WQD 7011 Numerical Optimization

Group Assignment

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Title: Optimizing satisfaction of sushi on a budget

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1. Introduction

Sushi is a delicious dish of Japanese origin that is traditionally made with rice mixed with vinegar and accompanied by various ingredients such as seaweed, seafood and vegetables. There are multiple ways to prepare and present the dish. The dish had also gain global popularity and more variations were added to suit locality palate. Whether it's the colourful and fancy Americanized sushi rolls, or the more authentic nigirizushi or makizushi, eating sushi is always a flavourful, delightful experience.

Any patron who enters a sushi restaurant will normally receive a menu with an assortment of sushi, with prices varying according to the serving size and ingredients. To those that have never or seldom eat sushi, they will be faced with a daunting task of ordering. Such menu will lead to choice-overload, where too many choices will overwhelm the customers. While certain sushi restaurants does offer omakase, which means "I'll leave it up to you(the chef)", they tend to be pricey due to rare ingredients used in making the meal. Nevertheless, for any patrons who would like to sample a variety of sushi while on a budget, satisfaction is still key to make the meal worth it's price.

2. Problem Statement

One of the difficult decisions to make in life is deciding what to eat. Even after we have picked a restaurant, we have to decide which items we want to order. Sushi restaurant is one of the restaurants with menus that can be choice-overload that may lead to customers having difficulty in ordering. Therefore in this study, an optimization method was used to help customers to choose and be satisfy with their order within their budget.

In this scenario, we have selected Sushi Zanmai, and 10 sushi items that the restaurant sold. For each item, we have ranked the satisfaction gain from consuming the item from 1 to 10. Our objective is to enjoy maximize the satisfaction gain with the limited money we have. Our budget is RM 25 for that meal. On top of that, the total calories intake for should be not more than 600. As we are trying to maintain our physique, the total fat consumed need to be not more than 8 grams, and total carbohydrates need to be not more than 300 grams. At the same time, total protein intake should be at least 25 grams. For each order, there will be two pieces of sushi in a plate. For each sushi, we will order maximum one plate to enjoy the variety of sushi.

3. Objective Function

$$\textbf{\textit{Objective Function}} : \; Max\, f(x) = \sum_i 2S_iX_i$$

$$\textbf{\textit{Subject To}}: \sum_i MX_i \leq 25 \; ; \sum_i 2C_iX_i \leq \; 600 \; ; \sum_i 2F_iX_i \leq 8 \; ; \sum_i 2B_iX_i \leq 300 \; ; \sum_i 2P_iX_i \geq 25$$

$$0 \leq X_i \leq 1$$

<u>**Where:**</u>
S = Satisfaction
M = Price of sushi per plate
C = Calories per sushi
F = Fat per sushi (grams)
B = Carbs per sushi (grams)
P = Protein per sushi (grams)

4. Consolidate dataset for sushi

Sushi Item	X	Calories	Fat	Carbs	Protein	Price (2 pieces)	Satisfaction
Amaebi (Sweet Shrimp)	X_1	60	0.5	8.4	6.3	4.8	7
Anago (Conger Eel)	X_2	63	2.1	8.2	3.9	5.8	4
Awabi (Abalone)	X_3	45	0.1	9.1	2.9	3.8	10
Hamachi (Young Yellowtail)	X_4	51	0.8	8.2	3.8	7.8	6
Ika (Squid)	X_5	43	0.2	8.7	2.7	3.8	6
Ikura (Salmon Roe)	X_6	39	0.5	8.3	2.1	14.8	9
Maguro (Tuna)	X_7	50	0.7	8.2	3.8	5.8	8
Sake (Salmon)	X_8	56	1.6	8.2	3.3	5.8	6
Tako (Octopus)	X_9	53	0.3	8.9	4.8	5.8	6
Tamago (Japanese Omelette)	X_{10}	75	2	13.2	2.5	2.8	4

5. Minimize Problem Of Highest Satisfaction

In order to find the combination of order that give highest satisfaction we will first reverse the maximize problem to an equivalent minimize problem by adding a negative sign.

$$Min\ f(x) = -\sum_i C_i X_i$$

In this case, we are going to use simplex method to find the solution. The initial equations are as below:

$$Min\ f(x) = -2(7X_1 + 4X_2 + 10X_3 + 6X_4 + 6X_5 + 9X_6 + 8X_7 + 6X_8 + 6X_9 + 4X_{10})$$

$$4.8X_1 + 5.8X_2 + 3.8X_3 + 7.8X_4 + 3.8X_5 + 14.8X_6 + 5.8X_7 + 5.8X_8 + 5.8X_9 + 2.8X_{10} \leq 25$$
$$2(60X_1 + 63X_2 + 45X_3 + 51X_4 + 43X_5 + 39X_6 + 50X_7 + 56X_8 + 53X_9 + 75X_{10}) \leq 600$$
$$2(0.5X_1 + 2.1X_2 + 0.1X_3 + 0.8X_4 + 0.2X_5 + 0.5X_6 + 0.7X_7 + 1.6X_8 + 0.3X_9 + 2X_{10}) \leq 8$$
$$2(8.4X_1 + 8.2X_2 + 9.1X_3 + 8.2X_4 + 8.7X_5 + 8.3X_6 + 8.2X_7 + 8.2X_8 + 8.9X_9 + 13.2X_{10}) \leq 300$$
$$2(6.3X_1 + 3.9X_2 + 2.9X_3 + 3.8X_4 + 2.7X_5 + 2.1X_6 + 3.8X_7 + 3.3X_8 + 4.8X_9 + 2.5X_{10}) \geq 25$$
$$0 \leq X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10} \leq 1$$

The nutrient data provided is per piece, while each order from Sushi Mentai come with two pieces. Therefore the constraints for nutrients were doubled to per order basis. After expanding, the following are the equations to be used:

$$Min\ f(x) = 14X_1 - 8X_2 - 20X_3 - 12X_4 - 12X_5 - 18X_6 - 16X_7 - 12X_8 - 12X_9 - 8X_{10}$$

$$4.8X_1 + 5.8X_2 + 3.8X_3 + 7.8X_4 + 3.8X_5 + 14.8X_6 + 5.8X_7 + 5.8X_8 + 5.8X_9 + 2.8X_{10} \leq 25$$

$$120X_1 + 126X_2 + 90X_3 + 101X_4 + 86X_5 + 78X_6 + 100X_7 + 112X_8 + 106X_9 + 150X_{10} \leq 600$$

$$X_1 + 4.2X_2 + 0.2X_3 + 1.6X_4 + 0.4X_5 + X_6 + 1.4X_7 + 3.2X_8 + 0.6X_9 + 4X_{10} \leq 8$$

$$16.8X_1 + 16.4X_2 + 18.2X_3 + 16.4X_4 + 17.4X_5 + 16.6X_6 + 16.4X_7 + 16.4X_8 + 19.8X_9 + 26.4X_{10} \leq 300$$

$$12.6X_1 + 7.8X_2 + 5.8X_3 + 7.6X_4 + 5.4X_5 + 4.2X_6 + 7.6X_7 + 6.6X_8 + 9.6X_9 + 5X_{10} \geq 25$$

$$0 \leq X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10} \leq 1$$

6. Octave Equation to Solve Minimize Problem Of Highest Satisfaction

```
c = [-14;-8;-20;-12;-12;-18;-16;-12;-12;-8]
A = [4.8 5.8 3.8 7.8 3.8 14.8 5.8 5.8 5.8 2.8;
120 126 90 101 86 78 100 112 106 150;
1 4.2 0.2 1.6 0.4 1 1.4 3.2 0.6 4;
16.8 16.4 18.2 16.4 17.4 16.6 16.4 16.4 19.8 26.4;
12.6 7.8 5.8 7.6 5.4 4.2 7.6 6.6 9.6 5]
b = [25;600;8;300;25]
lb =[0;0;0;0;0;0;0;0;0;0]
ub =[1;1;1;1;1;1;1;1;1;1]
ctype = "UUUUL"
vartype = "IIIIIIIIII"
sense = 1

[xmin, fmin, status, extra] = glpk (c, A, b, lb, ub, ctype, vartype, sense)
```

The result from executing above scripts return following results.

```
Long-step dual simplex will be used
xmin =1  0  1  0  1  0  1  1  0  0
fmin = -74
status = 0
extra =
  scalar structure containing the fields:
    time = 0
    status = 5
```

Thus, we can have these five types of sushi, with each order come with two same pieces:

Sushi Item	X	Calories	Fat	Carbs	Protein	Price (2 pieces)	Satisfaction
Amaebi (Sweet Shrimp)	X_1	60	0.5	8.4	6.3	4.8	7
Awabi (Abalone)	X_3	45	0.1	9.1	2.9	3.8	10
Ika (Squid)	X_5	43	0.2	8.7	2.7	3.8	6
Maguro (Tuna)	X_7	50	0.7	8.2	3.8	5.8	8
Sake (Salmon)	X_8	56	1.6	8.2	3.3	5.8	6
Total		254 * 2 = 508	3.1 * 2 = 7.2	42.6 * 2 = 85.2	19 * 2 = 38	24	37 2 = 74

7. Minimize Problem Of Ordering Sushi With New Constraint

During COVID-19 pandemic, the gyms are forced to be closed, and we are not able to perform any exercises at the gym and any sport activities. We can still order Sushi Mentai delivery with the exact same menu. There is free delivery promotion thus no changes on the price. However, our budget have reduced to RM 15 to conserve money in case of job loss. At the same time, we have to consume less calories to maintain healthy as exercises are reduced.

For this scenario, calories intake should be not more than 400, fat not more than 3 grams, with carbs not more than 150. Protein intake should be min 20 grams. For order this time, we are still targeting to maximize satisfaction and for each item maximum only one order. Given these changes of constrains, new equations are being formulated as below:

$$Min\ f(x) = -2(7X_1 + 4X_2 + 10X_3 + 6X_4 + 6X_5 + 9X_6 + 8X_7 + 6X_8 + 6X_9 + 4X_{10})$$

$$4.8X_1 + 5.8X_2 + 3.8X_3 + 7.8X_4 + 3.8X_5 + 14.8X_6 + 5.8X_7 + 5.8X_8 + 5.8X_9 + 2.8X_{10} \leq 15$$

$$2(60X_1 + 63X_2 + 45X_3 + 51X_4 + 43X_5 + 39X_6 + 50X_7 + 56X_8 + 53X_9 + 75X_{10}) \leq 300$$

$$2(0.5X_1 + 2.1X_2 + 0.1X_3 + 0.8X_4 + 0.2X_5 + 0.5X_6 + 0.7X_7 + 1.6X_8 + 0.3X_9 + 2X_{10}) \leq 3$$

$$2(8.4X_1 + 8.2X_2 + 9.1X_3 + 8.2X_4 + 8.7X_5 + 8.3X_6 + 8.2X_7 + 8.2X_8 + 8.9X_9 + 13.2X_{10}) \leq 150$$

$$2(6.3X_1 + 3.9X_2 + 2.9X_3 + 3.8X_4 + 2.7X_5 + 2.1X_6 + 3.8X_7 + 3.3X_8 + 4.8X_9 + 2.5X_{10}) \geq 20$$

$$0 \leq X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10} \leq 1$$

Which is equivalent to:

$$Min\ f(x) = 14X_1 - 8X_2 - 20X_3 - 12X_4 - 12X_5 - 18X_6 - 16X_7 - 12X_8 - 12X_9 - 8X_{10}$$

$$4.8X_1 + 5.8X_2 + 3.8X_3 + 7.8X_4 + 3.8X_5 + 14.8X_6 + 5.8X_7 + 5.8X_8 + 5.8X_9 + 2.8X_{10} \leq 15$$

$$120X_1 + 126X_2 + 90X_3 + 101X_4 + 86X_5 + 78X_6 + 100X_7 + 112X_8 + 106X_9 + 150X_{10} \leq 300$$

$$X_1 + 4.2X_2 + 0.2X_3 + 1.6X_4 + 0.4X_5 + X_6 + 1.4X_7 + 3.2X_8 + 0.6X_9 + 4X_{10} \leq 3$$

$$16.8X_1 + 16.4X_2 + 18.2X_3 + 16.4X_4 + 17.4X_5 + 16.6X_6 + 16.4X_7 + 16.4X_8 + 19.8X_9 + 26.4X_{10} \leq 150$$

$$12.6X_1 + 7.8X_2 + 5.8X_3 + 7.6X_4 + 5.4X_5 + 4.2X_6 + 7.6X_7 + 6.6X_8 + 9.6X_9 + 5X_{10} \geq 20$$

$$0 \leq X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10} \leq 1$$

8. Octave Equation to Solve Minimize Problem Of Ordering Sushi With New Constraint

We change the coding as below:

```
c = [-14;-8;-20;-12;-12;-18;-16;-12;-12;-8]
A = [4.8 5.8 3.8 7.8 3.8 14.8 5.8 5.8 5.8 2.8;
    120 126 90 101 86 78 100 112 106 150;
    1 4.2 0.2 1.6 0.4 1 1.4 3.2 0.6 4;
    16.8 16.4 18.2 16.4 17.4 16.6 16.4 16.4 19.8 26.4;
    12.6 7.8 5.8 7.6 5.4 4.2 7.6 6.6 9.6 5]
b = [15;300;3;150;20]
lb =[0;0;0;0;0;0;0;0;0;0]
ub =[1;1;1;1;1;1;1;1;1;1]
ctype = "UUUUL"
vartype = "IIIIIIIIII"
sense = 1

[xmin, fmin, status, extra] = glpk (c, A, b, lb, ub, ctype, vartype, sense)
```

The result from executing above scripts return following results.

```
Long-step dual simplex will be used
xmin =1   0   1   0   1   0   0   0   0   0
fmin = -46
status = 0
extra =
  scalar structure containing the fields:
    time = 0
    status = 5
```

In this time, only three type of sushi we are ordering:

Sushi Item	X	Calories	Fat	Carbs	Protein	Price (2 pieces)	Satisfaction
Amaebi (Sweet Shrimp)	X_1	60	0.5	8.4	6.3	4.8	7
Awabi (Abalone)	X_3	45	0.1	9.1	2.9	3.8	10
Ika (Squid)	X_5	43	0.2	8.7	2.7	3.8	6
Total		148* 2 = 296	0.8*2 = 1.6	26.2 * 2 = 52.4	11.9 * 2 = 23.8	12.4	23*2 = 46

9. Conclusion

From this study, we are able to build an optimization model to help customers to choose and gain maximum satisfaction within their budget. The proposed model could be modified to suit patron's palate by allowing the customer to rate their satisfaction level for each order item. Besides that, the proposed model could also be modified to devise a proper meal by adjusting the calorie and nutrient constraints.

Different people have different preference. Some may not take any raw meat in their meals while some may be vegetarian. By allowing the customers to rate their satisfaction level for each order item on the menu, restaurants may take the advantage of using this optimization model to come up with better set menus or promotions to suit different patron's preference. This may aid in reducing choice-overload for customers who aim to sample a variety of sushi with certain budget, while indirectly boost sales in the restaurants. Again, the customer's perceived satisfaction from the meal based on the budget constraint is still the key to a successful menu.

10. Appendix

[1] What Is the Best Sushi for Beginners? https://wasabifire.com/best-sushi-for-beginners/
[2] Clinehens, J. (2019, May 15) The Choice Overload Effect: Why simplicity is the key to winning customers. *Medium.* https://medium.com/choice-hacking/choice-overload-why-simplicity-is-the-key-to-winning-customers-2f8e239eaba6
[3] Chew, T. (2017, October 31) 5 Sushi Bars In KL With An Omakase Experience Worth Every Cent. *Malaysia Tatler.* https://my.asiatatler.com/dining/5-sushi-bars-in-kl-with-an-omakase-experience-worth-every-cent
[4] Sushi Mentai Menu. (2020, Jun 6). https://www.menus.my/sushi-zanmai-menu/
[5] Sushi Calories and Nutritional Information. (2020, June 6). https://www.sushifaq.com/sushi-health/calories-in-sushi/