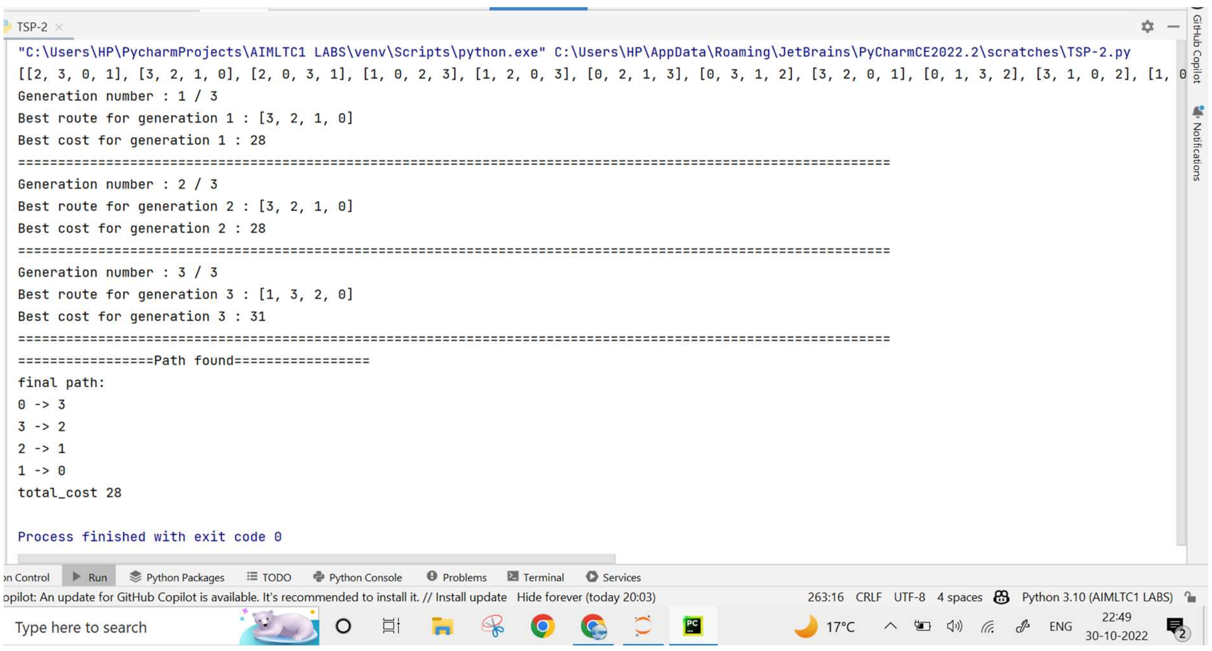
```
import random
from collections import defaultdict  # dictionary of lists
import numpy as np  # for generating random weights in large graph


# Population Initialization
def initialize_population(nodes, pop_size):
    max_nod_num = max(nodes)
    population = []
    for i in range(pop_size):
        chromosome = []
        # to create a fully connected path
        while len(chromosome) != len(nodes):
            rand_node = np.random.randint(max_nod_num + 1)
            # to prevent repeated additions of nodes in the same chromosome
            if rand_node not in chromosome:
                chromosome.append(rand_node)
        population.append(chromosome)
    return population

# Fitness Function
def cost(graph_edges, chromosome):
    total_cost = 0
    i = 1
    while i < len(chromosome):
        for temp_edge in graph_edges:
            if chromosome[i - 1] == temp_edge[0] and chromosome[i] == temp_edge[1]:
                total_cost = total_cost + temp_edge[2]
        i = i + 1
    for temp_edge in graph_edges:
        if chromosome[0] == temp_edge[0] and chromosome[len(chromosome) - 1] == temp_edge[1]:
            total_cost = total_cost + temp_edge[2]
    return total_cost

# Selecting the Fittest Chromosomes
def select_best(parent_gen, graph_edges, elite_size):
    costs = []
    selected_parent = []
    pop_fitness = []
    for i in range(len(parent_gen)):
        costs.append(cost(graph_edges, parent_gen[i]))
        pop_fitness.append((costs[i], parent_gen[i]))
    # sort according to path_costs
    pop_fitness.sort(key=lambda x: x[0])
    # select only top elite_size fittest chromosomes in the population
    for i in range(elite_size):
        selected_parent.append(pop_fitness[i][1])
    return selected_parent, pop_fitness[0][0], selected_parent[0]

# Mating
def breed(parent1, parent2):
    # let's say to breed from two parents (0,1,2,3,4) and (1,3,2,0,4)
    # if we choose parent1(0-2) i.e (0,1,2) then we have to choose (3,4) from parent2
    # i.e. we have to create two children from two parents which are disjoint w.r.t each other
    child = []
    childP1 = []
    childP2 = []

    # select two random numbers between range(0,len(parents)) which are used as index
    geneA = int(random.random() * len(parent1))
    geneB = int(random.random() * len(parent1))

    # define start and end index to select child1 from parent1
    if geneA < geneB:
        startGene, endGene = geneA, geneB
    else:
        endGene, startGene = geneA, geneB

    # add parent1(startGene,endGene) to child1
    for i in range(startGene, endGene):
        childP1.append(parent1[i])

    # add parent2 to child2 if parent2 not in child1
    childP2 = [item for item in parent2 if item not in childP1]

    # create new child using disjoint Child1 and Child2
    child = childP1 + childP2
    return child


def breedPopulation(parents, pop_size):
    children = []
    temp = np.array(parents)
    n_parents = temp.shape[0]
    # create new population of size pop_size from previous population
    for i in range(pop_size):
        # choose random parents
        random_dad = parents[np.random.randint(low=0, high=n_parents - 1)]
        random_mom = parents[np.random.randint(low=0, high=n_parents - 1)]
        # create child using random parents
        children.append(breed(random_dad, random_mom))
    return children

# Mutation
def mutate(parent, n_mutations):
    # we cannot randomly change a node from chromosome to another node
    # as this will create repeated nodes
    # we define mutation as mutation of edges in the path i.e. swapping of nodes in the
chromosome
    temp_parent = np.array(parent)
    size1 = temp_parent.shape[0]
    max_nod_num = max(parent)
    for i in range(n_mutations):
        # choose random indices to swap nodes in a chromosome
        rand1 = np.random.randint(0, size1)
        rand2 = np.random.randint(0, size1)
        # if rand1 and rand2 are same, then chromosome won't be mutated
        # so change rand2
        if rand1 == rand2:
            rand2 = (rand2 + 1) % size1
        parent[rand1], parent[rand2] = parent[rand2], parent[rand1]
    return parent


def mutatePopulation(population, n_mutations):
    mutatedPop = []
    # mutate population
    for ind in range(0, len(population)):
        mutatedInd = mutate(population[ind], n_mutations)
        mutatedPop.append(mutatedInd)
    return mutatedPop

# Genetic Algorithm implementation

# class that represents a graph
class Graph:
    def __init__(self, vertices):
        self.nodes = []  # list of nodes
        for i in range(len(vertices)):
            self.nodes.append(vertices[i])
        self.edges = []  # to store graph
        # dictionary with the lists of successors of each node, faster to get the successors
        # each item of list is a 2-tuple: (destination, weight)
        self.successors = defaultdict(list)

    # function that adds edges
    def addEdge(self, u, v, w):
        for edges in self.edges:
            # check if edge is already present
            if u == edges[0] and v == edges[1]:
                print("Edge already exists")
                return
        self.edges.append([u, v, w])
        self.successors[u].append((v, w))

    # function to get the cost of optimal path found
    def get_cost(self, visited_nodes):
        if len(visited_nodes) <= 1:
            return 0
        else:
            total_cost = 0
            i = 1
            while i < len(visited_nodes):
                for temp_edge in self.edges:
                    if visited_nodes[i - 1] == temp_edge[0] and visited_nodes[i] ==
temp_edge[1]:
                        total_cost = total_cost + temp_edge[2]
                i = i + 1
            for temp_edge in self.edges:
                if visited_nodes[0] == temp_edge[0] and visited_nodes[len(visited_nodes) - 1]
== temp_edge[1]:
                    total_cost = total_cost + temp_edge[2]
            return total_cost

    def disconnected(self, initial_node):
        is_disconnected = False
        for node in range(len(self.nodes)):
            neighbors = self.successors[node]
            # graph is fully connected if number of neighbours of each node will be 1 less
than total
            # number of nodes in the graph
            if len(neighbors) < (len(self.nodes) - 1):
                is_disconnected = True
                return is_disconnected
        return is_disconnected

    def gen_algo(self, source, generations):
        # check if a graph is fully connected
        if self.disconnected(source):
            print("Graph is not connected")
            return []
        # initialize population with a certain size
        pop_size = 20
        parent_gen = initialize_population(self.nodes, pop_size)
        print(parent_gen)
        # keep the track of minimum path cost for each generation
        overall_costs = []
        # keep track of best route with minimum path cost for each generation
        overall_routes = []
        for i in range(generations):
            print("Generation number :", i + 1, "/", generations)
            # choose only elite chromosome from population
            elite_size = 10
            parent_gen, min_cost, best_route = select_best(parent_gen, self.edges, elite_size)
            print("Best route for generation", i + 1, ":", best_route)
            print("Best cost for generation", i + 1, ":", min_cost)
            # store minimum path cost and best route for every generation
            overall_costs.append(min_cost)
            overall_routes.append(best_route)
            # mating
            parent_gen = breedPopulation(parent_gen, pop_size)
            # mutating
            n_mutations = 1
            parent_gen = mutatePopulation(parent_gen, n_mutations)
            print(

"==========================================================================================")
        # select the minimum path_cost
        minimum = min(overall_costs)
        min_index = -1
        # find the path with minimum path_cost from stored overall_routes
        # find the path with minimum path_cost from stored overall_routes
        for i in range(len(overall_costs)):
            if minimum == overall_costs[i]:
                min_index = i
        # return best route
        return overall_routes[min_index]


def print_path(path, source):
    print("================Path found================")
    print("final path:")
    start = path.index(source)
    for i in range(start, len(path) - 1):
        print(path[i], "->", path[i + 1])
    print(path[len(path) - 1], "->", path[0])
    for i in range(0, start):
        print(path[i], "->", path[i + 1])


g = Graph([0, 1, 2, 3])
```

```python
g.addEdge(0, 1, 10)
g.addEdge(1, 0, 5)
g.addEdge(0, 2, 20)
g.addEdge(2, 0, 8)
g.addEdge(0, 3, 15)
g.addEdge(3, 0, 6)
g.addEdge(1, 2, 10)
g.addEdge(2, 1, 8)
g.addEdge(1, 3, 9)
g.addEdge(3, 1, 13)
g.addEdge(3, 2, 9)
g.addEdge(2, 3, 12)

generations = 3
path = g.gen_algo(0, generations)  # executes the algorithm
total_cost = g.get_cost(path)
if total_cost:
    print_path(path, 0)
    print("total_cost", total_cost)
else:
    print('Did not reach the goal!')
```

OUTPUT:



```
"C:\Users\HP\PycharmProjects\AIMLTC1 LABS\venv\Scripts\python.exe" C:\Users\HP\AppData\Roaming\JetBrains\PyCharmCE2022.2\scratches\TSP-2.py
[[2, 3, 0, 1], [3, 2, 1, 0], [2, 0, 3, 1], [1, 0, 2, 3], [1, 2, 0, 3], [0, 2, 1, 3], [0, 3, 1, 2], [3, 2, 0, 1], [0, 1, 3, 2], [3, 1, 0, 2], [1, 0
Generation number : 1 / 3
Best route for generation 1 : [3, 2, 1, 0]
Best cost for generation 1 : 28
==============================================================================================================
Generation number : 2 / 3
Best route for generation 2 : [3, 2, 1, 0]
Best cost for generation 2 : 28
==============================================================================================================
Generation number : 3 / 3
Best route for generation 3 : [1, 3, 2, 0]
Best cost for generation 3 : 31
==============================================================================================================
================Path found================
final path:
0 -> 3
3 -> 2
2 -> 1
1 -> 0
total_cost 28

Process finished with exit code 0
```