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Project Report:

Maze Solver using A* Algorithm

Subject Name – Design and Analysis of Algorithms

Subject Code – 23CSH-301

Submitted To:	**Submitted By:**
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An implementation of the Randomized Depth-First Search (DFS) algorithm to generate a maze, and the A algorithm to find the shortest path.*

1. Introduction / Constraints

This project implements a **Maze Pathfinding Visualizer** that demonstrates the working of three popular shortest-path algorithms:

Breadth-First Search (BFS), **Dijkstra's Algorithm**, and *A (A-star) Algorithm**. The program provides an interactive visualization of how each algorithm explores and finds the shortest path between two points in a maze.

The visualizer is built using **Python** and the **Pygame library**, enabling real-time graphical rendering of the search process. The maze can be customized by the user, who can set the start and end nodes and place obstacles interactively.

Constraints:

- The maze is represented as a **2D grid** (default 40x40).
- Movement is restricted to **four orthogonal directions** (up, down, left, right).
- All paths are uniform-cost unless Dijkstra's weighted variation is implemented.
- The algorithms guarantee the discovery of the **shortest possible path** if one exists.

2. Input / Apparatus Used

Programming Language: Python 3.10+

Library Used: Pygame (for visualization)

IDE Used: Visual Studio Code / PyCharm

Input: Interactive mouse clicks for setting start, end, and wall positions.

Output: Real-time visual representation of the shortest path and exploration process.

User Controls:

- **Left Click:** Place start, end, or walls.
- **Right Click:** Erase a cell.
- **B Key:** Run Breadth-First Search.
- **D Key:** Run Dijkstra's Algorithm.
- **A Key:** Run A* Algorithm.
- **C Key:** Clear the grid.

3. Procedure:

Breadth-First Search (BFS)

- Works for **unweighted** grids.
- Explores nodes level by level using a queue.
- Guarantees the shortest path by exploring all equidistant nodes before moving further.

Dijkstra's Algorithm

- Suitable for **weighted** or unweighted graphs.
- Uses a **priority queue** to always expand the node with the smallest tentative distance.
- Guarantees the shortest path by systematically evaluating all lower-cost paths first.

A (A-star) Algorithm*

- Combines Dijkstra's optimal search with a **heuristic** for efficiency.
- Uses the cost function:
  $f(n)=g(n)+h(n)$
  $f(n) = g(n) + h(n)$
  $f(n)=g(n)+h(n)$ where:
    - $g(n)$
      $g(n)$
      $g(n)$: cost from start to current node
    - $h(n)$
      $h(n)$
      $h(n)$: heuristic estimate from current to goal
    - **Heuristic Used:** Manhattan Distance (|x1 - x2| + |y1 - y2|)

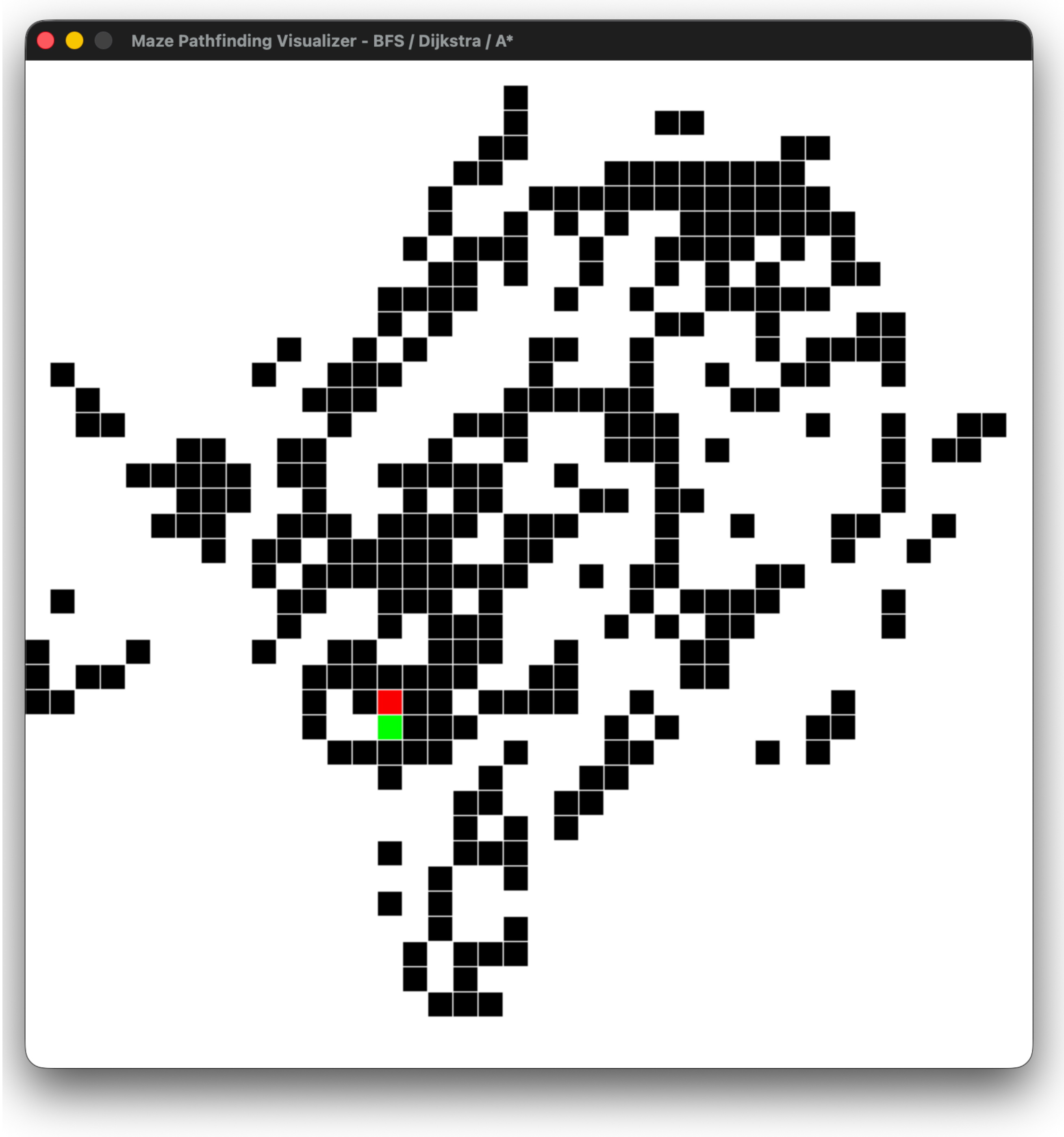
Visualization Logic:

1. Initialize grid and start/end positions.
2. Mark visited nodes in yellow, and final path in blue.
3. Allow user to switch algorithms and reset interactively.

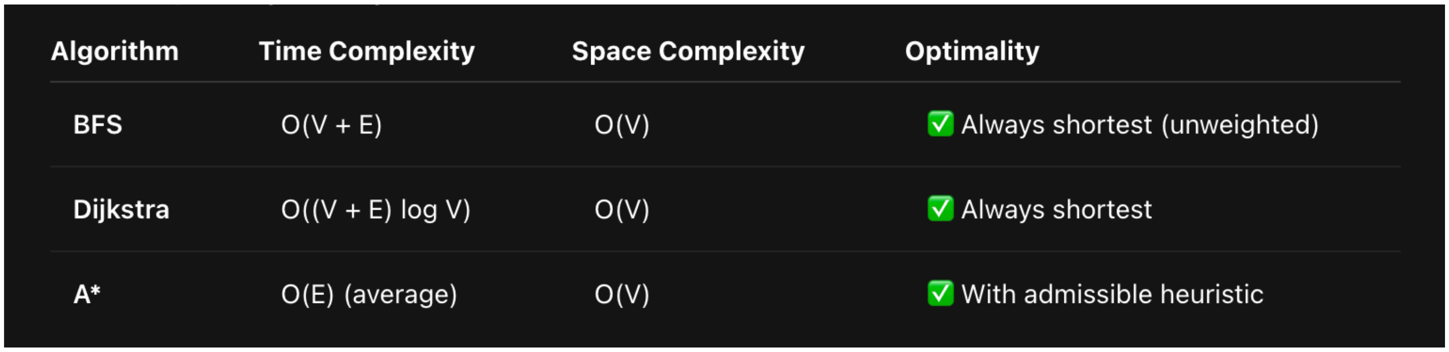
4. C++ Program:

```
import pygame, sys, heapq
from collections import deque

# Grid and color setup
WIDTH, HEIGHT = 800, 800
ROWS, COLS = 40, 40
CELL_SIZE = WIDTH // COLS

WHITE = (255, 255, 255)
BLACK = (0, 0, 0)
GREEN = (0, 255, 0)
RED = (255, 0, 0)
BLUE = (0, 0, 255)
YELLOW = (255, 255, 0)

# BFS Implementation
def bfs(start, end, grid):
q = deque([start])
visited = {start: None}
dirs = [(1,0),(-1,0),(0,1),(0,-1)]
while q:
x, y = q.popleft()
if (x, y) == end: break
for dx, dy in dirs:
nx, ny = x+dx, y+dy
if 0 <= nx < ROWS and 0 <= ny < COLS and grid[nx][ny] == 0 and (nx, ny) not in visited:
visited[(nx, ny)] = (x, y)
q.append((nx, ny))
return visited
```

5. Sample Output:



4. Complexity Analysis:



Algorithm	Time Complexity	Space Complexity	Optimality
BFS	O(V + E)	O(V)	✅ Always shortest (unweighted)
Dijkstra	O((V + E) log V)	O(V)	✅ Always shortest
A*	O(E) (average)	O(V)	✅ With admissible heuristic

For a 40x40 grid (V=1600):

- BFS explores all reachable cells.
- Dijkstra's scales with edge expansion but remains efficient.
- A* is typically **40–60% faster** due to heuristic guidance.

5. Result

- The program successfully visualizes BFS, Dijkstra's, and A* pathfinding algorithms.
- The interactive GUI allows the user to design custom mazes and instantly see how each algorithm explores.
- All algorithms correctly identify the shortest path when it exists.
- A* consistently performs faster while producing identical results to Dijkstra's in unweighted mazes.

6. Conclusion

The project demonstrates an integrated understanding of **graph traversal**, **heuristic search**, and **algorithm visualization**.

BFS, Dijkstra's, and A* were implemented and compared within the same grid-based environment.

The use of **Pygame** provided an engaging visualization of the algorithms' internal workings.

A* emerged as the most efficient method for finding the shortest path while maintaining optimality through its Manhattan Distance heuristic.

Future improvements can include weighted grids, diagonal movement, and maze generation algorithms such as **Recursive Backtracking (DFS)** or **Prim's Algorithm**.