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MOBILE HEALTHCARE MONITORING USING WEARABLE SENSORS

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Abstract: *This paper describes work in progress regarding personalized heart monitoring using smart phones. The research combines ubiquitous with mobile health technology. This system uses wireless sensors and smart phones to monitor the wellbeing of high risk cardiac patients. The smart phone analyses real-time the EGG data and determines whether the personal needs external help. Depending on the situation the smart phone can automatically alert pre-assigned caregivers or call the ambulance. It is also used to give advice (e.g. exercise more) or to reassure the patient based on the sensors and environmental data.*

Index Terms: *Mobile Healthcare, Wearable sensors, Ubiquitous Computing*

1.INTRODUCTION

The estimated direct and indirect cost of cardiovascular diseases is increasing worldwide. Statistics indicate that approximately $4 billion of noncardiac cases in hospital emergency departments. To reduce these costs and the anxiety of people with known cardiovascular problems this paper proposes a portable monitoring system that monitors the heart and notifies the person or external party in case of abnormalities. This monitoring system is meant for patients who have a cardiovascular disease and need to be monitored around the clock. Traditional heart monitoring solutions exist for many years such as the holder device which records the patient's ECG for 24-48 hours and is then analysed afterwards by the cardiology. The patient 'wear' the device and go home and resume his/her normal activities. The main drawback of these solution is when a major incident occurs during the monitoring phase it is recorded but no immediate action is taken to help the user.

Other solutions have been introduced that address this problem and J.Rodriguez et al have classified these solutions in two groups [2]: The first group uses smart phones (or PDA s) equipped with biosensors that record the heart signals and transmit them to a healthcare centre or hospital for analysis. Some solutions can store the signals locally as well examples include Alive technology [3], Vita phone [4], Ventracor pocketview [5] or Welch Allyn Micropaq [6]. Most are capable of recording, viewing and storing ECG s directly on the smart phone. Some solutions transmit the stored ECG to the healthcare center using wireless technologies (e.g. GPRS). The second group aims at building platforms for real time remote health monitoring. Examples are Mobihealth [7]. Telemedicare[8], Osiris_SE[9] and PhMon [10]. These solutions use(wearable) wireless sensors to monitor patient's vital signs (e.g. ECG,oximeter, blood pressure). The European project MY HEART [11] develops such a platform and focuses on heart patients. MY HEART aims at designing intelligent biomedical cloths for monitoring, diagnosing and treatment. The platform developed by this second group collects the bio data and sends it to a care centre or a hospital for processing and analysis. None of these solutions process the ECG data locally on the smartphone, and the ECG signals need to be continuously transferred to a health center if the patient needs to be monitored 24/7. This can be costly when GPRS is used for transmitting the data. To deal with this issue several research projects consider processing the ECG data on alert system targeting high-risk cardiac and respiratory Valeric GAY et al.: A Health Monitoring System Using Smart Phones and Wearable Sensors 30 patients. The system includes continuous collection and evaluation of several vital signs, smart medical emergency detection, and is connected to a medical centre. For heart monitoring, they are technically limited by the fact the device is worn on the wrist and therefore the ECG signal is very noisy and not suitable to diagnose cardiac abnormalities. The EPI medics project [13] defines an intelligent ECG monitor which can record, analyse ECG signals and other sensor information and can generate alarms.

It can also be personalized but it is not a device meant to monitor the patient 24/7. The patient connects to the 12-lead monitor periodically as directed by the heart specialist or when he/she doesn't feel well.

MOLEC [2] provides a solution that analyses the ECG locally on a PDA. It generates alarms to the hospital in case of high risk arrhythmias.

The objective of this paper is to investigate and develop an application hereby a heart patient is monitored using various types of sensors (ECG, accelerometer, oximeter, weight scale, blood pressure monitor). The sensor information is collected and transferred wirelessly to a smart phone. The proposed solution analyses the ECG and other sensor data on the local device. One distinction of the work compared to the others is that we can personalise the monitoring and we have mechanisms in place to locate the user in case of emergency whether the patient is indoors or outdoors. detect life threatening arrhythmias and give the patient general information for further use by the health providers.

This paper is organised as follows: section 2 discuss the overall architecture whereas section 3 focus on the implementation of our personalized heart monitoring system. Finally, section 4 concludes this paper.

II.ARCHITECTURE

The heart patients have one or more sensors (e.g. ECG and accelerometer) attached to his/her body. External devices are used, such as blood pressure monitor or weight scale, to collect periodically additional health data. Off the shelf sensor are used incorporate the best technology as they appear on the market. The sensors are Bluetooth enabled or integrated into the smart phone (E.g. GPS). The smart phone processes the sensor data and the monitors the patient's wellbeing, and in case of an emergency, it automatically calls an ambulance to the location of the patient. It can also warm caregivers or family members via SMS or phone when the patient is in difficulty.

The data collected by the smart phone can be transmitted to the health care data server via the internet. A patient can upload the data whenever the smart phone is connected to the internet via the desktop cradle/charger or wirelessly. This is the cost-efficient way to upload data which is not time critical. However, in case of an emergency, updates are immediately transferred to the data server using the best available connection (e.g. GPRS). The specialist can access the Data server via a secure internet connection to remotely monitor the patient and if necessary update the threshold levels for the sensors. Relevant sensor data is stored in the patient's health record and can be used for further analysis.

2.1. Sensors

Data from each sensor is collected and processed in the smart phone to establish a diagnosis for high risk cardiac patients the ECG signal is the obvious data that needs to be collected continuously and should be given priority overall other sensor data. It is also important to store the ECG for further analysis by the cardiologist. Detecting falls using an accelerometer is another important indication that something is wrong with the patient. Using an accelerometer and other contextual information, we can also evaluate the level of activity of the heart patient. This Iis assed against the heart specialists personalized guidelines and either congratulate the patient for reaching their goal or encourage them to exercise a bit more. The level of physical activity recommended for the heart patient depends on his/her for condition and health history. National Heart Foundation of Australia [14] says that physical exercise improves the live expectancy of heart patients and they set to help heart specialists in setting a personalized level of activity for their patients.

This system also integrates Bluetooth ECG/Accelerometer sensor from Alive Technologies [3].This sensor was selected since it has been demonstrated that it provides reasonably good signals for detecting normal or abnormal rhythms (arrhythmias). The Alive accelerometer has been used during a study of stroke patients at the Prince Charles Hospital (Australia) and can successfully detect falls [5]. The sensor is small (match box size) and can be easily worn without being noticed by other people. Bluetooth enabled blood pressure is another important risk factor for developing cardiovascular diseases [1] and regular monitoring is essential. Being overweight or obese can contribute to developing cardiovascular diseases and for some heart patients their weight is important.

Finally, to accurately obtain the location of a patient in case of an emergency a GPS sensor is used. However, GPS does not work indoors and need to complement it with other location sensors such as the GSM Cell ID or WiFi access point locations. With GSM Cell IDs and WIFI access points we can provide a rough indication of the location of the patient as described in [17].

2.2 Smart phone functionalities

The application in the smart phone receives the results from the sensors and determines whether an alarm should be raised. The results of the sensor can be inaccurate due to noise and readings. The monitoring system is only useful if we know the quality of the data we receive from the sensor various sensors and the quality of the diagnosis based on that data. Knowing the quality level, we can put mechanisms in place to compensate for the lack of accuracy of certain sensors or get feedback from the patient to confirm the diagnosis.

The application will therefore access the results of the sensors and if the threshold level has been reached the application needs to cross check whether the patient is in danger to avoid raising false alarms. In the current implementation additional data is collected from the sensor(s) and if we still measure a life-threatening situation the application will seek confirmation from A & D blood pressure monitor and alive ECG/Accelerometer monitor the user. The user can disable the alarm in case of false alarm. If the user does not react within a certain time (currently 30 seconds) an emergency call is automatically placed. This feature is included since many patients black out or experience speech and swallowing difficulties at the time of a heart attack. since our target group will be mainly elderly people, the interaction with the monitoring application needs to be simple, personalised and adapted to the user's health condition.

For example, we need voice interaction in case the patient has bad eyesight or vibration and flashing lights for hearing impaired patients. Furthermore, it is important to provide accurate but non-overwhelming information to the patient since we do not want to cause extra anxiety which would make the situation worse. For this reason, we do not show an ECG diagram to a patient since it was learned from discussions with cardiologists that this is a major source of anxiety for cardiac patients

The smart phone application shows the configuration data and sensor readings in a local database. Depending on the patients, thus the specialist can configure one or more sensors to be used to monitor the patient. The configuration section is password protected and is only accessible by a medical specialist. The specialist determines each sensor should be used and configures the monitoring frequency and threshold levels for each sensor. For example, cardiac patient need to monitor the glucose level, whereas others need to monitor the weight and blood pressure. Also, threshold levels for raising an along differ depending on the patient's agents condition.

III. ProtoType

The application was developed on the Microsoft WINDOWS MOBILE 5.0 packet PC platform using Microsoft visual studio 2005. This platform was selected due to easy access to lower level. APIs which are needed for the sensor modulus. Also, the tight integration with the operating system allows easier access to other applications running on the smart phones. Such as the calendar application WIFI and attaining GSM cell ID. The net Compact framework 2.0 extended with openNFTCF [18] modules was used to develop the application. Data stored in an SQL CE server which is a compact database for mobile devices. For the smart phone we use the I-mate K-JAM manufactured by HTC

3.1 Heart Monitoring

The ECG sensor is the most critical component of this architecture. ECG signals can be a sensor of errors which makes it hard to interpret arrhythmia correctly. This prototype works with a single channel. Two electrodes ECG sensors. Noise interface and non-rest condition of the patient can contaminate the signal. This implies that we focus on two life threatening arrhythmias: ventricular fibrillation (VF) and ventricular tachycardia (VT). VF is a lethal arrhythmia characterized by rapid, chaotic movements of the heart muscle that causes the heart to stop functioning and leads quickly to the cardiac arrest. VT is an abnormal heart beat usually to a rate 150-200 beats per minute. VT may result in fainting low blood pressure, shock or even sudden death. To detect these arrhythmias a beat detection and classifying algorithms for the smart phone has been implemented. For the patient to have a chance to survive VT/VF, a defibrillator should be applied within 5 minutes. Our System detects a VT/VF onset and alerts emergency services/caregivers/bystanders within 30 seconds. It therefore increases the chance that help can be given in time.

The open source heart beat detector and classifier was developed by Hamilton. which is based on the algorithms developed by Pan and Tompkins. The original open source implementation is in C and so it is ported into C for easy integration with the other software modules. The heartbeat detector and classifier are able to detect and classify a heartbeat as normal, PVC (Premature Ventricular Complexes - an extra heartbeats) or unknown. PVCs are often harmless, but when they occur very often or repetitively, they can lead to more serious rhythm disturbances. Also heartbeat rate calculation will be checked against the threshold levels set by the cardiologist for the patient. If the rate is too slow or too fast, the application will inform to the user.

The algorithm is also capable of processing the live ECG data in real time on the smart phone. Detailed description of the performance of the heart beat detector and classifier can be found. [24].

3.2 Fall detection:

Accelerometers are widely used to monitor the human body activity and an algorithm developed by Brown was implemented. [25]. This algorithm uses a state-machine that analysis the data from a 3-axis accelerometer worn on waist belt.

The algorithm focuses on large accelerations and the users upper body position. After a large acceleration the users position is analysed. A fall is detected shows how a user can automatically spot WIFI access points and GSM cells and assign these to an address. If GPS is available, the longitude/latitude coordinates are also assigned to the address.

An alarm is raised by the application automatically when the users position is horizontal or not upright after some period inactivity. An accelerometer is not classified as a fall when the position is upright or the accelerometer detects activity. Based on brown s testing (123 falls and 36 non falls), the algorithm is able to detect around 90% of all the falls along with 5% of false positives. The accelerometer sensitivity can be adjusted to the person s movement characteristics. High fall sensitivity implies that the algorithm classifies an acceleration faster as fall compared to low sensitivity level.

To accurately detect a fall, we need to calibrate the accelerometer. When a patient has attached the monitor to the human body will be asked to stand upright. This will set the accelerometer to the upright position and after an acceleration the algorithm can determine whether a fall has occurred based on the current position of the patient (e.g. bent down, horizontal)

3.3 Location detection:

We can use GPS to determine the location of a patient in case of an emergency. However GPS is only useful outdoors and in clear sights of GPS satellites. Many heart patients will spend most of their time in indoors and in order to automatically determine the location we use WIFI and GSM as a means to determine the location. Since GSM cell id WIFI access points are not automatically related to a location with the WIFI/GSM cell data. The patient can also track all the measurement in a weight or blood pressure log book. Based on the threshold levels set by the specialist the patient can monitor their progresses.

3.4 Emergency procedure:

In case of an emergency the application shows the alarm screen and plays a loud recorded message notifying the user. The user can disable the alarm in case of a false alarm. Otherwise the first aid message is played continuously on the smart phone instructing bystanders what to do in case the patient is unable to speak. Simultaneously an emergency call is placed automatically by the application.

IV Conclusion

This paper described a personalized health monitoring application using a smart phone and wireless sensors.

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