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Study on a Computational Model of Food Intake for a Body Weight Management System

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Abstract. *From health surveys for public, the overweight condition of people happens frequently due to three causes: eating too much, exercising too little, and eating incorrectly. This study tries to help users to achieve a balanced diet in body weight management. To achieve the objective, we build and provide a weight management information platform, which integrates dietary and exercise management with embedded system design, for users. For the body weight management system, it is developed for monitoring and managing the diet of users and calculating an appropriate recipe by integer linear programming for users. The system is composed of two subsystems, where one is based on a hand-held device (or a smart phone) for users, and the other is an application system located in a server computer connected via a wireless network. Our experimental results show that the system is feasible for the weight management of the users.*
Keywords: Overweight, Weight management, Food intake, Embedded systems, Integer linear programming.

1. **Introduction.** In daily living, our body needs three macro-nutrients, proteins, fats, and carbohydrates [1]. Proteins are essential for the growth, development, and metabolism of a human body. Fats and carbohydrates provide energy for daily physical activities. According to the report of investigating dietary behaviors, the intake of proteins and fats is frequently over due to the popularity of eating fast foods for daily breakfast and lunch outside, but the intake of carbohydrates is not sufficient due to the incorrect idea of avoiding to get fat [2]. Therefore, in terms of dietary food intake, the intake of the three macro-nutrients is not easy to get balanced for people. In addition, obesity is another common issue, especially when food supplies are plentiful in this era and the lifestyle of most people tends to sedentary and lacks of exercise [3].

To keep away from obesity, the habit of effective exercise is necessary [4]. To cope with the obesity problem, a moderate approach of weight management with effective exercise is useful [5]. In [6], Patient-Centered Assessment and Counseling Mobile Energy Balance (PmEB) was developed as an application for a mobile phone that helps users to monitor their calorie balance as a part of weight management. In our system, proprietary embedded sensor modules [7] are equipped to monitor the calorie consumption in exercise for balancing the calories ingested from daily food intake.

It is not easy to achieve both losing fat and balanced diet without suitable measures since users do not have good eating habits and even do not have enough information for nutrients from daily food intake [8]. Based on the above observations, we propose a new method to make the weight management become easier and more feasible for common people. To achieve a balanced diet with low calorie, the method can generate a recommended recipe for dinner, which intends to meet users' nutritional requirement according to their intake of breakfast and lunch.

It is obvious that the direct connection between food intake and physical activities is the assimilation and expenditure of calorie. In this study, we focus on the following requirements to build up a computational model of food intake for weight management.

- Track daily calorific consumption needed as accurately as possible for each person according to personal basal metabolic rate (BMR) [9], physical activities (PA), and diet-induced thermogenesis (DIT) [10].
- Monitor users' exercise and acquire physiological information to assist personal weight management [7].
- Convert the input of food intake by a user to the amounts of the three macro-nutrients and the calorie of the corresponding food intake.
- Design a computational model for producing a recommended recipe computed by using an integer linear programming method [11] according to users' food intake and physiological information [7].
- Send the recommended recipe to each user before dining.
- Generate a health status review for each user based on the long-term records of user's food intake, exercise, and personal weight.

In terms of nutritional requirement, minerals and vitamins, also called micro-nutrients, are required in only tiny amounts for users [12]. We can get most of the micro-nutrients by eating a variety of foods in our daily diet. Therefore, the minerals and vitamins are not included in the calculation of this work.

The remainders of this study are organized as follows. In Section 2, the architecture of our system is described. In Section 3, we specify algorithms and procedures for body weight management in this study. In Section 4, the experimental results of our system are discussed. Finally, we summarize our work in Section 5.

2. System Descriptions.

Figure 1 shows the system overview of our body weight management system, which is composed of a personal weight management system (PWMS) and a healthcare management system (HCMS). A user can input health related data such as personal food intake and exercise to PWMS. It is used to include personal health related information into an individual profile and then transmits the information to HCMS by a wireless network. Then, the information is processed by HCMS as follows. First, the collected information is stored into a database managed by HCMS, and then the amounts of nutrients and calories required by users are calculated. Next, HCMS combines user's information and makes a recipe recommendation computed by using integer linear programming for each user. Finally, it sends a complete health status report to each user, respectively.

2.1. Personal Weight Management System.

In PWMS, it includes three data collection modules: a profile module, tabular module, and sensor module.

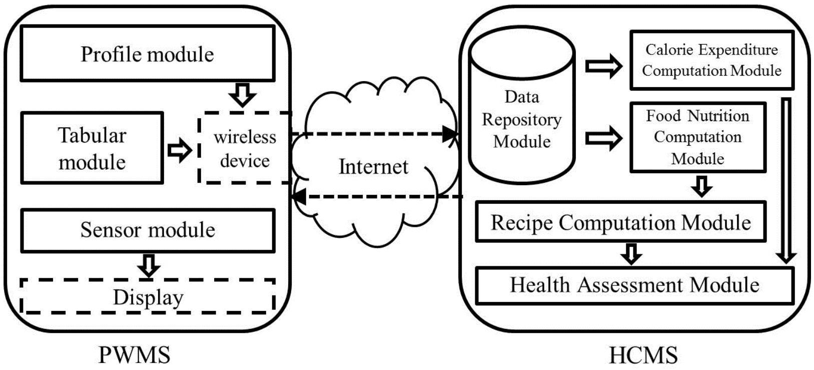

FIGURE 1. System architecture

2.1.1. *Profile Module.* Users are requested to input a personal profile into the profile module, such as name, gender, age, weight, and the goal of losing fat. In Figure 1, three computation modules of HCMS take the above data items as parameters for calculating calorie expenditure. For data accuracy, users also have to update the personal profile timely so that the parameters used by the three computation modules in HCMS can be refreshed.

2.1.2. *Tabular Module.* In the tabular module, users have to input the information from exercise and daily food intake. For exercise, users can choose a sport item and input the duration of the sport item from the sports' list in the tabular module of PWMS. Later, the sport information is sent to HCMS to get the information of calorie expenditure in exercise. In addition, we provide a friendly user interface, where users can input daily intake by filling a food intake list that we provide even if they have no specialized nutrition knowledge. In this study, we provide six food groups for users such as grains, protein, vegetables, oils, snacks, and fast food. They can choose and add one suitable food group with its corresponding portions into the food intake list at a time. To help users for understanding the portion size of different foods, an area of the user interface is designed to show the description of the portion size of food intake and guide users by hyperlink to an appropriate website for the details as the users fill into one specific food item.

Before filling the food intake list, users have to know how much food they eat. In [13], learning to recognize standard serving sizes can help them to judge how much food they eat. For example, a cup of barley is about the size of a fist. One medium fruit is about the size of a baseball.

2.1.3. *Sensor Module.* In PWMS, we have a sensor module, which contains a transmission unit and one or more sensors, as shown in Figure 2(a). The sensor is recognized by its sensor ID number. With the sensor ID, the sensor is activated by PWMS to get physiological data. When the sensor receives a polling command, it returns sensed data back to PWMS. If users wear a heartbeat sensor, the value of heart rate is transmitted to PWMS by the transmission unit as shown in Figure 2(a). For example, the PWMS subsystem issues a call of the No.1 sensor for heartbeat detection. When the No.1 heartbeat sensor receives the call, it returns the rate of heartbeats back to PWMS.

2.2. **Health Care Management System.** In our system, HCMS can provide a service for one or more users. After eating daily breakfast and lunch, each user is requested to input the food information for breakfast and lunch to HCMS as shown in Figure 2(b). For

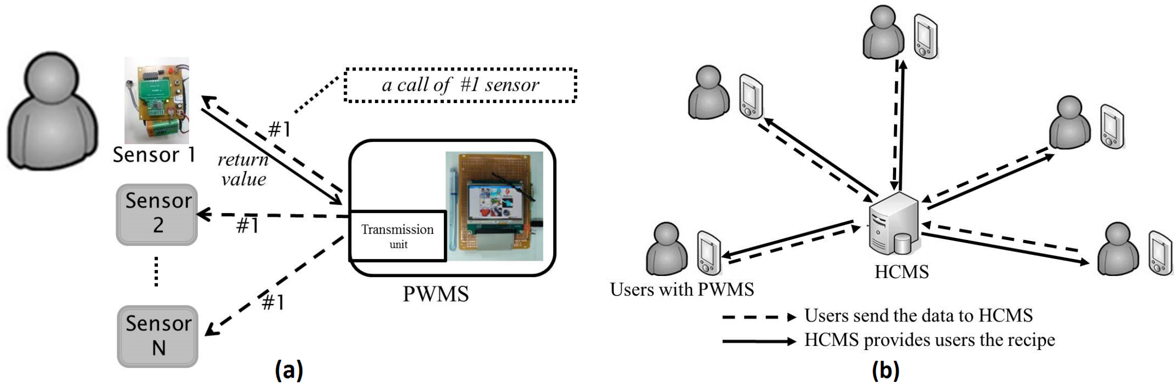

Figure 2. (a) Polling commands between a transmission unit and sensors; (b) A service scenario of HCMS.

the food intake of daily dinner, HCMS computes and generates a complete recipe using integer linear programming and sends the food intake recommendation to each user.

For HCMS, it is composed of a data repository module (DRM), a health assessment module (HAM), and three computation modules, which are Calorie Expenditure Computation Module (CECM), Food Nutrition Computation Module (FNCM), and Recipe Computation Module (RCM), as shown in Figure 1.

2.2.1. *Data Repository Module.* DRM creates and manages a personal database, including the information of personal profile and daily food intake and exercise. Users can interact with DRM through the user interface of HCMS. CECM and FNCM can send a database query command to get the information of exercise and food intake of users from the personal database in DRM.

2.2.2. *Calorie Expenditure Computation Module and Food Nutrition Computation Module.* CECM sums the exercise durations of each sport item and extracts the corresponding calorie consumption from the database, and then calculates the product of the two. The product value stands for the exercise calorie consumption of a user for that sport item. To get the exercise calorie consumption of users within a day, CECM sums up all the product values.

FNCM works out the amounts of the three macro-nutrients and calories according to the food intake of each user.

2.2.3. *Recipe Computation Module.* RCM sums up the food intake of breakfast and lunch of each user. It can calculate the shortage of the three macro-nutrients for each user based on the recommendation in the Daily Dietary Guidelines of the Department of Health (DOH) [14]. Afterward, the module provides a suitable recipe computed by using integer linear programming. The recipe can satisfy the low calorie requirement of the three macro-nutrients for each user.

If several users are in the same group such as a family, RCM can make a family recipe and sends it to a cook who is responsible to prepare a dinner. At the same time, RCM informs HAM to send the food intake recommendation to each family member.

2.2.4. *Health Assessment Module.* In HAM, it has two goals, fitness and food intake assessment, for health assessment.

- Fitness assessment: As users entered the individual information, they could set a goal of losing fat. After exercising, they would know the calories that had been consumed.

Based on the above, HAM can estimate and show the difference in kilogram between the present weight and the goal of losing fat to each user.

- Food intake assessment: For the food in a dinner recipe recommendation, HAM can provide the food intake recommendation according to the shortage of nutrients for each user.

3. **Algorithms for Weight Management.**

3.1. **Total Daily Calorie Requirement.**

To find out the total daily calorie requirements of users, we need to know their BMR, PA, and DIT, which contribute to the total daily calorie requirement for each person. They are described as follows.

3.1.1. *Basal Metabolic Rate.* The variables of weight (in *kg*), height (in *cm*), age (in *years*), and gender of a specific user are needed to calculate BMR. This is more accurate than calculating calorie needs based on personal weight alone as in [14]. Since the formulas of calculating BMR for male and female are different, they are given as below.

$$BMR_{Male} = 66 + (13.7 \times weight) + (5 \times height) - (6.76 \times age) \tag{1}$$

$$BMR_{Female} = 655 + (9.6 \times weight) + (1.8 \times height) - (4.7 \times age) \tag{2}$$

3.1.2. *Physical Activity.* Based on the computed BMR of male or female (*i.e.* by using Eq. (1) or (2)), Harris-Benedict principle [15] is a method to estimate a daily calorie requirement for the physical activity of an individual. The estimated value is then multiplied by a number that corresponds to the person's activity level listed in Table 1 below.

Table 1. Five levels of activity factor for calories

Activity levels	**Formulas**
Little to no exercise	$Daily\_calories\_needed = BMR \times 1.2$
Light exercise (1–3 days per week)	$Daily\_calories\_needed = BMR \times 1.375$
Moderate exercise (3–5 days per week)	$Daily\_calories\_needed = BMR \times 1.55$
Heavy exercise (6–7 days per week)	$Daily\_calories\_needed = BMR \times 1.725$
Very heavy exercise (twice per day, extra heavy workouts)	$Daily\_calories\_needed = BMR \times 1.9$

3.1.3. *Diet-Induced Thermogenesis.* When we have a meal, our body temperature tends to rise. This is because we need to expend energy to digest food, and to absorb and assimilate nutrients. It is estimated that DIT is about 5 to 10 percent of total energy in a meal, but the exact amount varies with the type of food as in [10]. The formula to compute DIT is given as below.

$$DIT = (BMR + PA) \times 0.1$$

3.1.4. *Calorie Expenditure in Sleeping.* It decreases about 10% of the BMR for the calorie expenditure while sleeping [16]. The formula computes the reduction of calorie expenditure in sleeping (or named as calorie expenditure reduction in sleeping (*CER_in_sleep*)), which is assumed to last 8 hours, is given below.

$$CER\_in\_sleep = BMR \times 0.1 \times 8/24$$

Since the BMR is calculated based on the whole day for every person, the computation of the total daily calorie requirement (TDCR) is given below.

$$TDCR = BMR + PA + DIT - CER\_in\_sleep \tag{3}$$

Based on the above Eq. (3), we can calculate the daily three nutrition requirements for users as in [14]. Afterward, the nutrition requirements will be used for recipe computation in RCM and health assessment in HAM. Let *ProtReq*, *FatReq*, and *CarbReq* be the daily proteins requirement, daily fats requirement, and daily carbohydrates requirement, respectively. According to the range of DOH's recommendation [14], the appropriate proportions of the three macro-nutrients for users can be calculated as the following formulas.

$$ProtReq = \frac{TDCR}{4} \times ProtReq\_Range \tag{4}$$

where *ProtReq_Range* is a value selected between 16.6% and 17.4%.

$$FatReq = \frac{TDCR}{9} \times FatReq\_Range \tag{5}$$

where *FatReq_Range* is a value selected between 27.6% and 28.7%.

$$CarbReq = \frac{TDCR}{4} \times CarbReq\_Range \tag{6}$$

where *CarbReq_Range* is a value selected between 54.0% and 55.3%.

According to users' health conditions and eating habit, we can decide the proportion of the three macro-nutrients for users with the help of nutritionists.

3.2. **Recipe Computation.** Suppose that there are N kinds of foods in the database of HCMS, and each food contains M kinds of nutrients. Parameters used in the integer linear programming of RCM are defined as below.

a_{ij}: the quantity of nutrient i that food j contains;
b_i: the minimum required quantity of nutrient i;
c_j: the quantity of calories that food j contains;
x_j: the quantity of food j;
y: the portion size of a dish in the recipe.

Therefore, we can meet the minimum required quantity of nutrient i based on the requirement of low calories. The problem can be formulated as an integer linear programming model in the following:

Minimize

$$f(x) = \sum_{j=1}^{n} c_j x_j \tag{7}$$

Subject to

$$\sum_{j=1}^{n} a_{ij} x_j \geq b_j,\ \ i = 1, 2, \cdots, m \tag{8}$$

For users, the ingredients of the three macro-nutrients in each dish must be greater than or equal to the minimum nutrition requirements as in the Eq. (8). Users can decide the servings of a dish in a recipe as the following formula:

$$x_j \leq q,\ \ q = 1, 2, \cdots, n, \text{ where } n \text{ is a constant.}$$

For instance, assume that a man's personal information is given as follows:

- Age: 28 years old;
- Height: 175 *cm*;
- Weight: 68 *kg*.

Assume that his food intake for breakfast and lunch is given as in Table 2. By using the Eqs. (3), (4), (5), and (6) to compute each nutrient requirement, we can conclude that he needs protein 77g, fat 57g, and carbohydrate 252g in a day.

Table 2. The food intake list of breakfast and lunch

Breakfast				
Food Name	*Protein (g)*	*Fat (g)*	*Carbohydrate (g)*	*Calorie*
Bagel	10	1	53	260
Iced Coffee	2	0	21	90
Lunch				
Food Name	*Protein (g)*	*Fat (g)*	*Carbohydrate (g)*	*Calorie*
2 pieces Chicken McCrispy	56	34	32	660
Medium French Fries	4	17	41	300
Diet Coke	0	0	0	0

Then, the remaining nutrients that can be allocated to a dinner for the man are proteins 5g, fats 5g, and carbohydrates 105g by using the following calculations, respectively.

- Protein: 77 - (10 + 2 + 56 + 4 + 0) = 5;
- Fat: 57 - (1 + 0 + 34 + 7 + 0) = 5;
- Carbohydrate: 252 - (53 + 21 + 32 + 41 + 0) = 105.

Assume that this man has a dinner preference, and his dinner options are listed as in Table 3.

Table 3. The options of a dinner

The options of a dinner					
Variable	*Food Name*	*Protein (g)*	*Fat (g)*	*Carbohydrate (g)*	*Calorie*
x_1	Cake	2	5	15	113
x_2	Chicken fried rice	31.5	30	77.5	706
x_3	Apple	0	0	15	60
x_4	Puff	6	7	21	171
x_5	Vegetarian pasta	9.5	12.5	67.5	420.5
x_6	Green salad	1	2.5	5	46.5
x_7	Cheese jam	4	2	11	78
x_8	Juice	0	0	36	144

The integer linear programming model can be built as follows:

Minimize

$$f = 113x_1 + 706x_2 + 60x_3 + 171x_4 + 420.5x_5 + 46.5x_6 + 78x_7 + 144x_8$$

Subject to

$$2x_1 + 31.5x_2 + 0x_3 + 6x_4 + 9.5x_5 + x_6 + 4x_7 + 0x_8 \geq 5$$
$$5x_1 + 30x_2 + 0x_3 + 7x_4 + 12.5x_5 + 2.5x_6 + 2x_7 + 0x_8 \geq 5$$
$$15x_1 + 77.5x_2 + 15x_3 + 21x_4 + 67.5x_5 + 5x_6 + 11x_7 + 36x_8 \geq 105$$

with the limit of 3 dishes in the dinner, *i.e.* $x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 = 3$, where $x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8 \in \{0, 1\}$.

By the above inequalities and conditions, we can get a solution, which includes the dishes of vegetarian pasta, green salad, and juice. These foods contain proteins 10.5g, fats 15g, and carbohydrates 108.5g.

3.3. **Food Nutrition Computation.** In this module, given the names (denoted by *FoodName*) and portions (denoted by it Portion) of foods in a specific database *PersonalDB* for a user, the functions, **SearchFoodDB** and **CalculateFunc**, are called to obtain the amounts of the three macro-nutrients and the corresponding calories for RCM. Figure 3(a) shows the pseudo code of the **SearchFoodDB** function. After getting the *PersonalDB.FoodName* and the *PersonalDB.Portion* from the *PersonalDB*, the *PersonalDB.FoodName* is sent to the **SearchFoodDB** function to get the ingredients of foods.

```
Query: Select PersonalDB.FoodName and PersonalDB.Portion from PersonalDB
    While(Query)
        SearchFoodDB(PersonalDB.FoodName);
            …
SearchFoodDB(PersonalDB.FoodName)
{
        ProtValue ← FoodDB.Prot;
        FatValue ← FoodDB.Fat;
        CarbValue ← FoodDB.Carb;
        CalValue ←FoodDB.Cal;
        CalculateFunc(ProtValue, FatValue, CarbValue, CalValue);
}
CalculateFunc(ProtValue, FatsValue, CarbValue, CalValue)
{
        ProtValue ← ProtValue × Portion;
        FatValue ← FatValue × Portion;
        CarbValue ← CarbValue × Portion;
        CalValue ← CalValue × Portion;
        UpdateDB(…);
}
```

(a)

```
Query: Select PersonalDB.SportName and PersonalDB.Time from PersonalDB
{
    While(Query)
        ExerciseCal = ExerciseCal +
    SearchExerciseDB(PersonalDB.SportName);
        …
}
SearchExerciseDB(PersonalDB.SportName)
{
        CalValue ←ExerciseDB.Cal;
        CalValue = CalValue × PersonalDB.Time;
        return CalValue;
}
```

(b)

FIGURE 3. (a) The **SearchFoodDB** and **CalculateFunc** functions; (b) the **SearchExerciseDB** function.

According to the *PersonalDB.Portion* searched from the *PersonalDB*, the **CalculateFunc** function is called to calculate the amounts of the three macro-nutrients and the corresponding calories as shown in Figure 3(a). Finally, the computing results are used to update the *PersonalDB*.

3.4. **Calorie Expenditure Computation.** In this module, given the names (denoted by *SportName*) and duration (denoted by $Time$) of sports in a specific database *PersonalDB* for a user, the function **SearchExerciseDB** is called to obtain the amount of calories expenditure for HAM. Figure 3(b) shows the pseudo code of the **SearchExerciseDB** function. The *PersonalDB.SportName* and the *PersonalDB.Time* are retrieved from the *PersonalDB*, and then the **SearchExerciseDB** function is called to calculate the calorie expenditure for the user.

3.5. **Health Assessment.** In this module, the assessment computations of the fitness and food intake are described as follows.

- Fitness Assessment: The main purpose of the fitness assessment is to show an accomplished percentage of scheduled progression in losing fat for each user. Again, let $DailyCalR$ stand for total daily calorie requirement in $Kcal$, $DailyIntake$ for daily dietary intake in $grams$, $FitGoal$ for the goal of losing fat in $grams$, and $ExerciseCal$ for daily exercise energy consumption in $Kcal$ of a user in one day. According to the requirement of energy balance described in [17], the daily quota for losing weight, say $DailyFitQuota$, is defined as below.

$$DailyFitQuota = DailyCalR - (DailyIntake - ExerciseCal) \tag{9}$$

Let D_i be $DailyFitQuota$ for the ith day. The accomplished percentage of the scheduled progression in losing fat is defined as follows.

$$FitProgression = \frac{\sum_{i=1}^{n} D_i}{FitGoal \times 7700} \times 100\% \tag{10}$$

Based on Eq. 10, we can advise users about the information on the progress of losing fat.

- Food Intake Assessment: The main goal of this assessment is to recommend a user the most necessary intake so that the user can get a quick balance in daily diet for weight management. The following work steps illustrate the procedure for the intake assessment.

Step 1: Calculate the daily three macro-nutrition requirements by Eqs. 4, 5, and 6.
Step 2: Find the maximum nutrition shortage as follows:

$$NutritionShortage = max \left\{ \begin{array}{l} Carbreq - TodayIntake.Carb, \\ ProtReq - TodayIntake.Prot, \\ FatReq - TodayIntake.Fat \end{array} \right\}.$$

Step 3: Find the corresponding food with the shortest nutrients for users from the recipe recommendation.
Step 4: Send an intake recommendation to that user according to the above results.

4. **Main Results.**

4.1. **Environment for Experiments.**

To conduct an experiment, a real case of a female subject was observed in her dietetic consultation for weight control. Her personal information is as follows.

Age: 25 years old;
Height: 160 cm;
Weight: 65 kg;
BMI: 25.39;
Goal of losing fat: 1.5 kg.

In this study, the method of 24-hour recall [18], which inquires about the items of foods and dishes and the food quantities consumed by the subject, is applied. In the beginning, the inherent food intake of the subject is inquired and recorded for the first week. After the first week, the subject begins to follow the instructions of dietetic consultation for dietary intake from the dietitian. Besides, the amounts of carbohydrate, fat, protein, and calories, which are converted from the subject's food intake, are recorded. To keep consistent in eating habit for a suggested recipe, we accumulate and store the food groups of her eating into a recipe database. Also, her weight is recorded to realize the progress of losing fat.

In the following illustrations, the curve name "*pro*" represents for *protein*, the curve name "fat" for fat, the curve name "*carb*" for *carbohydrate*, the curve name "*req*" for nutrient or food requirement, and the curve name "*total*" for total calorie intake. For a word "*consult*" before the curve name, it indicates the consultative diet control, and for "*compute*", it indicates our solution for a computational diet control.

4.2. **Experimental Results.**

The three macro-nutrients, total calorie, and variation of weight of the subject with the dietetic consultation are depicted in Figure 4.

In the first week, the subject is asked to keep her inherent diet for observations. Therefore, we can see the imbalance in the intake of the three macro-nutrients of the subject, especially in carbohydrate as shown in Figure 4(a). For the weight control of the subject, the dietetic consultation becomes effective in the days after the first week as shown in Figure 4(b). It is obvious to see that the total ingested calorie is lowered as well at the

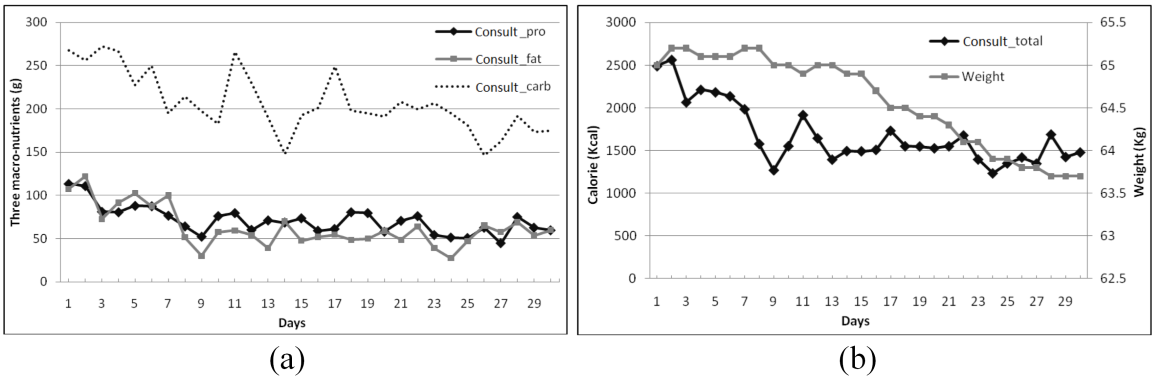

FIGURE 4. (a) The three macro-nutrients consumed by the subject; (b) the calorie intake and weight of the subject.

same time. In terms of averaging the percentages of nutrients for all days, she consumed 16.31% of the total calorie as protein, 39.32% as fat, and 44.37% as carbohydrate. The nutrient's percentages are clearly not conformant to the DOH's recommendation. This is what we mean that it is not easy for a user to achieve both losing fat and balanced diet, since the user may not have good eating habits and even enough information for nutrients from daily food intake.

To compare the effectiveness of our system with the actual dietetic consultation of the dietitian, the estimated nutrients' intake computed from the items of foods and dishes and the food quantities consumed by the subject recorded for this experiment is shown in Figure 5.

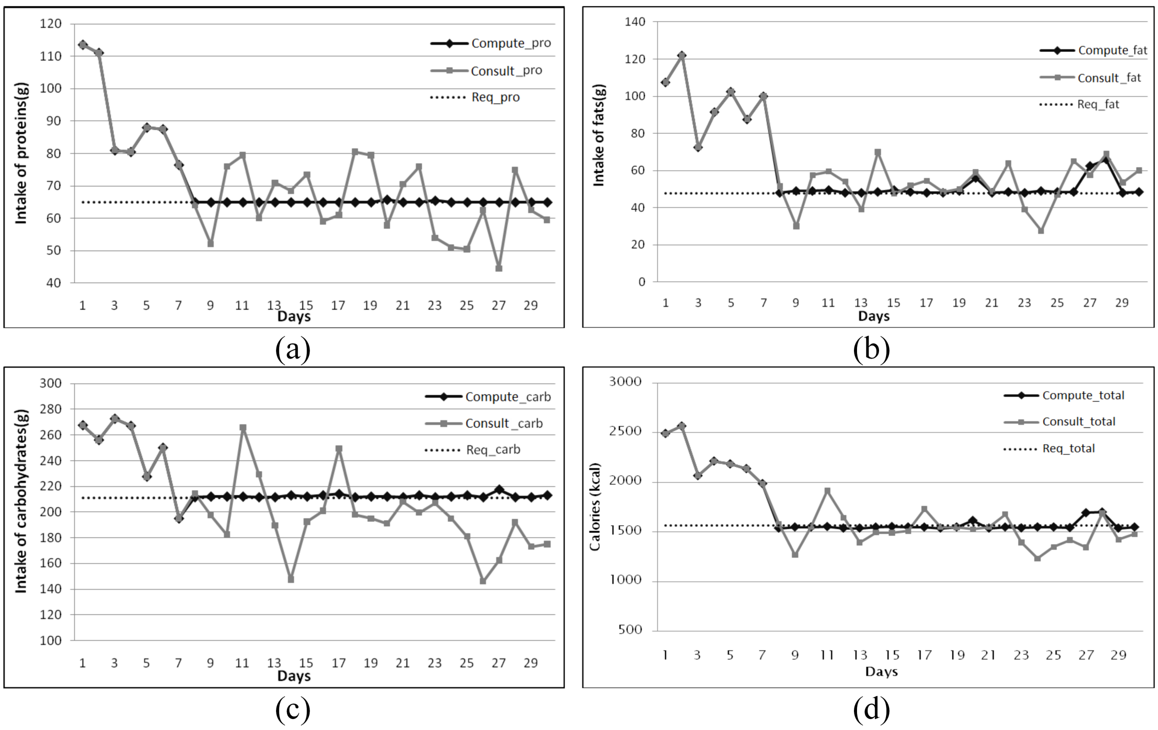

FIGURE 5. (a) Proteins, (b) Fats, and (c) Carbohydrates consumed by the subject; (d) the comparison in total calorie intake for the subject.

According to the DOH's recommendation [14], the requirements of nutrients (*i.e.* the curves Req_pro, Req_fat, and Req_carb in the figures) are set to protein $64.9g$ (17% of the total energy), fat 47.9g (28% of the total energy), and carbohydrate 211.2g (55% of the total energy). It can be found that the estimated nutrients (*i.e.* the curves *Compute_pro*, *Compute_fat*, and *Compute_carb* in Figure 5(a)–5(c)) are very close to the requirements of the three macro-nutrients recommended by DOH with low calories. In addition, the results with the actual dietetic consultation after the first week show that the subject ingests 17.13% of total calories from protein (the curve *Consult_pro* in Figure 5(a)), 33.76% from fat (the curve *Consult_fat* in Figure 5(b)), and 51.70% from carbohydrate (the curve *Consult_carb* in Figure 5(c)). This intake situation is better than the first week, and close to the quantity of the DOH's recommendation. However, the results from our system are much more accurate than the actual dietetic consultation in the proportions of nutrients, which are 16.67% for protein, 28.93% for fat, and 54.40% for carbohydrate.

Figure 5(d) shows a comparison in total calorie intake for the subject. It can be found that the result of our system (i.e. the curve *Compute_total*) is more stable than the total calorie intake (the curve *Consult_total*) under the dietician's consultation. However, it would be a little over the total calorie requirement (the curve *Req_total*) of the subject due to satisfying the balanced intake for the three macro-nutrients.

In summary, two advantages from the experiment can be found. First, our system can compute a feasible solution as the recommended recipe for the subject without changing her eating habit. Second, decisions from our system are not far from the dietician's consultation. In other words, our system can be an auxiliary system for a nutritionist to consult a patient's diet so that losing fat for the patient can become more convenient and feasible.

5. **Conclusions.** In this study, we have developed a body weight management system to recommend recipes for satisfying the requirements of the three macro-nutrients with low calories. The system is equipped with embedded sensor modules to monitor the calorie consumption from exercise. For users, their personal conditions and eating habits are considered in the system design. According to the experimental results, our system can provide a way to maintain stable nutrition and calorie intake for users. The experimental results also show that our system is feasible for helping users to achieve a balanced diet and provide sufficient information for personal weight management at the same time.

In the near future, we have two themes for the development of our system. First, new physiological sensor technology would be integrated into the embedded design of our system to monitor the exercise and physical fitness of users for evaluating their calorie consumption. Second, the automation of food recognition for dishes and calories by image processing is needed to persuade so that the burden of food data input can be released. In addition, we also consider adding more variables and options in our system for calculating the suitable recipe and increasing the variation of the recipe for user's flavor and taste.

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