Mobile Phone Sensors in Health Applications

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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.

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.

Index Terms: Mobile Healthcare, Sensor, Mobile Phone.

I. Introduction

Mobile phone or smartphone becomes the most important communication device in people lives. According to the International Telecommunication Union (ITU), by 2015 the whole world population will be covered by the mobile cellular networks and every other man will use a mobile phone [1].

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 [2].

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 [3] 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.

The remainder of the paper is organized as follows. In Sec. II we present most popular sensors, which are used in modern mobile phones and discuss their general applications. In Sec. III we review existing mHealth applications, which use embedded sensors of mobile devices and discuss the main advantages of internal sensors usage. In Sec. IV we make conclusion of our survey.

II. Mobile Phone Sensors

All embedded sensors of a mobile phone can be subdivided into two categories. The first one includes environment sensors and the other contains position and orientation sensors. Environment sensors are used to measure different properties of the mobile phone environment.

Microphone and camera are examples of the first sensor group. Such sensors as accelerometer, digital compass, gyroscope and GPS form position and orientation sensors group. They are used to determine orientation of the mobile phone in space and also device location.

All phones are equipped with a microphone sensor, which allows to capture environment sounds. Prevalence of these sensors make them attractive for various sensing applications, such as automatic phone context detection. For example, in [4] it is shown how to determine actual user context or kind of person activity by analysis of the audio signal from the mobile phone microphone. Such contexts as speaking, cafe visiting, car driving and others can be classified using only the audio signal.

Camera is another very popular mobile phone sensor and its general task is photo taking and often video recording. The use of camera sensor can be extended to interact with real world objects, in this case a local analysis of photos or video stream is needed. For example, such analysis was proposed to read 2D codes [5]. The other environment sensors are a light sensor and a proximity sensor. The light sensor measures intensity of ambient light and can be used to adjust brightness of the screen [6]. The proximity sensor detects presence of nearby objects. When the user holds the phone close to his or her ear to answer the call, the screen is blocked to prevent accidental touch.

Accelerometers and magnetometers are the sensors, which purpose is to determine a device orientation in space. Accelerometer measures acceleration across two or three directions. The resulted data are used to change screen orientation [6]. Accelerometers can also provide a new way of interaction with the phone, e.g., in motion-sensitive mini-games to control a game process. Whereas the accelerometer in the mobile device allows to measure the linear acceleration of the device, a gyroscope helps to directly determine the orientation relative to the earth magnetic field. Generally, these sensors are used for navigation but also can be applied in new techniques to interact with mobile device using properly shaped permanent magnet [7].

III. Mobile Phone Sensors in Healthcare Applications

In this section we survey a set of projects, in which embedded phone sensors are used in health applications.

A. Microphone sensor

There are several use cases of microphone in mHealth. In healthcare this sensor is obviously used for communication. It offers an effective means of bringing healthcare services to citizens that is extremely topical for developing countries. One of the key applications for mHealth in such countries are:

- Communication and training for healthcare workers;
- Disease and epidemic outbreak tracking;
- Diagnostic and treatment support.

In some cases the microphone can also be used to assess patient feels, e.g., it was shown for patients with the myotonic syndrome [8]. 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 to reduce the number of the doctor visits because assessment can be done automatically and allows to monitor such patients without hospitalization.

B. Camera sensor

The mobile phone camera sensor can be used to provide another 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.

Teledermatology solutions exist in the market of healthcare services. For instance, one of them is provided by ClickMedix [9]. The solution consists of the following parts: a mobile application, a data collection center and professionals in dermatology. To use this service a patient should be registered in the system. After registration the user is instructed on how to take a photos of their skin correctly. Then, using the mobile application, the patient takes photos of his/her skin and sends them to the data collection server. The doctor gets access to these data and prescribes a treatment according to the analysis.

The service provider suggests using such a remote consultation when a patient cannot have recourse to qualified specialists for one of the following reasons:

1) Lack of access: patients cannot easily reach doctors;
2) Lack of funds: patients cannot afford the high cost of healthcare;
3) Lack of medical resources: most countries face the severe shortages of trained healthcare professionals, especially medical specialists, to perform an adequate diagnosis and quality treatment in rural areas.

Another type of medical consultation involving mobile phone camera includes, for example, a remote doctor advising, which is used in Taiwan and China for teleconsultation and diagnostics of soft tissue injuries [2]. Such applications decrease overall number of medical center visits by patient and eventually lead to the improvement of the healthcare.

Several new applications in the cardiology field of mobile phone camera were proposed recently. There are two different ways to use phone camera in this field. The first one is to detect heart rate through human skin color analysis. It tracks color changes in the light that passes through a finger. This idea has been implemented in Instant Heart Rate application (available for iOS and Android platforms [10]). This application has been tested by nurses, MDs, EMTs and fitness coaches. Another way for pulse detection using mobile phone camera has been proposed by researches of MIT Media Lab. They have developed a digital filter for the detection of subtle periodic changes in video stream. This filter is used to detect heart rate by analysing video of patient's face. The measurement principles are the same as the clinical pulse oximeters use. Every time the heart beats, more blood rushes through the face vessels, causing them to expand. The increase in blood volume absorbs more light, resulting in a decrease in the amount of light reflected from the face. This solution is implemented in Cardiio application (available for iOS platform) [11]. The main benefit of the method is that it does not require any additional devices to measure heart rate, so it is easy and cheap to use.

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 [12]. 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 regions of the world where the required equipment is either unavailable or insufficiently

portable. Operators may also do not have high qualification to analyse obtained images. Moreover, the high availability of mobile cellular networks enables the system to be used in diagnostic imaging and telemedicine.

C. Accelerometer sensor and geolocation facilities

The main application of accelerometers for healthcare purposes is to track a person's physical activity level. It is important as it allows to reduce 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 to implement 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 [13, 14]. 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.

To recognize different activity patterns some studies use only a single accelerometer. For example, in [15] the data were collected from tri-axial accelerometer worn on person's waist. The authors use Bayesian classification for activity recognition. As a result, approximately 80% accuracy has been achieved using such activity classification technique. Similar studies [16, 17] have good accuracy in activity classification, but require additional equipment or use devices made only for research purposes [18]. The requirement for additional devices makes such systems inconvenient for a practical use.

Recently mobile phones equipped with different embedded sensors have been used in several studies to collect data for activity classification. To create classification model some of these approaches [19, 20] use data from several internal modules, such as microphone, GPS and camera. The other approaches [21, 22] use only accelerometer data and aimed to achieve phone orientation independence along with high accuracy of activity classification.

Accelerometer is also the central information source in human fall detection studies. In these studies fall detection is based on recognition of specific patters in accelerometer data. When the fall is detected, the system can send an emergency signal to the monitoring system. Such applications are very useful for elderly people monitoring. Unfortunately, the existing solutions for fall detection, for example Brickhouse [23], allows to detect falls only in limited environments, e.g., at home. Such systems are too expensive because they use special devices. To eliminate this issue mobile phone based solutions for fall detection have been proposed in [24, 25]. They use accelerometer data from mobile phone built-in accelerometer and do not need any external devices. Such systems give an advantage over the other solutions to detect falls everywhere. Moreover, vast coverage of mobile phone communication services allows to supplement emergency call information with exact patient location determined using GPS module.

Another useful application of mobile phone accelerometers has been proposed in project m-Physio [26, 27] to provide rehabilitation service. A patient using the system does not need to come to the rehabilitation center several times, but can perform rehabilitation exercises at home. To estimate training accuracy mobile phone with accelerometer is used. The first stage

of the system usage is the system learning when patient perform exercise under specialist supervision. The second stage is a personal rehabilitation when the patient perform his/her rehabilitation exercises at home. During these exercises the system captures the physical activity and classify it into four types: correct exercise, wrong exercise, exercise exceeds the maximum time, exercise does not exceed the minimum time. The system helps the patient to assess how accurately they perform exercises themselves. The experiments demonstrated that using this system the user constantly improves accuracy of personal rehabilitation exercises.

IV. Conclusion

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.

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