TSP_Anealing_Personal

February 26, 2023

[ ]:
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'''
Resources:
https://towardsdatascience.com/
↪how-to-solve-the-traveling-salesman-problem-a-comparative-analysis-39056a916c9f
https://github.com/syakoo/simulated-annealing
https://towardsdatascience.com/
↪how-to-solve-travelling-salesman-problem-with-simulated-annealing-c248447a8bcd
https://towardsdatascience.com/simulated-annealing-with-restart-a19a53d914c8
https://github.com/jedrazb/python-tsp-simulated-annealing
https://en.wikipedia.org/wiki/2-opt

'''

import math
import random
import numpy as np
import pandas as pd
import plotly.express as px
from plotly.subplots import make_subplots
import plotly.graph_objects as go
import os
import matplotlib.pyplot as plt
class tsp_utils:
    #Convert coordant information into distance matrix commonly used in TSP␣
↪Problems
    def vectorToDistMatrix(coords):
        '''
        Create the distance matrix
        '''
        return np.sqrt((np.square(coords[:, np.newaxis] - coords).sum(axis=2)))


    def nearestNeighbourSolution(dist_matrix):
        '''
        Computes the initial solution (nearest neighbour strategy)
        '''
        #grabs random node in the size of the matrix
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        node = random.randrange(len(dist_matrix))
        #stores node in result list
        result = [node]
        #sets nodes to visit equal to the size of the distance matrix
        nodes_to_visit = list(range(len(dist_matrix)))
        #removes first node
        nodes_to_visit.remove(node)
        #goes through and tries to find the nearest neighbour for every node
        while nodes_to_visit:
            nearest_node = min([(dist_matrix[node][j], j) for j in␣
 ↪nodes_to_visit], key=lambda x: x[0])
            node = nearest_node[1]
            nodes_to_visit.remove(node)
            result.append(node)

        return result
```

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#Class to store the data generated by the anealing algorithm
class solution:
    def __init__(self, coords):
        #converts data form coordants into distmatrix
        self.dist_matrix = tsp_utils.vectorToDistMatrix(coords)
        #uses distance matrix to find solution
        self.saved_solution = tsp_utils.nearestNeighbourSolution(self.
 ↪dist_matrix)

    def __iter__(self):
        return self

    def get_matrix(self):
        return self.dist_matrix
    def get_solution(self):
        return self.saved_solution
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class MSA:
    def __init__(self,coords, iterations, temp, gamma, stopping_temp):

        #intial coordant points
        self.coords = coords
        #size of array
        self.sample_size = len(coords)
        #initialize iteration counter
        self.iteration = 1
        #check point to stop iterations
        self.stopping_iter = iterations
```

```python
        #tempature
        self.temp = temp
        #tempature to stop program
        self.stopping_temp = stopping_temp
        #self.df = df
        #gamma value to multiply tempature by
        self.gamma = gamma
        #tmp varible to store the data in the solution object
        self.tmp_obj = solution(coords)
        #current solution based on the return value fo the object
        self.current = self.tmp_obj.get_solution()
        #gets the distance matrix from the object
        self.matrix = self.tmp_obj.get_matrix()
        #saves all the solutions in a list
        self.solution_history = [self.current]
        #saves the current solution as the best solution
        self.best = self.current
        #saves the weight as the current weight
        self.cweight = self.weight(self.current)
        #saves the current weight as the immediate weight weight of current solution
        self.iweight = self.cweight
        #saves the current weight as the minimum weight
        self.mweight = self.cweight
        #saves the weights into a list
        self.weight_list = [self.cweight]
        #prints the immediate weight
        print('Intial weight: ', self.iweight)

    #unused function to calcuate distance
    @staticmethod
    def total_distance(df):

        def euclidean_distance(x1, x2, y1, y2):
            return np.sqrt((x1-x2)**2+(y1-y2)**2)

        distance = 0
        for idx in range(0, len(df)):
            if idx + 1 >= len(df):
                break
            distance += euclidean_distance(df['x'].loc[idx], df['x'].loc[idx+1],
                                           df['y'].loc[idx], df['y'].loc[idx+1])
        return distance

    def weight(self, sol):
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        #Calcuate weight

        return sum([self.matrix[i, j] for i, j in zip(sol, sol[1:] + [sol[0]])])

    def probability(self, candidate_weight):
        '''
        Acceptance probability as described in:
        https://stackoverflow.com/questions/19757551/
↪basics-of-simulated-annealing-in-python
        '''
        return math.exp(-abs(candidate_weight - self.cweight) / self.temp)

    def accept(self, candidate):
        '''
        Accept with probability 1 if candidate solution is better than
        current solution, else accept with probability equal to the
        acceptance_probability()
        '''
        #sets the canidate_weight as the weight of the current solution being␣
↪tested
        candidate_weight = self.weight(candidate)
        #if the candiate weight is better than the current weight then the␣
↪current solution is updated with the candiate infromation as well as the␣
↪miniumm weight is checked and updated based on the canidate information
        if candidate_weight < self.cweight:
            self.cweight = candidate_weight
            self.current = candidate
            if candidate_weight < self.mweight:
                self.mweight = candidate_weight
                self.best_solution = candidate
        #if the candiate_weight is not better than than the current weight it␣
↪is run through the probabilty function and if that probibility is less than␣
↪the random that candidate is saved as the current weight
        else:
            if random.random() < self.probability(candidate_weight):
                self.cweight = candidate_weight
                self.current = candidate


    def anneal(self):
        '''
        Annealing process with 2-opt
        described here: https://en.wikipedia.org/wiki/2-opt
        '''
        #if the tempt threshold or the iteration threshold is not reached then␣
↪it continues through the while loop
```

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        while self.temp >= self.stopping_temp and self.iteration < self.
↪stopping_iter:
            #candidate is set to the current solution value
            candidate = list(self.current)
            #l and I are randomly generated based on the sample size defined␣
↪above
            l = random.randint(2, self.sample_size - 1)
            i = random.randint(0, self.sample_size - l)
            #goes through each element of the candiate based on the randomly␣
↪generated values and reverses them
            candidate[i: (i + l)] = reversed(candidate[i: (i + l)])
            #the reversed canidate is passed through the acceptance check if it␣
↪passes the current information will be updated for the next look
            self.accept(candidate)
            #the tempiture is decreased based on the predefined gamma value
            self.temp *= self.gamma
            #an itteration is added
            self.iteration += 1
            #the weight list is appened wit the current weight
            self.weight_list.append(self.cweight)
            #the solution history is appended with the current solution
            self.solution_history.append(self.current)

        #once the loop finishes the minimum weight is printed
        print('Minimum weight: ', self.mweight)
        #improvemnt calculation based on the starting weight and the minimum␣
↪weight
        print('Improvement: ',
              round((self.iweight - self.mweight) / (self.iweight), 4) * 100,␣
↪'%')

    #plot the output of the solutions
    def plotLearning(self):
        #plot the weight graph
        plt.plot([i for i in range(len(self.weight_list))], self.weight_list)
        line_init = plt.axhline(y=self.iweight, color='r', linestyle='--')
        line_min = plt.axhline(y=self.mweight, color='g', linestyle='--')
        plt.legend([line_init, line_min], ['Initial weight', 'Optimized␣
↪weight'])
        plt.ylabel('Weight')
        plt.xlabel('Iteration')
        #plt.show()

    def plotResults(self,name):
        #set up figure
        fig, ax = plt.subplots()
```

```
        #set line weight
        line, = plt.plot([], [], lw=2)
        ''' initialize node dots on graph '''
        x = [self.coords[i][0] for i in self.solution_history[0]]
        y = [self.coords[i][1] for i in self.solution_history[0]]
        plt.plot(x, y, 'co')

        ''' draw axes slighty bigger  '''
        extra_x = (max(x) - min(x)) * 0.05
        extra_y = (max(y) - min(y)) * 0.05
        ax.set_xlim(min(x) - extra_x, max(x) + extra_x)
        ax.set_ylim(min(y) - extra_y, max(y) + extra_y)
        #draw last solution on the graph using the starting solutions points␣
 ↪and the last solutions lines
        x = [self.coords[i, 0] for i in self.solution_history[len(self.
 ↪solution_history)-1] + [self.solution_history[len(self.
 ↪solution_history)-1][0]]]
        y = [self.coords[i, 1] for i in self.solution_history[len(self.
 ↪solution_history)-1] + [self.solution_history[len(self.
 ↪solution_history)-1][0]]]
        #set lines
        line.set_data(x, y)
        #add lable to print the final weight
        plt.xlabel('Weight:'+str(self.mweight))
        #create path to images
        if not os.path.exists("./images"):
            os.mkdir("./images")
        #save the plot for the graph based on the imput name with the default␣
 ↪being city_final
        plt.savefig("./images/"+name)
        #plt.show
    def get_mweight(self):
        #get minimum weight
        return self.mweight
```

[ ]:
```
#run funtion with all the data needed
def run(nodes,stopping_iter, temp, gamma, stopping_temp,name="cities_final.
 ↪png", weight= np.Inf ):
    '''run simulated annealing algorithm with 2-opt'''
    #run simulated annealing
    sa = MSA(nodes,stopping_iter, temp, gamma, stopping_temp)

    sa.anneal()
    #set base weight first itteration is infinity
    current_weight = weight
    # get min_weight from the simulated annealing instance
```

```
    min_wieght = sa.get_mweight()
    '''animate'''

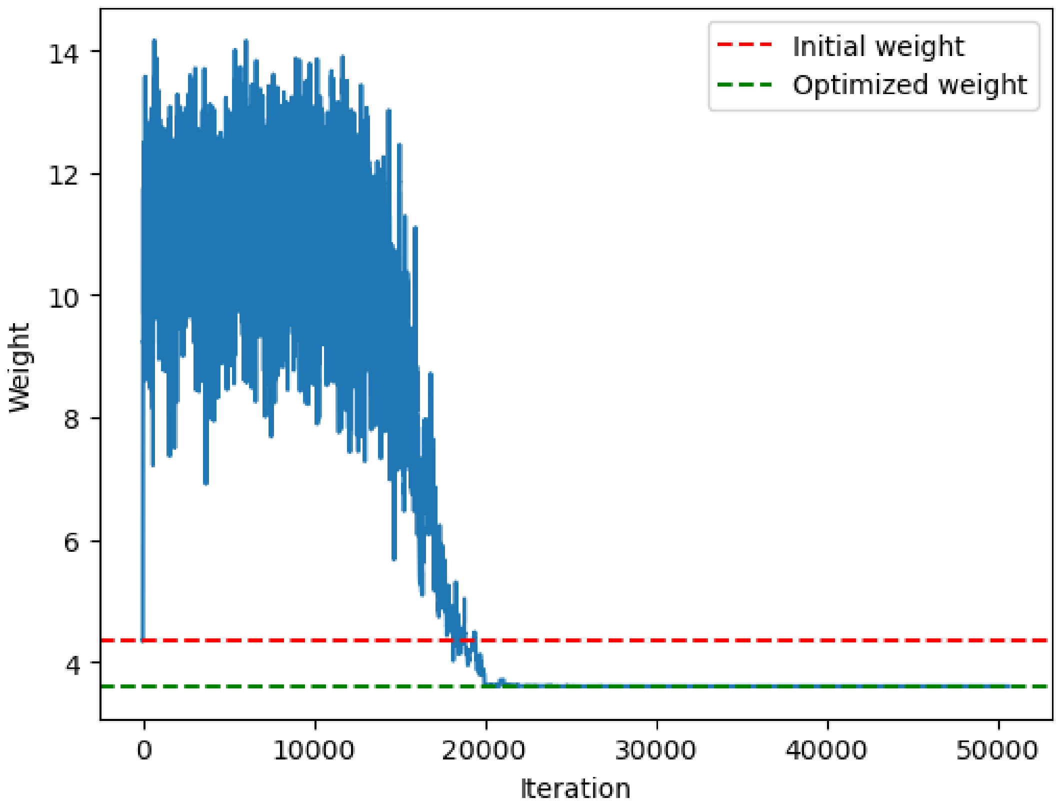
    #sa.animateSolutions()
    '''show the improvement over time'''
    if(min_wieght<current_weight):
        #if the min_weight is less than the current weight then the plot for␣
 ↪that annealing is generated and the new minweight is returend
        sa.plotLearning()
        sa.plotResults(name)
        return min_wieght
    else:
        #else the current weight is returned
        return current_weight
```

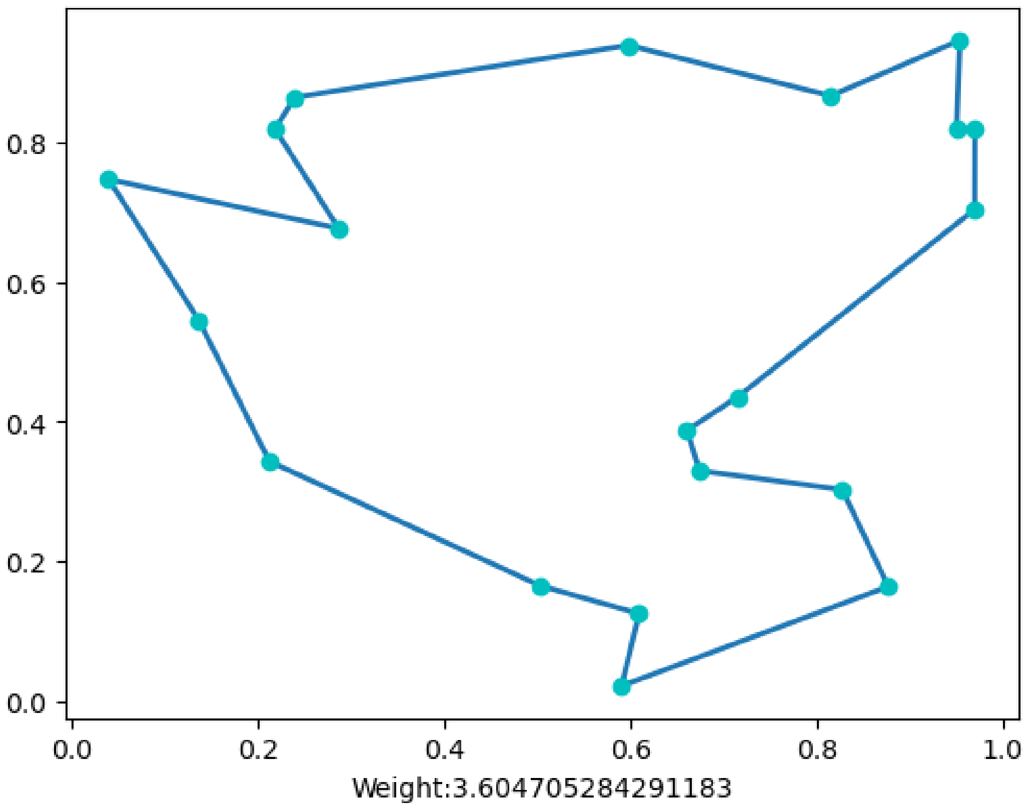
[ ]:

```
    '''set the simulated annealing algorithm params'''
    #test run based on wrong points
temp = 1000
stopping_temp = 0.00000001
gamma = 0.9995
stopping_iter = 10000000
xs = [0.6606,0.9695,0.5906, 0.2124, 0.0398, 0.1367,0.9536,0.6091,0.8767,0.
 ↪8148,0.9500,0.6740,0.5029,0.8274,0.9697,0.5979,0.2184,0.7148,0.2395,0.2867]
ys = [0.3876,0.7041,0.0213,0.3429,0.7471,0.5449,0.9464,0.1247,0.1636,0.8668,0.
 ↪8200,0.3296,0.1649,0.3025,0.8192,0.9392,0.8191,0.4351,0.8646,0.6768]
#print(f"X: {d} && Y:{s}",len(xs),len(ys))
nodes = np.column_stack((xs, ys))
run(nodes,stopping_iter, temp, gamma, stopping_temp)
```

```
Intial weight:  4.3580045910318415
Minimum weight:  3.604705284291183
Improvement:  17.29 %
```

[ ]: 3.604705284291183


Initial weight
Optimized weight
Weight
Iteration
14
12
10
8
6
4
0
10000
20000
30000
40000
50000



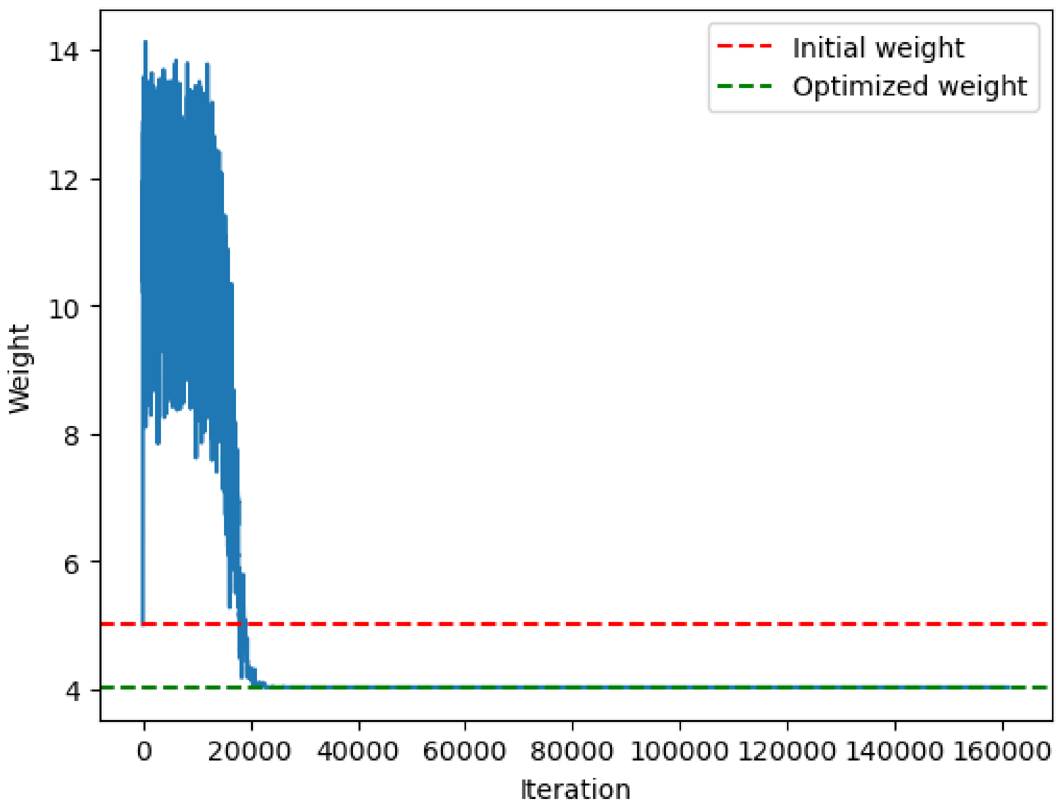
[ ]:
```
#actia run
temp = 1000
stopping_temp = 0.000000000000000000000000000000001
gamma = 0.9995
stopping_iter =␣
↪1000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
xs = [0.6606,0.9695,0.5906, 0.2124, 0.0398, 0.1367,0.9536,0.6091,0.8767,0.
↪8148,0.3876,0.7041,0.0213,0.3429,0.7471,0.5449,0.9464,0.1247,0.1636,0.8668]
ys = [0.9500,0.6740,0.5029,0.8274,0.9697,0.5979,0.2184,0.7148,0.2395,0.2867,0.
↪8200,0.3296,0.1649,0.3025,0.8192,0.9392,0.8191,0.4351,0.8646,0.6768]
#print(f"X: {d} && Y:{s}",len(xs),len(ys))
nodes = np.column_stack((xs, ys))
name="HW Question 1.png"
weight = np.inf
#for loop that run through the map 20 times to get the attempt the best␣
↪solution
for i in range(0,20):
    weight = run(nodes,stopping_iter, temp, gamma, stopping_temp,name, weight)

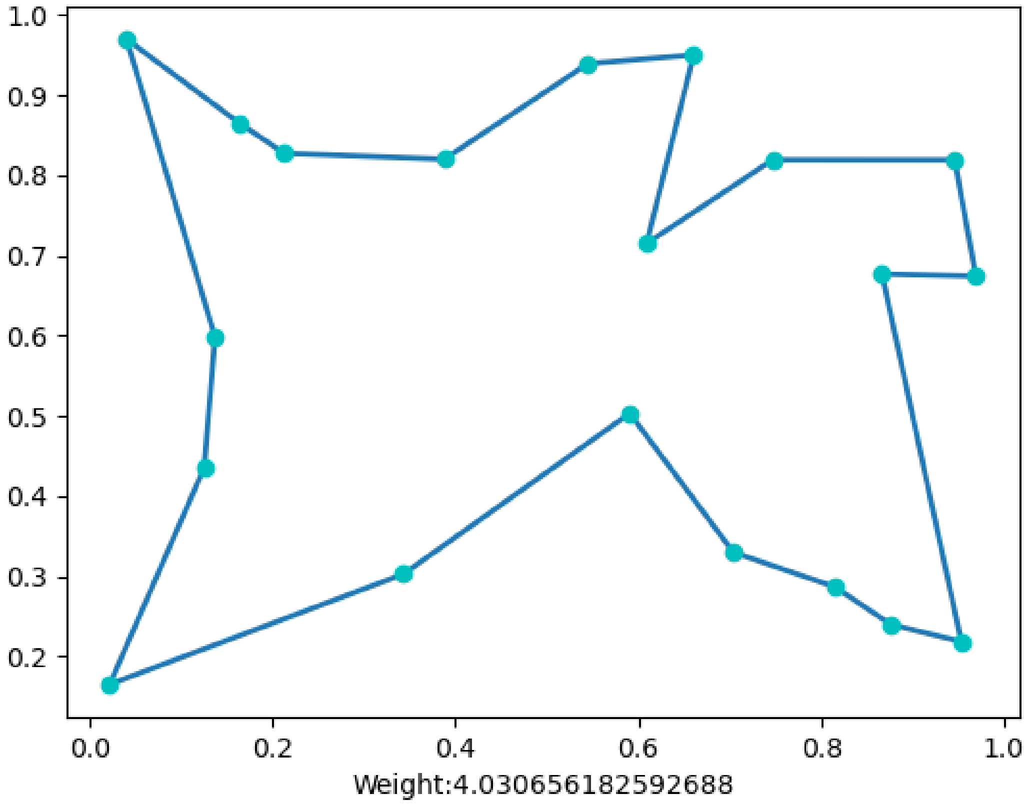

plt.show
```

```
Intial weight:  5.014274936724524
Minimum weight:  4.030656182592688
Improvement:  19.62 %
Intial weight:  4.502090428504454
Minimum weight:  4.076046089443103
Improvement:  9.46 %
Intial weight:  4.444147300922404
Minimum weight:  4.076046089443103
Improvement:  8.28 %
Intial weight:  4.8067459348638515
Minimum weight:  4.076046089443103
Improvement:  15.2 %
Intial weight:  5.452254618497038
Minimum weight:  4.054910629557462
Improvement:  25.629999999999995 %
Intial weight:  5.22894797811956
Minimum weight:  4.076046089443103
Improvement:  22.05 %
Intial weight:  4.909123268390923
Minimum weight:  4.030656182592689
Improvement:  17.89 %
Intial weight:  4.8322153627319455
Minimum weight:  4.030656182592688
Improvement:  16.59 %
Intial weight:  4.986850665914826
Minimum weight:  4.030656182592688
Improvement:  19.17 %
Intial weight:  4.908185133302875
Minimum weight:  4.076046089443103
Improvement:  16.950000000000003 %
Intial weight:  5.014274936724524
Minimum weight:  4.076046089443103
Improvement:  18.709999999999997 %
Intial weight:  4.887909931685917
Minimum weight:  4.054910629557462
Improvement:  17.04 %
Intial weight:  5.424835518657478
Minimum weight:  4.076046089443103
Improvement:  24.86 %
Intial weight:  4.444147300922404
Minimum weight:  4.030656182592688
Improvement:  9.3 %
Intial weight:  5.050834563973035
Minimum weight:  4.030656182592689
Improvement:  20.200000000000003 %
Intial weight:  4.8322153627319455
Minimum weight:  4.030656182592688
Improvement:  16.59 %
```

```
Intial weight:  4.502090428504454
Minimum weight:  4.030656182592689
Improvement:  10.47 %
Intial weight:  4.926483896898324
Minimum weight:  4.054910629557462
Improvement:  17.69 %
Intial weight:  4.502090428504454
Minimum weight:  4.030656182592688
Improvement:  10.47 %
Intial weight:  5.307040759194025
Minimum weight:  4.030656182592689
Improvement:  24.05 %
```

[ ]: <function matplotlib.pyplot.show(close=None, block=None)>





[ ]:
```
#data for the 101 cities
data = [1, 41, 49, 2, 35, 17, 3, 55, 45, 4, 55, 20, 5, 15, 30, 6, 25, 30, 7,␣
 ↪20, 50, 8, 10, 43, 9, 55, 60, 10, 30, 60, 11, 20, 65, 12, 50, 35, 13, 30,␣
 ↪25, 14, 15, 10, 15, 30, 5, 16, 10, 20, 17, 5, 30, 18, 20, 40, 19, 15, 60,␣
 ↪20, 45, 65, 21, 45, 20, 22, 45, 10, 23, 55, 5, 24, 65, 35, 25, 65, 20, 26,␣
 ↪45, 30, 27, 35, 40, 28, 41, 37, 29, 64, 42, 30, 40, 60, 31, 31, 52, 32, 35,␣
 ↪69, 33, 53, 52, 34, 65, 55, 35, 63, 65, 36, 2, 60, 37, 20, 20, 38, 5, 5, 39,␣
 ↪60, 12, 40, 40, 25, 41, 42, 7, 42, 24, 12, 43, 23, 3, 44, 11, 14, 45, 6, 38,␣
 ↪46, 2, 48, 47, 8, 56, 48, 13, 52, 49, 6, 68, 50, 47, 47, 51, 49, 58, 52, 27,␣
 ↪43, 53, 37, 31, 54, 57, 29, 55, 63, 23, 56, 53, 12, 57, 32, 12, 58, 36, 26,␣
 ↪59, 21, 24, 60, 17, 34, 61, 12, 24, 62, 24, 58, 63, 27, 69, 64, 15, 77, 65,␣
 ↪62, 77, 66, 49, 73, 67, 67, 5, 68, 56, 39, 69, 37, 47, 70, 37, 56, 71, 57,␣
 ↪68, 72, 47, 16, 73, 44, 17, 74, 46, 13, 75, 49, 11, 76, 49, 42, 77, 53, 43,␣
 ↪78, 61, 52, 79, 57, 48, 80, 56, 37, 81, 55, 54, 82, 15, 47, 83, 14, 37, 84,␣
 ↪11, 31, 85, 16, 22, 86, 4, 18, 87, 28, 18, 88, 26, 52, 89, 26, 35, 90, 31,␣
 ↪67, 91, 15, 19, 92, 22, 22, 93, 18, 24, 94, 26, 27, 95, 25, 24, 96, 22, 27,␣
 ↪97, 25, 21, 98, 19, 21, 99, 20, 26, 100, 18, 18, 101, 35, 35]
```

[ ]:
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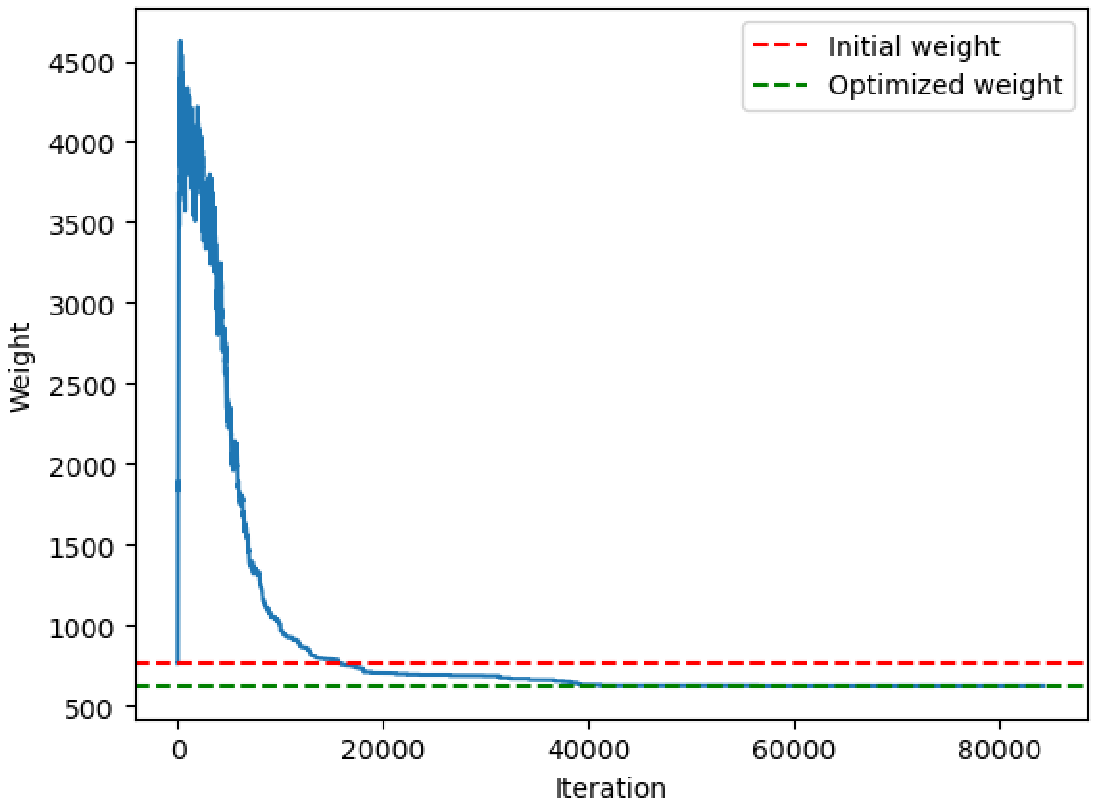
[ ]:
```python
#take every third data value for the number of each city
value = data[::3]
#pop off the first value
data.pop(0)
#get all the x valeus for the cities
xs = data[::3]
#pop again
data.pop(0)
#get all the y values
ys = data[::3]





#settings
temp = 200
stopping_temp = 0.0000000000000001
gamma = 0.9995
stopping_iter = 100000000000000000000000000000000000000000
#make array with x and y
nodes = np.column_stack((xs, ys))
#name the saved graph
name="HW Question 2.png"

weight = np.inf
#run 30 times
for i in range(0,30):
    #feedback the returned weight
    weight = run(nodes,stopping_iter, temp, gamma, stopping_temp,name, weight)


plt.show
#idk why the charts for this one mess up
```

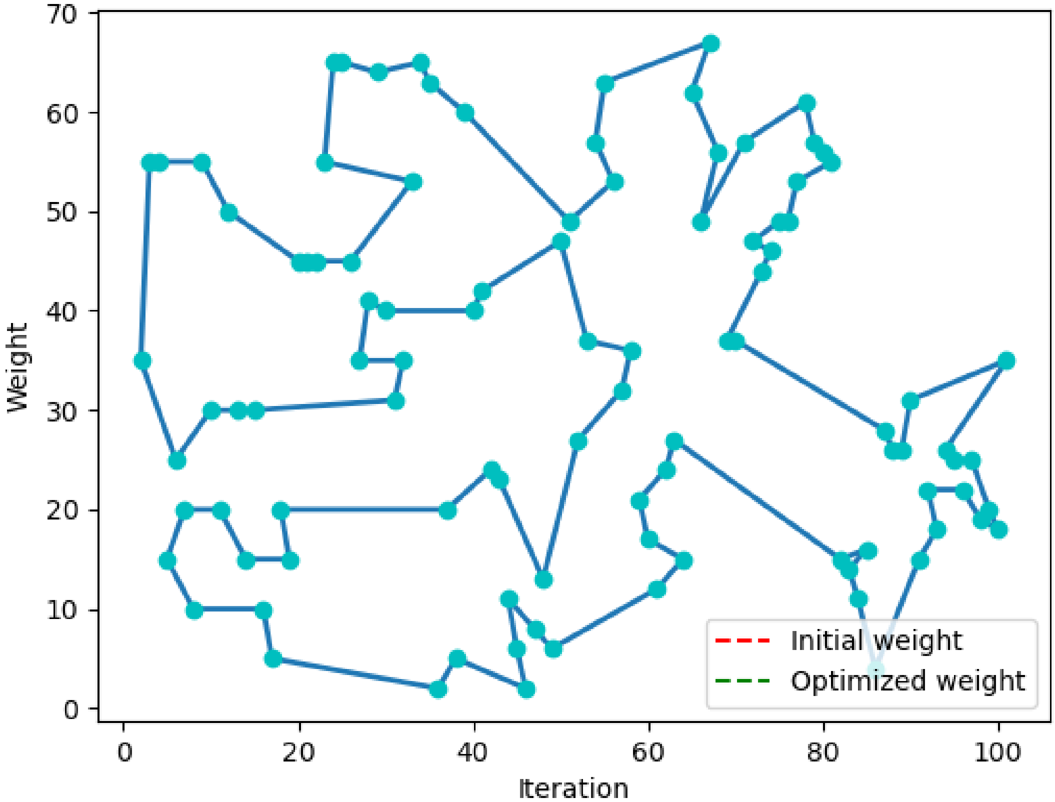
```
Intial weight:  765.5261608558586
Minimum weight:  625.3917060643012
Improvement:  18.310000000000002 %
Intial weight:  721.3758284564734
Minimum weight:  668.5266973498684
Improvement:  7.33 %
Intial weight:  738.5188202977614
Minimum weight:  633.2878190436267
Improvement:  14.249999999999998 %
Intial weight:  718.1690276678853
Minimum weight:  630.9923471175688
Improvement:  12.139999999999999 %
```

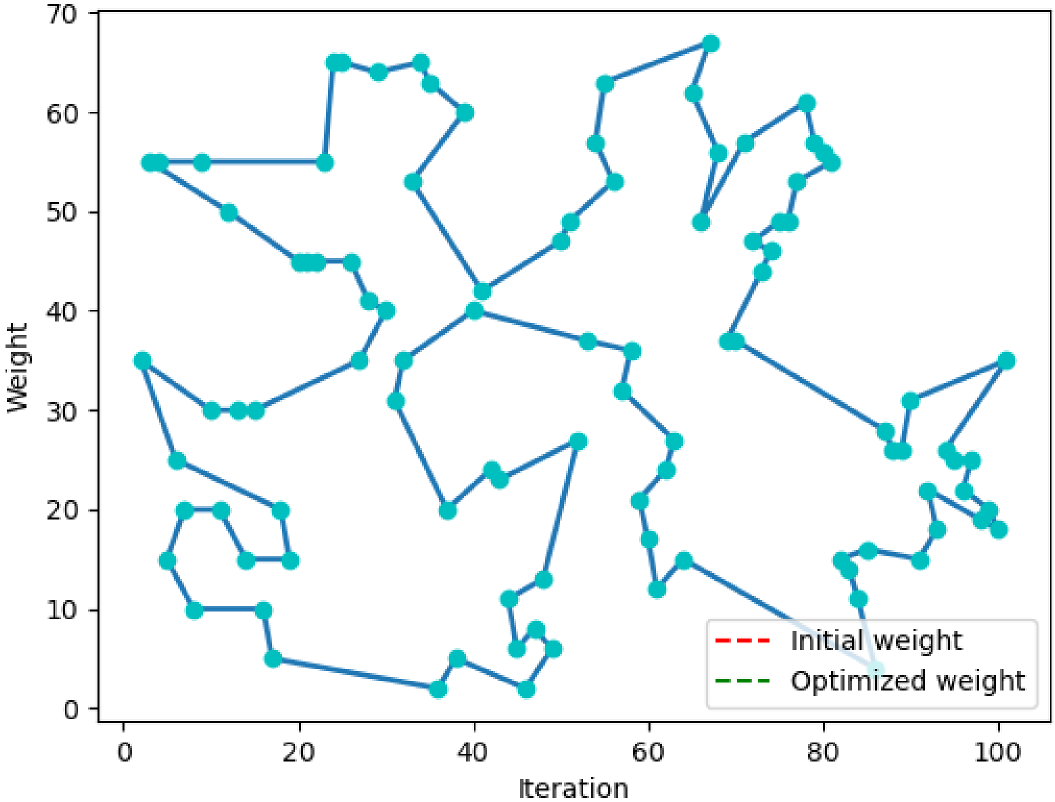
```
Intial weight:  690.4244499371883
Minimum weight:  656.5884713316545
Improvement:  4.9 %
Intial weight:  739.7171044878103
Minimum weight:  635.9543103610816
Improvement:  14.030000000000001 %
Intial weight:  716.8068069288466
Minimum weight:  631.4209182484159
Improvement:  11.91 %
Intial weight:  757.5822449590481
Minimum weight:  652.6573300302492
Improvement:  13.850000000000001 %
Intial weight:  714.5547584686362
Minimum weight:  651.4843068627639
Improvement:  8.83 %
Intial weight:  718.1690276678853
Minimum weight:  637.3444681942419
Improvement:  11.25 %
Intial weight:  757.5822449590481
Minimum weight:  631.2214191717109
Improvement:  16.68 %
Intial weight:  740.2210042365543
Minimum weight:  603.3790296087124
Improvement:  18.490000000000002 %
Intial weight:  743.2558992691793
Minimum weight:  603.269397662606
Improvement:  18.83 %
Intial weight:  685.9020640792157
Minimum weight:  621.7365808162575
Improvement:  9.35 %
Intial weight:  776.8879194254547
Minimum weight:  618.1219384703933
Improvement:  20.44 %
Intial weight:  721.4447971075517
Minimum weight:  620.1733156921345
Improvement:  14.04 %
Intial weight:  737.8696413893713
Minimum weight:  634.7078258663577
Improvement:  13.98 %
Intial weight:  757.5822449590481
Minimum weight:  617.0200530403616
Improvement:  18.55 %
Intial weight:  739.102229198969
Minimum weight:  652.8039757362905
Improvement:  11.68 %
Intial weight:  785.9984307333415
Minimum weight:  638.577744063067
Improvement:  18.759999999999998 %
```

```
Intial weight:  748.1413216793228
Minimum weight:  630.6103973859985
Improvement:  15.709999999999999 %
Intial weight:  742.1723015979768
Minimum weight:  609.7893925594691
Improvement:  17.84 %
Intial weight:  743.3439569772712
Minimum weight:  633.0655260866142
Improvement:  14.84 %
Intial weight:  774.5778980539324
Minimum weight:  627.7292744033464
Improvement:  18.96 %
Intial weight:  738.4029105009527
Minimum weight:  637.9221040511126
Improvement:  13.61 %
Intial weight:  725.2657342092399
Minimum weight:  622.9892644282279
Improvement:  14.099999999999998 %
Intial weight:  757.5822449590481
Minimum weight:  631.844006783133
Improvement:  16.6 %
Intial weight:  759.3522636136561
Minimum weight:  632.4211769519478
Improvement:  16.72 %
Intial weight:  738.4029105009527
Minimum weight:  634.4192052963676
Improvement:  14.08 %
Intial weight:  720.9008801406616
Minimum weight:  664.3924360680728
Improvement:  7.84 %
```

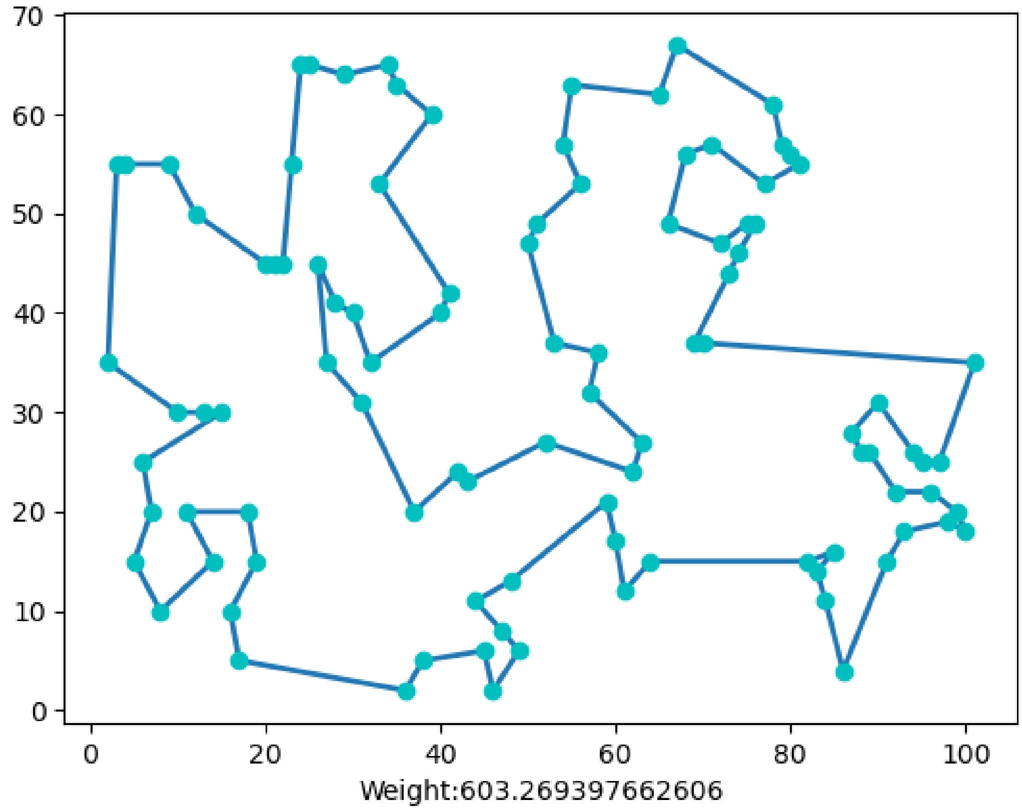
```
[ ]: <function matplotlib.pyplot.show(close=None, block=None)>
```


Initial weight
Optimized weight
4500
4000
3500
3000
2500
2000
1500
1000
500
Weight
0
20000
40000
60000
80000
Iteration


70
60
50
40
30
20
10
0
Weight
0
20
40
60
80
100
Iteration
Initial weight
Optimized weight



Weight
Iteration
Initial weight
Optimized weight
0
10
20
30
40
50
60
70
0
20
40
60
80
100


70
60
50
40
30
20
10
0
0
20
40
60
80
100
Weight:603.269397662606

[ ]: