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Mobile health architecture for obesity management using sensory and social data

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ABSTRACT

One of the principal causes of several chronic diseases (e.g., diabetes, high cholesterol, and hypertension) is the obesity epidemic in high and middle income countries. Obesity also leads to an increasingly negative effect on public health resources. Therefore, obesity and overweight have to be monitored to mitigate and prevent the potential risks generated from the threat of related diseases and from reducing productivity experienced by businesses. A mobile-health monitoring system includes sensing, transmitting, storing, processing, and analyzing intensive, continuous, and heterogeneous medical data. However, current approaches are standalone mobile applications, augmented mobile applications, or mobile health systems. These approaches only consider simple activities (assess, detect, or control obesity) and rely on a mobile phone to perform complex processing operations on the collected data. Such complex operations need (1) efficient data mining techniques, (2) more memory consumption and processing time, and (3) long life mobile battery. In this work, we develop a new comprehensive mobile architecture for tackling the challenging issues of obesity control, monitoring, and prevention. We introduce a set of business requirements considering stakeholders, sensor devices, and architecture requirements to meet our architecture's objectives. Our architecture system can also help individuals track food intake, lifestyle, calories intake, calories consumption, and exercise activities. We analyze the data collected from continuous monitoring using non-invasive sensors, in addition to the data collected from social communities created to propagate awareness and share appropriate information about the obesity problem and its solution. We develop data mining algorithms and sentiment analysis algorithms and generate intelligent suggestions, warnings, and recommendations to control and mitigate the risk of obesity and its related diseases. We develop schemes for reducing data and saving energy, which minimize the amount of network traffic within the community of sensors. Moreover, we totally implement our architecture system as a collection of Web services organized by the model–view–controller design pattern to write, retrieve, and access data to and from the cloud storage firebase. We finally evaluate the efficacy and scalability of the implemented system using a comprehensive cloud database including entered data, calculated data, sensory data, and social data of 50 underweight, overweight, normal, and obese volunteer subjects. The obtained results show our architecture's objectives are fulfilled.

1. Introduction

With respect to the World Health Organization, overweight and obesity chronic diseases are delineated as "abnormal or excessive fat accumulation that may impair health" [1]. The popularity of obesity has reached the degree of a global epidemic. In fact, around 1.4 billion adults were overweight and 0.5 billion adult persons were obese worldwide in 2008 [1]. The incidence of obesity has increased twice in the period 1980–2008 [1]. While obesity was associated with high-income countries, it is nowadays very common in both low-income nations and middle-income nations. The annual health survey in the England in 2012 reported that a quarter of adults were approximately obese [2]. The studied data in the National Health and Nutrition Examination Survey (2009–2010) within the United States indicate that more than 2 in 3 adults were either overweight people or obese people and about one-third of children and teenagers aged 6 to 19 were either overweight

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people or obese people [3]. There are 2.8 million persons dying per year as a consequence of overweight disease or obese disease [1]. The report of the Government's Foresight Program states that above than half of the UK adult persons could be obese ones by 2050 [4].

Overweight and obesity is related to more deaths worldwide than underweight [1]: 65% the inhabitance of the world live in high and middle income countries wherein overweight and obesity diseases cause to die more people than underweight disease. Specifically, 44% of diabetes and 23% of ischemic heart disease as well as 7–41% of particular cancers are related to obesity and overweight diseases. Obesity has an increasing impact on public health resources [5]. In the UK, the NHS costs related to overweight and obesity will be twice to £10 billion each year by 2050, and the indirect costs to community and business (e.g., reduced productivity experienced by businesses) are estimated to reach £49.9 billion per year [4]. In 2012, the United States Centers for Disease Control and Prevention expected that obesity might reach 42% and might cost $500 billion by 2030 [6].

In 2012, the Health Authority Abu Dhabi published a report revealing that people living in the United Arab Emirates (UAE) have high rates of chronic diseases [7]. In particular, 33% and 38% of the male and female population have a chronic obesity disease respectively. Obese persons are more probably to have high cholesterol level, high blood pressure, high lipids, cardiovascular diseases, hypertension, and type-2 diabetes. This will have an impact on life-threatening comorbidities and a burden on health care expenses and resources. For example, the UAE categorizes as the fifth most obese nation in the world [8] where male adults consume around 2500 calories and female adults around 2000 calories per day. Adults in the UAE and Qatar have been found to consume over 3000 calories per day, almost 20% above the worldwide average. The UAE Ministry of Health had warned that most children would be obese and 44.5% of women could become obese in the next three years with less physical activities. These rates will increase further without major lifestyle changes. Although causes of obesity on a broad scale are complex, Butland et al. [4] defined four determinants of obesity control and treatment (a) the level of primary appetite control, (b) the force of dietary habits, (c) the level of physical activity, and (d) the level of psychological ambivalence. At the level of the individual person, weight gain results primarily from excess calories resulting from the consumption of more calories than those required and burned out of metabolic activities and physical activity. Moreover, combining television viewing, snacking during watching television, and computer screening time has been obviously linked with high Body Mass Index (BMI) beside adiposity in children ([9,10]). In summary, one of the principal causes of several chronic diseases is the obesity epidemic in high and middle income countries and obesity leads to an increasingly negative effect on public health resources. Therefore, obesity and overweight have to be controlled by losing weight and monitored to mitigate and prevent the potential risks generated from the threat of related diseases and from reducing productivity experienced by businesses.

1.1. Mobile health systems and current challenges

Many health-care centers have emerged in modern and developing countries to improve health-care services and optimize medical resources. The core of all these centers is the investment in modern Information and Communication Technology (ICT) infrastructures to connect directly hospitals, clinics, and healthcare organizations to make the exchange of medical data possible. Most US health-care industries, research, and development agencies (e.g., NIH and NRC) have engaged in transforming healthcare ecosystems from hospital-centered to patient-centered and actively involving patients in the process of monitoring and accessing their health portfolios. To fight obesity, overweight, and chronic diseases, there is a major shift in the literature towards electronic healthcare services, which keep patients informed about their health conditions and continuously advise them with best lifestyle practices ([11,12]). With this major shift, electronic health (e-Health) and mobile health (m-Health) systems have been introduced to monitor, detect, control, and prevent obesity. Such systems devote to mitigate the potential risks generated from the threat of related diseases. Indeed, e-Health is a significant and emerging domain that combines medical informatics and public health disciplines. It refers to health-care services and a repository of medical information in an electronic form that can be delivered to patients over the Internet and its associated technologies [13]. This repository allows physicians and doctors to access medical information easily without asking patients directly [14,15]. M-Health systems extend typical e-Health systems with a set of new promises and benefits to patients as follows:

1. Mobile devices (e.g., smartphones, tablets, and wireless sensors) are used widely throughout different age groups in obese populations and provide a cost-effective platform to implement easy-to-use healthy programs [16,17].
2. Required data might be gathered in a real-time and secure way and meanwhile feedback can automatically and rapidly be delivered following obese patient's measurements and activities, anytime and anywhere [18].
3. Health and reliable telemedicine applications, interfaces, and mobile devices can readily be tailored and personalized to receive, for example, text messages about a weight loss management and calories intake and consumption to control obesity.
4. Patients/users can obtain and track information that enables them to self-monitor and access progress weight loss reports and provides them with the resources required to begin and/or maintain healthy behavior changes.
5. M-Health devices can visually display feedbacks, physicians' recommendations on appealing screens, and introduce exciting and entertaining games to make obese patients experience enjoyable. Such devices also overcome geographical and organizational barriers and do not disturb the obese patient's normal lifestyle activities.
6. M-Health systems can leverage existing social networks of obese peoples or establish new social networks to promote lifestyle changes. Using social networks is one of five strategies employed in the mobile-phone health treatments as shown in Ref. [19] as follows “1) tracking health information, 2) involving the healthcare team, 3) leveraging social influences, 4) increasing accessibility of medical health information, and 5) utilizing entertainment.”

As we will show in Section 3, the current m-Health approaches range from standalone mobile applications, mobile applications augmented with some capabilities to mobile health systems. However, these approaches are very few and not suitable because they provide a simple and partial solution to the obesity problem; for example, healthy diet programs alone cannot lead to weight loss. A combination of diet programs and physical activities with a strong spirit, motivation, proper guidelines to control the daily food intake, and behavior therapy is the most effective solution [20,21]. The success of this combination requires implementing a self-monitoring system [22] that reports clearly and easily the progress of the diet programs and produces awareness and appropriate recommendation to the users. Also, a combination self-monitoring, feedback, social support, structured program, and the personally tailored program would facilitate weight loss [23].

Using m-Health systems to monitor, prevent, and control obesity and overweight raises many challenging issues ranging from sensing, transmitting, and storing intensive, continuous, and heterogeneous data. Other challenging issues include, but not limited to, energy harvesting of sensors and mobile devices, intermittent network connection, pre/post-processing of collected data, seamless access to data, analysis, visualization and personalization of collected data, integration of various technologies, and assessing trade-offs between all of these issues combined together. Challenging issues linked to analyzing and visualizing big data are not suitably addressed. For data analytics, the challenges remain in extracting medically useful information from an array of biomedical