CS5960-Octavio-delSer-100873054-lab2

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1 CS5960-Octavio-delSer-100873054-lab2.ipynb

Quick Summary:

========== EXPANSION COUNTS ==========

DFS Adjacent cells No Heuristic: 27

DFS Adjacent and Diagonal cells No Heuristics: 29

DFS Adjancent cells with L2 Heuristic: 8

DFS Adjacent and Diagonal cells with L2 Heuristic: 6

BFS Adjacent cells: 18

BFS Adjacent and Diagonal cells: 15

Notes:

Code is written in python, in a Jupyter notebook for presentability.

I changed the print function so Latex would support generation of pdf

I changed the some code to support easier manipulation ov variables.

1.0.1 Imports

[1]:
```
import math
import os
import queue
import time
from copy import deepcopy
```

1.0.2 Statics:

[2]:
```
EXPANSION_COUNTER=0
AGENT_SYMBOL = 'A'
GOAL_SYMBOL = 'G'
WALL_SYMBOL = '#'
VISITED_CELL_SYMBOL = 'V'
```

```
EXPANDED_NOT_VISITED_CELL_SYMBOL = 'E'
EMPTY_SYMBOL = ' '
print_rate_per_sec = 0.01
agent_coord = [1, 3]
goal_coord = [4, 7]
initial_map = [
    ['#', '#', '#', '#', '#', '#', '#', '#', '#'],
    ['#', ' ', ' ', 'A', ' ', ' ', ' ', ' ', '#'],
    ['#', ' ', '#', ' ', '#', ' ', '#', '#', '#'],
    ['#', ' ', '#', '#', '#', ' ', '#', ' ', '#'],
    ['#', ' ', '#', ' ', '#', ' ', ' ', 'G', '#'],
    ['#', ' ', ' ', ' ', '#', ' ', '#', '#', '#'],
    ['#', ' ', '#', ' ', '#', ' ', ' ', ' ', '#'],
    ['#', ' ', '#', ' ', '#', '#', '#', ' ', '#'],
    ['#', '#', '#', '#', '#', '#', '#', '#', '#']]
```

1.0.3 Defining cells that can be explored:

As a sum of pos + cell L= left R= Right U= up D= down

[3]:
```
L, LU, U, RU, R, RD, D, LD = [-1, 0], [-1, -1], [0, -1], [1, -1], [1, 0], [1,␣
↪1], [0, 1], [-1, 1]
adj = (L, U, R, D)
diag = (LU, RU, RD, LD)
adj_diag = adj + diag
```

1.0.4 Map Printing

[4]:
```
def print_map():
    print("------EXPANSION: ",EXPANSION_COUNTER, "-------------")
    os.system('cls' if os.name == 'nt' else 'clear')
    for row in current_map:
        print(' '.join(row))
    print("----------------------------------------")
    time.sleep(print_rate_per_sec)
```

1.0.5 Valid cell definition:

I Adjusted this to not include expanded cells as that sould be invalid, we already have them so ignore them.

[5]:
```
def valid_cell(row, col):
    return row >= 0 and row < len(current_map) and col >= 0 and col <␣
↪len(current_map[0]) and current_map[row][
```

```
        col] is not WALL_SYMBOL and current_map[row][col] is not␣
↪VISITED_CELL_SYMBOL and current_map[row][col] is not␣
↪EXPANDED_NOT_VISITED_CELL_SYMBOL
```

1.0.6 Sum of two vectors

(assuming dimention 2)

[6]:
```
def s(p1, p2):
    return [p1[0] + p2[0], p1[1] + p2[1]]
```

1.0.7 Generating adjacent valid cells to point

takes an array of cells to be summed to point this way we can feely define what adjacent means.

[7]:
```
def generate_adjacent_cells(point, cells=adj):
    return list(s(cell, point) for cell in cells if valid_cell(*s(cell, point)))
```

1.0.8 L2 norm for heuristic function...

[8]:
```
def l2norm(x1, y1, x2, y2):
    return math.sqrt((x1 - x2) ** 2 + (y1 - y2) ** 2)
```

1.0.9 Ordering a set of points by a given heuristic and a goal.

for example, closest point to goal using l2norm defined above, this can be expanded for any heuristic and dimension. again apologies for the difficult to read code as I did not use numpy.

[9]:
```
def order_by_heuristic(points, goal, func=l2norm):
    """
    returns the points sorted by the heuristic function and goal
    the order of points that best match the function.
    """
    scores = [func(*point, *goal) for point in points]
    sorted_indices = sorted(range(len(scores)), key=lambda k: scores[k])
    return list(map(lambda k: points[k], sorted_indices))
```

1.1 BFS Implementation

takes adjacent cells that we want to explore given a point. Code is pretty self explanatory with provided names, hence I left it without comments as it would only make it more unreadable.

[10]:
```
def BFS(point, adjacent_cells=adj):
    global EXPANSION_COUNTER
    q = queue.Queue()
    q.put(point)

    # Run untill empty queue
    while not q.empty():
        current = q.get()
        current_map[current[0]][current[1]] = AGENT_SYMBOL
        if goal_coord == current:
            print_map()
            print("GOAL FOUND")
            return True
        #Expand current
        expand = generate_adjacent_cells(current, cells=adjacent_cells)
        #Add all expanded cells to queue Could add a heuristic, but would not␣
↪make
        # Sence unless branching factor is insanely large and depth 1 :D
        list = [q.put(cell) for cell in expand]
        #Check if there are any valid cells in expansion attempt to increment␣
↪the counter.
        if len(expand)>0:
            EXPANSION_COUNTER+=1
        # Mark cells as Expande
        for cell in expand:
            current_map[cell[0]][cell[1]] = EXPANDED_NOT_VISITED_CELL_SYMBOL
        print_map()
        #Mark current cell as visited.
        current_map[current[0]][current[1]] = VISITED_CELL_SYMBOL
    return False
```

1.2 DFS Implementation

I slightly modified the implementation of DFS so that it is clearer. DFS unlike BFS contains a heuristic for which points to explore next as well as the adjacent cells to explore at any given point.

[11]:
```
def DFS(agent_coord, heuristic=None, adjacent_cells=adj):
    """+=
    heuristic: function by which to sort points (order of exploration)
    y,x: point where to start
    cells: which cells to expand list of vectors to som onto point (y,x)+cell␣
↪-> (y',x')
    """
    # increment counter.
    global EXPANSION_COUNTER
    EXPANSION_COUNTER+=1
```

```
    # set agent coord to agent coord
    current_map[agent_coord[0]][agent_coord[1]] = AGENT_SYMBOL
    # set agent coord cell to visited

    # Check if the current state is goal state
    if agent_coord == goal_coord:
        print_map()
        print("GOAL FOUND")
        return True
    # get adjacent valid cells
    cells = generate_adjacent_cells(agent_coord, cells=adjacent_cells)
    if len(cells) <= 0:
        print_map()
        current_map[agent_coord[0]][agent_coord[1]] = VISITED_CELL_SYMBOL
        return False

    # check if heuristic is mentioned
    if heuristic is not None:
        cells = order_by_heuristic(cells, goal_coord, heuristic)

    # Mark cells as expanded
    for cell in cells:
        current_map[cell[0]][cell[1]] = EXPANDED_NOT_VISITED_CELL_SYMBOL
    print_map()
    current_map[agent_coord[0]][agent_coord[1]] = VISITED_CELL_SYMBOL

    # call dfs on all cells to visit in order.
    for cell in cells:
        if DFS(cell, heuristic=heuristic, adjacent_cells=adjacent_cells):
            return True
    return False
```

1.3 RUN DFS - Adj only, No heuristic

[12]:
```
EXPANSION_COUNTER=0
current_map = deepcopy(initial_map)
print_map()
DFS(agent_coord)
print("EXPANSIONS: ",EXPANSION_COUNTER)
```

```
------EXPANSION:  0 -------------
# # # # # # # # #
#     A         #
#   #   #   # # #
#   # # #   #   #
#   #   #     G #
```

```
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  1 -------------
# # # # # # # # #
#   E A E       #
#   # E #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  2 -------------
# # # # # # # # #
# E A V E       #
#   # E #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  3 -------------
# # # # # # # # #
# A V V E       #
# E # E #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  4 -------------
# # # # # # # # #
# V V V E       #
# A # E #   # # #
# E # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
```

```
--------------------------------------
------EXPANSION:  5 -------------
# # # # # # # # #
# V V V E       #
# V # E #   # # #
# A # # #   #   #
# E #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  6 -------------
# # # # # # # # #
# V V V E       #
# V # E #   # # #
# V # # #   #   #
# A #   #     G #
# E     #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  7 -------------
# # # # # # # # #
# V V V E       #
# V # E #   # # #
# V # # #   #   #
# V #   #     G #
# A E   #   # # #
# E #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  8 -------------
# # # # # # # # #
# V V V E       #
# V # E #   # # #
# V # # #   #   #
# V #   #     G #
# V E   #   # # #
# A #   #       #
# E #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  9 -------------
# # # # # # # # #
# V V V E       #
```

```
# V # E #   # # #
# V # # #   #   #
# V #   #     G #
# V E   #   # # #
# V #   #       #
# A #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  10 -------------
# # # # # # # # #
# V V V E       #
# V # E #   # # #
# V # # #   #   #
# V #   #     G #
# V A E #   # # #
# V #   #       #
# V #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  11 -------------
# # # # # # # # #
# V V V E       #
# V # E #   # # #
# V # # #   #   #
# V # E #     G #
# V V A #   # # #
# V # E #       #
# V #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  12 -------------
# # # # # # # # #
# V V V E       #
# V # E #   # # #
# V # # #   #   #
# V # A #     G #
# V V V #   # # #
# V # E #       #
# V #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  13 -------------
# # # # # # # # #
# V V V E       #
# V # E #   # # #
# V # # #   #   #
# V # V #     G #
# V V V #   # # #
```

```
# V # A #       #
# V # E # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  14 -------------
# # # # # # # # #
# V V V E       #
# V # E #   # # #
# V # # #   #   #
# V # V #     G #
# V V V #   # # #
# V # V #       #
# V # A # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  15 -------------
# # # # # # # # #
# V V V E       #
# V # A #   # # #
# V # # #   #   #
# V # V #     G #
# V V V #   # # #
# V # V #       #
# V # V # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  16 -------------
# # # # # # # # #
# V V V A E     #
# V # V #   # # #
# V # # #   #   #
# V # V #     G #
# V V V #   # # #
# V # V #       #
# V # V # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  17 -------------
# # # # # # # # #
# V V V V A E   #
# V # V # E # # #
# V # # #   #   #
# V # V #     G #
# V V V #   # # #
# V # V #       #
# V # V # # #   #
# # # # # # # # #
---------------------------------------
```

```
------EXPANSION:  18 -------------
# # # # # # # # #
# V V V V V E   #
# V # V # A # # #
# V # # # E #   #
# V # V #     G #
# V V V #   # # #
# V # V #       #
# V # V # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  19 -------------
# # # # # # # # #
# V V V V V E   #
# V # V # V # # #
# V # # # A #   #
# V # V # E   G #
# V V V #   # # #
# V # V #       #
# V # V # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  20 -------------
# # # # # # # # #
# V V V V V E   #
# V # V # V # # #
# V # # # V #   #
# V # V # A E G #
# V V V # E # # #
# V # V #       #
# V # V # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  21 -------------
# # # # # # # # #
# V V V V V E   #
# V # V # V # # #
# V # # # V #   #
# V # V # V E G #
# V V V # A # # #
# V # V # E     #
# V # V # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  22 -------------
# # # # # # # # #
# V V V V V E   #
# V # V # V # # #
```

```
# V # # # V #   #
# V # V # V E G #
# V V V # V # # #
# V # V # A E   #
# V # V # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  23 -------------
# # # # # # # # #
# V V V V V E   #
# V # V # V # # #
# V # # # V #   #
# V # V # V E G #
# V V V # V # # #
# V # V # V A E #
# V # V # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  24 -------------
# # # # # # # # #
# V V V V V E   #
# V # V # V # # #
# V # # # V #   #
# V # V # V E G #
# V V V # V # # #
# V # V # V V A #
# V # V # # # E #
# # # # # # # # #
---------------------------------------
------EXPANSION:  25 -------------
# # # # # # # # #
# V V V V V E   #
# V # V # V # # #
# V # # # V #   #
# V # V # V E G #
# V V V # V # # #
# V # V # V V V #
# V # V # # # A #
# # # # # # # # #
---------------------------------------
------EXPANSION:  26 -------------
# # # # # # # # #
# V V V V V E   #
# V # V # V # # #
# V # # # V #   #
# V # V # V A E #
# V V V # V # # #
# V # V # V V V #
```

```
# V # V # # # V #
# # # # # # # # #
--------------------------------------
------EXPANSION:  27 -------------
# # # # # # # # #
# V V V V V E   #
# V # V # V # # #
# V # # # V #   #
# V # V # V V A #
# V V V # V # # #
# V # V # V V V #
# V # V # # # V #
# # # # # # # # #
--------------------------------------
GOAL FOUND
EXPANSIONS:  27
```

1.4 RUN DFS - Adj and Diag, No Heuristic

[13]:
```
EXPANSION_COUNTER=0

current_map = deepcopy(initial_map)
print_map()
DFS(agent_coord, adjacent_cells=adj_diag)
print("EXPANSIONS: ",EXPANSION_COUNTER)
```

```
------EXPANSION:  0 -------------
# # # # # # # # #
#     A         #
#   #   #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  1 -------------
# # # # # # # # #
#   E A E       #
#   # E #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
```

```
---------------------------------------
------EXPANSION:  2 -------------
# # # # # # # # #
# E A V E       #
# E # E #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  3 -------------
# # # # # # # # #
# A V V E       #
# E # E #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  4 -------------
# # # # # # # # #
# V V V E       #
# A # E #   # # #
# E # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  5 -------------
# # # # # # # # #
# V V V E       #
# V # E #   # # #
# A # # #   #   #
# E #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  6 -------------
# # # # # # # # #
# V V V E       #
```

```
# V # E #   # # #
# V # # #   #   #
# A #   #     G #
# E E   #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  7 -------------
# # # # # # # # #
# V V V E       #
# V # E #   # # #
# V # # #   #   #
# V #   #     G #
# A E   #   # # #
# E #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  8 -------------
# # # # # # # # #
# V V V E       #
# V # E #   # # #
# V # # #   #   #
# V #   #     G #
# V E   #   # # #
# A #   #       #
# E #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  9 -------------
# # # # # # # # #
# V V V E       #
# V # E #   # # #
# V # # #   #   #
# V #   #     G #
# V E   #   # # #
# V #   #       #
# A #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  10 -------------
# # # # # # # # #
# V V V E       #
# V # E #   # # #
# V # # #   #   #
# V # E #     G #
# V A E #   # # #
```

```
# V # E #       #
# V #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  11 -------------
# # # # # # # # #
# V V V E       #
# V # E #   # # #
# V # # #   #   #
# V # E #     G #
# V V A #   # # #
# V # E #       #
# V #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  12 -------------
# # # # # # # # #
# V V V E       #
# V # E #   # # #
# V # # #   #   #
# V # E #     G #
# V V V #   # # #
# V # A #       #
# V # E # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  13 -------------
# # # # # # # # #
# V V V E       #
# V # E #   # # #
# V # # #   #   #
# V # E #     G #
# V V V #   # # #
# V # V #       #
# V # A # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  14 -------------
# # # # # # # # #
# V V V E       #
# V # E #   # # #
# V # # #   #   #
# V # A #     G #
# V V V #   # # #
# V # V #       #
# V # V # # #   #
# # # # # # # # #
---------------------------------------
```

```
------EXPANSION:  15 -------------
# # # # # # # # #
# V V V E       #
# V # A #   # # #
# V # # #   #   #
# V # V #     G #
# V V V #   # # #
# V # V #       #
# V # V # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  16 -------------
# # # # # # # # #
# V V V A E     #
# V # V # E # # #
# V # # #   #   #
# V # V #     G #
# V V V #   # # #
# V # V #       #
# V # V # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  17 -------------
# # # # # # # # #
# V V V V A E   #
# V # V # E # # #
# V # # #   #   #
# V # V #     G #
# V V V #   # # #
# V # V #       #
# V # V # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  18 -------------
# # # # # # # # #
# V V V V V A E #
# V # V # E # # #
# V # # #   #   #
# V # V #     G #
# V V V #   # # #
# V # V #       #
# V # V # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  19 -------------
# # # # # # # # #
# V V V V V V A #
# V # V # E # # #
```

```
# V # # #   #   #
# V # V #     G #
# V V V #   # # #
# V # V #       #
# V # V # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  20 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # A # # #
# V # # # E #   #
# V # V #     G #
# V V V #   # # #
# V # V #       #
# V # V # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  21 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # A #   #
# V # V # E E G #
# V V V #   # # #
# V # V #       #
# V # V # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  22 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V #   #
# V # V # A E G #
# V V V # E # # #
# V # V #       #
# V # V # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  23 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V #   #
# V # V # V E G #
# V V V # A # # #
# V # V # E E   #
```

```
# V # V # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  24 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V #   #
# V # V # V E G #
# V V V # V # # #
# V # V # A E   #
# V # V # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  25 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V #   #
# V # V # V E G #
# V V V # V # # #
# V # V # V A E #
# V # V # # # E #
# # # # # # # # #
--------------------------------------
------EXPANSION:  26 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V #   #
# V # V # V E G #
# V V V # V # # #
# V # V # V V A #
# V # V # # # E #
# # # # # # # # #
--------------------------------------
------EXPANSION:  27 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V #   #
# V # V # V E G #
# V V V # V # # #
# V # V # V V V #
# V # V # # # A #
# # # # # # # # #
--------------------------------------
------EXPANSION:  28 -------------
```

```
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V # E #
# V # V # V A E #
# V V V # V # # #
# V # V # V V V #
# V # V # # # V #
# # # # # # # # #
---------------------------------------
------EXPANSION:  29 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V # E #
# V # V # V V A #
# V V V # V # # #
# V # V # V V V #
# V # V # # # V #
# # # # # # # # #
---------------------------------------
GOAL FOUND
EXPANSIONS:  29
```

1.5 RUN DFS - Adj only, With l2norm Heuristic

[14]:
```
EXPANSION_COUNTER=0

current_map = deepcopy(initial_map)
print_map()
DFS(agent_coord, heuristic=l2norm)
print("EXPANSIONS: ",EXPANSION_COUNTER)
```

```
------EXPANSION:  0 -------------
# # # # # # # # #
#     A         #
#   #   #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  1 -------------
# # # # # # # # #
#   E A E       #
```

```
#   # E #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  2 -------------
# # # # # # # # #
#   E V A E     #
#   # E #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  3 -------------
# # # # # # # # #
#   E V V A E   #
#   # E # E # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  4 -------------
# # # # # # # # #
#   E V V V E   #
#   # E # A # # #
#   # # # E #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  5 -------------
# # # # # # # # #
#   E V V V E   #
#   # E # V # # #
#   # # # A #   #
#   #   # E   G #
#       #   # # #
```

```
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  6 -------------
# # # # # # # # #
#   E V V V E   #
#   # E # V # # #
#   # # # V #   #
#   #   # A E G #
#       # E # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  7 -------------
# # # # # # # # #
#   E V V V E   #
#   # E # V # # #
#   # # # V #   #
#   #   # V A E #
#       # E # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  8 -------------
# # # # # # # # #
#   E V V V E   #
#   # E # V # # #
#   # # # V #   #
#   #   # V V A #
#       # E # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
GOAL FOUND
EXPANSIONS:  8
```

1.6 RUN DFS - Adj and Diag, With l2norm Heuristic

[15]:
```
EXPANSION_COUNTER=0

current_map = deepcopy(initial_map)
print_map()
```

```
DFS(agent_coord, adjacent_cells=adj_diag, heuristic=l2norm)
print("EXPANSIONS: ",EXPANSION_COUNTER)
```

```
------EXPANSION:  0 -------------
# # # # # # # # #
#     A         #
#   #   #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  1 -------------
# # # # # # # # #
#   E A E       #
#   # E #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  2 -------------
# # # # # # # # #
#   E V A E     #
#   # E # E # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  3 -------------
# # # # # # # # #
#   E V V E E   #
#   # E # A # # #
#   # # # E #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
```

```
------EXPANSION:  4 -------------
# # # # # # # # #
#   E V V E E   #
#   # E # V # # #
#   # # # A #   #
#   #   # E E G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  5 -------------
# # # # # # # # #
#   E V V E E   #
#   # E # V # # #
#   # # # V # E #
#   #   # E A E #
#       # E # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  6 -------------
# # # # # # # # #
#   E V V E E   #
#   # E # V # # #
#   # # # V # E #
#   #   # E V A #
#       # E # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
GOAL FOUND
EXPANSIONS:  6
```

1.7 RUN BFS - Adj Only

[16]:
```
EXPANSION_COUNTER=0

current_map = deepcopy(initial_map)
print_map()
BFS(agent_coord)
print("EXPANSIONS: ",EXPANSION_COUNTER)
```

```
------EXPANSION:  0 -------------
# # # # # # # # #
```

```
#     A         #
#   #   #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  1 -------------
# # # # # # # # #
#   E A E       #
#   # E #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  2 -------------
# # # # # # # # #
# E A V E       #
#   # E #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  2 -------------
# # # # # # # # #
# E V V E       #
#   # A #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  3 -------------
# # # # # # # # #
# E V V A E     #
#   # V #   # # #
#   # # #   #   #
#   #   #     G #
```

```
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  4 -------------
# # # # # # # # #
# A V V V E     #
# E # V #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  5 -------------
# # # # # # # # #
# V V V V A E   #
# E # V # E # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  6 -------------
# # # # # # # # #
# V V V V V E   #
# A # V # E # # #
# E # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  7 -------------
# # # # # # # # #
# V V V V V E   #
# V # V # A # # #
# E # # # E #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
```

```
--------------------------------------
------EXPANSION:  8 -------------
# # # # # # # # #
# V V V V V A E #
# V # V # V # # #
# E # # # E #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  9 -------------
# # # # # # # # #
# V V V V V V E #
# V # V # V # # #
# A # # # E #   #
# E #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  10 -------------
# # # # # # # # #
# V V V V V V E #
# V # V # V # # #
# V # # # A #   #
# E #   # E   G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  10 -------------
# # # # # # # # #
# V V V V V V A #
# V # V # V # # #
# V # # # V #   #
# E #   # E   G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  11 -------------
# # # # # # # # #
# V V V V V V V #
```

```
# V # V # V # # #
# V # # # V #   #
# A #   # E   G #
# E     #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  12 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V #   #
# V #   # A E G #
# E     # E # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  13 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V #   #
# V #   # V E G #
# A E   # E # # #
# E #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  14 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V #   #
# V #   # V E G #
# V E   # A # # #
# E #   # E     #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  15 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V #   #
# V #   # V A E #
# V E   # V # # #
```

```
# E #   # E     #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  16 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V #   #
# V #   # V V E #
# V E   # V # # #
# A #   # E     #
# E #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  17 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V #   #
# V #   # V V E #
# V A E # V # # #
# V #   # E     #
# E #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  18 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V #   #
# V #   # V V E #
# V V E # V # # #
# V #   # A E   #
# E #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  18 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V #   #
# V #   # V V A #
# V V E # V # # #
# V #   # V E   #
# E #   # # #   #
# # # # # # # # #
--------------------------------------
```

```
GOAL FOUND
EXPANSIONS:  18
```

1.8 RUN BFS - Adj And Diag

[17]:
```
EXPANSION_COUNTER=0
current_map = deepcopy(initial_map)
print_map()
BFS(agent_coord,adjacent_cells=adj_diag)
print("EXPANSIONS: ",EXPANSION_COUNTER)
```

```
------EXPANSION:  0 -------------
# # # # # # # # #
#     A         #
#   #   #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  1 -------------
# # # # # # # # #
#   E A E       #
#   # E #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  2 -------------
# # # # # # # # #
# E A V E       #
# E # E #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  2 -------------
# # # # # # # # #
# E V V E       #
```

```
# E # A #   # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  3 -------------
# # # # # # # # #
# E V V A E     #
# E # V # E # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  3 -------------
# # # # # # # # #
# A V V V E     #
# E # V # E # # #
#   # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  4 -------------
# # # # # # # # #
# V V V V E     #
# A # V # E # # #
# E # # #   #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  5 -------------
# # # # # # # # #
# V V V V A E   #
# V # V # E # # #
# E # # #   #   #
#   #   #     G #
#       #   # # #
```

```
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  6 -------------
# # # # # # # # #
# V V V V V E   #
# V # V # A # # #
# E # # # E #   #
#   #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  7 -------------
# # # # # # # # #
# V V V V V E   #
# V # V # V # # #
# A # # # E #   #
# E #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  8 -------------
# # # # # # # # #
# V V V V V A E #
# V # V # V # # #
# V # # # E #   #
# E #   #     G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
------EXPANSION:  9 -------------
# # # # # # # # #
# V V V V V V E #
# V # V # V # # #
# V # # # A #   #
# E #   # E E G #
#       #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
--------------------------------------
```

```
------EXPANSION:  10 -------------
# # # # # # # # #
# V V V V V V E #
# V # V # V # # #
# V # # # V #   #
# A #   # E E G #
# E E   #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  10 -------------
# # # # # # # # #
# V V V V V V A #
# V # V # V # # #
# V # # # V #   #
# V #   # E E G #
# E E   #   # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  11 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V #   #
# V #   # A E G #
# E E   # E # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  12 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V # E #
# V #   # V A E #
# E E   # E # # #
#   #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  13 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
```

```
# V # # # V # E #
# V #   # V V E #
# A E   # E # # #
# E #   #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  14 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V # E #
# V # E # V V E #
# V A E # E # # #
# E # E #       #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  15 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V # E #
# V # E # V V E #
# V V E # A # # #
# E # E # E E   #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
------EXPANSION:  15 -------------
# # # # # # # # #
# V V V V V V V #
# V # V # V # # #
# V # # # V # E #
# V # E # V V A #
# V V E # V # # #
# E # E # E E   #
#   #   # # #   #
# # # # # # # # #
---------------------------------------
GOAL FOUND
EXPANSIONS:  15
```