A Mobile Health Monitoring Application for Obesity Management and Control Using the Internet-of-Things

[1]Mohamed Alloghani, [1]Abir Jaafar Hussain, [1]Dhiya Al-Jumeily, [1]Paul Fergus, [1]Omar Abuelma'atti, [2]Hani Hamdan
[1]Applied Computing Research Group
Department of Computer Science
Liverpool John Moores University
Liverpool, Merseyside, UK

[2]Department Signal & Statistics
CentraleSupélec
Plateau de Moulon
France

{M.AlLawghani@2014.ljmu.ac.uk; A.Hussain, D.Aljumeily, P.Fergus, O.E.Abuelmaatti}@ljmu.ac.uk,
Hani.Hamdan@centralesupelec.fr

Abstract— Obesity is one of the most serious and dangerous nutritional diseases around the world. Usually, people develop patterns of unhealthy eating that lead to increased body weight and accumulation of fat in the body. This mass happens due to an imbalance between the energy intake from food and energy consumed in the body. One of the primary treatments for this serious health risk include diets, physical activity, weight-loss training and adoption of health programs that promote healthy eating. As such, reliable mechanism to prevent and control the obesity levels is vital. It led many experts and researchers who are interested in the health sector to explore more solutions that help to combat the obesity phenomenon. This paper presents a mobile health application intended to increase the awareness levels of parents and children about the obesity risks and help them to sustain balanced and healthy eating lifestyle. The proposed mobile application is an educational tool for the evaluation of interventions to prevent obesity risk levels. The application is based on the Internet-of-Things approach, which allows tracking food intake, remote capturing and constant monitoring of children data with interactive feedback displayed on the mobile application.

Keywords— Internet of Things, eHealth, mHealth, Geolocation, Internet

I. INTRODUCTION

The prevalence of obesity among children, youth and adults have become a serious problem worldwide. According to [1], the prevalence of obesity among middle-aged adults 40.2% and older adults aged 60 and above 37% that was significantly higher than adults aged 20-39 (32.3%). A recent study [2] showed that adults in UK spend on average more than five hours a day sedentary. Another study [3] indicated that in England, the age group of 13-15 years old of boys who spent the lowest sedentary time compared to Scotland and Northern Ireland. The study [3] also reported that obesity and overweight rates increased by a 2-3% in France, Australia, Switzerland and Mexico but have been stable in Canada, Italy, England, United States, Spain and Korea. On the other hand, the Gulf Countries witnessed a freighting rise in the obesity rates particularly Qatar and Kuwait, which recorded the highest female obesity rates worldwide [5]. According to a recent study [6], [7] showed that more than 60% of the UAE locals are obese and this figure is expected to rise. The data trend is not slowing down and the number of obese adults and children continued to increase dramatically. Authors in [4] suggested methods to prevent obesity such as frequent health checkups, prevention of lifestyle diseases and adoption of changes in consumption and eating patterns. In UAE, the child obesity reached alarming proportion levels where more than 40% of children are either overweight or obese [8]. In most cases, the lack of parental attention and not spending enough time can lead children to suffer some health issues and behavioral problems. Such behavioral changes will negatively motivate them to consume meals, including high calorie foods, unhealthy food like chocolate, chips, pizza and burger away from home. This makes it very difficult for parents to control their children's food choices and time of meals. The parents should practice their role and promote healthy lifestyle behaviors among their children. The parental involvement can help to prevent and mitigate the obesity levels of children by providing the required guidance and food orientation to children to foster healthy lifestyle and become aware of nutritional facts of each meal before their undertake [9]. In recent years, many eHealth and mHealth solutions presented and successfully implemented taking the advantages of recent computing technologies and mobile powerful advancements. Such solutions offer many level of services to users and huge intensity of interaction including the data exchange, information retrieval and user's feedback details [10]. Improving the healthcare outcomes require the adoption of a suitable solution that will facilitates enhancements of medical care outcomes [11]. The Internet of Things (IoT) can provide a useful tool to achieve this need. The IoT is a newly developed approach that is core objective to achieve and facilitate the communications between smart objects such as devices, sensors, vehicles, applications and enable these objects to collect and exchange data [12]. Nowadays, the mobile devices are equipped with advanced sensors and features such as the Bluetooth technology, GPS, NFC, Wi-Fi, voice recognition that make mobile device a prospective tool [13].

This paper presents a mobile health monitoring application to help prevention of obesity levels in children and encourage them to become well educated about healthy nutritional practices. The paper is organized as follows Section II presents a brief review of related work. Section III provides a summary for the architecture of the proposed solution using the IoT concept. Section IV outlines the technologies used in the proposed mobile App. Section V details the evaluation and analysis of the system. Section VI describes the conclusion and future work.

II. RELATED WORK

Many studies demonstrated that mobile applications could offer interesting useful solutions to promote healthier lifestyle. Some works reported in [14] and [15] indicated that most of these proposed applications designed to a targeted group of people such as adults and

elderly. The work in [16] presented a mobile health architecture intended to prevent the obesity in children through a set of mHealth applications. Another example of mobile monitoring application designed to prevent the obesity of adult patients is myPace [17] that is a management system for behavior change of complete patients' weight loss deployed on smartphone devices. According to [18], [19] some interesting collaborative games for obesity prevention and control were developed for adults and youth. The majority of the existing research development of mobile applications for the prevention of obesity have focused on adults, adolescents and elderly. Very few studies focused on children' obesity prevention using the latest advancement of mobility and ubiquity capabilities. On the other hand, several Apps are available on different mobile platforms to download for fitness, diabetes, obesity and health control [20]. However, most of these mobile Apps considered as stand-alone applications, which are not adequate to prevent obesity of children, as they need to receive a proper orientation and guidance from their parents or adults who may support them to maintain a healthy lifestyle. There is currently a lack of rigorous research and assessment to determine the best practices for feasible healthcare solutions. Most of the published literature focused on prevention of chronic diseases using health apps. To some extent, it's not clear how these mobile Apps can be successful at facilitating the prevention of children obesity and health behavior change [20]. In the U.S., around 90% of healthcare service providers have deployed mobile devices that engage with patients [21]. Authors in [22] present an android application designed for elderly caregivers. This App takes into account the feature of SMS to send messages to an elders' device without any intervention, locate his place through GPS location, and send these details to a caregiver to provide required medication where required.

In this paper, a novel implementation is proposed for the use of mobile App for children, parents and healthcare professionals. The children will only be able to use this App with the permission of their parents. The children who are above the age of 13 can use this App. The system utilizes the social media services including the Facebook and Instagram that requires kids' age to be 13 years and older to sign up with these services. Aside from this, the mobile App complies with the Children Online Privacy Protection Act (COPPA) [34]. On the other hand, the App utilizes the features of the newly emerged concept of IoT for data capturing and information retrieval of foodstuff items. A fitness-tracking device fitted with 3D motion sensor is used for tracking children steps, distances travelled and burned calories. The quick response code (QR-Code) is used to decode the nutrimental information of the selected food items. The Geolocation API is used to detect and track the devices locations.

III. SYSTEM DESCRIPTION

The main idea behind this paper is to propose a mobile application that will support parents to monitor, control and educate their children about the healthy eating habits and rapidly increasing their level of alertness prior to undertaking unhealthy meals. The assigned doctors at schools are also able to use this App to view the children captured food data, send feedback, monitor a group of children following the automatic transmission of uploaded data to the Internet every time the tracking device is near a base station or when Wi-Fi feature has been enabled. The transmitted data to the Internet using the IoT can then be accessed and viewed by the parents and doctors. They can then be provided with advice, suggest a proper alternative healthy food, and suggest nearby healthy restaurants and grocery shops zone areas which they can safely find fresh and healthier food.

The development methodology of the mobile was based on the agile method as recommended in [23] which provides potential to deliver enhanced and high quality of mobile application development lifecycle. The users centered interface principles included in this work as per the proposed approach in [24]. The architecture of the mobile app comprises of three main layers; physical, network and web portal. These aspects are summaries as follows:

A. Physical Layer

This layer also called the perception/ hardware layer that serves the function of data acquisition from the implemented environment with support of involved devices' sensors. It runs the communications among smart objects and exchanges, processes and transmits the data to the network layer [25].

B. Network Layer

This layer represents and serves the function of the connectivity between the perception layer and the application layer. The devices' sensor nodes are designed to send data to the base station [26]. At this layer, data routing to different IoT devices are carried over the internet. The network gateways, internet and switching operate through telecommunication technologies such as Wi-Fi, 3G and Bluetooth. The internet is used as essential component of this solution which facilitates the networking infrastructure for the IoT nodes.

C. Application Layer

The establishment of IoT smart environment is usually achieved in this layer. The proposed mobile health monitoring solution lies on top of the aforementioned layers. The web system and mobile App interfaces with different IoT objects residing at the perception layer such as other third part systems, healthcare specialists, schools and hospitals. A collection of web services exposed to users with the associated back-office related modules that are facilitated through the integration with other components including the SMS gateway and map location services. These are referenced and called thru public API and with regards to identification, authentication and data privacy that are maintained and assured at the application layer. Furthermore, the application serves the function of data storage, processing, monitoring and decisions based on the constraints specified for users' authentication and verification operations. For the user's access, different access modules created that include children, parents and healthcare professionals. These stated modules are explained in the following section.

D. End-users Modules

When designing applications using the IoT, users' interaction with proposed systems must be considered [27]. As there is a large amount of data transmitted from the connected IoT devices that require authentication protocols to monitor and control the data exchanged. For that purpose, identification of users' access has been set to different profiles and privileges. The first module created for the children where a child uses the mobile App to track food consumption by scanning food items that have the QR codes. Reading and scanning QR codes usually available as built-in features that most smartphone devices have. However, some other smartphone devices do not have this feature which requires manual installations of readers to read the QR codes on items. The wearable device attached to the child's body allows transmission of such data when synched over the internet using network access point, Wi-Fi and Bluetooth to send the nutrimental information of scanned data. Parents as well as health professionals upon receipt of data and access to the web system can view, analyze and communicate with children through a web portal to provide required notifications that include advices, evaluations and recommendation of appropriate food items to take, find safe zone areas of fresh food and healthy shops. The mobile App uses the geolocation enabled feature to capture the location of child's position indoors and outdoors and attach it with submitted nutrimental data to the webserver. The parents and health professional module includes a management system that enables accessing the web system to monitor, view and analyze the logged data of users. The logged data shows complete children profiles about their nutrimental status, Body Mass Index (BMI), food consumption, steps taken, calorie burned and weight. Apart from the management module, a communication system is included to allow parents and health professionals to send messages to children to encourage them on energetic needs, follow certain rules, go to a food safe zone areas to undertake healthy meals...etc.

The research carried out by [28] showed that text messages intervention acts as a mean to lose weight. In this research paper, a Short Messages Service (SMS) has been used as text message-based personalized services sent to the App's users twice a day. To make the presented work as a complete solution for children obesity and control, the social networks were utilized. Children tends to use social networks such as Facebook and Instagram. Children, young and old people are using the social networks to connect and share [31]. The proposed mobile App has the functionality of utilizing social networks that allows children to share their achievements to their parents, friends as well as other users using different social networks. Figure 1 shows the various layers with respect to the devices and services for the proposed mobile application.

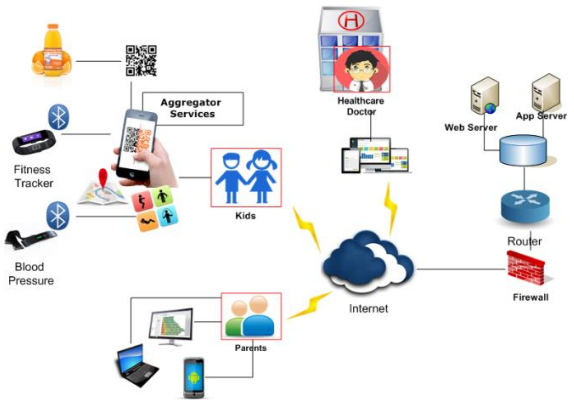

Figure 1 Abstract architecture of the System

Figure 1 presents the abstract architecture of the proposed mobile app for obesity management and control with the main defined components. In the meanwhile, the proposed system can be divided into three main parts. The first part is the physical objects that include devices such as fitness tracking, body sensors and attached medical devices. The second part includes the smartphone that is primarily used by end users including the children, parents and healthcare doctors. The smartphone acts as an intermediary that receives the data from various devices and processes them then automatically uploads data to the server. In the servers' farm, a server that host the mobile App act as healthcare information management system for obesity monitoring and control. The backend server stores and manages App's component's data. This data is saved on a remote backed server using HTTP with implemented web services. The backend server contains all information related to children personal data namely total volume of physical activities, calories burned, blood pressure, intake food, saved QR codes, and tracked geolocation information. The notification component allow to send alert messages to end users on selected food items that may not be healthy and encourage them with alternative food they should undertake from the healthy food zone areas.

The IoT objects used in this paper include sensors and medical devices that play a vital role to collect data from children. The fitness tracking media [32] provides accurate calorie burn measurement, temperature sensor, steps, sleeps and comes with accelerometer/ Bluetooth enabled that displays data in real time and automatically synchronize wirelessly/ Bluetooth to upload logged food to the mobile App repository server (backend). The QR-code has been used for this mobile App as an alternative to Radio Frequency Identification (RFID) as it requires all food items to include tags that may lead lot of end users to change their devices to enabled Near Field Communication (NFC) mobile phones. The QR codes are decoded easily with modern devices as it requires having camera with built in reader/ scanner to scan food items' QR-codes. The mobile App has different modules that include a module for data receiving, processing and transmission to the server, data retrieval, data settings, communication messages and location tracking.

E. Children-Data Collection & Monitoring

The data collection, transmission and processing is illustrated in Figure 2 and Figure 3.

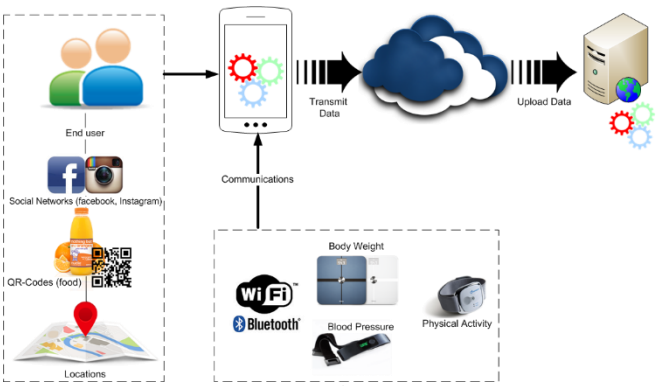

Figure 2 Collection of data process

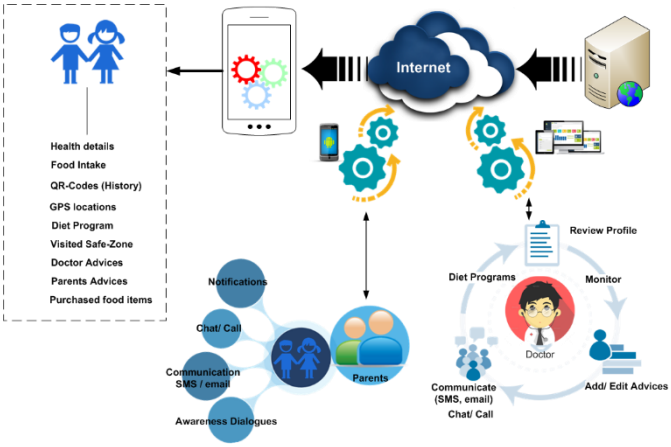

Figure 3 Parents and Doctors Feedback to Children

As depicted in Figure 1 the process of data collection involves the measurement from the IoT attached objects such as the fitness tracking device, blood pressure instrument and medical weight scale. All collected measurements are then uploaded to the system backend and data can be viewed by health doctors through the portal system as tabular and graphical ways. Parents can also view the data using the mobile App to view and track children's health status and history of the food intake along with all relevant child's profile. Figure 2 provides the necessary feedback based on the data collected and data processed including the summary of health profile and medical status. (you need to refer to Figure 3 in the text)

IV. TECHNOLOGIES USED IN THE MOBILE SYSTEM

With the rapid increase of mobile devices usage, it is common that targeting an independent applications that have very limited features is not all the time feasible. The developed mobile applications must be able to share and exchange data among users through various mobile component features including the web services, data repository and push notifications. There are many mobile Apps that offer such features which can run across multiple platform and devices [33]. The proposed mobile App targets Android platform devices which include key applications, operating system and system middleware features for integration. The Eclipse Android Developer Tool (ADT) was used for the application development. The rest web services transmits messages over HTTP protocol with the portal online services. The returned feedback from the system is passed through the Extensible Markup Language (XML). For the maintainability purposes, the look and feel of the mobile and online portal has been unified for future updates and changes as per the design pattern needed. For security improvements, the Model View Control (MVC) handles all the end-users' functionalities and isolates the system data from any potential direct access.

Additionally, the MVC supports the system scalability of users' growth, access and entire data resources that may increase. The PHP was used for the implementation of the server side. The Java script, HTML5 and CSS used for the front-end implementation.

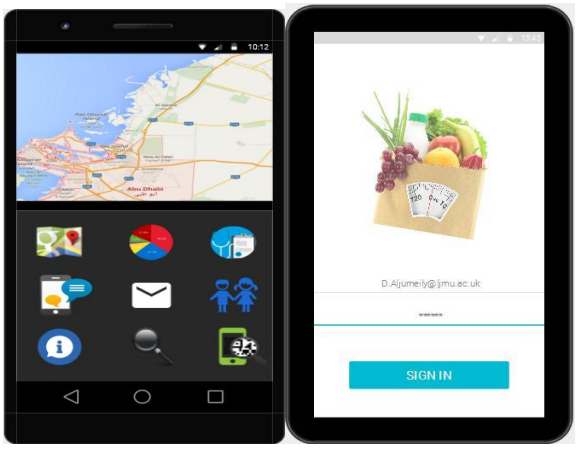

Figure 4 Homepage & Login screens

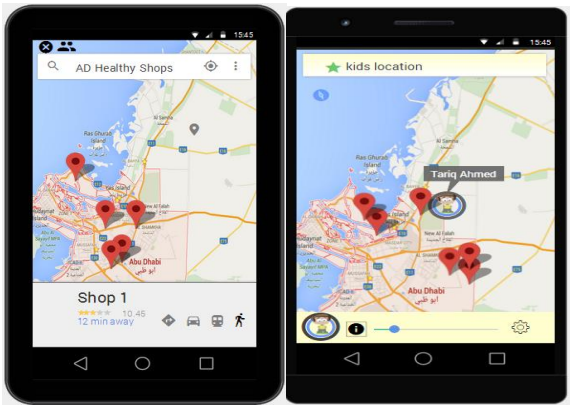

Figure 5 Users tracking location and safe food areas screens

The primary design objectives of the mobile App have been demonstrated with the extent to meet the expected users' needs. Figure 4 presents the users' homepage and login screens. In Figure 5, the parents and healthcare professionals can use the geolocation button to track the location of a child and use the interaction dialogues via SMS and email for communications. Scanned food items' QR-codes are saved and stored on the repository file upon successful synchronization with the system's server to upload and process. For the advices and training programs, doctors can use the advices module to generate and push notification to a child or a group of children to follow certain instructions or dietary program. Parents and doctors also can use this App to track the health conditions and food intake status of children. As outlined in the aforementioned section, users can access using account registered with social media including the Instagram and Facebook which allows children to share their achievements with friends and parents. This feature is very helpful way to encourage them using the App.

V. MOBILE APP EVALUATION

To evaluate the use and acceptance levels of users, a pilot study had been exercised which involved a sample size of 144 users. A correlation analysis was conducted to identify the mutual relationship of system's measurement variables that include trust, security, ease of use and usefulness.

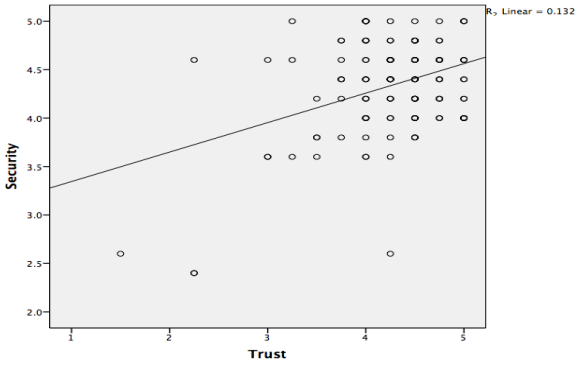

Figure 6 Correlation between Trust and Security

Figure 6 shows a significant correlation between Security and Trust (R=0.362; p=0.00) which depicts that measure variable of security and trust are highly correlated.

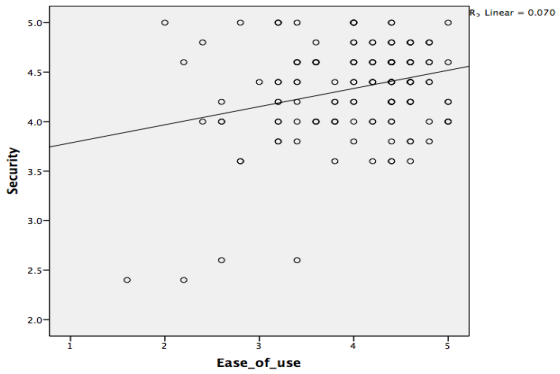

Figure 7 Correlation between Trust and Ease of Use

Figure 7 shows the association between Ease of Use and Security is Significantly correlated (R=0.265; p=0.00) and which shows people are taking care of these two factors together while choosing a mobile application usage.

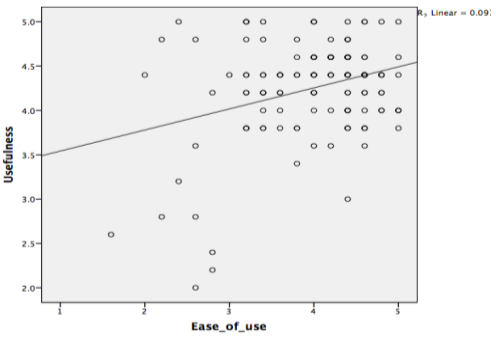

Figure 8 Correlation between Usefulness and Ease of Use

As depicted from Figure 8, Usefulness and Ease of use are significantly, positively correlated (R=0.311; p=0.00). Which implies the users are giving importance to ease of use and Usefulness

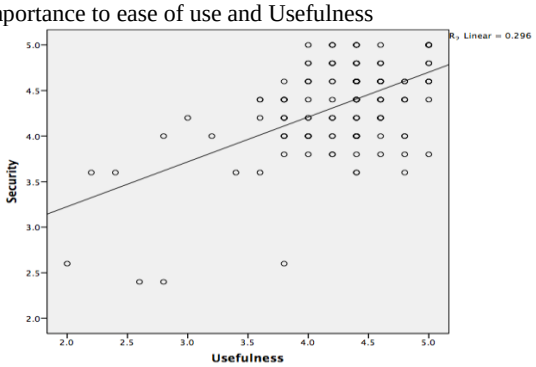

Figure 9 Correlation between Usefulness and Security

Figure 9 shows the correlation between security and usefulness is highly significant and both are positively associated (R=0.577; p=0.000).

VI. CONCLUSION

This research paper presented a development of a mobile App for obesity management and control targeting children as one of the main objectives. The children as we mentioned in the earlier sections should be 13 years and older to be able to use this App and with permission of their parents. The proposed mobile App intended to help parents and health doctors to monitor children who suffer from high obesity rates and would use the technological advancement like mobile App to encourage children to lose weight or maintain a healthy food intake. Doctors can use online health system as well as mobile App to encourage children to follow healthy instructions and dietary training programs and monitor their progression via shared data on children social accounts such as Instagram and Facebook. The IoT concept has been applied to support the scan of food items using the QR-codes that enable children to capture items' QR-codes and save them on the mobile devices using the App and then upload it to the server for further data processing and references. The fitness tracking devices has been used in this study to allow monitoring users' health condition which include body weight, blood pressure, calories burned, steps and physical activities. As future work, the introduced mobile system has to be tested by different schools such elementary and middle ones for testing and validation purposes. The main contribution of this work are the integration of multiple mobile devices. This is achieved using Android platform devices such as the implementation of IoT concept, geolocation for tracking the children locations, QR-codes as alternative way for quickly capturing food items nutrimental information. All of which are integrated into this App as a new approach of integrating recent mobile technology advancements.

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