Personalized Healthy Diet Planning

DSC5101 DETERMINISTIC OPERATIONS RESEARCH MODELS
Final Project Report

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Abstract

In this paper we consider diversified dietary planning problem, which comes from the real-life situation: an average student or teacher chooses a five-day breakfast, lunch and dinner plan based on food available on campus. Based on different profiles of users, mainly including age, gender and physical activity level, a mixed integer programming model is used to find an optimal diet, so that daily recommended intake is satisfied and over consumption of undesirable nutrients is minimized. After required user's properties are entered, our program will automatically generate a specific food plan with drinks and dessert. The results obtained for a specific case of a 18-year-old female who has a sedentary lifestyle were found to be very reasonable.

Introduction

Diet problem is considered to be one of the huge lifelong topics for every person to be concerned about all over the world. People are trying to eat as healthily as possible as a part of their health lifestyle. We want to make a dynamic plan based on user input for people in different gender and different age.

The data sets of this project about various types of nutrients and the boundaries of the constraints are from the health.gov official websites and some well-known information websites about recommended daily nutrition needs and limits. By recognizing a variety of assumptions for the model including the setting of targets breakfast and dinner, we have used some special ratios to convert these bounds into the boundaries for lunches. The constraints are set up based on all the information and the objective function is established using different penalties for each element based on the average intake correspondingly. Gurobi is utilized to solve this linear programming problem after all the data are inputted into Excel. An optimal five-day lunch plan is reached with the nutrition intakes on a daily basis based on the model as well as a minimum intake of Energy, Protein, Fiber and Carbohydrate, a maximum total intake of Total fat, Saturated fat, cholesterol, and Cholesterol.

The method used in this project shows an approach to deal with diet meal plans for people with all lifestyles. To add breakfasts and dinners into consideration, and to change the number or

name of fast-food restaurants by altering the input data sets of the corresponding information. We believe that this presents a great down-to-earth solution to the diet problem.

Background

Both linear programming and integer programming are used in solving this diet problem. Classical diet problem is "to select a set of foods that will satisfy a set of daily nutritional requirement at minimum cost. The problem is formulated as a **linear program** where the objective is to minimize cost and the constraints are to satisfy the specified nutritional requirements. The diet problem constraints typically regulate the number of calories and the amount of vitamins, minerals, fats, sodium, and cholesterol in the diet."

As we personalize diet plan for our NUS students and stuffs, we investigate the food supply in campus. The fact is that, the price of different dishes vary very little to each other, so the expenditure on food in campus in a day is not a critical consideration: everybody spends roughly the same amount. So in the special condition in our problem, we conform the nutritional part of classical problem, while not try to set cost as objective function. On the other hand, health issue is our major condition, so we try to optimize nutrition intake. First, for specific type nutrition, different people have different dominant concerning: some care sugar intake most, some care protein, etc. So to maximize or minimize a certain kind of nutrition is an objective. Second, we combine all kinds of nutrition intake as a total utility function: some people care about the balance of a nutrition structure.

Besides linear programming, we introduce integer programming in our project, because we consider some special diet requirements such as: no repetition in a day, allergy to certain kind of food, etc. These constraints can be well formulated using binary variables.

Data Description

Data resources are classified into two types: food data and user data.

Food data are collected from Singapore Health Promotion Board website. We collected 59 main courses, 27 breakfast types, 17 beverage choices, 10 kinds of fruit and 25 desserts &

snacks. Most food is available in hawker centers or canteens.Nutrition information samples are sorted as follows:

Food	Energy (kcal)	Protein (g)	Total fat (g)	Saturated fat (g)	Dietary fibre (g)	Carbohydrate (g)	Cholesterol (mg)	Sodium (mg)	Sugar (g)
Bak kut teh	323.71	28.11	23.43	9.37	0	0	153.34	1316.15	0
Wanton noodles soup	318.04	25.14	7	1.85	1.74	36.57	76.03	1969.63	4.63
Black carrot cake	556.47	13.16	26.74	10.05	1.54	65.77	205.8	1937.08	13.62

Table 1. Sample Nutrition Information

User data are provided by Office of Disease Prevention and Health Promotion, US, who published 2015-2020 dietary guidelines and contributed to our problem constraints. Table 2 shows sample daily recommended dietary intake below and users are grouped by age, gender and physical activity level:

Nutrient		18-30 yrs Men (Sedentary)	18-30 yrs Women (Sedentary)	18-30 yrs Men (Active)	18-30 yrs Women (Active)
Energy (Kcal)	>	2400	1800	3100	2400
Protein (g)	>	56	46	127	109
Fiber (g)	>	33	28	33	28
Carbohydrate (g)	>	130	130	230	244
Cholesterol	<	300	300	300	300
Sodium	<	2400	2400	2400	2400
Total fat	<	90	69	90	69
Saturated fat	<	30	23	30	23

Table 2. Sample Daily Recommended Dietary Intake

We defined two different lifestyles that the user are required to choose from: Sedentary, Moderately Active and Active. Sedentary lifestyle only includes the physical activity of independent living. Moderately active lifestyle includes physical activity equivalent to walking about 1.5 to 3 miles per day at 3 to 4 miles per hour, in addition to the activities of independent living. Active lifestyle includes physical activity equivalent to walking more than 3 miles per day at 3 to 4 miles per hour, in addition to the activities of independent living.

Model Assumptions

The following assumptions are introduced:

1) Every person should have two main meals, one breakfast , at most two desserts, at most two beverages and at most two fruit per day.

2) Maximum two repetition for each kind of food within 5 days period.
3) Vitamins are not examined because of the lack of data.
4) For people of the same gender, age, physical activity level, they are assumed to be homogenous for the planning problem.
5) Activity level is assumed to be invariable within a week. Since the diet plan is generated prior to the target weekdays, the user will estimate their activity level in advance. Also basal metabolic rate for an average person is unlikely to change greatly.
6) We assumed the final utility function format is the same for each user. Denominators of the fractions denoted as min_require or max_require are intake requirements per day for a specific user, which can normalize cholesterols, fat, sugar and calories to a comparable or addable scale. We expect to minimize the excessive amounts of these undesirable nutrients for the sake of users.

Objective Function & Decision Variables

Objective Function

- Min fat: $\sum_{i=1}^{136}\sum_{d=1}^{5} fat_{i,d} * x_{id}$
- Min calories: $\sum_{i=1}^{136}\sum_{d=1}^{5} \text{calories}_{i,d} * x_{id}$
- Min sugar: $\sum_{i=1}^{136}\sum_{d=1}^{5} \text{sugar}_{i,d} * x_{id}$
- Min cholesterol: $\sum_{i=1}^{136}\sum_{d=1}^{5} \text{cholesterol}_{i,d} * x_{id}$
- Max utility: $-\sum_{i=1}^{136}\sum_{d=1}^{5} x_{id} * \left(\frac{\text{cholesterol}_{i,d}}{\text{min\_require}_{cholesterol}} + \frac{\text{fat}_{i,d}}{\text{max\_}intake_{fat}} + \frac{\text{sugar}_{i,d}}{\text{min\_require}_{sugar}} + \frac{\text{calories}_{i,d}}{\text{min\_require}_{carlories}}\right)$

Decision Variables

- $x_{id} = 1\ or\ 0 \qquad i \in \{1,2 \dots 136\},\ d \in \{1,2 \dots 5\}$

*where 1 means choosing the meal **i** on day **d**, 0 means not choosing the meal **i** on day **d***

Constraints

Consider the fact of daily life, one should meet the requirements of: the amount of nutrition intake, the number and structure of meals, and personal special requirements. Besides, the

same dish should be be repeated more than twice in a week for the sake of diversity of the diet. The details are listed below:

Constraint 1: nutrition requirement.

The daily intake of energy, protein, fibre and carbohydrate should be no less than a certain amount according to the age, gender and physical exercise condition. For example, a 22-year-old female should intake at least 46g protein a day.

The daily intake of cholesterol, sugar, sodium, total fat and saturated fat should be no more than a certain amount according to the age, gender and physical condition. For example, a 20-year-old male should intake at most 2400 mg sodium a day.

Constraint 2: number and structure of meals

Within a day, there should be a breakfast, a lunch and a dinner. Breakfast needs to choose from breakfast category. Dinner and lunch can be chosen from the main, drink, dessert and fruit; main and drink are compulsory while fruit and drink are optional.

Besides, food is not allowed to be repeated within weekdays.

Constraint 3: personal special requirements

If the person has to eat certain food such as mcdonalds, milk tea ect.

If the person has certain allergies, eg. no fish.

Constraint 4: week diet repeatition

The same dish should be be repeated more than twice in a week for the sake of diversity of the diet.

Model Parameters

1) Index i represents different food,range from 1 to 136
2) index j represents different nutritions, range from 1 to 9
3) index d represents different days, range from 1-5.
4) nutrients(i,j), represents the the jth nutrient of food i.
5) req(j), represent the daily requirement of different nutrients.

Constraint 1: Nutrition requirement

- $\sum_{i=1}^{136} nutrients_{i,j} * x_{id}$ >= min_requirement, $\forall d \in \{1,2 \dots 5\}$, $\forall j \in \{1,2 \dots 9\}$

- $\sum_{i=1}^{136} nutrients_{i,j} * x_{id}$ <= max_intake , $\forall d \in \{1,2 \dots 5\}$, $\forall j \in \{1,2 \dots 9\}$

Constraint 2: Every day has 1 breakfast ($\forall i \in [111,136]$), 2 mains ($\forall i \in [0,58]$), and at most of 2 beverages($\forall i \in [84,100]$), fruits($\forall i \in [101,110]$), dessert($\forall i \in [59,83]$), optional: (python index), $\forall d \in \{1,2 \dots 5\}$

- $x_{0,d} + \cdots + x_{58,d} = 2$(main)
- $x_{111,d} + \cdots + x_{136,d} = 1$ (breakfast)
- $x_{59,d} + \cdots + x_{83,d} \leq 2$ (at most 2 desserts)
- $x_{84,d} + \cdots + x_{100,d} \leq 2$ (at most 2 beverages)
- $x_{101,d} + \cdots + x_{110,d} \leq 2$ (at most 2 fruits)

Constraint 3: allergy for food **i**

- $x_{id} = 0 \quad \forall d \in \{1,2 \dots 5\}$

Constraint 4: max repetition of the meal choices (allow 2 times of repetition in 5 days)

- $\sum_{d=1}^{5} x_{id} \leq 2 \quad \forall i \in \{1,2 \dots 136\}$

Results & Interpretation

After running our code for several hours, we got the following results (Taking a one-week plan with an objective of minimizing sugar intake for a 22-year-old sedentary female as an example):

Day	Category	Food Name	Sugar(g)	DaySum
Mon	Main	Claypot rice with salted fish, chicken and chi...	4.07	21.09
Mon	Main	Beef and Teriyaki Chicken Bento	4.4	
Mon	Dessert & Snack	Beancurd Dessert with Red Bean Toppings	10.58	
Mon	Fruit	Passion fruit	2.04	
Mon	Breakfast	Plain porridge	0	
Tue	Main	Nasi Lemak with chicken wing	0.8	22.7
Tue	Main	Salmon and Teriyaki Chicken Bento	5.35	
Tue	Dessert & Snack	Pan-fried turnip cake	1.5	
Tue	Fruit	Dragonfruit	14.26	
Tue	Fruit	Mandarin orange	0.79	
Tue	Breakfast	Red rice porridge, plain	0	
Wed	Main	Claypot rice with salted fish, chicken and chi...	4.07	27.93
Wed	Main	Beef and Teriyaki Chicken Bento	4.4	
Wed	Dessert & Snack	Beancurd Dessert with Red Bean Toppings	10.58	

Wed	Fruit	Orange	8.88	
Wed	Breakfast	Pow, char siew, steamed	0	
Thu	Main	Chicken rice with steamed chicken	0	28.66
Thu	Main	Chinese rojak	0	
Thu	Dessert & Snack	Vietnam spring roll	2.17	
Thu	Beverage	Soya bean milk, without sugar	2.75	
Thu	Beverage	Brewed coffee	0.6	
Thu	Fruit	Dragonfruit	14.26	
Thu	Fruit	Orange	8.88	
Thu	Breakfast	Plain porridge	0	
Fri	Main	Nasi Lemak with chicken wing	0.8	18.89
Fri	Main	Salmon and Teriyaki Chicken Bento	5.35	
Fri	Dessert & Snack	Yoghurt muesli bar	7.16	
Fri	Beverage	Soya bean milk, without sugar	2.75	
Fri	Fruit	Passion fruit	2.04	
Fri	Fruit	Mandarin orange	0.79	
Fri	Breakfast	Red rice porridge, plain	0	

Table 3. Sample Weekday Food Plan for 22 year-old sedentary female

From the table above we can see that, the daily sugar intake ranges from 18.89 to 28.66, and the requirement is 46.55g. All five days of this week meet the requirement. That is to say, if we don't put the requirement of sugar into constraints, it can still output a good solution. Constraints for other nutrition such as calories, cholesterol and others are all satisfied. This solution recommended some food like bean curd and yoghurt, and this result complies our common sense. Also, the plan recommends different types food, ensuring the diversity of the diet. Meantime we have run our code with other objectives, and similar results can be seen: the optimal result mostly can also meet the intake requirement, despite the fact that it is not added in the constraints. Also, we take into consideration the specific condition of a user, and make it an user-friendly application. At the very beginning a user can input his or her basic information like age, gender and exercise level, then the solve will optimize according to the information provided.

Although our solutions turn out to be a very flexible, feasible and reasonable one, there is still improvement to be done. A major problem is that our codes runs quite slowly especially when taking maximizing utility as the objective. In this step we have already complicated to an extend that need a lot of computation. Another problem is that if we constrain the number of main strictly to 2 in each day, many cases will have no optimal output, such as 18-25 years old active women and men, as only two main meals a day simply cannot meet the minimum requirement

of energy even if then just choose the meals with highest calories. To solve this, we may relax the constraints for main meals – people exercise more will surely eat more, and the result will correspond to real life more.

References

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