AI Assignment 4

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1. Best First Search

CODE:

```
import copy
from math import nextafter
from colorama import Fore,Back,Style,init
init(autoreset=True)

class Puzzle():
    board = [
        [1,2,3],
        [0,4,6],
        [7,5,8]
    ]
    goal = [
        [1,2,3],
        [4,5,6],
        [7,8,0]
    ]
    startX = 0
    startY = 0
    queue = []
    generatedBoards = []

    def calcHeuristic(self,board):
        h = 0
        for i in range(3):
            for j in range(3):
                if board[i][j] != self.goal[i][j]:
                    h = h+1
        return h-1
```

```
def getValidMoves(self,board):
    for i in range(3):
        for j in range(3):
            if board[i][j] == 0:
                self.startX = j
                self.startY = i
    position = [0]*4
    validMoves = []
    position[0] = [self.startX+1,self.startY]
    position[1] = [self.startX-1,self.startY]
    position[2] = [self.startX,self.startY-1]
    position[3] = [self.startX,self.startY+1]
    for i in range(4):
        if position[i][1]>-1 and position[i][1]<3 and position[i][0]>-1 and position[i][0]<3:
            validMoves.append(position[i])
    return validMoves

def playMove(self, move:list, board:list):
    newBoard = copy.deepcopy(board)

    temp = newBoard[move[1]][move[0]]
    newBoard[move[1]][move[0]] = newBoard[self.startY][self.startX]
    newBoard[self.startY][self.startX] = temp
    return newBoard

def bestFirstSearch(self):
    self.calcHeuristic(self.board)
    self.queue.append((self.calcHeuristic(self.board), self.board))
    self.generatedBoards.append(self.board)
    i = 0
    while(1<1000):
        next = self.queue.pop()
        moves = self.getValidMoves(next[1])
        print('\n---------------\n')
        print(f"  step {i}\n")
        for j in range(3):
            print("   ",next[1][j])
        if next[1] == self.goal:
            print(f"\nGoal state reached in {i} steps")
            print('\n------------------------------\n')
```

```
                exit(1)
            for move in moves:
                newBoard = self.playMove(move,next[1])
                if newBoard not in self.generatedBoards:
                    self.generatedBoards.append(newBoard)
                    self.queue.append((self.calcHeuristic(newBoard), newBoard))
                    self.queue.sort(reverse=True)
            i+=1
        return None

class Robot():
    table = [
        ['-','-','-','-','-','-','-','-','-','-','-'],

    ['-',Fore.YELLOW+'#','-','-','-',Fore.YELLOW+'#',Fore.YELLOW+'#',Fore.YELLOW+'#',Fore.YELLOW+'#',Fore.YELLOW+'#','-'],
        ['-',Fore.YELLOW+'#',Fore.YELLOW+'#','-','-','-','-','-','-',Fore.YELLOW+'#','-'],

    ['-','-',Fore.YELLOW+'#',Fore.YELLOW+'#',Fore.YELLOW+'#',Fore.YELLOW+'#',Fore.YELLOW+'#',Fore.YELLOW+'#',Fore.YELLOW+'#',
Fore.YELLOW+'#','-'],
        ['-','-','-','-','-','-','-','-','-','-','-']
    ]
    goalX = 6
    goalY = 2
    startX = 0
    startY = 3
    newTable = copy.deepcopy(table)
    queue = []
    visited = []

    def calcManhatten(self):
        self.table[self.startY][self.startX] = Fore.BLUE+'S'
        self.table[self.goalY][self.goalX] = Fore.RED+'G'
        print("\n Manhatten Distance: \n")
        for i in range(5):
            for j in range(11):
                if self.table[i][j]!=Fore.YELLOW+'#':
                    self.newTable[i][j] = abs(self.goalX - j) + abs(self.goalY-i)
                print('\t',self.newTable[i][j], end='')
            print('\n')
        position = [self.startX,self.startY]
        self.queue.append((self.newTable[self.startY][self.startX],position))
```

```python
def getNeighbors(self):
    position = [0]*4
    value = [0]*4
    position[0] = [self.startX+1,self.startY]
    position[1] = [self.startX-1,self.startY]
    position[2] = [self.startX,self.startY-1]
    position[3] = [self.startX,self.startY+1]

    for i in range(4):
        if position[i][1]>-1 and position[i][1]<5 and position[i][0]>-1 and position[i][0]<11:
            value[i] = self.newTable[position[i][1]][position[i][0]]
            if value[i] != Fore.YELLOW+'#' and ((value[i], position[i]) not in self.visited) :
                self.queue.append((value[i], position[i]))

    self.queue.sort(reverse=True)

def bestFirstSearch(self):
    steps = 0

    while (self.queue) :
        input()
        print(f"Steps taken: {steps}")
        print(f"Queue: {self.queue}")
        next = self.queue.pop()
        print(f"Selecting: {next}")
        print(f"Current queue: {self.queue}")
        if next[1][0] == self.goalX and next[1][1] == self.goalY :
            print(f"Goal State reached in {steps} steps")
            exit(1)
        if next[1] == [self.startX,self.startY]:
            self.table[next[1][1]][next[1][0]] = Fore.BLUE+'S'
        else:
            self.table[next[1][1]][next[1][0]] = Fore.GREEN+str(next[0])
        self.visited.append(next)
        self.startX = next[1][0]
        self.startY = next[1][1]
        self.getNeighbors()
        print(f"Adding neighbours of {next} to queue\nCurrent queue: {self.queue}\n")
        self.printTable(self.table)
```

```
            print('\t--------------------------------------------------------------------------------')
            steps+=1
            # print(self.queue)

    def printTable(self,table):
        for i in range(5):
            for j in range(11):
                print("\t"+Fore.WHITE+table[i][j], end='')
            # print(self.table[i][j], end='|')
            print('\n')

class cityDistance():
    cityMap = {
    'Delhi' : [(800, 'Indore'),(1300, 'Kolkata')],
    'Indore': [(600, 'Mumbai'),(500, 'Nagpur'),(800,'Delhi')],
    'Kolkata': [(1200,'Nagpur'),(1500,'Hyderabad'),(1300,'Delhi')],
    'Mumbai': [(800,'Hyderabad'),(1000,'Bangalore'),(600,'Indore')],
    'Nagpur':[(500,'Indore'),(1200,'Kolkata'),(500,'Hyderabad')],
    'Hyderabad':[(800,'Mumbai'),(500,'Nagpur'),(1500,'Kolkata'),(500,'Bangalore')],
    'Bangalore':[(1000,'Mumbai'),(500,'Hyderabad')]
    } #based on ppt bfs cities distance problem

    hSLD = {
        'Delhi':0,
        'Indore':800,
        'Mumbai':1300,
        'Hyderabad':1500,
        'Bangalore':1800,
        'Nagpur':1000,
        'Kolkata':1300
    }

    queue = []
    open = []
    closed = []
    start = "Hyderabad"
    end = "Delhi"
    totalDistance = 0

    def expand(self,s:str):
        near_cities:list = self.cityMap.get(s)
```

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        near_cities.sort(reverse=True)
        return near_cities

    def validMove(self,near_cities:list):
        distance = 0
        for city in near_cities:
            self.queue.append((self.hSLD.get(city[1]),city[1],city[0]))
            if city[1] not in self.closed:
                self.open.append(city[1])
            if self.open.count(city[1])>1:
                self.open.remove(city[1])

        self.queue.sort(reverse=True)

    def bestFirstSearch(self):
        self.queue.append((self.hSLD.get(self.start),self.start,0))
        self.open.append(self.start)
        i = 0
        while(1):
            next:str = self.queue.pop()
            near_cities = self.expand(next[1])
            self.closed.append(next[1])
            self.totalDistance = self.totalDistance + int(next[2])
            self.validMove(near_cities)
            self.open.remove(next[1])
            print(f"\nOpen List: {self.open}\nClosed List: {self.closed}")
            if next[1] == self.end:
                print("Path Reached")
                print(f"Total Distance from {self.start} to {self.end}: {self.totalDistance} km")
                exit(1)
            i+=1

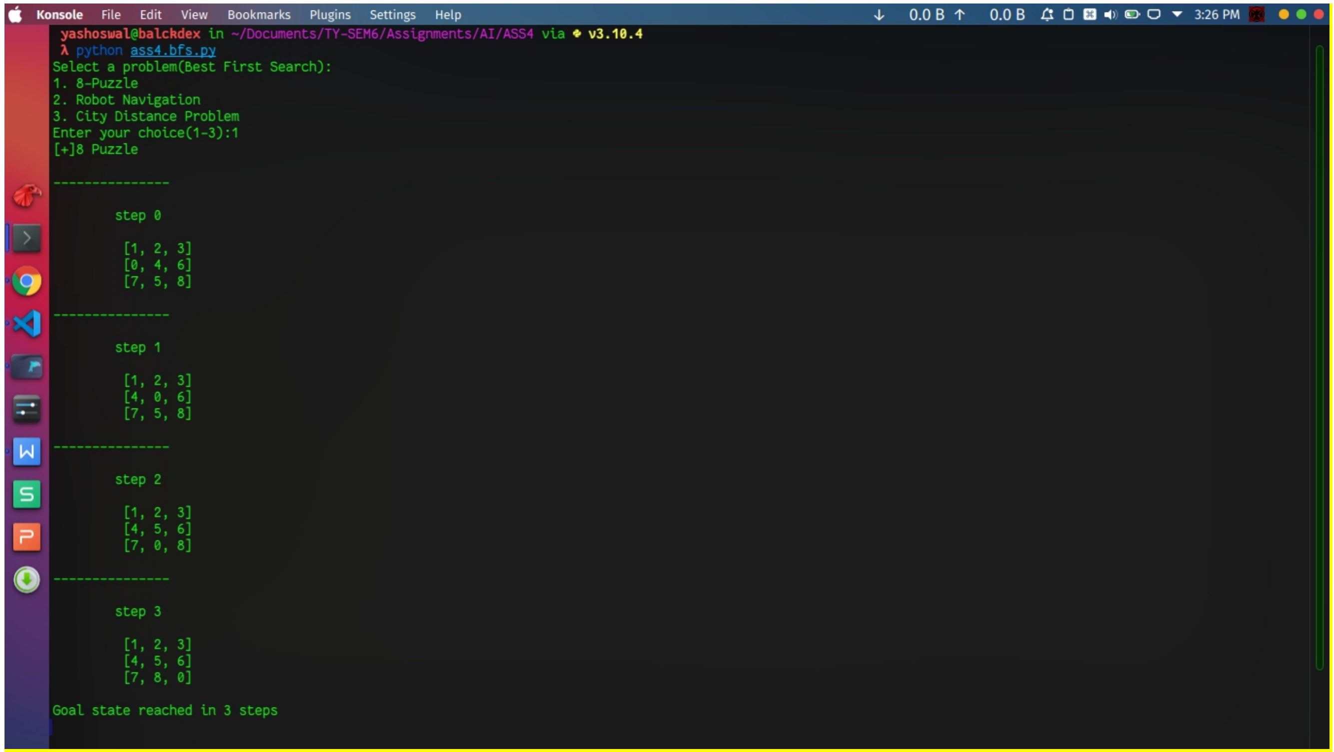
print("Select a problem(Best First Search): ")
print("1. 8-Puzzle")
print("2. Robot Navigation")
print("3. City Distance Problem")
ch = int(input("Enter your choice(1-3):"))

if ch == 1:
    print("[+]8 Puzzle")
    s = Puzzle()
```

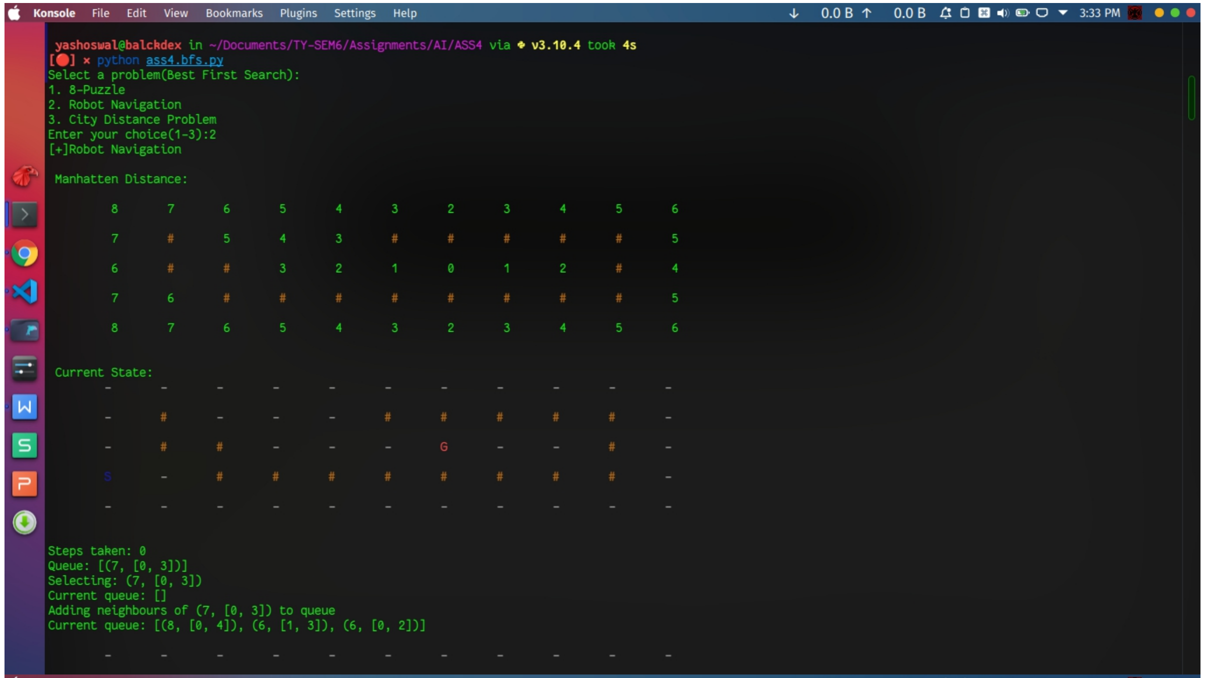
```
    s.bestFirstSearch()
elif ch == 2:
    print('[+]Robot Navigation')
    s = Robot()
    s.calcManhatten()
    print('\n Current State:')
    s.printTable(s.table)
    s.bestFirstSearch()
elif ch == 3:
    print('[+]City Distance')
    s = cityDistance()
    s.bestFirstSearch()
else:
    print("[-]Run again and enter valid choice")
    exit(1)
```

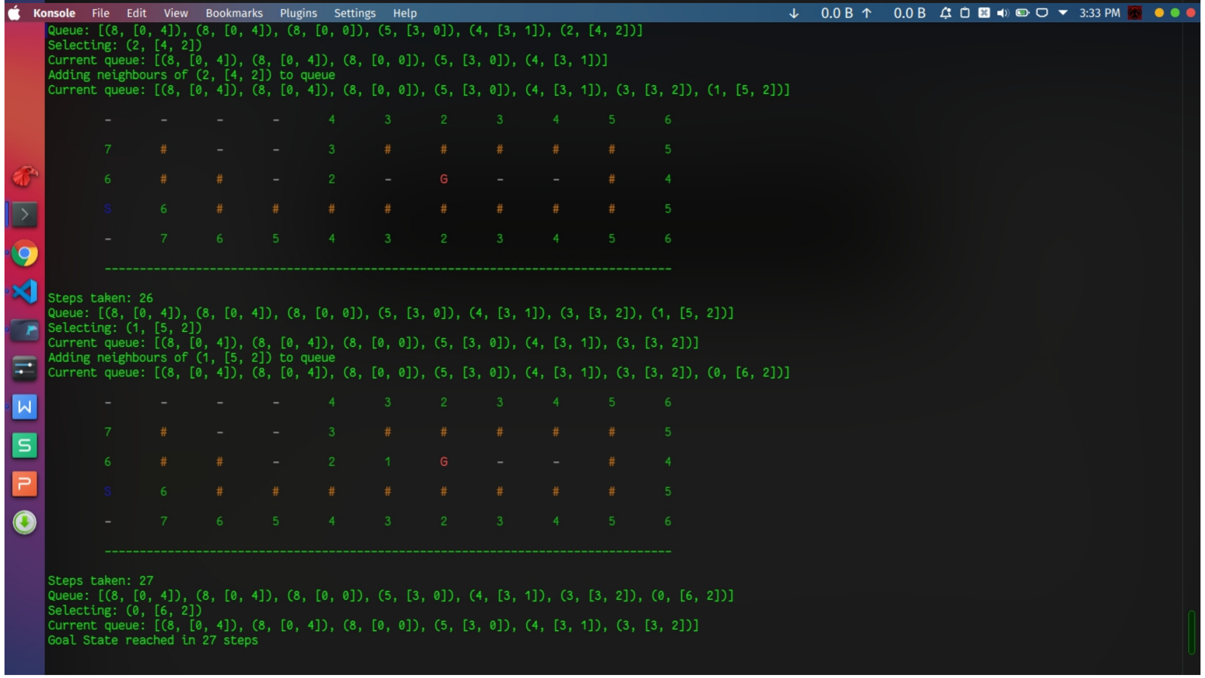
OUTPUT:

a. 8-Puzzle:

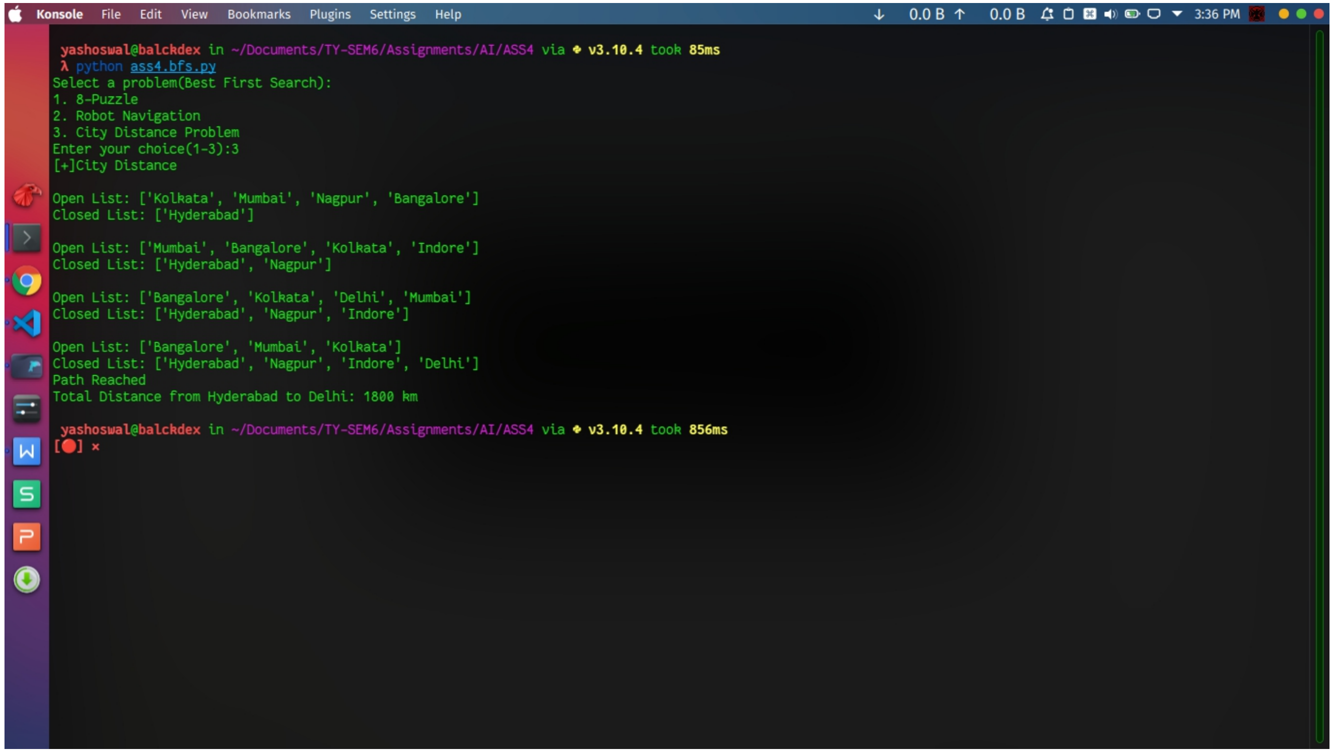


b. Robot Navigation:





c. City Distance:



2. A star:

CODE:

```
from colorama import Fore,Back,Style,init
init(autoreset=True)
import copy
from copy import deepcopy
class Puzzle():

    goal = [[1, 2, 3],
    [8, 0, 4],
    [7, 6, 5]]

    board_config = [[2, 3, 4],
    [1, 8, 0],
    [7, 6, 5]]
```

```
steps = 0

def calculate_fOfn(self, cal_config):



    h = 0
    for i in range(0, 3):
        for j in range(0, 3):
            if cal_config[i][j] != self.goal[i][j]:
                h += 1
    return h
def isSafe(self, x, y):
    return x >= 0 and x < 3 and y >= 0 and y < 3
def print_board(self, print_config):
    for i in range(0, 3):
        for j in range(0, 3):
            print(" " + str(print_config[i][j]) + " ", end="")
        print()

def find_all_configs(self, all_config):
    config_boards = []
    config1 = deepcopy(all_config)
    config2 = deepcopy(all_config)
    config3 = deepcopy(all_config)
    config4 = deepcopy(all_config)
    for i in range(0, 3):
        for j in range(0, 3):
            if all_config[i][j] != 0:

                if self.isSafe(i - 1, j):
                    if all_config[i - 1][j] == 0:

                        config1[i - 1][j] = config1[i][j]
                        config1[i][j] = 0
                        config_boards.append(config1)

                if self.isSafe(i + 1, j):
                    if all_config[i + 1][j] == 0:

                        config2[i + 1][j] = config2[i][j]
```

```
                    config2[i][j] = 0
                    config_boards.append(config2)

            if self.isSafe(i, j + 1):
                if all_config[i][j + 1] == 0:
                    config3[i][j + 1] = config3[i][j]
                    config3[i][j] = 0
                    config_boards.append(config3)

            if self.isSafe(i, j - 1):
                if all_config[i][j - 1] == 0:
                    config4[i][j - 1] = config4[i][j]
                    config4[i][j] = 0
                    config_boards.append(config4)
    return config_boards

def puzzle_start(self, config, goal_heuristic):
    objective_values = []
    new_config = deepcopy(config)
    boards_configs = []
    open_list = []
    closed_list = []
    visited = []
    open_list.append(new_config)
    visited.append(new_config)
    print(Fore.RED+"\t\t\tLIST IS DISPLAYED IN ROW MAJOR ORDER\n\n")
    print("Initially - ")

    print("Open List - ")
    print(open_list)

    print("Closed List - ")
    print(closed_list)
    print("\n\n")
    while True:
        self.steps += 1
        boards_configs.clear()
        open_list.remove(new_config)
        closed_list.append(new_config)

        heuristic_value = self.calculate_fOfn(new_config)
```

```
            if heuristic_value == goal_heuristic:
                print("Solution Reached !!")
                print(f"\nIn {self.steps} Steps\n")
                break
            boards_configs = self.find_all_configs(new_config)

            for i in boards_configs:
                visited.append(i)
                open_list.append(i)
                h = self.calculate_fOfn(i)
                objective_values.append(h)
            print("Open List - ")
            print(open_list)
            print("Closed List - ")
            print(closed_list)
            print("\n\n")

            min_value = min(objective_values)
            min_value_index = objective_values.index(min_value)
            new_config = boards_configs[min_value_index]
            print(f"Board Configuration Selected With Heuristic Value - {str(self.steps)} + {str(min_value)}")
            self.print_board(new_config)
            print("\n")
            objective_values.clear()
    def Start_Puzzle(self):
        print("8-Puzzle Problem Using Best First Search\n")
        goal_heuristic = self.calculate_fOfn(self.goal)
        self.puzzle_start(self.board_config, goal_heuristic)

class Robot():
    table = [
        ['-','-','-','-','-','-','-','-','-','-','-'],

    ['-',Fore.YELLOW+'#','-','-','-',Fore.YELLOW+'#',Fore.YELLOW+'#',Fore.YELLOW+'#',Fore.YELLOW+'#',Fore.YELLOW+'#','-'],
        ['-',Fore.YELLOW+'#',Fore.YELLOW+'#','-','-','-','-','-','-',Fore.YELLOW+'#','-'],

    ['-','-',Fore.YELLOW+'#',Fore.YELLOW+'#',Fore.YELLOW+'#',Fore.YELLOW+'#',Fore.YELLOW+'#',Fore.YELLOW+'#',Fore.YELLOW+'#',
Fore.YELLOW+'#','-'],
        ['-','-','-','-','-','-','-','-','-','-','-']
    ]
    goalX = 6
```

```
    goalY = 2
    startX = 0
    startY = 3
    newTable = copy.deepcopy(table)
    newTable_2 = copy.deepcopy(table)
    newTable_3 = copy.deepcopy(table)
    queue = []
    visited = []

    def calcManhatten(self):
        self.table[self.startY][self.startX] = Fore.BLUE+'S'
        self.table[self.goalY][self.goalX] = Fore.RED+'G'
        print("\n Manhatten Distance: \n")
        for i in range(5):
            for j in range(11):
                if self.table[i][j]!=Fore.YELLOW+'#':
                    self.newTable_2[i][j] = abs(self.goalX - j) + abs(self.goalY-i)
                    self.newTable_3[i][j] = abs(self.startX - j) + abs(self.startY-i)
                    self.newTable[i][j] = self.newTable_2[i][j] + self.newTable_3[i][j]
                print(f'\t{self.newTable_2[i][j]}+{self.newTable_3[i][j]}', end='')
            print('\n')
        position = [self.startX,self.startY]
        self.queue.append((self.newTable[self.startY][self.startX],position))



    def getNeighbors(self):
        position = [0]*4
        value = [0]*4
        position[0] = [self.startX+1,self.startY]
        position[1] = [self.startX-1,self.startY]
        position[2] = [self.startX,self.startY-1]
        position[3] = [self.startX,self.startY+1]

        for i in range(4):
            if position[i][1]>-1 and position[i][1]<5 and position[i][0]>-1 and position[i][0]<11:
                value[i] = self.newTable[position[i][1]][position[i][0]]
                if value[i] != Fore.YELLOW+'#' and ((value[i], position[i]) not in self.visited) and ((value[i], position[i]) not
in self.queue) :
                    self.queue.append((value[i], position[i]))
        self.queue.sort(reverse=True)
```

```
    def bestFirstSearch(self):
        steps = 0
        while (self.queue) :
            input()
            print(f"Steps taken: {steps}")
            print(f"Queue: {self.queue}")
            next = self.queue.pop()
            print(f"Selecting: {next}")
            print(f"Current queue: {self.queue}")
            if next[1][0] == self.goalX and next[1][1] == self.goalY :
                print(f"Goal State reached in {steps} steps")
                exit(1)
            if next[1] == [self.startX,self.startY]:
                self.table[next[1][1]][next[1][0]] = Fore.BLUE+'S'
            else:
                self.table[next[1][1]][next[1][0]] =
f"{Fore.GREEN+str(self.newTable_2[next[1][1]][next[1][0]])}+{str(self.newTable_3[next[1][1]][next[1][0]])}"
            self.visited.append(next)
            self.startX = next[1][0]
            self.startY = next[1][1]
            self.getNeighbors()
            print(f"Adding neighbours of {next} to queue\nCurrent queue: {self.queue}\n")
            self.printTable(self.table)
            print('\t---------------------------------------------------------------------------------')
            steps+=1

    def printTable(self,table):
        for i in range(5):
            for j in range(11):
                print("\t"+Fore.WHITE+str(table[i][j]), end='')
            print('\n')

class City_Distance():
    class Graph:
        def __init__(self, graph_dict=None, directed=True):
            self.graph_dict = graph_dict or {}
            self.directed = directed
            if not directed:
                self.make_undirected()
```

```
    def make_undirected(self):
        for a in list(self.graph_dict.keys()):
            for (b, dist) in self.graph_dict[a].items():
                self.graph_dict.setdefault(b, {})[a] = dist

    def connect(self, A, B, distance=1):
        self.graph_dict.setdefault(A, {})[B] = distance
        if not self.directed:
            self.graph_dict.setdefault(B, {})[A] = distance

    def get(self, a, b=None):
        links = self.graph_dict.setdefault(a, {})
        if b is None:
            return links
        else:
            return links.get(b)

    def nodes(self):
        s1 = set([k for k in self.graph_dict.keys()])
        s2 = set([k2 for v in self.graph_dict.values() for k2, v2 in v.items()])
        nodes = s1.union(s2)
        return list(nodes)
    def display_graph(self):
        print(Fore.YELLOW+"\n\t\t\tTHE GRAPH IS - \n")
        for key in self.graph_dict:
            print(Fore.CYAN+key, Fore.WHITE+' -> ', self.graph_dict[key])

class Node:

    def __init__(self, name: str, parent: str):
        self.name = name
        self.parent = parent
        self.g = 0
        self.h = 0
        self.f = 0

    def __eq__(self, other):
        return self.name == other.name

    def __lt__(self, other):
        return self.f < other.f
```

```
    def __repr__(self):
        return ('({0},{1})'.format(self.position, self.f))

def best_first_search(self, graph, heuristics, start, end):

    open = []
    closed = []

    start_node = self.Node(start, None)
    goal_node = self.Node(end, None)

    open.append(start_node)

    while len(open) > 0:
        print(Fore.BLUE+"\n\nOpen List - ")
        for i in open:
            print(i.name, end=" | ")
        print()
        print(Fore.BLUE+"Closed List - ")
        for i in closed:
            print(i.name, end=" | ")

        open.sort()

        current_node = open.pop(0)

        closed.append(current_node)

        if current_node == goal_node:
            path = []
            while current_node != start_node:
                path.append(current_node.name)
                current_node = current_node.parent
            path.append(start_node.name)

            return path[::-1]

        neighbors = graph.get(current_node.name)

        for key, value in neighbors.items():
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```
            neighbor = self.Node(key, current_node)

            if (neighbor in closed):
                continue

            neighbor.g = current_node.g + graph.get(current_node.name, neighbor.name)
            neighbor.h = heuristics.get(neighbor.name)
            neighbor.f = neighbor.g + neighbor.h

            if (self.add_to_open(open, neighbor) == True):
                open.append(neighbor)
    return None

def add_to_open(self, open, neighbor):
    for node in open:
        if (neighbor == node and neighbor.f >= node.f):
            return False
    return True
def start(self):

    graph = self.Graph()

    graph.connect('Oradea', 'Zerind', 71)
    graph.connect('Oradea', 'Sibiu', 151)
    graph.connect('Zerind', 'Arad', 75)
    graph.connect('Arad', 'Sibiu', 140)
    graph.connect('Arad', 'Timisoara', 118)
    graph.connect('Timisoara', 'Lugoj', 111)
    graph.connect('Lugoj', 'Mehadia', 70)
    graph.connect('Mehadia', 'Drobeta', 75)
    graph.connect('Drobeta', 'Craiova', 120)
    graph.connect('Craiova', 'Pitesti', 138)
    graph.connect('Craiova', 'Rimnicu Vilcea', 146)
    graph.connect('Sibiu', 'Fagaras', 99)
    graph.connect('Fagaras', 'Bucharest', 211)
    graph.connect('Sibiu', 'Rimnicu Vilcea', 80)
    graph.connect('Rimnicu Vilcea', 'Pitesti', 97)
    graph.connect('Pitesti', 'Bucharest', 101)
    graph.connect('Bucharest', 'Giurgui', 90)
```

```
        graph.make_undirected()
        graph.display_graph()
        heuristics = {}
        heuristics['Arad'] = 366
        heuristics['Bucharest'] = 0
        heuristics['Craiova'] = 160
        heuristics['Drobeta'] = 242
        heuristics['Fagaras'] = 176
        heuristics['Guirgiu'] = 77
        heuristics['Lugoj'] = 244
        heuristics['Mehadia'] = 241
        heuristics['Oradea'] = 380
        heuristics['Pitesti'] = 100
        heuristics['Rimnicu Vilcea'] = 193
        heuristics['Sibiu'] = 253
        heuristics['Timisoara'] = 329
        heuristics['Zerind'] = 800
        path = self.best_first_search(graph, heuristics, 'Arad', 'Bucharest')
        print(Fore.GREEN+"\n\nThe Path Is - ")
        if path is not None:
            for i in range(len(path)):
                print(path[i])

print(Fore.BLUE+"\t\t\t\t\t\tA* Search\n")
choice = int(input("Enter Your Choice - \n1. 8-Puzzle Problem\n2. Robot Navigation\n3. City-Distance Problem\nChoice - "))
if(choice == 1):
    temp = Puzzle()
    temp.Start_Puzzle()
elif(choice == 2):
    temp = Robot()
    temp.calcManhatten()
    print('\n Current State:')
    temp.printTable(temp.table)
    temp.bestFirstSearch()
elif(choice == 3):
    temp = City_Distance()
    temp.start()
```

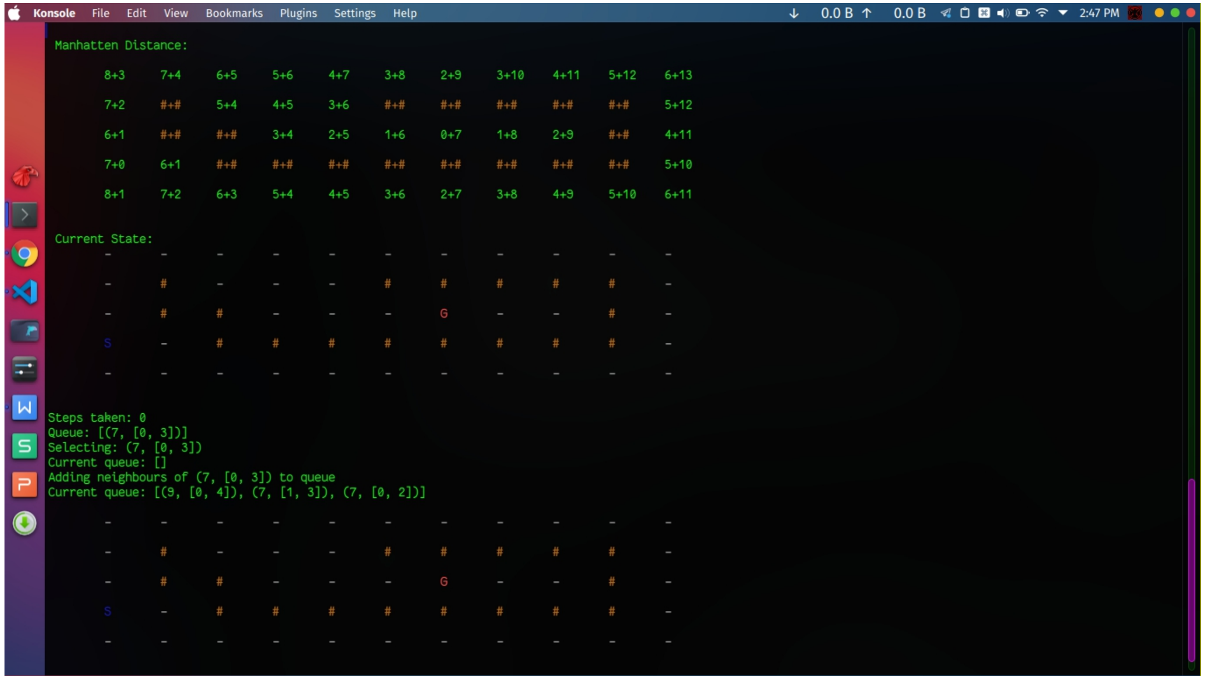
OUTPUT:

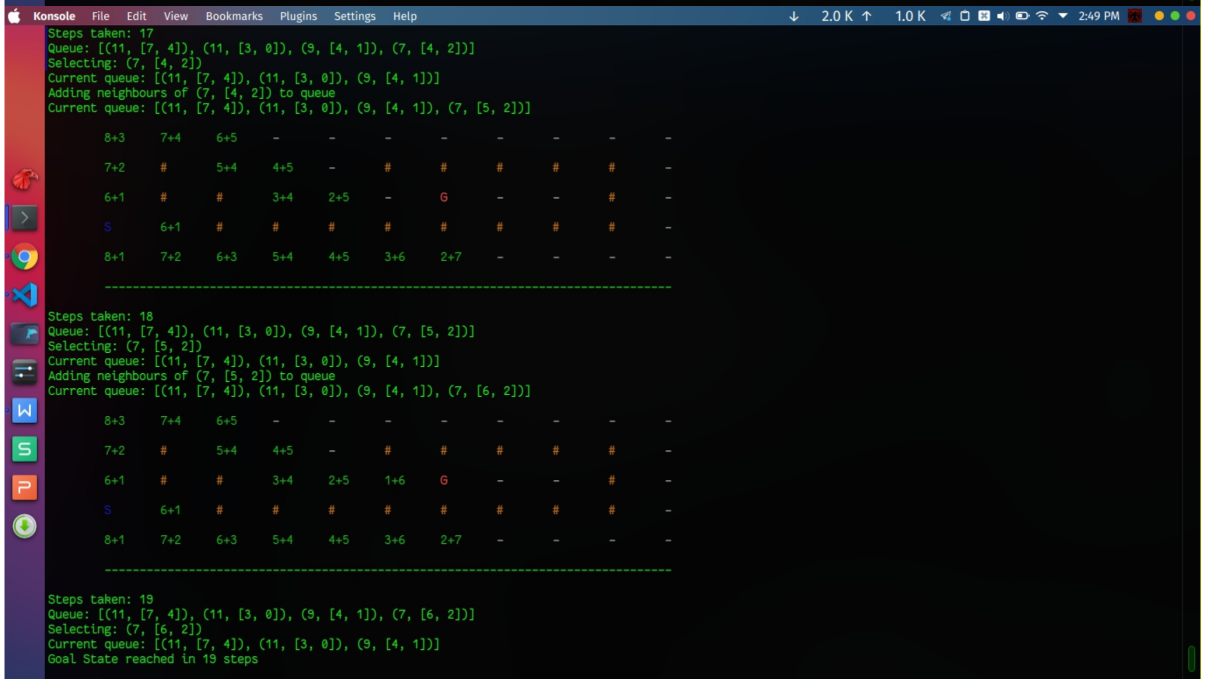
a. 8 Puzzle

```
Initially -
Open List -
[[[2, 3, 4], [1, 8, 0], [7, 6, 5]]]
Closed List -
[]


Open List -
[[[2, 3, 0], [1, 8, 4], [7, 6, 5]], [[2, 3, 4], [1, 0, 8], [7, 6, 5]], [[2, 3, 4], [1, 8, 5], [7, 6, 0]]]
Closed List -
[[[2, 3, 4], [1, 8, 0], [7, 6, 5]]]


Board Configuration Selected With Heuristic Value - 1 + 5
 2  3  0
 1  8  4
 7  6  5


Open List -
[[[2, 3, 4], [1, 0, 8], [7, 6, 5]], [[2, 3, 4], [1, 8, 5], [7, 6, 0]], [[2, 0, 3], [1, 8, 4], [7, 6, 5]], [[2, 3, 4], [1, 8, 0], [7, 6, 5]]]
Closed List -
[[[2, 3, 4], [1, 8, 0], [7, 6, 5]], [[2, 3, 0], [1, 8, 4], [7, 6, 5]]]


Board Configuration Selected With Heuristic Value - 2 + 4
 2  0  3
 1  8  4
 7  6  5


Open List -
[[[2, 3, 4], [1, 0, 8], [7, 6, 5]], [[2, 3, 4], [1, 8, 5], [7, 6, 0]], [[2, 3, 4], [1, 8, 0], [7, 6, 5]], [[0, 2, 3], [1, 8, 4], [7, 6, 5]], [[2, 3, 0], [1, 8, 4
], [7, 6, 5]], [[2, 8, 3], [1, 0, 4], [7, 6, 5]]]
Closed List -
[[[2, 3, 4], [1, 8, 0], [7, 6, 5]], [[2, 3, 0], [1, 8, 4], [7, 6, 5]], [[2, 0, 3], [1, 8, 4], [7, 6, 5]]]
```


```
Initially -
Open List -
[[[2, 3, 4], [1, 8, 0], [7, 6, 5]]]
Closed List -
[]


Open List -
[[[2, 3, 0], [1, 8, 4], [7, 6, 5]], [[2, 3, 4], [1, 0, 8], [7, 6, 5]], [[2, 3, 4], [1, 8, 5], [7, 6, 0]]]
Closed List -
[[[2, 3, 4], [1, 8, 0], [7, 6, 5]]]


Board Configuration Selected With Heuristic Value - 1 + 5
 2  3  0
 1  8  4
 7  6  5


Open List -
[[[2, 3, 4], [1, 0, 8], [7, 6, 5]], [[2, 3, 4], [1, 8, 5], [7, 6, 0]], [[2, 0, 3], [1, 8, 4], [7, 6, 5]], [[2, 3, 4], [1, 8, 0], [7, 6, 5]]]
Closed List -
[[[2, 3, 4], [1, 8, 0], [7, 6, 5]], [[2, 3, 0], [1, 8, 4], [7, 6, 5]]]


Board Configuration Selected With Heuristic Value - 2 + 4
 2  0  3
 1  8  4
 7  6  5


Open List -
[[[2, 3, 4], [1, 0, 8], [7, 6, 5]], [[2, 3, 4], [1, 8, 5], [7, 6, 0]], [[2, 3, 4], [1, 8, 0], [7, 6, 5]], [[0, 2, 3], [1, 8, 4], [7, 6, 5]], [[2, 3, 0], [1, 8, 4
], [7, 6, 5]], [[2, 8, 3], [1, 0, 4], [7, 6, 5]]]
Closed List -
[[[2, 3, 4], [1, 8, 0], [7, 6, 5]], [[2, 3, 0], [1, 8, 4], [7, 6, 5]], [[2, 0, 3], [1, 8, 4], [7, 6, 5]]]
```

b. Robot Navigation





c. City Distance Problem