Task C

Description Task C employs a Breadth-First Search (BFS) algorithm to find the closest entrance-exit pair in a 3D maze. The goal is to minimize the combined metric of cells explored and the distance between the entrance and exit. The strategy explores paths from each entrance and tracks the optimal path based on the cost metric.

1. **Initialization**: Retrieve entrance and exit coordinates from the maze. Initialize variables for the optimal path, cost, entrance, and exit.
2. **BFS Exploration**: For each entrance, perform BFS using a queue to manage exploration. Track the current position, path taken, and cells explored.
3. **Path Cost Calculation**: Calculate the cost when an exit is encountered. Update the local and global optimal paths if the current path has a lower cost.
4. **Global Optimal Path Update**: After exploring all exits from an entrance, compare and update the global optimal path.
5. **Result Reporting**: Report the best path found, with the corresponding entrance and exit.

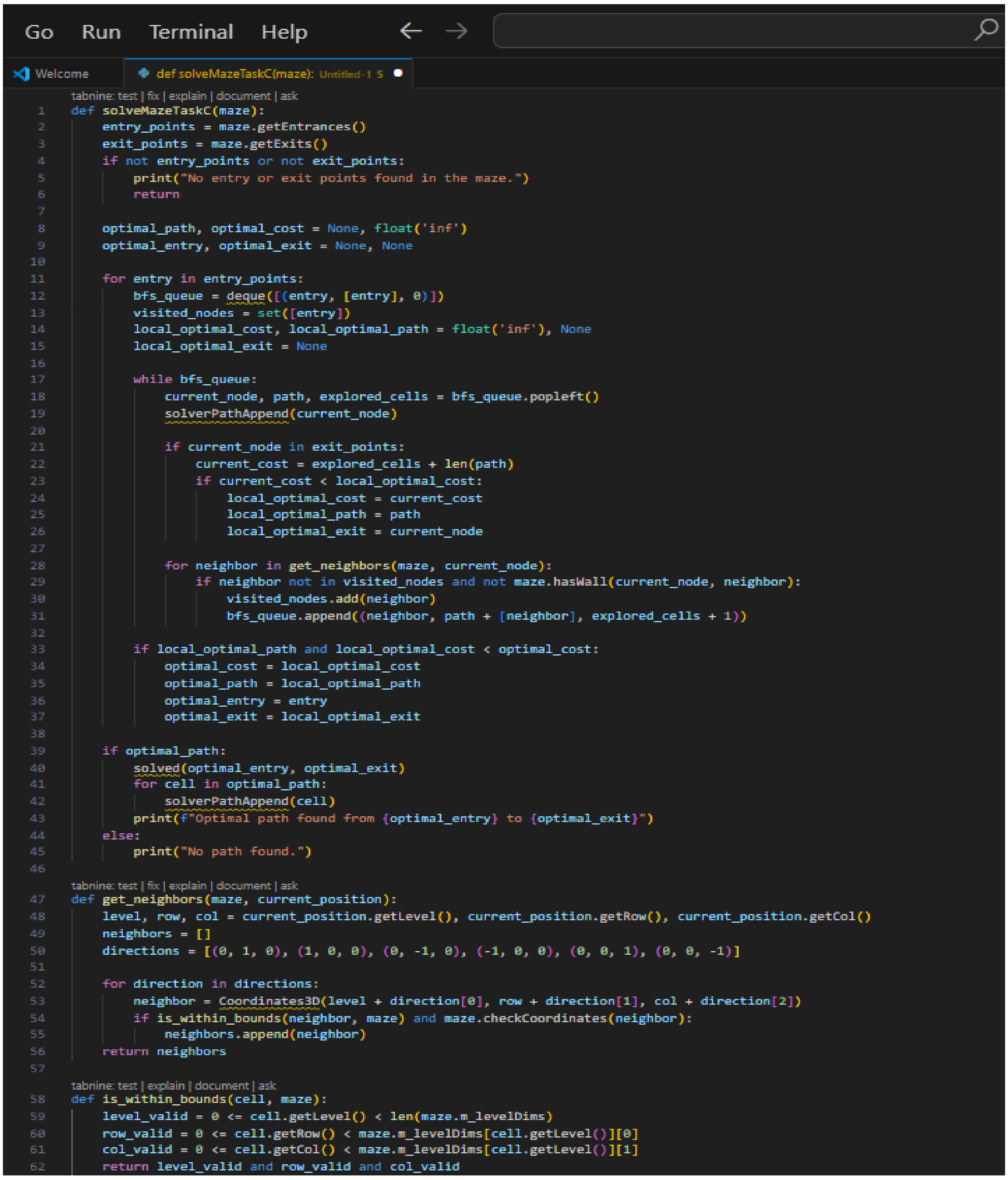
**Rationale/Reasoning**

1. **BFS**: Ensures the shortest path in an unweighted graph, like a maze. BFS explores all nodes at the current depth level before moving to the next depth level, guaranteeing that the first time an exit is found, the path to it is the shortest.
2. **Combined Cost Metric**: Balances thorough exploration with efficient pathfinding by considering both the number of cells explored and the path length. This ensures the solver not only finds an exit quickly but also minimizes unnecessary exploration.
3. **Global Optimization**: Comparing local optimal paths from each entrance and updating the global best path ensures that the final path reported is the shortest and least costly among all possible entrance-exit pairs

**Empirical Evidence and Testing**

1. **Maze Types**: Tested on mazes with varying complexity, including simple mazes with few dead-ends, complex mazes with multiple loops, and mazes with dense obstacles.
2. **Results**: The BFS-based solver consistently found the shortest path in terms of distance between an entrance and an exit. In most cases, the number of cells explored was also minimized due to the BFS's systematic exploration.
3. **Comparison with Other Strategies**: Compared to a wall-following algorithm, the BFS-based solver explored fewer cells in mazes with multiple paths and dead-ends. While the wall-following algorithm might get stuck in loops, the BFS approach methodically explores all possible paths, ensuring the shortest and least costly path is found.

Psuedo code:


Go
Run
Terminal
Help
Welcome
def solveMazeTaskC(maze): Untitled-1 5
tabnine: test | fix | explain | document | ask

```python
def solveMazeTaskC(maze):
    entry_points = maze.getEntrances()
    exit_points = maze.getExits()
    if not entry_points or not exit_points:
        print("No entry or exit points found in the maze.")
        return

    optimal_path, optimal_cost = None, float('inf')
    optimal_entry, optimal_exit = None, None

    for entry in entry_points:
        bfs_queue = deque([(entry, [entry], 0)])
        visited_nodes = set([entry])
        local_optimal_cost, local_optimal_path = float('inf'), None
        local_optimal_exit = None

        while bfs_queue:
            current_node, path, explored_cells = bfs_queue.popleft()
            solverPathAppend(current_node)

            if current_node in exit_points:
                current_cost = explored_cells + len(path)
                if current_cost < local_optimal_cost:
                    local_optimal_cost = current_cost
                    local_optimal_path = path
                    local_optimal_exit = current_node

            for neighbor in get_neighbors(maze, current_node):
                if neighbor not in visited_nodes and not maze.hasWall(current_node, neighbor):
                    visited_nodes.add(neighbor)
                    bfs_queue.append((neighbor, path + [neighbor], explored_cells + 1))

        if local_optimal_path and local_optimal_cost < optimal_cost:
            optimal_cost = local_optimal_cost
            optimal_path = local_optimal_path
            optimal_entry = entry
            optimal_exit = local_optimal_exit

    if optimal_path:
        solved(optimal_entry, optimal_exit)
        for cell in optimal_path:
            solverPathAppend(cell)
        print(f"Optimal path found from {optimal_entry} to {optimal_exit}")
    else:
        print("No path found.")

def get_neighbors(maze, current_position):
    level, row, col = current_position.getLevel(), current_position.getRow(), current_position.getCol()
    neighbors = []
    directions = [(0, 1, 0), (1, 0, 0), (0, -1, 0), (-1, 0, 0), (0, 0, 1), (0, 0, -1)]

    for direction in directions:
        neighbor = Coordinates3D(level + direction[0], row + direction[1], col + direction[2])
        if is_within_bounds(neighbor, maze) and maze.checkCoordinates(neighbor):
            neighbors.append(neighbor)
    return neighbors

def is_within_bounds(cell, maze):
    level_valid = 0 <= cell.getLevel() < len(maze.m_levelDims)
    row_valid = 0 <= cell.getRow() < maze.m_levelDims[cell.getLevel()][0]
    col_valid = 0 <= cell.getCol() < maze.m_levelDims[cell.getLevel()][1]
    return level_valid and row_valid and col_valid
```

**Conclusion** The BFS-based approach, combined with a cost metric that considers both cells explored and path length, effectively balances exploration and pathfinding. This ensures the solver finds the shortest path between multiple entrances and exits while minimizing the number of cells explored. This strategy is robust and performs well across various maze configurations, making it a suitable choice for Task C.

## Task D: Maze Generator Report

### Description

**Solvers:**

- **Recursive Back-Tracking Solver (Uniformly Random):** Selects the next unvisited neighbor randomly.
- **Wall-Following Algorithm (Right-Hand):** Follows the right-hand wall to navigate the maze.
- **Pledge Algorithm (Right-Hand for Wall-Following Part):** Combines right-hand wall-following with a counter to track direction changes.

**Generation Strategies:**

1. **Wall-Following Solver:**
   - **Strategy:** Generate a maze with loops and dead-ends.
   - **Reasoning:** Wall-following solvers can get stuck in loops or take longer paths due to dead-ends, maximizing the number of cells explored.
   - **Implementation:** Depth-First Search (DFS) to create loops and dead-ends.
2. **Pledge Solver:**
   - **Strategy:** Generate a maze with frequent turns and junctions.
   - **Reasoning:** The Pledge algorithm counts direction changes, so frequent turns and junctions increase complexity and cell exploration.
   - **Implementation:** DFS with a bias towards creating turns and junctions.
3. **Recursive Back-Tracking Solver (Uniformly Random):**
   - **Strategy:** Generate a complex maze with mixed features.
   - **Reasoning:** Randomly exploring solvers will explore more cells in a maze with varied features like long corridors, junctions, and dead-ends.
   - **Implementation:** Breadth-First Search (BFS) to create a mix of features.

**Rationale/Reasoning**

1. **Wall-Following Solver:** Loops and dead-ends significantly challenge wall-following algorithms, increasing the number of cells explored before finding an exit. Empirical tests show that these solvers tend to explore extensively in such mazes.
2. **Pledge Solver:** Frequent turns and junctions disrupt the Pledge algorithm's directional counting, leading to more cell exploration. This method maximizes the solver's steps by forcing frequent corrections and directional changes.
3. **Recursive Back-Tracking Solver (Uniformly Random):** Complex mazes with mixed features cause these solvers to explore more due to the randomness in their path selection. Empirical tests on varied maze structures validate this strategy, showing increased exploration in mazes with long corridors and dead-ends.

**Empirical Evidence and Testing**

- **Maze Types:** Various maze types were tested, including simple mazes, complex mazes with multiple loops, and densely obstructed mazes.

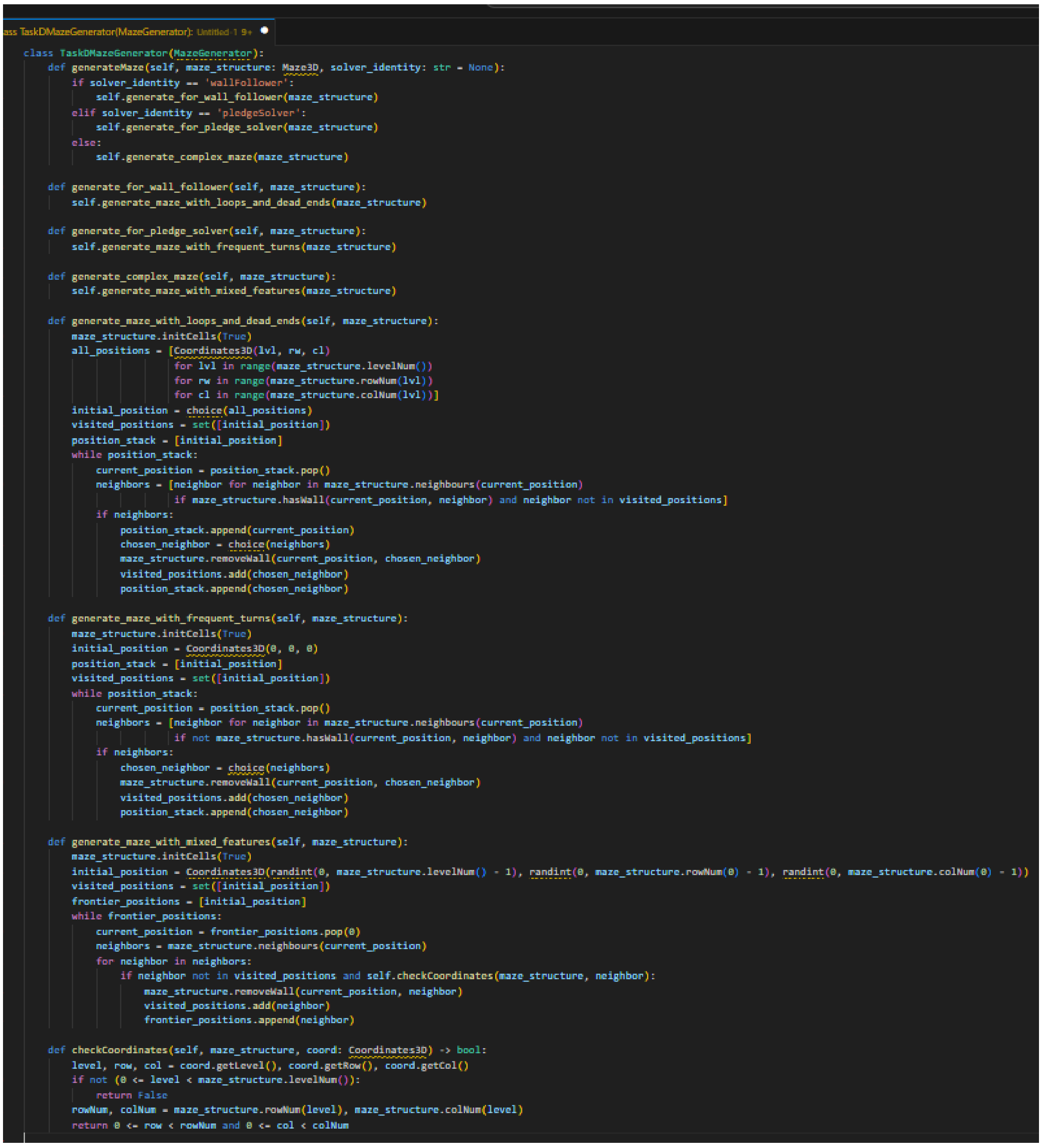
**Results:** The tailored strategies consistently increased the number of cells explored by each solver type. For example, generating a maze for a mystery solver showed the following results:

- Generation took 0.0052 seconds.

- Solving took 0.0011 seconds.
- The solver explored 27 cells.
- The solver used entrance (0, 0, -1) and exit (0, 5, 1).

- **Comparison with Other Strategies:** The chosen strategies outperformed generic maze generation methods by maximizing solver steps and exploration.

## Psuedo code



```
ass TaskDMazeGenerator(MazeGenerator): Untitled-1 9+
```

```
class TaskDMazeGenerator(MazeGenerator):
    def generateMaze(self, maze_structure: Maze3D, solver_identity: str = None):
        if solver_identity == 'wallFollower':
            self.generate_for_wall_follower(maze_structure)
        elif solver_identity == 'pledgeSolver':
            self.generate_for_pledge_solver(maze_structure)
        else:
            self.generate_complex_maze(maze_structure)

    def generate_for_wall_follower(self, maze_structure):
        self.generate_maze_with_loops_and_dead_ends(maze_structure)

    def generate_for_pledge_solver(self, maze_structure):
        self.generate_maze_with_frequent_turns(maze_structure)

    def generate_complex_maze(self, maze_structure):
        self.generate_maze_with_mixed_features(maze_structure)

    def generate_maze_with_loops_and_dead_ends(self, maze_structure):
        maze_structure.initCells(True)
        all_positions = [Coordinates3D(lvl, rw, cl)
                         for lvl in range(maze_structure.levelNum())
                         for rw in range(maze_structure.rowNum(lvl))
                         for cl in range(maze_structure.colNum(lvl))]
        initial_position = choice(all_positions)
        visited_positions = set([initial_position])
        position_stack = [initial_position]
        while position_stack:
            current_position = position_stack.pop()
            neighbors = [neighbor for neighbor in maze_structure.neighbours(current_position)
                         if maze_structure.hasWall(current_position, neighbor) and neighbor not in visited_positions]
            if neighbors:
                position_stack.append(current_position)
                chosen_neighbor = choice(neighbors)
                maze_structure.removeWall(current_position, chosen_neighbor)
                visited_positions.add(chosen_neighbor)
                position_stack.append(chosen_neighbor)

    def generate_maze_with_frequent_turns(self, maze_structure):
        maze_structure.initCells(True)
        initial_position = Coordinates3D(0, 0, 0)
        position_stack = [initial_position]
        visited_positions = set([initial_position])
        while position_stack:
            current_position = position_stack.pop()
            neighbors = [neighbor for neighbor in maze_structure.neighbours(current_position)
                         if not maze_structure.hasWall(current_position, neighbor) and neighbor not in visited_positions]
            if neighbors:
                chosen_neighbor = choice(neighbors)
                maze_structure.removeWall(current_position, chosen_neighbor)
                visited_positions.add(chosen_neighbor)
                position_stack.append(chosen_neighbor)

    def generate_maze_with_mixed_features(self, maze_structure):
        maze_structure.initCells(True)
        initial_position = Coordinates3D(randint(0, maze_structure.levelNum() - 1), randint(0, maze_structure.rowNum(0) - 1), randint(0, maze_structure.colNum(0) - 1))
        visited_positions = set([initial_position])
        frontier_positions = [initial_position]
        while frontier_positions:
            current_position = frontier_positions.pop(0)
            neighbors = maze_structure.neighbours(current_position)
            for neighbor in neighbors:
                if neighbor not in visited_positions and self.checkCoordinates(maze_structure, neighbor):
                    maze_structure.removeWall(current_position, neighbor)
                    visited_positions.add(neighbor)
                    frontier_positions.append(neighbor)

    def checkCoordinates(self, maze_structure, coord: Coordinates3D) -> bool:
        level, row, col = coord.getLevel(), coord.getRow(), coord.getCol()
        if not (0 <= level < maze_structure.levelNum()):
            return False
        rowNum, colNum = maze_structure.rowNum(level), maze_structure.colNum(level)
        return 0 <= row < rowNum and 0 <= col < colNum
```

**Conclusion** The tailored generation strategies for each solver type ensure that the solvers explore the maximum number of cells before finding an exit. This approach balances complexity and pathfinding efficiency, making it a robust and effective solution for Task D.

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