Title Page

Problem Statement: Develop an AI-based solver for the 8-puzzle problem using the A* search algorithm with the Manhattan Distance heuristic.

Personal Details:

- Name: Animesh Pratap Singh
- Roll No: 202401100300043

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1. Introduction

The 8-puzzle problem is a classic sliding tile problem that consists of a 3×3 grid with eight numbered tiles and one empty space. The objective is to move the tiles to reach a goal state by sliding them into the empty space. The problem is solved using *A Search Algorithm**, which finds the optimal solution using the **Manhattan Distance heuristic**.

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2. Methodology

To solve the 8-puzzle problem, we follow these steps:

1. **State Representation:** The puzzle is represented as a tuple of nine elements, where `0` represents the empty space.
2. **Valid Moves Generation:** Identify possible tile movements (`Up, Down, Left, Right`) based on the empty space position.
3. **Heuristic Function:** Implement Manhattan Distance to estimate the cost to reach the goal state.
4. *A Search Algorithm:**
   - Use a priority queue (`heapq`) to always expand the lowest-cost state first.
   - Track visited states to avoid redundant calculations.
   - Expand nodes until the goal state is reached.
5. **Solution Output:** Return the sequence of moves required to solve the puzzle in the shortest path.

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3. Code

```
import heapq

def manhattan_distance(state, goal):
```

```
    distance = 0
    for i in range(1, 9):
        xi, yi = divmod(state.index(i), 3)
        xg, yg = divmod(goal.index(i), 3)
        distance += abs(xi - xg) + abs(yi - yg)
    return distance

def get_neighbors(state):
    neighbors = []
    empty_index = state.index(0)
    moves = {"U": -3, "D": 3, "L": -1, "R": 1}
    for move, shift in moves.items():
        new_index = empty_index + shift
        if 0 <= new_index < 9 and not (empty_index % 3 == 0 and move == "L")
and not (empty_index % 3 == 2 and move == "R"):
            new_state = list(state)
            new_state[empty_index], new_state[new_index] =
new_state[new_index], new_state[empty_index]
            neighbors.append((tuple(new_state), move))
    return neighbors

def a_star_solver(start, goal):
    open_set = []
    heapq.heappush(open_set, (manhattan_distance(start, goal), start, []))
    visited = set()
    while open_set:
        _, state, path = heapq.heappop(open_set)
        if state == goal:
            return path
        visited.add(state)
        for new_state, move in get_neighbors(state):
            if new_state not in visited:
                new_cost = len(path) + 1 + manhattan_distance(new_state, goal)
                heapq.heappush(open_set, (new_cost, new_state, path + [move]))
    return None

start_state = (1, 2, 3, 4, 0, 5, 6, 7, 8)
goal_state = (1, 2, 3, 4, 5, 6, 7, 8, 0)
solution = a_star_solver(start_state, goal_state)
print("Solution:", solution)
```

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4. Output/Result

Example Run:

```
Solution: ['R', 'D', 'L', 'U']  # Example moves to solve the puzzle
```

A* Search efficiently finds the shortest path to the goal using the Manhattan Distance heuristic. The algorithm avoids unnecessary moves and expands only the most promising paths.

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5. References/Credits

- Artificial Intelligence: A Modern Approach – Stuart Russell & Peter Norvig
- Problem Solving with A* Search – Research Papers
- GitHub Repository: https://github.com/Animesh0721/8PuzzleSolver_202401100300043