

A new mobile ubiquitous computing application to control obesity: SapoFit

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Abstract

The objective of this work was the proposal, design, construction and validation of a mobile health system for dietetic monitoring and assessment, called SapoFit. This application may be personalized to keep a daily personal health record of an individual's food intake and daily exercise and to share this with a social network. The initiative is a partnership with SAPO – Portugal Telecom. SapoFit uses Web services architecture, a relatively new model for distributed computing and application integration. SapoFit runs on a range of mobile platforms, and it has been implemented successfully in a range of mobile devices and has been evaluated by over 100 users. Most users strongly agree that SapoFit has an attractive design, the environment is user-friendly and intuitive, and the navigation options are clear.

Keywords: *E-Health, m-health, mobile computing, Android, iPhone, obesity, Web services*

1. Introduction

Electronic health (e-health) brings new hope for patients with more accessible and affordable healthcare solutions [1–3]. In the last decade, with the advent of mobile communications and the development of smart mobile devices, mobile computing has increasingly attracted attention from the research and business communities [4]. Thus, it offers many opportunities for creating efficient mobile telemedicine applications. Mobile health (m-health) is the cutting edge in healthcare innovation. Its aim is to deliver healthcare anytime and anywhere, overcoming geographical, temporal and even organizational barriers [5,6]. Physicians are able to download medical records, lab results, images and drug information to handheld devices such as personal digital assistants (PDAs) and smartphones. Patients in turn are able to see their diagnosis, disease control and monitoring with easy-to-use mobile devices that accompany them everywhere. M-health systems and their inherent mobility functionalities have a strong impact on typical healthcare monitoring and alerting systems, clinical and administrative data collection, record maintenance, healthcare delivery programs, medical information awareness, detection and prevention systems, etc. [7].

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According to a Gartner press release, worldwide mobile application store downloads are forecast to reach 17.7 billion in 2011, a 117% increase from an estimated 8.2 billion downloads in 2010 [8]. Moreover, the Global Mobile Health Market Report 2010–2015 by ‘research2guidance’ commented that in 2015 about 500 million people will use m-health applications [9]. This raises several important and complex questions about these medical applications, such as, security, reliability, efficiency and quality of service.

Usually, healthcare providers keep and maintain patient health records. However, it is becoming increasingly common that patients also request access to these data. Medical records allow doctors to easily access patient information without the need to ask them in person. E-health systems are typically kept on electronic health records (EHRs) [7]. An EHR system is basically a repository of information regarding the health records of a patient/consumer in an electronic form [10]. In mobile context, a mobile EHR system complements a typical EHR system enabling access to health information regardless of where the patient is or what the time is. M-health systems use the Internet and Web services to provide an authentic interaction between physicians and patients.

Nowadays, in the context of public health, a big problem is obesity and the EHR systems have been focusing on this area. Obesity is a disease with an important risk factor [11] for the emergence, development and worsening of other diseases. There are so many obese people worldwide that the World Health Organization (WHO) declared the disease a global epidemic of the twenty-first century [12]. The Center for Disease Control and Prevention and the US National Health and Nutrition Examination Survey indicate that an estimated 17% of children and adolescents between ages 2 and 19 years are obese [13]. The main treatment for obesity includes dieting and frequent physical activity. Diet programs promote weight loss over the short, medium or long term. However, frequent physical exercise is necessary to maintain balanced body energy. Nevertheless, to maintain such treatments, it is crucial to have a strong will, motivation and constant monitoring of food intake [12]. According to the WHO, obesity is a disease in which excess body fat build-up may reach levels that can affect health. It is a chronic disease, with marked prevalence in developed countries, which affects men and women of all ethnicities and all ages, reduces the quality of life and has high rates of morbidity and mortality. The link between obesity and diabetes is well established and some studies suggest that obese people have more than just social motivations for losing weight. Moreover, obesity frequently is associated with life-threatening comorbidities such as cardiovascular disease, type 2 diabetes and some types of cancer [14]. The cause of obesity is the excess fat which results from a successive positive energy balance, where energy intake exceeds the amount expended. The factors that determine this imbalance are complex and they may be genetic, metabolic, environmental or behavioral. Moreover, obesity may also causes changes in socio-economic and psychosocial factors, discrimination in education, difficulty of employment, social isolation, depression, etc. [15].

In this paper, we are proposing a global mobile solution to control obesity and physical activity, called SapoFit. An important aspect of this system is its usability and inbuilt universal accessibility. The proposed application for mobile devices is a daily diet diary, in which the user records the meals eaten throughout the day, allowing the system to monitor in real time the calories eaten by the user and, at the same time, the calories burned when physical activity is undertaken. This paper also shows a performance comparison study and user evaluation of the SapoFit application using Android and iPhone OS. This work has got two main objectives: to present a new mobile application using different operating systems and to evaluate the performance and the usability of the proposed application with real users.

The remainder of this paper is organized as follows. Section 2 elaborates on the related work. Section 3 describes the methodology of developing the mobile system, whereas Section 4 focuses on the results achieved (application, demonstration and validation). Finally, Section 5 presents the conclusions and future work.

2. Related work

Increasingly, mobility is part of our life, every day there are new technologies that can be applied to a range of applications, but these can only work if they contain the mobility that is necessary today. Mobile computing embraces a host of portable technologies that make Internet access on the go not only possible but also integral to everyday life.

In [16], the authors suggest a prototype system that uses a mobile phone with built-in camera, network connectivity and integrated image analysis to provide an accurate account of daily food and nutrient intake. Their objective is to use visualization tools with databases to compare and record food eaten. Acquired images are used to approximate the quantity of food and nutrients consumed.

A mobile phone application for real-time monitoring of caloric balance, called Patient-Centered Assessment and Counseling Mobile Energy Balance (PmEB), is presented in [13]. This approach allows users to self-monitor caloric balance in real time. The PmEB is a client mobile application and uses a Web interface that allows users to register and personalize the application. The application allows the user interaction with the PmEB system. The server application sends updated caloric reminders to the client, stores food and activity information, keeping data updated about the users daily calorie consumption. The approach available in [17], called StepUp, is a step counter application that uses sensor-enabled mobile phones to automatically count the number of steps walked by the user. Its main goal is to provide the user with the measured quantity of his/her daily activities and to create a healthy competition which serves as a source of positive feedback. The StepUp application also aims to increase the user's awareness and understanding of the importance of physical activity and simplify the integration of regular exercise into their daily life.

A mobile phone short message service (SMS) for behavior modification in a community-based weight control program in Korea is presented in [18]. Mobile phones were used to deliver weekly SMS about weight loss. It delivers information about diet, exercise and behavior modification once a week. A total of 927 participants who visited a public healthcare center tested this service. Post-results showed that the majority of the participants were satisfied and attested this service may be an effective method of behavior modification in weight control.

Patrick et al. [19] presented a text message-based intervention for weight loss. This study describes the development and evaluation of a text message-based intervention intended to help a person to lose or keep weight in a 4-month period. This service includes personalized SMS and multimedia message service sent two to five times a day, printed materials and brief monthly phone calls from a health counselor. Post-results have shown that 92% of participants would recommend this intervention for weight control to friends and family. It proved that text-based services might be a productive communication channel to support weight loss.

In [20], the authors present MyDS – My Dietary Supplements, an iPhone application that allows an easy way to keep track of the intake of vitamins, minerals, herbs and other products.

Another iPhone application, called BMI Calculator, is one of the most popular tools from the National Heart, Lung, and Blood Institute Webpage. BMI is an indicator of

total body fat, which is related to the risk of disease and death. It receives 1.6 million visitors a month and ranks #1 on Google [21].

A mobile game/application called 'It's time to eat!' is presented in [22]. It uses a mobile phone game to promote and motivate healthy eating habits among children. This game gives to children the control of a pet that responds with photos containing the food they will consume. The pet interacts with the children by sending healthy eating reminders via email. The messages change depending on the day of the week. Each player must take a photo of the meal and submit it, and then the pet will give a score based on the healthiness of the food and the amount of the eaten food. In [23], the authors propose a technological solution to assist people with obesity problems. They have conducted a field study to visualize and inform their design. It is called Virtual Specialist, and it stays with the patient and advises him/her at all the times on issues related to diet and physical activities. In [24], the authors developed a prototype PDA decision support system based on a clinical practice guideline for the management of obesity. In [25], a study presents a waist circumference measurable belt with the resolution accurate to 5 mm, with the ability to decide if someone has the potential for obesity. This system can assist in obesity and overweight management. The system is composed of magnets and magneto-resistive sensors to measure the waist circumference. An algorithm was also developed to distinguish the belt moving direction.

SapoFit gathered contributions from the above-described solutions and also from the most popular applications on online markets, CardioTrainer [26], My Fitness Calculator [27] and CalorieCounter [28]. These applications are basically dietary assessment tools, and their main goal is the same: weight loss. However, they complement each other with different functionalities. CardioTrainer uses GPS to track the meters walked by the user and measure the calories burned. MyFitnessPal and CalorieCounter are similar applications and both keep track of the user food intake, and CalorieCounter even allows for the input of physical activities. However, neither of the applications has a suggestion for a diet or exercise plan. SapoFit complements all the above approaches and tries to be a more complete solution for weight control concerning obesity prevention and treatment. The main contribution of SapoFit is the advantage of all the inherent characteristics of each of the proposed Web services and the concept of mobile Internet that allows the system to be used anytime and anywhere. Moreover, SapoFit also motivates the user to interact with social networks instead of focusing only on the individual. As a motivation tool for losing weight, the application has a social network function that allows the user to share achievements with other users or with friends in several social networks, such as Twitter and Facebook. These contributions and the application are described, in detail, in the next sections.

3. Methods and procedures

This section explains the system architecture, technologies used and activity diagrams of the SapoFit system.

3.1. System architecture and overview

SapoFit is a mobile system that requires several daily inputs from users, mainly food and exercise, and other inputs such as weight, age and height. These data are updated on the user personal health record (PHR) through a Web service for easy and immediate access. The user profile makes use of the PHR for determining the user's nutritional status. This status includes the user's body mass index (BMI), the user daily caloric intake and energetic needs. SapoFit must keep its user well motivated not only to use the application but also to lose weight. Thus, it allows its user to share his/her performance and

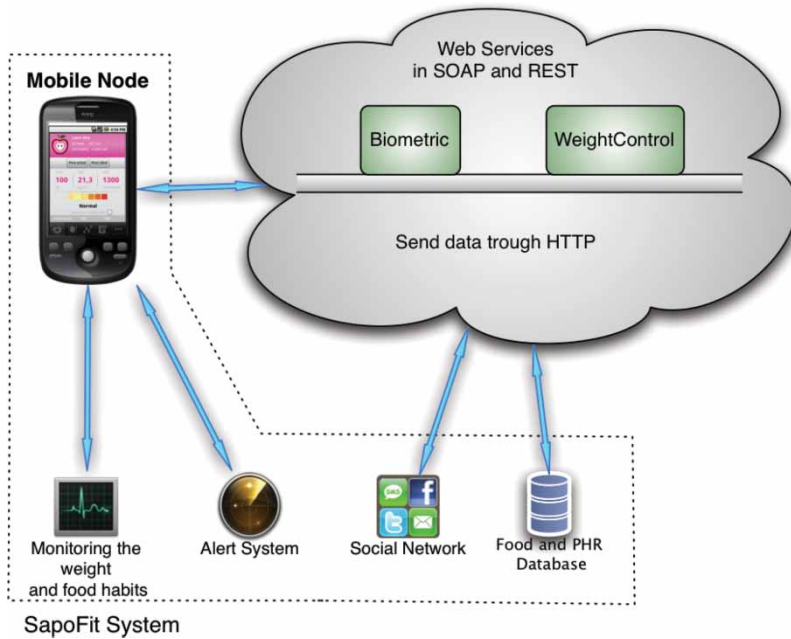


Figure 1. SapoFit system architecture.

achievements through well-known social networks (such as Facebook, Twitter, Hi5, Myspace, etc.). Figure 1 presents the SapoFit system architecture with main actions defined for the system communication. All data are collected and saved on a remote database through Hypertext Transfer Protocol (HTTP) on Simple Object Access protocol (SOAP) and Representational State Transfer (REST) Web services that furnish all the required information.

The database contains the user personal data, EHRs and all the user food intake and physical activities. This information will customize the alert system and its messages to the user. This alert system maintains frequent application–user interaction and motivates the user to follow the respective diet program and physical activities. The user food habit monitoring is essential to update the user profile.

Figure 2 shows typical m-health services framework. The healthcare providers offer Remote Monitoring Systems, Physician User Interface and Emergency Response in the PHR through a global communication network for healthcare users in various ways such as mobile devices, sensors and specialized devices in applications that allow health data gathering and health records.

SapoFit targets mobile devices running Android and iPhone platforms [26]. The major solution for application development was Java programming language and Objective-C. The implemented Web service communicates through SOAP and through REST messages over the HTTP with the PHR and the SapoFit services. The information is returned to the mobile application through the JavaScript Object Notation (JSON) or Extensible Markup Language (XML).

3.2. Activity diagrams

The activity diagrams are used to describe step by step the operational business components of a system, and the overall flow of control. Figure 3 presents the activity diagram with the main actions defined for the SapoFit application.

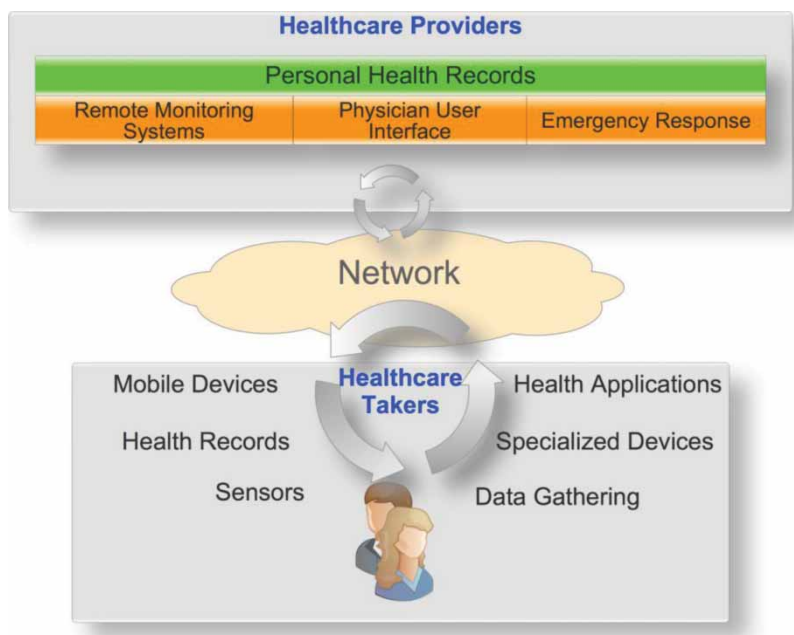


Figure 2. M-health services framework.

Figure 4 presents the decision algorithm for the meal alert, verifying if a meal was taken, comparing it with the previous day to see the user habits and also alerting the user if the meal was missed. In Figure 5, the decision algorithm for the weight is shown, verifying if the weight has been updated and comparing it with the previous weight. If the weight was not according to the plan, the system will suggest other meals.

The intake and energy needs decision algorithm for application–user interaction is shown in Figure 6. This diagram presents the main functions of the system and how they interact with the user. This interaction is based on text alerts sent to the user depending on their nutritional evolution. This procedure begins with the evaluation of caloric intake and energy needs. By comparing the balance between both and also the amount of daily exercise, the system will suggest and alert the user to their next step on food intake and physical activities.

4. Results

This section shows the developed system, the questionnaire answered by users and also the performance evaluation of the platform.

4.1. Application demonstration

The application controls the user's weight, even running in the background and alerting the user whenever necessary, all in accordance with the customization specified for the user.

After loading all the data, the application goes directly to the Profiles window. The user Profile is the main window of SapoFit (Figure 7). In the background, an image of the user's gender is portrayed, with pink for women (Figure 7a) and green for men (Figure 7b). This window (also shown in Figure 8) is a Profile sub-window, where it is possible to see the weight range in which the user must remain and also have an idea of the time it will

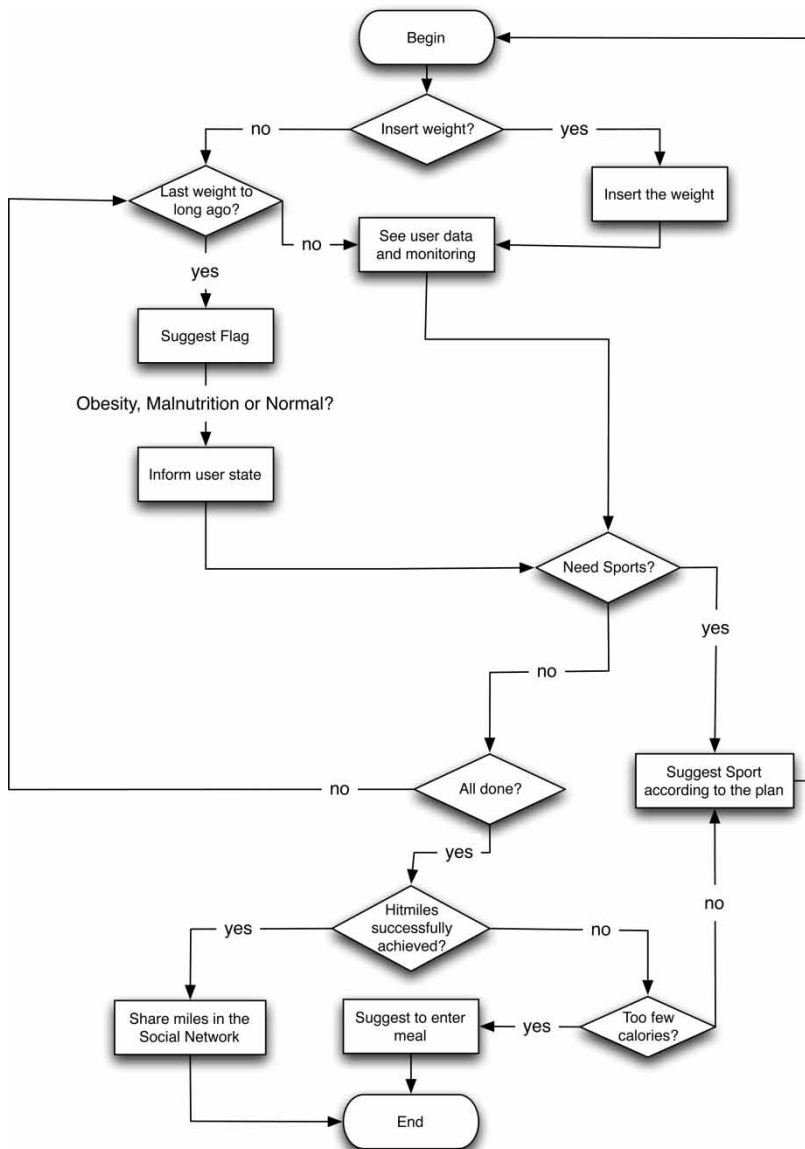


Figure 3. Activity diagram of SapoFit.

take to reach the desired weight. In the Edit Profile window (Figure 9), the user enters all necessary information such as his/her height, weight, age and sex, for determining the BMI and the maximum daily calories intake allowed. Thus, it automatically sets a sort of user profile and the system basically tells the user if he/she is overweight or not and other information, such as target weight and date and calories to be consumed.

In the window presented in Figure 10, the user records eating habits and observes their diet progress. The diary shows the current date and time, how many calories the user has eaten until the time shown and how many calories he/she should consume on average per day. Meals and physical activity information must be recorded daily. Based on this information, it is possible to calculate the daily consumed calories and also a weekly weight loss

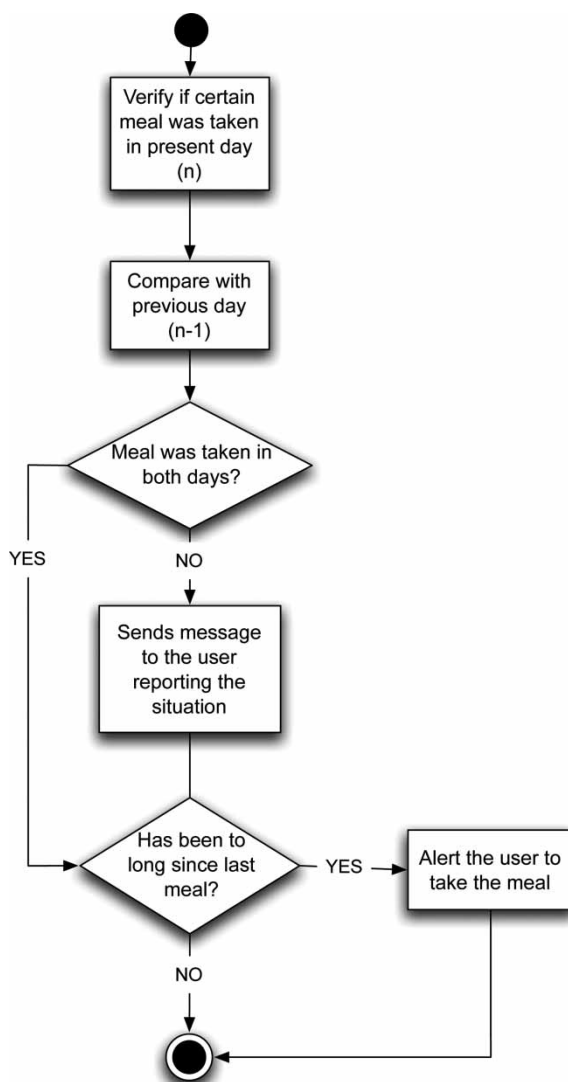


Figure 4. Decision algorithm for the meal.

that can be validated or corrected by the user. In the evolution window (Figure 11), it is possible to see the changes in weight and BMI in the form of four types of graphics, and it also allows the user to share this information in social networks. In the Physical Activities window, the user can see daily activities and the corresponding calories expended. The user can choose different types of exercises and their intensity, and observe the corresponding number of calories burnt depending on the duration of the exercise.

4.2. Application validation

The performance evaluation and real deployment of SapoFit are presented in this section. The application validation was undertaken using exhaustive tests. Real devices were used in all the performed experiments. Figure 12 presents SapoFit deployed in three different devices with four different screen sizes (Sony Ericsson Xperia X10 mini, HTC Magic,

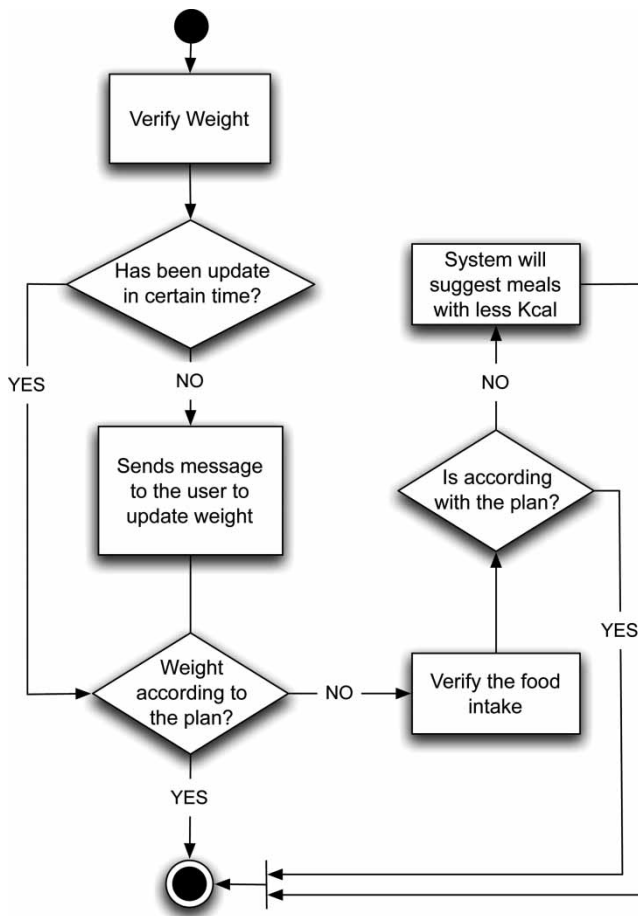


Figure 5. Decision algorithm for the weight.

TMN a1 and Samsung Galaxy Tab). The application user interface performed very well, as expected. General application functionality experiments were performed focusing on local application functionalities (such as database testing, Web server connections, PDA screen sizes and stability issues). These experiments enabled various debugging operations in order to verify the behavior of the system.

4.2.1. Performance evaluation

A comparison between the response times of messages in SOAP and RESTful was performed. The times in the application were measured and evaluated with SoapUI (using Android and iPhone). SoapUI is an open source tool written in Java whose main function is testing and consumer Web services.

The times were not always the same, but their averaged values are presented in Table I and Figure 13. For the three services, the differences are small but on every occasion the *PhysicalActivity* service, in the Android and iPhone applications, was faster. This is due to the fact that the connection was made in JSON for both applications. The message length is shorter in JSON when compared with XML, which also helps in reducing the response time, as can be seen in Figure 14. These experiments prove that RESTful Web services are more suitable for mobile environments. Similar results have been shown in [29].

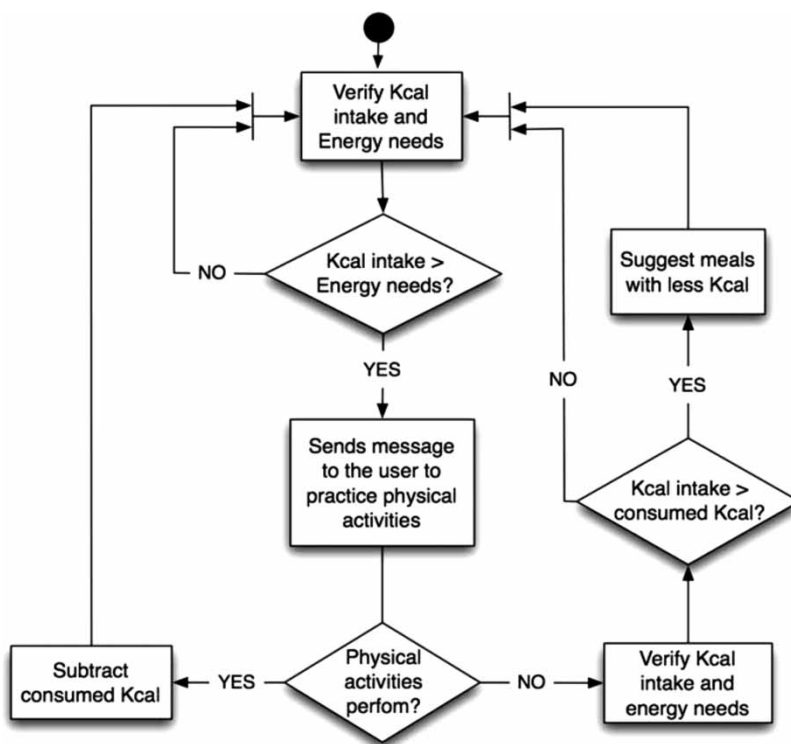


Figure 6. Decision algorithm for intake and energy needs.



For women

For men

Figure 7. Profile screen – current weight.



Figure 8. Profile screen – ideal weight.



Figure 9. Edit profile.



Figure 10. Plan screen.



Figure 11. Evolution screen.



Figure 12. SapoFit deployment in four different devices with four different screen sizes (Sony Ericsson Xperia X10 mini, HTC Magic, TMN a1 and Samsung Galaxy Tab).

Table I. Request comparison to Web service.

Web services	GetUserProfile	PhysicalActivity
SoapUI time (milliseconds)	1,384	348
SapoFit time Android (milliseconds)	1,797	295
SapoFit time iPhone (milliseconds)	1,985	331
SapoUi size (bytes)	1,252	79,516
SapoFit size (bytes)	1,252	48,670

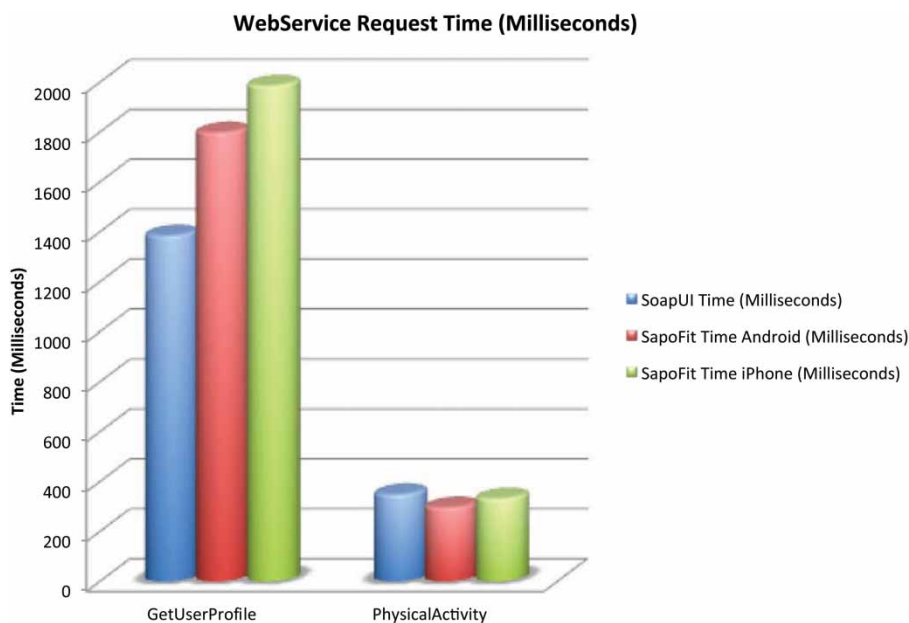


Figure 13. Web service request time (in milliseconds).

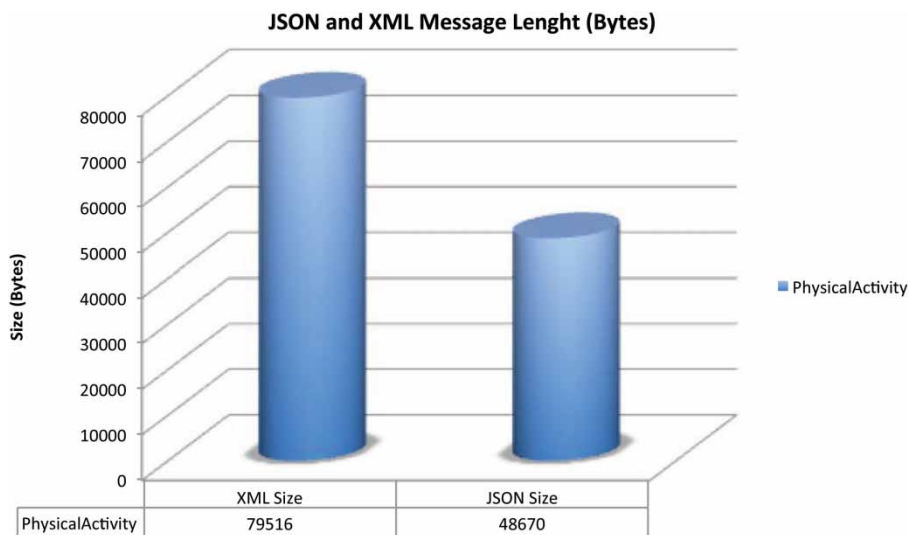


Figure 14. JSON and XML message length (bytes).

RESTful offers a good solution in mobile implementations, with lower overheads and higher flexibility.

4.2.2. User evaluation

SapoFit was installed, configured and was accessible through the PDAs. A total of 106 users from the University of Beira Interior, Portugal, answered the survey. Ethical approval for the SapoFit project was obtained from the Health Ethics Committee. They used the system for some time in order to test it and become familiar with it. After the experiment, they completed a SapoFit survey. The questions are available in Table II.

In Figures 15 and 16, it can be seen that the majority of users strongly agree that the platform has an attractive design, the environment is user-friendly and intuitive, navigation options are clear and consistent, and text blocks are written in minimalist style, fonts are easy to read on the screen and the application helps to understand the problem of obesity. A large percentage of users also think that the platform is very easy to use and the application is helpful for meal control. In almost all the remaining questions, the users gave a positive response. Half of the users were unhappy with the application

Table II. Questions in the SapoFit survey.

Question	Description
Q1	Is the design of the application attractive?
Q2	Is the application easy to use?
Q3	Is the application environment user-friendly and intuitive?
Q4	Are the navigation options clear and consistent?
Q5	Text blocks are written in minimalist style. Are they compact and useful?
Q6	Are fonts easy to read on the screen?
Q7	Is the feedback and response time of the application fast enough?
Q8	Is the application helpful for meal control?
Q9	Does the application help to understand the problem of obesity?

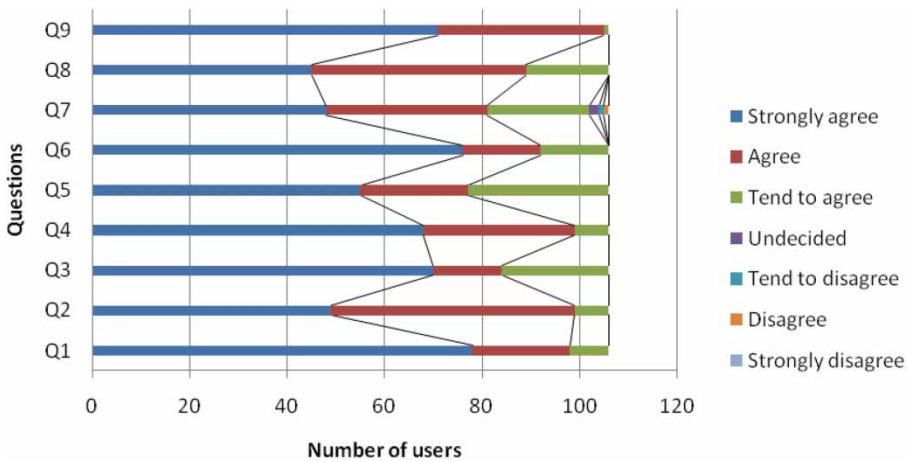


Figure 15. Results of SapoFit users' survey.

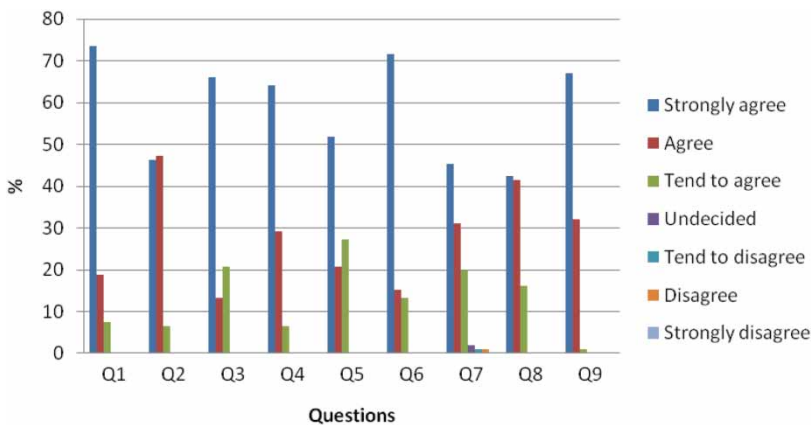


Figure 16. Results of the users' survey (percentages).

response time, which is because the server connection is still a prototype version and its performance is worse than the exploration server.

5. Conclusion and future work

Nowadays, obesity is a disease with an important risk factor for the emergence, development and worsening of other diseases. There are so many obese people worldwide that the WHO has declared the disease a global epidemic of the current century. The cause of obesity is the excess fat resulting from a successive positive energy balance, where energy intake exceeds the amount of energy expended. The factors that determine this imbalance are complex and may be genetic, metabolic, environmental and behavioral. The main treatment for obesity includes dieting and frequent physical activity. According to the WHO, obesity is a disease in which excess body fat build-up may reach levels that can affect health. It is considered a chronic disease, with marked prevalence in developed countries, and it causes serious health consequences [13].

In the current health era, engineers, physical scientists and physicians are researching to develop useful tools and technologies to facilitate the search for a better life, the

possibility of re-engineering the environment to inspire patients to take more physical activity. In this paper, different m-health and u-health applications in the nutrition field were analyzed. For example, 'It's time to eat!' was proposed to promote and motivate healthy eating habits among children [22], PmEB performs a real-time monitoring caloric balance [13], StepUp is a step counter application that uses sensor-enabled mobile phones to automatically count the number of steps walked by an user [17] and MyDS is an iPhone application that allows an easy way to keep track of the intake of different products [20].

This paper proposed and analyzed the performance of a new mobile system solution for Android and iPhone OS, SapoFit, that offers a tool to control weight, caloric intake and physical activity of the users. An important aspect of this system is the usability and inbuilt universal accessibility. Moreover, a comparison between response times of different messages using SOAP and RESTful (with Android and iPhone) was analyzed. The *PhysicalActivity* service presented the best performance for both Android and iPhone applications. The message length is shorter in JSON than in XML, which helps in reducing the response times. JSON messages were then used on the system.

SapoFit was installed, configured and was accessible through different PDAs. A total of 106 users evaluated the system. Most of the users "strongly agree" that the platform has an attractive design, a friendly and intuitive user interface, clear and consistent navigation options, and text blocks which are written in minimalist style.

Based on this work, following are a number of suggestions for future research:

- Increasing the number of mobile platforms where the application can be executed.
- Including the use of geo-referential technologies and algorithms to provide context and location-aware services. These services could enable collaboration and cooperation among real users, socializing and helping each other to reach pre-defined thresholds.

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