**Project 1: Robot Path Planning**

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**Program Running Instructions:**

Program should be run via the terminal with 4 arguments being the python file containing the project code, input file path, k, and output file path in the format: **python3 <robot\_path\_finding\_code\_file> <input\_file\_path> <k\_value> -o <output\_file\_path>**.

**For example, with input 1 and k of 0:**

*python3 RobotPathPlanning.py "Inputs/Input3.txt" 0 -o Output3.txt*

There are also 3 folders in the same directory as the code file that we utilized when making/testing the project:

1. Inputs: stores all the inputs
2. Outputs: the folder the outputs are generated to
3. Logs: stores all logs generated during testing

**Program Source Code:**

*"""  
Robot Path Finding Project  
Authors: Anna Teng, Sunny Li  
"""*import os  
import logging  
import heapq  
import math  
import copy  
import argparse  
from datetime import datetime  
  
  
DIRECTIONS = [(1, 0), (1, 1), (0, 1), (-1, 1), (-1, 0), (-1, -1), (0, -1), (1, -1)]  
  
  
# Set up logging configuration  
def setup\_logging(input\_file\_name, output\_file\_name, k):  
 os.makedirs('Logs', exist\_ok=True)  
 timestamp = datetime.now().strftime("%Y%m%d\_%H%M%S")  
 log\_filename = os.path.join('Logs', f"{timestamp}.log")  
  
 logging.basicConfig(  
 filename=log\_filename,  
 level=logging.INFO,  
 format='%(message)s'  
 )  
  
 logging.info("========= A\* Search Run Log =========")  
 logging.info(f"Input File: {input\_file\_name}")  
 logging.info(f"Output File: Outputs\\{output\_file\_name}")  
 logging.info(f"k: {k}")  
 logging.info("=====================================\n")  
  
  
# OutputModel class to simplify the code relating to the output  
class OutputModel:  
 def \_\_init\_\_(self, output\_dict: dict):  
 self.depth = output\_dict["depth"]  
 self.generated\_nodes = len(output\_dict["generated\_nodes"])  
 self.moves = " ".join(map(str, output\_dict["moves"]))  
 self.f\_values = " ".join(map(str, output\_dict["f\_values"]))  
   
 rows = [" ".join(map(str, row)) for row in output\_dict["workspace"]]  
 self.output\_workspace = "\n".join(rows)  
  
  
# Node class  
class Node:  
 def \_\_init\_\_(self, pos, path\_cost, total\_cost, last\_angle=0, parent=None):  
 self.pos = pos  
 self.path\_cost = path\_cost  
 self.total\_cost = total\_cost  
 self.last\_angle = last\_angle  
 self.parent = parent  
  
 def \_\_lt\_\_(self, other):  
 # Used for heapq  
 return self.total\_cost < other.total\_cost  
  
 def \_\_repr\_\_(self):  
 # Used for debugging  
 return str(self.pos)  
  
  
def process\_input(input\_file\_path):  
 *"""  
 Used to process input file into workable data  
 :param input\_file\_path: path of input file  
 :return: tuple of starting and goal positions, and a 2D array of the robot workspace  
 """* try:  
 input\_file = open(input\_file\_path, 'r')  
 except FileNotFoundError:  
 print("File not found!")  
 return  
 first\_line = input\_file.readline()  
 first\_line\_data = first\_line.strip().split()  
 start\_pos = (int(first\_line\_data[0]), int(first\_line\_data[1]))  
 goal\_pos = (int(first\_line\_data[2]), int(first\_line\_data[3]))  
 workspace = []  
 for line in input\_file:  
 if line != "\n":  
 curr\_line = []  
 nums = line.strip().split()  
 for num in nums:  
 curr\_line.append(int(num))  
 workspace.append(curr\_line)  
 input\_file.close()  
 workspace.reverse()  
 return start\_pos, goal\_pos, workspace  
  
  
def calculate\_heuristic(curr\_pos, goal\_pos):  
 *"""  
 Calculate the h(n) value based on current and goal position  
 :param curr\_pos: tuple of current location  
 :param goal\_pos: tuple of goal position  
 :return: The heuristic value calculated  
 """* return math.sqrt((curr\_pos[0]-goal\_pos[0])\*\*2+(curr\_pos[1]-goal\_pos[1])\*\*2)  
  
  
def is\_valid\_pos(pos, workspace):  
 *"""  
 Returns whether a position is valid (not out of bound and not blocked)  
 :param pos: position to check  
 :param workspace: 2D list of workspace  
 :return: boolean of validity  
 """* if pos[1] < 0 or pos[0] < 0 or pos[1] >= len(workspace) or pos[0] >= len(workspace[0]):  
 return False  
 return workspace[pos[1]][pos[0]] != 1  
  
  
def calculate\_angle\_cost(curr\_angle, new\_angle, k):  
 *"""  
 Calculates the angle cost for changing direction based on curr\_angle and new\_angle  
 :param curr\_angle: angle of current node in degrees  
 :param new\_angle: angle of next node in degrees  
 :param k: penalty coefficient for direction change  
 :return: angle cost as a float  
 """* delta\_theta = abs(new\_angle - curr\_angle)  
 if delta\_theta > 180:  
 delta\_theta = 360 - delta\_theta  
  
 return k \* (delta\_theta / 180)  
  
  
def calculate\_distance\_cost(curr\_node, new\_pos):  
 *"""  
 Calculates the distance cost to get to new\_pos from curr\_pos  
 :param curr\_node: coordinates of curr position  
 :param new\_pos: coordinates of new position  
 :return: distance cost as a float  
 """* # Check if horizontal or vertical move  
 if abs(new\_pos[0] - curr\_node.pos[0]) + abs(new\_pos[1] - curr\_node.pos[1]) == 1:  
 distance\_cost = 1  
 else:  
 distance\_cost = math.sqrt(2)  
  
 return distance\_cost  
  
  
def calculate\_step\_cost(curr\_node, new\_pos, k):  
 *"""  
 Calculates the step cost by adding distance and angle costs  
 :param curr\_node: coordinates of curr position  
 :param new\_pos: coordinates of new position  
 :param k: penalty coefficient for direction change  
 :return: total step cost as a float  
 :return: new angle in degrees  
 """* dx, dy = new\_pos[0] - curr\_node.pos[0], new\_pos[1] - curr\_node.pos[1]  
 new\_angle = math.degrees(math.atan2(dy, dx)) % 360  
   
 if curr\_node.parent is None:  
 angle\_cost = 0

new\_angle = 0  
 else:  
 angle\_cost = calculate\_angle\_cost(curr\_node.last\_angle, new\_angle, k)  
  
 distance\_cost = calculate\_distance\_cost(curr\_node, new\_pos)  
  
 return distance\_cost + angle\_cost, new\_angle  
  
  
def a\_star\_search\_algo(start\_pos, goal\_pos, workspace, k):  
 *"""  
 Implementation of the A\* search algorithm  
 :param start\_pos: starting coordinate  
 :param goal\_pos: goal coordinate  
 :param workspace: workspace 2D list  
 :return: None if no solution; curr\_node, generated if solution is found  
 """* start\_node = Node(start\_pos, 0, calculate\_heuristic(start\_pos, goal\_pos))  
 reached = {start\_pos: start\_node.total\_cost}  
 frontier = []  
 heapq.heappush(frontier, start\_node)  
  
 logging.info(f"Generated node:\t\t{start\_node}")  
  
 while frontier:  
 # Get the smallest value  
 curr\_node = heapq.heappop(frontier)  
  
 logging.info(f"Frontier popped:\t{curr\_node}")  
  
 # If solution is found  
 if curr\_node.pos == goal\_pos:  
 logging.info("======GOAL REACHED!!!======")  
 logging.info("Reached: " + str(len(reached)))  
 return curr\_node, reached  
  
 # Generate all child nodes  
 for direction in DIRECTIONS:  
 new\_pos = (curr\_node.pos[0] + direction[0], curr\_node.pos[1] + direction[1])  
  
 # Append node to generated and frontier if it's valid  
 if is\_valid\_pos(new\_pos, workspace):  
 step\_cost, new\_angle = calculate\_step\_cost(curr\_node, new\_pos, k)  
 child\_path\_cost = curr\_node.path\_cost + step\_cost  
 child\_heuristic = calculate\_heuristic(new\_pos, goal\_pos)  
 child\_total\_cost = child\_path\_cost + child\_heuristic  
 if new\_pos in reached and reached[new\_pos] <= child\_total\_cost:  
 continue  
 child\_node = Node(new\_pos, child\_path\_cost, child\_total\_cost, last\_angle=new\_angle, parent=curr\_node)  
 reached[child\_node.pos] = child\_node.total\_cost  
 heapq.heappush(frontier, child\_node)  
  
 logging.info(f"Generated node:\t\t{child\_node}")  
 logging.info(f"Added to frontier:\t{child\_node}")  
  
  
def calculate\_output\_values(final\_node, workspace):  
 *"""  
 Function used to calculate several values needed for output  
 :param final\_node: The last node in the path found  
 :param workspace: 2D list of the workspace  
 :return: dictionary of all the values  
 """* # Just didn't want to change the original workspace  
 new\_workspace = copy.deepcopy(workspace)  
  
 curr\_node = final\_node  
 depth = -1  
 moves = []  
 f\_values = []  
  
 while curr\_node:  
 pos = curr\_node.pos  
 if new\_workspace[pos[1]][pos[0]] != 2 and new\_workspace[pos[1]][pos[0]] != 5:  
 new\_workspace[pos[1]][pos[0]] = 4  
 depth += 1  
 f\_values.append(curr\_node.total\_cost)  
   
 if curr\_node.parent is not None:  
 direction = (curr\_node.pos[0] - curr\_node.parent.pos[0],  
 curr\_node.pos[1] - curr\_node.parent.pos[1])  
 move = DIRECTIONS.index(direction)  
 moves.append(move)  
  
 curr\_node = curr\_node.parent  
  
 moves.reverse()  
 f\_values.reverse()  
 new\_workspace.reverse()  
  
 return {  
 "depth": depth,  
 "moves": moves,  
 "f\_values": f\_values,  
 "workspace": new\_workspace  
 }  
  
  
def output\_into\_file(output: OutputModel, file\_name):  
 *"""  
 Used to write all output data into a output file  
 :param output: The OutputModel used to help with output generation  
 :param file: the filepath of the output file  
 :return: None  
 """* os.makedirs('Outputs', exist\_ok=True)  
  
 # Construct the full path  
 output\_file\_path = os.path.join('Outputs', file\_name)  
  
 output\_file = open(output\_file\_path, "w")  
  
 print(output.depth, file=output\_file)  
 print(output.generated\_nodes, file=output\_file)  
 print(output.moves, file=output\_file)  
 print(output.f\_values, file=output\_file)  
 print(output.output\_workspace, file=output\_file)  
  
 output\_file.close()  
  
  
def main():  
 parser = argparse.ArgumentParser(description="Run A\* search on a robot workspace")  
 parser.add\_argument("input\_file", type=str, help="Path to the input file")  
 parser.add\_argument("k", type=int, nargs='?', default=0, help="Angle cost penalty parameter (default: 0)")  
 parser.add\_argument("-o", "--output\_file", type=str, default="Output.txt", help="Name of the output file (default: 'Output.txt')")  
 args = parser.parse\_args()  
  
 setup\_logging(args.input\_file, args.output\_file, args.k)  
  
 start\_pos, goal\_pos, workspace = process\_input(args.input\_file)  
 result = a\_star\_search\_algo(start\_pos, goal\_pos, workspace, args.k)  
 if result:  
 final\_node, generated\_nodes = result  
 output\_dict = calculate\_output\_values(final\_node, workspace)  
 output\_dict["generated\_nodes"] = generated\_nodes  
 output = OutputModel(output\_dict)  
 output\_into\_file(output, args.output\_file)  
  
  
if \_\_name\_\_ == "\_\_main\_\_":  
 main()

**Program Output Files:**

**Input 1 K = 0:**

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32.57299494980466 32.622776601683796 32.67572330035593 32.82509590207858 32.988682805403634 33.1684647227918 33.366774513857266 33.586369156128 33.830516434096076 34.103098247786185 34.40873160871375 34.413459741226546 34.41868167352756 34.4244787752596 34.43095126760845 35.006742657457565 35.02498060213621 35.045743124634214 35.06958612548419 35.097238938210836 35.12967631234924 35.16822857026841 35.214755041863 35.388346874966274 35.627416997969526 35.63911171640227 35.65536869969684 35.67945481172171 35.71862684627243 35.792417163603844 35.97056274847714 35.97056274847714

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**Input 1 K = 2:**

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**Input 1 K = 4:**

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37.8021163428716 38.013511046643494 38.235341863986875 39.538997298749976 39.797825588281356 40.06966046470001 40.069967401935514 40.07030161279838 40.07066690098348 40.071067811865476 40.071509822506016 40.07199959321647 40.35533905932738 40.65833174289156 40.98268409419626 40.98527659649403 40.98821368682716 40.991568865010166 41.24710879827376 41.52691193458119 41.83394163668508 41.83516978220376 42.112698372208094 42.42241793342256 42.76901958965595 42.77681122334285 42.78653056184162 42.798989873223334 43.01853433051622 43.2842712474619 43.60923954912999 43.616327673029275 43.62741699796952 44.0995529529691 44.20390822051099 44.2776985378424 44.4558441227157 44.4558441227157

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**Input 2 K = 2:**

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37.8021163428716 39.05727401181051 39.29239139154464 39.538997298749976 39.797825588281356 40.06966046470001 40.35533905932737 40.85533905932738 40.85533905932738 40.85533905932738 40.85533905932738 40.85533905932738 40.85533905932738 41.65833174289156 41.98268409419626 42.48527659649403 42.48821368682716 42.491568865010166 43.24710879827376 43.52691193458119 43.83394163668508 44.33516978220376 45.112698372208094 45.42241793342256 45.76901958965595 46.27681122334284 46.286530561841616 46.29898987322333 47.01853433051622 47.284271247461895 47.60923954912998 48.0100924241513 48.54415533044172 48.59955295296909 48.70390822051098 48.955844122715696 49.455844122715696 49.455844122715696

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**Input 2 K = 4:**

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602

7 0 0 0 0 0 1 1 1 1 1 1 0 0 1 1 1 2 2 2 1 0 0 0 1 1 1 2 2 2 2 1 1 1 1 0 0

37.8021163428716 39.05727401181051 39.29239139154464 39.538997298749976 39.797825588281356 40.06966046470001 40.35533905932737 41.35533905932738 41.35533905932738 41.35533905932738 41.35533905932738 41.35533905932738 41.35533905932738 42.65833174289156 42.98268409419626 43.98527659649403 43.98821368682716 43.991568865010166 45.24710879827376 45.52691193458119 45.83394163668508 46.83516978220376 48.112698372208094 48.42241793342256 48.76901958965595 49.77681122334284 49.786530561841616 49.79898987322333 51.01853433051622 51.284271247461895 51.60923954912998 52.0100924241513 53.04415533044172 53.09955295296909 53.20390822051098 53.455844122715696 54.455844122715696 54.455844122715696

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**Input 3 K = 0:**

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1 1 2 2 2 2 2 1 0 0 1 1 1 1 2 1 0 0 0 0 7 0 0 0 0 0 7 0 0 0 1 1 1 1 0 0 0 0 0 0 1 0 1 0 1 0 0 1

46.51881339845203 46.602707673153105 46.69185152366881 47.29105474894765 47.90974558182222 48.548445851333845 49.207667325580374 49.88790881437237 50.047052213325614 50.092358377461835 50.13994136467273 50.299914698929804 50.47161725826807 50.656292164376524 50.85534862931096 51.633750523477666 51.87134969118418 51.88901530667865 51.90782558054147 51.92789428890646 51.94935062553747 52.620573423320565 52.65374609703038 52.689432032852196 52.72792206135786 52.76955262170047 52.81471482258825 53.614340677975186 53.68279485226897 53.75766375181925 53.83985122732316 53.94112549695428 54.0585702391122 54.196164611692126 54.359209651784354 54.400460381958766 54.44810051389684 54.503689783942946 54.56931948749233 54.64784767501942 54.74326178322248 54.82897654146032 54.921407368095785 55.012581805104006 55.099552952969084 55.203908220510975 55.27769853784238 55.45584412271569 55.45584412271569

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**Input 3 K = 2:**

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**Input 3 K = 4:**

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