Nutrition Monitor
: A Food Purchase and Consumption Monitoring Mobile System

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Abstract. The challenge of monitoring food intake can be facilitated by the truly transformational power of mobile phones. Mobile phones provide a pervasive and fairly ubiquitous infrastructure, which we leverage to provide cost-effective, high quality aids to behavior monitoring and modification. Additionally, the technology allows public health messages to reach certain target groups, such as youth and members of low-income communities, which may not otherwise be practical. Our system leverages the existing mobile phone infrastructure. We use the highly capable computational and data-gathering platform of mobile phones to facilitate the collection, transmission and processing of data for purposes of monitoring in the field, behavior and activity classification, and timely behavioral cuing. The nature of mobile phones coupled with a web-interface also allow for customization and personalization, retrieval of nutrition information on demand, as well as the ability to truly monitor the user's consumption trends.

1 Introduction

The development and the incorporation of wireless technologies to promote healthy lifestyle behavior, specifically healthy eating and weight control, has the potential to address our ultimate goal of enabling healthier lifestyle choices and behavior modifications needed to prevent obesity and obesity-related diseases.

The obesity epidemic can be ameliorated by the truly transformational power of mobile phones [22] and other wireless embedded technologies that have become well-incorporated into our lives. Mobile phones provide a pervasive and fairly ubiquitous infrastructure, which we can leverage to provide cost-effective, high quality aids to behavior monitoring, evaluation, and modification. Additionally, the technology can be used to provide personalized services that may otherwise be unavailable to certain target groups, youth, for example, and members of low-income communities.

This wireless and mobile technology, specifically, provides a highly capable computational and networked platform, which we are using in combination with wearable sensors for the collection, processing, and retrieval of data for purposes such as monitoring behavior in the field, behavior and activity classification, and timely behavioral cuing. The nature of mobile phones allows for customization and personalization, as well as the ability to dynamically and automatically adapt to the user's environment.

Today's American population lives in an obesigenic environment that puts them all at a high risk of obesity. Age appropriate, culturally aware and gender specific solutions will have a higher likelihood of success in this environment, particularly for achieving prevention. Consider, for example, that while older adults are motivated by reducing their risk of disease, the youth are more health-enhancement oriented and also have a higher potential for social contagion. Bearing in mind this aspect of youth culture, we are incorporating both mobile phone technology and social networking websites into one specific approach for healthy behavior change.

This project involves an interdisciplinary effort to address a national crisis of obesity and preventable obesity-related chronic diseases. It leverages the most personal and beloved of all technologies to have come about in this generation, the mobile phone.

We have developed a system that leverages mobile phones for monitoring food purchases, food consumption and providing timely and appropriate informational cues for making healthier eating choices. This can be coupled with a web-based scheme, to provide self-monitoring and progress comparison with peers.

This food purchases and food intake monitoring system allows the entry of names of foods through the use of manual keyed entry or, more conveniently, the use of the mobile phone camera for scanning the UPC code on packaged foods. The system connects with various databases to provide ingredient lists, nutritional information as is commonly seen on packaged foods, as well as nutrients and nutrition information that typically are not described on food packaging, such as food water content and satiety value. The information is stored by the system for later examination on the web.

The system can cue the user if food choices inconsistent with adherence to the Dietary Guidelines for Americans are being made. The information is also be used for subtle reminders such as "you are 50% over your daily energy density intake goal" or "you are consuming 'trans fats'." Additionally, the system allows users to obtain information about how well each scanned product could help the purchaser to adhere to the Dietary Guidelines, to help in choices made during grocery shopping. Upon availability, suggestions for other related foods choices, which would be in stricter adherence to these guidelines, can also be provided. Finally, the long term tracking of a person's food intake can be useful for motivating longer-term adherence to the Dietary Guidelines.

In addition to interfacing with mobile phones, patients can go online to personalize the system, obtain more information about their food choices, and view detailed summaries of their food purchases and consumption habits. Using the online interface is common with weight management programs, such as Weight Watchers [21]. It allows for a more thorough examination of past activities, as well as different data presentation formats. Additionally, it enables a social networking framework where patients monitoring their food intake can compare notes, compete, and develop a support system.

The system provides increased accuracy of monitoring and ease of use and hence has the potential for pervasive use. Due to the nature of the technology, the system reduces bias by relying less on memory by collecting data in real time, and avoids the difficult or inexact calculations of food portions.

2 Obesity Crisis

Overweight adults are defined as those who have a Body Mass Index (kg/m2) (BMI) between 25 and 29.9. Obese adults are those who have a BMI of 30 or higher. Figure 1 shows obesity trends from 1985 to 1997; this does not even include overweight adults and are based on self-reported weight, and yet the numbers are still unbelievably high, reaching 22.6% in California alone.

Obesity increases the risk of many negative health consequences, such as coronary heart disease, type 2 diabetes, and hypertension. It also had an estimated cost of $78.5 billion in medical expenditures in 1998 [24]. The Centers for Disease Control (CDC) believes that overweight and obesity are caused by what they call an energy imbalance: too many calories and too little physical activity. They believe the best areas for treatment and prevention are monitoring behavior and environment settings [24]. This epidemic needs to be stopped and reversed as soon as practicable.

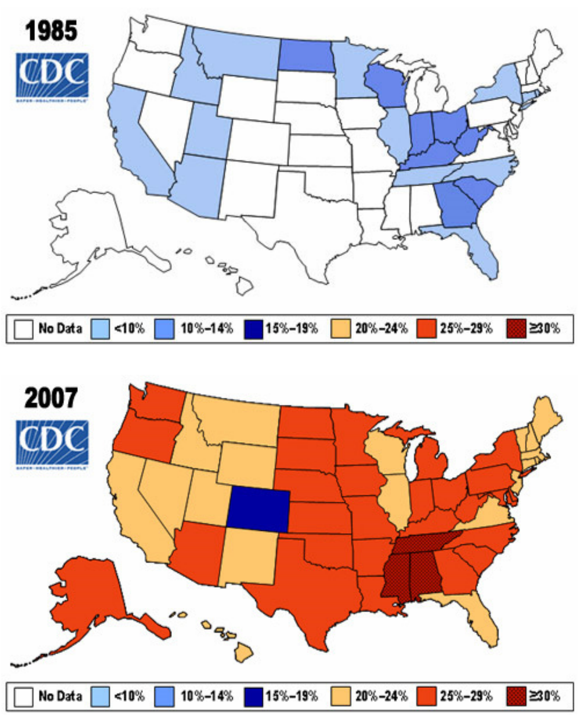

Fig 2.1. Percent of obese (BMI $\geq$ 30) U.S. adults [24]

3 Related Work

Automatic monitoring has been found to be beneficial in a variety of fields. Berckmans [13] studied how automatic monitoring of livestock production processes help not only replace the farmer's eyes and ears but also provides a framework to help monitor variables such as infections and stress. Bhatia et al. [14] discuss a remote system that can monitor the blood pressure in a patient. This allows blood pressure to be taken even without the physician being present which is beneficial to both the patient and his/her doctor.

Diamond et al. [15] use current computing technologies to present an environmental nervous system that can automatically monitor certain factors such as water in lakes and at water treatment plants. However, wireless sensors are still very young technologies and can be applied in many different areas. S. Gupta et al. [17] help fill this need by studying the potential of smart sensors in biomedical applications. They stress that as new mobile sensing applications are developed, the knowledge learned from these sensors should be applied to even newer applications. An example of a unique application that uses remote sensing is presented by Lukowicz et al. [20]. They discuss how sensing can actually be used in meetings to automatically annotate meeting notes. The wearable sensors will allow for easy recording and user friendly retrieval of data.

Health monitoring is important in a variety of fields. For example, Linz et al. [19] study how remote monitoring actually helps patients manage their stress levels. They use textile contactless sensors integrated into a shirt, which measures their angular distance from certain muscles to measure stress. This illustrates another way in which automatic monitoring can help improve a person's health.

Wireless food intake systems have been attempted before and will be discussed in this section. One such system monitors real-time caloric balance [1]. Users interfaced with a food and activity database by selecting foods they have eaten and the amount of exercise they have engaged in. Thus the number of kilocalories eaten and burned during the course of a day is monitored. This system is similar to our work in the sense that its goal is one of our main objectives, caloric intake monitoring. However, the limitation of this system is that the selection of foods is manual; the user must browse a list to try to find the matching food. If the food item is not on the list, the user can enter an estimated number of kilocalories but this can affect accuracy. Also, it takes time to enter each entry and therefore compliance may be reduced. Our system attempts to bridge this gap by allowing for automatic and precise input of items by scanning the barcode of a consumed item.

Jovanov et al. [18] mention the limitations of using wires to connect different sensors to a person's body. They propose a Personal Area Network where a Wireless Intelligent Sensor can be integrated onto a single chip to eliminate the bulkiness of wires. They apply this to an environment where a patient's vital signs need to be measured consistently.

Brown et al. [2] present an application where users could take pictures of the food they eat and upload the pictures later using a desktop application. Users could later add kilocalorie amounts to the food images. This was found to be very successful when the users were tested about remembering what they ate. Again, this has the limitation that the user would have to look up each individual food item. Estrin et al. [12] discuss a system where a mobile phone is hung around the participant's neck and automatically takes pictures when it is on, in this case, during mealtimes. The pictures are then uploaded and analyzed to determine eating patterns and to attempt modeling nutritional intake.

Boissy et al. [6] present a study in which individuals over 60 used barcode scanners to self-report their health status. The study showed that users found the barcode scanner easy to learn and use and pleasant to use. This is an important reaction because the project in this paper utilizes a barcode scanner to provide automatic collection of foods.

Sensei.com [7] is a system that focuses more on customized recommendations. The program will send the user meal recommendations, weekly shopping lists, fitness tips and motivational messages. The motivation for the system is the same as ours: help users make healthier choices. Myca Nutrition [8] provides a service for nutritionists. Once the software is purchased, nutritionists can have clients send images of food to create a food journal. This improves nutritionists' understanding of their patient's eating habits and thereby helps them to devise more informed nutrition recommendations.

Toscos et al. [3] focuses on fitness monitoring, specifically targeting teenage girls. They created a mobile application that would allow teenage girls to create 'cliques' of 4 friends who could then compete against each other for how much exercise they did. This system was widely successful, showing that there is a latent demand for mobile applications that could help with developing healthier bodies. Similarly, [4] presents a system that would encourage activity by sharing step counts with friends. [5] has a mobile fitness demonstrator with different sensors to test user perceptions of mobile fitness systems.

As far as barcode scanners are concerned, many systems exist that scan 2D barcodes. However, these systems are not compatible with 1D barcodes, or UPC codes. I-Nigma [9] and iPhone 2D Barcode Reader [10] are examples of such systems. Other systems say they can scan 1D barcodes but they are all external devices. Microsoft was developing a system called AURA that would capture 1D barcodes with a Windows Mobile device camera and extract the number [11]. Unfortunately, development on this system has stopped. After extensive testing of the latest version on the HP iPAQ, we found that the system failed on processing every barcode captured.

4 Architecture

This food purchases and food intake monitoring system allows the entry of names of foods consumed through the use of manual keyed entry or by scanning UPC codes on packaged foods. The system connects with various databases to provide ingredient lists and nutritional information. The information is stored by the system for later examination on the web.

The system cues the user if food choices are inconsistent with the Dietary Guidelines for Americans, by subtle reminders such as "you are 50% over your daily energy density intake goal" or "you are consuming 'trans fats'." Additionally, the system allows users to obtain information about how well each scanned product could help the purchaser to adhere to the Dietary Guidelines, to help in choices made during grocery shopping.

The system helps users easily track what foods they have been eating with running totals of calories, fats, etc. We have developed three different versions of this application, on the Nokia N95 using the Symbian operating system, a Windows Mobile version on the HP iPAQ hw6945, and an Android version on the new G1 phone. The following sections discuss the architecture of each version.

4.1 Symbian Operating System

The first version of the application was developed on the Nokia N95, which uses the Symbian operating system. We chose this phone because it is one of the more popular operating systems and we had experience developing on the N95. It was programmed in Python and was under development for approximately nine weeks.

The software requires the user to first register an account on a public website and choose from a list of predefined diets or create a personalized one, consisting of the desired amount of calories, total fat, carbohydrates, sodium, and protein. This information is later used in the mobile phone application so the user can make an informed decision about the foods that they are about to eat or have eaten.

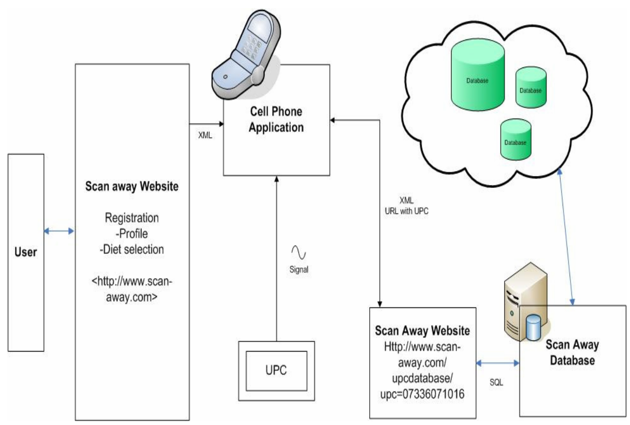

Figure 2 Architecture of the Nokia application

The user can then choose whether to use an external Bluetooth scanner or manually input the barcode of an item. The application supports the LaserChamp Mobile Barcode Scanner [23]; this device scans a UPC barcode and transmits the code to the mobile device via Bluetooth. This barcode is then embedded in an XML query and sent to the web server. This server contains a list of barcodes and nutritional information, as this information is unavailable in a public database.

If the scanned item is not in the database, the query is sent to www.upcdatabase.com, a website that contains barcodes and their product descriptions. The product description is then sent to http://caloriecount.about.com/ that contains nutritional information about a large number of items. The HTML of that page is then parsed and the nutritional information is pulled out. The relevant data, such as kilocalories and fat, is then stored in the database on the application's server. In this manner, the server contains a self-learning database; with every item scanned, the database would "learn" the item and allow for processing the next time.

After scanning the barcode, the user then has a choice of whether to enter "grocery mode" or "meal mode". In Grocery Mode, the user can see detailed nutrition information about a single item and how this item would affect his/her overall daily diet. This mode is useful when a user is in a grocery store and would like to choose between two items. It is an important distinction whether an item, such as a frozen entrée, is 25% of a user's allotted daily kilocalories or 10%.

Figure 1 Use case for the Nokia application

Meal Mode is used to keep track of a user's caloric intake throughout the day. The user can select to which meal an item is added: breakfast, lunch, dinner or a snack. S/he then scans the item and enters the serving size s/he is eating. The kilocalorie amount is added to his/her daily total so the user knows immediately whether or not s/he is sticking to his/her diet. This real-time knowledge allows informative decisions to be made about food consumed.

4.2 Windows Mobile Operating System

The second version of the application was developed on the HP iPAQ hw6945, which uses the Windows Mobile operating system. This is because there are many Smartphones that use this operating system and therefore this would help penetrate the market further. We used the Windows Mobile 5.0 SDK and programmed using Visual Studio 2007.

User procedures are similar to those required by the Symbian operating system. The user first enters his username and password into the mobile phone application. S/he then enters the barcode of a food product. In this system, however, the barcode can only be entered manually as there is a lack of research in embedded barcode scanner applications. The barcode is then sent directly to www.upcdatabase.com where a query is done to get the product description. That information is then sent to http://caloriecount.about.com/ where another query is done with that description. The returning HTML is then parsed and relevant information is displayed on the screen.

The user now has the option of adding this item to his/her total calorie count, or "consuming" this item. If s/he chooses to do that, the size of one standard serving is displayed and a query asks him/her how many serving sizes s/he is having. The user enters in a number and can then view how many calories have been added by that one meal.

Finally, the user can view how many kilocalories s/he has consumed for the day. This number is kept as a running total until the user quits the application. Windows Mobile allows for many programs running in the background and therefore the user should keep this program open until s/he wants to reset his/her total calorie amount.

A few distinctions need to be emphasized between the first and second versions of the application. First, the "modes" were removed in the second version. Instead, the user is only able to see the nutritional information of a food product. Future work includes displaying the percentage of the total diet as well, on the same screen as the nutritional information.

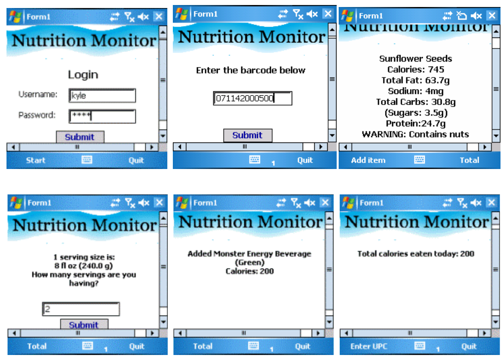

Figure 2 Use case for the Windows Mobile application

The second variation is that the items are not separated into meals; we felt this was a step that would not be important to most users. Third, an allergy feature was added to the Windows Mobile version. That is, when an item is scanned, the nutritional information includes a warning if the product includes nuts. This is to help users who have a nut allergy; it provides an easy, immediate way to see whether or not a product would set off any allergic response.

4.3 Android Operating System

The software on the G-phone consists of three modes: eating, shopping and report mode. Each of these modes is described in detail below.

4.3.1 Eating Mode

In this mode, the user is presented with a text area where s/he can input the name or the UPC code of the item that s/he has eaten to generate a list of the consumed products. The menu consists of two other options: a product scan and the common list of foods.

The product scan provides the user with an interface that allows a photo to be taken of the UPC barcode. This is another way that the user can add an item to his/her list. The common list is a list of items that the user consumes frequently. This makes the management of a daily food list even easier; the system simply asks the user to select items from the common list.

4.3.2 Shopping Mode

When the user is in shopping mode, s/he is provided with the same options as the previous mode. However, after pushing the 'add' button, the user is directed to a view which shows him/her the sum of the nutrition facts of the shopping basket. The system also outputs warnings on the high-level amounts of some of the factors, such as calories and fat.

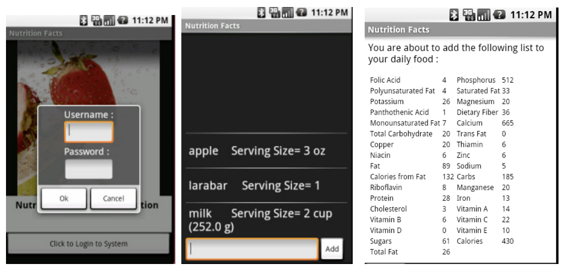

Figure 5 Use case for the Android application

4.3.3 Report Mode

The information about the daily food intake or the shopping basket is recorded in a database upon the user's request. This information goes into related tables about food and shopping. Using the report mode, the user can input two dates to get a comprehensive report about the foods s/he consumed in that period of time.

4.3.4 User Information

The first page of the system prompts the user to login to the application by entering a user name and password. This account will link to his/her profile on the web page and will locate the relevant information in the database, located on a server.

The current database consists of three tables: the user's login information, data from shopping mode and data from eating mode. The eating mode table keeps a record of the nutritional facts of the items that the user consumes. Each row in this database represents a food that the user entered into the system. The shopping mode table records information about the shopping history of the user. Each row in this table represents the accumulated nutrition facts of the items inside a shopping basket on a certain date.

5 Conclusions

The obesity epidemic is real and threatening to affect the majority of the United State's population. With healthcare costs and the number of obese individuals increasing every year, new, low-cost measures are needed to turn this epidemic around, such as our proposed system. We propose a system that leverages mobile phones and provides the following:

1. A handheld system that is constantly with the user
2. A (mostly) automatic and accurate way to enter names of foods
3. A method to track user consumption and trends over time
4. A system that can be programmed to warn the user against unhealthy food choices

The future of this application is threefold. First, users will be able to access and view statistical data about their eating pattern history. That is, they will be able to see a daily history analysis of their food choices. Second, the application will support non-UPC foods, which is important because the eating of minimally processed fruits and vegetables, which typically have no UPC codes, are high-satiety foods. High-satiety foods fill people up with fewer calories and their consumption must therefore be encouraged. Third, users will be able to enter any dietary restrictions they have and, by scanning the barcode of an item, be able to see immediately whether or not their body can handle that food. This has been implemented with the nut detection on the Windows Mobile application but should be expanded to include other common allergies.

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