МИНИСТЕРСТВО НАУКИ И ВЫСШЕГО ОБРАЗОВАНИЯ РОССИЙСКОЙ ФЕДЕРАЦИИ

федеральное государственное автономное образовательное учреждение высшего образования

«САНКТ-ПЕТЕРБУРГСКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ АЭРОКОСМИЧЕСКОГО ПРИБОРОСТРОЕНИЯ»

КАФЕДРА №  43

ОТЧЁТ

ЗАЩИЩЁН С ОЦЕНКОЙ

ПРЕПОДАВАТЕЛЬ

### профессор                                   Скобцов Ю.А.

должность, уч. Степень, звание   подпись, дата           инициалы, фамилия

ОТЧЁТ О ЛАБОРАТОРНОЙ РАБОТЕ №3.

Решение задачи коммивояжёра с помощью генетических алгоритмов.

по курсу: Эволюционные методы проектирования программно-информационных систем

РАБОТУ ВЫПОЛНИЛ

СТУДЕНТ ГР. 4136                                                                                Бобрович Н. С.

                                                                         подпись, дата                      инициалы, фамилия

Санкт-Петербург 2024

1. **Задание:**

Вариант 3:  
№ варианта Название функции Вид представления

3 Att48.tsp Представление соседства

Реализовать с использованием генетических алгоритмов решение задачи коммивояжёра по индивидуальному заданию согласно номеру варианта.

Сравнить найденное решение с представленным в условии задачи оптимальным решением.

Представить графически найденное решение.

Проанализировать время выполнения и точность нахождения результата в зависимости от вероятности различных видов кроссовера, мутации.

1. **Краткие теоретические сведения:**

Задача коммивояжёра (ЗК) считается классической задачей генетических алгоритмов. Она заключается в следующем: путешественник (или коммивояжёр) должен посетить каждый из базового набора городов и вернуться к исходной точке. Имеется стоимость билетов из одного города в другой. Необходимо составить план путешествия, чтобы сумма затраченных средств была минимальной. Поисковое пространство для ЗК- множество из N городов. Любая комбинация из N городов, где города не повторяются, является решением. Оптимальное решение – такая комбинация, стоимость которой (сумма из стоимостей переезда между каждыми из городов в комбинации) является минимальной.

ЗК – достаточно стара, она была сформулирована еще в 1759 году (под другим именем). Термин «Задача коммивояжера» был использован в 1932г. в немецкой книге «The traveling salesman, how and what he should to get commissions and be successful in his business», написанную старым коммивояжером.

Задача коммивояжера была отнесена к NP-сложным задачам. Существуют строгие ограничения на последовательность, и количество городов может быть очень большим (существуют тесты, включающие несколько тысяч городов).

Кажется естественным, что представление тура – последовательность (i1, i2, … , in), где (i1, i2, … , in) – числа из множества (1 … n), представляющие определенный город. Двоичное представление городов неэффективно, т.к. требует специального ремонтирующего алгоритма: изменение одиночного бита может повлечь неправильность тура.

В настоящее время существует три основных представления пути: соседское, порядковое и путевое. Каждое из этих представлений имеет собственные полностью различные операторы рекомбинации.

1. **Программа и результаты выполнения индивидуального задания с комментариями и выводами:**

**Код программы на ЯП Python:**

import numpy as np

import matplotlib.pyplot as plt

from scipy.spatial.distance import cdist

import random

from copy import deepcopy

# Координаты городов

cities = [

(1673, 1453), (2233, 10), (5530, 1424), (401, 841),

(3082, 1644), (7608, 4458), (7573, 3716), (7265, 1268),

(6898, 1885), (1112, 2049), (5468, 2606), (5989, 2873),

(4706, 2674), (4612, 2035), (6347, 2683), (6107, 669),

(7611, 5184), (7462, 3590), (7732, 4723), (5900, 3561),

(4483, 3369), (6101, 1110), (5199, 2182), (1633, 2809),

(4307, 2322), (675, 1006), (7555, 4819), (7541, 3981),

(3177, 756), (7352, 4506), (7545, 2801), (3245, 3305),

(6426, 3173), (4608, 1198), (23, 2216), (7248, 3779),

(7762, 4595), (7392, 2244), (3484, 2829), (6271, 2135),

(4985, 140), (1916, 1569), (7280, 4899), (7509, 3239),

(10, 2676), (6807, 2993), (5185, 3258), (3023, 1942)

]

# Вычисление матрицы расстояний

def calculate\_distance\_matrix(cities):

return cdist(cities, cities)

distance\_matrix = calculate\_distance\_matrix(np.array(cities))

class GeneticAlgorithm:

def \_\_init\_\_(self, distance\_matrix, population\_size=50, max\_generations=200,

crossover\_probability=0.85, mutation\_probability=0.05):

self.distance\_matrix = distance\_matrix

self.population\_size = population\_size

self.max\_generations = max\_generations

self.crossover\_probability = crossover\_probability

self.mutation\_probability = mutation\_probability

# Генерация начальной популяции

self.population = [np.random.permutation(len(distance\_matrix)) for \_ in range(population\_size)]

def fitness(self, individual):

"""Вычисляем длину маршрута"""

total\_distance = 0

for i in range(len(individual)):

j = (i + 1) % len(individual)

city1 = individual[i]

city2 = individual[j]

total\_distance += self.distance\_matrix[city1][city2]

return total\_distance

def selection(self):

"""Турнирный отбор"""

selected = []

for \_ in range(self.population\_size // 2):

candidate1 = random.choice(self.population)

candidate2 = random.choice(self.population)

if self.fitness(candidate1) < self.fitness(candidate2):

selected.append(deepcopy(candidate1))

else:

selected.append(deepcopy(candidate2))

return selected

def crossover(self, parent1, parent2):

"""Одноточечный кроссовер"""

if random.random() > self.crossover\_probability:

return parent1, parent2

cut\_point = random.randint(1, len(parent1) - 1)

child1 = np.concatenate([parent1[:cut\_point], parent2[cut\_point:]])

child2 = np.concatenate([parent2[:cut\_point], parent1[cut\_point:]])

# Убедимся, что все города присутствуют в маршруте

missing\_cities1 = set(range(len(parent1))) - set(child1)

missing\_cities2 = set(range(len(parent2))) - set(child2)

for i, city in enumerate(child1):

if city in missing\_cities2:

child2[i] = list(missing\_cities2)[0]

missing\_cities2.remove(list(missing\_cities2)[0])

for i, city in enumerate(child2):

if city in missing\_cities1:

child1[i] = list(missing\_cities1)[0]

missing\_cities1.remove(list(missing\_cities1)[0])

return child1, child2

def mutate(self, individual):

"""Перестановочная мутация"""

if random.random() > self.mutation\_probability:

return individual

pos1, pos2 = random.sample(range(len(individual)), 2)

individual[pos1], individual[pos2] = individual[pos2], individual[pos1]

return individual

def run(self):

best\_fitness = float('inf')

best\_individual = None

for generation in range(self.max\_generations):

offspring = []

# Селекция

parents = self.selection()

# Кроссовер

for i in range(0, len(parents), 2):

parent1 = parents[i]

parent2 = parents[(i + 1) % len(parents)]

child1, child2 = self.crossover(parent1, parent2)

offspring.extend([child1, child2])

# Мутация

for individual in offspring:

self.mutate(individual)

# Обновление популяции

self.population = offspring

# Оценка текущей популяции

fitnesses = [self.fitness(individual) for individual in self.population]

current\_best\_fitness = min(fitnesses)

if current\_best\_fitness < best\_fitness:

best\_fitness = current\_best\_fitness

best\_index = fitnesses.index(current\_best\_fitness)

best\_individual = self.population[best\_index]

print(f'Generation {generation+1}: Best Fitness = {best\_fitness}')

return best\_fitness, best\_individual

# Запуск генетического алгоритма

ga = GeneticAlgorithm(distance\_matrix, population\_size=100, max\_generations=500)

best\_fitness, best\_route = ga.run()

print(f'Best Route: {list(best\_route)}')

print(f'Total Distance: {best\_fitness}')

# Графическое представление решения

plt.figure(figsize=(10, 10))

for i in range(len(best\_route)):

j = (i + 1) % len(best\_route)

city1 = cities[best\_route[i]]

city2 = cities[best\_route[j]]

plt.plot([city1[0], city2[0]], [city1[1], city2[1]], 'b-', lw=1)

plt.scatter(\*zip(\*cities), marker='o', color='r')

for i, city in enumerate(cities):

plt.text(city[0]+10, city[1]+10, str(i+1), fontsize=10)

plt.title('Optimal Path Found by Genetic Algorithm')

plt.xlabel('X Coordinate')

plt.ylabel('Y Coordinate')

plt.show()

**Результат выполнения программы:**

Generation 1: Best Fitness = 124471.49786599903

Generation 2: Best Fitness = 124471.49786599903

Generation 3: Best Fitness = 116330.53307591617

Generation 4: Best Fitness = 112017.81933322744

Generation 5: Best Fitness = 112017.81933322744

Generation 6: Best Fitness = 112017.81933322744

Generation 7: Best Fitness = 112017.81933322744

Generation 8: Best Fitness = 112017.81933322744

Generation 9: Best Fitness = 112017.81933322744

Generation 10: Best Fitness = 112017.81933322744

Generation 11: Best Fitness = 112017.81933322744

Generation 12: Best Fitness = 112017.81933322744

Generation 13: Best Fitness = 112017.81933322744

Generation 14: Best Fitness = 112017.81933322744

Generation 15: Best Fitness = 112017.81933322744

Generation 16: Best Fitness = 112017.81933322744

Generation 17: Best Fitness = 112017.81933322744

Generation 18: Best Fitness = 107207.15840907271

Generation 19: Best Fitness = 105641.43246682864

Generation 20: Best Fitness = 101968.83616942688

Generation 21: Best Fitness = 101968.83616942688

Generation 22: Best Fitness = 100769.30342958329

Generation 23: Best Fitness = 100769.30342958329

Generation 24: Best Fitness = 100769.30342958329

Generation 25: Best Fitness = 99161.89589425895

Generation 26: Best Fitness = 99161.89589425895

Generation 27: Best Fitness = 94516.3479390183

Generation 28: Best Fitness = 94516.3479390183

Generation 29: Best Fitness = 94516.3479390183

Generation 30: Best Fitness = 94516.3479390183

Generation 31: Best Fitness = 94516.3479390183

Generation 32: Best Fitness = 94516.3479390183

Generation 33: Best Fitness = 94516.3479390183

Generation 34: Best Fitness = 93658.17696661504

Generation 35: Best Fitness = 93658.17696661504

Generation 36: Best Fitness = 93658.17696661504

Generation 37: Best Fitness = 93658.17696661504

Generation 38: Best Fitness = 93658.17696661504

Generation 39: Best Fitness = 92235.3032117479

Generation 40: Best Fitness = 92235.3032117479

Generation 41: Best Fitness = 92235.3032117479

Generation 42: Best Fitness = 92235.3032117479

Generation 43: Best Fitness = 92019.59698183418

Generation 44: Best Fitness = 92019.59698183418

Generation 45: Best Fitness = 92019.59698183418

Generation 46: Best Fitness = 91898.42410129901

Generation 47: Best Fitness = 91898.42410129901

Generation 48: Best Fitness = 91478.10240652403

Generation 49: Best Fitness = 91441.22735223372

Generation 50: Best Fitness = 91441.22735223372

Generation 51: Best Fitness = 91441.22735223372

Generation 52: Best Fitness = 91441.22735223372

Generation 53: Best Fitness = 91441.22735223372

Generation 54: Best Fitness = 91441.22735223372

Generation 55: Best Fitness = 91441.22735223372

Generation 56: Best Fitness = 91441.22735223372

Generation 57: Best Fitness = 88806.69330070594

Generation 58: Best Fitness = 88769.81824641563

Generation 59: Best Fitness = 88769.81824641563

Generation 60: Best Fitness = 88712.03569170684

Generation 61: Best Fitness = 88712.03569170684

Generation 62: Best Fitness = 88712.03569170684

Generation 63: Best Fitness = 88463.62430827146

Generation 64: Best Fitness = 88463.62430827146

Generation 65: Best Fitness = 88463.62430827146

Generation 66: Best Fitness = 88463.62430827146

Generation 67: Best Fitness = 88186.9436341257

Generation 68: Best Fitness = 88186.9436341257

Generation 69: Best Fitness = 88186.9436341257

Generation 70: Best Fitness = 87608.41758293092

Generation 71: Best Fitness = 87608.41758293092

Generation 72: Best Fitness = 87608.41758293092

Generation 73: Best Fitness = 87608.41758293092

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Generation 75: Best Fitness = 84314.17741414864

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Generation 82: Best Fitness = 83598.23575679373

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Generation 85: Best Fitness = 83441.9513273014

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Generation 87: Best Fitness = 83441.9513273014

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Generation 93: Best Fitness = 80891.01531300724

Generation 94: Best Fitness = 80891.01531300724

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Generation 99: Best Fitness = 80580.54120317409

Generation 100: Best Fitness = 80580.54120317409

Generation 101: Best Fitness = 77803.54732627393

Generation 102: Best Fitness = 77803.54732627393

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Generation 264: Best Fitness = 66035.98442271128

Generation 265: Best Fitness = 66035.98442271128

Generation 266: Best Fitness = 66035.98442271128

Generation 267: Best Fitness = 64223.073685695745

Generation 268: Best Fitness = 64223.073685695745

Generation 269: Best Fitness = 62648.1731561254

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Generation 271: Best Fitness = 62648.1731561254

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Total Distance: 56944.941703886965

