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A Recommender System for Healthy Food Choices Based on Integer Programming

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Abstract. With the change of life style, more and more people are eating out, and the dietary content is high in calories, fat and sugar, resulting in the increasing number of obesity in children, adolescents and adults, and the prevalence of chronic diseases continues to grow. Therefore, preventive health care has become the focus of health policy in the 21st century. The pursuit of health must start from the daily diet. This paper proposes an intelligent recipe recommendation model based on integer planning, which customize personalized balanced diet according to the limitations of food type and meal cost and other restrictions.

Keywords. Recommendation Model, Integer Planning, Balanced Diet

1. Introduction

Recommender systems is an information filtering system that can solve the information overload problem [1]. The technology applied by the recommendation system can filter information and narrow the information according to user preferences or needs, and help users select relevant information. Referral systems, commonly adopted in e-commerce websites, social networks and entertainment industries, can also support nutrition-based health management to giving individuals more food choices based not only on one's preferred tastes but also on one's dietary needs and limitations.

In 2016 the World Health Organization (WHO) estimates that, globally, 39% of the adults were overweight and 13% were obese [2]. Good nutrition and balanced dietary patterns play a vital role in leading a healthy lifestyle. Previous studies have shown that a healthy diet can successfully reduce the risk of chronic diseases (such as type 2 diabetes and cancer), with other well-documented benefits. However, existing food recommendation models tend to rely only on user feedback (e.g., click and purchase data), which aims to optimize click rate (CTR) but ignore the importance of users' health needs. Intuitively, healthy eating recommendations require comprehensive consideration of different types of information such as nutrition, ingredients, and cooking methods.

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Overweight and obesity can cause many health problems, including diabetes, blood pressure, heart disease, and many other chronic conditions. A balanced diet plays a vital role in maintaining and improving a person's overall health, but many factors have contributed to finding it difficult to choose healthy diet choices [2]. Exploring healthier dishes can be tedious, time-consuming, and expensive. However, the recipe recommendation system can help narrow the richness of online information and consider our personal needs. Liu et al. focused on the study of the homotopy method [3, 4], and the combination of homotopy and multigrid [5, 6] or wavelet [7, 8]. Based on certain assumptions, this study introduces the design, implementation and evaluation of an intelligent recipe recommendation model based on the balanced diet and economic level of patients with diabetes mellitus.

2. Intelligent Recipe Recommendation Model for Diabetic Patients

2.1. Data Preparation and Index Construction

In this study, we adopted a cross-industry data-mining standard process (crisp-DM), which provides a framework for our data-mining approach [9].

The data collection phase is the basis for the recommendation engine accuracy. It is helpful to generate user profiles or models for making recommendations. Subsequently, we performed the basic data cleaning and feature extraction. Processed datasets were used for model building.

In big data analysis, pre-processing is needed to extract representative features for analysis. For example, ingredients from a single formula contains many unrelated words such as "boiled cabbage", "frozen" in "frozen beef", etc. After data cleaning, etymology is performed to convert a word into a root word. At the same time, we also considered the nature of words, focusing only on nouns and adjectives, for example, "tomatoes" becomes "tomato".

Subsequently, we extracted nutrient composition tables from several foods, including the contents of carbohydrates, fat, energy, calcium, phosphorus, iron, vitamin A, and vitamin B2. Correspondingly, the units of measurement are g, g, kcal/100g, mg, mg, mg, micrograms and mg.

Finally, an important feature is the number of calories in the recipe. Calories is a calorie unit used to quantify the amount of energy in food. Although calories are essential, excessive calorie intake can lead to weight gain. Daily heat required for adults as formula 1.

$$K_r = K_m + K_p + K_d \tag{1}$$

Where K_r is the daily calories of adults, k_m is the basic calories for basic metabolism, k_p is the calories for physical activity, and k_d is the calories for digesting food. The calories needed to digest the food as formula 2.

$$K_d = 10\% \times (K_m + K_p) \tag{2}$$

Daily heat required for adults as formula 3.

$$K_r = 1.1 \times (K_m + K_p) \tag{3}$$

Therefore, we obtain the exact algorithm for basic heat, such as equation 4.

$$K_m = K_c \times W + K_b \tag{4}$$

Where K_c is a coefficient, k_b is a constant term and the specific values are shown in table 1.

Table 1. Caloric calculation parameters

Age	female		male	
	K_c	K_b	K_c	K_b
18-30	14.6	450	15.2	680
31-60	8.6	830	11.5	830
60+	10.4	600	13.4	490

We collected the nutrient content and price data of various foods in the Huinong website, and some of the data are shown in table 2.

Table 2. Nutrient component content and unit price

Food	fat	Carbo-hydrate	Protein	VA	VB2	VC	K	Ca	P	Fe	Zn	En-ergy	Price
Yogurt	2.7	9.3	2.5	26	0.15	1	150	118	85	0.4	0.53	72	0.7
Niu Milk	3.7	5.3	3.1	14	0.11	1	159	98	94	0.2	0.51	67	1.5
soybean	5	10.5	13.1	22	0.07	27	478	135	188	3.5	1.73	131	0.7
sprouts	1.6	2.2	2.9	0	0.04	1	50	24	43	0.4	0.3	34	1.2
carrot	0.2	8.1	1	685	0.02	9	119	27	38	0.3	0.22	25	0.1
asparagus	0.2	4.1	2.4	50	0.14	7.7	224	23	54	0.9	0.6	22	2.8
laver	0.3	5.1	5.8	260	0.45	39	356	70	58	1.8	1.05	35	9
mushroom	0.2	14.4	1.6	0	0.17	0.3	117	3	29	0.4	1.33	56	7
cauliflower	0.9	2.1	2.9	10	0.04	27	120	17	52	0.4	0.40	28	0.2
cabbage	0.1	2.9	0.9	0	0.01	10	160	43	33	0.3	0.2	13	0.7
cucumber	0.2	2.9	0.8	15	0.03	9	102	24	24	0.5	0.18	16	0.4
crowndaisy	0.1	4.3	1.6	129	0.16	23.9	569	69	43	3.7	0.2	20	0.2
broccoli	0.6	4.3	4.1	120	0.13	51	17	67	72	1	0.78	36	0.2
orange	0.3	15.5	1.3	13	0.05	71	196	70	22	0.8	0.11	63	0.6
avocado	21	0.5	2	28	0.14	11	509	14	48	0.6	0.56	206	1.8
Kiwi	0.5	14.7	1.1	4	0.03	92.7	312	34	34	0.3	0.14	61	1

2.2. Intelligent Recipe Recommendation Model

The paper used an integer programming model. An integer programming model is built with the minimum daily nutritional requirements required by people and the objective function with the minimum cost, and the formula is solved at the minimum cost to meet the minimum daily nutritional requirements required.

To simplify the model, we make some reasonable assumptions:

- All kinds of vegetables will not have the situation of crazy price rise and price drop, so as to ensure the reasonable cost.
- All kinds of vegetables contained nutrients will not be affected by the outside worl d, the nutrients will not change, to ensure the unity of model data and the actual sit uation.
- The professor has no allergic reaction to all kinds of food.
- All kinds of food in the state of raw and cooked nutrients content unchanged, to en sure the unity of nutrient intake and model.
- All kinds of fresh foods contain the same nutrients and proportion.

The recipe planning problem is an optimization problem in standard linear programming. To solve this problem ,we can establish the optimal solution model for the purpose of minimum cost. The first step is to establish an objective function to mini mize the cost of food. Then, according to the objective function, we list out the constrai ned conditions. Within the constrained conditions, we find the optimal solution, that is, we get the recipe that can meet the minimum daily needs and cost the least.Meanwhile, since the model is targeted at diabetic patients, we considered only the five nutritional limitations of protein, fat, carbohydrate, calories, and inorganic salts and their explanations.

Establish an objective function with the minimum cost:

$$\min Z = \sum_{i=1}^{7} \sum_{j=1}^{n} x_{ij} A_{maj} \tag{5}$$

Where decision variable $x_{ij}(i = 1,2,\cdots,7, j = 1,2,\cdots,n)$ indicates the number of portions of the j-th food purchased and consumed in the i-th week. And then, constraint condition (6) were established to meet the restriction on carbohydrate intake.

$$\sum_{j=1}^{n} A_{carj} x_{ij} \geq N_{car} \tag{6}$$

Where A_{carj} represent the contents of carbohydrate in food j, N_{car} is the required daily carbohydrate intake, and then constraint condition (7) were established to meet the restriction on fat intake.

$$\sum_{j=1}^{n} A_{fatj} x_{ij} \geq N_{fat} \tag{7}$$

Where A_{fatj} represent the contents of fat in food j, N_{fat} is the required daily fat intake, and then constraint condition (8) were established to meet the restriction on calorie intake.

$$1980 \leq \sum_{j=1}^{n} A_{kaj} x_{ij} \leq N_{ka} \tag{8}$$

Where A_{kaj} represent the contents of energy in food j, N_{ka} is the required daily energy intake, and then constraint condition (9) were established to meet the restriction on calcium intake.

$$\sum_{j=1}^{n} A_{caj} x_{ij} \geq N_{ca} \tag{9}$$

Where A_{caj} represent the contents of calcium in food j, N_{ca} is the required daily calcium intake, and then constraint condition (10) were established to meet the restriction on phosphorus intake.

$$\sum_{j=1}^{n} A_{pj} x_{ij} \geq N_{p} \tag{10}$$

Where A_{pj} represent the contents of phosphorus in food j, N_{p} is the required daily phosphorus intake, and then constraint condition (11) were established to meet the restriction on iron intake.

$$\sum_{j=1}^{n} A_{fej} x_{ij} \geq N_{fe} \tag{11}$$

Where A_{fej} represent the contents of iron in food j, N_{fe} is the required daily iron intake, and then constraint condition (12) were established to meet the restriction on vitamin A intake.

$$\sum_{j=1}^{n} A_{vaj} x_{ij} \geq N_{va} \tag{12}$$

Where A_{vaj} represent the contents of vitamin A in food j, N_{va} is the required daily vitamin A intake, and then constraint condition (13) were established to meet the restriction on vitamin B2 intake.

$$\sum_{j=1}^{n} A_{vbj} x_{ij} \geq N_{vb} \tag{13}$$

Where A_{vbj} represent the contents of vitamin B2 in food j, N_{vb} is the required daily vitamin B2 intake.

The intake data of various nutrients are from the reasonable dietary composition in dex recommended by Chinese Nutrition Society and Baidu Encyclopedia. At the beginning of this model, integer programming is used, and the calculation is based on the least amount of money in one day's nutrition, and can only calculate the optimal sol ution of one day, the decision variable is not integer, so it can't be used in practice. Afte r the improvement and optimization, the decision variable is set to an integer matrix of 7 days a week. Under the condition of meeting the material needs of just every day, the total recipe of 7 days and the daily recipe can be obtained. In addition: if further improv ement is needed, the basic requirements of material and nutrition need to be accurate to each meal (more troublesome), or on the basis of the original, a variable is used to set t he limited food (such as milk) as the corresponding eating time by using conditional sta tements, and the rest can be randomly matched according to the free combination.

We solved the model with the Hungarian algorithm, which is divided into two steps:

First, transform the coefficient matrix, assign the problem coefficient matrix (c_{ij}) to transform into the (b_{ij}) coefficient matrix, in each row of the (b_{ij}) matrix, each column appears 0.

Then try to assign and find as many independent 0 elements as possible in the (b_{ij}) coefficient matrix. If you can find n independent 0 elements, these n independent 0 elements correspond to 1 in the solution matrix (x_{ij}) and the rest are 0, so the optimal solution is obtained.

3. Implementation

We developed a one-week recipe for a diabetic male patient by solving the model. He was a former athlete weighing 98 kg, standing 180 cm, had a family history of adult diabetes, and had to eat at least 15 different foods per week, including four basic foods (dairy, fruits and vegetables, meat and grains). The diet should meet the minimum needs of daily essential minerals and vitamins, and keep yourself healthy and control your weight. Do not eat Brussels sprouts, sweet potatoes, pears and liver and kidney organs, any canned fruits or vegetables, frozen dinner, and do not drink milk in addition to breakfast. The professor may consider taking vitamin pills to get his nutritional needs, but he prefers to eat some foods. Keep weekly costs below \$500 (lower as possible). Apart from carrying a 5 kg briefcase and walking 0.5 km a day from the car, you should not exercise no more than once a week, and your weight should be controlled. The calculated demand of each index is shown in table 3.

Table 3. The customer's demand for each index

N_{car}	N_{fat}	N_{ka}	N_{ca}	N_{p}	N_{fe}	N_{va}	N_{vb}
122.5	122.5	2340	600	720	10	1.5	1.5

Using an integer programming model. The integer programming model is established with the minimum daily nutrient requirement as the constraint and the minimum cost as the objective function. According to the model calculation results, the minimum dietary cost of a week is 157.2 yuan. The specific recipe recommendations are as table 4.

Table 4. One-week recipes are recommended for diabetics

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Breakfast	yogurt, oat, broccoli, carrot, coix, cauliflower	yogurt, oat, peach, carrot, coix, cauliflower	corn, coix, oat, yogurt, broccoli, cauliflower	yogurt, oat, broccoli, carrot, coix, buckwheat	yogurt, oat, broccoli, carrot, coix, cauliflower	yogurt, oat, broccoli, carrot, coix, cauliflower	yogurt, oat, broccoli, carrot, coix, cauliflower
Lunch	Rice, clam, Maodou, yam, corn, wax gourd	Rice, clam, Maodou, yam, corn, wax gourd	Rice, clam, Maodou, yam, carrot, wax gourd	Rice, clam, Maodou, yam, corn, wax gourd	Rice, clam, Maodou, yam, corn, wax gourd	Rice, clam, Maodou, yam, corn, wax gourd	Rice, clam, Maodou, yam, corn, wax gourd
Dinner	Spinach, peach, buckwheat	Spinach, broccoli, buckwheat	Spinach, peach, buckwheat	Spinach, peach, cauliflower	Spinach, peach, buckwheat	Spinach, peach, buckwheat	Spinach, peach, buckwheat

4. Conclusion

In this study, combining the dietary needs and characteristics of diabetic people, we constructed a recipe planning model for a balanced diet based on integer planning. This study expands the existing study by considering individual calorie intake needs and intake needs of various nutritional indicators. Based on the dietary characteristics of diabetic people, the weekly diet is given for the hyperparameters such as food diversity and budget.

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