A Wearable Kids' Health Monitoring System on Smartphone

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ABSTRACT
Nowadays, several commercial and academic studies are available to measure and monitor health status of people. However, most of these applications have remained in research laboratories and are not being used pervasively while our survey pointed out that there is a high demand for this kind of solutions in the society. In this paper, we have examined some of the practical challenges in developing health monitoring systems by designing, developing and evaluating a simple wearable mobile health monitoring system for kids. The project started with a survey among parents to understand user requirements, also we interviewed a doctor as a domain expert, and finally a wearable prototype of the system was developed and evaluated. Our finding shows that downsizing the wearable sensors increases the acceptability of these devices by children; however, placing different sensors in one point would increase noise of observed data, but removing outliers, smoothing data and using domain experts' knowledge help increasing reliability of the system results.

Author Keywords
Pervasive healthcare; Ubiquitous Computing; Wearable computing; Mobile computing; Health monitoring system.

ACM Classification Keywords
J.3 Life and medical sciences

INTRODUCTION
The main goal of a health monitoring system is to identify a situation in which a person moves from a healthy state to a compromised state. For individuals with particular diseases, everyday activities could pose situations that quickly threaten their health. For instance, some changes in physical activities or dietary patterns of diabetic individuals can lead to life threatening. From diabetes management point of view, a hypoglycemic shock can really be dangerous for an artificial pancreas [1]. Therefore, the ability to estimate and guard against these critical situations is an important step on the path to save humans' life. Today, wearable physiological sensors are being used in a wide variety of applications including home health care, elderly monitoring, and physical training [2]. These systems can provide non-invasive physiological measurements such as heart rate, movement from accelerometers, and skin surface temperature. However, there are many challenges to collect precise data and analyze it correctly to realize compromised states. This paper describes development of a wearable health-monitoring system for kids, which can log and communicate health-related data to improve health level of kids and save parents' time to care their children.

RELATED WORK
Over the past few years, the main focus of health monitoring systems has been to monitor more vulnerable people such as elders, and children. Some of the researchers, focused on analyzing and correlating different signs such as voice, body temperature, and heart rate to find meaningful patterns of different diseases [4], while some others have worked on power efficiency and downsizing wearable sensors [5]. Also, smartphone platform, as an inseparable part of our life, has been considered in developing health-monitoring systems by some researchers [3]. Rodriguez et al. [6] has classified monitoring systems into three main categories. Solutions in the first group capture signals and react in an offline mode e.g. KiMS [4]. The second group systems have the capability of remote real-time processing e.g. IMHMS [8], iCalm [5], Mobihealth [9], and systems in the third category provide local real-time processing e.g. iCare [7]. Our system is a real-time personal alert system, which could be classified in the third group.

REQUIREMENT ANALYSIS
At the first step of the project, we evaluated the usefulness of our main idea and tried to discover requirements of potential users through an online survey among 21 parents. The survey shows that most of the respondents found useful an alerting system that can recognize kid's sickness during night and when their child is in the childcare center. Moreover, they prefer to be informed about their kid's sickness by receiving SMS and e-mail from the monitoring system rather than seeing real-time information on a webpage. We also interviewed a doctor and discussed the idea of the project. The main findings from our interview with the doctor are as follows.

- This system should be used for none-critical situations.
- To recognize kids' sickness, we need to monitor several vital signs such as heart rate and body temperature.
- The best place for temperature sensors is inside the ear.
- An acceptable sampling period for measuring body temperature and heart rate is between 10 to15 minutes.
- In the infection risk situations, for 1°C increase of the temperature the heart rate grows about 10 beats/minute.

SYSTEM DESIGN

Design space analysis

Regarding our system domain and identified requirements, the system should be real-time to alert the compromised situations. Also, since the focus of this project is developing a personal health monitoring system for parents, we chose smartphone as the local server of our system. One of the challenges in designing and building wearable health monitoring systems was placing sensors. However, inside of the ear is the best place to measure body temperature, but it is not easy to convince a child to put a sensor in her ear for a long time. Therefore, we decided to put the temperature sensor in an armband that can fix the sensor under the kid's arm. We also tried to place the pulse sensor in the armband but the heart rate data from the armband was really noisy compared to the lobule of ear.

System Architecture

The mobile application

The mobile application plays a vital role in the system by receiving physiological data from wearable device, processing data and alerting after detecting a critical situation. The threshold for each measure could be defined manually or automatically based on age, gender, and weight of the kid. Also, the user can choose informing methods such as alarming, receiving SMS, or e-mail.

The wearable device

The wearable device is constituted of 4 main parts: a TMP102 digital temperature sensor breakout from Sparkfun, a pulse sensor to measure heart rate, a Mini Pro Arduino microcontroller (3v), which collects data, removes outliers and transmits data every 5 minutes, and a Bluetooth Mate Gold communication module from Sparkfun to send the data to the mobile application.

EVALUATION

In order to confirm the feasibility of monitoring vital signs with the system, a simple experiment has been conducted. In this experiment, a 5-year old kid wore the wearable device, and we started capturing vital signs by the monitoring system. Concurrently, we measured body temperature and heart rate with a commercial medical device as a reference. The experiment was repeated 20 times and results of the experiment showed an acceptable error in captured data. For body temperature, the average observed deviation was 0.19°C and the maximum deviation was 0.31°C. During our experiment, we received just about 17% of the data packets over Bluetooth so that we decided to increase the frequency of observations to ensure that the system collects necessary amount of data.

CONCLUSION

In this project, we designed and developed a mobile health monitoring system for none-critical situations using wearable sensors. While advances in information and communication technologies have opened new horizons in front of the healthcare systems, there are still several challenges that should be solved by collaboration between engineers and medical professionals. For instance, the skin temperature is not a precise estimation of core body temperature; therefore, as the future work we intend to extract systematic rules from the domain experts' knowledge and find appropriate data mining techniques to analyze the correlation between collected data to draw more reliable conclusions.

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