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CIRCLE: A Cloud-Based Mobile Wellness Management System

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ABSTRACT

With the rapid pace of technological advancement, more people are spending hours in front of TVs or computers, therefore consuming more calories than their physical bodies need. However, even with the help of these diet applications, most diets still do not last long because people: 1) are tired of repetitive meal plans; 2) have no successful weight-management program to keep their food diaries and activity logs; 3) don't see much weight decrease due to nutritional deficiencies or slow metabolism. Thus, we have developed a user-centered mobile wellness system which: 1) allows users to choose their desired recipes; 2) utilizes USDA's NHANES and MPED 2.0 databases and ensures users getting enough nutrients and intake calories; 3) manages users' weights and exercise activities; 4) utilizes cloud technology. Based on users' overall feedback, we conclude that our system can promote user-centered weight and nutrition management, thus keeping users' bodies fit and healthy.

Keywords: USDA's NHANES, MPED 2.0, and MyPyramid; Overweight/Obesity and Exercise; Nutrition management; Cloud Computing; Internet-Of-Things; Android health applications and e-Health

1 Introduction

With the rapid growth of technology and the global economy, people tend to spend more time sitting in front of TVs and computers as part of their work or leisure activities. As more and more activities have become sedentary, people are taking in more calories than their physical bodies need, creating health risks like overweight and obesity problems. According to [27], obesity could be caused by: 1) overeating, 2) wrong eating patterns, 3) inactivity, 4) heredity, and/or 5) disturbance in thermogenesis. As a result, overweight and obesity have considerable impacts on both health and economic issues in the healthcare system [44][41]. Wolf [44][45] shows that obesity and overweight involve both indirect and direct costs: treatment and diagnostic services as well as decreased activity and lost income due to premature death.

Research has shown that both obesity and overweight have major health consequences, and may shorten people's lives. Prior to 1997, the World Health Organization [46] listed obesity as a chronic disease. According to Taiwan's Ministry of Health and Welfare [33], the prevalence of overweight and obesity among adults there increased from 33% in 1996 to 44% in 2008, and the numbers are still rising sharply. In addition, [11][17] has shown that obesity affects multiple organs, as well as leading to other diseases, such as: 1) coronary heart disease, 2) Type 2 diabetes, 3) cancer, 4) hypertension, 5) liver disease, 6) stroke, 7) sleep apnea, 8) respiratory problems, 9) osteoarthritis, 10) gynecological problems, 11) dyslipidemia and 12) depression. Moreover, the WHO [10] states that more than 30% of cancer

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cases could be prevented if people could lose weight, since losing weight reduces the risk of developing chronic diseases. In addition, [46] shows that regular diet and exercise could reduce the threat of cancer epidemics.

Meanwhile, with the rise of digital technologies, mobile phones have become ubiquitous in day-to-day life. According to recent studies [16], there are currently about 7 billion mobile devices on the planet as people are using mobile applications for communication and entertainment. As a result, the emergence of digital technologies has pushed developers to design applications that use mobile devices for dieting. For example, there are innumerable "health and fitness" apps available in Google Play or in Apple's App Store that help users to achieve their diet goals. Even with the help of these apps, most diets still do not last long because: 1) people get bored with following repetitive healthy meal plans; 2) people have no successful weight-management program to keep their food diaries and activity logs; 3) people quit diets when they don't see their scale readings decrease as much as they expected due to the fact of nutritional deficiencies or slow metabolism. Thus, it is important to have a user-centered mobile app that: 1) allows users to customize their recipes on their own to avoid repetitive meal plans; 2) manages users' weights and exercise activities regularly; 3) ensures users get enough nutrients and calories to avoid low metabolism.

In this paper, we develop a user-friendly app called CIRCLE, a cloud-based mobile wellness system to promote user-centered weight and nutrition management. Our system provides the following services: 1) it first calculates the user's daily calorie intake and nutrition model, then displays all the recipes from the USDA's NHANES and the MPED 2.0 databases that fit into the calculated daily calorie intake and the servings of the six MyPyramid food groups, and finally asks users to choose their desired meals; 2) it tracks daily exercise activities and weight measurements along with displays of historical data as a list or a graph; 3) it provides health-related articles based on the user's personal information; 4) it adapts cloud computing technology for greater data access and flexibility; 5) it provides an adapted transmission system using the IoT (Internet-Of-Things) operation process for lower cost and greater efficiency. We hope to ultimately encourage more users to become more engaged in understanding and monitoring their weight problems through activities such as constantly taking measurements, monitoring changes in weight, tracking exercise progress, achieving their nutrition goals, and controlling daily caloric intake. In this way, we will promote user-centered weight and nutrition management, and can ultimately keep users' bodies fit and healthy.

We first discuss the related work in Section 2. In Section 3, we introduce the overall framework of CIRCLE. Next, we provide the system implementation in Section 4. In Section 5, we present the user interface. We then explain how we utilize CIRCLE to promote user-centered weight and nutrition management in Section 6. After that, we discuss the evaluation of CIRCLE in Section 7. Finally, we conclude our work and discuss possible future work in Section 8.

2 Related Work

In this section, we will discuss some relevant work that addresses: 1) health effects of obesity and overweight, 2) health and nutrition, 3) Bluetooth transmission technology, 4) RFC2898 password-based encryption standards, 5) Android application technology, 6) cloud computing technology, 7) health and fitness app, and 8) the USDA's NHANES and MPED 2.0 database.

2.1 Health effects of obesity and overweight

Scholarship has shown that health and weight are correlated, and obesity often leads to chronic diseases. According to [38], obesity and overweight can lead to negative psychological effects as well as social consequences. In addition, [14] states that obesity in children may result in low self-esteem, poor social skills, greater anxiety, and depression. Moreover, Katzmarzyk [28], who surveyed 19,173 people between the ages of 20 and 83 for about 10 years, determined that the death rate for obese people is about 1.55 times greater than the normal people. Furthermore, the World Health Organization [47] has announced that obesity can cause serious problems, such as: 1) primary diseases which have a relative risk greater than 3, including diabetes, metabolic syndrome, gallbladder disease, dyslipidemia, difficulty breathing, sleep apnea, etc.; 2) secondary diseases with a relative risk between 2 and 3, including hypertension, hyperuricemia (gout), osteoarthritis, and coronary heart disease; and 3) tertiary diseases with relative risks between 1 and 2, including breast cancer, endometrial cancer, colorectal cancer, female hormone abnormalities, polycystic ovarian syndrome, infertility, lower back pain, anesthesia risk, and fetal malformation. Similarly, the American Cancer Society [4] explains that for every five people who die of cancer-related diseases, one person is obese. Moreover, [23] states that the WHO survey reveals that about 7 million people in the world suffer from cancer each year, and more than 60% of these are preventable; 30% to 40% of them could be prevented by adjusting diet or exercise, and about 80% of breast cancer and colorectal cancer could be avoided. As a result, it is important to have a such user-centered weight and nutrition management that can satisfy people's basic needs to manage their wellness, and can ultimately keep users' bodies fit and healthy.

2.2 Health and Nutrition

In 2011, the United States Department of Agriculture [42] converted its diet model from the Food Guide Pyramid, as shown in Figure 1(b)[39], into MyPlate, as shown in Figure 1(a)[15], to assist with the interpretation of the 2010 Dietary Guidelines for Americans [1]. Traditionally the Food Guide Pyramid was developed to teach us what to eat, and the amount we should eat of each food a day. On the other hand, MyPlate was introduced to illustrate the food groups in a "more simple but powerful" way, allowing users to think about choosing appropriate food on their plates at mealtimes. In MyPlate nutrition guide, the number of categories has decrease from 6 to 5, and because of the missing oil category, fruits and vegetables are considered half of the total diet. Similarly, CIRCLE makes sure that users get the proper nutrition from every category of the Food Guide Pyramid, and thus ultimately stay fit and healthy.

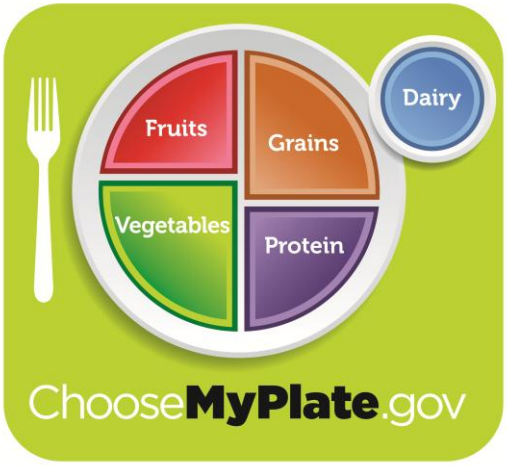


Figure 1. (a) MyPlate [15]

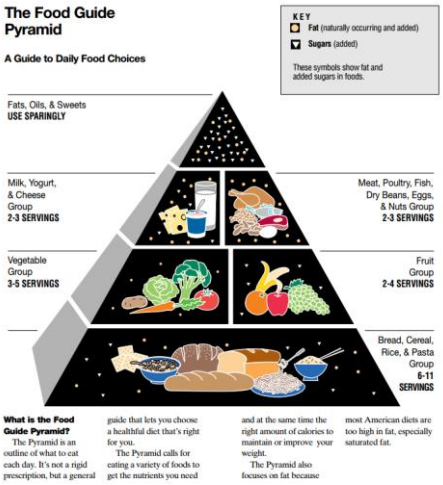


Figure 1(b). The Food Guide Pyramid [39]

2.3 Bluetooth transmission technology

Lee et al. [26] present an extensive survey that examines the popular wireless communication standards such as Bluetooth, UWB, ZigBee, Wi-Fi, evaluates their features, and finally analyzes their performance metrics. According to the Bluetooth Special Interests Group [7][8], Bluetooth technology is a worldwide wireless internet standard through which data transmission can be protected safely and conveniently. Bluetooth technology has been widely adopted in cars, mobile phones, and medical devices, and the data are transmitted between paired devices. Bluetooth 4.0 has helped to connect even more appliances altogether. One of the main contributions of Bluetooth 4.0 is to reduce power consumption, provide greater flexibility to developers, and thus allow developers to come up with more innovative products for the development of the Internet of Things (IoT). Therefore, after carefully reading through all of these wireless protocols from this paper, we adapted both Wi-Fi and Bluetooth for our system, since both technologies have relatively low costs and easy installation, and are both are enabled for almost every mobile phone.

2.4 RFC2898 password-based encryption standard

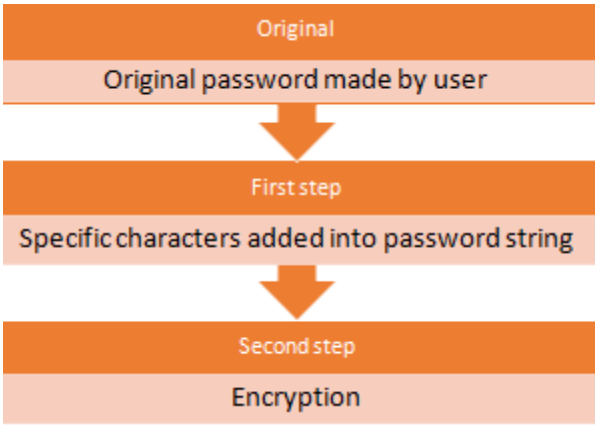


Figure 2. The process of RFC2898 Encryption Standard

The RFC2898 encryption standard was developed by RSA Laboratories in 2000 [6] as a password-based cryptography specification. The Windows Phone is a typical example of the use of this standard to maintain security. Nowadays, passwords under this system can be stored in three ways: 1) as plain text, 2) using a reversible encryption, and 3) using an irreversible encryption. Most of the systems that include RFC2898 choose to use irreversible encryption to protect their passwords, because it's not easy for hackers to guess the passwords correctly. In addition, if some users happen to choose the same passwords, the encrypted passwords would be different, providing better security to all users. The process of RFC2898 works as follows, and is shown in Figure 2: 1) the user generates the desired password; 2) RFC2898 then adds some special characters into the string; 3) RFC2898 encrypts the whole string to increase the password's complexity and give better protection. Thus, in order to better protect users' privacy, our CIRCLE employs the RFC2898 standard to ensure each user's encrypted results will be different even if different users choose the same password.

2.5 Android application technology

According to [12][13], the Android system architecture is composed of four layers, as shown in Figure 3. The benefits of having such an architecture are: 1) it is easier to develop Android applications independently, 2) it is faster to develop Android applications, 3) it is easier to maintain Android applications, and 4) it is easier to debug Android applications. The bottom layer is the Linux kernel, which contains some of the hardware drivers. The second layer contains libraries that provide software functions. In addition, core libraries and Dalvik virtual machines both provide a runtime environment for Android applications. The third layer offers an application programming interface for Android applications, and the last layer provides the interface for the Android applications [5]. Developers have to build applications from the upper layer to the lower layer, and use method calls to control hardware functions. In addition, developers are required to set up Android emulators to emulate the application, or to export the software into an application package file (APK) and test it through Android devices. Furthermore, Google Play allows developers to share their Android applications with others, thus creating greater accessibility and availability for users. Similarly, in CIRCLE mobile app is suitable for any Android operating system, as the app was developed and tested on Android smartphones.

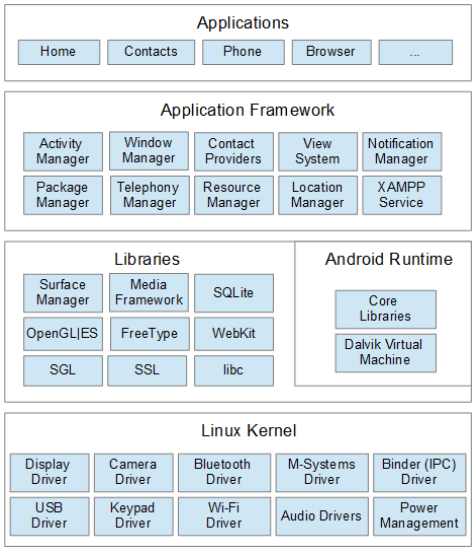


Figure 3. Android development structure

2.6 Cloud computing technology

Mell and France [31] state that cloud computing is a model that provides a convenient demand network and on-demand network access to share computing resources, such as networks, servers, storage, applications, services, etc. In addition, cloud computing can be established and released with minimal management effort. Dillion et al. [19] describes five essential characteristics of cloud computing: 1) on-demand self-service, 2) broad network access, 3) resource pooling, 4) rapid elasticity, and 5) measured service. According to Foster et al. [20], cloud computing is composed of three service models: 1) Software as a Service (Saas), 2) Platform as a Service (PaaS), and 3) Infrastructure as a Service (IaaS). SaaS allows users to place their service or application in a hosting environment and share it with others at any time and place with the addition of a subscription fee. PaaS, on the other hand, is a developmental platform that allows cloud users to develop or test services and applications directly on the provided platform (i.e programming environment, tools, configuration, etc). The last service is IaaS, which integrates the particular hardware, software and devices altogether through the internet, providing the software application environment and resources for a fee. Our CIRCLE belongs to a SaaS application, where users can synchronize, update, store, and access data across multiple mobile devices.

2.7 Health and Fitness app.

Some popular health and fitness mobile apps, like Workout Planner, Fooducate, or Exercise Book, aim for tracking workouts and diet. The common factor in these apps is that they provide user-friendly interfaces that allow users to operate easily based on their personal needs, such as providing light when users are running, employing larger-screen devices when users are indoors, and displaying limited suggestions for healthy foods. We have similarly developed a health and fitness mobile app that can manage users' nutrition and ultimately reduce the obesity and overweight problem. However, the differences between our CIRCLE and these existing fitness and health apps are that we allow users to: 1) customize their own recipes; 2) manage their weight and exercise activities; 3) ensure proper nutrition and calorie intake.

2.8 USDA's NHANES and MPED 2.0 database

Some research utilizes the USDA Food and Nutrient databases to investigate the relationship between food and nutrition, nutrition monitoring, nutrition policy, and dietary practice [2]. Daniel et al. [18] examines trends and health implication of meat consumption in the United States using the FSO and USDA databases, as well as analyzing meat consumption by type via the NHANES database, which is connected with the MPED 2.0 database. In addition, [37] uses USDA's National Nutrient and MPED 2.0 databases to investigate how low-income households spend their money on food, and discusses whether the chosen food can satisfy MyPyramid fruit and vegetable guidelines. Moreover, Fulgoni et al. [25] analyzes the NHANES 2001-2008 databases, and discovered that avocados provide better diet quality, higher nutrient intake, and lower risk of metabolic syndrome. Similarly, [34] adapts NHANES and examines the relationship between whole-grain consumption and body weight measurement, and confirmed that adults who consume the most servings of whole grains have lower body-weight measurements. In [35], scholars use the NHANES database to examine the relationship between 100% orange-juice consumption and overall diet quality, and learned that 100% orange juice provides better diet quality with no risk of overweight or obesity. Albertson et al. [3] uses NHANES to examine the

relationship between sugar content in cereal and associated health issues among children and adolescents, and further confirms that weight indicators do not differ by sugar content. Moreover, [48] studies NHANES databases and examines the relationship between whole grains, fiber consumption, and body-weight measures between the ages of 6 and 18. Our paper does not analyze the food data from either USDA's NHANES or MPED 2.0 databases, but rather utilizes those databases to develop our nutrition model.

3 Design of CIRCLE

The design of CIRCLE utilizes two main components: 1) the CIRCLE mobile app, and 2) concepts of the CIRCLE nutrition method. We describe these two components in the following subsections.

3.1 Design of the CIRCLE mobile app

An overview of our CIRCLE is shown in Figure 4. Arrows on the connecting lines indicate the direction of the communication flow. The real lines show the direct communications between users and our system, and the dotted lines show the virtual communications, via the internet, to retrieve or store data from the cloud. The rectangle shown on the top of figure indicates that the user can connect to our system through computers, laptops, or mobile phones.

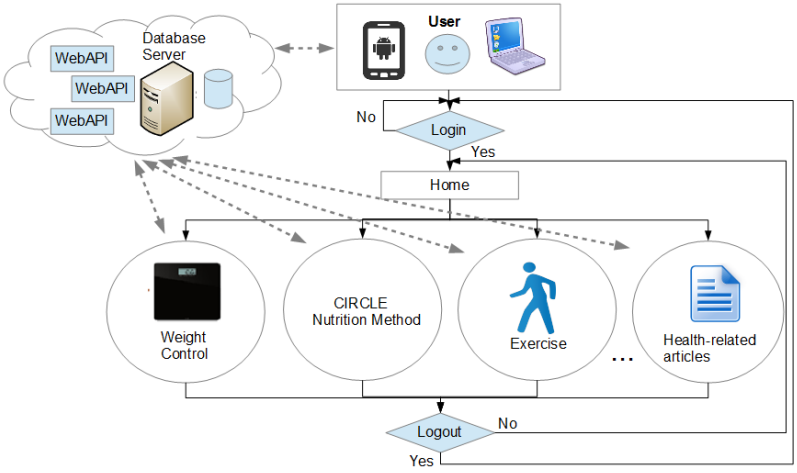


Figure 4. Overview of CIRCLE System.

Once the user starts the app, our system first determines whether this mobile device has been logged in before. If the user has not been logged in before, or the user's current token has expired, the system then asks the user to go through the login process. In addition, our app provides an interface for the new user to register to the system.

For the login page, we employ the OAuth2.0 standard to enable the system to send the login and password to the server. Once the server receives both login and password, it compares these against the data saved in its database. Next, the server encrypts the user's information, combines the encrypted information along with the timestamp and private key into a token, and passes this token to the client. The server can later recognize the sender's identity and its authority based on the token retrieved from its HTTP header.

After the user has successfully registered and logged into the system, the system directs the user to the CIRCLE home page, where he or she can view or update personal information (i.e. name, gender, age, height, etc.). On the CIRCLE home page, users can choose from four subpages: 1) Weight Control, 2) Nutrition, 3) Exercise, and 4) Health-Related Articles.

On the Weight Control page, the user can search previous weight measurements or view them in a list or a graph. In addition, the user can insert a new measurement manually or automatically through a Bluetooth weight scale. If the user chooses the Bluetooth method, our app would first receive data directly from the Bluetooth weight scale right after the measurement, and then record this measurement to cloud storage.

On the Nutrition page, our system employs the nutrition method, as described in Section 3.2, to calculate an user's daily calorie intake and nutrition model, display all the recipes from the USDA's NHANES and the MPED 2.0 databases that fit the calculated daily calorie intake and the servings of the six MyPyramid food groups, and allow the user to choose his/her desired recipes. If a user modifies any aspect of his or her profile—for example, by adding a new dietary goal—our system will update these changes and re-calculate the user's daily calorie intake and nutrition model immediately. In addition, our app can retrieve and display all the previous chosen menus to the user, sorted by chosen date. In other words, our Nutrition page not only allows users to choose their desired recipes, but also helps them to achieve their nutrition goals, to control their daily caloric intake, and to develop healthy eating habits.

On the Exercise page, our system enables a motion tracker, retrieves user profiles, calculates consumed calories every hour, synchronizes data with the cloud, and then displays data either in a list or in a graph. Meanwhile, our app also summarizes the overall calories burned in a day. On the Health-Related Articles page, our system first selects the proper health-related information based on a person's gender, age, BMI, and displays the appropriate health-related articles from the iHealth e-commerce website in a list.

The user can choose to go back to the Home page for switching to other pages, or can choose to log out of the system from there. In addition, our system synchronizes data with the cloud immediately after the user finishes updating his/her data. In this way, we ensure the most up-to-date information for all users, all the time.

3.2 Concepts of the CIRCLE nutrition method

People who wish to lose weight usually adopt diet plans recommended by professional nutritionists for a certain time. The disadvantage of this method is that people can get bored and give up on an inflexible, unvarying plan. Our system addresses this problem by proposing a nutrition method in which users are free to choose their own meals, and can also keep both their daily calorie intake and their intake of the six MyPyramid food groups within acceptable ranges. There are four characteristics of our nutrition method: 1) it calculates an appropriate nutrition model and daily calorie intake based on the user's personal profile; 2) it displays all the recipes from the USDA's NHANES and MPED 2.0 databases that fit the remaining calorie intake and six MyPyramid food groups; 3) it allows users to choose their desired meals, rather than asking them to obey a meal plan; and 4) it iteratively updates the user’s remaining calorie intake and the servings of the six MyPyramid food groups to the system after each selection. We have kept these characteristics in mind throughout the development of CIRCLE.

The flow of the nutrition function is shown in Figure 5. As we can see from this figure, there are three main steps in our nutrition function: 1) retrieving user profiles, 2) obtaining a nutrition model and 3) getting recipes. We discuss each step in detail in the following paragraphs.

Step 1: Retrieving user profiles.

After the user passes the login page, the system uses this login to retrieve the user's profile from the database.

Step 2: Obtaining a nutrition model.

In this step, the system chooses an appropriate nutrition model based on the calculated daily recommended calories (DRC). According to Vaughan et al. [43], there are three factors that affects our daily energy expenditure (EE): 1) basal metabolic rate (BMR), the calories that we need to maintain for our body to function properly; 2) energy to support physical activity, the number of calories that the body needs for daily life, including exercise; and 3) thermic effect of food, the number of calories that the body requires to digest, absorb, transport, and store food.

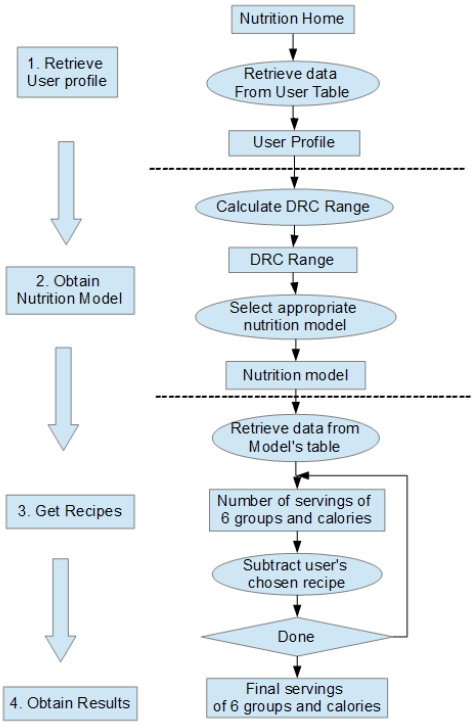


Figure 5. Flowchart of CIRCLE nutrition method

Therefore, in order to calculate the required EE for a person, we need to first obtain the user's personal information, such as gender, weight, height, activity, and stress factors. Once we have all of the required information, our server calculates basal energy expenditure (BEE), which represents the amount of energy that is required when we are at rest. The BEE is then calculated using the Harris and Benedict formula [21][36]:

$$\text{BEE for men} = 66+(13.7*\text{Weight in kg})+(5*\text{Height in cm})-(6.8*\text{Age}) \quad (1)$$

BEE for women= 665+(9.6*Weight in kg)+(1.7*Height in cm)-(4.7*Age) (2)

Next, we calculate energy expenditure (EE), which is calculated using BEE multiplied by activity and stress factors as given in [29][30], and is displayed in **Error! Reference source not found.**:

Our energy expenditure (EE) is then calculated as below:

EE= BEE* activity and stress factors (3)

Table 1 Activity and stress factors for calculating total energy expenditure

Activity and stress factors	
Bedrest	1.2
Low activity	1.3
Moderate activity	1.5-1.75
Highly active	2
Injury factors	
Minor surgery	1.1
Major surgery	1.3
Mild infection	1.2
Moderate infection	1.2-1.4
Sepsis	1.4-1.8
Skeletal trauma	1.2-1.4
Skeletal or head trauma (treated with steroids)	1.6-1.8

[a] Table retrieved From: [29][30]

The user sets his or her diet options initially while creating a profile. After the system retrieves the desired diet options from the profile, it calculates the daily recommended calories (DRC) as follows:

$$\mathrm{DRC} = \begin{cases} \mathrm{EE} - 500, \text{for losing weight} \\ \mathrm{EE}, \text{for maintaing same weight} \\ \mathrm{EE} + 500, \text{for gaining weight} \end{cases} \quad (4)$$

After the system calculates the recommended calories, our server retrieved all the nutrition models that fit into the calculated DRC range. Finally, our system randomly chooses one nutrition model from these retrieved nutrition models. Please be aware that our system DOES NOT suggest which recipes are better than others, nor does it mandate what recipes users should eat in order to achieve the required DRC. The goal of our system is to have a well-balanced diet rather than only eating a certain type of repetitive food with vitamin supplements. Thus, using the calculation of energy expenditure as discussed above, the user may choose any menu that appeals to his or her individual taste .

Step 3: Acquiring the chosen recipes.

Our system first displays the suggested servings of the six MyPyramid food groups and daily calorie intake to the user, where these suggestions are retrieved from the nutrition model

chosen during the second step. Next, our system displays all the appropriate recipes from the USDA's NHANES and the MPED 2.0 databases that fit the selected nutrition model (i.e. the recipes that fit the suggested servings for the six food groups) and the user's recommended calorie intake. After the user finishes picking his/her desired recipes, our system subtracts the corresponding servings of those food groups and that calorie intake from among the chosen recipes. The system subsequently shows all the recipes that fit the chosen criteria. The above two processes iterate and finish when there are no more recipes to select, or when the user has finished choosing the all the recipes for a day. The system will then display the overall servings from each food group and calories that a user has chosen for that particular day.

4 Implementation of CIRCLE system

4.1 System developmental environment

The system architecture can be divided into three layers: 1) presentation, 2) business logic and 3) data service, as shown in Figure 6. We explain the developmental environment for each tier in the following paragraphs.

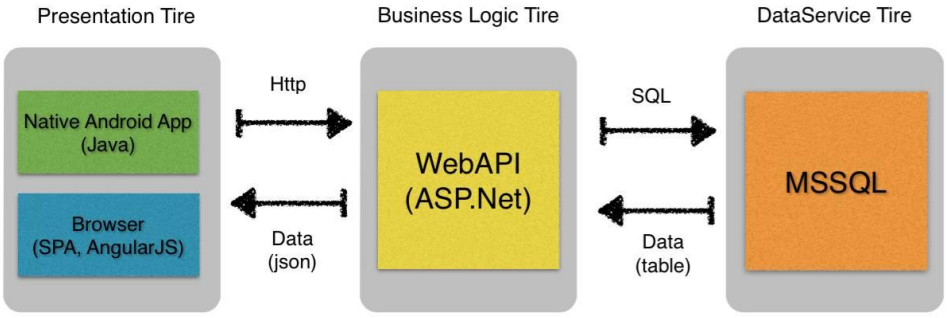


Figure 6. Three-tier architecture

The presentation tier contains both NAAs (native Android apps) and SPAs (single-page applications). We use Eclipse IDE to create our native Android app, written in the Java programming language. This app first retrieves data from the data-service tier, and then provides services via human-computer interaction devices. In addition, we allow the Bluetooth weight scale to send measurements to our app automatically, thus preventing the user from manually entering a wrong weight. Furthermore, our app constantly synchronizes data with the data-service tier and website. In addition, we use AngularJS, in which we employ Sublime Text 3 to create our single-page application (SPA). Our SPA is a totally client-rendered website model in which all the data are first retrieved from the data-service tier through Ajax, and then displayed in final graphs to users.

The business-logic tier, located right below the presentation tier, is responsible for data processing and computation. That is, the business-logic tier is a bridge between client and server that receives the requests from clients, decides what data should be sent back, and processes the web server's data and calculations. We apply Microsoft Visual Studio 2013 to create our RESTful (REpresentational State Transfer) APIs, which are cloud-based APIs using the ASP.NET Web API platform. Our system initially retrieves data from the database-service tier, and then passes the retrieved data to the presentation tier. In addition, in our login mechanism, we employ OAuth 2.0 standards with token authentication for

easier identification in different platforms. In order to better protect users' privacy, we employ the RFC2898 standard to ensure each user's encrypted results will be different even if different users choose the same password.

The data-service tier stores a lot of data in order in order to manage the software, and provides the data to the business-logic and presentation tiers. Our system uses MySQL Server Management 2012 to create our database, where users are allowed to add, access, and process data. We first create our tables and necessary columns for each table. Next, we set indexes, related foreign keys, and properties for each table. We then create relationships between these tables. Finally, we configure the SQL authentication and listening port. In addition, our system ensures that the clients from the presentation tier cannot save data directly from the data-service tier for greater security and protection.

4.2 Database development

Our system applies the United States Department of Agriculture (USDA) MyPyramid Equivalents Database (MPED) 2.0, 2003-2004 [9], to construct our database. MPED 2.0 is the database that translates the amounts of foods eaten in USDA's What We Eat in America Survey into the MyPyramid 6 major groups and 32 subgroups. USDA's What We Eat in America includes the records surveyed from individuals ranges from 2 years to 85 years of age, and is the component provided from National Health and Examination Survey (NHANES) from 2003-2004, whereas NHANES data were originally used to record all the participants' daily total energy, nutrient intakes from foods and beverages, and water consumed [22]. We list all the database files retrieved from MPED 2.0 and USDA NHANES databases, and classify them into "MPED 2.0" and "USDA NHANES 2003-2004" folders, as shown in Figure 7.

Figure 7. List of all the database from MPED 2.0 and USDA NHANES 2003-2004.

The first database file inside the "MPED 2.0" folder, Equiv0304.mdb, contains 7751 recipes, each with a unique "FOODCODE" along with its food description. Next, both pyr_iff_d1.sas7bdat and pyr_iff_d2.sas7bdat contain about 120868 records in each database, listing all the interviewees' daily consumed food and its associated MyPramid food groups for the first or second day. According to [32], MyPyramid lists seven major groups, which are: 1) grain group, 2) vegetable group, 3) fruit group, 4) meat and beans group, 5) milk group, 6) oil group, and 7) extras group. In our application, we combine MyPyramid's last two groups (oil and extra groups) into one group, resulting six major groups like the reference in [40]. Furthermore, pyr_tot_d1.sas7bdat and pyr_tot_d2.sas7bdat both contain about 9643 records in each database, where these records list all of the interviewee's total consumed food and food groups for the first or second day.

The first two database files inside the "USDA NHANES 2003-2004" folder, Dr1iff_c.xpt and Dr2iff_c.xpt, contain about 131164 records in each database. Both Dr1iff_c.xpt and Dr2iff_c.xpt database files are

similar to pyr_iff_d1.sas7bdat and pyr_iff_d2.sas7bdat, except that they list the interviewees' daily consumed food and its associated nutrition facts. Similarly, both Dr1tot_c.xpt and Dr2tot_c.xpt database files are similar to pyr_tot_d1.sas7bdat and pyr_tot_d2.sas7bdat, except that they list the interviewees' total consumed food for a day and its total associated nutrition facts.

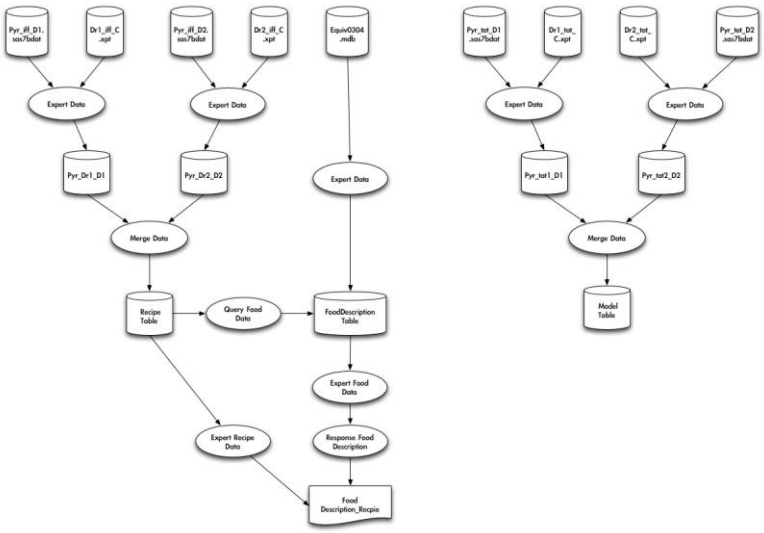


Figure 8. CIRCLE Data Flow Diagram

Figure 8 shows the data-flow diagram of our system. In this figure, we can see that there are two major tables named Model and FoodDescriptionRecipe. First, we construct our Model table using the following steps: 1) we merge Pyr_tot_d1.sas7bdat with Dr1_tot_C.xpt to give a result in table Pyr_tot1_D1, and merge Pyr_tot_D2.sas7bdat with Dr2_tot_C.xpt to give a result in table Pyr_tot2_D2; 2) we then combine table Pyr_tot1_D1 and table Pyr_tot2_D2 together, and name it Model table. The columns in our Model table contains the following major components: 1) total servings of grains needed per day, 2) total servings of vegetables needed per day, 3) total servings of fruits needed per day, 4) total servings of meat and beans needed per day, 5) total servings of milk needed per day, 6) total servings of oil and extras needed per day, and 7) total energy (Kcal) needed per day, and 8) total associated nutrition facts needed per day. Our Model table has about 15921 records with calorie ranges from 31 calories to 9724 calories, where each record contains the daily total intake energy, the nutrient intakes from food and beverages, and the six major food groups that an individual might consume in a day.

Our FoodDescriptionRecipe table is build using the following steps: 1) we create Pyr_Dr1_D1 table by merging both Pyr_iff_d1.sas7bdat with Dr1_iff_C.xpt, and build Pyr_Dr2_D2 table by joining Pyr_iff_d2.sas7bdat together with Dr2_iff_c.xpt; 2) we then combine table Pyr_Dr1_D1 and table Pyr_Dr2_D2, and name it Recipe table; 3) we finally create the Food_Description_Recipe table by merging the Recipe table and Equiv0304.mdb database file. The columns in our Food_Description_Recipe table contains the following components: 1) the name of the food, 2) total servings of grains, 3) total servings of vegetables, 4) total servings of fruits, 5) total servings of meat and beans, 6) total servings of milk, 7) total servings of oil and extras, 8) amount of food eaten in grams, 9) amounts of energy (Kcal), and 10) associated nutrition facts. Our FoodDescriptionRecipe table contains about 232527 records, including all the possible recipes that a user might choose for a meal.

5 User Interface of CIRCLE System

In this section, we describe some user interfaces of the CIRCLE System. We present some screenshots of the CIRCLE System in both mobile (app) and web-based versions (SPA) in the below subsections.

(a) (b)

Figure 9. Screenshot of (a) "Login" page, (b) "Register" page

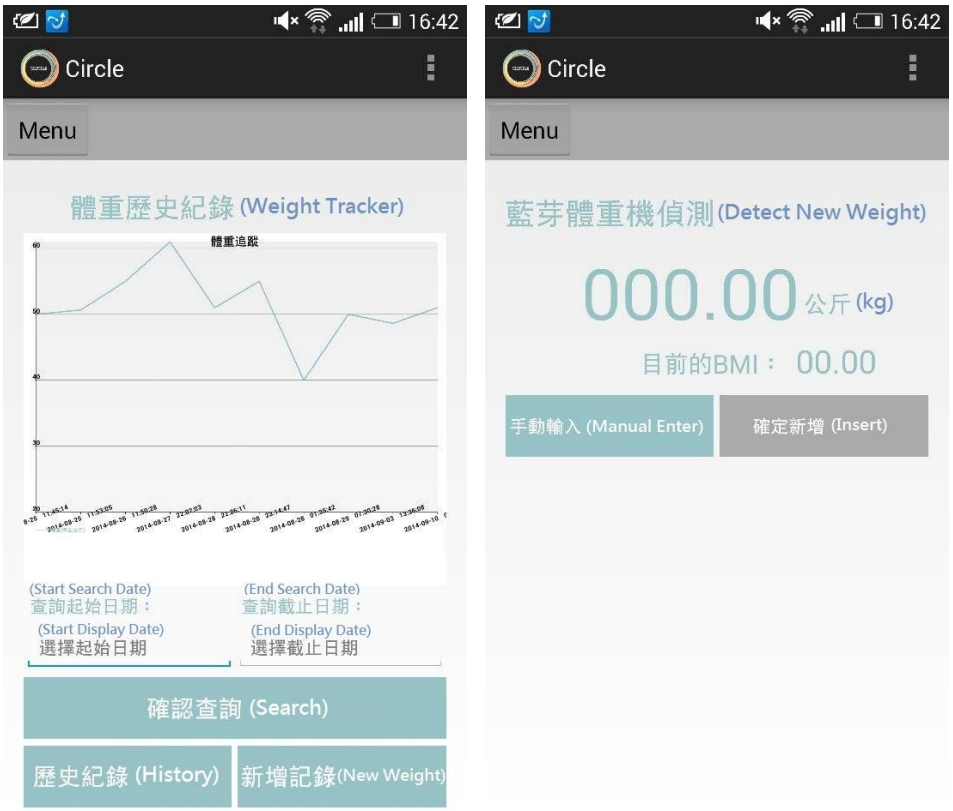
5.1 Mobile version:

Our CIRCLE mobile app is suitable for any Android operating system, as the app was developed and tested on Android smartphones. When a user starts the app, our system determines whether this mobile device has been logged in previously. If the user has not been logged in before, or the client's current token has expired, our system will direct to the login page, as shown in Figure 9(a), where the user can log into the system. In addition, a new user can click on the "New Account" button, in which case our system will navigate to the "Register" page shown in Figure 9(b). Our system is built on membership functionality, which means that someone who does not pass the login step cannot further access the system.

Once the user successfully logs into the system, it will display four options, as shown in Figure 10: 1) Weight Control, 2) Nutrition, 3) Exercise, and 4) Health-Related Articles. The explanations of the four options are discussed below.

Figure 10. Screenshot of "Home" page

1. **Weight Control:** Once the user selects the "Weight" option, the system links to the page as shown in **Error! Reference source not found.**(a). The user can search and view his previous weight measurements in a trend chart, where the x-axis represents measured time and the y-axis represents measured weight. Our system displays all of the saved weight measurements by default, but the user is free to view his measurements over a particular time period. In addition, the user can manually insert new weight measurements, or can have a Bluetooth scale automatically send his weight measurements to the system, as shown in **Error! Reference source not found.**(b).
2. **Nutrition:** When the user chooses the Nutrition page, the system takes the user to the page as shown in **Error! Reference source not found.**(a). The Nutrition page displays the remaining calorie intake and corresponding servings of the six MyPyramid food groups that the user should take for that day, which is calculated from Equation (4). The user can click "Edit Profile" to manually edit his or her profile, including editing activity and stress factors, weight goal, current weight, current height, and current age. Our system calculates the daily calorie intake and nutrition model based on a user's current profile. In addition, the user can view the calories of a particular meal by pressing the "Information" icon shown at the upper right corner. The user can also view his/her past menus, nutrition facts, recipes, and calorie information from the "History Menu" button.
   In addition, the user can choose a new dish by pressing "Choose Menu" button, where the system will direct to another page like the page shown in **Error! Reference source not found.**(b). The user first would need to select the desired food group, followed by selecting desired food category, and then finally selecting a desired dish. **Error! Reference source not found.**(b) shows an example in which a user first chooses the protein group, then the pork category, and finally a pork-chop dish. Once the user finishes choosing his or her desired dish, the system navigates to another page where the user can view detailed information about the chosen dish, including ingredients, instructions, condiments, and then total calorie intake. In addition, the user can also enter the desired portion that he or she wants to consume, and the system will calculate and update the calories and corresponding servings of the six MyPyramid food groups accordingly.

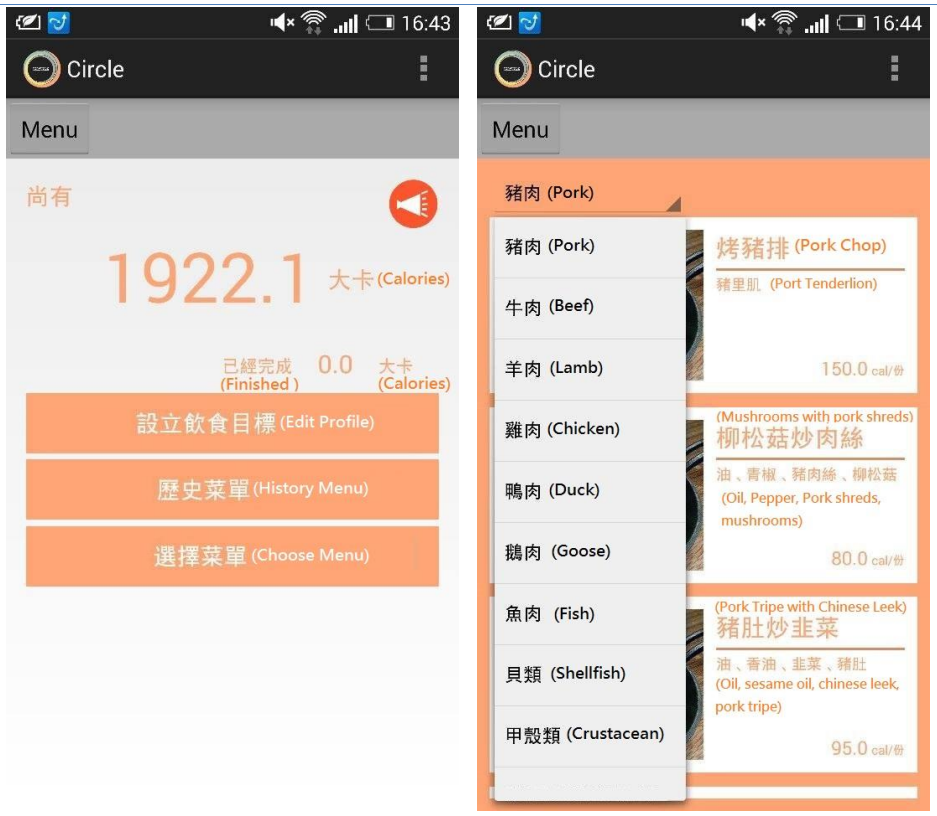


(a) **(b)**

Figure 11. Screenshot of (a) "Weight Control", (b) "Insert New measurement" page

3. **Exercise:** The Exercise page shows the exercise records in a bar chart, where the x-axis represents hours and y-axis represents total burned calories. Our system uses the phone's built-in pedometer to track the user's total steps for a day, total exercise time for a day, total calories burned for a day, and total distance for a day. Please note that our system prevents users from manually entering any of the information mentioned above to ensure that the system records accurate exercise information from the user. **Error! Reference source not found.**(a) shows a screenshot of the Exercise page.

4. **Health-Related Articles:** The Health-Related Articles page provides articles from iHealth [24], a website that contains Chinese health information. In addition, our system displays the most relevant articles to the user using his/her current BMI and gender information. **Error! Reference source not found.**(b) shows the list of articles retrieved from [24] for a female with normal BMI. After the user has made a selection, the system will retrieve and display the article from iHealth.



(a) **(b)**

Figure 12. Screenshot of (a) "Nutrition", (b) "Menu Selection" page

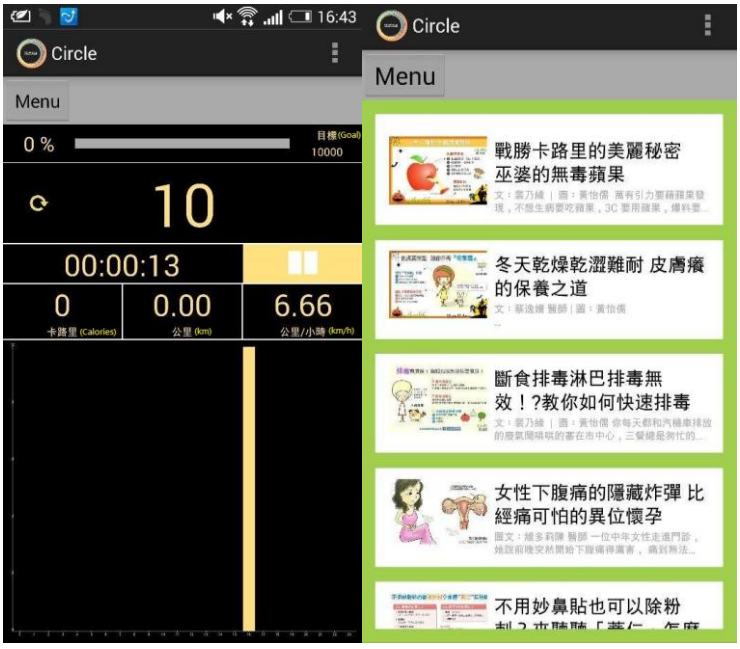


Figure 13. Screenshot of (a) "Exercise", (b) "Health-related articles" page

5.2 Web-based version (SPA):

Our Web-based version of the system provides functionalities similar to those of the mobile version, including a login page, an account-registration page, a weight-control page, and a nutrition page. The system first determines whether the user has logged in before. If the user has not logged in before, or the client's current token has expired, our system requests a login and password as shown in Figure 14. In addition, the user can also log into the system using his existing Twitter, Facebook, or Google account. If the user does not have such an account, he or she can also create a new account by clicking the "Sign Up" link.

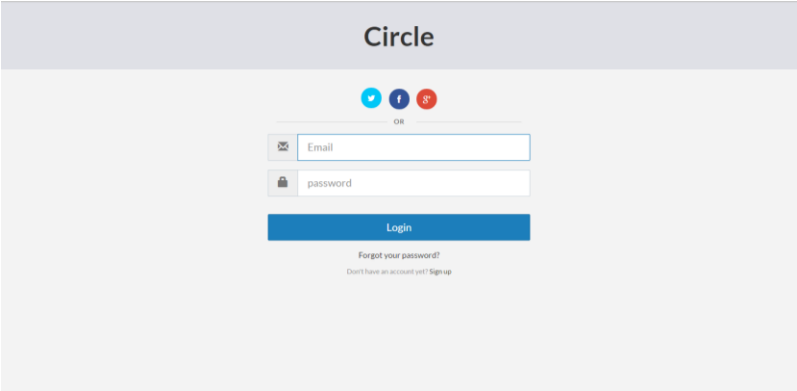


Figure 14. Screenshot of Web-based login page

Once the user successfully logs into the system, he or she sees his or her personal information, (e.g. user name, email, birthday, contact phone number, height, weight, and BMI), as well as past weight measurements in a trend chart like that shown in Figure 15. When the user rolls the mouse over any point on the trend chart, a text box pops out, showing that point's individual date and measurement.

Figure 15. Screenshot of Web-based home page

When the user selects "ScaleRecord" from the left menu, the system will move to a page displaying past weight measurements, as shown in Figure 16. In addition, the user can manually insert new weight measurements on this page.

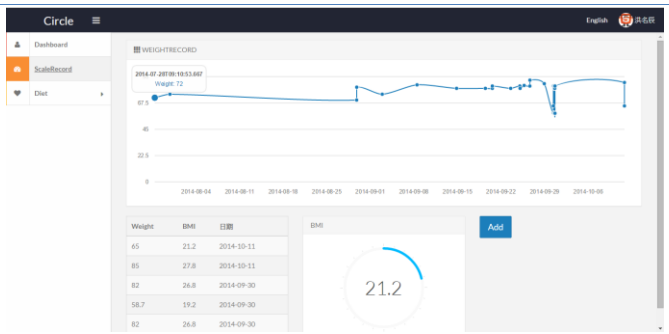


Figure 16. Screenshot of Web-based Weight page

When a user clicks "Dish" from the left menu, our system navigates to the Nutrition page (Figure 17), which shows the total calorie intake, remaining calorie quota, remaining servings of the six MyPyramid food groups, and detailed information for all chosen recipes for the current day. As previously mentioned, the user can edit his or her profile at any time by clicking the "Edit Profile Record" button in the upper right corner to edit his or her age, weight, activity factors, stress factors, and weight goal. Total calorie intake and nutrition model is calculated based on the user's current profile. In addition, the user can also view detailed information about a dish before selecting it.

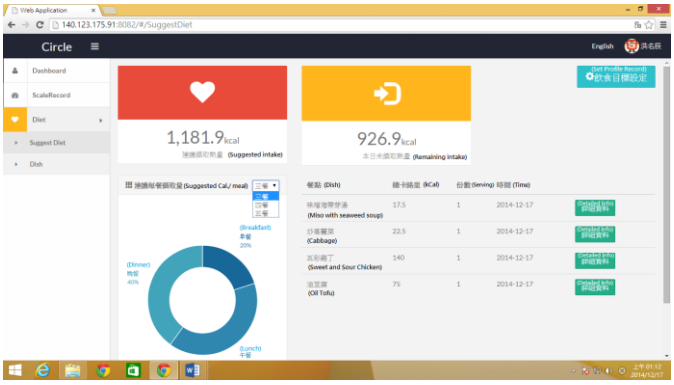


Figure 17. Screenshot of Web-based Nutrition page.

6 Use Case

In this section, we explain how we calculate the appropriate calorie intake and nutrition model based on the user's personal profile, how we display all the recipes from the USDA's NHANES and MPED 2.0 databases that fit the calculated calorie intake and servings of the six MyPyramid food groups, and how to assist users in maintaining their health through a healthy and balanced diet.

For example, let us assume we have a male user: age 21, 173 cm tall, weighing 88.1 kg, with no serious disease and a low activity level (i.e. sitting for long periods). Thus, we use Equation (1) to calculate BEE:

$$BEE = 66 + (13.7 * 88.1\ kg) + (5*173) - (6.8 * 21) = 1995.17$$

Next, we retrieve the appropriate activity and stress factors for this user, which come out to 1.3, based on the information provided in **Error! Reference source not found.**. We then adapt Equation (3) to calculate the corresponding EE for this user:

$$EE = BEE * \text{activity and stress factors} = 1995.17 * 1.3 = 2593.72$$

Since this user wishes to lose weight, we calculate final daily calorie intake using Equation (4):

$$DRC = EE - 500 = 2593.72 - 500 = 2093.72 \text{ calories}$$

We next calculate our intake calorie ranges with an error of plus or minus 50 calories. In other word, the calorie ranges from our previous example would be between 2043.72 and 2143.72 calories. After that, we compare these calorie ranges against 15921 nutrition models from the Model table, and retrieve 688 appropriate models that fit into this calorie range. Because there is more than one model that fits into this calorie range, we randomly choose one nutrition model from the 688 options, and display the final chosen model to the user. **Error! Reference source not found.** displays detailed information on the chosen nutrition model for this example.

In this table, we can see that the recommended daily calorie intake is 2,045 with about 7.804 servings of grains, 0.701 servings of vegetables, 0.124 servings of fruits, 2.105 servings of dairy, 6.63 servings of meat & beans, 57.763 grams of oil, and 25.34 teaspoons of added sugars. Our system first eliminates improper recipes that do not meet the requirements, any recipe in which one or more values exceeds the values shown in **Error! Reference source not found.**. Our system then eliminates inappropriate recipes and recommends the remaining 196,802 recipes to this user.

Table 2 The chosen nutrition model

Grain	Veg.	Fruit	Dairy	Meat	Oil (g)	Sugars (ts)
7.804	0.701	0.124	2.105	6.63	57.763	25.34
Recommended calories		2045	Calories left		2045	

Suppose that the user selects 2% fat milk with Kellogg's Smart Start cereal, and a small plain bagel added with honey for his breakfast. This meal is about 436.6 calories, and contains about 2.427 servings of grains, 0 servings of vegetables, 0 servings of fruits, 1 servings of dairy, 0 servings of meat & beans, 4.607 grams of oil, and 9.667 teaspoons of added sugars. Our system then subtracts these consumed calories and nutrition ingredients, which alters the selected nutrition model as shown in Table 3:

Table 3 The chosen nutrition model after breakfast

Grain	Veg.	Fruit	Dairy	Meat	Oil (g)	Sugars (ts)
5.377	0.701	0.124	1.105	6.63	53.156	15.673
Recommended calories		2045	Calories left		1608.4	

Our system similarly filters out the improper recipes that do not meet the requirements shown in **Error! Reference source not found.**, which reduces the number of suitable recipes to about 189,893 records. Assuming that the user chooses corn tortilla rolled with chicken breast, lettuce, sliced tomato, honey mustard sauce, chicken broth soup, some mixed nuts and nonfat chocolate yogurt for his lunch. Overall, the meal is about 941 calories, and contains about 4.089 servings of grains, 0.119 servings of vegetables, 0 servings of fruit, 0.605 servings of dairy, 6.373 servings of meat & beans, 18.609 grams of oil, and 8.312 teaspoons of added sugars, which alters the selected nutrition model as shown in Table 4:

Table 4 The chosen nutrition model after lunch

Grain	Veg.	Fruit	Dairy	Meat	Oil (g)	Sugars (ts)
1.288	0.582	0.124	0.5	0.257	34.547	7.361
Recommended calories		2045	Calories left		667.4	

Our system further eliminates improper records, and leaves about 118,889 recipes for the user to choose. Suppose that the user chooses Caesar's salad, whole wheat roll bread, some chopped almonds, fruit yogurt, and strawberries for his dinner. In all the meal is about 660 calories, and contains 1.288 servings of grains, 0.577 servings of vegetables, 0.124 servings of fruits, 0.5 servings of dairy, 0.257 servings of meat & beans, 32.436 grams of oil, and 4.622 teaspoons of added sugars. The chosen nutrition model would now become as the one shown in Table 5:

Table 5 The chosen nutrition model after dinner

Grain	Veg.	Fruit	Dairy	Meat	Oil (g)	Sugars (ts)
0	0.005	0	0	0	2.111	2.739
Recommended calories		2045	Calories left		7.4	

Table 6 The summary of nutrition intake example, where G=Grain, V=Vegetable, F=Fruit, D=Dairy, M & B=Meats & Beans, O = Oils, S = Added Sugars

Meal	G	V	F	D	M & B	O	S	KCal
Breakfast	0.299	0	0	0	0	0	0.808	45
	0	0	0	1	0	4.607	0	122
	2.128	0	0	0	0	0	0.639	141.6
	0	0	0	0	0	0	8.22	128
Lunch	4.089	0	0	0	0	0	0	214
	0	0	0	0	6.373	1.489	0	212
	0	0.058	0	0	0	0	0	1
	0	0.056	0	0	0	0	0	2
	0	0.005	0	0	0	6.518	3.966	125
	0	0	0	0	0	1.562	0	52
	0	0	0	0.605	0	0	4.346	191
	0	0	0	0	0	9.04	0	144
Dinner	0	0	0.124	0	0	0	0	6
	1	0	0	0	0	1.01	0.508	74
	0	0	0	0	0	15.846	0	283
	0	0	0	0.5	0	3.854	4.045	146
	0.288	0.577	0	0	0.257	11.726	0.069	151
Total	7.804	0.696	0.124	2.105	6.63	55.652	22.601	2037.6
Model	7.804	0.701	0.124	2.105	6.63	57.763	25.34	2045

The overall consumed calories and nutrition ingredients are shown in **Error! Reference source not found.**. From this table, we can see that the total consumed calories for the current day, as well as nutrition ingredients (shown in red color) are all very close to the chosen nutrition model (shown in blue color).

7 Evaluation

In this section, we asked 100 participants who really eager to lose weight to voluntarily participate in a survey to evaluate CIRCLE. There are almost equal numbers of female and male participants in this survey (54 males and 46 females), and the age for the majority of participants lies between 18 and 30

(44 people aged below 20, 37 people aged 21-29, 7 people aged 30-39, 4 people aged 40-49, 4 people aged 50-59, and 4 people aged above 60). The survey was designed and accessed using Google Forms, and was conducted over 1 week. The survey contains 11 questions that evaluate the practicability of CIRCLE, user interface satisfaction, ease of use, satisfaction of incorporating the Bluetooth weight scale, smooth operation of CIRCLE, satisfaction with the variety of recipes, satisfaction of using CIRCLE's exercise section, satisfaction with the health-related articles section, achievement of personal health management, and inclination to recommend the app to others. Most of the questions were on a Likert scale, ranging from "strongly agree" to "strongly disagree". Since there were no invalid questionnaires (i.e., as all of the surveyed people claim that they were indeed following the diet suggestions given by the app), we collected a total of 100 survey responses. Table 7 shows the survey questions with the statistics obtained from the participants.

Table 7. Student Survey Responses

Questions	5	4	3	2	1
CIRCLE is a practical application	22	51	22	5	0
CIRCLE has a nice user interface	27	30	32	10	1
CIRCLE is easy to use	31	39	19	12	0
I appreciate the feature that allows me to import measurements from a Bluetooth-enabled weight scale	25	26	32	12	5
I felt that CIRCLE operates smoothly	26	44	23	6	1
I felt the system provides a variety of recipes	29	43	24	4	0
I am satisfied with the CIRCLE exercise section	32	28	32	8	0
I am satisfied with the CIRCLE health-related articles section	47	36	15	2	0
CIRCLE supports user-centered weight and nutrition management	40	34	25	1	0
I would recommend CIRCLE to other people	25	41	27	7	0

5: Strongly Agree, 4: Agree, 3: Average, 2: Disagree, 1: Strongly Disagree

In summary, most participants showed positive attitudes toward the use of CIRCLE. Our survey indicates high practicability (73%) and high results on our system's ease of use (70%). In addition, most participants believed that CIRCLE operates smoothly (70%), and contains a variety of recipes (72%). Moreover, about 50% of the participants were satisfied with the exercise section, and 83% of the participants were satisfied with the health-related articles section. Furthermore, most participants believed that CIRCLE supports self-management of health and well-being (74%), and about 66% of participants would recommend using CIRCLE for their future classes.

However, it was disappointing to find out that only about 57% of participants believed our interface is user-friendly. After further investigation, we figured out that some users do not like our interface due to the following reasons: 1) font choices, 2) missing images of recipes. Thus, in the future, we plan to examine options, such as including pre-survey questions that ask users for suggestions for improving the CIRCLE user interface, and modify our interfaces accordingly.

Error! Reference source not found. illustrates the overall ratings for CIRCLE. In this figure, we combined our previous 10 survey questions from **Error! Reference source not found.**, and broke them down into seven categories. We observed that more than 65% of the participants believed that CIRCLE: 1) contains high practicability, 2) is designed for the ease of use, 3) ensures smooth operation, 4) supports system functionality, 5) includes high user-satisfaction, and 6) has very high user-recommendation.

Overall, the participants' positive feedback further confirmed that CIRCLE supports user-centered weight and nutrition management. Most of the surveyed participants feel that CIRCLE is a practical application, and are satisfied with how the system helps them to achieve their nutritional needs, and to ultimately keep their bodies fit. In addition, participants believe that our system provides smooth operation, contains satisfactory system functionalities, and helps them to become more aware of their weight. Finally, most of them would recommend CIRCLE to other people.

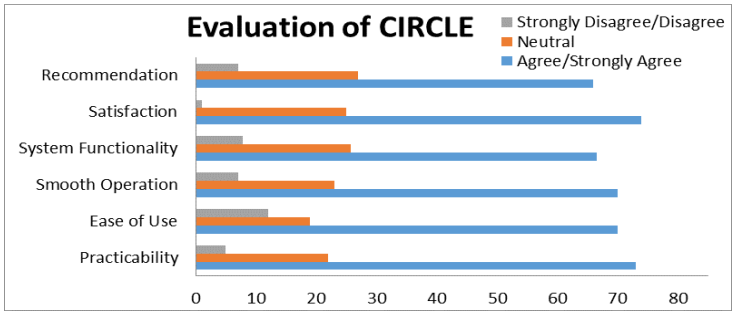


Figure 18. Overall rating for CIRCLE

However, the major limitation of this current survey is that we did not track whether the surveyed people indeed lost weight using our app. Therefore, in the future, we plan to extend the survey period so that participants can have the time to test their ability to lose weight using the app.

8 Conclusions & Future Work

We present CIRCLE, a cloud-based mobile wellness system, to promote user-centered weight and nutrition management from users' own mobile devices. We present a nutrition method that calculates the recommended daily calorie intake and nutrition model based on the user's personal profile, displays all the recipes from the USDA's NHANES and MPED 2.0 databases that fit the calculated calorie intake and the servings of the six MyPyramid food groups, and allows users to choose their desired recipes. In addition, our system tracks users' exercise activities, records their weight measurements, and offers health-related articles based on the user's personal information. Moreover, by embracing cloud technology, we synchronize data across multiple mobile devices, allowing users to access the CIRCLE system anywhere and anytime. Furthermore, we adapt data transmission using the Internet-Of-Things operation process, reducing unnecessary cost and increasing efficiency. Lastly, we ask users to evaluate their experiences and provide feedback about CIRCLE. Based on users' overall feedback, we conclude that our CIRCLE can promote user-centered weight and nutrition management, and can ultimately keep users' bodies fit and healthy. Our CIRCLE acts like a "physical dietitian", encouraging users to become more engaged in understanding and monitoring their weight problems, allowing them to choose their desired recipes and health-related information, promoting user-centered weight and nutrition management via their own mobile devices, and ultimately keeping their bodies fit and healthy.

In the future, we plan to further refine our system, perhaps by incorporating wearable devices. Users might employ pedometers, for example, rather than mobile phones when they exercise. In addition, we plan to expand our system so that users can share their exercise records with their friends on social networks (e.g. Facebook, Twitter, etc.). In addition, we plan to extend the survey period to test whether participants indeed lose weight using this system. Furthermore, we plan to add notification features, informing users about their total consumed calories so far and their remaining calorie allowances for a

day. Over the long term, we plan to cooperate with restaurants to give users a greater variety of recipe selections. We believe that this feature will be especially beneficial to users who frequently dine out, thus helping them to meet their nutritional needs even when they don't often eat at home.

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