



College of Computer and
Information Sciences

IT426: ARTIFICIAL INTELLIGENCE SYSTEMS
INFORMATION TECHNOLOGY DEPARTMENT

Best Meal Synthesis using GA Optimization

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ROLES AND RESPONSIBILITIES:

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Table of Contents

Best Meal Synthesis using GA Optimization	1
Prepared by	1
ROLES AND RESPONSIBILITIES:	2
1.Intoduction.....	3
2. Solution representation.....	3
3. termination condition.....	4
4. Fitness function.	4
5. Genetic operators:.....	5
6. Analysis of results.....	23
References:.....	24

1.Intoduction.

A **genetic algorithm** is a search heuristic that is inspired by Charles Darwin's theory of natural evolution. This algorithm reflects the process of natural selection where the proper individuals are selected by the fitness function to produce the fittest offspring of the next generation. [1]

To implement the GA algorithm, you need to go through 8 steps which are:

- 1- Choose a solution representation.
- 2- Initiate a population.
- 3- Fitness function.
- 4- Selection method (Roulette wheel).
- 5- Crossover.
- 6- Mutate.
- 7- Replace method.
- 8- Terminate condition.

In this report we will talk about each step in details, also we will represent the results.

2. Solution representation.

]:

	CATEGORY	ITEM	CALORIES	TYPE	PRICE
0	STARTER	Dynamite shrimp	770.0	Vegetarian	74
1	STARTER	Halloumi fries	530.0	Vegetarian	48
2	STARTER	Baked eggplant	270.0	Vegan	36
3	STARTER	Fish cake	480.0	Vegetarian	60
4	STARTER	Lentil soup	290.0	Vegan	26
...
63	COLD DRINK	Ice Latte	160.0	Vegetarian	18
64	COLD DRINK	Large Water	0.0	Vegan	10
65	COLD DRINK	Small Water	0.0	Vegan	10
66	COLD DRINK	Raspberry Mojito	129.4	Vegan	28
67	COLD DRINK	Blueberry Mojito	136.0	Vegan	30

68 rows × 5 columns

Figure 1 population representation

We represented the population in a DataFrame. Each row represents a dish, and each column represents the CATEGORY, ITEM, CALORIES, TYPE and PRICE of the dish. So, the solution at the end will be represented as the population, since it an understandable format to the user.

3. termination condition

Termination code determines when a GA run will be ended. The termination condition is when the number of generations exceed 300 generation. We tried multiple numbers to find the best one and use it to as termination condition, after that we found 300 is the best one, where there is no or little change in the fitness after 300 generations as shown in Figure 2.

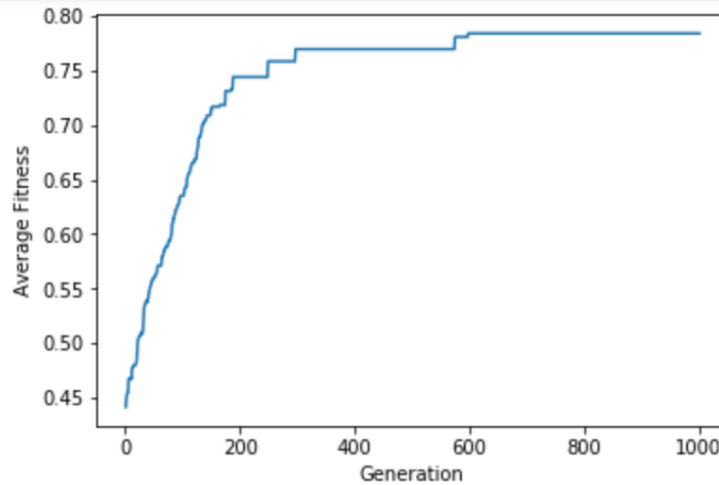


Figure 2 GA performance

4. Fitness function.

```
def fitness_function(meal):
    typeWeight = 0.4
    budgetWeight = 0.4
    calorieWeight = 0.2
    totalCost = 0.0
    totalCalories = 0.0
    totalWeight = 0.0

    counter = 0

    for item in meal:

        if(userType.lower() == "regular"):
            totalWeight = totalWeight + typeWeight
            totalCost = totalCost + item[4]
            totalCalories = totalCalories + item[2]
            counter = counter+1

        elif (userType.lower() == "vegetarian"):
            if(item[3].lower() in ["vegetarian", "vegan"]):
                totalWeight = totalWeight + typeWeight
                totalCost = totalCost + item[4]
                totalCalories = totalCalories + item[2]
                counter = counter+1

        else:
            if (item[3].lower() == "vegan"):
                totalWeight = totalWeight + typeWeight
                totalCost = totalCost + item[4]
                totalCalories = totalCalories + item[2]
                counter = counter+1

    if(counter > 0):
        totalWeight = totalWeight/counter

    if(totalCost <= userBudget):
        totalWeight = totalWeight + budgetWeight

    if(totalCalories<= userCalories):
        totalWeight = totalWeight + calorieWeight

    return totalWeight
```

Figure 3 Fitness function Implementation

The **fitness function** determines how fit an individual is. it calculates **fitness score** for each individual. The probability that an individual (meal) will be selected for reproduction is based on its **fitness score**, the higher the score is, the closer to optimal solution [1].

The **fitness score** calculated based on the TYPE, CALORIES and PRICE. The item type and budget are equally important, and the calories is half important.

The fitness function designed as weighted sum and $\sum w = 1$. So:

TYPE = 0.4

PRICE = 0.4

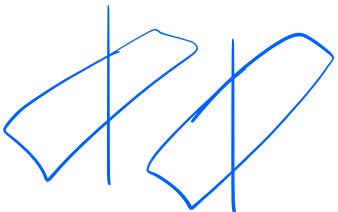
CALORIES = 0.2

To implement the code, we use if statement and loop to ensure that:

1. Vegan individuals can choose only vegan items.
2. Vegetarian individuals can choose vegan or vegetarian items.
3. People with no dietary preferences can choose vegan, vegetarian and/or regular items.
4. The sum of price and sum of calories should be less than or equals than the user entered.

5. Genetic operators:

i. Crossover.




```
def Crossover(Parmeal1 , parmeal2 , crosspoint):  
    i = crosspoint  
    while (i <= 4):  
        temp = Parmeal1[i].copy()  
        Parmeal1[i] = parmeal2[i].copy()  
        parmeal2[i] = temp  
        i = i + 1  
  
    return [Parmeal1 , parmeal2]
```

Figure 4 Crossover Implementation

The crossover operator is analogous to reproduction and biological crossover.

In crossover, more than one parent is selected, and more than offspring are produced using the genetic material of the parents. Crossover in the GA is applied on most of the generations produced. In order to produce new offspring, random crossover point is selected and the tails of the two parents are swapped to get new off-springs. As shown in Figure 5, we combine the genetic information of two parents, the crossover point selected depending on a random number.



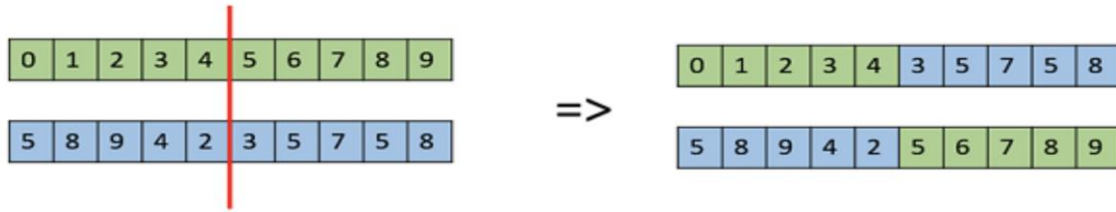


Figure 5 Crossover [2]

ii. Mutation.

```
def mutation(Parent):
    rand_meal = random.randint(0, pop_size-1)
    rand_dish = random.randint(0, 4)
    Parent[rand_dish] = initial_population[rand_meal][rand_dish].copy()
    return Parent
```

Figure 6 Mutation Implementation

Mutation is a GA operator and low number of individuals genes can be subjected to a **mutation**. **mutation** is the process of randomly change one of the genes in the chromosome [1]. In our case, we change one dish in the meal by a random dish from the population.

Using a random number to choose what gene will be changed

Ex: random number = 2

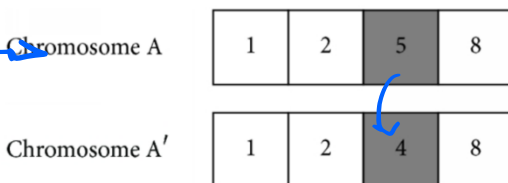


Figure 7 mutation example

iii. Selection by roulette wheel selection.

```
def roulette_wheel(fitnesses):  
    totalFitnesses = sum(fitnesses)  
    random_number = random.uniform(0, totalFitnesses)  
    p = 0.0 # partial sum  
    index = 0  
    for item in fitnesses:  
        p = p + item  
        if(p >= random_number):  
            return index  
        index = index + 1
```

Figure 8 Roulette wheel Implementation

Roulette wheel selection is a method used to select individuals from the population to form the next generation base. Using Roulette wheel method in GA results in improving the generations where in every iteration we choose the potentially useful individuals. The probability to select an individual by Roulette wheel is calculated by dividing the individual fitness over the sum of generation fitness, the individual fitness is directly related with the probability to be selected. As shown in Figure 9, the individual that has high fitness, has the largest share of the roulette wheel, and accordingly has the highest chance to be selected by the selection point. Roulette wheel selection implemented in the GA code as shown in Figure 8.

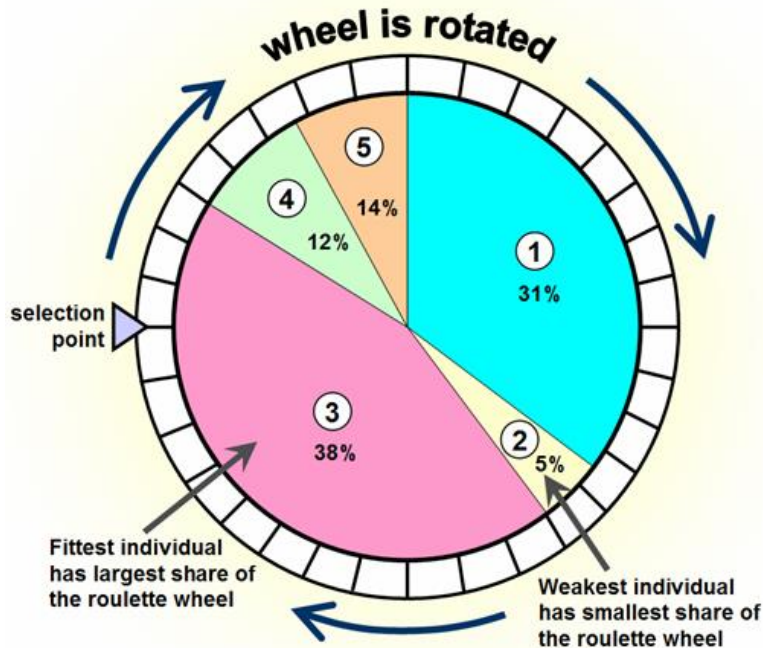


Figure 9 Roulette Wheel [3]

iv. Replacement.

```
def replacement (parent , child):  
    for item in initial_population:  
        if(item == parent):  
            initial_population.remove(parent)  
            initial_population.append(child)
```

Figure 10 Replacement Implementation

Replacement method is the final step where the old "parent" is replaced with the new generated "child" if the child fitness is better than the parent.

Experiment setup:

We chose the following inputs to be as the user inputs:

- Meal type: Vegetarian.
- Calories: 1100.
- Budget: 250 SR.

GA parameters:

Population size	50	100	150
Crossover rate	0.9	0.85	0.8
Mutation rate	0.2	0.25	0.3

Crossover rate: we chose the highest rate because we need to crossover most of the time to improve the generation.

Mutation rate: the lowest the better since its increase the randomness

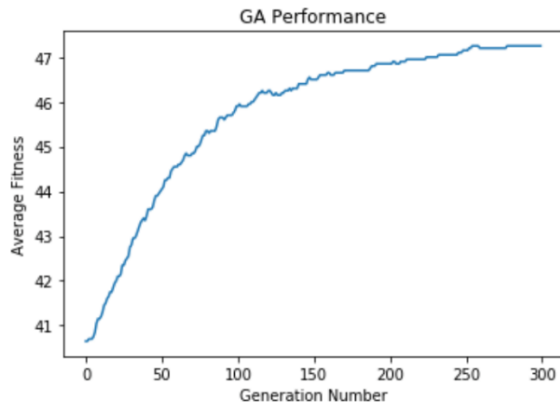
Population size: we chose population size as multiple of 10 with suitable difference between them.

1)

Population Size:50

Crossover rate:0.9

Mutation rate:0.2



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	DESSERT	Almond Delight	509.0	Vegan	42
1	HOT DRINK	Hot Chocolate	350.0	Vegetarian	21
2	COLD DRINK	Blueberry Mojito	136.0	Vegan	30

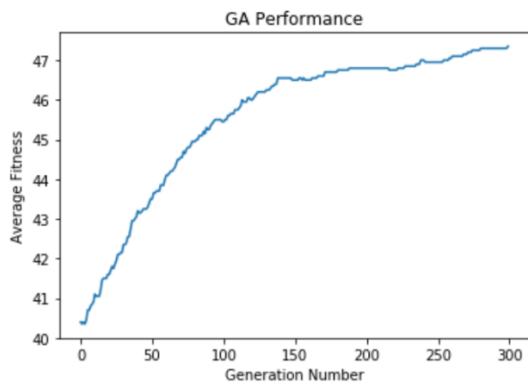
The fitness value of the meal: 1.0
The meal price: 93.0 SR
The meal calories: 995.0 Calories

2)

Population Size:50

Crossover rate:0.9

Mutation rate:0.25



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	DESSERT	Classic Cheesecake	798.0	Vegetarian	64
1	HOT DRINK	Macchiato	250.0	Vegetarian	20
2	COLD DRINK	Diet Pepsi	0.0	Vegan	10

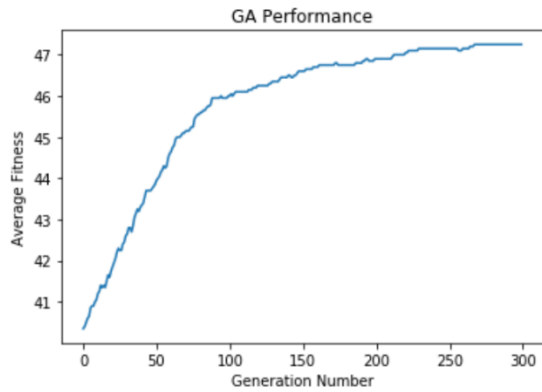
The fitness value of the meal: 1.0
The meal price: 94.0 SR
The meal calories: 1048.0 Calories

3)

Population Size:50

Crossover rate:0.9

Mutation rate:0.3



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	STARTER	Lentil soup	290.0	Vegan	26
1	DESSERT	Chocolate Brownie	580.0	Vegetarian	57
2	HOT DRINK	Espresso	9.0	Vegan	13
3	COLD DRINK	Mirinda	90.0	Vegan	10

The fitness value of the meal: 1.0

The meal price: 106.0 SR

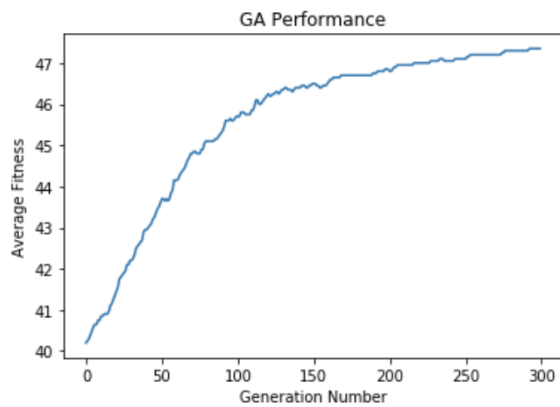
The meal calories: 969.0 Calories

4)

Population Size:50

Crossover rate:0.85

Mutation rate:0.2



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	STARTER	Burrata salad	360.0	Vegetarian	65
1	DESSERT	Mango & Passion Fruit Crèmeux	498.0	Vegetarian	34
2	HOT DRINK	Americano	15.0	Vegan	18
3	COLD DRINK	Mirinda	90.0	Vegan	10

The fitness value of the meal: 1.0

The meal price: 127.0 SR

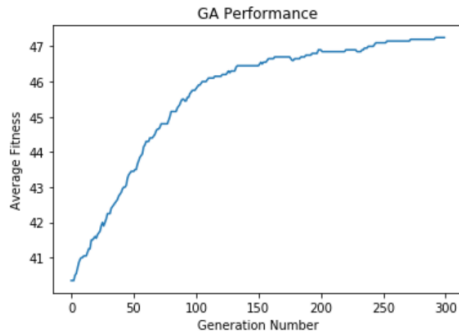
The meal calories: 963.0 Calories

5)

Population Size:50

Crossover rate:0.85

Mutation rate:0.25



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	STARTER	Baked eggplant	270.0	Vegan	36
1	DESSERT	Almond Delight	509.0	Vegan	42
2	HOT DRINK	Macchiato	250.0	Vegetarian	20
3	COLD DRINK	Large Water	0.0	Vegan	10

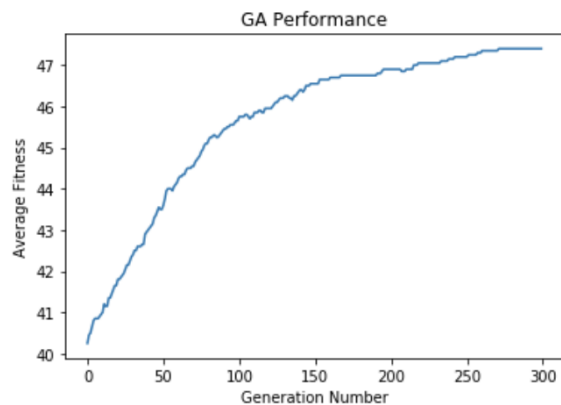
The fitness value of the meal: 1.0
The meal price: 108.0 SR
The meal calories: 1029.0 Calories

6)

Population Size:50

Crossover rate:0.85

Mutation rate:0.3



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	STARTER	Quinoa salad	320.0	Vegan	36
1	DESSERT	Millefeuille	296.0	Vegetarian	52
2	HOT DRINK	Cappuccino	120.0	Vegetarian	19
3	COLD DRINK	Blueberry Mojito	136.0	Vegan	30

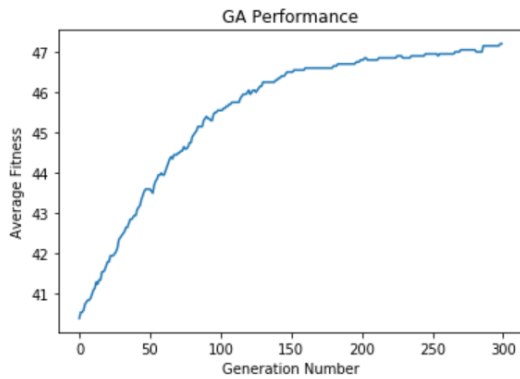
The fitness value of the meal: 1.0
The meal price: 137.0 SR
The meal calories: 872.0 Calories

7)

Population Size:50

Crossover rate:0.8

Mutation rate:0.2



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	DESSERT	Chocolate Brownie	580.0	Vegetarian	57
1	HOT DRINK	Black tea	0.0	Vegan	15
2	COLD DRINK	Mirinda	90.0	Vegan	10

The fitness value of the meal: 1.0

The meal price: 82.0 SR

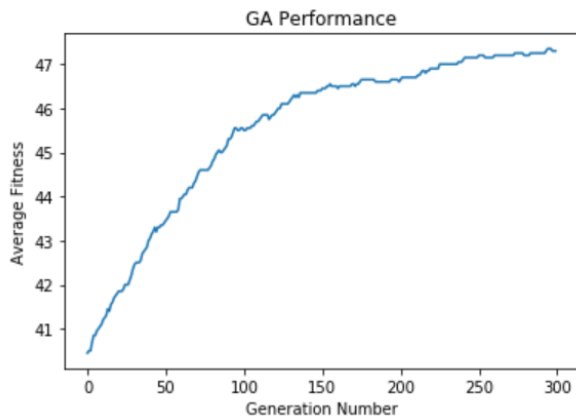
The meal calories: 670.0 Calories

8)

Population Size:50

Crossover rate:0.8

Mutation rate:0.25



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	STARTER	Fish cake	480.0	Vegetarian	60
1	DESSERT	Vegan coconut ice cream	520.0	Vegan	25
2	HOT DRINK	Green tea	0.0	Vegan	15
3	COLD DRINK	Small Water	0.0	Vegan	10

The fitness value of the meal: 1.0

The meal price: 110.0 SR

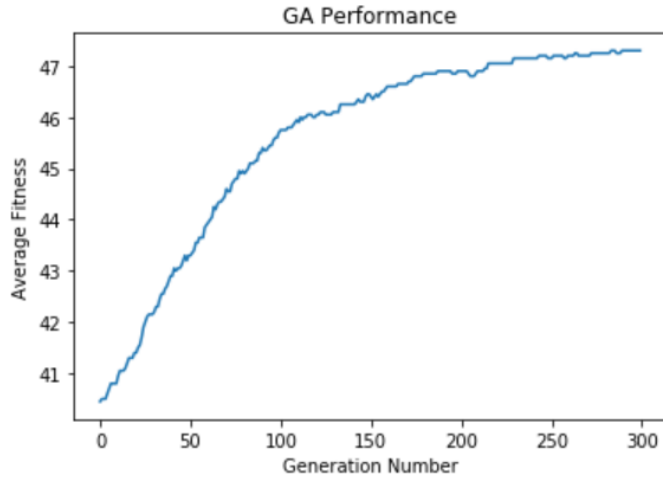
The meal calories: 1000.0 Calories

9)

Population Size:50

Crossover rate:0.8

Mutation rate:0.3



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	DESSERT	Almond pistachio croissant	533.0	Vegan	52
1	HOT DRINK	Espresso	9.0	Vegan	13
2	COLD DRINK	Tropical Juice	340.0	Vegan	25

The fitness value of the meal: 1.0

The meal price: 90.0 SR

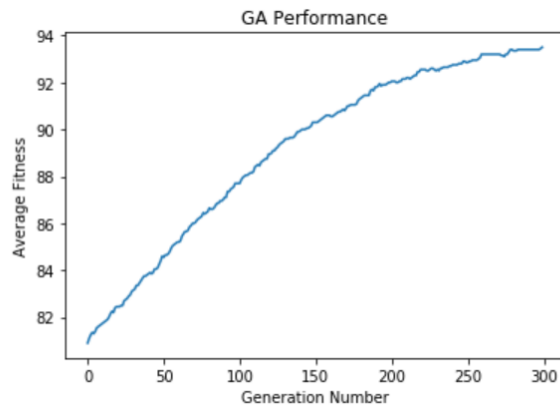
The meal calories: 882.0 Calories

10)

Population Size:100

Crossover rate:0.9

Mutation rate:0.2



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	STARTER	Burrata salad	360.0	Vegetarian	65
1	DESSERT	Signature Apricot almond tart	334.0	Vegan	68
2	HOT DRINK	Cappuccino	120.0	Vegetarian	19
3	COLD DRINK	Diet Pepsi	0.0	Vegan	10

The fitness value of the meal: 1.0

The meal price: 162.0 SR

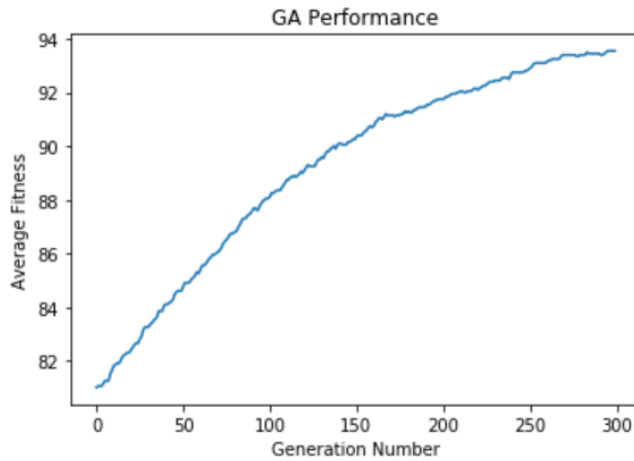
The meal calories: 814.0 Calories

11)

Population Size:100

Crossover rate:0.9

Mutation rate:0.25



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	DESSERT	Vegan coconut ice cream	520.0	Vegan	25
1	HOT DRINK	Macchiato	250.0	Vegetarian	20
2	COLD DRINK	7up	120.0	Vegan	10

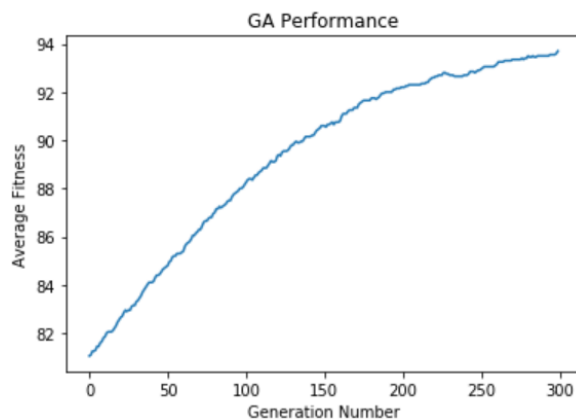
The fitness value of the meal: 1.0
The meal price: 55.0 SR
The meal calories: 890.0 Calories

12)

Population Size:100

Crossover rate:0.9

Mutation rate:0.3



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	DESSERT	Assorted fruits platter	238.0	Vegan	22
1	HOT DRINK	Black tea	0.0	Vegan	15
2	COLD DRINK	Strawberry milkshake	210.0	Vegetarian	20

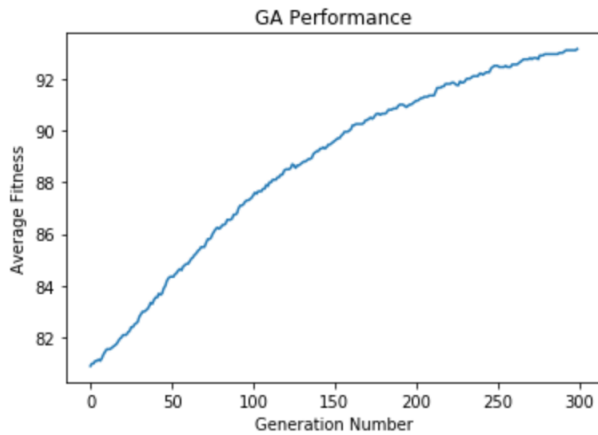
The fitness value of the meal: 1.0
The meal price: 57.0 SR
The meal calories: 448.0 Calories

13)

Population Size:100

Crossover rate:0.85

Mutation rate:0.2



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	STARTER	Baked eggplant	270.0	Vegan	36
1	DESSERT	Assorted fruits platter	238.0	Vegan	22
2	HOT DRINK	Green tea	0.0	Vegan	15
3	COLD DRINK	Orange Juice	130.0	Vegan	16

The fitness value of the meal: 1.0

The meal price: 89.0 SR

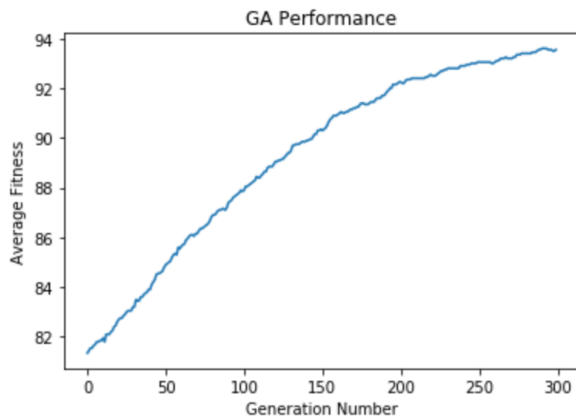
The meal calories: 638.0 Calories

14)

Population Size:100

Crossover rate:0.85

Mutation rate:0.25



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	STARTER	Lentil soup	290.0	Vegan	26
1	DESSERT	Date Pudding	322.0	Vegetarian	38
2	HOT DRINK	Green tea	0.0	Vegan	15
3	COLD DRINK	Raspberry Mojito	129.4	Vegan	28

The fitness value of the meal: 1.0

The meal price: 107.0 SR

The meal calories: 741.4 Calories

15)

Population Size:100

Crossover rate:0.85

Mutation rate:0.3



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	DESSERT	Millefeuille	296.0	Vegetarian	52
1	HOT DRINK	Macchiato	250.0	Vegetarian	20
2	COLD DRINK	Ice Latte	160.0	Vegetarian	18

The fitness value of the meal: 1.0

The meal price: 90.0 SR

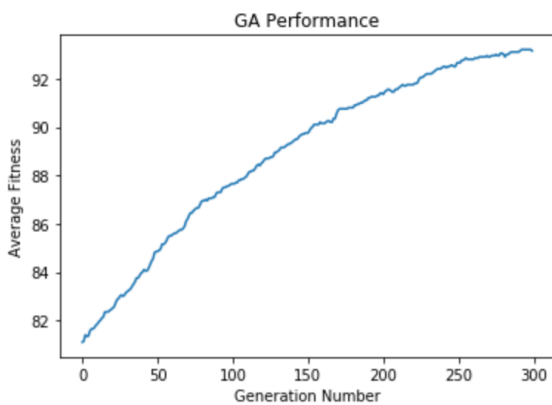
The meal calories: 706.0 Calories

16)

Population Size:100

Crossover rate:0.8

Mutation rate:0.2



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	STARTER	Kale salad	280.0	Vegan	38
1	DESSERT	Chocolate Fondant	587.0	Vegetarian	45
2	HOT DRINK	Green tea	0.0	Vegan	15
3	COLD DRINK	Ice Latte	160.0	Vegetarian	18

The fitness value of the meal: 1.0

The meal price: 116.0 SR

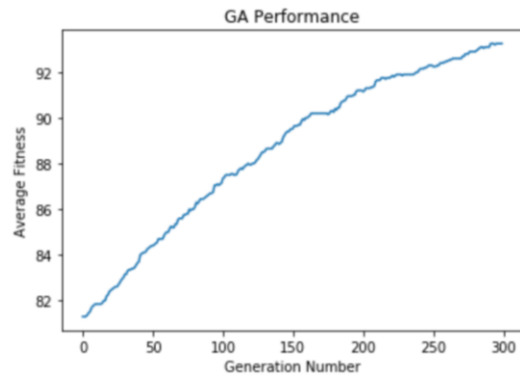
The meal calories: 1027.0 Calories

17)

Population Size:100

Crossover rate:0.8

Mutation rate:0.25



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	STARTER	Hummus and bread	620.0	Vegan	28
1	DESSERT	Signature Apricot almond tart	334.0	Vegan	68
2	HOT DRINK	Cappuccino	120.0	Vegetarian	19
3	COLD DRINK	Large Water	0.0	Vegan	10

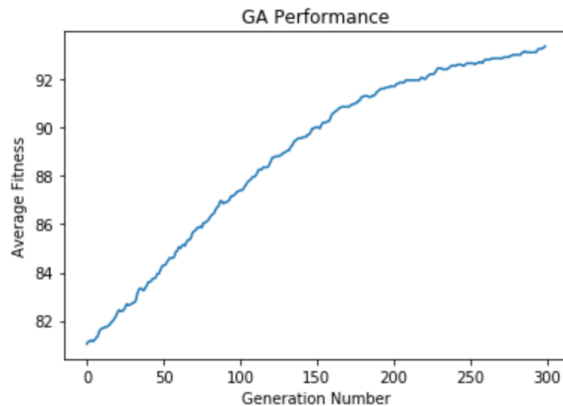
The fitness value of the meal: 1.0
The meal price: 125.0 SR
The meal calories: 1074.0 Calories

18)

Population Size:100

Crossover rate:0.8

Mutation rate:0.3



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	STARTER	Lentil soup	290.0	Vegan	26
1	DESSERT	Carrot Cake	290.0	Vegetarian	26
2	HOT DRINK	Green tea	0.0	Vegan	15
3	COLD DRINK	Raspberry Mojito	129.4	Vegan	28

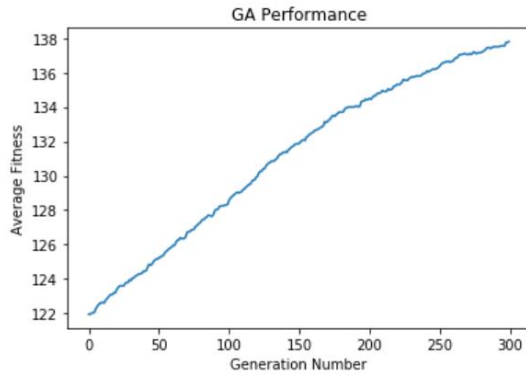
The fitness value of the meal: 1.0
The meal price: 95.0 SR
The meal calories: 709.4 Calories

19)

Population Size:150

Crossover rate:0.9

Mutation rate:0.2



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	STARTER	Hummus and bread	620.0	Vegan	28
1	DESSERT	Signature Apricot almond tart	334.0	Vegan	68
2	HOT DRINK	Espresso	9.0	Vegan	13
3	COLD DRINK	Small Water	0.0	Vegan	10

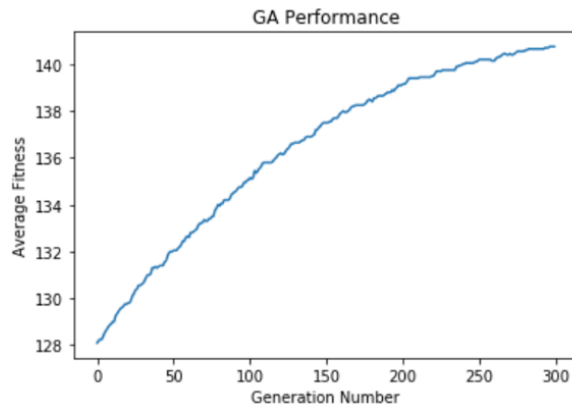
The fitness value of the meal: 1.0
The meal price: 119.0 SR
The meal calories: 963.0 Calories

20)

Population Size:150

Crossover rate:0.9

Mutation rate:0.25



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	STARTER	Fish cake	480.0	Vegetarian	60
1	DESSERT	Date Pudding	322.0	Vegetarian	38
2	HOT DRINK	Cafe Latte	190.0	Vegetarian	19
3	COLD DRINK	Mirinda	90.0	Vegan	10

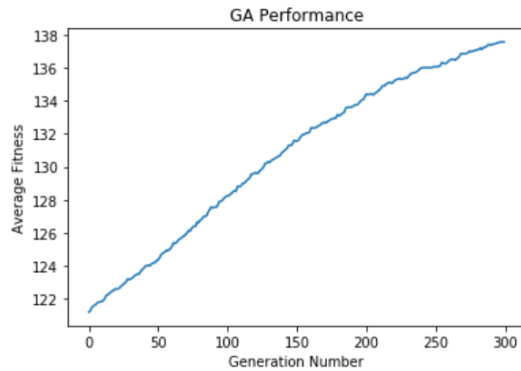
The fitness value of the meal: 1.0
The meal price: 127.0 SR
The meal calories: 1082.0 Calories

21)

Population Size:150

Crossover rate:0.9

Mutation rate:0.3



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	DESSERT	Chocolate Fondant	587.0	Vegetarian	45
1	HOT DRINK	Black tea	0.0	Vegan	15
2	COLD DRINK	Diet Pepsi	0.0	Vegan	10

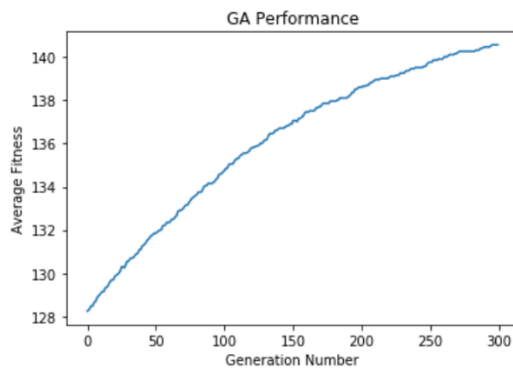
The fitness value of the meal: 1.0
The meal price: 70.0 SR
The meal calories: 587.0 Calories

22)

Population Size:150

Crossover rate:0.85

Mutation rate:0.2



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	STARTER	Baked eggplant	270.0	Vegan	36
1	DESSERT	Millefeuille	296.0	Vegetarian	52
2	HOT DRINK	Macchiato	250.0	Vegetarian	20
3	COLD DRINK	Orange Juice	130.0	Vegan	16

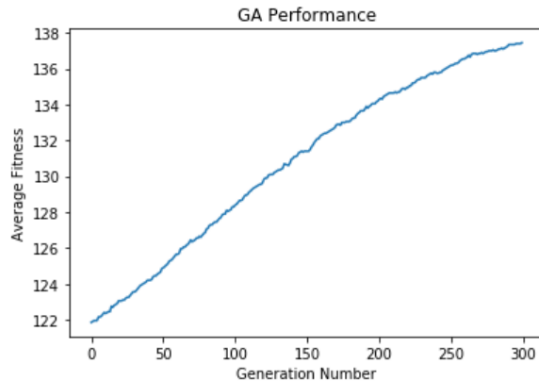
The fitness value of the meal: 1.0
The meal price: 124.0 SR
The meal calories: 946.0 Calories

23)

Population Size:150

Crossover rate:0.85

Mutation rate:0.25



CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	DESSERT Assorted fruits platter	238.0	Vegan	22
1	HOT DRINK Black tea	0.0	Vegan	15
2	COLD DRINK Large Water	0.0	Vegan	10

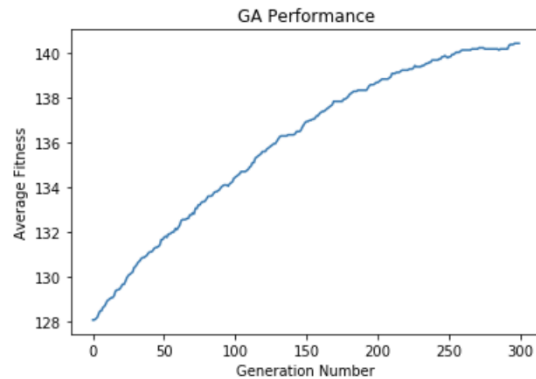
The fitness value of the meal: 1.0
The meal price: 47.0 SR
The meal calories: 238.0 Calories

24)

Population Size:150

Crossover rate:0.85

Mutation rate:0.3



CATEGORY	ITEM	CALORIES	TYPE
0	STARTER Baked eggplant	270.0	Vegan
1	DESSERT Coconut and almond vanilla tart	320.0	Vegan
2	HOT DRINK Macchiato	250.0	Vegetarian
3	COLD DRINK Small Water	0.0	Vegan

PRICE (SR)
0 36
1 45
2 20
3 10

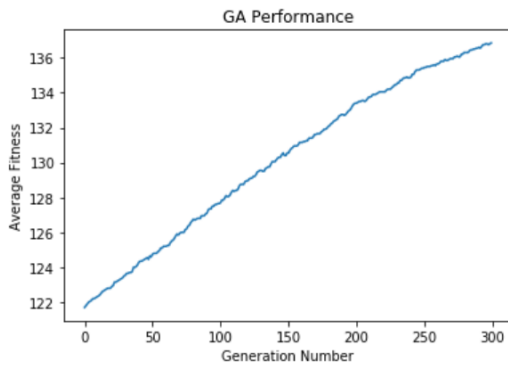
The fitness value of the meal: 1.0
The meal price: 111.0 SR
The meal calories: 840.0 Calories

25)

Population Size:150

Crossover rate:0.8

Mutation rate:0.2



	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	STARTER	Baked eggplant	270.0	Vegan	36
1	DESSERT	Signature Apricot almond tart	334.0	Vegan	68
2	HOT DRINK	Americano	15.0	Vegan	18
3	COLD DRINK	Small Water	0.0	Vegan	10

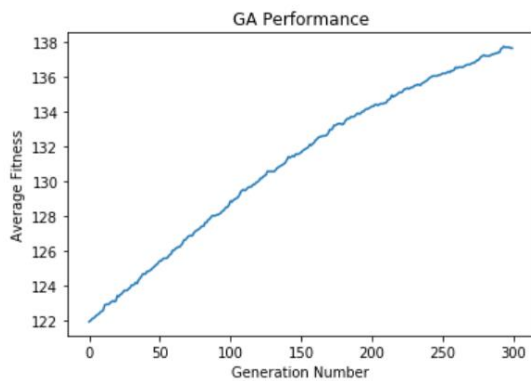
The fitness value of the meal: 1.0
The meal price: 132.0 SR
The meal calories: 619.0 Calories

26)

Population Size:150

Crossover rate:0.8

Mutation rate:0.25



	CATEGORY	ITEM	CALORIES	TYPE
0	DESSERT	Coconut and almond vanilla tart	320.0	Vegan
1	HOT DRINK	Hot Chocolate	350.0	Vegetarian
2	COLD DRINK	Diet Pepsi	0.0	Vegan

PRICE (SR)

0	45
1	21
2	10

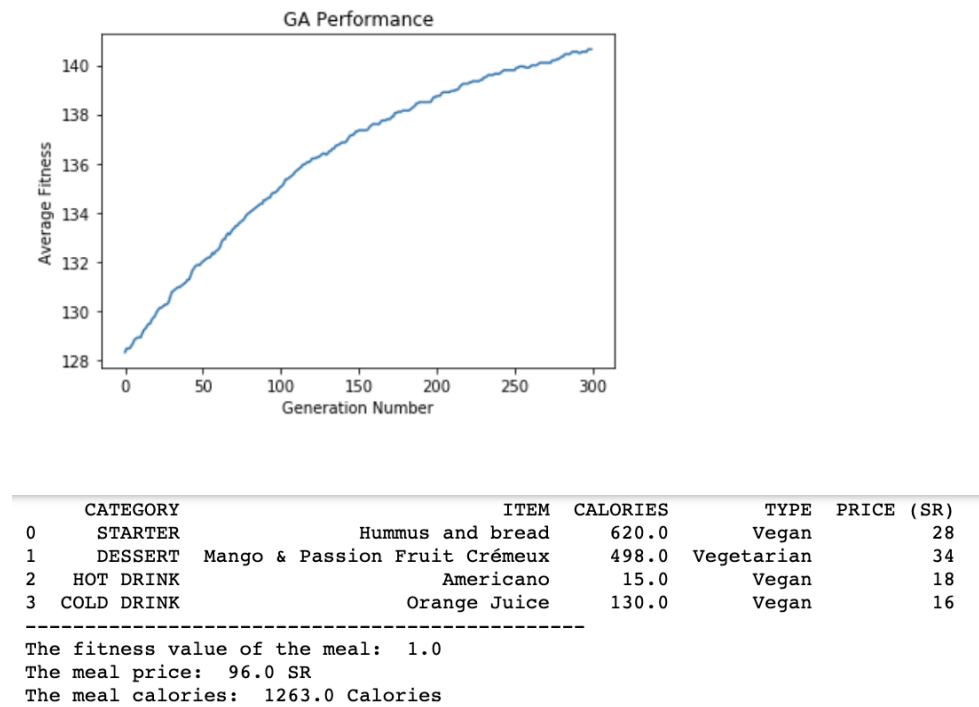
The fitness value of the meal: 1.0
The meal price: 76.0 SR
The meal calories: 670.0 Calories

27)

Population Size:150

Crossover rate:0.8

Mutation rate:0.3



6. Analysis of results

According to the 27 combinations we have done before to find the best meal that fits customer's needs which are food type, calories and price we found that all meals resulted have 1 as a fitness value, so we decided to find the meal that have highest number of dishes and lowest price. The meal is:

	CATEGORY	ITEM	CALORIES	TYPE	PRICE (SR)
0	STARTER	Baked eggplant	270.0	Vegan	36
1	DESSERT	Assorted fruits platter	238.0	Vegan	22
2	HOT DRINK	Green tea	0.0	Vegan	15
3	COLD DRINK	Orange Juice	130.0	Vegan	16

The fitness value of the meal: 1.0
The meal price: 89.0 SR
The meal calories: 638.0 Calories

This meal fits the user needs, as the user is vegetarian, all dishes are suit the user type, also the price and calories. This meal is the result of the following combination:

Population Size:100
Crossover rate:0.85
Mutation rate:0.2

From the results of running genetic algorithms with various population size, crossover rate and mutation rate, the following assumptions can be made:

1. In order to making a good fitness choice, the other parameters of the genetic algorithm, such as population size, mutation and crossover rate, must be carefully selected as they have a high impact of the results.
2. A minimal population size will not give the Genetic Algorithm sufficient solution space to produce accurate results.
3. A higher population size will give the Genetic Algorithm sufficient solution space to produce accurate results.
4. The higher the crossover rate, the smaller the Wiggle of the average fitness of the generations.
5. The higher the mutation rate, the higher the Wiggle of the average fitness of the generations

References:

- [1] V. Mallawaarachchi, "towards Data science," 8 Jul 2017. [Online]. Available: <https://towardsdatascience.com/introduction-to-genetic-algorithms-including-example-codee396e98d8bf3>.
- [2] Tutorialspoint.com. 2020. *Genetic Algorithms - Crossover - Tutorialspoint*. [online] Available at: <https://www.tutorialspoint.com/genetic_algorithms/genetic_algorithms_crossover.htm
- [3] JAD, 2., 2020. *GA Roulette Wheel Selection*. [online] Edc.ncl.ac.uk. Available at: <<http://www.edc.ncl.ac.uk/highlight/rhjanuary2007g02.php>> [Accessed 22 November 2020].