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Food Intake for Body Weight Management System using Linear Programming Model

Phyu Phyu, Thin Thin Swe

Lecturer, Faculty of Information Science University of Computer Studies, Pathein, Myanmar

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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. For the normal person, it is difficult to know the situation means that acquiring and maintaining a healthy body weight. Therefore, this system tries to help the users to achieve a balanced diet in body weight management. For the body weight management system, the appropriate recipe will be calculated by linear programming for the users. To achieve a balanced diet with low calorie, the system can generate a recommended recipe for dinner, which intends to meet users' nutritional requirement according to their intake of breakfast and lunch. For the body weight management system, the appropriate recipe will be calculated by integer linear programming for the users. To achieve a balanced diet with low calorie, the system can generate a recommended recipe for dinner, which intends to meet users' nutritional requirement according to their intake of breakfast and lunch.

KEYWORDS: *linear programming, body weight management*

I. INTRODUCTION

In daily life, the human body needs three macro-nutrients, proteins, fats, and carbohydrates. 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.

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. Reaching and maintaining a healthy weight is important for overall health and can help to prevent and control many diseases and conditions. Therefore, the habit of effective exercise and weight management system are necessary to keep away from obesity. Food Intake for Body Weight Management System is developed as an application for a mobile phone that helps users to monitor their calorie balance as a part of weight management. In this system, 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. Based on the above observations, this paper proposed 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.

This system develops the mobile application intended for the user who wants to lost body weight. Firstly, the system will accept the user profile as input such as user's name, age and height and so on. Based on the user inputted profile, the system computes the BMR associated with their selected physical activities. Based on the BMR, the system computes the total daily calorie requirement for getting the balance three micro-nutrients for the normal person should have. Then, the users have to choose the breakfast and lunch they already had. Finally, the system generates a recommended recipe computed by using an integer linear programming method according to users' food intake. Therefore, the system is feasible for the weight management of the users.

II. Computational Model for Body Weight Management System Design

This system is the development of Food Intake for Body Weight Management System using Linear Programming Model. To build up this body weight management system, three modules are mainly focused: a profile module, computational module for weight management system, and recipe computation module.

A. Profile Module

In this module, users are requested to input a personal profile such as name, gender, age and weight. As shown in Figure 1, these data items are inputted as the parameters for calculating calorie expenditure. According to the user input, the calorie expenditure for each user can be changed.

B. Tabular Module

In the tabular module, users have to input the information of exercise and daily food intake for breakfast and lunch. For exercise, users can choose the types of physical activities

which are also parameters for calculation of calorie requirement for each user. In addition, the system provides a friendly user interface, where they can input daily intake for breakfast and lunch by filling a food intake list that the system provides. In this study, the system mainly provides only special meal and drink for dinner. They can choose and add one suitable food group with its corresponding portions into the food intake list at a time.

C. Computational Model for Body Weight Management

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. Therefore, in this study, we focus on the following requirements (see Figure 1) to build up a computational model of food intake for weight management.

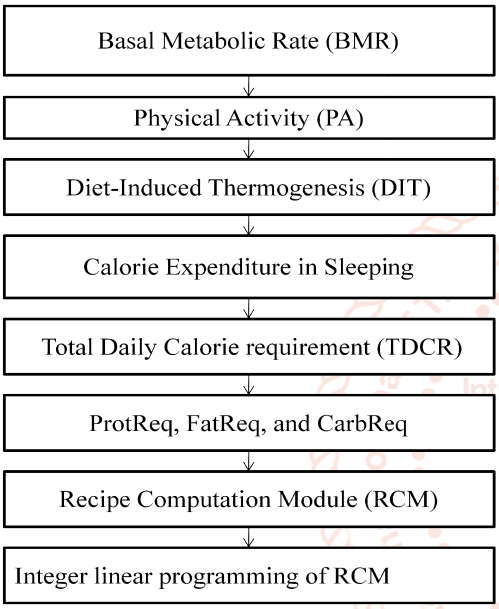

Fig. 1.The architecture design for body weight management system

- Track daily calorie consumption needed as accurately as possible for each person according to personal basal metabolic rate (BMR), physical activities (PA), and diet-induced thermogenesis (DIT).
- Convert the input of food intake taken 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 a linear programming method according to users' food intake and physiological information.
- Finally, the system will generate the recommended recipe to each user before dining.

D. Main Components of Total Daily Calorie Requirement

The important thing for weight management system is to know the total daily calorie requirement for each user. Daily energy expenditure consists of three components: basal metabolic rate, diet-induced thermogenesis and the energy cost of physical activity. Therefore, the following three components are important to find out it.

- Basal Metabolic Rate (BMR)
- Physical Activity (PA)
- Diet-Induced Thermogenesis (DIT)

1. Basal Metabolic Rate (BMR)

Basal metabolic rate, or BMR, is the measurement of an organism's energy expenditure when at rest. In other words, when the person at rest, not digesting any food and at a comfortable temperature, BMR is the amount of energy it takes for their body to maintain life. About 70% of the energy they use every day is due to their organs functioning to keep them alive and healthy. The remaining 30% is broken down into digestion of food (10%) and energy needed for activity (20%).

Knowing BMR can be useful for trying to gain or lose weight. Since BMR is a calculation of how much energy it takes to maintain life, consuming more kilocalories in a day than the BMR calls can cause to gain weight, while eating fewer kilocalories than BMR requires is likely to cause to lose weight. However, these numbers are also dependent upon how active they are. Since exercising burns calories, if persons are very active, they will need more calories to sustain life than someone who is not active.

The BMR formula uses the variables of height, weight, age and gender to calculate the Basal Metabolic Rate (BMR). Since the formulas of calculating BMR for male and female are different, they are given as below [4].

- BMR_{Male} = 66 + (13.7×weight) + (5×height) − (6.76 × age)
- BMR_{Female} = 655+(9.6×weight) + (1.8×height)−(4.7× age)

2. Physical Activity (PA)

A much more accurate method for determining total daily calorie requirement (TDCR) is to determine basal metabolic rate (BMR) using multiple factors, including height, weight, age, and sex, then multiply the BMR by an activity factor to calculate TDCR. To calculate the daily calorie requirement, the user's physical activities are also required. There are five level of activity. The following table enables calculation of an individual's recommended daily kilocalorie intake to maintain current weight

Table1Physical Activity Measure

Activity levels	Physical Activity	Formulars
Little to no exercise	1.2	Daily_calories_needed = BMR × 1.2
Light exercise (1–3 days per week)	1.375	Daily_calories_needed = BMR × 1.375
Moderate exercise (3–5 days per week)	1.55	Daily_calories_needed = BMR × 1.55
Heavy exercise (6–7 days per week)	1.725	Daily_calories_needed = BMR × 1.725
Very heavy exercise (twice per day, extra heavy workouts)	1.9	Daily_calories_needed = BMR × 1.9

3. Diet-Induced Thermogenesis (DIT)

Diet Induced Thermogenesis (DIT) can be defined as the increase in energy expenditure above basal fasting level divided by the energy content of the food ingested and is commonly expressed as a percentage. It is, with basal metabolic rate and activity induced thermogenesis, one of the three components of daily energy expenditure. Although DIT is the smallest component, it could play a role in the development and/or maintenance of obesity. When user has a meal, body temperature tends to rise. This is because user needs to expend energy to digest food, and to absorb and assimilate nutrients. It typically represents only about 10%

of total daily energy expenditure and is related to the type and amount of food ingested. Therefore, the formula to compute DIT is given as below:

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

4. Calorie Expenditure in Sleeping (CER)

It may seem like the human body is not doing much while it's sleeping, but it is still burning calories. Calories burned during sleep are used to sustain vital functions in the body. Monitoring and maintaining the internal temperature of the body, repairing cells and pumping blood are some of the nighttime activities that human body naturally does. If food is eaten in the evenings it is digested the same exact way food eaten during the day is digested. Therefore, it decreases about 10% of the BMR for the calorie expenditure while sleeping. 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 [5]:

$$CER \text{ in sleep} = BMR \times 0.1 \times 8/24$$

5. Total Daily Calorie requirement (TDCR)

Energy expenditure is the amount of energy (or calories) that a person needs to carry out a physical function such as breathing, circulating blood, digesting food, or physical movement. Your total daily energy expenditure (TDCR) is the total number of calories burned each day. To prevent weight gain, energy intake or calorie intake must be balanced with energy expenditure. To provide fuel for movement and daily functions, your body creates energy in the form of heat. The energy is measure in the form of kilocalories, or calories. The total number of calories you burn for energy each day is your total daily energy expenditure or TDEE. Total daily energy expenditure can vary from person to person depending on body size, gender, body composition, genetics and activity level [5]. It can be calculate by using the following equation.

$$TDCR = BMR + PA + DIT - CER \text{ in sleep}$$

6. Three Macro Nutrients

After calculating that how many calories the user will be eating per day, it needs to determine three nutrients makeup of user's diet. Nutrients are environmental substances used for energy, growth, and bodily functions by organisms. Depending on the nutrient, these substances are needed in small amounts or larger amounts. Those that are needed in large amounts are called macronutrients. There are three macronutrients required by humans: carbohydrates (sugar), lipids (fats), and proteins. Each of these macronutrients provides energy in the form of calories. The amount of calories that each one provides varies. Therefore, there are 4 calories per gram in proteins and carbohydrate and 9 calories per gram in fat. This means that if the person look at a food label and it lists 10 grams of carbohydrates, 0 grams of protein, and 0 grams of fat, that food would contain 40 calories.

The three nutrients are used the nutrition requirements will be used in recipe computation module. 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, the appropriate proportions of the three macro-nutrients for users can be calculated as the following formulas [3]. Three nuterient requirement calculation:

- ProtReq = TDCR / 4 × ProtReq_ Range
- FatReq = TDCR / 9 × FatReq_ Range
- CarbReq = TDCR / 4 × CarbReq_ Range

where ProtReq Range is a value selected between 16.6% and 17.4%, FatReq Range is a value selected between 27.6% and 28.7% and 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 [6].

7. Recipe Computation Module (RCM)

In this module, based on the user inputted profile and the amount of foods taken by the user for breakfast and lunch, the system computes the recipe for dinner by using linear programming. Therefore, suppose that there are N kinds of foods in the Asian food database provided by, and each food contains M kinds of nutrients. Parameters used in the integer linear programming of RCM are defined as below.

- aij: the quantity of nutrient i that food j contains;
- bi: the minimum required quantity of nutrient i;
- cj: the quantity of calories that food j contains;
- xj: the quantity of food j;
- y: the portion size of a dish in the recipe.

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

Minimize:

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

Subject to:

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

For users, the ingredients of the three macro-nutrients in each dish must be greater than or equal to the minimum nutrition requirements. Users can decide the servings of a dish in a recipe as the following formula: $xj \leq q$, $q = 1, 2, \ldots, n$, where n is a constant [1,2,7].

III. Proposed System architecture

The overall system architecture is shown in Figure 2. It describes how to build and develop the computational model of body weight management system. It contains three main phase:

- Food Data Entry
- Searching Food Information and
- Building Computational Model for Body Weight Management.

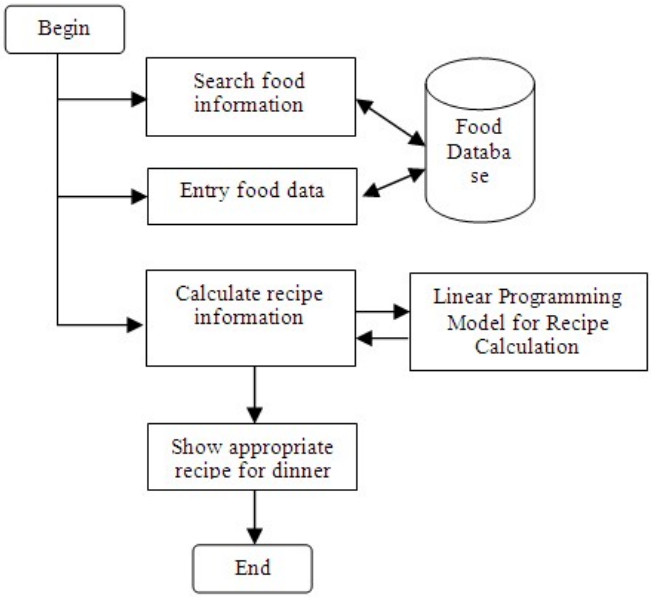

Fig.2. Overall system architecture

IV. Experimental Result

In this section, the experimental result of the system is presented as a real case of three types of person who have different ages. So, the young age, subjectives are shown in TABLE II.

Table2 The information of the subjective for young age group

No	User	Age	Gender	Weight	Height
1	User 1	14	female	125	4'8"
2	User 2	15	male	100	5'1"
3	User 3	16	male	140	5'
4	User 4	18	female	110	5'3"
5	User 5	20	female	90	4'11"
6	User 6	20	male	100	5'
7	User 7	17	female	120	5'3"
8	User 8	19	male	95	5'2"
9	User 9	16	female	105	5'3"
10	User 10	13	female	100	4'11"
11	User 11	15	male	115	4'10"
12	User 12	18	female	120	5'
13	User 13	12	male	90	5'2"
14	User 14	14	female	110	5'4"
15	User 15	17	male	85	5'1"

For the experiment, the inherent food intake of the young age subjective are inquired and recorded for one month together with the amounts of carbohydrate, fat, protein, and calories, which are converted from the subject's food intake, are also recorded. Then, they are comuted with the computational model to recommend the dinner recipe to the subjects based on their required three macro-nutrients by using linear programming. It can get the best suitable dinner recipes that contain the similar required three macro nutrients of subject. Therefore, we show that by comparing the actual required nutrients of the subjects and the nutrients generated by the system using linear programming. According to experimental result, the proposed system can recommend the most suitable dinner recipes with the nearest three macro nutrients that are required by the subject. The comparison results of the three macro-nutrients, protein, fat and carbohydrate of the first age (yound) with the system body weight management system is depicted in Figure 3 to Figure5.

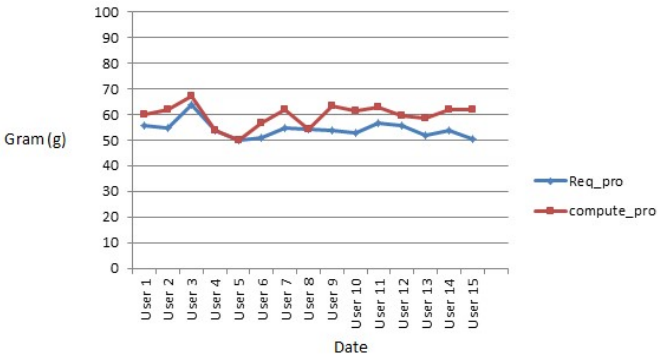

Fig3. Protein intake by the young age person

In the figures 3, 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 a word "compute" before the curve name, it indicates our solution for a computational diet control.

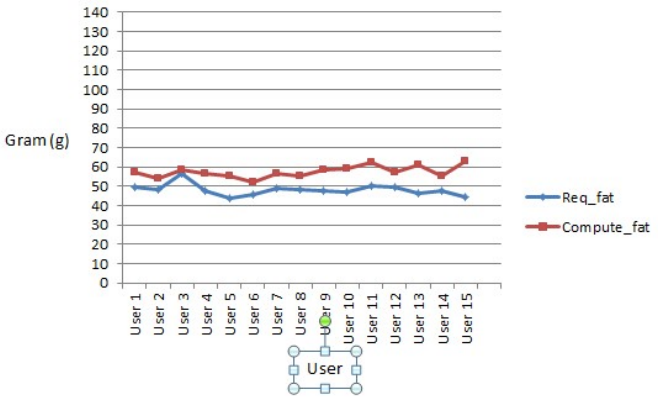

Fig.4. Fat intake by the first person

According to the young age subject's required nutrients (i.e. the curves req_pro, req_fat and req_carb in the Figure 4.3 to Figure 4.5) are set to protein 15% of the total energy, fat 30% of the total energy and carbohydrate 55% of the total energy. Our system achieved that protein 16.44% of the total energy, fat 35.50 % of the total energy and carbohydrate 61.97 % of the total energy. As an average, our system is different only 1.44 % of the protein, 5.50% of the fat and 6.97% of the carbohydrates with the actual requirements of the subject.

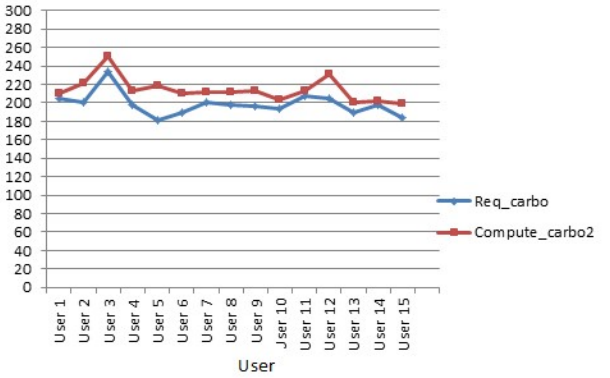

Fig.5. Carbohydrate intake by the first person

Conclusion

This paper presents the system design and implementation of food intake body weight management system. Then, it also describes the detail explanation of how to compute food intake to get the appropriate recipe for dinner Linear programming approach is used to calculate the amount of nutrient in food. Thus, the balance diet and nutrient requirement can be determined. It is very important because mostly people just eat without considering the amount of nutrient in the food. Therefore, this system can provide a way to maintain stable nutrition and calorie intake for users and it is feasible for helping users to achieve a balanced diet and provide sufficient information for personal weight management at the same time. According to experimental and the required three macro nutrients of the subject who are young age means that adult.

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