Solving a Catering Problem with the Greedy Set Cover Algorithm

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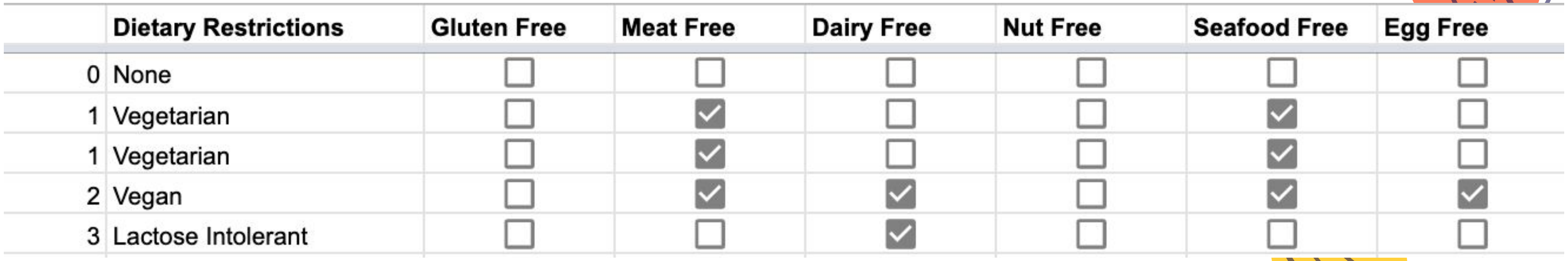
Introduction

- The Cheesecake Factory
- Clients supply:
  - Number of attendees (20)
  - Dietary restrictions of attendees
  - Minimum number of dishes they want
    - 2 appetizers, 4 main dishes, 2 desserts
- Goal: choose set of dishes that
  - Maximizes expected revenue
  - Meets dietary restrictions of all attendees

Data (Attendees)

Note: we created this data based on the percentages for these food allergies in the United States

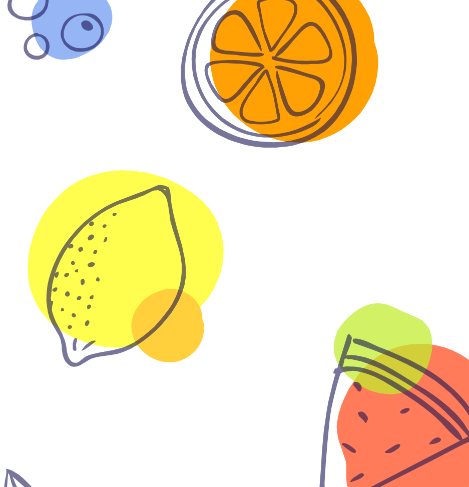
0 -> none	(8/20 - 40%)
1 -> vegetarian	(2/20 - 10%)
2 -> vegan	(1/20 - 5%)
3 -> lactose intolerant	(4/20 - 20%)
4 -> seafood free	(1/20 - 5%)
5 -> nut allergy	(1/20 - 5%)
6 -> gluten free	(1/20 - 5%)
7 -> no meat or dairy	(1/20 - 5%)
8 -> gluten free vegetarian	(1/20 - 5%)

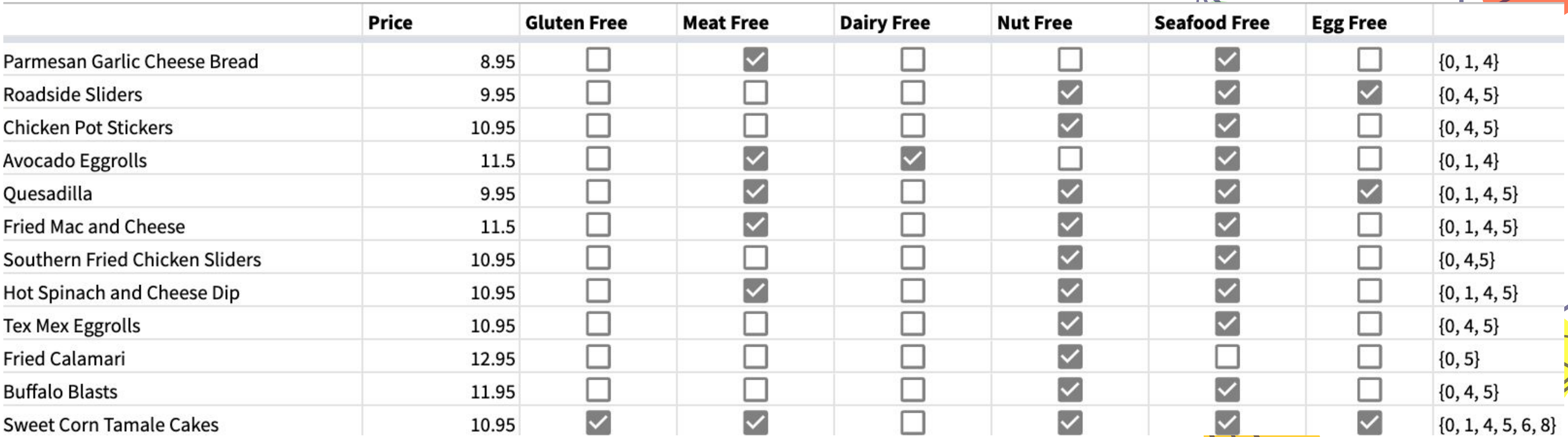


	Dietary Restrictions	Gluten Free	Meat Free	Dairy Free	Nut Free	Seafood Free	Egg Free
0	None	☐	☐	☐	☐	☐	☐
1	Vegetarian	☐	☑	☐	☐	☑	☐
1	Vegetarian	☐	☑	☐	☐	☑	☐
2	Vegan	☐	☑	☑	☐	☑	☑
3	Lactose Intolerant	☐	☐	☑	☐	☐	☐

Data (Food)

- Based on our encoding of attendees, we represented each dish on the menu as a set of types of individuals who could consume that food

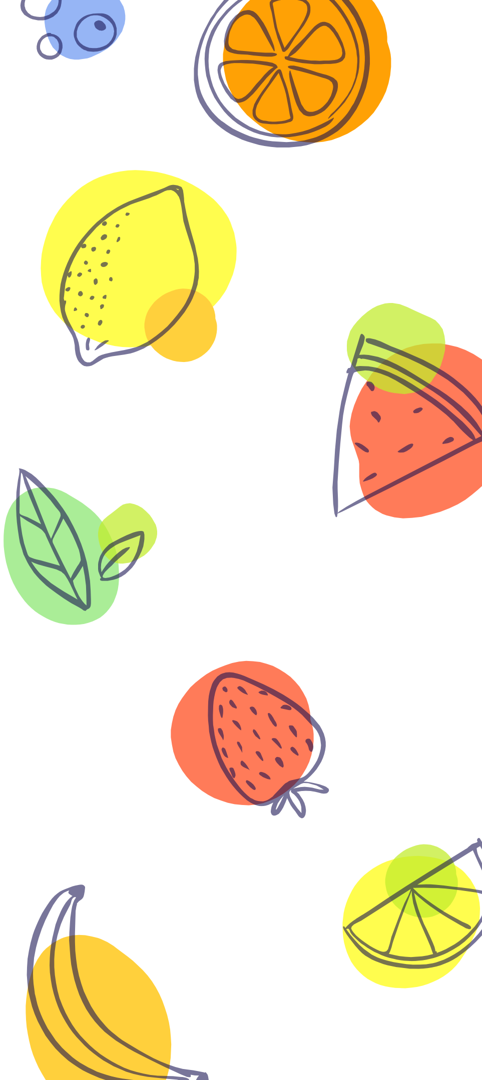




	Price	Gluten Free	Meat Free	Dairy Free	Nut Free	Seafood Free	Egg Free	
Parmesan Garlic Cheese Bread	8.95	□	☑	□	□	☑	□	{0, 1, 4}
Roadside Sliders	9.95	□	□	□	☑	☑	☑	{0, 4, 5}
Chicken Pot Stickers	10.95	□	□	□	☑	☑	□	{0, 4, 5}
Avocado Eggrolls	11.5	□	☑	☑	□	☑	□	{0, 1, 4}
Quesadilla	9.95	□	☑	□	☑	☑	☑	{0, 1, 4, 5}
Fried Mac and Cheese	11.5	□	☑	□	☑	☑	□	{0, 1, 4, 5}
Southern Fried Chicken Sliders	10.95	□	□	□	☑	☑	□	{0, 4,5}
Hot Spinach and Cheese Dip	10.95	□	☑	□	☑	☑	□	{0, 1, 4, 5}
Tex Mex Eggrolls	10.95	□	□	□	☑	☑	□	{0, 4, 5}
Fried Calamari	12.95	□	□	□	☑	□	□	{0, 5}
Buffalo Blasts	11.95	□	□	□	☑	☑	□	{0, 4, 5}
Sweet Corn Tamale Cakes	10.95	☑	☑	□	☑	☑	☑	{0, 1, 4, 5, 6, 8}

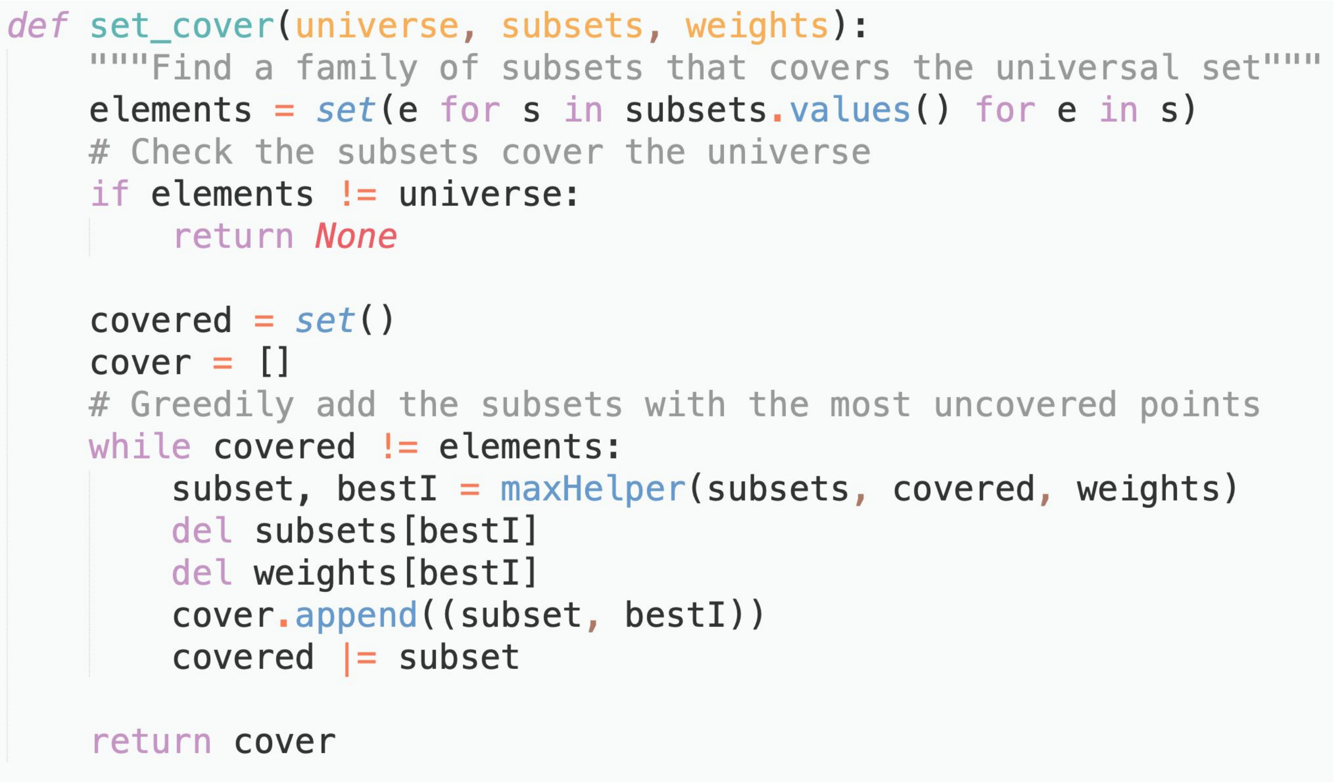
Set Cover Algorithm

- Have a universe
  - In our case it would be a set of the types of people present : {0, 1, 2, 3, 4, 5, 6, 7, 8}
- Have a set of subsets whose union equals the universe
  - Would be the dishes
  - Ex. { {0}, {0, 1, 2, 3, 4, 7}, {0, 5, 6}, {0, 1, 5, 6, 8} }
- Find the smallest set of subsets whose union equals the universe
  - i.e. find the smallest number of dishes that satisfies everyone (and maximises revenue)



Algorithm

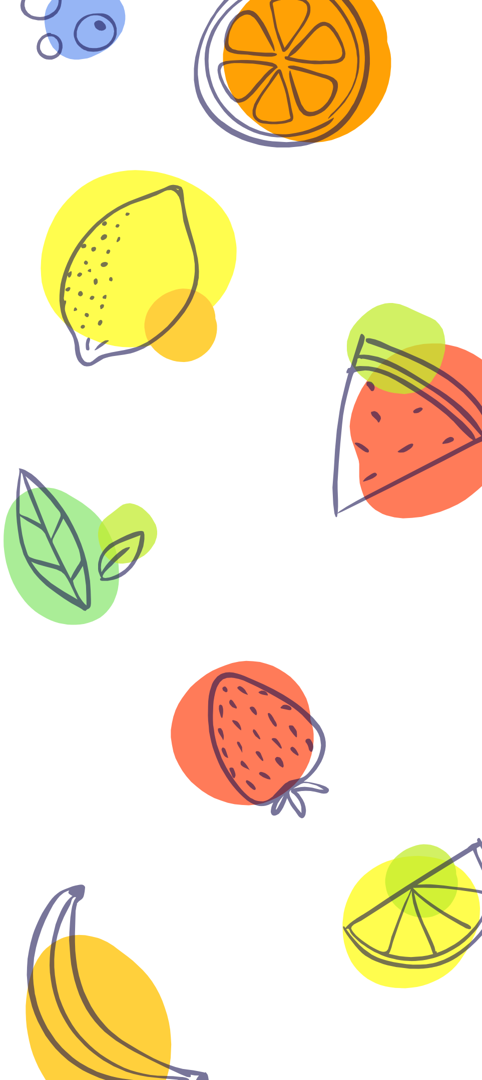
- Greedy Set Cover Algorithm



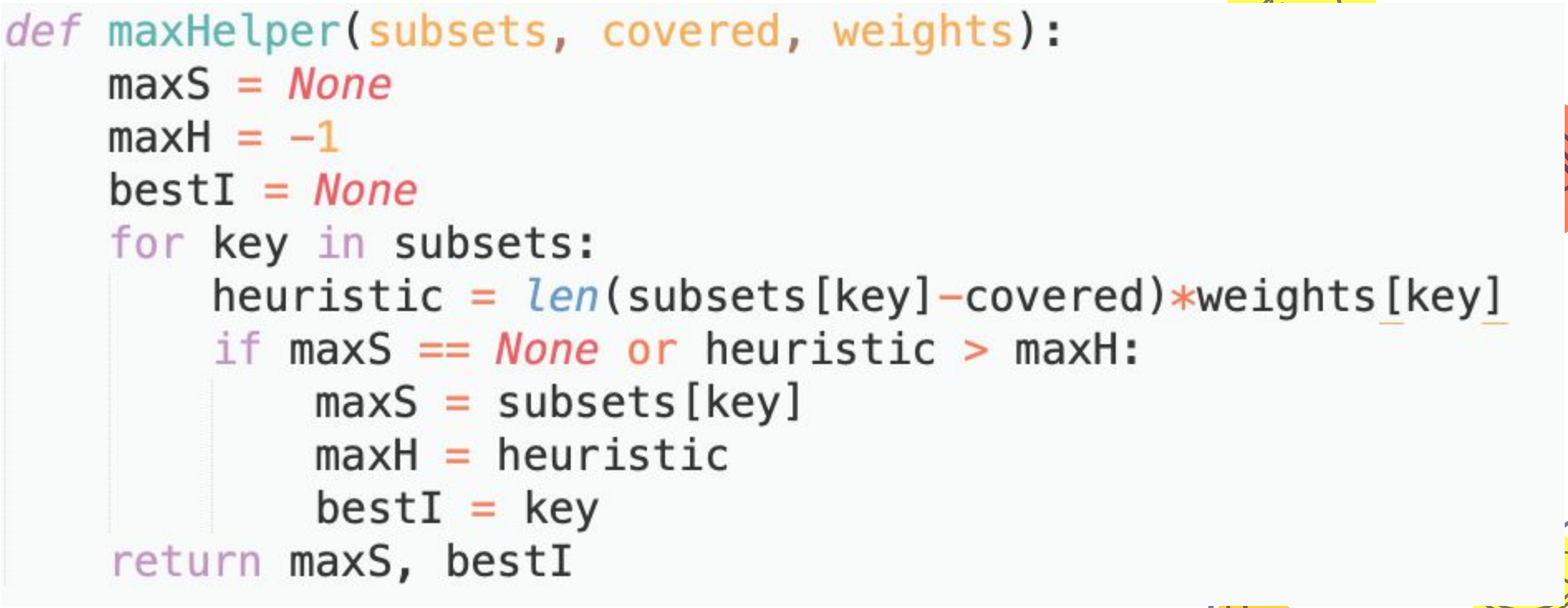
```python
def set_cover(universe, subsets, weights):
    """Find a family of subsets that covers the universal set"""
    elements = set(e for s in subsets.values() for e in s)
    # Check the subsets cover the universe
    if elements != universe:
        return None

    covered = set()
    cover = []
    # Greedily add the subsets with the most uncovered points
    while covered != elements:
        subset, bestI = maxHelper(subsets, covered, weights)
        del subsets[bestI]
        del weights[bestI]
        cover.append((subset, bestI))
        covered |= subset

    return cover
```



Algorithm (cont.)

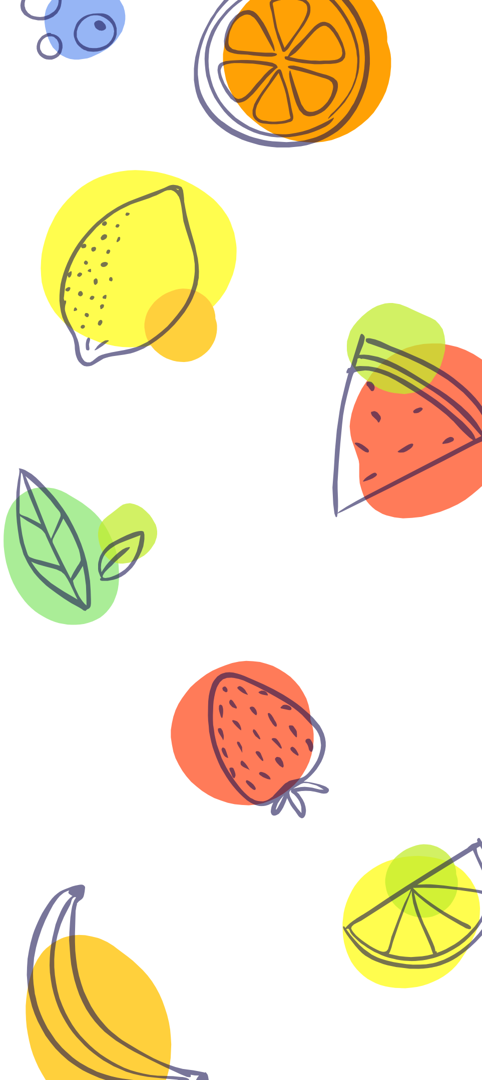


```
def maxHelper(subsets, covered, weights):
    maxS = None
    maxH = -1
    bestI = None
    for key in subsets:
        heuristic = len(subsets[key]-covered)*weights[key]
        if maxS == None or heuristic > maxH:
            maxS = subsets[key]
            maxH = heuristic
            bestI = key
    return maxS, bestI
```

Results

Appetizers:

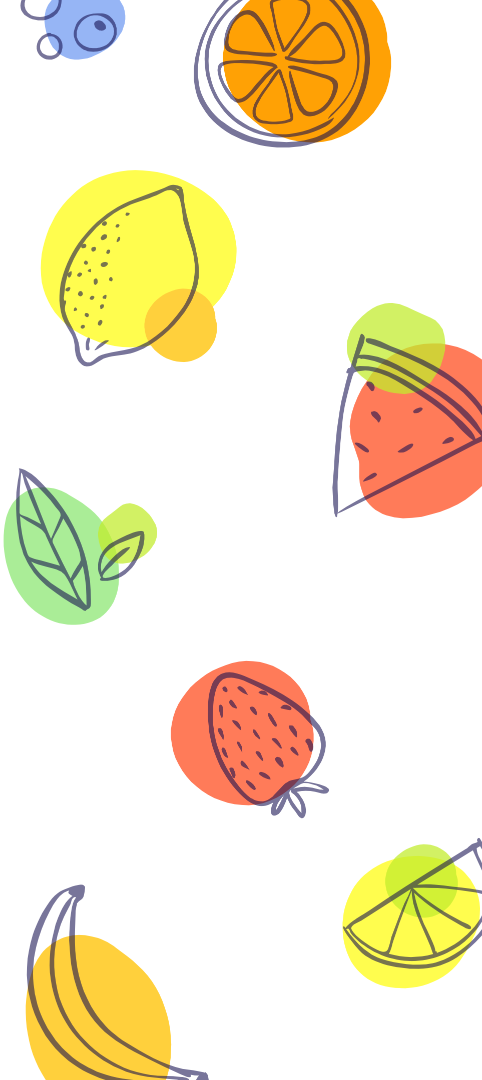
- Factory Chopped Salad -- $12.50
- Guacamole Made-To-Order -- $11.95
- Factory Nachos -- $12.50



Results (cont.)

Main Dishes:

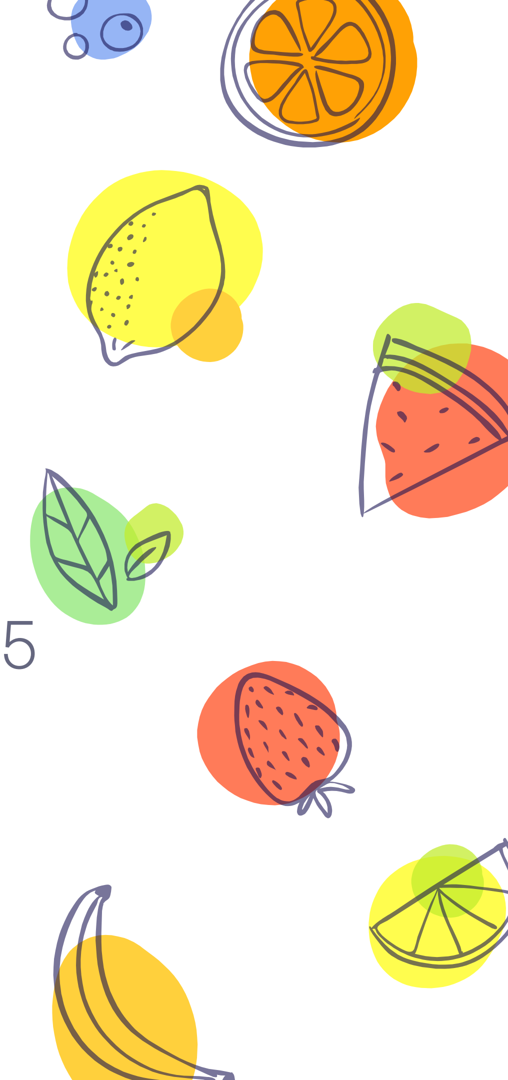
- Chinese Chicken Salad -- $14.95
- Cobb Salad -- $14.95
- Sante Fe Salad -- $15.50
- Four Cheese Pasta -- $15.95
- Luau Salad -- $14.95
- Evelyn's Favorite Pasta -- $15.95



Results (cont.)

Desserts:

- Bowl of Fresh Strawberries -- $7.50
- Dairy-Free Key Lime Pie -- $7.95
- Godiva Chocolate Cheesecake -- $7.95



Results (cont)

- We assumed that of the foods an individual can consume, they have an equal chance of choosing each dish

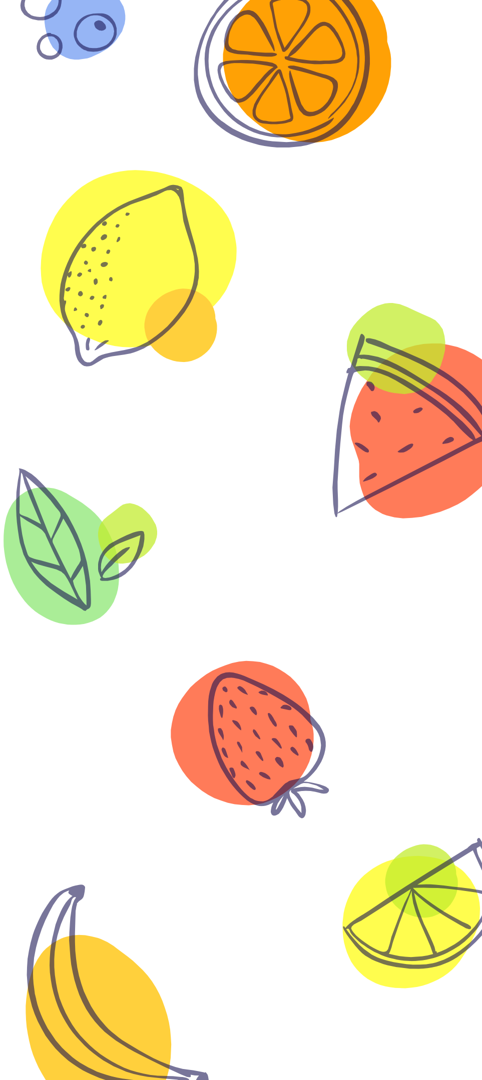
  E [Appetizers] = $245.97

  E [Main Dishes] = $305.81

  E [Dessert] = $155.40

  Total Expected Revenue: $707.18

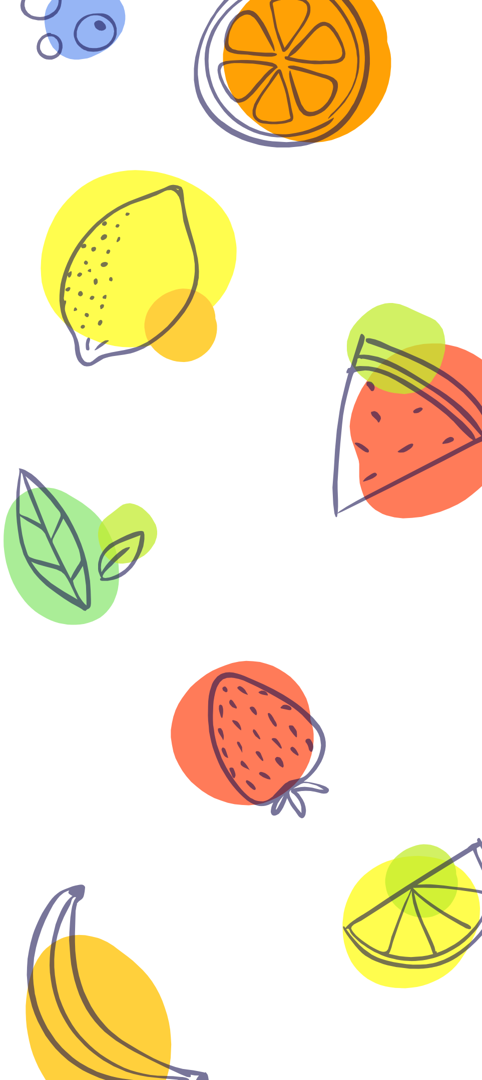
  Expected Revenue/Person: $35.36



Conclusion

- Compared to a visual inspection of the data, the algorithm chose the correct dishes

- This specific example can be generalized to different menus, number of attendees, number of dietary restrictions, number of dishes requested, etc.



Acknowledgements

- Dr. Alan Frieze
- Cheesecake Factory
  - Menu
  - Nutrition Information
- Martin Broadhurst
  - Greedy Set Covering Algorithm