London Metropolitan University

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**CS7050 Artificial Intelligence**

Coursework

**Heuristic Search problem The Maze Problem**

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**ABSTRACT**

The Heuristic Search Problem is the application of heuristic search methods to find the most efficient path from a beginning node to a designated goal node. In particular, this research discusses the difficulties that agent mobility presents when creating realistic Artificial Intelligence (AI) for video games. The Maze Problem is the main emphasis. The goal is to find the shortest and most convenient path from the beginning point to the goal state while navigating around blocked cells.

The report uses the A\* Search algorithm, which is improved by heuristic functions, to solve this issue. The visualization and animation of the maze and its solution are made easier by the use of pre-existing libraries. Moreover, The system's capacity to find the quickest path to the goal node is demonstrated by its overall performance, which is judged adequate. This study advances artificial intelligence (AI) in computer games by offering a practical solution to the labyrinth navigation problem, which incorporates heuristic search techniques for increased effectiveness.

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5. **Introduction**

Heuristic search algorithms are essential for resolving intricate issues because they can navigate solution spaces with intelligence. Heuristic search has exciting applications for solving labyrinth problems, which involve figuring out the best routes across complex networks of pathways. A well-known puzzle in artificial intelligence and computer science, the maze issue provides an interesting platform for examining the performance of heuristic search algorithms.

Mazes present distinct pathfinding issues since they are reflective of a variety of real-world circumstances, including robotics navigation, game design, and network routing. Finding the most effective path through a maze's turns, twists, and dead ends to go from a certain start point to a predetermined goal is the aim. Heuristic search algorithms, which incorporate domain-specific knowledge to steer the search towards more possible answers, provide a strategic approach in this context.

This assignment uses Python to implement the A\* path finding algorithm. The report provides an explanation of the instructions and outputs of the Python program that was created in Spyder . The nodes' coordinates are stored in a tuple data structure in this model, and the path traversed is traced using a priority queue. With the aid of the A\* method, we are able to determine the shortest path from the start node (0,0) to the finish node (5,6) in our 5 by 6 grid, which contains some blocks that cannot be traversed.

The algorithm's traversal condition states that steps may only be taken either vertically or horizontally, meaning that one can only proceed east (E), west (W), North (N) or South (S) however it’s Not allowed to travel in a diagonal manner.

However, the query "How do I get from source to destination?" could have responses provided using pathfinding. Most of the time, there may be multiple ways to get from the source (current point) to the destination (next point); nevertheless, if more than one is feasible, the solution must address the following objectives:

1.The route that connects point A with point B.

2.The method for avoiding roadblocks.

3.The method for determining the shortest path.

4. A fast approach to locate the path.

A diagram of a position of nodes

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**Figure 1. The maze problem**

1. **Implementation**
2. **Maze Node Class Explanation:**

The model for representing individual nodes in the maze is provided by the `MazeNode` class. A node's position in the labyrinth (represented by a tuple of row and column coordinates), a boolean flag indicating if it is an obstacle, and many scores important for pathfinding algorithms are all contained in each instance of this class:

**position:** A tuple containing the node's (row, column) coordinates.

**obstacle:** A boolean that indicates whether the node is an obstacle and gives details on how easily the relevant maze cell may be traversed.

**g\_score:** The cost of traversing from the start node to the current node is represented by the variable g\_score. The initial value of this variable is infinity.

**h\_score:** The heuristic value, or "h\_score," is an indicator of the approximate cost of traveling from the current node to the objective node.

**f\_score:** A thorough assessment of the overall cost involved in achieving the goal through the current node is provided by the f\_score, which is the sum of the `g\_score} and `h\_score}.

**parent:** Maintains track of the path's parent node, assisting in the reconstruction of the ideal path after the objective is accomplished.

**make\_maze Operation Justification:**

A two-dimensional maze is created via the `create\_maze` function utilizing `MazeNode} class objects. It controls how each maze node is initialized, establishing important parameters including parent references, scores, and obstacle status. Important actions in this process include:

**Initialization:** The function builds a 2D array called {maze}, in which each member represents a different node in the maze and is an instance of the `MazeNode} class.

**Node Configuration:** Based on established obstacle positions, the function assigns a position to each node and decides whether or not it is an obstacle.

It identifies the start and goal nodes in the labyrinth and sets the initial values for their `g\_score~, {h\_score~, and `f\_score}. The goal node is the endpoint, whereas the start node is the starting point of exploration.

**Calculation of the Heuristic:** The function makes the assumption that there is a `calculate\_heuristic` function that determines the heuristic value for a specific node. This heuristic value aids in the decision-making process of the A\* search algorithm by helping to estimate the cost from a node to the target.The `MazeNode} class and the `create\_maze} function help to make an informative and structured maze representation by using this organized representation, which paves the way for effective pathfinding algorithms like A\*.

1. **Success criteria**

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**Figure 2**

Finding the most effective route through the maze from the starting node to the goal node is the main goal of the perform A\*search function. When the node under exploration aligns with the pre-established goal node, the success criteria are determined.

When the equality between the present node and the goal node is detected, the algorithm's journey towards the designated objective has successfully reached its end.

Then, the algorithm calls the reconstruct\_path function to go smoothly into the next stage. Reconstructing the route taken from the starting node to the designated goal node is greatly aided by this function.

The return of the reconstructed path from the perform\_astar\_search function marks the end of this procedure. This result provides a concrete demonstration that the A\* algorithm has fulfilled its task by effectively identifying the best route from the beginning to the target.

To put it briefly, the success criteria depend on how well the algorithm locates the desired node among the investigated nodes. The successful execution of the A\* algorithm is indicated by the call to the reconstruct\_path function later on and the return of the reconstructed path. The function gracefully ends by returning None, indicating that there isn't a feasible path to the stated destination, in the event that the goal node is still unreachable and the open set exhausts without reaching the intended goal.

1. **Path function**

In the A\* search algorithm, the accumulate\_path function is essential to path reconstruction. Below is a detailed explanation of its features:

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**Figure 3**

**Parameters:** admits the came from dictionary, which keeps track of parent-child relationships while a search is being conducted.

considers the goal node and the start node to be necessary parameters.

**Starting Point:** Sets the current variable's initial value to the goal node, making it the path reconstruction's beginning point.

assembles the path list, where the goal node is the first entry.

**Iterative Construction of Paths:** uses a while loop to add parent nodes to the path iteratively until it reaches the start node.

By updating the current node with its corresponding parent at each iteration, the path is essentially traced backward.

**Order Modification:** To guarantee that the path is in the right chronological order from the start node to the goal node, it is reversed.

**Return Path:** The final step of the function returns the painstakingly assembled path, which contains the node order from the beginning to the end.

**Changes to perform\_astar\_search:** To improve readability and code organization, a deliberate change has been made to the perform A\* search function. After the A\* search successfully locates the goal node:

**Route Delegation:** It transfers this task to the accumulate\_path function from the perform\_astar\_search function, which handles path reconstruction directly.

**Invocation of a Function:** The came\_from dictionary, start node, and target node are the three parameters that are required when the accumulate\_path function is used.

**Path Recovery:** The accumulate\_path function is seamlessly given the task of reconstructing and obtaining the path.

1. **Heuristic functions**

A heuristic function is a function that is used in search algorithms, especially in pathfinding problems, to estimate the cost or distance from a given state (or node) to the objective. It is commonly written as (h(n)). A heuristic function's job is to direct the search process by offering a "guess" as to how near the goal state a given state is. The search is more effective because of this guidance, which the algorithm uses to decide which paths to investigate first.

The heuristic function plays a critical role in the A\* search algorithm. To determine which nodes to investigate next, A\* combines the expected cost from the goal (( h(n) )) with the actual cost to attain a given state (( g(n) )). Nodes in the search process are prioritized using the evaluation function (f(n) = g(n) + h(n) ), where (f(n) ) reflects the total estimated cost from the start node to the goal node passing via the node (n ).

Essential characteristics of a heuristic function:

1. Admissibility: If a heuristic function never overestimates the actual cost of achieving the objective, it is considered admissible. Put differently, (h(n) leq h^\*(n) ), where (h^\*(n)) represents the true cost to reach the destination from node (n).

2. Consistency (also known as monotonicity): A heuristic is considered consistent if the estimated costs of a node to its successor and the successor to the goal are consistently higher than or equal to the anticipated costs of the node to the goal. From a mathematical perspective, ( h(n) leq c + h(m) ), where ( c ) is the fare from node (n) to successor (m).

3. Example: The Manhattan distance, often known as the taxicab distance, between the present state and the destination state is a popular heuristic in pathfinding problems. The Manhattan distance for a node ((x, y)) in a grid is ( |x - x\_{\text{goal}}| + |y - y\_{\text{goal}}| ) to the goal ((x\_{text{goal}}, y\_{text{goal}}) ).

Selecting a useful heuristic is essential to the A\* algorithm's performance. An effective heuristic can drastically shrink the search space and increase the algorithm's effectiveness in locating the best course of action.

**A computer screen shot of a code

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**Figure 4**

**Parameters:**An input node that represents the current position in the grid is given to the heuristic function.

**Calculate a Heuristic:** By calculating the Manhattan distance between the current node (x1, y1) and the destination node (x2, y2), it determines the heuristic value.

**Manhattan's Distance:**The total of the absolute differences in the x and y coordinates between the present node and the objective node is the Manhattan distance.

In essence, the heuristic function calculates the bare minimum of horizontal and vertical motions from the current node to the target.

**Value Returned:**An estimate of the cost from the present node to the target is given by returning the computed heuristic value.

**Suitability of the Heuristic:**

**Acceptability:** Because the heuristic never overestimates the cost, it is acceptable. The accuracy of the A\* algorithm depends on this feature.

**Continuity:** The Manhattan distance is always less than or equal to the true cost between two places, making the heuristic consistent, or monotonic.

**Effectiveness:** The Manhattan distance works well for grid-based pathfinding issues and is computationally efficient to compute.

1. **Algorithm for Heuristic Search - A Algorithm\***

**Success Criteria:** Taking barriers into account, the A\* algorithm finds a path from the start node to the objective node. The shortest path must be found based on the overall cost, which is determined by adding the cost of reaching the present node (g\_score) and the heuristic estimate of reaching the objective node (h\_score).

**Permitted Moves:** The get\_neighbors function, which finds nearby nodes inside the grid bounds without any impediments, determines the permissible moves at each node.

**Estimating Costs:**

The total cost from the starting node to the current node is the cost of reaching a node (g\_score). The Manhattan distance between the current node and the desired node is used to calculate the heuristic estimate (h\_score).

**Steps of an Algorithm:**

**Starting Point:**

The g\_score and f\_score dictionaries, as well as the open and closed sets, are initialized.

The start node's g\_score is set to 0, and the heuristic function is used to determine the h\_score.

The start node's entire cost (f\_score) is pushed into the open set.

**Loop of Search:**

The node with the lowest total cost (f\_score) is removed from the open set, even though it is not empty.

For visualization purposes, the current node is logged on the canvas.

The came\_from dictionary is used to recreate the path if the current node is the goal node.

**Extension and Assessment:**

The current node is assessed by being added to the closed set.

Every neighbor of the node in question is skipped if it is part of the closed set.

The neighbor's tentative g\_score is determined.

Update the required scores and move the neighbor into the open set if it is not there already or has a lower g\_score.

**Illustration:**

The canvas is the algorithm's visual representation of the search procedure.

Nodes in the closed set are indicated as assessed, and nodes in the open set are shown in cyan.

When the final path reaches the goal node, it is indicated in green.

**Finalization:**

A path does not exist if the open set gets empty and the goal node is inaccessible, in which case False is returned.

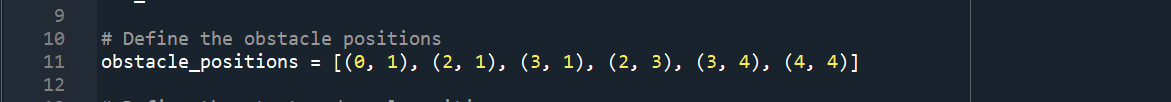
1. **Representation of maze**
2. **Grid Size Definition:**
   * The **NUM\_ROWS** and **NUM\_COLS** variables define the dimensions of the grid, indicating the number of rows and columns in the maze.

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**Figure 5**

1. **Obstacle Positions:**
   * The **obstacle\_positions** list specifies the coordinates of red nodes (obstacles) in the grid.



**Figure 6**

1. **Start and Goal Positions:**
   * **start\_position** and **goal\_position** variables represent the coordinates of the start and end nodes, respectively.

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**Figure 7**

1. **GUI Application Initialization:**
   * A Tkinter window is created as the GUI application, titled "Shortest Path."
   * A canvas is defined within the window, with a specified width and height.

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**Figure 8**

1. **Grid Drawing:**
   * Using nested loops, the code iterates through each cell in the grid.
   * For each cell, it calculates the coordinates and dimensions of a rectangle (**x1**, **y1**, **x2**, **y2**).
   * The color of the rectangle is set to "white" by default, and if the cell is in the **obstacle\_positions** list, its color is changed to "red."

A computer screen with white text

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**Figure 9**

**Representation Summary:**

* White cells represent open paths.
* Red cells represent obstacles.
* The start node is located at **(0, 0)**.
* The end node is located at **(4, 5)**.

1. **Run & Output of the program**

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**Figure 10**

As show in the figure10 when we run the program it shows matrix in canvas and red spot is the obstacles

* The grid is defined with specified obstacle positions, start position, and goal position.
* The heuristic function **calculate\_heuristic** calculates the Manhattan distance between a node and the goal position.

A screenshot of a computer

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**Figure 11**

* The perform\_astar\_search function initializes open and closed sets, as well as dictionaries for g\_score and f\_score.
* The algorithm iteratively explores nodes, considering their total cost (g\_score + heuristic) to prioritize the most promising paths.
* Nodes are visualized on the canvas during the search process, allowing observation of the algorithm's exploration.

A screenshot of a computer game

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**Figure 12**

* The GUI application is created using Tkinter, with a canvas representing the grid.
* The grid is drawn, and obstacles are marked in red.
* The "Find Shortest Path" button triggers the find\_shortest\_path function, which executes the A\* search and highlights the optimal path in green on the canvas.

A screenshot of a computer

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**Figure 13**

* After the search, a message box is shown with the result.
* If a path is found, it displays "Shortest path found!" along with the optimal path.
* Moreover, also provide the shortest path of the matrix
* If no path is found, it displays "No path found!"

1. **Additional Implementation**
2. **Design board in 2D**

**A computer screen shot of a code

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**Figure 14**

**Grid Size and Placement of Obstacles:**NUM\_ROWS and NUM\_COLS specify the grid's dimensions.

The coordinates of red nodes, which stand in for obstacles in the maze, are contained in the obstacle\_positions list.

**Drawing with a canvas and grid:** A canvas (canvas) is formed inside of a Tkinter window (root).

The canvas has a 600 x 500 pixel dimension.

The grid's cells are iterated over using a nested loop.

A rectangle is placed on the canvas for every cell at the computed coordinates (x1, y1, x2, y2).

By default, the rectangle's color is set to "white," but if a cell is in the way, it changes to "red."

**Illustration:** Red cells serve as barriers and white cells serve as open pathways in the visual representation of the maze on the painting.

1. **Visualization & Trace the attempted**

**A screenshot of a computer screen

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**Figure 15**

Here is the complete execution of the maze code so the yellow small square is the trace agent of the shortest path of the end point

1. **A\* Algorithm**

A popular pathfinding and graph traversal algorithm that quickly determines the shortest path from a start node to a goal node in a graph is called the A\* (A-star) search algorithm. In 1968, Peter Hart, Nils Nilsson, and Bertram Raphael presented it. In artificial intelligence, robotics, and computer gaming, A\* is especially well-liked for tasks like navigation and route planning.

The main components of the A\* algorithm are as follows:

**1. Heuristic Function (h(n)):** To determine the cost of moving from the current node to the objective node, A\* makes use of a heuristic function. The notation for this heuristic function is (h(n)). The heuristic must never overestimate the actual cost of achieving the objective in order for it to be considered accepted. The A\* algorithm gets more efficient the better the heuristic.

**2. Cost Function (g(n)):** A\* records the real cost from the start node to each node. The notation for this cost function is (g(n)).

**3. Evaluation Function (f(n)):** The A\* algorithm creates an evaluation function, represented as (f(n) = g(n) + h(n)), by combining the heuristic estimate ((h(n))) with the real cost ((g(n))). To identify the best course, (f(n)) must be minimized.

**4. Open and Closed Sets:** A\* keeps an open set and a closed set of nodes. Nodes in the closed set have already undergone evaluation, whereas nodes in the open set are candidates for exploration.

**5. Main Loop:** Using their (f(n)) values, the algorithm chooses nodes from the open set iteratively. It assesses nearby nodes, adds them to the open set, and modifies their costs and heuristics in the event that a shorter path is discovered. Until the objective node is achieved or the open set is empty, the procedure keeps going.

6. Path Reconstruction: Using the data saved throughout the search, A\* reconstructs, if the goal node is reached, the best route from the start node to the goal node.

The A\* algorithm is renowned for its optimality, which ensures that the best course at the lowest cost will be found. Its effectiveness is contingent upon the caliber of the heuristic function, though. An effective heuristic can greatly shrink the search space and enhance the efficiency of the program.

1. **Conclusion**

In overall, the heuristic search algorithm—best represented by the highly regarded A\* algorithm—is a fundamental tool for resolving complex issues in the field of maze navigation in artificial intelligence games. Our investigation into this area has highlighted the algorithm's importance as well as its adaptability and effectiveness in solving challenging problems.

The capacity to efficiently navigate mazes with the primary goal of locating the shortest path is the essential basis of the heuristic search algorithm. These kinds of algorithms are used in many domains where pathfinding and optimization are essential elements, not just labyrinth solution. In this work, we concentrated on applying the A\* algorithm in practice and made use of the Payamaze library's features to solve and visually portray mazes.

There is good reason for the A\* algorithm's widespread use in the field of heuristic search algorithms. One of its unique characteristics is its capacity to discern the best course of action while retaining the flexibility to retrace steps if needed. This focused approach demonstrates the algorithm's efficacy and efficiency, as does its ability to determine the shortest path between source and destination.

The focus of our investigation was not just the algorithm's capabilities but also its usefulness. The A\* algorithm's incorporation of backtracking adds a level of complexity and makes problem-solving more dynamic and adaptable. The algorithm is a valuable tool in maze-solving settings because of its capacity to calculate heuristic functions and estimate absolute pathways, both of which add to the accuracy of its results.

Furthermore, the A\* algorithm is a preferred option for both developers and academics due to its versatility in handling various labyrinth topologies and varying levels of complexity. Its importance extends beyond the boundaries of a particular application, impacting the fields of robotics, artificial intelligence, and optimization.

1. **References**

Certainly! Here are the references formatted in a more standard citation style:

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9. **Appendix**

import tkinter as tk

import time

import heapq

from tkinter import messagebox

# Define the grid size

NUM\_ROWS = 5

NUM\_COLS = 6

# Define the obstacle positions

obstacle\_positions = [(0, 1), (2, 1), (3, 1), (2, 3), (3, 4), (4, 4)]

# Define the start and goal positions

start\_position = (0, 0)

goal\_position = (4, 5)

# Define the heuristic function

def calculate\_heuristic(node):

x1, y1 = node

x2, y2 = goal\_position

return abs(x1 - x2) + abs(y1 - y2)

# Define the A\* search algorithm

def perform\_astar\_search(canvas, start\_node, goal\_node):

# Initialize the open and closed sets

open\_set = []

closed\_set = set()

# Initialize the start node

heapq.heappush(open\_set, (0, start\_node))

g\_score = {start\_node: 0}

f\_score = {start\_node: calculate\_heuristic(start\_node)}

# Start the search

while open\_set:

\_, current = heapq.heappop(open\_set)

# Log the current node

x, y = current

canvas.create\_rectangle(y \* cell\_width, x \* cell\_height, (y + 1) \* cell\_width, (x + 1) \* cell\_height, fill="cyan")

canvas.update()

time.sleep(0.2)

if current == goal\_node:

# Found the goal, reconstruct the path

path = []

while current in came\_from:

path.append(current)

current = came\_from[current]

path.append(start\_node)

path.reverse()

return path

closed\_set.add(current)

for neighbor in get\_neighbors(current):

if neighbor in closed\_set:

continue

tentative\_g\_score = g\_score[current] + 1

if neighbor not in [node[1] for node in open\_set] or tentative\_g\_score < g\_score[neighbor]:

came\_from[neighbor] = current

g\_score[neighbor] = tentative\_g\_score

f\_score[neighbor] = tentative\_g\_score + calculate\_heuristic(neighbor)

heapq.heappush(open\_set, (f\_score[neighbor], neighbor))

# No path found

return False

# Define the function to get the neighbors of a node

def get\_neighbors(node):

x, y = node

neighbors = []

if x > 0 and (x - 1, y) not in obstacle\_positions:

neighbors.append((x - 1, y))

if x < NUM\_ROWS - 1 and (x + 1, y) not in obstacle\_positions:

neighbors.append((x + 1, y))

if y > 0 and (x, y - 1) not in obstacle\_positions:

neighbors.append((x, y - 1))

if y < NUM\_COLS - 1 and (x, y + 1) not in obstacle\_positions:

neighbors.append((x, y + 1))

return neighbors

# Create the GUI application

root = tk.Tk()

root.title("Shortest Path")

canvas = tk.Canvas(root, width=600, height=500)

canvas.pack()

# Draw the grid

cell\_width = 100

cell\_height = 100

for row in range(NUM\_ROWS):

for col in range(NUM\_COLS):

x1 = col \* cell\_width

y1 = row \* cell\_height

x2 = x1 + cell\_width

y2 = y1 + cell\_height

color = "white"

if (row, col) in obstacle\_positions:

color = "red"

canvas.create\_rectangle(x1, y1, x2, y2, fill=color)

# Find the shortest path

came\_from = {}

path = []

# Function to find the shortest path

def find\_shortest\_path():

global path

path = perform\_astar\_search(canvas, start\_position, goal\_position)

if path is not None:

for node in path:

x, y = node

x1 = y \* cell\_width

y1 = x \* cell\_height

x2 = x1 + cell\_width

y2 = y1 + cell\_height

canvas.create\_rectangle(x1, y1, x2, y2, fill="green")

# Add a small square box for tracing

# canvas.create\_rectangle(x1 + cell\_width \* 0.3, y1 + cell\_height \* 0.3,

# x2 - cell\_width \* 0.3, y2 - cell\_height \* 0.3, fill="yellow")

time.sleep(0.2)

canvas.update()

# Trace the green path with a small square

for node in path:

x, y = node

x1 = y \* cell\_width + cell\_width \* 0.3

y1 = x \* cell\_height + cell\_height \* 0.3

x2 = x1 + cell\_width \* 0.4

y2 = y1 + cell\_height \* 0.4

canvas.create\_rectangle(x1, y1, x2, y2, fill="yellow")

canvas.update()

time.sleep(0.2)

# Create the "Find Shortest Path" button

find\_button = tk.Button(root, text="Find Shortest Path", command=find\_shortest\_path)

find\_button.pack()

root.mainloop()

# Show a message box with the result

if path:

messagebox.showinfo("Shortest path found!", path)

else:

messagebox.showinfo("Shortest Path", "No path found!")