Mobile Phone Sensing System for Health Monitoring

Snehal D. Nanhore[1], Mahip M. Bartere[2]

[1]G.H. Raisoni College of Engineering and Management, Amravati
snehal.nanhore@gmail.com

[2]G.H. Raisoni College of Engineering and Management, Amravati
mahip_media@yahoo.com

Abstract: *One of the most important device in our lives is a mobile phone. For now, it is a powerful computing platform equipped with various sensors. Embedded sensors can be used in multiple domains, such as environmental monitoring, social networks, safety and also healthcare. Sensor enabled mobile phones or smart phones are hovering to be at the center of a next revolution in social networks, green applications, global environmental monitoring, personal and community healthcare, sensor augmented gaming, virtual reality and smart transportation systems. Health monitoring is repeatedly mentioned as one of the main application areas for Pervasive computing. Mobile Health Care is the integration of mobile computing and health monitoring. It is the application of mobile computing technologies for improving communication among patients, physicians, and other health care workers. As mobile devices have become an inseparable part of our life it can integrate health care more seamlessly to our everyday life. In this paper we survey the main use cases of mobile phone sensors in mobile healthcare. We classify the proposed mHealth sensing applications according to sensor types they use and discuss the main advantages provided by these applications.*

Keywords: Mobile Health Monitoring, Smartphone, Mobile phone sensing, Body sensor network, Smart phone sensors

1. Introduction

Smart Phones are becoming increasingly successful in the area of health monitoring. The commonality of Health monitoring systems is that they use either in-built sensors of smart phones, or a combination of biosensors and smart phone sensors for collecting information about persons health like blood pressure, pulse, Electrocardiogram (ECG),Electroencephalogram(EEG) etc, depending upon the system requirements. These systems work in following way: First the data is collected from the sensors and is transferred through wireless transmission using Bluetooth, GPRS, GSM for further processing. Individual mobile phones collect raw sensor data from sensors embedded in the phone including camera, GPS, microphone etc. The information is extracted from the sensor data by applying machine learning and data mining techniques. These operations are performed either directly on the phone or in the central processing unit. After this processing, the data is informed to a medical centre or hospital. In some systems the information is used for persuading a person to give attention to his health. These types of systems have proven to be effective in improving health such as encouraging more exercise. Rising health care costs and an increasing elderly population are placing a strain on current health care services. Elderly patients, particularly those with chronic conditions, require continuous long-term monitoring to detect changes in their condition as early as possible .According to the Algerian National Office of Statistics, the percentage of the total population of persons over the age of 65 has increased and is expected to increase further, the number reached 2.7 million out of a population of 35.5 million Algerians and it will reach 20 percent in 2030. In general, the greater part of elderly suffer from various chronic diseases, based on World Health Statistics (WHO) and other sources, chronicle diseases and psychological pressures are behind the death of 80 percent of elderly people in Algeria [8].In recent years, initiatives have been taken both from academia and by the industries with a view for improving the health care and safety of the public by taking use of information and communication technologies. Most research activities have been focused on achieving common platform for medical records, monitoring health status of the patients in a real-time manner, improving the concept of online diagnosis, enhancing security and integrity of the patients, developing or enhancing telemedicine solutions, which deals with remote delivery of health care services applying telecommunications, etc For now, mobile phones can use a variety of wireless communication techniques (GSM, Wi-Fi, Bluetooth and others). It allows to integrate mobile phones into existing healthcare services and also to create new services and applications in this area. Practical medicine and healthcare services supported by mobile devices are called mHealth solutions. This field is growing fast recently [6].mHealth applications are delivered via online stores, such as App Store, Google Play, Ovi Store and others that increases availability of mobile healthcare solutions. Another important factor, which determines applicability of mobile phones for healthcare purposes, is that a modern mobile phone is equipped with powerful embedded sensors, such as microphone, accelerometer, camera and others. There are surveys of mobile phone sensing applications, e.g., in [6] variety of domains including healthcare, social networks, safety, environmental monitoring and transportation. Researchers notice that these sensors open new horizons for mobile healthcare applications, but they did not review a lot of such applications, so the main use cases of mobile phone sensors in mHealth were not disclosed. In this article we survey mHealth applications, which use embedded sensors and also demonstrate the main use cases for such sensors in these applications.

2. Biosensors used in Mobile

The most widely accepted definition of biosensors is: "a self-contained analytical device that incorporates a biologically active material in intimate contact with an appropriate transduction element for the purpose of detecting (reversibly and selectively) the concentration or activity of chemical species in any type of sample."[1] The first biosensor, an enzyme-based glucose sensor, was developed by Clark and Lyons.[2] Since then, hundreds of biosensors have been developed in many research laboratories around the world. Over 200 research papers about biosensors have been published each year for because in many cases the transduction technology is well established; most of the research is focused on improving immobilization techniques of the biological element to increase sensitivity, selectivity, and stability. While critical, the latter has received relatively little attention probably in part because there is a tendency to design disposable devices that are most useful in quality assurance laboratories but do not allow on-line implementation for process control. Another dynamic area of research is miniaturization of sensors and flow systems. Development of these technologies is mainly driven by the need for in vivo applications for medical diagnosis and may not find immediate use in the agricultural and food industries. After almost 40 yr of research in biosensors, a wide gap between research and application is evident. The lack of validation, standardization, and certification of biosensors has resulted in a very slow transfer of technology. With faster computers and automated systems this process should accelerate in the future the past three years. In this section we survey a set of projects, in which embedded phone sensors are used in health applications.

A. Microphone Sensor: In some cases the microphone can also be used to assess patient feels, e.g., it was shown for patients with the myotonic syndrome. Myotonia is a disorder characterized by slow relaxation of muscles after contraction, which may cause a difficulty to move. According the proposed method, within 8 weeks patients had to call to the data collection service and to talk about their health. Automated voice response system classified symptoms into the four categories: muscle stiffness, weakness, pain and tiredness. Thus the system allows reducing.

B. Camera Sensor: The mobile phone camera sensor can be used to provide useful information about a patient images and videos that applies in such applications as remote doctor consultation. The more significant example of using mobile device camera in healthcare services is the teledermatology, where the patient skin images are used by the doctor to make a diagnosis. The sphere of mobile device camera application can be extended by using special devices together with the phone. For example, it is possible to create light microscope based on mobile phone [6]. In this microscope an optical system is attached to the phone in such way that zoomed image can be received via the phone camera. Researches noticed that camera resolution exceed the necessary level to detect blood cell and microorganism morphology that enables an automatic local analysis. As a case study of such system, the tuberculosis detection is

proposed. Such system is extremely cheap and portable that can be very useful in many in many reasons in the world.

C. Accelerometer Sensor and Geo-Location Facilities: The main application of accelerometers for healthcare purposes is to track a person's physical activity level. It is important as it allows reducing the risk of having many chronic diseases. There are specially designed accelerometer-based devices that measure activity level as a number of steps performed by the person. Such devices are called pedometers. To detect steps they capture readings from accelerometers and recognize the step pattern. Some pedometers can also calculate approximate number of burned calories. Embedded accelerometer of a mobile phone allows implementing the same functionality as pedometers provide. The main advantage of such a solution is that there is no need to have an additional sensing device. Several mobile pedometer applications are available for different popular mobile platforms [6]. Although pedometer-like systems can be very useful for physical activity tracking, they are usually focused only on step counting and do not consider other daily activities, such as walking or running. For more accurate physical activity monitoring a system has to be able to detect different types of activity, including walking, running, bicycle riding, car driving and others. Another useful application of mobile phone accelerometers has been proposed in project m-Physio [6] to provide rehabilitation service. A patient using the system does not need to come to the rehabilitation centre several times, but can perform rehabilitation exercises at home. To estimate training accuracy mobile phone with accelerometer is used.

3. System Architecture

MHMS collects patient's physiological data through the bio-sensors. The data is aggregated in the sensor network and a summary of the collected data is transmitted to a patient's personal computer or cell phone/PDA. These devices forward data to the medical server for analysis. After the data is analyzed, the medical server provides feedback to the patient's personal computer or cell phone/PDA. The patients can take necessary actions depending on the feedback. The MHMS contains three components. They are

A. Wearable Body Sensor Network [WBSN]
B. Patients Personal Home Server [PPHS]
C. Intelligent Medical Server [IMS]. They are described below.

A. Wearable Body Sensor Network [WBSN]: WBSN consist of one or multiple sensors put and adapted to the body of patient; the sensors gather their appropriate data and transmit that information to the second component (ICN) via Bluetooth communication protocol. Wearable Body Sensor Network is formed with the wearable or implantable bio-sensors in patient's body. These sensors collect necessary readings from patient's body. For each organ there will be a group of sensors which will send their readings to the group leader. The group leaders can communicate with each others. They send the aggregated information to the central controller. The central controller is responsible for transmitting patient's data to the personal

computer or cell phone/PDA. Suggested that for wireless communication inside the human body, the tissue medium acts as a channel through which the information is sent as electromagnetic (EM) radio frequency (RF).
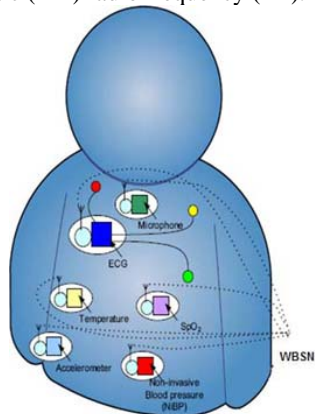

Figure 1. WBSN

B. Patient's Personal Home Server [PPHS]

The patient's personal home server can be a personal computer or mobile devices such as cell phone/PDA. We suggest mobile devices because it will be more suitable for the users to use their mobile devices for this purpose. PPHS collects information from the central controller of the WBSN. PPHS sends information to the Intelligent Medical Server [IMS].PPHS contains logics in order to determine whether to send the information to the IMS or not. Personal Computer based PPHS communicates with the IMS using Internet. Mobile devices based PPHS communicates with the IMS using GPRS / Edge / SMS. The best way to implement IMS is by Web Service or Servlet based architecture. The IMS will act as the service provider and the patients PPHS will act as the service requester. By providing these types of architecture, a large number of heterogeneous environments can be supported with security. So personal computer or cell phone/PDA can be connected easily to a single IMS without any problem.

C. Intelligent Medical Server [IMS]

Intelligent Medical Server (IMS) receives sensors data from all the ICN. Once the data is uploaded to the server, it is stored in elderly's database to be analyzed. This analysis is performed autonomously, without human's intervention, comparing the patient's vitals against pre-existing knowledge of his/her condition as well as any recommendations prescribed by the patient's doctor or healthcare professional. Our system uses logistic regression technique in ICS to mine data and predict health risk from knowledge of the patient's mobility, location and bio-signal sensor data. ICN also uses the combination of input parameters of GSM location (MCC, MNC, LAC, CI) and input body sensors data, because it was noticed that there is a direct factor between health status and place of the Algerian elderly1.

4. Implementation

We have implemented a prototyping system of MHMS. The current sensor being used in the Wireless Wearable Body Area Network (WWBAN) component of MHMSE\ is the Nonin 4100 Bluetooth pulse oximeter. It measures blood-

oxygen saturation levels (Sp02) as well as heart rate (HR) .We have considered a Nokia Smartphone N95 as hardware platforms of the intelligent central node (ICN) with operating System Symbian v 9.2 based on S60 interface[2]. We developed a Python application for S60 in ICN. Python for S60 is a powerful programming language, it has efficient high-level data structures and a simple but effective approach to object-oriented programming. It is an ideal language for scripting and rapid application development in many areas on most platforms [2]. Our Python application gathers the sensor data from Nonin sensor (SpO2, HR) and Smartphone integrated sensors (Accelerometer, MCC, MNC, LAC, CI). ICN uses Python APIs (Application Program Interfaces) to manage BT connections. Once data is received, ICN uses algorithms to compare currents data with the previous; if it detects changes it forwards that data on to the ICS (intelligent central server), figure 4. ICS includes MySQL database and Apache Server web. All server side functionality is implemented in HTML and PHP (figure 5). Client (ICN) communicates with the server (ICS) using HTTP protocol. The using of Open Source Software (MySQL, PHP, Apache, and Python for S60) implementation will reduce the implementation cost of MHMS.

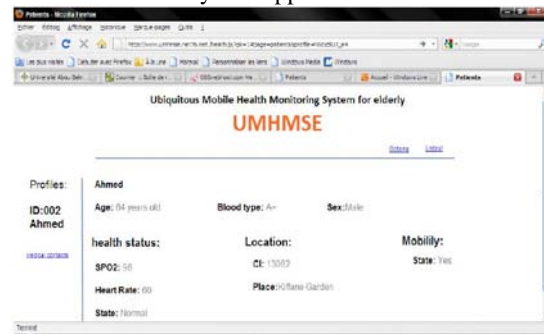**Figure 2.** Screenshot of the ICN implementation based on Python application

Figure 3. Web interface of UMHMSE

5. Conclusion and Future Work

In the paper we have surveyed different recently developed applications of embedded to mobile phone sensors. Some of these applications are already distributed and used for medical purposes, but the other are research projects so far. The main reason to use mobile phones in healthcare domain is to improve quality and availability of the healthcare services, because very many people in the world already have a mobile phone. Mobile phone based solutions can decrease healthcare services cost and it is another reason to use them. This paper reviewed the state of the art in research and development of Mobile Phone Sensing

Systems. Smart Phones are getting smarter because of all the sensors being added to them. It is shown that the current status of Smart Phone sensors have the potential to revolutionize various fields of human life. In-built mobile phone sensors have many such capabilities that can improve people lives cutting down the time it takes to find things, to prevent people from getting lost, improve health conditions, and even more serious applications are emerging that could actually save lives. Security and privacy is one of the utmost issues that needs more attention while developing mobile phone sensing systems as when Mobile phone is used for social interactions users main concern is to secure their private data. However, this study highlights the fact that there are still a lot of challenges and issues that need to be resolved for mobile phone sensing systems to become more applicable to real-life situations and spawn further research in this area. The whole system of mobile health care using biosensor network places forward some future works such as finding the most effective mechanism for ensuring security in biosensors considering the severe restrictions of memory and energy, representing the collected data in the most informative manner with minimal storage and user interaction, modelling of data so that the system will not represent all the data but only relevant information thus saving memory. These are the generic works that can be done in future in the sector of mobile health care. For MHMS our vision is much wider.

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