

TSP with Genetic Algorithm

November 6, 2021

1 Getting input

saving Adjacency matrix with weight of edges

```
[2]: graph = []
n = int(input("Number of cities: "))

for i in range(n):
    l = [0 for i in range(n)]
    graph.append(l)

l=list(map(int, input().split()))
cnt = 0
for i in range(n-1):
    for j in range(n-1-i):
        graph[i][j+i+1] = l[cnt]
        graph[j+i+1][i] = l[cnt]
        cnt += 1

#sample view
for i in range(4):
    for j in range(4):
        print(graph[i][j], end=' ')
    print('\n')
```

Number of cities: 29

```
97 205 139 86 60 220 65 111 115 227 95 82 225 168 103 266 205 149 120 58
257 152 52 180 136 82 34 145 129 103 71 105 258 154 112 65 204 150 87 176
137 142 204 148 148 49 41 211 226 116 197 89 153 124 74 219 125 175 386 269
134 184 313 201 215 267 248 271 274 236 272 160 151 300 350 239 322 78 276 220
60 167 182 180 162 208 39 102 227 60 86 34 96 129 69 58 60 120 119 192
114 110 192 136 173 173 51 296 150 42 131 268 88 131 245 201 175 275 218 202
119 50 281 238 131 244 51 166 95 69 279 114 56 150 278 46 133 266 214 162
302 242 203 146 67 300 205 111 238 98 139 52 120 178 328 206 147 308 172 203
165 121 251 216 122 231 249 209 111 169 72 338 144 237 331 169 151 227 133 104
242 182 84 290 230 146 165 121 270 91 48 158 200 39 64 210 172 309 68 169
286 242 208 315 259 240 160 90 322 260 160 281 57 192 107 90 140 195 51 117
```

```

72 104 153 93 88 25 85 152 200 104 139 154 134 149 135 320 146 64 68 143
106 88 81 159 219 63 216 187 88 293 191 258 272 174 311 258 196 347 288 243
192 113 345 222 144 274 124 165 71 153 144 86 57 189 128 71 71 82 176 150
56 114 168 83 115 160 61 165 51 32 105 127 201 36 254 196 136 260 212 258
234 106 110 56 49 91 153 91 197 136 94 225 151 201 205 215 159 64 126 128
190 98 53 78 218 48 127 214 61 155 157 235 47 305 243 186 282 261 300 252
105 100 176 66 253 183 146 231 203 239 204 113 152 127 150 106 52 235 112 179
221 79 163 220 119 164 135 152 153 114 236 201 90 195 90 127 84 91 273 226
148 296 238 291 269 112 130 286 74 155 291 130 178 38 75 180 281 120 205 270
213 145 36 94 217 162
0 97 205 139

97 0 129 103

205 129 0 219

139 103 219 0

```

2 Creating random chromosomes

generating a random permutation

```

[3]: import random
def first_population(number_of_samples, size):
    l = []
    for i in range(number_of_samples):
        chromosome = []
        for j in range(size):
            a = random.randint(0,size-1)
            while a in chromosome:
                a = random.randint(0,size-1)
            chromosome.append(a)
        l.append(chromosome)
    return l

first_population(3,5)

```

```

[3]: [[0, 4, 1, 2, 3], [1, 2, 0, 4, 3], [1, 2, 4, 3, 0]]

```

3 Fitness function (sum of weights in chromosome path)

```
[4]: def fitness(chromosome):  
    w = 0  
    for i in range(len(chromosome)):  
        w += graph[chromosome[i]][chromosome[(i+1) % len(chromosome)]]  
    return w  
  
chromosome = first_population(1,29)[0]  
print(chromosome)  
print(fitness(chromosome))
```

```
[24, 5, 1, 8, 18, 2, 20, 9, 4, 22, 25, 13, 11, 6, 3, 10, 14, 16, 23, 15, 7, 17,  
0, 26, 28, 27, 12, 21, 19]  
5091
```

4 Cross over(ordered crossover)

```
[40]: def cross_over(parent1, parent2):  
  
    size = len(parent1)  
    # result  
    res = [-1 for i in range(size)]  
    a = random.randint(0, size-1)  
    b = -1  
    while b == a or b == -1:  
        b = random.randint(0, size-1)  
    if (a > b):  
        a, b = b, a  
    # putting parent1 genes  
    i = a  
    while i != b:  
        res[i] = parent1[i]  
        i = (i + 1) % size  
  
    # putting parent2 genes  
    cnt = 0  
    i = b  
    while cnt < size:  
  
        if parent2[cnt] not in res:  
            res[i] = parent2[cnt]  
            i = (i + 1) % size  
        cnt += 1
```

```

        return res
parents = first_population(2,5)
print(parents)
print(cross_over(parents[0], parents[1]))

```

```

[[4, 3, 1, 2, 0], [3, 4, 0, 1, 2]]
[0, 3, 1, 2, 4]

```

5 Mutation

```

[6]: def mutation(chromosome, mutation_rate):
        for i in range(len(chromosome)):
            if (random.random() < mutation_rate):
                x = random.randint(0, len(chromosome)-1)
                # swap:
                chromosome[i], chromosome[x] = chromosome[x], chromosome[i]
        return chromosome

print(mutation([1,2,3,4,5], 0.5))

```

```

[3, 5, 4, 1, 2]

```

6 Main Function

in every iteration i printed the two best answers (weight) in next experiments they are comment(so there is no more printing just showing the plot...) at first my answers didn't converge to anything and the plot was like a sin(x) graph. (the first examines were like second plot below. then i tried to change numbers but nothing changed. first tries were something like *genetic(100, 100, 0.1, 20)* and *genetic(1000, 100, 0.5, 20)* and ...) *genetic(iterations, population_number, mutation_rate, elite_size)*

then i radically changed almost everything to be more stable like below: *genetic(100, 1000, 0.01, 100)* mutation rate was 10times bigger and elite size was 10times smaller... and you can see the result plot that finally converged!

```

[43]: import matplotlib.pyplot as plt
def reverse(l):
    return float(1) / float(1)

def genetic(iterations, population_number, mutation_rate, elite_size):
    population = first_population(population_number, n)
    progress = []
    for i in range(iterations):

```

```

print(i)
population.sort(key = fitness)
print(fitness(population[0]), fitness(population[1]))
progress.append(fitness(population[0]))
child = []
# moving elites to next generation
for j in range(elite_size):
    child.append(population[j])

# selection based on fitness(normalize fitness)
select = []
normalized_fitness = [(reverse(fitness(j))) for j in population]
reversed(population)
sum_fitness = sum(normalized_fitness)
while(len(select) < population_number - elite_size):
    for j in range(population_number):
        if (random.random() < normalized_fitness[j] / sum_fitness):
            select.append(population[j])
# making new child from selected parents
j = 0
#print(select)
while (len(child) < population_number):
    child.append(cross_over(select[j], select[len(select) - 1 - j]))
    j = (j + 1) % len(select)
# mutate next generation
for j in range(population_number):
    child[j] = mutation(child[j], mutation_rate)
population = child

population.sort(key = fitness)
print(population[0], fitness(population[0]))

plt.plot(progress)
plt.ylabel('Distance')
plt.xlabel('Generation')
plt.show()

genentic(100, 1000, 0.01, 100)

```

```

0
3765 3770
1
3621 3622
2
3549 3577
3
3447 3462

```

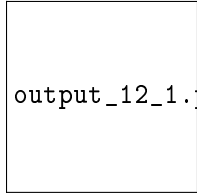
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3230 3447
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3230 3403
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3230 3281
7
3282 3334
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3282 3334
9
3166 3282
10
3132 3166
11
3001 3132
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2732 2812
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2732 2812
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2812 2863
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2799 2809

28
2747 2799
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2747 2809
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2747 2809
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2747 2777
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2747 2752
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2747 2765
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2776 2777
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2776 2777
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2106 2156
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2007 2146
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```
[2, 25, 8, 28, 19, 1, 9, 20, 12, 3, 14, 10, 21, 17, 16, 13, 18, 24, 6, 22, 23,  
15, 26, 7, 0, 27, 11, 5, 4] 2007
```



output_12_1.png

```
[44]: genentic(100, 1000, 0.1, 20)
```

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0  
3612 3678  
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3495 3610  
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3343 3546  
3  
3445 3469  
4  
3591 3606  
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3450 3560  
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3556 3560  
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3342 3358  
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3542 3572  
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3437 3460  
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3417 3444  
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3466 3515  
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3573 3598  
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3343 3432  
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3560 3579  
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3490 3648  
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3238 3415
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3246 3471
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3238 3246
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3492 3555
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3638 3689
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3650 3686
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3410 3546
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3427 3482
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3524 3584
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3586 3608
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3430 3572
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3532 3669
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3543 3596
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3633 3653
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3493 3588
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3365 3509
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3483 3659
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3481 3596
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3579 3631
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3401 3549
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3260 3598
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3330 3539
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3540 3569
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3577 3595
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3532 3676

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3562 3564
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3147 3549
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3131 3415
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3305 3453
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3443 3474
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3501 3633
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3434 3522
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3387 3499
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3174 3512
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3500 3556
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3382 3397
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3516 3594
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3662 3710
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3526 3640
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3452 3627
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3546 3673
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3559 3662
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3523 3605
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3547 3684
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3318 3360

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3456 3458
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3436 3556
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3377 3557
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3631 3640
94
3386 3497
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3520 3570
96
3494 3609
97
3442 3482
98
3428 3544
99
3533 3606
[22, 8, 27, 10, 21, 13, 16, 17, 18, 28, 20, 11, 15, 0, 3, 4, 19, 12, 14, 23, 1,
2, 25, 5, 9, 6, 24, 7, 26] 3503

```

output_13_1.png

now i take the iterations from 100 to 500 because in the last plot it seems to be decreasing in the future iterations! this time running time of code was very longer but answer didn't change a lot.

```

[48]: def genetic_just_plot(iterations, population_number, mutation_rate, elite_size):
    population = first_population(population_number, n)
    progress = []
    for i in range(iterations):
        #print(i)
        population.sort(key = fitness)
        #print(fitness(population[0]), fitness(population[1]))
        progress.append(fitness(population[0]))
        child = []
        # moving elites to next generation
        for j in range(elite_size):

```

```

        child.append(population[j])

        # selection based on fitness(normalize fitness)
        select = []
        normalized_fitness = [(reverse(fitness(j))) for j in population]
        reversed(population)
        sum_fitness = sum(normalized_fitness)
        while(len(select) < population_number - elite_size):
            for j in range(population_number):
                if (random.random() < normalized_fitness[j] / sum_fitness):
                    select.append(population[j])
        # making new child from selected parents
        j = 0
        #print(select)
        while (len(child) < population_number):
            child.append(cross_over(select[j], select[len(select) - 1 - j]))
            j = (j + 1) % len(select)
        # mutate next generation
        for j in range(population_number):
            child[j] = mutation(child[j], mutation_rate)
        population = child

    population.sort(key = fitness)

    plt.plot(progress)
    plt.ylabel('Distance')
    plt.xlabel('Generation')
    plt.show()

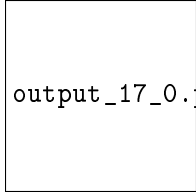
genentic_just_plot(500, 1000, 0.01, 100)

```

output_15_0.png

so this time i changed the number of iterations back to first value and increased the size of population

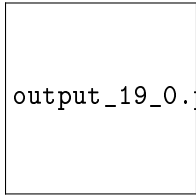
```
[49]: genentic_just_plot(100, 2000, 0.01, 100)
```



output_17_0.png

this time i changed the mutation rate to 10times smaller and this time was the best answer so far!

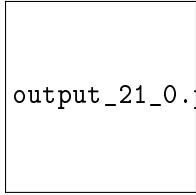
```
[50]: genentic_just_plot(100, 1000, 0.001, 100)
```



output_19_0.png

and now increasing the elite size x2.even beat the previous result!

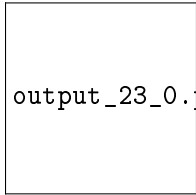
```
[51]: genentic_just_plot(100, 1000, 0.001, 200)
```



output_21_0.png

elite2 *and iteratio*2 again better result!

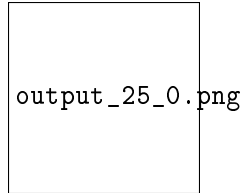
```
[52]: genentic_just_plot(200, 1000, 0.001, 400)
```



output_23_0.png

I end my exprience with this plot that looks like a human face :)) and i think it can't get better result...


```
[57]: genetic_just_plot(500, 1000, 0.001, 400)
```



```
[59]: genetic(500, 1000, 0.001, 400)
```

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0
3642 3753
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3642 3670
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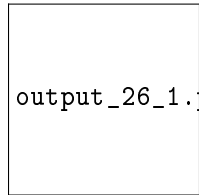
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this is my approximate answer for bayg29