Lab Report

Course Name: Artificial Intelligence

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Professional Class: CST-Batch2018

Session (2021-2022-1)

Henan Polytechnic University

Score Standard of Lab Report

IDX	Evaluation Index	Points	Evaluation grade and reference score					Points
			Excellent	Good	Medium	Qualified	Poor	
1	The experimental report is complete and substantial	10	10	8	7	6	3	
2	The experiments are written in a standard and neat way	10	10	8	7	6	3	
3	Detailed description of the experiment process, correct concept, accurate language expression, rigorous structure, clear and logical, no plagiarism.	30	30	26	23	20	10	
4	Analyze the problems in the process of the experiment in detail, thoroughly, profoundly, comprehensively and standardized. Have personal opinions and ideas, and can put forward relevant problems and give solutions.	30	30	26	23	20	10	
5	The experimental results, analysis and conclusion are correct	20	20	17	15	13	6	
Total Points:								

Signature (seal):

Date:

Lab Report of Henan Polytechnic University

Date: 12.05

Lab Name: <u>**A***</u>

Lab Aim And Requirement:

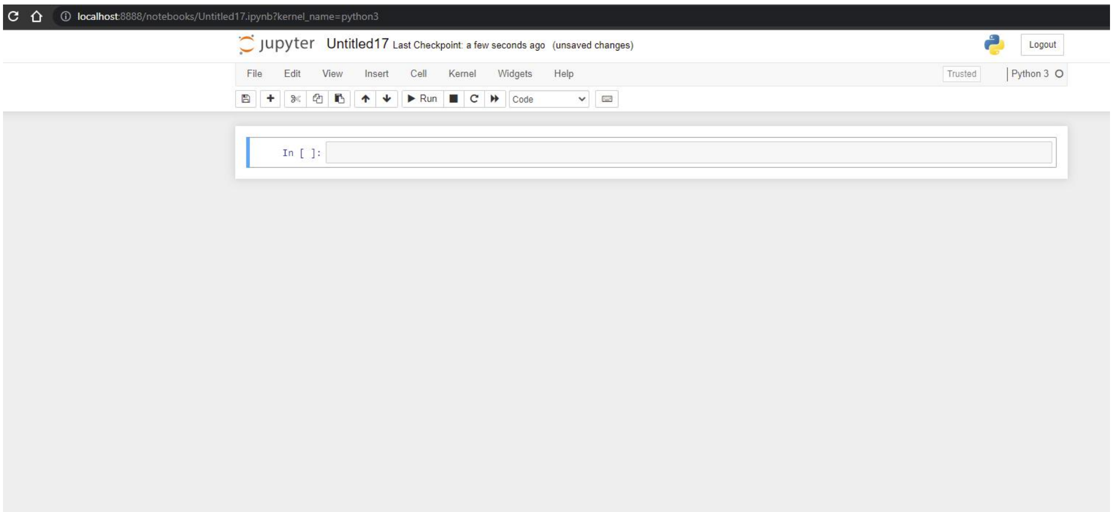
1) Be familiar with and master the definition of heuristic search, evaluation function and algorithm process.

2) Use A* algorithm to solve N-number problems, understand the solution process and search order.

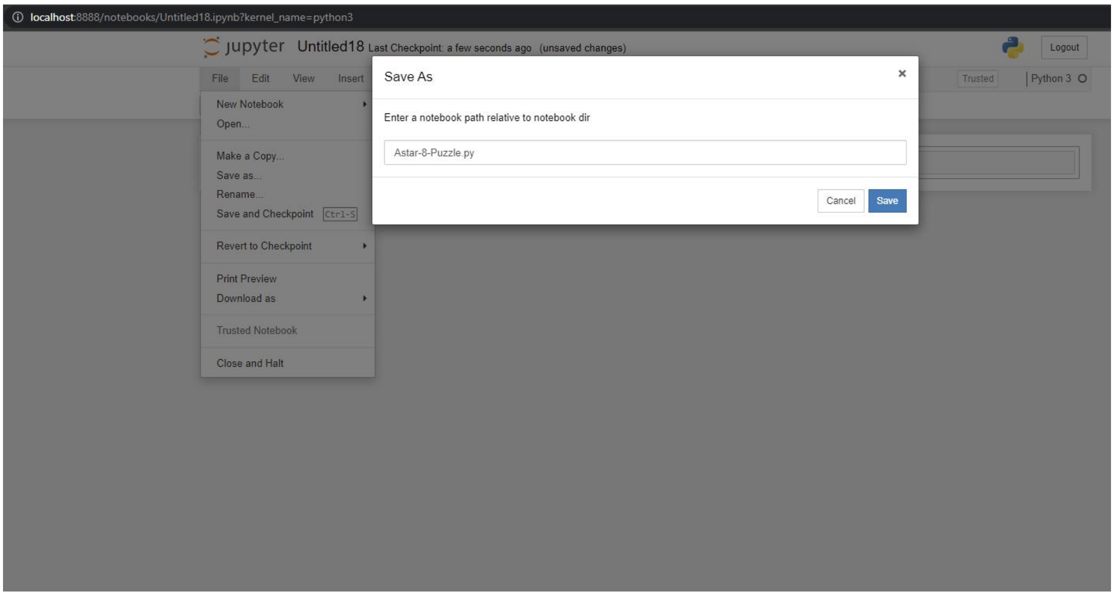
3) Master related functions of numpy library.

Lab Steps:

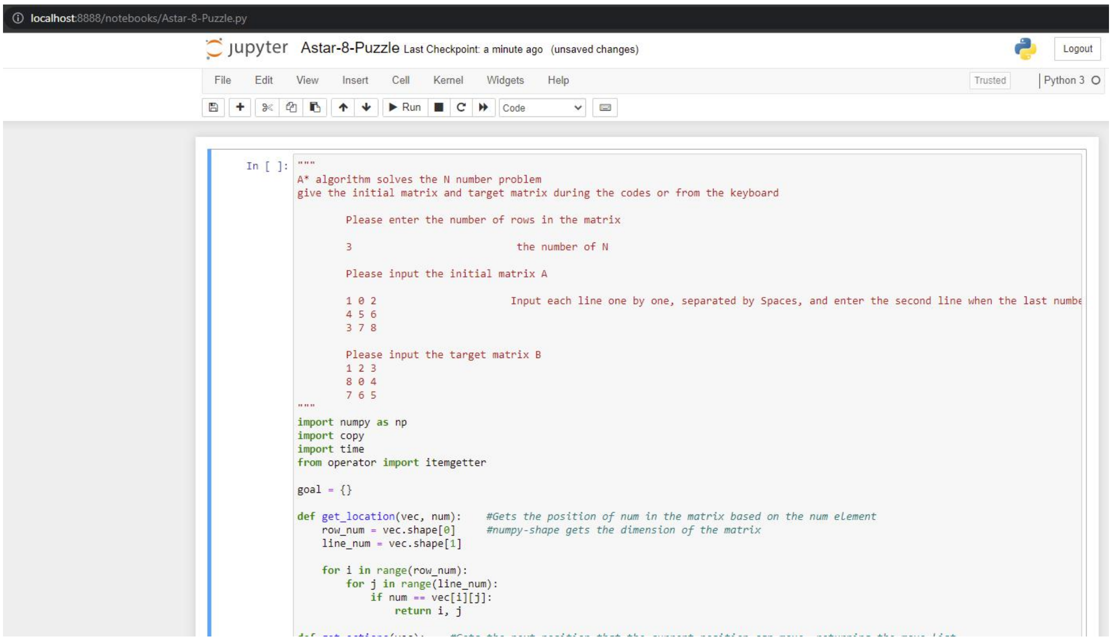
1. As Python IDE, I used Jupyter notebook. So I opened a new file.



2. Named the file as Astar-8-Puzzle and saved it as .py file



3. Wrote all the code. Below some picture of the code



localhost:8888/notebooks/Astar-8-Puzzle.py

jupyter Astar-8-Puzzle Last Checkpoint: 2 minutes ago (autosaved)

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```python
def get_actions(vec):    #Gets the next position that the current position can move, returning the move list
    row_num = vec.shape[0]
    line_num = vec.shape[1]

    (x, y) = get_location(vec, 0)    #Gets the location of the 0 element
    action = [(0, 1), (0, -1), (1, 0), (-1, 0)]

    if x == 0:    #If 0 is on the edge, reduce the movable position of 0 depending on the position
        action.remove((-1, 0))
    if y == 0:
        action.remove((0, -1))
    if x == row_num - 1:
        action.remove((1, 0))
    if y == line_num - 1:
        action.remove((0, 1))

    return list(action)

def result(vec, action):    #Move the element, do the matrix transformation
     (x, y) = get_location(vec, 0)    #Gets the location of the 0 element
     (a, b) = action    #Gets the removable location

     n = vec[x+a][y+b]    #Move positions, swap elements
     s = copy.deepcopy(vec)
     s[x+a][y+b] = 0
     s[x][y] = n

     return s

def get_ManhattanDis(vec1, vec2):    #Manhattan distance of two matrices is calculated. Vec1 is the target matrix and Vec2 is the
    row_num = vec1.shape[0]
    line_num = vec1.shape[1]
    dis  = 0

    for i in range(row_num):
        for j in range(line_num):
            if vec1[i][j] != vec2[i][j] and vec2[i][j] != 0:
                k, m = get_location(vec1, vec2[i][j])
                d = abs(i - k) + abs(j - m)
                dis += d

    return dis

def expand(p, actions, step):          #Actions is the list of extensible states for the current matrix, P is the current matrix
    children = []                                  #Use Children to save the extension node of the current state
    for action in actions:
        child = {}
        child['parent'] = p
        child['vec'] = (result(p['vec'], action))
```

localhost:8888/notebooks/Astar-8-Puzzle.py

jupyter Astar-8-Puzzle Last Checkpoint: 2 minutes ago (autosaved)

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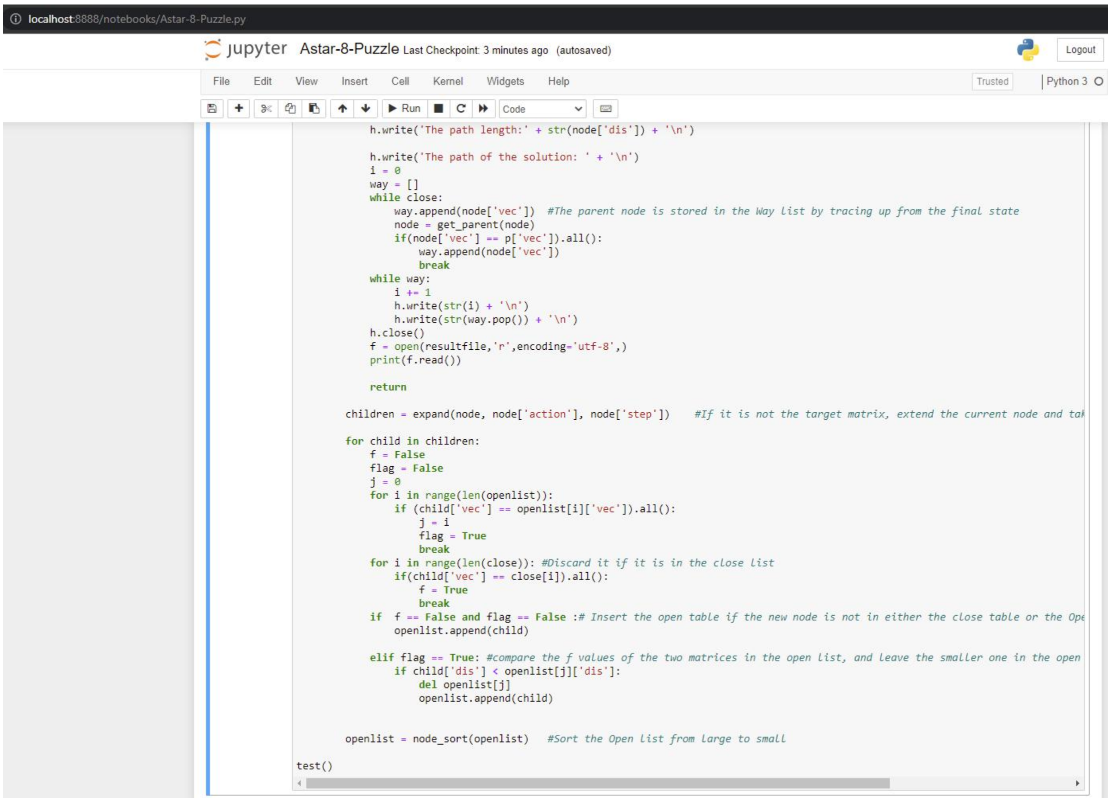
```python
def node_sort(nodelist):    #Sort the list by the distance field of the dictionary of the node, from large to small
    return sorted(nodelist, key = itemgetter('dis'), reverse=True)

def get_input(num):
    A = []
    for i in range(num):
        temp = []
        p = []
        s = input()
        temp = s.split(' ')
        for t in temp:
            t = int(t)
            p.append(t)
        A.append(p)

    return A

def get_parent(node):
    q = {}
    q = node['parent']
    return q

def test():
    openlist = []    #open list
    close = []       #Store the parent nodes of the extension

    print('Please enter the number of rows of the matrix')
    #num = int(input())
    num=3;
    print("Please enter the initial matrix A")
    #A = get_input(num)
    A=np.mat('1 0 2;4 5 6;3 7 8')

    print("Please enter the target matrix B")
    #B = get_input(num)
    B=np.mat('1 2 3;8 0 4;7 6 5')

    print("Please enter the filename of the result")
    #resultfile = input()
    resultfile = "a.txt"
    goal['vec'] = np.array(B)   #Establish a matrix

    p = {}
    p['vec'] = np.array(A)
    p['dis'] = get_ManhattanDis(goal['vec'], p['vec'])
    p['step'] = 0
    p['action'] = get_actions(p['vec'])
    p['parent'] = {}
```




```python
            h.write('The path length:' + str(node['dis']) + '\n')

            h.write('The path of the solution: ' + '\n')
            i = 0
            way = []
            while close:
                way.append(node['vec'])  #The parent node is stored in the Way list by tracing up from the final state
                node = get_parent(node)
                if(node['vec'] == p['vec']).all():
                    way.append(node['vec'])
                    break
            while way:
                i += 1
                h.write(str(i) + '\n')
                h.write(str(way.pop()) + '\n')
            h.close()
            f = open(resultfile,'r',encoding='utf-8',)
            print(f.read())

            return

        children = expand(node, node['action'], node['step'])    #If it is not the target matrix, extend the current node and tak

        for child in children:
            f = False
            flag = False
            j = 0
            for i in range(len(openlist)):
                if (child['vec'] == openlist[i]['vec']).all():
                    j = i
                    flag = True
                    break
            for i in range(len(close)): #Discard it if it is in the close list
                if(child['vec'] == close[i]).all():
                    f = True
                    break
            if  f == False and flag == False :# Insert the open table if the new node is not in either the close table or the Ope
                openlist.append(child)

            elif flag == True: #compare the f values of the two matrices in the open list, and leave the smaller one in the open
                if child['dis'] < openlist[j]['dis']:
                    del openlist[j]
                    openlist.append(child)


        openlist = node_sort(openlist)   #Sort the Open List from large to small

test()
```

1.For getting the location:

```
def get_location(vec, num):
        row_num = vec.shape[0]
        line_num = vec.shape[1]
    for i in range(row_num):
                for j in range(line_num):
                        if num == vec[i][j]:
                                return i, j
```

2.Getting position of num matirix.

```
def get_actions(vec):
        row_num = vec.shape[0]
        line_num = vec.shape[1]
        (x, y) = get_location(vec, 0)
        action = [(0, 1), (0, -1), (1, 0), (-1, 0)]
        if x == 0:
          on the position
                action.remove((-1, 0))
        if y == 0:
                action.remove((0, -1))
        if x == row_num - 1:
                action.remove((1, 0))
        if y == line_num - 1:
                action.remove((0, 1))
        return list(action)
```

```
def result(vec, action):
        (x, y) = get_location(vec, 0)
        (a, b) = action
        n = vec[x+a][y+b]
        s = copy.deepcopy(vec)
        s[x+a][y+b] = 0
        s[x][y] = n
        return s
```

3. Manhattan distance of two matrices is calculated.

```
def get_ManhattanDis(vec1, vec2):
    row_num = vec1.shape[0]
    line_num = vec1.shape[1]
    dis   = 0
    for i in range(row_num):
        for j in range(line_num):
            if vec1[i][j] != vec2[i][j] and vec2[i][j] != 0:
                k, m = get_location(vec1, vec2[i][j])
                d = abs(i - k) + abs(j - m)
                dis += d
    return dis
```

4. Expanding the node:

```
def expand(p, actions, step):
    children = []
    for action in actions:
        child = {}
        child['parent'] = p
        child['vec'] = (result(p['vec'], action))
        child['dis'] = get_ManhattanDis(goal['vec'], child['vec'])
        child['step'] = step + 1
        child['dis'] = child['dis'] + child['step']
        child['action'] = get_actions(child['vec'])
        children.append(child)
    return children
```

5. Sorting and getting the input:

```
def node_sort(nodelist):
    return sorted(nodelist, key = itemgetter('dis'), reverse=True)
def get_input(num):
    A = []
    for i in range(num):
        temp = []
        p = []
        s = input()
        temp = s.split(' ')
        for t in temp:
```

```
                t = int(t)
                p.append(t)
            A.append(p)
        return A
def get_parent(node):
        q = {}
        q = node['parent']
        return q

def test():
        openlist = []
        close = []
        print('Please enter the number of rows of the matrix')
        num=3;
        print("Please enter the initial matrix A")
        A=np.mat('1 0 2;4 5 6;3 7 8')
        print("Please enter the target matrix B")
        B=np.mat('1 2 3;8 0 4;7 6 5')
        print("Please enter the filename of the result")
        resultfile = "a.txt"
        goal['vec'] = np.array(B)
        p = {}
        p['vec'] = np.array(A)
        p['dis'] = get_ManhattanDis(goal['vec'], p['vec'])
        p['step'] = 0
        p['action'] = get_actions(p['vec'])
        p['parent'] = {}
        if (p['vec'] == goal['vec']).all():
                return
        openlist.append(p)
        while openlist:
                children = []
                node = openlist.pop()
                close.append(node)
                if (node['vec'] == goal['vec']).all():
                        h = open(resultfile,'w',encoding='utf-8',)
                        h.write('Size of the search tree:' + str(len(openlist)+len(close)) + '\n')
                        h.write('close：  ' + str(len(close)) + '\n')
                        h.write('openlist：  ' + str(len(openlist)) + '\n')
                        h.write('The path length:' + str(node['dis']) + '\n')
                        h.write('The path of the solution: ' + '\n')
                        i = 0
                        way = []
                        while close:
```

```
                way.append(node['vec'])
                node = get_parent(node)
                if(node['vec'] == p['vec']).all():
                    way.append(node['vec'])
                    break
            while way:
                i += 1
                h.write(str(i) + '\n')
                h.write(str(way.pop()) + '\n')
            h.close()
            f = open(resultfile,'r',encoding='utf-8',)
            print(f.read())
            return
        children = expand(node, node['action'], node['step'])
        for child in children:
            f = False
            flag = False
            j = 0
            for i in range(len(openlist)):
                if (child['vec'] == openlist[i]['vec']).all():
                    j = i
                    flag = True
                    break
            for i in range(len(close)):
                if(child['vec'] == close[i]).all():
                    f = True
                    break
            if    f == False and flag == False :
                openlist.append(child)
            elif flag == True:
                if child['dis'] < openlist[j]['dis']:
                    del openlist[j]
                    openlist.append(child)
        openlist = node_sort(openlist)
test()
```

Lab Result:

jupyter Astar-8-Puzzle Last Checkpoint: 14 minutes ago (unsaved changes)

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Run Code

```
Size of the search tree:1015
close: 702
openlist: 313
The path length:21
The path of the solution:
1
[[1 0 2]
 [4 5 6]
 [3 7 8]]
2
[[1 5 2]
 [4 0 6]
 [3 7 8]]
3
[[1 5 2]
 [4 7 6]
 [3 0 8]]
4
[[1 5 2]
 [4 7 6]
 [0 3 8]]
5
[[1 5 2]
 [0 7 6]
 [4 3 8]]
6
[[1 5 2]
 [7 0 6]
 [4 3 8]]
7
[[1 5 2]
 [7 3 6]
 [4 0 8]]
8
[[1 5 2]
 [7 3 6]
 [4 8 0]]
9
[[1 5 2]
 [7 3 0]
 [4 8 6]]
10
[[1 5 2]
 [7 0 3]
 [4 8 6]]
11
[[1 0 2]
 [7 5 3]
 [4 8 6]]
```

jupyter Astar-8-Puzzle Last Checkpoint: 14 minutes ago (autosaved)

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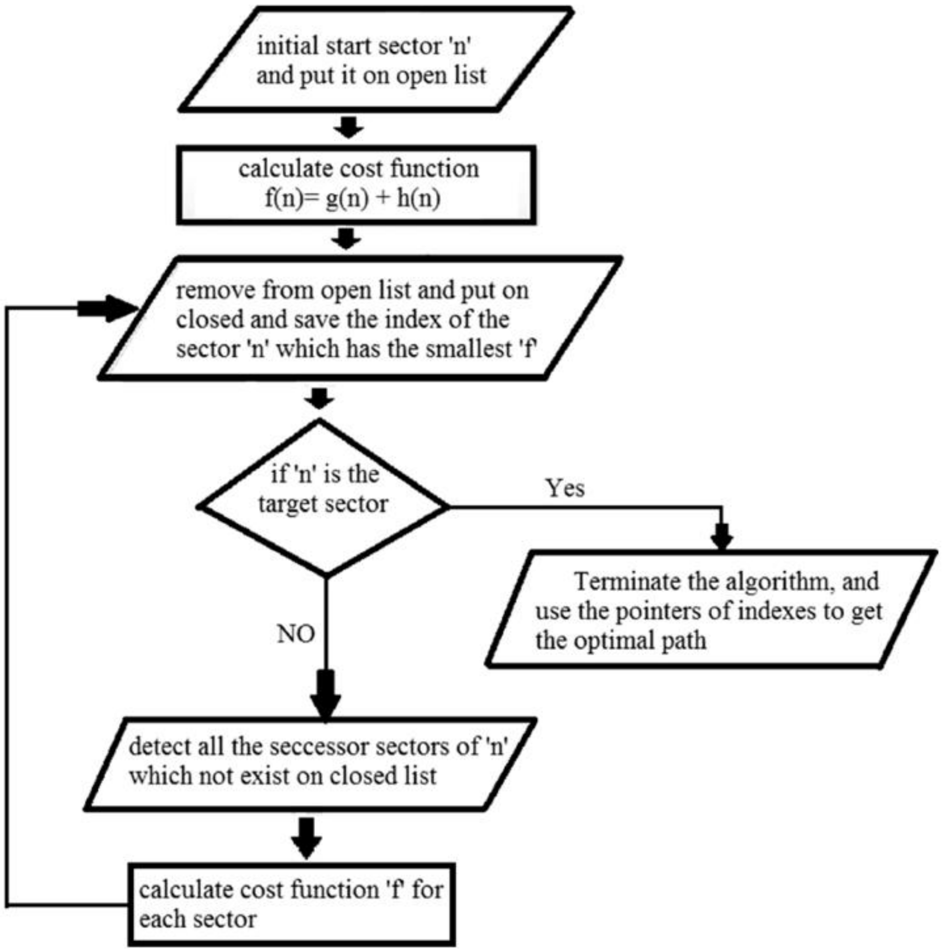
Run Code

```
12
[[1 2 0]
 [7 5 3]
 [4 8 6]]
13
[[1 2 3]
 [7 5 0]
 [4 8 6]]
14
[[1 2 3]
 [7 0 5]
 [4 8 6]]
15
[[1 2 3]
 [7 8 5]
 [4 0 6]]
16
[[1 2 3]
 [7 8 5]
 [0 4 6]]
17
[[1 2 3]
 [0 8 5]
 [7 4 6]]
18
[[1 2 3]
 [8 0 5]
 [7 4 6]]
19
[[1 2 3]
 [8 4 5]
 [7 0 6]]
20
[[1 2 3]
 [8 4 5]
 [7 6 0]]
21
[[1 2 3]
 [8 4 0]
 [7 6 5]]
22
[[1 2 3]
 [8 0 4]
 [7 6 5]]
```

In [ ]:

Lab Analysis:

Block Diagram of A* algorithm:



Through this experiment, I learned the basic idea of the A-star algorithm, got a preliminary understanding of the AI algorithm. The application of the star algorithm has a deeper understanding; the comparison of different valuation functions, and the understanding of the calculation of different valuation functions. A* search is the most commonly known form of best-first search. It uses heuristic function h(n), and cost to reach the node n from the start state g(n). It has combined features of UCS and greedy best-first search, by which it solve the problem efficiently. A* search algorithm finds the shortest path through the search space using the heuristic function. This search algorithm expands less search tree and provides optimal result faster. A* algorithm is similar to UCS except that it uses g(n)+h(n) instead of g(n). In A* search algorithm, we use search heuristic as well as the cost to reach the node. Hence we can combine both costs as following, and this sum is called as a fitness number.

In code we used get_location() function to get the position of num in the matrix then get_action() function to find next position where current position can move. Later, get_ManhattanDis() function is used to find the distance between two matrices.

Inside expand() function, p is the current matrix, step indicates the number of step taken and actions is the list of extensible states for the current matrix. Node_sort() is used to sort the nodes form large to small then the get_input(), get_parent() and test() function is used.
Grade: **Date:**

Lab Report of Henan Polytechnic University

Date: 12.12

Lab Name: <u>**The genetic algorithm**</u>

Lab Aim And Requirement:

1) Be familiar with and master the principle, process and coding strategy of genetic algorithm
2) Use genetic algorithm to solve function optimization problem
3) Understand the process of solving the TSP problem and test the impact of major parameters on the results.

Lab Steps:

1. Coding: through coding, the problem variable to be solved is expressed as genotype string structure data-chromosome;
2. Generate the initial population: N chromosomes are randomly generated after encoding to construct the initial population of the genetic algorithm, and then use the
Start the iterative search with the initial population as the starting point;
3. Calculate the fitness of the individual: use the fitness function to evaluate the pros and cons of the solution;
4. Selection: also known as duplication or reproduction, that is, to select a chromosome with strong vitality from the current population, so that it has the opportunity to retain its use.
To breed offspring;
5. Crossover; also known as recombination or pairing, that is, from individuals in the chromosomes used for reproduction, randomly cross and interchange the dyes in the individuals
Mutation: Mutation typically works by making very small changes at random to an individual's genome.
6. Repeat : Now we have our next generation we can start again from step two until we reach a termination condition
7. Plotting the best path found

Code:

```
#.Importing the relevant package and declaration of variable:
from random import shuffle, random, randint
from math import sqrt, floor
import matplotlib.pyplot as plt
# constants
GENERATION_COUNT = 1000
```

```
POPULATION_COUNT = 500
SATURATION_PERCENTAGE = 0.5
MUTATION_PROBABILITY = 0.9
# Giving the city coordinates:
coordinates = [(20,20), (20,40), (20,160), (40,120),(60,20), (60,80), (60,200), (80,180),
(100,40), (100,120), (100,160), (120,80), (140,140), (140,180), (160,20), (180,60),
(180,100), (180,200), (200,40), (200,160)]
# creating a path object:
class Path:
    def __init__(self, sequence):
        self.sequence = sequence
        self.distance = 0
        self.fitness = 0
    def __repr__(self):
        return "{ " + f"Path: {self.sequence}, Fitness: {self.fitness}" + " }"
# initialization: Create an initial population. This population is usually randomly
generated and can be any desired size, from only a few individuals to thousands.
def initialization(path, populationCount):
    population = [path]
    for i in range(populationCount - 1):
        newPath = path.sequence[:]
        while pathExists(newPath, population):
            shuffle(newPath)
        population.append(Path(newPath))
    return population
# Returns true if the path exists and false otherwise
def pathExists(path, population):
    for item in population:
        if item.sequence == path:
            return True
    return False
# Evaluation: Each member of the population is then evaluated and we calculate a
'fitness' for that individual. The fitness value is calculated by how well it fits with our
desired requirements. These requirements could be simple, 'faster algorithms are
better', or more complex, 'stronger materials are better but they shouldn't be too
heavy'
def calculateDistance(path):
    total = 0
    for i in range(len(path.sequence)):
        if i == len(path.sequence) - 1:
            distance = sqrt((coordinates[path.sequence[0]][0] -
coordinates[path.sequence[i]][0])**2 + (
                coordinates[path.sequence[0]][1] -
coordinates[path.sequence[i]][1])**2)
```

```
                total += distance
            else:
                distance = sqrt((coordinates[path.sequence[i+1]][0] - coordinates[path.sequence[i]][0])**2 + (
                    coordinates[path.sequence[i+1]][1] - coordinates[path.sequence[i]][1])**2)
                total += distance
    path.distance = total
    return total
def calculateFitness(population):
    sum = 0
    for path in population:
        distance = calculateDistance(path)
        sum += 1/distance
        path.fitness = 1/distance
    for path in population:
        path.fitness /= sum
    return sorted(population, key=lambda x: x.fitness, reverse=True)
```

Selection: We want to be constantly improving our populations overall fitness. Selection helps us to do this by discarding the bad designs and only keeping the best individuals in the population. There are a few different selection methods but the basic idea is the same, make it more likely that fitter individuals will be selected for our next generation.

```
def select(population):
    randomNumber = random()
    third = floor(0.3 * len(population))
    randomIndex = randint(0, third)
    if randomNumber <= 0.7:
        return population[randomIndex]
    else:
        return population[randint(third+1, len(population) - 1)]
```

Crossover: During crossover we create new individuals by combining aspects of ourselected individuals. from two or more individuals we will create an even 'fitter' offspring which will inherit the best traits from We can think of this as mimicking how sex works in nature. The hope is that by combining certain traits each of its parents.

```
def crossOver(population):
    father = select(population)
    mother = select(population)
    while(mother == father):
        mother = select(population)
    startIndex = randint(0,len(mother.sequence) - 2)
    endIndex = randint(startIndex + 1, len(mother.sequence) - 1)
    childSequence = [None] * len(population[0].sequence)
```

```
    for i in range(startIndex, endIndex + 1):
        childSequence[i] = mother.sequence[i]
    for i in range(len(childSequence)):
        if childSequence[i] is None:
            for j in range(0, len(childSequence)):
                if father.sequence[j] not in childSequence:
                    childSequence[i] = father.sequence[j]
                    break
    return Path(childSequence)
def crossOverTwoHalfandHalf(population):
    father = select(population)
    mother = select(population)
    while(mother == father):
        mother = select(population)
    mid = len(mother.sequence) // 2
    childSequence = [None] * len(mother.sequence)
    for i in range(mid):
        childSequence[i] = mother.sequence[i]
    for i in range(mid, len(father.sequence)):
        for k in range(len(father.sequence)):
            if father.sequence[k] not in childSequence:
                childSequence[i] = father.sequence[k]
                break
    return Path(childSequence)
```

Mutation :We need to add a little bit randomness into our populations' genetics otherwise every combination of solutions we can create would be in our initial population. Mutation typically works by making very small changes at random to an individual’s genome.

```
def mutation(path):
    firstIndex = randint(0, len(path.sequence) - 1)
    secondIndex = randint(0, len(path.sequence) - 1)
    while secondIndex == firstIndex:
        secondIndex = randint(0, len(path.sequence) - 1)
    probability = random()
    if probability < MUTATION_PROBABILITY:
        temp = path.sequence[firstIndex]
        path.sequence[firstIndex] = path.sequence[secondIndex]
        path.sequence[secondIndex] = temp
    return path
def mutationTwoInsertion(path):
    firstIndex = randint(0, len(path.sequence) - 1)
    secondIndex = randint(0, len(path.sequence) - 1)
    while secondIndex == firstIndex:
        secondIndex = randint(0, len(path.sequence) - 1)
```

```
        probability = random()
        if probability < MUTATION_PROBABILITY:
                city = path.sequence[firstIndex]
                path.sequence.remove(path.sequence[firstIndex])
                path.sequence.insert(secondIndex, city)
        return path
# Repeat : Now we have our next generation we can start again from step two until we reach a termination condition
def geneticAlgorithm(path, populationCount, generationCount):
        path = Path(path)
        population = initialization(path, populationCount)
        population = calculateFitness(population)
        best = population[0]
        print(f"Generation 1: Fitness: {best.fitness}, Distance: {round(best.distance, 2)}")
        saturation = 0
        for i in range(2, generationCount + 1):
                print(f"Generation {i}: Fitness: {best.fitness}, Distance: {round(best.distance, 2)}")
                newGeneration = []
                for _ in range(populationCount):
                        child = crossOver(population)
                        # child = crossOverTwoHalfandHalf(population)
                        newGeneration.append(mutation(child))
                        # newGeneration.append(mutationTwoInsertion(child))
                population = calculateFitness(newGeneration)
                if population[0].fitness > best.fitness:
                        best = population[0]
                        saturation = 0
                else:
                        saturation += 1
                if saturation > (SATURATION_PERCENTAGE * GENERATION_COUNT):
                        break
        return best
# Plotting the best path found
def plotData(path):
        x = []
        y = []
        for i in range(len(path.sequence)):
                x.append(coordinates[path.sequence[i]][0])
                y.append(coordinates[path.sequence[i]][1])
        x.append(coordinates[path.sequence[0]][0])
        y.append(coordinates[path.sequence[0]][1])
        plt.xlabel("x")
        plt.ylabel("y")
```

```
    plt.title(f"Traveling Sales Person\nSequence:\n{path.sequence}")
    plt.plot(x, y, "bo-")
    plt.show()
# program entry point
if __name__ == "__main__":
    cities = list(range(20))
    best = geneticAlgorithm(cities, POPULATION_COUNT, GENERATION_COUNT)
    plotData(best)
```

In [4]:

```python
from random import shuffle, random, randint
from math import sqrt, floor
import matplotlib.pyplot as plt

# constants
GENERATION_COUNT = 1000
POPULATION_COUNT = 500
SATURATION_PERCENTAGE = 0.5
MUTATION_PROBABILITY = 0.9

# city coordinates
coordinates = [(20,20), (20,40), (20,160), (40,120),(60,20), (60,80), (60,200), (80,180), (100,40), (100,120), (100,160), (120,8

# creating a path object
class Path:
    def __init__(self, sequence):
        self.sequence = sequence
        self.distance = 0
        self.fitness = 0

    def __repr__(self):
        return "{ " + f"Path: {self.sequence}, Fitness: {self.fitness}" + " }"

# initialization
# Create an initial population. This population is usually randomly generated and can be any desired size, from only a few indivi
def initialization(path, populationCount):
    population = [path]
    for i in range(populationCount - 1):
        newPath = path.sequence[:]
        while pathExists(newPath, population):
            shuffle(newPath)
        population.append(Path(newPath))
    return population

# Returns true if the path exists and false otherwise
def pathExists(path, population):
    for item in population:
        if item.sequence == path:
            return True
    return False

# evaluation
# Each member of the population is then evaluated and we calculate a 'fitness' for that individual. The fitness value is calculat
def calculateDistance(path):
    total = 0
    for i in range(len(path.sequence)):
        if i == len(path.sequence) - 1:
```

```python
# Repeat
# Now we have our next generation we can start again from step two until we reach a termination condition
def geneticAlgorithm(path, populationCount, generationCount):
    path = Path(path)
    population = initialization(path, populationCount)
    population = calculateFitness(population)
    best = population[0]
    print(f"Generation 1: Fitness: {best.fitness}, Distance: {round(best.distance, 2)}")
    saturation = 0
    for i in range(2, generationCount + 1):
        print(f"Generation {i}: Fitness: {best.fitness}, Distance: {round(best.distance, 2)}")
        newGeneration = []
        for _ in range(populationCount):
            child = crossOver(population)
            # child = crossOverTwoHalfandHalf(population)
            newGeneration.append(mutation(child))
            # newGeneration.append(mutationTwoInsertion(child))
        population = calculateFitness(newGeneration)
        if population[0].fitness > best.fitness:
            best = population[0]
            saturation = 0
        else:
            saturation += 1
        if saturation > (SATURATION_PERCENTAGE * GENERATION_COUNT):
            break
    return best

# Plotting the best path found
def plotData(path):
    x = []
    y = []
    for i in range(len(path.sequence)):
        x.append(coordinates[path.sequence[i]][0])
        y.append(coordinates[path.sequence[i]][1])
    x.append(coordinates[path.sequence[0]][0])
    y.append(coordinates[path.sequence[0]][1])
    plt.xlabel("x")
    plt.ylabel("y")
    plt.title(f"Traveling Sales Person\nSequence:\n{path.sequence}")
    plt.plot(x, y, "bo-")
    plt.show()

# program entry point
if __name__ == "__main__":
    cities = list(range(20))
    best = geneticAlgorithm(cities, POPULATION_COUNT, GENERATION_COUNT)
    plotData(best)
```

Lab Result:

```
Generation 1: Fitness: 0.002718583105922784, Distance: 1697.08
Generation 2: Fitness: 0.002718583105922784, Distance: 1697.08
Generation 3: Fitness: 0.0028578645998264002, Distance: 1551.14
Generation 4: Fitness: 0.0028578645998264002, Distance: 1551.14
Generation 5: Fitness: 0.0028578645998264002, Distance: 1551.14
Generation 6: Fitness: 0.0028578645998264002, Distance: 1551.14
Generation 7: Fitness: 0.0028578645998264002, Distance: 1551.14
Generation 8: Fitness: 0.0028578645998264002, Distance: 1551.14
Generation 9: Fitness: 0.0028578645998264002, Distance: 1551.14
Generation 10: Fitness: 0.0028578645998264002, Distance: 1551.14
Generation 11: Fitness: 0.0028578645998264002, Distance: 1551.14
Generation 12: Fitness: 0.0028578645998264002, Distance: 1551.14
Generation 13: Fitness: 0.0028578645998264002, Distance: 1551.14
Generation 14: Fitness: 0.0028578645998264002, Distance: 1551.14
Generation 15: Fitness: 0.0028578645998264002, Distance: 1551.14
Generation 16: Fitness: 0.0028578645998264002, Distance: 1551.14
Generation 17: Fitness: 0.0028578645998264002, Distance: 1551.14
Generation 18: Fitness: 0.002960717946567022, Distance: 1388.68
Generation 19: Fitness: 0.002960717946567022, Distance: 1388.68
```

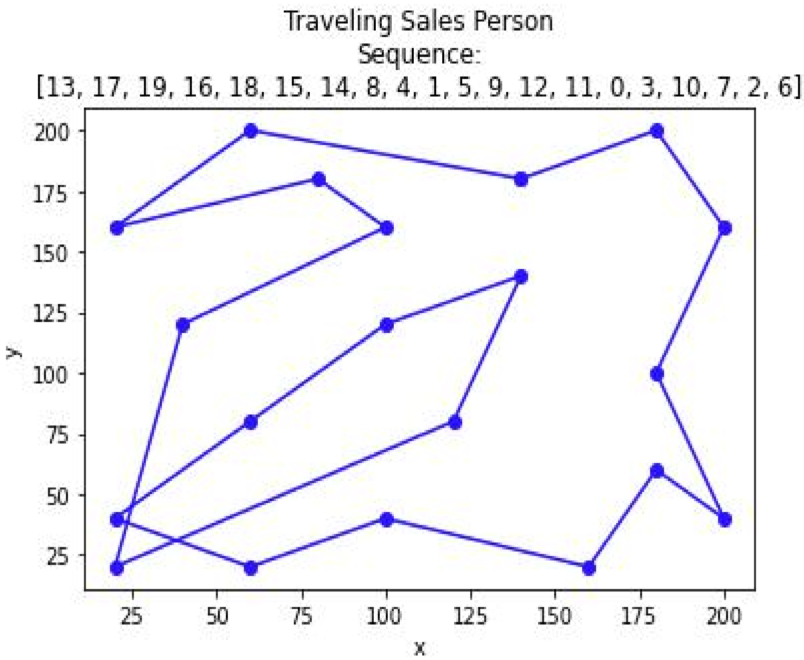
```
Generation 22: Fitness: 0.002960717946567022, Distance: 1388.68
Generation 23: Fitness: 0.002960717946567022, Distance: 1388.68
Generation 24: Fitness: 0.002960717946567022, Distance: 1388.68
Generation 25: Fitness: 0.002960717946567022, Distance: 1388.68
Generation 26: Fitness: 0.002960717946567022, Distance: 1388.68
Generation 27: Fitness: 0.002960717946567022, Distance: 1388.68
Generation 28: Fitness: 0.002960717946567022, Distance: 1388.68
Generation 29: Fitness: 0.002960717946567022, Distance: 1388.68
Generation 30: Fitness: 0.002960717946567022, Distance: 1388.68
Generation 31: Fitness: 0.002960717946567022, Distance: 1388.68
Generation 32: Fitness: 0.002960717946567022, Distance: 1388.68
Generation 33: Fitness: 0.002960717946567022, Distance: 1388.68
Generation 34: Fitness: 0.002960717946567022, Distance: 1388.68
Generation 35: Fitness: 0.002960717946567022, Distance: 1388.68
Generation 36: Fitness: 0.0029717018347653, Distance: 1382.54
Generation 37: Fitness: 0.0029717018347653, Distance: 1382.54
Generation 38: Fitness: 0.0029717018347653, Distance: 1382.54
Generation 39: Fitness: 0.0029717018347653, Distance: 1382.54
Generation 40: Fitness: 0.0029717018347653, Distance: 1382.54
```

```
Generation 102: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 103: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 104: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 105: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 106: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 107: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 108: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 109: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 110: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 111: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 112: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 113: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 114: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 115: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 116: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 117: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 118: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 119: Fitness: 0.003238127562531763, Distance: 1268.34
```

```
Generation 200: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 201: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 202: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 203: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 204: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 205: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 206: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 207: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 208: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 209: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 210: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 211: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 212: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 213: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 214: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 215: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 216: Fitness: 0.003238127562531763, Distance: 1268.34
Generation 217: Fitness: 0.003238127562531763, Distance: 1268.34
```

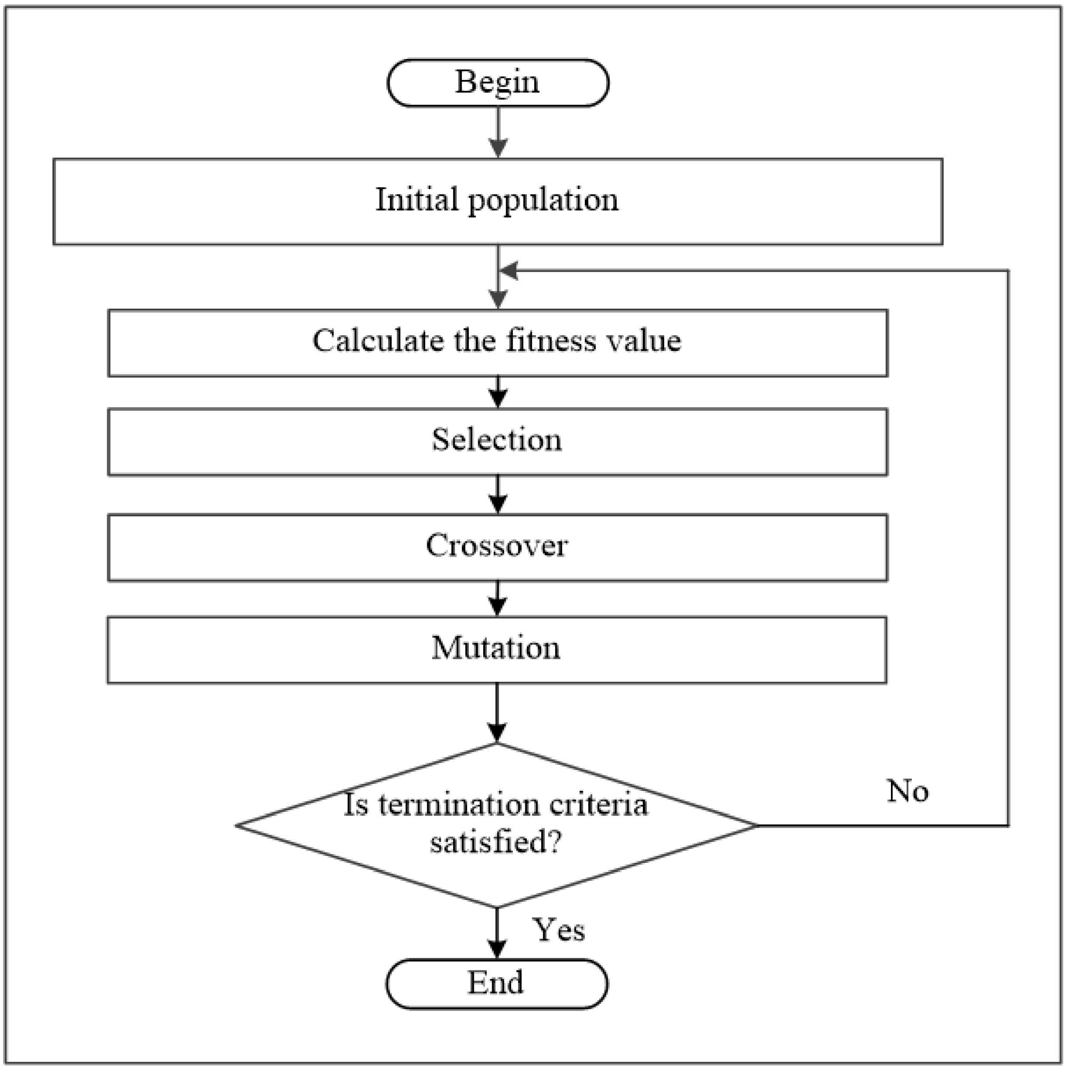
```
Generation 370: Fitness: 0.00331124459967089З, Distance: 1219.38
Generation 371: Fitness: 0.003311244599670893, Distance: 1219.38
Generation 372: Fitness: 0.003311244599670893, Distance: 1219.38
Generation 373: Fitness: 0.003311244599670893, Distance: 1219.38
Generation 374: Fitness: 0.003311244599670893, Distance: 1219.38
Generation 375: Fitness: 0.003311244599670893, Distance: 1219.38
Generation 376: Fitness: 0.003311244599670893, Distance: 1219.38
Generation 377: Fitness: 0.003311244599670893, Distance: 1219.38
Generation 378: Fitness: 0.003311244599670893, Distance: 1219.38
Generation 379: Fitness: 0.003311244599670893, Distance: 1219.38
Generation 380: Fitness: 0.003311244599670893, Distance: 1219.38
Generation 381: Fitness: 0.003311244599670893, Distance: 1219.38
Generation 382: Fitness: 0.003311244599670893, Distance: 1219.38
Generation 383: Fitness: 0.003311244599670893, Distance: 1219.38
Generation 384: Fitness: 0.003311244599670893, Distance: 1219.38
Generation 385: Fitness: 0.003311244599670893, Distance: 1219.38
Generation 386: Fitness: 0.003311244599670893, Distance: 1219.38
Generation 387: Fitness: 0.003311244599670893, Distance: 1219.38
Generation 388: Fitness: 0.003311244599670893, Distance: 1219.38
```

```
Generation 983: Fitness: 0.0032386947376718185, Distance: 1280.05
Generation 984: Fitness: 0.0032386947376718185, Distance: 1280.05
Generation 985: Fitness: 0.0032386947376718185, Distance: 1280.05
Generation 986: Fitness: 0.0032386947376718185, Distance: 1280.05
Generation 987: Fitness: 0.0032386947376718185, Distance: 1280.05
Generation 988: Fitness: 0.0032386947376718185, Distance: 1280.05
Generation 989: Fitness: 0.0032386947376718185, Distance: 1280.05
Generation 990: Fitness: 0.0032386947376718185, Distance: 1280.05
Generation 991: Fitness: 0.0032386947376718185, Distance: 1280.05
Generation 992: Fitness: 0.0032386947376718185, Distance: 1280.05
Generation 993: Fitness: 0.0032386947376718185, Distance: 1280.05
Generation 994: Fitness: 0.0032386947376718185, Distance: 1280.05
Generation 995: Fitness: 0.0032386947376718185, Distance: 1280.05
Generation 996: Fitness: 0.0032386947376718185, Distance: 1280.05
Generation 997: Fitness: 0.0032386947376718185, Distance: 1280.05
Generation 998: Fitness: 0.0032386947376718185, Distance: 1280.05
Generation 999: Fitness: 0.0032386947376718185, Distance: 1280.05
Generation 1000: Fitness: 0.0032386947376718185, Distance: 1280.05
```



Lab Analysis:

Flow Chart of Genetic Algorithm:



Basically realized the genetic algorithm process, and realized the visualization with matplotlib, and carried out the parameters in the experiment.

The gradient is increased and the graph is compared. Different parameters have different effects on the genetic algorithm. Therefore, parameter tuning is very important in the AI algorithm, but there are also shortcomings. Sometimes the final result cannot be found, but it is just close to the final result.

In the experiment, a comparative analysis of the single-variable principle was carried out on different parameters. I found that the number of iterations has an effect on the accuracy of the algorithm.

The accuracy has a great influence. When the number of iterations is too small, the accuracy of the result will be lower. Therefore, for different problem scales, it is necessary to set

Reasonable parameters.

Through this experiment, I found that if you want to get the best plan of the travel route, you must have parameters suitable for the algorithm.

It also illustrates the importance of tuning. By writing this algorithm, I also improved my programming ability and my perspective on the problem. Methods used to solve different problems. The disadvantage is that the efficiency of the algorithm is relatively low, and the result of the operation is only close to the final result. As a result, the efficiency of the algorithm needs to be improved.
Grade: **Date:**

Lab Report of Henan Polytechnic University

Date: 12.19

Lab Name: Animal Recognition

Lab Aim And Requirement:

1) Be familiar with the representation of knowledge

2) Master the operating mechanism of the production system

3) Basic methods of production system reasoning.

Using the learned knowledge, design and program a small animal recognition system, so that this production system can identify the tiger, leopard, zebra, giraffe, ostrich, penguin, and albatross.

Rule base：

R1: IF The animal has hair THEN The animal is a mammal

R2: IF The animal has milk THEN The animal is a mammal

R3: IF The animal has feathers THEN The animal is a bird

R4: IF The animal can fly AND The animal lays eggs, THEN The animal is a bird

R5: IF The animal eats meat THEN The animal is a carnivore

R6: IF The animal has canine teeth AND The animal has claws AND The animal gazes ahead THEN The animal is a carnivore

R7: IF The animal is a mammal AND The animal has hooves THEN The animal is an ungulate

R8: IF The animal is a mammal AND The animal is a ruminant THEN The animal is an ungulate

R9: IF The animal is a mammal AND The animal is a predator AND The animal is tawny AND There are dark spots on its body THEN The animal is the leopard

R10: IF The animal is a mammal AND The animal is a predator AND The animal is tawny AND There are black stripes on its body THEN The animal is a tiger

R11: IF The animal is an ungulate AND The animal has a long neck AND The animal has long legs AND There are dark spots on its body THEN The animal is a giraffe

R 12: IF The animal is an ungulate AND There are black stripes on its body THEN The animal is a zebra

R13: IF The animal is a bird AND The animal has a long neck AND The animal has long legs AND The animal can't fly AND The animal is black and white THEN The animal is an ostrich

R14: IF The animal is a bird AND The animal can swim AND The animal can't fly AND The animal is black and white THEN The animal is a penguinR15: IF The animal is a bird AND The animal is good at flying THEN The animal is an albatross

Lab Steps:

1. Creating an indirect rule base where the individual animal will be added

```
def addup_indirect_ruleslibrary(list, key1, key2, value1, value2):
    while (1):
        str1 = input("Please enter animal properties (space separated, end with 0): ")
        if (str1 == '0'): break
        a = str1.split()
        key1.append(a)
        str2 = input("Please enter the result： ")
        value1.append(str2)
        len1 = len(a)
        for i in range(0, len1):
            if i not in list:
                list.append(a[i])
    return 1
```

2. Create direct rule base and adding individual attributes of the animal to the rule base

```
def addup_direct_ruleslibrary(list, key1, key2, value1, value2):
    while (1):
        str1 = input("Please enter animal properties (space separated, end with 0): ")
        if (str1 == '0'): break
        a = str1.split()
        key2.append(a)
        str2 = input("Please enter the result： ")
        value2.append(str2)
        len2 = len(a)
        for i in range(0, len2):
            if i not in list:
                list.append(a[i])
    return 1
```

3. Animal identification and initialize the comprehensive database

```
def recognize(list, key1, key2, value1, value2):
    map = { }
    len1 = len(list)
    for i in range(0, len1): map[list[i]] = 0
    str = input("Please enter animal properties :(space separated)")
    list1 = str.split()
    len1 = len(list1)
    for i in range(0, len1): map[list1[i]] = 1
        len1 = len(key1)
    for i in range(0, len1):
```

```
        list2 = key1[i]
        len2 = len(list2)
        flag = 1
        for j in range(0, len2):
            if(map[list2[j]] == 0):
                flag = 0
                break
        if(flag):
            map[value1[i]] = 1
    len1 = len(key2)
    for i in range(0, len1):
        list2 = key2[i]
        len2 = len(list2)
        flag = 1
        for j in range(0, len2):
            if (map[list2[j]] == 0):
                flag = 0
                break
        if (flag):
            return value2[i]
    return "Failed identification ! "
```

4. Solve:

```
def solve(list, key1, key2, value1, value2):
    while(1):
        print("\n1. Add the direct rule library."
              "2. Add the indirect rule library."
              "3. Do animal identification."
              "4. Exit the program!\n")
        n = int(input("Please select ： "))
        if (n == 1):
            addup_direct_ruleslibrary(list, key1, key2, value1, value2)
        elif(n == 2):
            addup_indirect_ruleslibrary(list, key1, key2, value1, value2)
        elif(n == 3):
            str = recognize(list, key1, key2, value1, value2)
            print("The animal is： ",str)
        elif(n == 4):
            print("\nSuccessful exit procedure！ \n")
            break
        else:
            print("\nPlease re-enter！ \n")
    return 1
```

5. Main function to store in rule, indirect, direct base antecedents and also initialize

```
def main():
```

```
list = [ ]
key1 = [ ]
key2 = [ ]
value1 = [ ]
value2 = [ ]
init(list, key1, key2, value1, value2)
solve(list, key1, key2, value1, value2)
```

In [1]:

```
# Create an indirect rule base
def addup_indirect_ruleslibrary(list, key1, key2, value1, value2):
    while (1):
        str1 = input("Please enter animal properties (space separated, end with 0): ")
        if (str1 == '0'): break
        a = str1.split()
        key1.append(a)

        str2 = input("Please enter the result: ")
        value1.append(str2)

        # Add the individual attributes of the animal to the rule base antecedent
        len1 = len(a)
        for i in range(0, len1):
            if i not in list:
                list.append(a[i])

    return 1

# Create a direct rule base
def addup_direct_ruleslibrary(list, key1, key2, value1, value2):
    while (1):
        str1 = input("Please enter animal properties (space separated, end with 0): ")
        if (str1 == '0'): break
        a = str1.split()
        key2.append(a)

        str2 = input("Please enter the result: ")
        value2.append(str2)

        # Add the individual attributes of the animal to the rule base antecedent
        len2 = len(a)
        for i in range(0, len2):
            if i not in list:
                list.append(a[i])

    return 1
```

```python
    # Identified in the direct rule base
    len1 = len(key2)
    for i in range(0, len1):
        list2 = key2[i]
        len2 = len(list2)
        flag = 1
        for j in range(0, len2):
            if (map[list2[j]] == 0): # An element of the antecedent item of the rule library does not exist in the comprehensive
                flag = 0
                break

        if (flag):
            return value2[i]

    return "Failed identification ! "

def solve(list, key1, key2, value1, value2):
    while(1):
        print("\n1. Add the direct rule library."
              "2. Add the indirect rule library."
              "3. Do animal identification."
              "4. Exit the program!\n")
        n = int(input("Please select : "))
        if (n == 1):
            addup_direct_ruleslibrary(list, key1, key2, value1, value2)
        elif(n == 2):
            addup_indirect_ruleslibrary(list, key1, key2, value1, value2)
        elif(n == 3):
            str = recognize(list, key1, key2, value1, value2)
            print("The animal is: ",str)
        elif(n == 4):
            print("\nSuccessful exit procedure! \n")
            break
        else:
            print("\nPlease re-enter! \n")

    return 1

def main():
    list = [ ]  # Store rule base antecedents
    key1 = [ ]  # Store indirected rule base antecedents
    key2 = [ ]  # Store directed rule base antecedents
    value1 = [ ] # Store indirected rule base antecedents
    value2 = [ ] # Store directed rule base antecedents
    init(list, key1, key2, value1, value2) # Initializes the rule base
    solve(list, key1, key2, value1, value2)

main()
```

Lab Result:

```
Create an indirect rule base!

Please enter animal properties (space separated, end with 0): hair
Please enter the result: mammal
Please enter animal properties (space separated, end with 0): milk
Please enter the result: mammal
Please enter animal properties (space separated, end with 0): feathers
Please enter the result: bird
Please enter animal properties (space separated, end with 0): fly egg
Please enter the result: bird
Please enter animal properties (space separated, end with 0): meat
Please enter the result: carnivore
Please enter animal properties (space separated, end with 0): teech claws ahead
Please enter the result: carnivore
Please enter animal properties (space separated, end with 0): mammal hooves
Please enter the result: ungulate
Please enter animal properties (space separated, end with 0): 0

The indirect rule base is built!

Create a direct rule base!

Please enter animal properties (space separated, end with 0): mammal predator tawny darkspots
Please enter the result: leopard
Please enter animal properties (space separated, end with 0): mammal predator tawny blackstripes
Please enter the result: tiger
Please enter animal properties (space separated, end with 0): ungulate longneck longlegs darkspots
Please enter the result: giraffe
Please enter animal properties (space separated, end with 0): ungulate blackstripes
Please enter the result: zebra
Please enter animal properties (space separated, end with 0): bird longneck longlegs cantfly blackandwhite
Please enter the result: ostrich
Please enter animal properties (space separated, end with 0): bird swim cantfly blackandwhite
Please enter the result: penguin
Please enter animal properties (space separated, end with 0): 0

The rule base is established!
```

```
1. Add the direct rule library.2. Add the indirect rule library.3. Do animal identification.4. Exit the program!

Please select : 1
Please enter animal properties (space separated, end with 0): bird flying
Please enter the result: albatross
Please enter animal properties (space separated, end with 0): 0

1. Add the direct rule library.2. Add the indirect rule library.3. Do animal identification.4. Exit the program!

Please select : 2
Please enter animal properties (space separated, end with 0): mammal ruminant
Please enter the result: ungulate
Please enter animal properties (space separated, end with 0): 0

1. Add the direct rule library.2. Add the indirect rule library.3. Do animal identification.4. Exit the program!

Please select : 3
Please enter animal properties :(space separated)bird flying
The animal is:  albatross

1. Add the direct rule library.2. Add the indirect rule library.3. Do animal identification.4. Exit the program!

Please select : 4

Successful exit procedure!
```

Lab Analysis:

This lab was really fun and I enjoyed this lab very much because this lab gave me feeling of creating machine which can give a solution with the data it was fetched. We actually did production system experiment which means this system is based on a set of rules about behavior. These rules are a basic representation found helpful in expert systems, automated planning, and action selection. I also learned about the two kind of database, first one is indirect and second one is direct database. A two-dimensional list and an one-dimensional list are used to store the key and value. The second part is to add the database and recognize the animal, added when being queried, can effectively expand the database, make the database more flexible and perfect. The complexity of the query is O(1). Creating the base is pretty tough and the data entry need to be specific and error less because if one attribute is wrong then the machine will not be able to identify the animal clearly that’s why I needed to be more cautious while adding the information about the animals. Although this production system not so highly accurate compared with the other high performing machine because the information about a animal I used is really little knowledge about that animal. So if I want to use this system for the real life testing purpose I need to add more properties to the database for every animal. Although, while running the code the machine was able to identify the bird albatross. For future using, this machine need more improvement.

Grade:

Date:

Lab Report of Henan Polytechnic University

Date: 12.26

Lab Name: Savage and Missionary

Lab Aim And Requirement:
1. Understand and master the depth-first search algorithm
2. Understand the idea of recursion

Lab Steps:

1.Problem analysis

Suppose the number N of missionaries and wild men is 3, and the maximum passenger capacity K of the ship at one time is 2 for analysis.

Initial state: 3 savages and 3 missionaries on the left bank of the river; 0 savages and 0 missionaries on the right bank of the river; the boat stops at

On the left bank, there are 0 people on board.

Target status: 0 savages and 0 missionaries on the left bank of the river; 3 savages and 3 missionaries on the right bank of the river; the boat stops at

On the right bank, there are 0 people on board.

The whole problem is abstracted into how to go from the initial state to a series of intermediate states to reach the goal state, state change

It was triggered by boating across the river.

According to the requirements, a total of 5 possible river crossing plans are drawn as follows:

(1) Crossing 2 Missionaries
(2) Cross 2 Savage
(3) Crossing 1 Savage 1 Missionary
(4) Cross 1 missionary
(5) Crossing 1 Savage

This program uses classes to define state nodes, uses collections to store state nodes, and uses the idea of recursion (depth first query) To find the target state.

2. Constructing the state space

The state set is (m, c, b) triples, c represents the number of wild people on the left bank, m represents the number of missionaries on the left bank, and m, c take values from 0 to 3. b is 0

Means the ship is on the left, b is 1 means the ship is on the right

The action set is one missionary from left to right, two missionaries from left to right, one savages from left to right, and two savages from left

To the right, a savage and a missionary from left to right; from right to left, there are similarly 5 actions, a total of 10 actions, so

You can draw a state transition diagram. The initial state is (3, 3, 1), and the destination state is (0, 0, 0).

3.Def safe(s): #weather the state is safe

```
def safe(s):
    if s.m > M or s.m < 0 or s.c > C or s.c < 0 or (s.m != 0 and s.m < s.c) or (s.m != M and M - s.m < C - s.c):
        return False
    else:
        return True
```

4.def back(new, s): # Determine weather current state is consistent with parent state

```
    if s.father is None:
        return False
    #Determines whether the current state is consistent with the ancestor state
    c=b=s.father
    while(1):
        a,c=equal(new, b)
        if a:
            return True
        b=c.father
        if b is None:
            return False
```

5.# Recursive print path

```
def printPath(f):
    if f is None:
        return
    printPath(f.father)
    print(f.node )
```

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File Edit View Language

```python

import operator

__metaclass__ = type

M = int(input("Please enter the number of missionaries: "))  # missionaries
C = int(input("Please enter the number of savages:"))  # savages
K = int(input("Please enter the maximum capacity of the ship: "))
# Number of passengers per boat
child = []  # child: To store all extension nodes
open_list = []  # open label
closed_list = []  # closed label


class State:
    def __init__(self, m, c, b):
        self.m = m  #Number of missionaries on the Left Bank
        self.c = c  #Number of Left Bank savages
        self.b = b  # b = 1: The ship Left bank; b = 0: The ship on the right bank
        self.g = 0
        self.f = 0  #f = g+h
        self.father = None
        self.node = [m, c, b]

init = State(M, C, 1)  # The initial node
goal = State(0, 0, 0)  # The target

#0 ≤ m ≤ 3,0 ≤ c ≤ 3, b ∈ {0,1}, On the left bank m > c(m is not 0), On the right bank 3-m > 3-c(m is not 3)
def safe(s):
    if s.m > M or s.m < 0 or s.c > C or s.c < 0 or (s.m != 0 and s.m < s.c) or (s.m != M and M - s.m < C - s.c):
        return False
    else:
        return True


# Inspired by the function
def h(s):
    return s.m + s.c - K * s.b
    # return M - s.m + C - s.c

def equal(a, b):
    if a.node == b.node:
        return 1,b
    else:
        return 0,b

# Determines whether the current state is consistent with the parent state
def back(new, s):
    if s.father is None:
```

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                    child.append(new)
                    #print(1)
                else:  # The current ship is on the right bank. The next state counts the ship on the left bank
                    new = State(get.m + i, get.c + j, 1)
                    child.append(new)
                    #print(2)
                #priority: not>and>ture, If the state is not secure or the node to be extended is in the same state as the parent of the
current node.
                if not safe(new) or back(new, get):  # Status illegal or new reentry
                    child.pop()
                #If the node to be expanded meets the above conditions, set its father to the current node, calculate F, and sort open_list
                else:
                    new.father = get
                    new.g = get.g + 1  #The distance from the starting point
                    new.f = get.g + h(get)  # f = g + h

                    open_list.append(new)
                    #print(len(open_list))
                    open_sort(open_list)
        # Print open or closed tables
        #for o in open_list:
        # for o in closed_list:
            #print(o)
            #print(o.node)
           # print(o.father)
        #print(a)
    return(A)


# Recursive print path
def printPath(f):
    if f is None:
        return
    printPath(f.father)
    #Notice the difference between the print() statement before and after a recursive call. In the back to achieve a flashback output
    print(f.node )


if __name__ == '__main__':
    print ('There are %d missionaries, %d savages, ship capacity :%d' % (M, C, K))
    final = A_star(init)
    print("There are {} schemes".format(len(final)))
    if final:
        for i in(final):
            print ('There is a solution, and the solution is : ')
            printPath(i)
    else:
        print ('There is no solution! ')

```

Lab Result:

```
Please enter the number of missionaries: 3
Please enter the number of savages:3
Please enter the maximum capacity of the ship: 2
There are 3 missionaries, 3 savages, ship capacity :2
There are 4 schemes
There is a solution, and the solution is :
[3, 3, 1]
[3, 1, 0]
[3, 2, 1]
[3, 0, 0]
[3, 1, 1]
[1, 1, 0]
[2, 2, 1]
[0, 2, 0]
[0, 3, 1]
[0, 1, 0]
[0, 2, 1]
[0, 0, 0]
There is a solution, and the solution is :
[3, 3, 1]
[3, 1, 0]
[3, 2, 1]
[3, 0, 0]
[3, 1, 1]
[1, 1, 0]
[2, 2, 1]
[0, 2, 0]
[0, 3, 1]
[0, 1, 0]
[1, 1, 1]
[0, 0, 0]

There is a solution, and the solution is :
[3, 3, 1]
[2, 2, 0]
[3, 2, 1]
[3, 0, 0]
[3, 1, 1]
[1, 1, 0]
[2, 2, 1]
[0, 2, 0]
[0, 3, 1]
[0, 1, 0]
[0, 2, 1]
[0, 0, 0]
There is a solution, and the solution is :
[3, 3, 1]
[2, 2, 0]
[3, 2, 1]
[3, 0, 0]
[3, 1, 1]
[1, 1, 0]
[2, 2, 1]
[0, 2, 0]
[0, 3, 1]
[0, 1, 0]
[1, 1, 1]
[0, 0, 0]
```

Lab Analysis:

In this lab we learned the use of depth-first search algorithm and also recursion . Initial and target states: (3, 3, 1) and (0, 0, 0), the same as the problem of eight digital games, a production system description is established. After that, the state space can be searched through the control strategy, and a ferry operation sequence can be obtained to achieve the target state.

When discussing the use of production systems to solve problems, it is sometimes helpful to introduce the concept of state space diagrams. The state space diagram is a directed graph whose nodes can represent various states of the problem, and the arcs between nodes represent some operations (production rules), they can lead one state to another. The state space diagram established in this way describes all possible problems. The state and the relationship between state and operation, so the solution path and nature of the problem can be seen more intuitively.

To establish the state space,we set the state variable like, in left bank missionaries m={0,1,2,3} and right side, 3-m. Cannibals in left c={0,1,2,3}, and right 3-c. Boat b={0,1} in left and in right 1-b. So, M<=N, C<=N, boat =K, so that M>=C and M+C<=K. We followed a set of operation and rule set. Some state were illegal because the number of cannibals can not be greater than missionaries and also four states were impossible because ships can not dock on uninhabited shores. After running the code we can see there are total four solution which means in four way the missionaries and cannibal can cross the river without violating the requirements.

Grade:

Date: