

# ISE 533    Meal Planning



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# Workflow

The goal of the project :

Select 7 dishes for one week that maximize the total of each group member ratings.

The sequence of the project:

**Data scraping and cleaning** : Organize the scraping data into a standard form for next steps.

**Matrix Completion** : Simulating the matrix factorization to do matrix completion by gradient descent.

**Mixed Integer Programming** : Optimizing to choose dishes that maximize the group member ratings.

# Problem Statement

The goal of the project is to select 7 dishes for one week that maximize the total of each group member ratings. In the meantime, the model is satisfied with the following constraints.

- 1) Daily nutrition requirements (each member & group, lower & upper)
- 2) Weekly budget requirements (each member & group)
- 3) Equitable cooking time
- 4) Dishes cannot be duplicated in the menu
- 5) Only one member completes each dish in the plan.

# Data Processing

- Data Source: Scraping from [epicurious.com](https://www.epicurious.com)
- Data Cleaning:
  - Get the average rating of each user for each dish (group by)
  - Add our own ratings on some of the dishes
  - Finally, we get 2888 rows (users) and 289 columns (dishes)

	Curried Lentil, Tomato, and Coconut Soup	Roasted Butternut Squash with Herb Oil and Goat Cheese	Pumpkin Muffins	Chopped Salad with Shallot Vinaigrette, Feta, and Dill	Grain Salad with Olives and Whole-Lemon Vinaigrette	Chilled Coconut Corn Soup	Vietnamese-Style Spaghetti Squash "Noodle" Bowls with Skirt Steak	Honey-Roasted Vegetable Salad	Roasted Squash with Mint and Toasted Pumpkin Seeds	Butternut Squash Steaks with Brown Butter-Sage Sauce	...	Twice-Roasted Squash with Parmesan Butter and Grains	Kale Salad with Butternut Squash, Pomegranate, and Pumpkin Seeds
rhaeredekop from Winnipeg, MB	5.0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	...	NaN	NaN
lizgoldsmith1960 from Lincoln, MA	5.0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	...	NaN	NaN
bmaybeegeorge from Canada	5.0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	...	NaN	NaN
adventurousz from Boulder, CO	3.0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	...	NaN	NaN
epaul77 from Mississippi	5.0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	...	NaN	NaN
...	...	...	...	...	...	...	...	...	...	...	...	...	...
mynwt from Annapolis, MD	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	...	NaN	NaN
Heidi Z	NaN	NaN	NaN	NaN	NaN	NaN	NaN	5.0	NaN	NaN	...	NaN	NaN
Zhaoqi X	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	3.0	...	NaN	NaN
Simon S	NaN	NaN	4.0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	...	NaN	NaN
Yongjun K	NaN	5.0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	...	2.0	NaN

# Data Processing

**Missing Values** (in nutritions, cooking time, and recipe price):

There're only 105 dishes without missing values at beginning;

We tried to scrape data from other websites by changing the regular expression of the scrapping code;

There're **179** dishes without missing values.

	calories	sodium	fat	protein	time	price
Vietnamese-Style Spaghetti Squash "Noodle" Bowls with Skirt Steak	503.0	1574.0	34.0	29.0	75.0	2.120
Freeform Chicken Meatballs with Carrots and Yogurt Sauce	488.0	985.0	32.0	29.0	45.0	9.889
Grain Bowls with Chicken, Spiced Chickpeas, and Avocado	1448.0	784.0	102.0	56.0	20.0	7.759
Ancho Chile Pork Tenderloin with Brussels Sprouts and Squash	620.0	1482.0	31.0	53.0	45.0	2.780
Shrimp with Herby White Beans and Tomatoes	578.0	1151.0	23.0	34.0	20.0	2.260
...	...	...	...	...	...	...
10-Minute Chicken Flatbreads with Hummus and Yogurt	463.0	917.0	18.0	35.0	10.0	3.839
Sausage and Greens Sheet-Pan Dinner	665.0	855.0	63.0	17.0	25.0	8.862
White Chicken Chili	534.0	968.0	14.0	45.0	30.0	6.839
One-Pot Curried Cauliflower with Couscous and Chickpeas	606.0	1365.0	15.0	27.0	45.0	9.208
Hummus Dinner Bowls with Spiced Ground Beef and Tomatoes	329.0	327.0	26.0	20.0	20.0	10.070

# Matrix Completion

Simulating the **matrix factorization** to do matrix completion

- Objective Function: 
$$\min_{X \in \mathbb{R}^{m \times k}, Y \in \mathbb{R}^{k \times n}} \frac{1}{2} \sum_{(i,j) \in \Omega} [M_{ij} - (PQ^T)_{ij} - bias]^2 + \lambda (\|P\|_F^2 + \|Q\|_F^2)$$
  - Alpha: 0.1
  - Regularization parameter: 0.01
- Latent Features:
  - Started from 20 and chose 24 since the number of dimensions larger than 24 no longer reducing MSE significantly.
  - P and Q were updated until training errors stop decreasing (Early Stop).
- Biases:
  - Added biases related to global, users and dishes since we assumed that some biases may affect when ratings are generated.

# Results - Matrix Completion

## P Matrix

	0	1	2	3	4	5	6	7	8	9	...	14
rhaeredekop from Winnipeg, MB	-0.04	0.04	-0.01	-0.05	0.11	0.09	0.06	-0.00	-0.01	0.03	...	0.08
lizgoldsmith1960 from Lincoln, MA	-0.05	-0.01	-0.04	-0.03	0.09	0.01	-0.00	0.08	-0.00	-0.03	...	0.01
bmaybeegeorge from Canada	-0.03	0.04	-0.02	-0.03	0.08	0.02	0.08	0.06	-0.02	-0.08	...	0.04
adventurousz from Boulder, CO	0.38	0.43	0.36	0.10	-0.30	-0.43	-0.36	0.02	0.15	0.10	...	-0.25
epaul77 from Mississippi	-0.03	-0.07	-0.06	-0.03	0.08	0.07	0.03	0.08	-0.01	-0.00	...	-0.04
...	...	...	...	...	...	...	...	...	...	...	...	...
mynwt from Annapolis, MD	-0.03	0.03	-0.04	-0.03	-0.04	0.07	-0.01	0.03	-0.04	-0.01	...	0.08
Heidi Z	-0.01	-0.15	0.08	0.47	-0.00	0.21	-0.06	0.52	0.11	-0.06	...	0.18
Zhaoqi X	0.13	0.01	-0.09	-0.09	0.22	-0.13	0.06	0.42	0.28	0.20	...	0.67
Simon S	0.05	-0.35	0.16	0.04	0.76	0.06	-0.27	-0.03	-0.15	-0.14	...	0.55
Yongjun K	0.12	-0.46	0.03	0.23	0.47	0.33	-0.19	-0.07	0.21	0.02	...	-0.14

2888 rows x 24 columns

## Q Matrix

	0	1	2	3	4	5	6	7	8	9	...	14
Curried Lentil, Tomato, and Coconut Soup	-0.24	-0.25	-0.29	-0.07	0.18	0.27	0.20	0.07	-0.10	-0.06	...	0.10
Roasted Butternut Squash with Herb Oil and Goat Cheese	0.12	-0.37	-0.04	0.23	0.31	0.34	-0.16	-0.07	0.22	0.05	...	-0.29
Pumpkin Muffins	0.54	0.31	0.48	-0.45	0.35	-0.38	-0.32	-0.20	0.08	-0.08	...	0.38
Chopped Salad with Shallot Vinaigrette, Feta, and Dill	0.01	-0.02	-0.01	0.04	-0.06	0.13	0.15	-0.01	0.00	-0.07	...	0.05
Grain Salad with Olives and Whole-Lemon Vinaigrette	0.13	0.08	-0.00	-0.10	-0.10	-0.28	-0.29	0.03	0.13	0.08	...	-0.21
...	...	...	...	...	...	...	...	...	...	...	...	...
One-Pot Curried Cauliflower with Couscous and Chickpeas	-0.12	0.00	-0.34	-0.07	0.06	-0.09	-0.30	0.05	-0.18	-0.04	...	-0.05
Acorn Squash with Kale and Sausage	0.38	-0.08	-0.15	0.23	-0.14	-0.00	0.25	0.02	-0.06	-0.11	...	-0.05
Hummus Dinner Bowls with Spiced Ground Beef and Tomatoes	0.07	0.23	-0.13	0.05	0.09	-0.12	-0.15	0.04	0.31	-0.22	...	0.21
Autumn Kale Salad	-0.03	-0.07	0.05	-0.09	-0.03	-0.03	0.03	-0.06	0.05	-0.00	...	-0.00
Pumpkin Icebox Pie With Snickerdoodle Crust	0.10	0.15	-0.04	0.37	-0.17	0.64	0.17	0.23	-0.49	0.28	...	0.58

289 rows x 24 columns

# Results - Matrix Completion

The completed personal rating matrix

	Curried Lentil, Tomato, and Coconut Soup	Roasted Butternut Squash with Herb Oil and Goat Cheese	Pumpkin Muffins	Chopped Salad with Shallot Vinaigrette, Feta, and Dill	Grain Salad with Olives and Whole-Lemon Vinaigrette	Chilled Coconut Corn Soup	Vietnamese-Style Spaghetti Squash "Noodle" Bowls with Skirt Steak	Honey-Roasted Vegetable Salad	Roasted Squash with Mint and Toasted Pumpkin Seeds	Butternut Squash Steaks with Brown Butter-Sage Sauce	...	Twice-Roasted Squash with Parmesan Butter and Grains	Kale Salad with Butternut Squash, Pomegranate, and Pumpkin Seeds	Kabocha Squash Pilaf with Coconut
Heidi Z	4.34	4.50	3.69	4.51	3.23	3.43	4.73	5.00	2.91	4.47	...	2.45	4.69	3.65
Zhaoqi X	3.87	2.94	2.56	3.36	2.56	3.17	2.79	3.56	1.38	3.00	...	1.89	3.75	2.53
Simon S	3.49	3.69	4.00	3.75	2.69	3.50	3.87	4.00	3.46	3.76	...	2.34	3.98	2.93
Yongjun K	3.34	5.00	4.39	3.83	3.23	3.14	3.97	4.51	2.29	4.16	...	2.00	4.18	3.21

4 rows x 289 columns



# Mixed Integer Programming (MIP)

- Objective Function: 
$$\max \sum_{j=1}^K r_j x_j - \sum_{i \in \{c,p,f,s\}} \beta_i f_i^+ - \alpha w$$

Set alpha as 0.1/100 because of the difference between rating and time dimensions.

- Nutrition Constraint:
  - Calories: [700, 3000]
  - Sodium: [950, 3800]
  - Fat: [35, 250]
  - Protein: [30, 100]
- Budget Constraint: \$250 for each person (\$1000 for the whole meals).
- Cooking Time Constraint: Within 25% of different cooking time is acceptable.

# Mixed Integer Programming (MIP)

The average values of nutritions

```
print('calories_avg: ' + str(info_final['calories'].mean()))  
print('sodium_avg: ' + str(info_final['sodium'].mean()))  
print('fat_avg: ' + str(info_final['fat'].mean()))  
print('protein_avg: ' + str(info_final['protein'].mean()))
```

```
calories_avg: 626.0  
sodium_avg: 913.6761904761905  
fat_avg: 34.89523809523809  
protein_avg: 27.923809523809524
```

The maximum values of nutritions

```
print('calories_max: ' + str(info_final['calories'].max()))  
print('sodium_max: ' + str(info_final['sodium'].max()))  
print('fat_max: ' + str(info_final['fat'].max()))  
print('protein_max: ' + str(info_final['protein'].max()))
```

```
calories_max: 2887.0  
sodium_max: 3495.0  
fat_max: 205.0  
protein_max: 83.0
```

# Results - MIP

Dishes that we choose to cook in a week

```
plan = info_final.iloc[[32, 43, 58, 70, 80, 84, 104]]  
plan
```

	calories	sodium	fat	protein	time	price
Garlic Mojo Sauce	368.0	329.0	36.0	1.0	30.0	9.060
10-Minute Sausage Skillet with Cherry Tomatoes and Broccolini	467.0	1050.0	36.0	21.0	10.0	7.380
Dill-Crusted Pork Tenderloin with Farro, Pea, and Blistered Tomato Salad	756.0	1041.0	32.0	51.0	35.0	9.337
Hot Sesame Noodles with Scallions and Pork	941.0	837.0	61.0	31.0	30.0	22.977
Sweet-Cream Coffee Butter	236.0	45.0	24.0	0.0	50.0	3.180
Big-Batch Roasted Kale	302.0	170.0	30.0	8.0	40.0	4.860
Hummus Dinner Bowls with Spiced Ground Beef and Tomatoes	329.0	327.0	26.0	20.0	20.0	10.070

# Results - MIP

```
meal_plan.solve()
meal_plan.print_solution()
```

objective: 117.474

X\_32=1

X\_43=1

X\_58=1

X\_70=1

X\_80=1

X\_84=1

X\_104=1

Heidi\_0\_58=1

Heidi\_4\_104=1

Zhaoqi\_2\_32=1

Zhaoqi\_6\_70=1

YJ\_1\_43=1

YJ\_3\_84=1

Simon 5\_80=1

## Recommended Dishes:

Day	Members	Dishes
Monday	Heidi	Dill-Crusted Pork Tenderloin with Farro, Pea, and Blistered Tomato Salad
Tuesday	YJ	10-Minute Sausage Skillet with Cherry Tomatoes and Broccoli
Wednesday	Zhaoqi	Garlic Mojo Sauce
Thursday	YJ	Big-Batch Roasted Kale
Friday	Heidi	Hummus Dinner Bowls with Spiced Ground Beef and Tomatoes
Saturday	Simon	Sweet-Cream Coffee Butter
Sunday	Zhaoqi	Hot Sesame Noodles with Scallions and Pork

**Thank You!**