4. 8 puzzle Manhattan distance heuristic

```
def manhattan_distance(state, goal):
    distance = 0
    for i in range(3):
        for j in range(3):
            tile = state[i][j]
            if tile != 0:  # Ignore the blank space (0)
                # Find the position of the tile in the goal state
                for r in range(3):
                    for c in range(3):
                        if goal[r][c] == tile:
                            target_row, target_col = r, c
                            break
                # Add the Manhattan distance (absolute difference in rows and columns)
                distance += abs(target_row - i) + abs(target_col - j)
    return distance



def findmin(open_list, goal):
    minv = float('inf')
    best_state = None
    for state in open_list:
        h = manhattan_distance(state['state'], goal)  # Use Manhattan distance here
        f = state['g'] + h
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        if f < minv:
            minv = f
            best_state = state
    open_list.remove(best_state)
    return best_state


def operation(state):
    next_states = []
    blank_pos = find_blank_position(state['state'])
    for move in ['up', 'down', 'left', 'right']:
        new_state = apply_move(state['state'], blank_pos, move)
        if new_state:
            next_states.append({
                'state': new_state,
                'parent': state,
                'move': move,
                'g': state['g'] + 1
            })
    return next_states


def find_blank_position(state):
    for i in range(3):
        for j in range(3):
            if state[i][j] == 0:
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```
            return i, j
    return None


def apply_move(state, blank_pos, move):
    i, j = blank_pos
    new_state = [row[:] for row in state]
    if move == 'up' and i > 0:
        new_state[i][j], new_state[i - 1][j] = new_state[i - 1][j], new_state[i][j]
    elif move == 'down' and i < 2:
        new_state[i][j], new_state[i + 1][j] = new_state[i + 1][j], new_state[i][j]
    elif move == 'left' and j > 0:
        new_state[i][j], new_state[i][j - 1] = new_state[i][j - 1], new_state[i][j]
    elif move == 'right' and j < 2:
        new_state[i][j], new_state[i][j + 1] = new_state[i][j + 1], new_state[i][j]
    else:
        return None
    return new_state


def print_state(state):
    for row in state:
        print(' '.join(map(str, row)))


# Initial state and goal state
initial_state = [[2,8,3], [1,6,4], [7,0,5]]
```

```
goal_state = [[1,2,3], [8,0,4], [7,6,5]]


# Open list and visited states
open_list = [{'state': initial_state, 'parent': None, 'move': None, 'g': 0}]
visited_states = []


while open_list:
    best_state = findmin(open_list, goal_state)


    print("Current state:")
    print_state(best_state['state'])


    h = manhattan_distance(best_state['state'], goal_state)  # Using Manhattan distance here
    f = best_state['g'] + h
    print(f"g(n): {best_state['g']}, h(n): {h}, f(n): {f}")


    if best_state['move'] is not None:
        print(f"Move: {best_state['move']}")
    print()
    if h == 0:  # Goal is reached if h == 0
        goal_state_reached = best_state
        break


    visited_states.append(best_state['state'])
```

```
    next_states = operation(best_state)

    for state in next_states:
        if state['state'] not in visited_states:
            open_list.append(state)

# Reconstruct the path of moves
moves = []
while goal_state_reached['move'] is not None:
    moves.append(goal_state_reached['move'])
    goal_state_reached = goal_state_reached['parent']
moves.reverse()

print("\nMoves to reach the goal state:", moves)
print("\nGoal state reached:")
print_state(goal_state)
```

```
Current state:
2 8 3
1 6 4
7 0 5
g(n): 0, h(n): 5, f(n): 5

Current state:
2 8 3
1 0 4
7 6 5
g(n): 1, h(n): 4, f(n): 5
Move: up

Current state:
2 0 3
1 8 4
7 6 5
g(n): 2, h(n): 3, f(n): 5
Move: up

Current state:
0 2 3
1 8 4
7 6 5
g(n): 3, h(n): 2, f(n): 5
Move: left

Current state:
1 2 3
0 8 4
7 6 5
g(n): 4, h(n): 1, f(n): 5
Move: down
```

```
Current state:
1 2 3
8 0 4
7 6 5
g(n): 5, h(n): 0, f(n): 5
Move: right


Moves to reach the goal state: ['up', 'up', 'left', 'down', 'right']

Goal state reached:
1 2 3
8 0 4
7 6 5
```