measured data (heart rate). This results in the reduction of overall costs considering patients, hospitals and overall improvement of life quality. The system is implemented on Android mobile phone, web/cloud and is developed using Eclipse, PHP and MySQL database.*

1. INTRODUCTION

Wearable technology [1] is becoming very valuable for monitoring patients 24/7 inside and outside the hospital. Wearable medical devices are often independent, applied to the patient body and perform various medical functions, for example, monitoring vital functions. Such devices transmit information about the health condition of the patients, which can include the heart rate monitor sensors. Often wearable medical devices due to the general abundance of cheap sensors have low price combined with low power consumption.

Mobile devices have many forms and shapes (mobile/tablet) have revolutionized the use of technology in automation of routine task. The widespread adoption and portability make it the prime IoT technology contender. In our research, we have used mobile devices based on Android that covers a huge range, allowing a custom solution.

The system is designed that the mobile phone application gets data from the wearable device. The wearable device monitors the heart rate whether the patient is at home or in the hospital. The patient is monitoring all the time, thus avoiding the risk of increased/decreased heart rate. The real-time monitoring provides an alert for patients in case of emergencies.

Wearable devices are often limited in their ability to saving and process data, therefore, it is necessary to build completely integrated system, which contains the wearable device, mobile application and web/cloud application.

2. LITERATURE REVIEW

There are several devices and approaches for measuring heart rate are researched:

- Use the index finger [2]. The most common technique used is the Photoplethysmographic (PPG) to obtain information on the heart rate. Results of heart rate showed that mobile phone and proper ECG are with significant differences in the lying position and tilt. The difference due to the fact, those current phones cannot have a stable surface on which the patient can hold with the finger.

- Holter [3] monitoring is one of the first application for the wearable devices. The “Holter” is attaching to the patient body often for 24 hours, and after the data is transferred from the “Holter” to a PC, and afterward analyzed . The first obvious difference between the “Holter” and our proposed system in the real-time monitoring and alert feature. The “Holter” do not provide real-time monitoring.

- Choi et al. [4] proposed a system for ubiquitous health monitoring in the bedroom using Wireless LAN and Bluetooth. The information gathered from sensors connected to the patient’s bed is transmitting to a monitoring station outside of the room where the data is processed and analyzed.

➢ Epi-medics [5] project is an intelligent ECG monitor that can record and analyze ECG signals, other sensor information and generate alarms. This device cannot monitor the patient for 24/7.

3. PURPOSE OF THE RESEARCH

There are obvious limitations of the presented previous systems. For example, the "Holter" do not provide real-time data and therefore, alert features. Epi-medics cannot monitor the patient for 24/7. Our main idea is to research and develop a prototype state-of-the-art health care application using wearable devices and integrating them with mobile technologies and web/cloud applications. In our research, we have focused on heart rate as one of the easiest to monitor and important vital condition. The presented system produces real-time monitoring of heart rate condition of the patients to the doctor, have an alert feature, to inform the doctor when the patient is in emergency.

The purpose of this research is to demonstrate that there are technologies that can significantly improve patient care and that these technologies are already available. The presented application is a prototype and can extend to measuring and monitoring other vital functions.

4. SYSTEM DESIGN

This system divided into three main parts. The system components are:

- ❖ Wearable device (Polar H7),
- ❖ Mobile phone application (Android OS),
- ❖ Web/Cloud application

Figure 1: Levels of the system

System model it presented in Figure 1. The first part includes the use of the wearable device with a sensor to monitor heart rate. The second is mobile phone application, which gets data from the heart rate sensor. The third part is the web/cloud application that stored patients' data, analyze the data, if necessary, issues an alert to the doctor, presents historical and real-time data to the doctor.

4.1 WEARABLE DEVICE POLAR H7

We researched several wearable devices [6] for measuring heart rates such as Apple watch, Mio Alpha 2, Armour39 and Polar H7. From the research, we concluded that Polar H7 showing perfect results and is the most accurate wearable device for measuring heart rate. Polar H7 needs to be attached to the patient chest. The Polar H7 sensor measures patient heart rate and communicates with other devices via Bluetooth. That allows heart rate data to be display in mobile phones, sports watches, and compatible fitness equipment. Polar H7 features are:

- Portable,
- Comfortable,
- Easily attaches to the patient,
- 24-hour monitoring heart rate,
- The patient is able to change position or move,
- Polar H7 do not interfere with other devices such as telephone, radio or TV.

4.2 MOBILE HEALTH APPLICATION

The mobile health monitoring application is developed on Android using Eclipse and prototype Java code. The health application makes the Bluetooth connection with Polar H7 and receives real-time data. The data from the sensor are taken and temporarily stored in the local database on the mobile phone. After 1 minute, these data are sent to the web/cloud application and are deleted from the database of the mobile phone.

The health application identifies each patient and grants using permission. When the patient is logged, it can connect with Polar H7 and starts monitoring heart rate. The health application provides an interface for viewing heart rate data.

Figure 2: The interface of the application

Also from the mobile application, patients can access to the web/cloud application to check the data for heart rate and can insert daily data for sugar, high and low blood pressure, body weight and height. The heart rate application sent data to the web/cloud application over Wi-Fi. Each data packet contains the patient's ID, heart rate data and the exact time when the heart rate it was measured. The application interface is shown in Figure 2.

4.3 WEB/CLOUD APPLICATION

The web/cloud application provides the interface for both patients and doctors. The doctor interface has these features:

- Log in with name and password to identify himself,
- Add new patients,
- Monitoring patients heart rate real-time data including the minimum, maximum and the average value of the pulse,

- Downloads all patient data in a single document,
- Visualize patient heart rate data,
- Receive alert notification for patient heart rate emergencies.

The patients interface has these features:

- Log in with name and ID provided by the doctor (The patient cannot sign in directly in the system),
- Data forms for entering blood sugar, high and low blood pressure, body weight and height,
- View owns the heart rate data.

The database is designed to support previously described doctor and patient features. The database entity relationship diagram (ER) is shown in Figure 3:

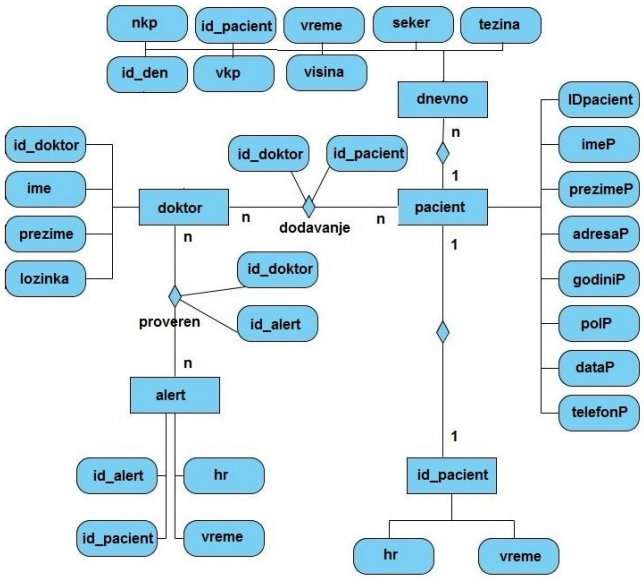

Figure 3: ER diagram for database

4.4 APPLICATION ACTIVITY DIAGRAM

The activity diagram for doctors is shown in Figure 4. First, the doctors login on the web/cloud application. If the entered data is correct, the ID from added patients displayed. Doctors can choose to add a new patient, to display a graph or display heart rate data and details from the patient. If the doctor selects add patient, he must insert the information's for the patient. ID must be different for each patient and told to the patient. The doctor can see the results and graph after transmitting.

Logged doctor can receive alert notification if the patient heart rate is increment or decrement outside of normal value. In cases where doctors not logged into the web/cloud application, it is possible to monitor alerts all the time from the mobile application with alarm sound and details of the critical patient.

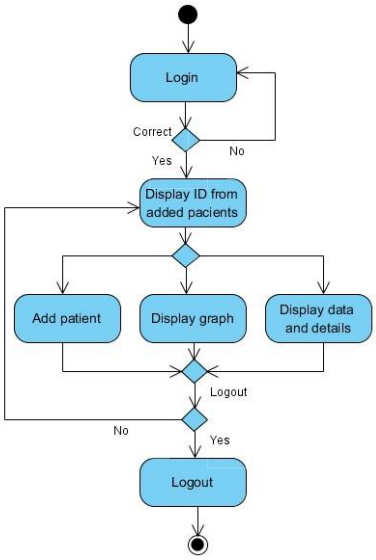

Figure 4: Activity diagram for doctor

The activity diagram for the patient is shown in Figure 5. When patient attaches the Polar H7 device it should launch the application on Android mobile phone.

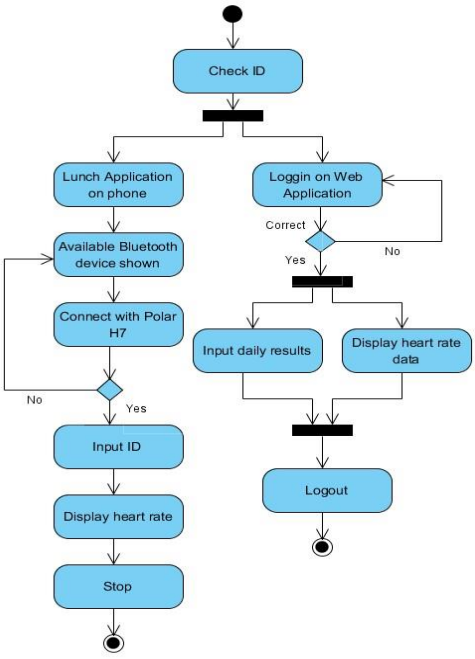

Figure 5: Activity diagram for patient

The mobile phone application requests Wi-Fi and Bluetooth permission. Upon the execution of the program, the application checks if Bluetooth already enabled on the phone. The patient login to the web/cloud application with its individual data. When the patient is logged in he can view the stored heart rate data.

5. TESTING AND DISCUSSION

The prototype system and application was tested only in several cases or patients, in this case on our self. There are different kinds of heart rate measurements with physical activities, sleeping, running, reading, etc. and various lengths,

starting from several minutes up to 48 hours continuous measures.

We have compared our health monitoring system with a portable Biocare ie 12a in Shtip hospital. The idea was to compare our Polar H7 heart measuring device with a Biocare ie 12a used in hospitals. Both devices were attached to the same patient and 20 minutes data was saved. After a detailed analysis of both devices data, the main conclusion was the Polar H7 produce very good heart rate measurements, and its data is almost identical with hospital device Biocare ie 12a. The difference between the data results is 0,0116%.

The system design and functionality is simple so that any patient regardless of age would easily operate with it. The patients only need to install the mobile application, connect it with the Polar H7 wearable device, input their ID and start measuring their heart rate. Figure 6 shows heart rate data presented on the web/cloud application. Figure 7 presents a graph for heart rate measured data.

	Пулс	Време
99		Tuesday,October 06,2015 18:55:52
98		Tuesday,October 06,2015 18:56:53
95		Tuesday,October 06,2015 18:57:53
93		Tuesday,October 06,2015 18:58:53
97		Tuesday,October 06,2015 19:00:54
92		Tuesday,October 06,2015 19:01:55
91		Tuesday,October 06,2015 19:02:55

Минимална
61
Tuesday,October 06,2015 21:42:53
Максимална
99
Tuesday,October 06,2015 18:55:52
Средна
79.8767

Figure 6: Heart rate data presented on the web/cloud application

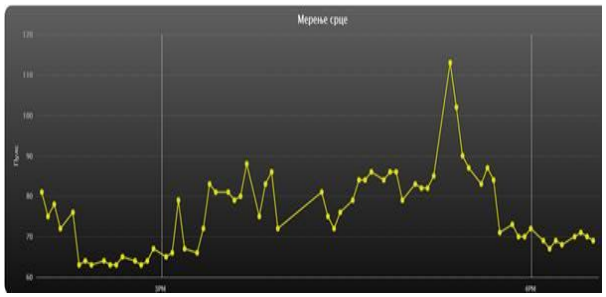

Figure 7: Graph for received data from patient

The system is tested with more than 48 hours of continuous monitoring in real time without any problems and data displayed and saved as expected. The mobile application for monitoring heart rate will work in the background as before without problems.

ProGuard tool is used for optimization and obfuscation in Android application. The protocol used between Android and Web application is HTTP. Because we are storing user data, in the future should encrypting communications with HTTPS and SSL [7], which allows sensitive information transmitted securely. For keep privacy for the patient's in the application, we will add permissions for ensuring the patient's knowledge and consent before data is transmitted.

6. CONCLUSION

This paper presents a system for real-time monitoring of the patient's heart rate. The system is compared with other similar systems and described the advantages of the proposed solution. The system components are the wearable device, mobile phone, and web/cloud application.

This solution is cheaper and allows patients to freely move and live their daily life, offers 24-hour monitoring of the patient's condition, the possibility of alert notification worsening of the patient and recording the measured data (heart rate). The application only works on Android but we plan to develop iOS version.

A future step is to implement the system. We hope to find a medical institution that will be willing to cooperate in our research and development.

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