MnM : Meal Planning for the New Millennium

1. Introduction

The Diet Problem, which is a famous application of linear programming (LP), was first stated by George Stigler in the 1930's. It was first solved by George Dantzig using the simplex method and has become the most widely studied model in introductory optimization (linear programming) books. The goal of this project is to bring more accurate and reasonable meal plans utilizing the informative and accessible data from the websites these days.

We will bring Internet resources, popular crowd-sourced recipes, as well as the idea of human-machine intelligence into this completely revamped version of the diet problem. Consider two people A and B who are planning for their meals each week. A and B are both males with age of 25 and they are attending for a graduate school in Los Angeles. They are close enough to share cook and shopping responsibilities, but like all millennials, having limitation for time and money. However, they do have well-trained taste buds, and focus on eating healthy, tasty meals, and eating within budgetary and dietary restrictions. There are, however, other restrictions as well: they are committed to school-work, participates in social causes, take extra time for relaxing other than studying, shopping, and cooking.

The MnM problem will focus on meal planning with nutritions and preferences: A and B will share shopping, cooking, and meal selection responsibilities, and will also have to respect each others schedules, budgets, dietary restrictions, and of course, their likes/dislikes. They may use social media (and web sites) to get a sense of how much each will like a certain recipe. Likewise, several constraints are formulated for A and B's preferences. The plan should cover food requirements for 5 weekdays. Also, the recipes will be restricted by how much of each ingredient is necessary for 5 days. There should also be constraints on how much cooking time may be used on any given day, and constraints on total foods. Thus, the data set should include costs and preparation times for each recipes.

2. Methodology

The recipe data is collected from epicurious.com website with all the ingredients and nutritional information. The recipe data also contains user's ratings that can be used for our future analysis on the planner's preferences. Since the meal planning is based on A and B's own preferences, we derived ratings that were uploaded on the website expressed as likes (and dislikes) for similar foods. Such correlations will be used in predicting preferences of recipes for A and B. The matrix-completion concepts is introduced to decide whether someone likes/dislikes each recipe. The objective function is the sum of the chosen recipes' ratings and introduced to predict individual's preferences. Based on the derived ratings, nutritional requirements, plan and budget restrictions, we will formulate the mixed integer programming to plan which recipe should be prepared each day and who will be in charge of the recipe fairly.

3. Data Crawling for recipes

As mentioned above, the recipe data is collected from epicurious.com with beautifulsoup library in python. This study is based on the recipe and its ratings in the Epicurious dataset. For model simplification, we only consider protein, fat, sodium and calories, excluding black pepper, olive oil, salt etc. We first performed data crawling for 298 recipes with ingredients and personal ratings. Among 298, the recipes with NaN data and recipes having less than 9 reviews were deleted. Then, we have 116 recipes. We reorganized and analyzed the recipes and users in a matrix to construct the final dataset, recipes-user-rating. For model simplification, 20 recipes were chosen as the candidates for the weekly meal planning problem. The details are in the table 1-1.

ID	Title	Calories (kcal)	Fat(g)	Protein(g)	Sodium(mg)
2	Easy Green Curry with Chicken, Bell Pepper, and Sugar Snap Peas	549	36	42	760
10	Persian-Spiced Chicken with Spaghetti Squash, Pomegranate, and Pistachios	704	44	49	1002
13	Istanbul-Style Wet Burger (Islak Burger)	691	34	46	779
15	Pumpkin Spice Bundt Cake with Buttermilk Icing	372	14	5	282
18	Pumpkin Cheesecake with Bourbon sour Cream Topping	429	32	6	316
24	Kale Salad with Butternut Squash, Pomegranate, and Pumpkin Seeds	162	5	8	539
26	Stuffed Sweet Potatoes with Beans and Guacamole	733	34	23	1509
28	Slow Cooker Pork Shoulder with Zesty Basil Sauce	470	45	8	289
29	Easy General Tso's Chicken	699	35	50	1189
30	White Chicken Chili	534	14	45	968
38	One-Pot Curried Cauliflower with Couscous and Chickpeas	606	15	27	1365
48	Navy Bean and Escarole Stew with Feta and Olives	461	23	21	407
49	Butternut Squash, Kale, and Crunchy Pepitas Taco	233	17	7	363
50	Sheet-Pan Skirt Steak With Balsamic Vinaigrette, Broccolini, and White Beans	820	56	45	977
75	Summer Corn, Tomato, and Salmon Salad with Za'atar Dressing	810	53	40	1372
77	Curried Lentil, Tomato, and Coconut Soup	437	28	13	667
92	Sheet-Pan Cumin Chicken Thighs with Squash, Fennel, and Grapes	497	30	29	1177
104	Curried Pumpkin Soup	165	14	2	373
109	Persian Chicken with Turmeric and Lime	563	23	40	813
113	Baked Feta and Greens with Lemony Yogurt	577	38	23	839

Table 1-1. Nutrition Data for 20 popular recipes

4. Restrictions and Budget

The missing price and preparation time of each recipe are filled with the sum of all ingredients' price in the recipe at 'instacart.com' and by our own experiences. The price and preparation time is in the table 1-2. The available hours, free times, are set as 2 hours (120 minutes) everyday for both A and B. The nutritional restrictions for A and B (both 25 years old, male) are referred from 'mydailyintake.net' and details are in table 1-3.

ID	Title	Price ($)	Preparation Time (min.)
2	Easy Green Curry with Chicken, Bell Pepper, and Sugar Snap Peas	7.2	30
10	Persian-Spiced Chicken with Spaghetti Squash, Pomegranate, and Pistachios	5.1	25
13	Istanbul-Style Wet Burger (Islak Burger)	4.3	25
15	Pumpkin Spice Bundt Cake with Buttermilk Icing	3.1	50
18	Pumpkin Cheesecake with Bourbon sour Cream Topping	4.5	120
24	Kale Salad with Butternut Squash, Pomegranate, and Pumpkin Seeds	4.3	10
26	Stuffed Sweet Potatoes with Beans and Guacamole	5.2	25
28	Slow Cooker Pork Shoulder with Zesty Basil Sauce	9.8	30
29	Easy General Tso's Chicken	6.1	30
30	White Chicken Chili	6.5	25

38	One-Pot Curried Cauliflower with Couscous and Chickpeas	4.5	35
48	Navy Bean and Escarole Stew with Feta and Olives	5.5	20
49	Butternut Squash, Kale, and Crunchy Pepitas Taco	3.5	30
50	Sheet-Pan Skirt Steak With Balsamic Vinaigrette, Broccolini, and White Beans	13	40
75	Summer Corn, Tomato, and Salmon Salad with Za'atar Dressing	12.5	20
77	Curried Lentil, Tomato, and Coconut Soup	4.8	45
92	Sheet-Pan Cumin Chicken Thighs with Squash, Fennel, and Grapes	7.5	25
104	Curried Pumpkin Soup	3.5	60
109	Persian Chicken with Turmeric and Lime	6.3	25
113	Baked Feta and Greens with Lemony Yogurt	5	30

Table 1-2. Price and Preparation Time

	Calories (Kcal)	Protein (g)	Fat (g)	Sodium (mg)
Lower	2700	140	150	2400
Upper	3600	200	250	3000

Table 1-3. Nutritional Restrictions

5. Singular Vector Decomposition

We used singular vector decomposition method for deriving the preference for both A and B. From the ratings matrix we got from the Epicurious.com website, we leveraged a latent factor model to capture the similarity between users and recipes. Essentially, we turned the recommendation problem into an optimization problem. We treated randomly chosen 40 users as one user so that the biased preference for some recipes can be relieved. Then we normalized the ratings per recipe to properly represent latent factor. Therefore we could derive A and B's preference for the chosen 40 recipes as in table 1-4.

ID	Title	Expected Rating
2	Easy Green Curry with Chicken, Bell Pepper, and Sugar Snap Peas	3.81465519
10	Persian-Spiced Chicken with Spaghetti Squash, Pomegranate, and Pistachios	5
13	Istanbul-Style Wet Burger (Islak Burger)	4
15	Pumpkin Spice Bundt Cake with Buttermilk Icing	1
18	Pumpkin Cheesecake with Bourbon sour Cream Topping	1.64170688
24	Kale Salad with Butternut Squash, Pomegranate, and Pumpkin Seeds	3.01206504
26	Stuffed Sweet Potatoes with Beans and Guacamole	2.42544632
28	Slow Cooker Pork Shoulder with Zesty Basil Sauce	4
29	Easy General Tso's Chicken	3.398837002
30	White Chicken Chili	3
38	One-Pot Curried Cauliflower with Couscous and Chickpeas	2.180336854
48	Navy Bean and Escarole Stew with Feta and Olives	2.489009934
49	Butternut Squash, Kale, and Crunchy Pepitas Taco	3
50	Sheet-Pan Skirt Steak With Balsamic Vinaigrette, Broccolini, and White Beans	4
75	Summer Corn, Tomato, and Salmon Salad with Za'atar Dressing	3.240245716
77	Curried Lentil, Tomato, and Coconut Soup	3.695716906

92	Sheet-Pan Cumin Chicken Thighs with Squash, Fennel, and Grapes	2.159726666
104	Curried Pumpkin Soup	2
109	Persian Chicken with Turmeric and Lime	2.72080467
113	Baked Feta and Greens with Lemony Yogurt	1

Table 1-4. Expected Ratings of chosen 20 recipes for A and B

6. Mixed Integer Programming for the meal plan

The mixed integer programming is formulated with the preferences on the recipes (based on ratings), nutritions, free time in a week, expenses and fair preparation schedule for the meal plan. The mixed integer programming is set as a function that can be used repeatedly with different scenarios each week. (such as more proteins, less sodium etc...) The definition for variables are represented in table 1-4.

$x_i \in (0,1)$	Decision variable for a recipe	c_i, p_i, f_i, s_i	Calories, protein, fat, sodium in recipe i
$y_{ij} \in (0,1)$	A's decision for recipe i on day j	$price_i$	Price($) in recipe i
$z_{ij} \in (0,1)$	B's decision for recipe i on day j	Pt_i	Preparation time for recipe i
R_i	Rating for recipe i	$At1_j, At2_j$	Available time for each person's day j
C_{lb}, C_{ub}	Calories lower bound and upper bound	c_{adj}, p_{adj}	Control parameter for calories, protein
P_{lb}, P_{ub}	Protein(g) lower bound and upper bound	f_{adj}, s_{adj}	Control parameter for fat and sodium
F_{lb}, F_{ub}	Fat(g) lower bound and upper bound	α	Control parameter for time balance, 0.01
S_{lb}, C_{ub}	Sodium(mg) lower bound, upper bound	w	Meal preparation time difference

Table 1-5. Notation for Mixed Integer Programming

$$Maximize \sum_{i=1}^{20} R_i \times x_i - \alpha * w$$

$$subject\ to \sum_{i=1}^{20} x_i = 5$$

Selection Constraints

$$\sum_{i=1}^{20}\sum_{j=1}^{5} y_{ij} \le 5$$

$$\sum_{i=1}^{20}\sum_{j=1}^{5} z_{ij} \le 5$$

$$\sum_{i=1}^{20} x_i = \sum_{i=1}^{20}\sum_{j=1}^{5} y_{ij} + \sum_{i=1}^{20}\sum_{j=1}^{5} z_{ij}$$

$$\left|\sum_{i=1}^{20}\sum_{j=1}^{5} y_{ij} - \sum_{i=1}^{20}\sum_{j=1}^{5} z_{ij}\right| \le 1$$

One-one Constraint

$$\sum_{i=1}^{20} y_{ij} + \sum_{i=1}^{20} z_{ij} = 1,\ j \in (1,2,3,4,5)$$

Nutritional Constraints

$$C_{lb} \le \sum_{i=1}^{20} x_i \times c_i \le C_{ub} \times c_{adj}$$

$$P_{lb} \times p_{adj} \le \sum_{i=1}^{20} x_i \times p_i \le P_{ub}$$

$$F_{lb} \le \sum_{i=1}^{20} x_i \times f_i \le F_{ub} \times f_{adj}$$

$$S_{lb} \le \sum_{i=1}^{20} x_i \times s_i \le S_{ub} \times s_{adj}$$

Preparation Time Constraints

$$\sum_{i=1}^{20} Pt_i \times y_{ij} \le At1_j,\ j \in (1,2,3,4,5)$$

$$\sum_{i=1}^{20} Pt_i \times z_{ij} \le At2_j,\ j \in (1,2,3,4,5)$$

Time Balance Constraints

$$\sum_{i=1}^{20}\sum_{j=1}^{5} y_{ij} - \sum_{i=1}^{20}\sum_{j=1}^{5} z_{ij} \le w$$

$$-\sum_{i=1}^{20}\sum_{j=1}^{5} y_{ij} + \sum_{i=1}^{20}\sum_{j=1}^{5} z_{ij} \le w$$

Redundancy Constraints

$$\sum_{i=1}^{20} y_{ij} \le 1,\ j \in (1,2,3,4,5)$$

$$\sum_{i=1}^{20} z_{ij} \le 1,\ j \in (1,2,3,4,5)$$

$$\sum_{j=1}^{5} x_{ij} \le 1,\ i \in (1,2,3,....19,20)$$

Budget Constraints

$$\sum_{i=1}^{20} price_i \times x_i \le 100$$

7. Conclusion

The defined function 'mnmplans(cal_rate=0, pro_rate=0, fat_rate=0, sod_rate=0)' is with default adjustment parameter values of 0 for $c_{adj}, p_{adj}, f_{adj}, s_{adj}$. We used the function to print meal plan for 5 days. The result for default adjustment parameters are in table 1-5. We also examined the 'mnmplans(cal_rate=20)' which is for 20% restriction on calories. The result for this situation is in table 1-6.

	Day 1	Day 2	Day 3	Day 4	Day 5
A	Easy Green Curry with Chicken, Bell Pepper, and Sugar Snap Peas	Slow Cooker Pork Shoulder with Zesty Basil Sauce	Istanbul-Style Wet Burger (Islak Burger)	-	-
B	-	-	-	Curried Pumpkin Soup	Pumpkin Cheesecake with Bourbon Sour Cream Topping

Table 1-5. Meal Plan with no adjustments

	Day 1	Day 2	Day 3	Day 4	Day 5
A	-	-	Pumpkin Cheesecake with Bourbon Sour Cream Topping	-	Curried Pumpkin Soup
B	Easy Green Curry with Chicken, Bell Pepper, and Sugar Snap Peas	Slow Cooker Pork Shoulder with Zesty Basil Sauce	-	Istanbul-Style Wet Burger (Islak Burger)	-

Table 1-6. Meal Plan with 20% Calorie restriction

We found two example plans of meal plans for the new millennium using singular vector decomposition and mixed integer programming. The plan is constructed to follow the nutritional restrictions and preparation and is fairly divided for both A and B. The defined function 'mnmplans()' can be reused repeatedly each week by setting the parameters following the week's meal planning purposes.