Robot Pathfinding Project Report

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1 Introduction

This report describes the implementation of a robot pathfinding algorithm using the A* search algorithm. The robot must navigate through a grid with obstacles, starting from a specified start position to reach a goal position. This report outlines how to run the program, the source code, and the output generated during the execution of the algorithm.

2 Running the Program

To run the program, ensure that you have Python 3.x installed on your machine. You also need the following libraries:

- heapq
- math
- matplotlib
- numpy

The program can be executed with the following command:

```
python3 Robot_planning.py
```

Make sure that the input file is correctly specified in the source code. The input file contains the start and goal positions, as well as the grid layout.

3 Program Compilation

The Python program does not require compilation, as it is an interpreted language. However, you need to ensure that all the necessary libraries are installed. You can install any missing libraries using the following commands:

```
pip install matplotlib numpy
```

4 Source Code

The source code for the program is provided below:

```
import heapq
import math

def read_input(file_path):
    with open(file_path, 'r') as f:
        start_i, start_j, goal_i, goal_j = map(int, f.readline().split())
        grid = []
        for line in f:
            row = [int(x) for x in line.strip().split()]
            if len(row) == 50:
                grid.append(row)
        if len(grid) != 30 or len(grid[0]) != 50:
            print(f"Current dimensions: {len(grid)}x{len(grid[0])}")
            raise ValueError(f"Invalid grid dimensions: {len(grid)}x{len(grid[0])}. Expected
        grid.reverse()
    return (start_i, start_j), (goal_i, goal_j), grid

def format_output(start, goal, grid, path, actions, f_values, nodes_generated):
    output = f"{len(actions)}\n"
    output += f"{nodes_generated}\n"
    output += ' '.join(map(str, actions)) + "\n"
    output += ' '.join(f"{f:.1f}" for f in f_values) + "\n"
    for j in range(len(grid)-1, -1, -1):
        for i in range(len(grid[0])):
            if (i, j) == start:
                output += "2 "
            elif (i, j) == goal:
                output += "5 "
            elif (i, j) in path[1:-1]:
                output += "4 "
            else:
                output += f"{grid[j][i]} "
        output += "\n"
    return output.strip()

def heuristic(a, b):
    return math.sqrt((b[0] - a[0])**2 + (b[1] - a[1])**2)

def get_neighbors(node, grid):
    directions = [(1, 0), (1, 1), (0, 1), (-1, 1), (-1, 0), (-1, -1), (0, -1), (1, -1)]
    neighbors = []
    for idx, (di, dj) in enumerate(directions):
```

```
            ni = node[0] + di
            nj = node[1] + dj
            if (0 <= ni < len(grid[0]) and 0 <= nj < len(grid) and grid[nj][ni] != 1):
                neighbors.append((idx, (ni, nj)))
        return neighbors

    def angle_cost(prev_move=None, next_move=None, k=2):
         if prev_move==None:
             return(0)
         diff=abs(next_move-prev_move)
         if diff>4:
             diff=8-diff
         return(k*(diff/8))

    def distance_cost(move):
         if move%2==0:
             return(1)
         else:
             return(math.sqrt(2))

    def reconstruct_path(came_from, current, g_score, f_score):
        path = []
        actions = []
        f_values = []
        while current in came_from:
            path.append(current)
            f_values.append(f_score[current])
            current, action = came_from[current]
            actions.append(action)
        path.append(current)
        f_values.append(f_score[current])
        return path[::-1], actions[::-1], f_values[::-1]

    def astar(start, goal, grid, k, max_iterations=100000):
        open_list = [(0, start, None)]
        came_from = {}
        g_score = {start: 0}
        f_score = {start: heuristic(start, goal)}
        closed_set = set()
        nodes_generated = 1
        iterations = 0

        while open_list and iterations < max_iterations:
            iterations += 1
            current_f, current, prev_move = heapq.heappop(open_list)
```

```
            if current == goal:
                print("Goal reached!")
                path, actions, f_values = reconstruct_path(came_from, current, g_score, f_score)
                return path, actions, f_values, nodes_generated
            closed_set.add(current)

            for move_index, neighbor in get_neighbors(current, grid):
                if neighbor in closed_set:
                    continue
                tentative_g_score = g_score[current] + distance_cost(move_index) + angle_cost(pr

                if neighbor not in g_score or tentative_g_score < g_score[neighbor]:
                    came_from[neighbor] = (current, move_index)
                    g_score[neighbor] = tentative_g_score
                    f_score[neighbor] = g_score[neighbor] + heuristic(neighbor, goal)
                    heapq.heappush(open_list, (f_score[neighbor], neighbor, move_index))
                    nodes_generated += 1

        print(f"No path found after exploring {nodes_generated} nodes.")
        return None

    def main(input_file, output_file, k):
        start, goal, grid = read_input(input_file)
        print(f"Start: {start}, Goal: {goal}")
        print(f"Grid size: {len(grid)}x{len(grid[0])}")

        result = astar(start, goal, grid, k)

        if result is not None:
            path, actions, f_values, nodes_generated = result
            output = format_output(start, goal, grid, path, actions, f_values, nodes_generated)
            with open(output_file, 'w') as f:
                f.write(output)
            print(f"Path found! Check {output_file} for results.")
            print(f"Path length: {len(path)}")
            print(f"Nodes generated: {nodes_generated}")
        else:
            print("No path found.")
            with open(output_file, 'w') as f:
                f.write("No path found.\n")

    if __name__ == "__main__":
        input_file = "inputfile.txt"
        output_file = "output.txt"
        k = 2
        main(input_file, output_file, k)
```

5 Program Output

```
Input File 1:
Start: (6, 15), Goal: (37, 5)
Grid size: 30x50

For K=0

31
224
0 0 7 7 7 7 7 7 7 0 0 0 0 1 0 0 0 0 0 0 0 7 7 0 0 0 0 0 7 0
32.6 32.6 32.7 32.8 33.0 33.2 33.4 33.6 33.8 34.1 34.4 34.4 34.4 34.4 34.4 35.0 35.0 35.0 35
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 0 0 1 1 0 0 1 0 0 0 0 1 1 0 0 0 1 0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 1 1 0 0 1 1 1 0 0 1 0 0 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 2 4 4 0 1 1 0 1 1 0 0 0 0 0 0 0 0 1 0 1 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 4 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 1 1 1 0 0 0 0 0 0 0 0 0
0 0 0 1 1 1 1 1 1 1 4 0 0 1 1 1 0 0 1 1 0 1 1 1 1 1 1 0 0 0 1 0 1 1 0 0 0 1 1 0 0 0 0 0 0 0
0 0 0 1 1 1 1 1 1 1 0 4 0 0 1 1 0 0 1 1 0 1 1 1 1 1 1 0 0 0 1 0 0 1 1 0 0 0 1 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 1 0 0 0 0 0 4 0 1 1 1 0 1 0 0 1 1 1 1 1 1 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 4 0 1 1 0 0 0 0 0 0 0 1 1 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 1 1 1 0 1 1 0 0 0 0 4 1 1 0 0 0 0 4 4 4 4 4 4 4 4 1 1 1 0 0 1 1 1 0 0 0 0 0 0
0 0 0 1 1 0 1 1 1 1 0 1 1 0 0 0 0 4 4 4 4 4 1 0 0 0 0 0 0 0 0 4 1 1 0 0 0 1 1 1 1 0 0 0 0 0
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0 0 0 1 1 0 1 1 1 0 0 0 0 0 0 1 1 0 0 0 0 0 0 1 0 0 0 1 1 1 0 0 0 0 0 0 1 1 4 5 1 1 0 0 0 0
0 0 0 1 1 0 1 1 1 0 0 0 0 0 1 1 0 0 1 1 0 1 1 1 1 1 0 0 1 1 1 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 1 1 0 0 1 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

For K=2

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31
388
0 0 7 7 7 7 7 7 7 7 0 0 0 0 1 0 0 0 0 0 0 0 7 7 0 0 0 0 0 7 0
32.6 32.6 32.7 33.1 33.2 33.4 33.6 33.8 34.1 34.4 34.7 34.9 34.9 34.9 34.9 35.8 36.0 36.0 36
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 1 0 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0
1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 0 0 0 1 1 0 0 1 1 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 0 0 1 0 0 0 1 1 0 1 1 1 1 1 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 1 1 0 0 1 0 0 0 0 1 1 0 0 0 1 0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 1 1 0 0 1 1 1 0 0 1 0 0 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 2 4 4 0 1 1 0 1 1 0 0 0 0 0 0 0 0 0 1 0 1 1 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 4 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 1 1 1 0 0 0 0 0 0 0 0
0 0 0 1 1 1 1 1 1 1 4 0 0 1 1 1 0 0 1 1 0 1 1 1 1 1 0 0 0 1 0 1 1 0 0 0 1 1 0 0 0 0 0 0 0 0
0 0 0 1 1 1 1 1 1 1 0 4 0 0 1 1 0 0 1 1 0 1 1 1 1 1 0 0 0 1 0 0 1 1 0 0 0 1 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 1 0 0 0 0 4 0 1 1 1 0 1 0 0 1 1 1 1 1 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 4 0 1 1 0 0 0 0 0 0 1 1 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 1 1 1 0 0 0 0 0 4 1 1 1 0 0 1 1 0 0 1 1 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 1 1 1 0 1 1 0 0 0 4 1 1 0 0 0 4 4 4 4 4 4 4 4 1 1 1 0 0 1 1 1 0 0 0 0 0 0 0 0 0
0 0 0 1 1 0 1 1 1 0 1 1 0 0 0 0 4 4 4 4 4 1 0 0 0 0 0 0 0 4 1 1 0 0 0 1 1 1 1 0 0 0 0 0 0 0
0 0 0 1 1 0 1 1 1 0 1 1 0 0 0 1 1 0 0 0 0 1 1 1 0 0 1 1 0 0 4 4 4 4 4 4 1 0 1 1 0 0 0 0 0 0
0 0 0 1 1 0 1 1 1 0 0 0 0 0 0 1 1 0 0 0 0 0 1 0 0 0 1 1 1 0 0 0 0 0 1 1 4 5 1 1 0 0 0 0 0 0
0 0 0 1 1 0 1 1 1 0 0 0 0 0 1 1 0 0 1 1 0 1 1 1 1 0 0 1 1 1 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 1 1 0 0 1 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

For K=4

```
31
458
0 0 7 7 7 7 7 7 7 7 0 0 0 0 1 0 0 0 0 0 0 0 7 7 0 0 0 0 0 0 7 0
32.6 32.6 32.7 33.3 33.5 33.7 33.9 34.1 34.3 34.6 34.9 35.4 35.4 35.4 35.4 36.5 37.0 37.0 37
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 1 0 0 0 1 1 1 1 0 0 0 0 0 0 0 0
1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 0 0 0 1 1 0 0 1 1 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0
1 1 1 1 1 1 1 1 1 0 0 0 1 1 1 1 1 1 1 1 0 0 0 1 1 0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 0 1 1 1 1 0 1 1 0 0 1 1 1 1 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 0 0 0 1 1 1 0 0 1 1 0 0 1 1 1 1 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 1 0 0 0 0 1 1 0 1 1 1 1 1 1 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 1 1 0 0 1 0 0 0 0 1 1 0 0 0 1 0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 1 1 0 0 1 1 1 1 0 0 1 0 0 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 2 4 4 0 1 1 0 1 1 0 0 0 0 0 0 0 0 0 1 0 1 1 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 4 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 1 1 1 0 0 0 0 0 0
0 0 0 1 1 1 1 1 1 1 4 0 0 1 1 1 0 0 1 1 0 1 1 1 1 1 1 0 0 0 1 0 1 1 0 0 0 1 1 0 0 0 0 0 0 0
0 0 0 1 1 1 1 1 1 1 0 4 0 0 1 1 0 0 1 1 0 1 1 1 1 1 1 0 0 0 1 0 0 1 1 0 0 0 1 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 1 0 0 0 0 4 0 1 1 1 0 1 0 0 1 1 1 1 1 1 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 4 0 1 1 0 0 0 0 0 0 1 1 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 1 1 1 0 0 0 0 0 4 1 1 1 0 0 1 1 0 0 1 1 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 1 1 1 0 1 1 0 0 0 4 1 1 0 0 0 4 4 4 4 4 4 4 4 1 1 1 0 0 1 1 1 0 0 0 0 0 0 0 0
0 0 0 1 1 0 1 1 1 0 1 1 0 0 0 0 0 4 4 4 4 4 1 0 0 0 0 0 0 0 0 4 1 1 0 0 0 1 1 1 1 0 0 0 0 0
0 0 0 1 1 0 1 1 1 0 1 1 0 0 0 1 1 0 0 0 0 0 1 1 1 0 0 1 1 0 0 4 4 4 4 4 4 1 0 1 1 0 0 0 0 0
0 0 0 1 1 0 1 1 1 0 0 0 0 0 0 1 1 0 0 0 0 0 0 1 0 0 0 1 1 1 0 0 0 0 0 1 1 4 5 1 1 0 0 0 0 0
0 0 0 1 1 0 1 1 1 0 0 0 0 0 0 1 1 0 0 1 1 0 1 1 1 1 0 0 1 1 1 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 1 1 0 0 1 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

Input File 2:
Start: (3, 2), Goal: (33, 25)
Grid size: 30x50

For k=0

```
37
509
0 0 7 0 0 1 1 1 1 1 1 0 0 0 1 1 1 2 2 2 1 0 0 0 1 1 1 2 2 2 1 1 2 1 0 0 1
37.8 38.0 38.2 39.5 39.8 40.1 40.1 40.1 40.1 40.1 40.1 40.1 40.4 40.7 41.0 41.0 41.0 41.0 4
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 0 1 1 1 0 0 0 5 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 4 4 4 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 1 0 0 4 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0
1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 0 0 0 1 1 0 0 1 1 0 4 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0
1 1 1 1 1 1 1 1 0 0 0 1 1 1 1 1 1 1 1 0 0 0 1 1 0 0 0 0 4 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 0 1 1 1 1 4 1 1 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 0 0 0 1 1 1 4 0 1 1 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 1 0 0 0 1 1 0 1 1 1 1 1 0 0 0 0 1 1 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 0 0 0 1 1 0 1 1 0 0 0 0 0 0 0 0 0 1 4 1 1 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 4 4 4 4 0 0 0 0 1 1 1 1 0 0 1 1 1 0 0 0 0 0 0 0 0
0 0 0 1 1 1 1 1 1 1 0 0 0 1 1 1 0 0 1 1 4 1 1 1 1 1 0 0 0 1 0 1 1 0 0 0 1 1 0 0 0 0 0 0 0 0
0 0 0 1 1 1 1 1 1 1 0 0 0 0 1 1 0 0 1 1 4 1 1 1 1 1 0 0 0 1 0 0 1 1 0 0 0 1 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 1 0 0 0 0 0 0 1 1 1 0 1 0 4 1 1 1 1 1 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 4 0 0 1 1 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 1 1 1 0 4 1 1 0 0 1 1 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 1 1 1 0 1 1 0 0 0 0 1 1 4 0 0 0 0 0 0 0 0 0 0 1 1 1 0 0 1 1 1 0 0 0 0 0 0 0 0 0
0 0 0 1 1 0 1 1 1 0 1 1 0 0 4 4 4 4 0 0 0 1 0 0 0 0 0 0 0 0 1 1 0 0 0 1 1 1 1 0 0 0 0 0 0 0
0 0 0 1 1 0 1 1 1 0 1 1 0 4 0 1 1 0 0 0 0 1 1 1 0 0 1 1 0 0 0 0 0 0 0 1 0 1 1 0 0 0 0 0 0 0
0 0 0 1 1 0 1 1 1 0 0 0 4 0 0 1 1 0 0 0 0 0 1 0 0 0 1 1 1 0 0 0 0 1 1 0 0 1 1 0 0 0 0 0 0 0
0 0 0 1 1 0 1 1 1 0 0 4 0 0 1 1 0 0 1 1 0 1 1 1 1 0 0 1 1 1 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 1 1 1 0 4 0 0 0 0 1 1 0 0 1 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 2 4 4 1 1 1 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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For K=2

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37
750
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Fok K=4

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37
779
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Input File 3:
Start: (3, 3), Goal: (45, 23)
Grid size: 30x50

For K=0

48
469
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 0 7 0 0 0 1 1 1 1 0 0 0 0 0 0 0 1 0 1 0 1 0
46.5 46.6 46.7 47.3 47.9 48.5 49.2 49.9 50.0 50.1 50.1 50.3 50.5 50.7 50.9 51.6 51.9 51.9 51
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For K=2

48
648
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46.5 46.6 46.7 47.5 48.2 48.8 49.5 50.1 50.5 50.8 50.9 51.3 51.5 51.7 51.9 52.9 53.4 53.6 53
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For K=4

48
708
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0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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```

6 Conclusion

The A* algorithm successfully navigates the grid and reaches the goal while avoiding obstacles. The program provides a detailed output, including the path taken, the sequence of moves, the f-values of nodes, and a visualization of the grid with the robot's path.