
بِسْمِ اللهِ الرَّحْمنِ الرَّحِيمِ
"In the name of Allah,
the entirely merciful, the especially merciful."
-Quran 1:1
HolyQuran.co

# Simulated Annealing Algorithm to Solve TSP

## Exercise 5

## Simulated Annealing To Solve TSP


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# Simulated Annealing Algotithm to sove Travelling Salesman Problem (TSP) in Python From Scratch

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# Simulated Annealing Algorithm to Solve TSP

## What is Simulated annealing algorithm?

**Simulated Annealing** is a stochastic global search optimization algorithm.
This means that it makes use of randomness as part of the search process. This makes the algorithm appropriate for nonlinear objective functions where other local search algorithms do not operate well.

Like the stochastic hill climbing local search algorithm, it modifies a single solution and searches the relatively local area of the search space until the local optima is located. Unlike the hill climbing algorithm, it may accept worse solutions as the current working solution.

The likelihood of accepting worse solutions starts high at the beginning of the search and decreases with the progress of the search, giving the algorithm the opportunity to first locate the region for the global optima, escaping local optima, then hill climb to the optima itself.

Click here for read more.

## What is Travelling salesman problem?

The **travelling salesman problem** (also called the **traveling salesperson problem** or **TSP**) asks the following question: "Given a list of cities and the distances between each pair of cities, what is the shortest possible route that visits each city exactly once and returns to the origin city?" It is an NP-hard problem in combinatorial optimization, important in theoretical computer science and operations research.

Click here for read more.

# Simulated Annealing Algorithm to Solve TSP

## Introduction

In the following, we will implement the simulated annealing algorithm to solve Traveling Salesman Problem step by step...

## Importing libraries

A simple implementation which provides decent results. Requires python3, matplotlib and numpy to work :

```
import random
import numpy as np
import math
import matplotlib.pyplot as plt
from matplotlib.animation import FuncAnimation
import numpy as np
```

## NodeGenerator Class

This class allows to us to generate random list of nodes :

```
class NodeGenerator:
    def __init__(self, width, height, nodesNumber):
        self.width = width
        self.height = height
        self.nodesNumber = nodesNumber

    def generate(self):
        xs = np.random.randint(self.width, size=self.nodesNumber)
        ys = np.random.randint(self.height, size=self.nodesNumber)

        return np.column_stack((xs, ys))
```

# vectorToDistMatrix function

This function Creates the distance matrix :

```
def vectorToDistMatrix(coords):

    return np.sqrt((np.square(coords[:, np.newaxis]-coords).sum(axis=2)))
```

# nearestNeighbourSolution function

Computes the initial solution (nearest neighbor strategy) :

```
def nearestNeighbourSolution(dist_matrix):

    node = random.randrange(len(dist_matrix))

    result = [node]

    nodes_to_visit = list(range(len(dist_matrix)))

    nodes_to_visit.remove(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
```

# animateTSP function

This function animate the solution over times :

```
 Parameters
-------------
   hisotry : list
       history of the solutions chosen by the algorith
   points: array_like
       points with the coordinates
```

```
def animateTSP(history, points):
```

First we create a variable for approximate the number of frames for animation :

```
    key_frames_mult = len(history) // 1500
```

Path is a line coming through all the nodes :

```
    line, = plt.plot([], [], lw=2)
```

`def init():` is a function for initialization value of `line`:

1) Initialize node dots on graph :

```
        x = [points[i][0] for i in history[0]]
        y = [points[i][1] for i in history[0]]
        plt.plot(x, y, 'co')
```

2) 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)
```

3) Initialize solution to be empty :

```
    line.set_data([], [])
    return line,
```

`def update(frame):` is a function for every frame update the solution on the graph :

```
def update(frame):

    x = [points[i, 0] for i in history[frame] + [history[frame][0]]]
    y = [points[i, 1] for i in history[frame] + [history[frame][0]]]
    line.set_data(x, y)
    return line
```

Animate precalulated solutions :

```
ani = FuncAnimation(fig, update,
                    frames=range(0, len(history), key_frames_mult),
                    init_func=init, interval=3, repeat=False)
```

Plot the result :

```
plt.show()
```

# SimulatedAnnealing Class

This class implement simulated annealing algorithm and use animateTSP function for animating the solution over times.

```
Parameters
----------
coords: array_like
    list of coordinates
temp: float
    initial temperature
alpha: float
    rate at which temp decreases
stopping_temp: float
    temerature at which annealing process terminates
stopping_iter: int
    interation at which annealing process terminates
```

# Simulated Annealing Algorithm to Solve TSP

`class SimulatedAnnealing:`

`def __init__(self, coords, …, stopping_iter):` Initializing property of class :

```
def __init__(self, coords, temp, alpha, stopping_temp, stopping_iter):

        self.coords = coords
        self.sample_size = len(coords)
        self.temp = temp
        self.alpha = alpha
        self.stopping_temp = stopping_temp
        self.stopping_iter = stopping_iter
        self.iteration = 1

        self.dist_matrix = vectorToDistMatrix(coords)
        self.curr_solution = nearestNeighbourSolution(self.dist_matrix)
        self.best_solution = self.curr_solution

        self.solution_history = [self.curr_solution]

        self.curr_weight = self.weight(self.curr_solution)
        self.initial_weight = self.curr_weight
        self.min_weight = self.curr_weight

        self.weight_list = [self.curr_weight]

        print('Intial weight: ', self.curr_weight)
```

`def weight(self, sol):` Calcuating weight of distance matrix :

```
    def weight(self, sol):

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

# Simulated Annealing Algorithm to Solve TSP

`def acceptance_probability(self, candidate_weight):` Acceptance probability as described in :

```
def acceptance_probability(self, candidate_weight):

    return math.exp(abs(candidate_weight-self.curr_weight)/self.temp)
```

Click here for read more…

`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() :

```
def accept(self, candidate):

    candidate_weight = self.weight(candidate)
    if candidate_weight < self.curr_weight:
        self.curr_weight = candidate_weight
        self.curr_solution = candidate
        if candidate_weight < self.min_weight:
            self.min_weight = candidate_weight
            self.best_solution = candidate

    else:
        if random.random() < self.acceptance_probability(candidate_weight):
            self.curr_weight = candidate_weight
            self.curr_solution = candidate
```

Annealing process with 2-opt (described here):

```
def anneal(self):

    while self.temp >= self.stopping_temp and self.iteration < self.stopping_iter:
        candidate = list(self.curr_solution)
        l = random.randint(2, self.sample_size - 1)
```

```
            i = random.randint(0, self.sample_size - l)

            candidate[i: (i + l)] = reversed(candidate[i: (i + l)])

            self.accept(candidate)
            self.temp *= self.alpha
            self.iteration += 1
            self.weight_list.append(self.curr_weight)
            self.solution_history.append(self.curr_solution)

        print('Minimum weight: ', self.min_weight)
        print('Improvement: ',
              round((self.initial_weight - self.min_weight)/(self.initial_weight), 4) * 100, '%')
```

`def animateSolutions(self):` Send solution_history and coords to animateTSP function for animating the solution over times :

```
    def animateSolutions(self):
        animateTSP(self.solution_history, self.coords)
```

`def plotLearning(self):` Ploting learning curve based on Weight and Number of Iterations. This function :

```
    def plotLearning(self):

        plt.plot([i for i in range(len(self.weight_list))], self.weight_list)
        line_init = plt.axhline(y=self.initial_weight, color='r',linestyle='--')
        line_min = plt.axhline(y=self.min_weight, color='g', linestyle='--')
        plt.legend([line_init, line_min], ['Initial weight', 'Optimized weight'])
        plt.ylabel('Weight')
        plt.xlabel('Iteration')
        plt.show()
```

# Let’s run the code

Step 1) First we have to set the simulated annealing algorithm params :

```
temp = 1000
stopping_temp = 0.00000001
alpha = 0.9995
stopping_iter = 10000000
```

Step 2) In next step we must set the dimensions of the grid :

```
size_width = 200
size_height = 200
```

Step 3) Set the number of nodes :

```
population_size = 70
```

Step 4) Generate random list of nodes :

```
nodes = NodeGenerator(size_width, size_height, population_size).generate()
```

Step 5) Run simulated annealing algorithm with 2-opt :

```
sa = SimulatedAnnealing(nodes, temp, alpha, stopping_temp, stopping_iter)
sa.anneal()
```

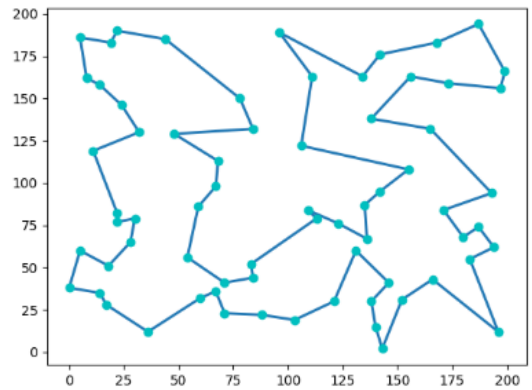
Step 6) Animate :

```
sa.animateSolutions()
```

# Simulated Annealing Algorithm to Solve TSP

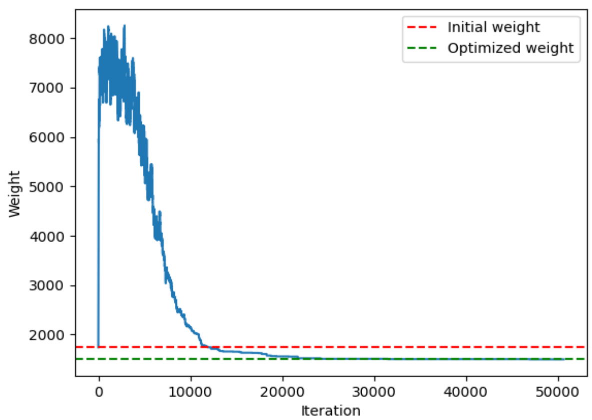
Click here for see sample An example of the resulting route on a TSP with 70 nodes on 200x200 grid …

Note: Animation may not paly properly on jupyter ! for see the sample of result run "Simulated Annealing Algorithm to solve Travelling Salesman Problem (TSP) in Python From Scratch.py" in another python environment.




Step 7) Show the improvement over time

```
sa.plotLearning()
```




...The End...