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Artificial Intelligence Lab

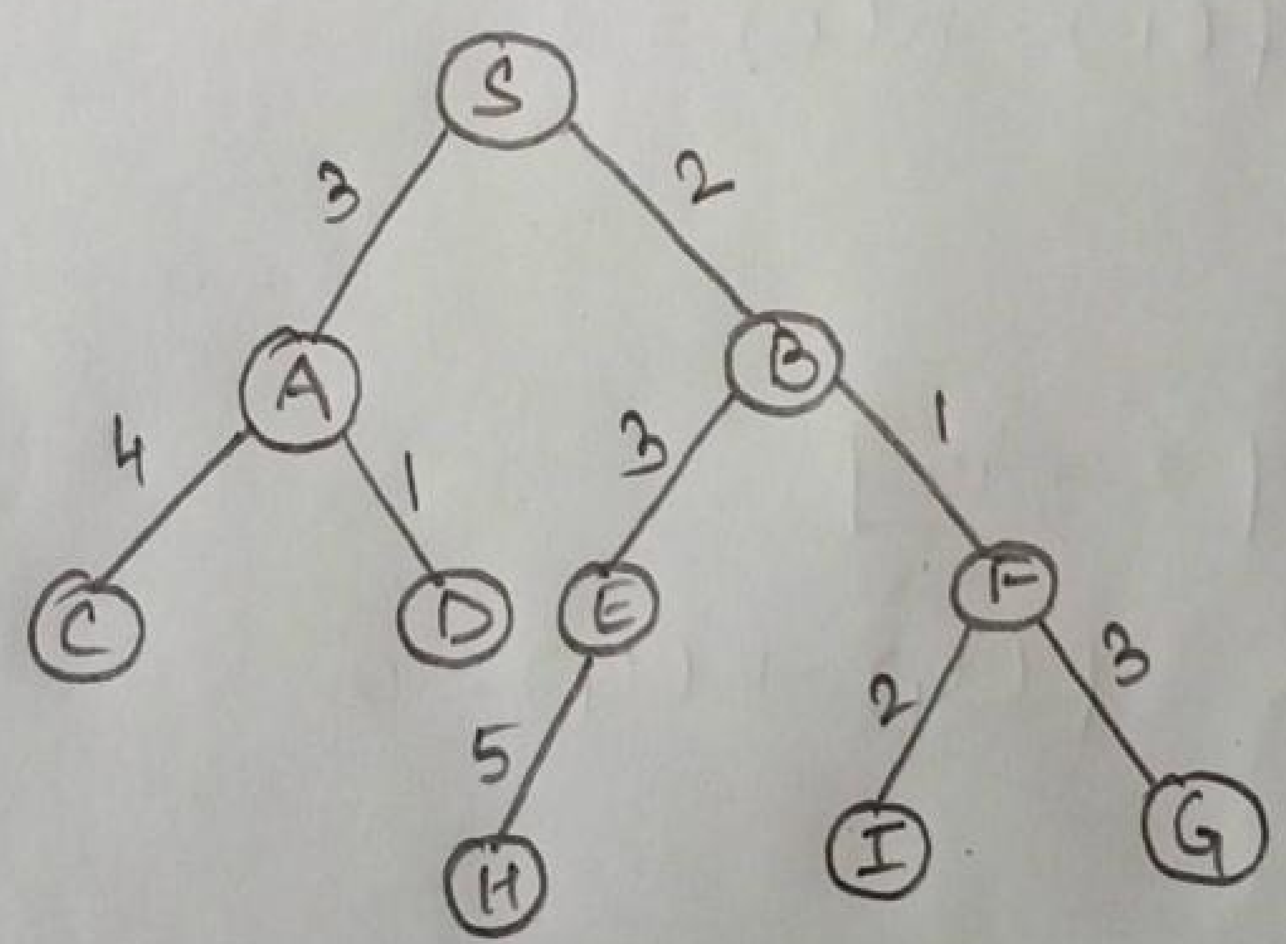
Lab 5

Aim: Developing Best first search and A* algorithm for real world problems.

(i) Developing Best First Search Algorithm for real world problem.

Problem Formulation:

Given a graph, starting node and h(n), use the evaluation function to decide which is the most promising node for reaching to the destination and explore it till reaches the destination.
Display the path and cost function.



Node	h(n)
A	12
B	4
C	7
D	3
E	8
F	2
G	0
H	4
I	9
S	13

Initial State

Open: [S]

Closed: []

Final State

Open: [I, E, A]

Closed: [S, B, F, G]

Path: S → B → F → G

Cost: 2+1+3+0

= 6

Problem solving:

- Open: [S]

  Priority Queue (h(n)): [13]

  Closed: [ ] $f(S) = h(S) = 13$

- Open: [B, A]

  Priority Queue (h(n)): [4, 12]

  Closed: [S] $f(B) = h(B) = 4$

- Open: [F, E, A]

  Priority Queue (h(n)): [2, 8, 12]

  Closed: [S, B]

- Open: [G, I, E, A]

  Priority Queue (h(n)): [0, 8, 9, 12]

  Closed: [S, B, F] $f(F) = h(F) = 2$

- Open: [E, I, A]

  Priority Queue (h(n)): [8, 9, 12]

  Closed: [S, B, F, G] $f(G) = h(G) = 0$

  Goal state reached.

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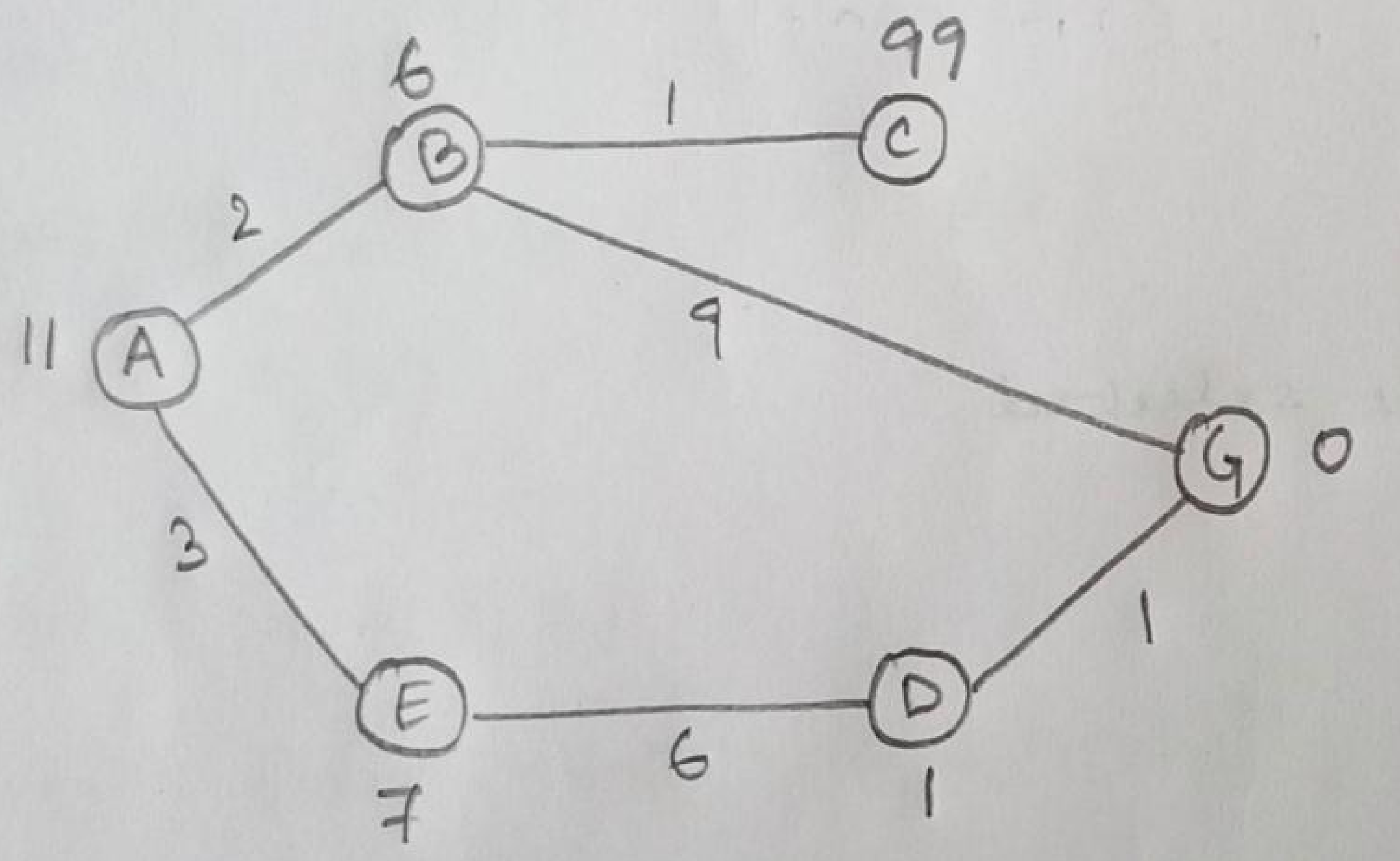
(ii) Developing A* Algorithm for real word problems:

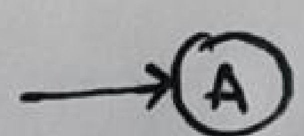
Problem formulation:

Given a graph with the numbers written on edges representing the distance between the nodes while the numbers written on nodes representing heuristic values.

Find the most cost-effective path to reach from start A to final state G using A* Algorithm.



Initial State



Open: [A]

Closed: []

Final State

open: []

Closed: [A, E, D, G]

Path: A → E → D → G

Cost: 3+6+1+0

= 10

Problem Solving

- Open: [A]
  Closed: []

  $g(A) = 0$
  $h(A) = 11$
  $f(A) = 11$

- A has two nodes B and E.

  $f(B) = 2+6 = 8$
  $f(E) = 3+7 = 10$
  $f(B) < f(E)$, so B is selected

- Open: [B, E]
  Closed: [A]

- B has two nodes C and G

  $f(C) = 2+1+99 = 102$
  $f(G) = 2+9+0 = 11$

  But $f(G) > f(E)$
  ∴ we explore path from E

- Open: [E]
  Closed: [A]

- E has only one node D

  $f(D) = 3+6+1 = 10$
  Open: [D]
  Closed: [A, E]

- D has only one node G
  $f(G) = 3+6+1+0 = 10$

  Open: [G]
  Closed: [A, E, D]

  Since goal state is reached.
  → Open: []
  Closed: [A, E, D, G]

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ARTIFICIAL INTELLIGENCE LAB

EXPERIMENT NO: 5

DEVELOPING BEST FIRST SEARCH AND A* ALGORITHM FOR REAL WORLD PROBLEMS

(i) Developing Best first search for real world problems

Algorithm:

Step-1: Start

Step-2: Create 2 empty lists: OPEN and CLOSED

Step-3: Start from the initial node (say N) and put it in the ‘ordered’ OPEN list

Step-4: Repeat the next steps until GOAL node is reached

a. If OPEN list is empty, then EXIT the loop returning ‘False’
b. Select the first/top node (say N) in the OPEN list and move it to the CLOSED list. Also capture the information of the parent node
c. If N is a GOAL node, then move the node to the Closed list and exit the loop returning ‘True’. The solution can be found by backtracking the path
d. If N is not the GOAL node, expand node N to generate the ‘immediate’ next nodes linked to node N and add all those to the OPEN list
e. Reorder the nodes in the OPEN list in ascending order according to an evaluation function f(n)

Step-5: Stop

Source code:

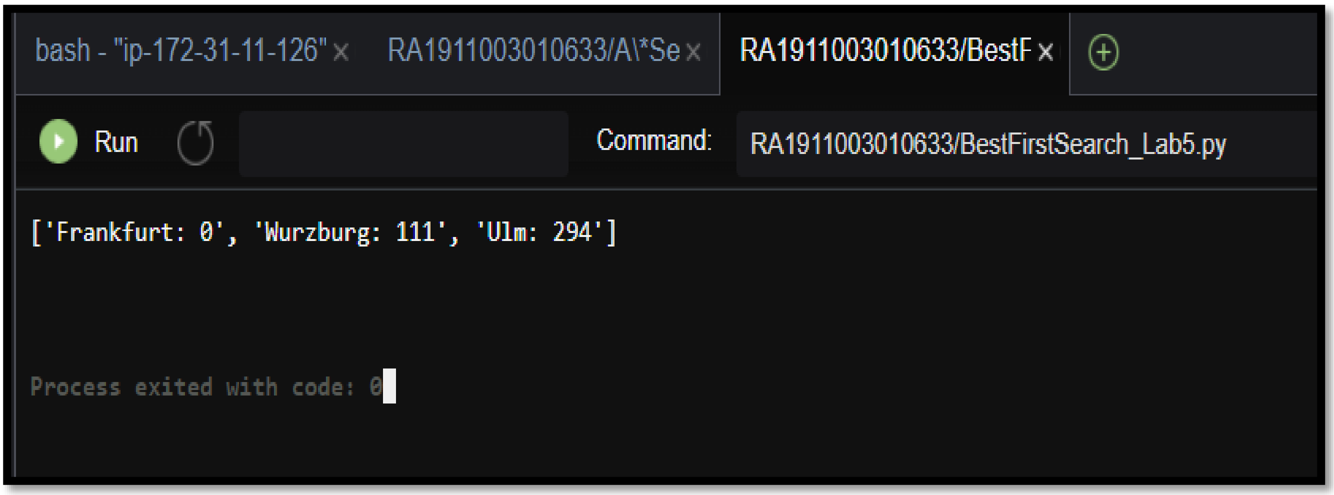
```
class Graph:
    # Initialize the class
    def __init__(self, graph_dict=None, directed=True):
        self.graph_dict = graph_dict or {}
        self.directed = directed
        if not directed:
            self.make_undirected()
    # Create an undirected graph by adding symmetric edges
    def make_undirected(self):
        for a in list(self.graph_dict.keys()):
            for (b, dist) in self.graph_dict[a].items():
                self.graph_dict.setdefault(b, {})[a] = dist
    # Add a link from A and B of given distance, and also add the inverse link if
the graph is undirected
    def connect(self, A, B, distance=1):
        self.graph_dict.setdefault(A, {})[B] = distance
        if not self.directed:
            self.graph_dict.setdefault(B, {})[A] = distance
    # Get neighbors or a neighbor
    def get(self, a, b=None):
        links = self.graph_dict.setdefault(a, {})
        if b is None:
            return links
        else:
            return links.get(b)
    # Return a list of nodes in the graph
    def nodes(self):
        s1 = set([k for k in self.graph_dict.keys()])
        s2 = set([k2 for v in self.graph_dict.values() for k2, v2 in v.items()])
        nodes = s1.union(s2)
        return list(nodes)
# This class represent a node
class Node:
    # Initialize the class
    def __init__(self, name:str, parent:str):
        self.name = name
        self.parent = parent
        self.g = 0 # Distance to start node
        self.h = 0 # Distance to goal node
        self.f = 0 # Total cost
```

```
    # Compare nodes
    def __eq__(self, other):
        return self.name == other.name
    # Sort nodes
    def __lt__(self, other):
         return self.f < other.f
    # Print node
    def __repr__(self):
        return ('({0},{1})'.format(self.position, self.f))
# Best-first search
def best_first_search(graph, heuristics, start, end):

    # Create lists for open nodes and closed nodes
    open = []
    closed = []
    # Create a start node and an goal node
    start_node = Node(start, None)
    goal_node = Node(end, None)
    # Add the start node
    open.append(start_node)

    # Loop until the open list is empty
    while len(open) > 0:
        # Sort the open list to get the node with the lowest cost first
        open.sort()
        # Get the node with the lowest cost
        current_node = open.pop(0)
        # Add the current node to the closed list
        closed.append(current_node)

        # Check if we have reached the goal, return the path
        if current_node == goal_node:
            path = []
            while current_node != start_node:
                path.append(current_node.name + ': ' + str(current_node.g))
                current_node = current_node.parent
            path.append(start_node.name + ': ' + str(start_node.g))
            # Return reversed path
            return path[::-1]
        # Get neighbours
        neighbors = graph.get(current_node.name)
        # Loop neighbors
        for key, value in neighbors.items():
```

```
            # Create a neighbor node
            neighbor = Node(key, current_node)
            # Check if the neighbor is in the closed list
            if(neighbor in closed):
                continue
            # Calculate cost to goal
            neighbor.g = current_node.g + graph.get(current_node.name,
neighbor.name)
            neighbor.h = heuristics.get(neighbor.name)
            neighbor.f = neighbor.h
            # Check if neighbor is in open list and if it has a lower f value
            if(add_to_open(open, neighbor) == True):
                # Everything is green, add neighbor to open list
                open.append(neighbor)
    # Return None, no path is found
    return None
# Check if a neighbor should be added to open list
def add_to_open(open, neighbor):
    for node in open:
        if (neighbor == node and neighbor.f >= node.f):
            return False
    return True
# The main entry point for this module
def main():
    # Create a graph
    graph = Graph()
    # Create graph connections (Actual distance)
    graph.connect('Frankfurt', 'Wurzburg', 111)
    graph.connect('Frankfurt', 'Mannheim', 85)
    graph.connect('Wurzburg', 'Nurnberg', 104)
    graph.connect('Wurzburg', 'Stuttgart', 140)
    graph.connect('Wurzburg', 'Ulm', 183)
    graph.connect('Mannheim', 'Nurnberg', 230)
    graph.connect('Mannheim', 'Karlsruhe', 67)
    graph.connect('Karlsruhe', 'Basel', 191)
    graph.connect('Karlsruhe', 'Stuttgart', 64)
    graph.connect('Nurnberg', 'Ulm', 171)
    graph.connect('Nurnberg', 'Munchen', 170)
    graph.connect('Nurnberg', 'Passau', 220)
    graph.connect('Stuttgart', 'Ulm', 107)
    graph.connect('Basel', 'Bern', 91)
    graph.connect('Basel', 'Zurich', 85)
    graph.connect('Bern', 'Zurich', 120)
```

```python
    graph.connect('Zurich', 'Memmingen', 184)
    graph.connect('Memmingen', 'Ulm', 55)
    graph.connect('Memmingen', 'Munchen', 115)
    graph.connect('Munchen', 'Ulm', 123)
    graph.connect('Munchen', 'Passau', 189)
    graph.connect('Munchen', 'Rosenheim', 59)
    graph.connect('Rosenheim', 'Salzburg', 81)
    graph.connect('Passau', 'Linz', 102)
    graph.connect('Salzburg', 'Linz', 126)
    # Make graph undirected, create symmetric connections
    graph.make_undirected()
    # Create heuristics (straight-line distance, air-travel distance)
    heuristics = {}
    heuristics['Basel'] = 204
    heuristics['Bern'] = 247
    heuristics['Frankfurt'] = 215
    heuristics['Karlsruhe'] = 137
    heuristics['Linz'] = 318
    heuristics['Mannheim'] = 164
    heuristics['Munchen'] = 120
    heuristics['Memmingen'] = 47
    heuristics['Nurnberg'] = 132
    heuristics['Passau'] = 257
    heuristics['Rosenheim'] = 168
    heuristics['Stuttgart'] = 75
    heuristics['Salzburg'] = 236
    heuristics['Wurzburg'] = 153
    heuristics['Zurich'] = 157
    heuristics['Ulm'] = 0
    # Run search algorithm
    path = best_first_search(graph, heuristics, 'Frankfurt', 'Ulm')
    print(path)
    print()
# Tell python to run main method
if __name__ == "__main__": main()
```

Output:


bash - "ip-172-31-11-126"
RA1911003010633/A*Se
RA1911003010633/BestF
Run
Command:
RA1911003010633/BestFirstSearch_Lab5.py
['Frankfurt: 0', 'Wurzburg: 111', 'Ulm: 294']
Process exited with code: 0

(ii) Developing A Algorithm for real world problems*

Algorithm:

Step-1: Start.
Step-2: Firstly, add the beginning node to the open list
Step-3: Then repeat the following step
– In the open list, find the square with the lowest F cost – and this denotes the current square.
– Now we move to the closed square.
– Consider 8 squares adjacent to the current square and

- Ignore it if it is on the closed list, or if it is not workable. Do the following if it is workable
- Check if it is on the open list; if not, add it. You need to make the current square as this square's a parent. You will now record the different costs of the square like the F, G and H costs.
- If it is on the open list, use G cost to measure the better path. Lower the G cost, the better the path. If this path is better, make the current square as the parent square. Now you need to recalculate the other scores – the G and F scores of this square.

– You'll stop:

- If you find the path, you need to check the closed list and add the target square to it.
- There is no path if the open list is empty and you could not find the target square.

Step-4: Now you can save the path and work backwards starting from the target square, going to the parent square from each square you go, till it takes you to the starting square. You've found your path now.
Step-5 Stop.

Source code:

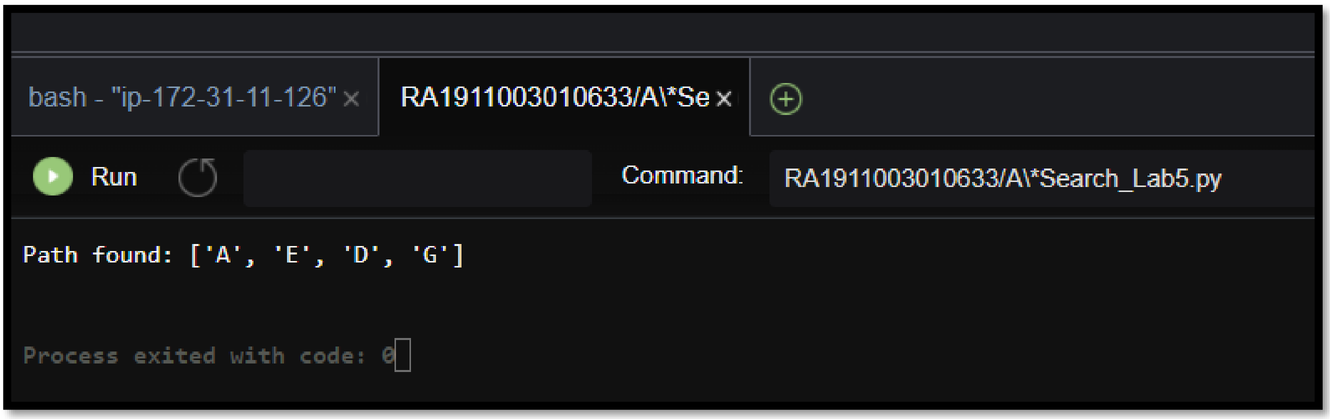
```
def aStarAlgo(start_node, stop_node):

    open_set = set(start_node)
    closed_set = set()
    g = {} #store distance from starting node
    parents = {}# parents contains an adjacency map of all nodes

    #ditance of starting node from itself is zero
    g[start_node] = 0
    #start_node is root node i.e it has no parent nodes
```

```
#so start_node is set to its own parent node
parents[start_node] = start_node


while len(open_set) > 0:
    n = None

    #node with lowest f() is found
    for v in open_set:
        if n == None or g[v] + heuristic(v) < g[n] + heuristic(n):
            n = v


    if n == stop_node or Graph_nodes[n] == None:
        pass
    else:
        for (m, weight) in get_neighbors(n):
            #nodes 'm' not in first and last set are added to first
            #n is set its parent
            if m not in open_set and m not in closed_set:
                open_set.add(m)
                parents[m] = n
                g[m] = g[n] + weight


            #for each node m,compare its distance from start i.e g(m) to the
            #from start through n node
            else:
                if g[m] > g[n] + weight:
                    #update g(m)
                    g[m] = g[n] + weight
                    #change parent of m to n
                    parents[m] = n

                    #if m in closed set,remove and add to open
                    if m in closed_set:
                        closed_set.remove(m)
                        open_set.add(m)

    if n == None:
        print('Path does not exist!')
        return None
```

```
            # if the current node is the stop_node
            # then we begin reconstructin the path from it to the start_node
            if n == stop_node:
                path = []

                while parents[n] != n:
                    path.append(n)
                    n = parents[n]

                path.append(start_node)

                path.reverse()

                print('Path found: {}'.format(path))
                return path


            # remove n from the open_list, and add it to closed_list
            # because all of his neighbors were inspected
            open_set.remove(n)
            closed_set.add(n)

        print('Path does not exist!')
        return None

#define fuction to return neighbor and its distance
#from the passed node
def get_neighbors(v):
    if v in Graph_nodes:
        return Graph_nodes[v]
    else:
        return None
#for simplicity we ll consider heuristic distances given
#and this function returns heuristic distance for all nodes
def heuristic(n):
        H_dist = {
            'A': 11,
            'B': 6,
            'C': 99,
            'D': 1,
            'E': 7,
            'G': 0,
```

```
        }

        return H_dist[n]

#Describe your graph here
Graph_nodes = {
    'A': [('B', 2), ('E', 3)],
    'B': [('C', 1),('G', 9)],
    'C': None,
    'E': [('D', 6)],
    'D': [('G', 1)],

}
aStarAlgo('A', 'G')
```

Output:



Result:

Hence, the Development of Best first search and A* Algorithm for real world problems is done successfully.