Design and Implementation of Intelligent Personalized Dietary Meal Recommendation System

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Abstract. This study proposes an “intelligent personalized healthy diet recommendation system”. It uses personal background data, personal preference data, physiological parameter data, and diet control plan requirements input by users and uses the classification and reasoning engine built into the program to build a personal knowledge base, and it analyzes the future state to evaluate the user's health situation; then it uses the optimization method to find out the best meal package combination to meet the user's nutritional, dietary and consumption constraints. It is expected that by utilizing this easy-to-use dietary recommendation APP will help the users to afford the best nutritional combination and healthy eating recommendations according to their situation and health status to achieve the effects of healthcare.

Introduction

In recent years, the social structure has entered an aging society in Taiwan, and the demand for health care is increasing. At the same time, the number of patient with chronic diseases also grows rapidly [1][2]. On the other hand, the Department of Health of the Ministry of Economic Affairs of Taiwan said that blood sugar is one of the main control projects in chronic disease control, and it should start from the basic diet of nutrient intake to achieve blood sugar control [3]. In fact, the patient with chronic diseases can follow the health guidance and consultation to track down the symptoms [4]. Therefore, effective self-regulation of physiological values (such as blood sugar, blood pressure, blood lipids) is quite important. It is known that the normal and balanced diet will reduce the chance of suffering from chronic diseases and enable people to enjoy a healthy life. However, there is currently lacking of automated food recommendation system for public or patients. Food and Drug Administration, MOHW in Taiwan recently held a press conference on the publication of food and drug open data application results, and praised 10 author groups that developed software tools such as medical records and health management which includes documenting dietary calories and consulting food sources or additives [5]. After referring to the existing APP systems on the market with similar functions in nutrition dietary meal recommendation, this study aims to establish a diet recommendation system to highly meet the personalized requirement to enhance the health of the public and the awareness and effectiveness of self-care [6]. On the other hand, in the social context of big data, the so-called personalized recommendation is to recommend information and products to users according to their interests and purchasing behavior [7][8]. In this study, a two-stage approach will be used to recommend the best meal combination for the user. In order to achieve this goal, the system must first collect the basic information input by the user to understand the user's habits, preferences, diseases and other related restrictions, then use the classification algorithm to classify the users into different categories. The combination of meals corresponding to different group of user are finally recommended to the user and the meals about the last selected by the user are recorded to form the reference sample to improve the model.

Introduction

The system block diagram of this study is depicted in Figure 1.
The functions and contents of each block are explained as follows:

1. Basic personal data: includes demographic variables such as age, gender, education level, job attributes, family situation, marital status, social relationship, life habits, as well as personal disease history and current self-conscious symptoms. There are a total of 36 input options for this section.

2. Dietary and sports data: collects information on current dietary habits and exercise habits, including diet patterns, intervals of eating time, diet volume, the length of time and consumption, and the type of exercise, duration of exercise, length of exercise, and amount of exercise. In addition, since each person has different requirements on the content and attributes of the food, it is also necessary to select the food of preference for the users to be the basis for the recommended meals. There are a total of 18 input options for this section.

3. Physiological parameter data: these values are entered and recorded here to be used as an assessment of the user's health, which include height, weight, blood pressure, blood sugar, blood lipid and other relevant indicators for various chronic diseases. There are total of 23 input options for this section.

4. Dietary restriction data: according to the physiological needs of each person and the caloric restriction of disease control, the upper and lower limits of the calories for per person per day are entered here for use in optimization module.

5. Fee restriction data: according to the economic situation of each person or the price limit caused by dietary diversity, the upper and lower limits of the budgets for per person per day are entered here for use in optimization module.

6. Inference engine: a simple Bayesian classifier will be used as an analysis engine to classify the most likely diseases of the user in this study. This model is built to by using the expert knowledge database, and then perform the classification by using the parameters input by the user injected to the model. The accuracy of the model will be assessed and verified using a weighted scoring method of 5 experts, at the same time the results will also be used in the feedback manner to re-train the model. The combination of 64 meals and their calories, cost and nutrition information are stored in the data table. The recommended diet set corresponding to the health status is transmitted to the optimization module after the table lookup operation.

7. Optimized module: the recommended dietary meal collections will calculate in this module with the user's preferred food restriction, calorie restriction and budget limit to provide the most
suitable meal combinations for the user. Meals types and calories with their price information will be confirmed, planned and designed into the module with the nutritionist. Because the combinations of variables are quite large, heuristic algorithm is used here to accelerate the approaching to the best solution.

It is worth mentioning that in order to get the best recommendation package, the problem has to be studied to build the mathematical model. A linear programming model will be established with the highest intake of nutrients as the objective function according to the food constraints, calorie restriction and cost constraints as constraints. The assumptions as follows are made first:

1. Various meals are supplied sufficiently per week.
2. The price and volume of various meals will not raise or drop dramatically, which guarantees the costs are reasonable.
3. The nutrients contained in various meals are not affected by the environment, which means the nutrients contained in each meal will not change.
4. The information of each type of meal can be updated instantly to ensure the integrity of the meal combination table.

Next, the decision variables and parameters are declared as follows:

Let $x_{ij}$ indicate that $j$th meal package is selected for $i$th meal of the day

Let $D_{day}$ express the daily heat limit, generated by the inference engine

Let $C_{day}$ indicate the daily fee limit which is input by the user

Let $d_i$ denote the total calories of meal $i$

Let $c_i$ represent the total cost of meal $i$

Let $n_i$ be the nutrient amount of meal $i$

Let $m$ denote the user's daily meal number

Let $t$ be the total number of meals per day

Then the optimization problem can be formulated by the following integer linear programming model,

$$\text{Maximize } \sum_{i,j} x_{ij} n_j \text{ where } i \leq m, j \leq t$$

subject to

$$\sum_{i,j} d_j x_{ij} \leq D_{day}$$

$$\sum_{i,j} c_j x_{ij} \leq C_{day}$$

Experiments Results

The system is implemented with the Apache PHP/MySQL and Android Studio development environment. The collection of experimental subjects is conducted by the physician to explain the project to the patient in the hospital outpatient clinic and accept the case after the patients signing the informed consent form. The subjects are instructed the basic operations after the system was installed. The system covers a variety of nutritional recommendations for 12 types of chronic diseases. Total of 83 subjects were accepted from all department, and a 4-month evaluation proceeded. Several factors investigated here include the follows: (1) Improvement rate: including the conscious improvement rate and the actual improvement rate, indicating the actual impact of this APP on health improvement. (2) Usage time: it represents the user's continued usage willingness to use the system, and also represents its dependence and support to the system. (3) Satisfaction: contains the satisfaction of the physician with the system and the satisfaction of the patient with the system. The options include the accuracy and ease of use, etc., and which will play an important role to investigate the influencing factor which affecting the willingness to use. First, for the improvement rate, 72% of patients believe that by using of APP-provided meal recommendations for dietary management did improve their physical health, and 68% of them were verified to improve indeed after physiological evaluation is
performed. In terms of use time, most people tend to use the system about three to four hours before the meal, but the overall use time is not long. It is speculated that the interactive components are not so sufficiently provided which reduces their willingness to spend more time to this system. Finally, in order to evaluate the effectiveness and satisfaction of the system, the physician conducts a satisfaction survey of the patient when each patient's revisited. After repeated questionnaires for the same subjects are removed, a total of 75 valid questionnaires were collected. By using the five-point Likert scale, the physician's satisfaction with the system was 4.28 in average, and the satisfaction degree for the continuous use by patients was 3.86 in average. The average patient satisfaction with the system was 3.72, while the satisfaction rating for continuous use was 4.02 in average.

Conclusion
This study proposes and implements a smart personalized diet recommendation system. It collects the user data and the inference engine is built to analyze the user's future state and evaluate the user's health situation. It uses the optimization method to find the best combination plan under the constraints of users' nutrition, diet and budget constraints. This dietary recommendation APP can achieve the best nutritional combination of the individual, and make healthy food recommendations according to their situation and health status at any time. The results show that both the physician and the patients have good evaluation and satisfaction of the portable recommendation system. Future work includes the inclusion of continuous records and correction mechanisms, as well as integration with the Internet of Things and food logistics systems.

References