# ARTIFICIAL INTELLIGENCE.

## LAB 5

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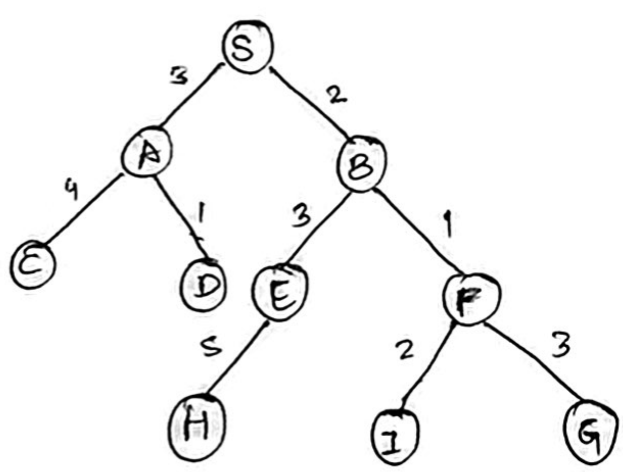
AIM: Developing Best first Search and A* Algorithm for real world problems.

(i) 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 it reaches the destination.




| 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:

1. open : [S]
   priority queue $(h(n))$ : [13]
   closed : [ ]     $f(S) = h(S) = 13$

2. open : [B, A]
   priority queue [4, 12]
   closed : [S]     $f(B) = 4$

3. open : [F, E, A]
   priority queue [2, 8, 12]
   closed : [S, B]

4. open : [G, E, I, A]
   priority queue : [0, 8, 9, 12]
   closed : [S, B, F]   $f(F) = 2$

5. open : [E, I, A]
   priority queue : [8, 9, 12]
   closed : [S, B, F, G]   $f(G) = 0$.

   Goal state reached.

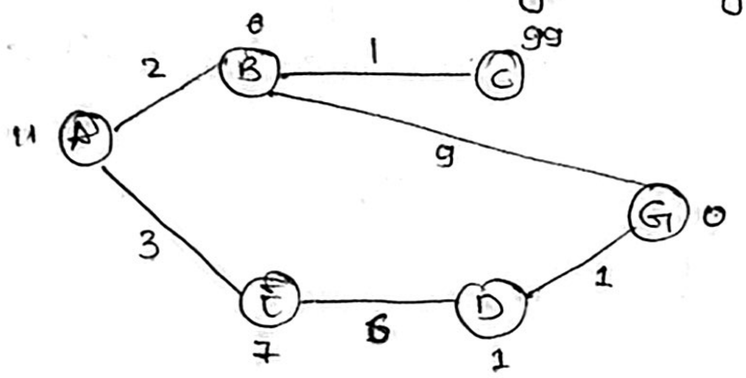
## ALGORITHM:

1. Start
2. Create 2 empty lists: OPEN & CLOSED.
3. Start from the initial node (say N) and put it in the 'ordered' OPEN list.
4. Repeat the next steps until GOAL node is reached.
   i. If OPEN list is empty, then EXIT the node returning FALSE
   ii. 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.
   iii. 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.
   iv. 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.
   v. Reorder the nodes in the OPEN list in ascending order according to ~~an~~ evaluation function $f(n)$.
5. Stop.

## Q11 PROBLEM FORMULATION:

Given a graph with the numbers written on edge represent 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:

→ A

open: [A]

closed: []

final state:

open: []

closed: [A, E, D, G]

path: A → E → D → G

cost: 3+6+1+0

: 10.

## PROBLEM SOLVING:

1. open: [A]

   closed: []

   g(A) = 0

   h(A) = 11

   f(A) = 11

   A has two nodes B, E.

   f(B) = 2+6 = 8

   f(E) = 3+7 = 10.

   f(B) < f(E)

2. open: [A, B]

   closed: [A]

   B has two nodes C & G

   f(C) = 2+1+99 = 102

   f(G) = 2+9+0 = 11

   but, f(G) > f(E).

   ∴ we explore path from E.

3. open : [E]

closed : [A]

E has only one node D

f(D) = 3+6+1 = 10

4. open : [D]

closed : [A, E].

D has only one node G

f(G) = 3+6+1+0.

= 10

5. open : [G]

closed : [A, E, D]

since goal state is reached

open : []

closed : [A, E, D, G].

ALGORITHM :

1. Start
2. Firstly, add the beginning node to the open list.
3. The 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 parent. You will now record the diff. 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 will stop:

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

9. Save the path and work backwards to get the path.

**A* Algorithm**:

```
class Graph:

    # init 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 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 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 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)

# node class
class Node:

    # init 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.name, self.f))

# A* search
def astar_search(graph, heuristics, start, end):

    # lists for open nodes and closed nodes
    open = []
    closed = []

    # a start node and an goal node
    start_node = Node(start, None)
    goal_node = Node(end, None)

    # add start node
    open.append(start_node)

    # loop until the open list is empty
    while len(open) > 0:


        open.sort()                                 # sort open list
to get the node with the lowest cost first
        current_node = open.pop(0)                  # get node with
the lowest cost
        closed.append(current_node)                 # add current
node to the closed list

        # 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 path[::-1]


        neighbors = graph.get(current_node.name)    # get neighbours

        # loop neighbors
        for key, value in neighbors.items():
            neighbor = Node(key, current_node)      # create neighbor
node
            if(neighbor in closed):                 # check if the
neighbor is in the closed list
                continue

            # calculate full path cost
            neighbor.g = current_node.g +
graph.get(current_node.name, neighbor.name)
            neighbor.h = heuristics.get(neighbor.name)
            neighbor.f = neighbor.g + 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

# create a graph
graph = Graph() # user-based input for edges will be updated in the
upcoming days
# create graph connections (Actual distance)
```

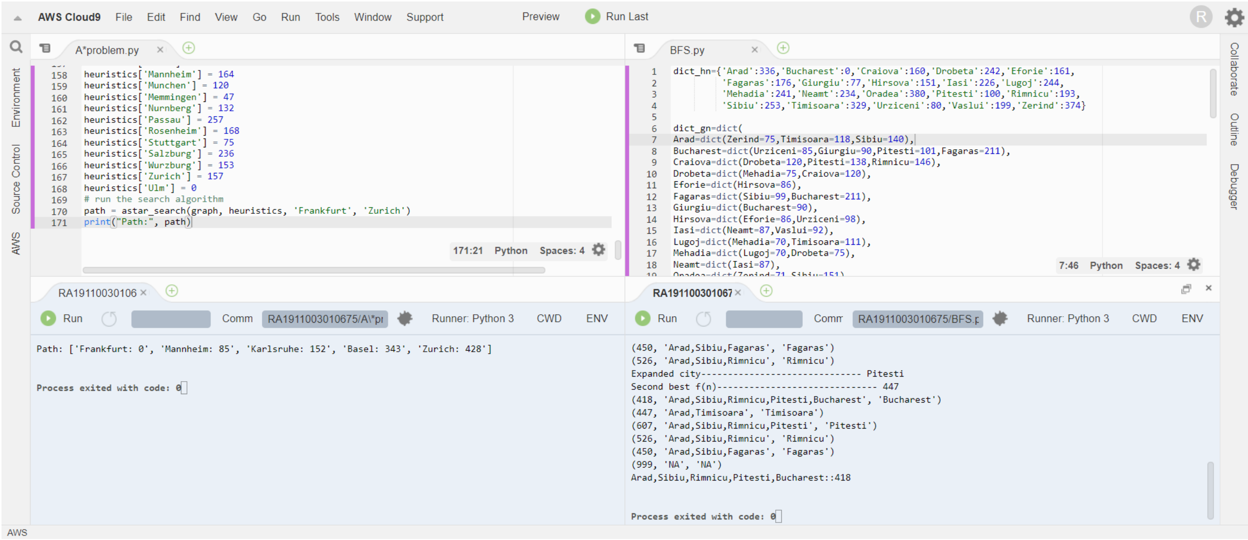
```
graph.connect('Frankfurt', 'Wurzburg', 111)
graph.connect('Frankfurt', 'Mannheim', 85)
graph.connect('Wurzburg', 'Nurnberg', 104)
graph.connect('Wurzburg', 'Stuttgart', 140)
graph.connect('Wurzburg', 'Ulm', 183)
graph.connect('Mannheim', 'Nurnberg', 230)
graph.connect('Mannheim', 'Karlsruhe', 67)
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)
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 the search algorithm
path = astar_search(graph, heuristics, 'Frankfurt', 'Zurich')
print("Path:", path)
```

**Best First Search**:

```
dict_hn={'Arad':336,'Bucharest':0,'Craiova':160,'Drobeta':242,'Eforie
':161,

'Fagaras':176,'Giurgiu':77,'Hirsova':151,'Iasi':226,'Lugoj':244,

'Mehadia':241,'Neamt':234,'Oradea':380,'Pitesti':100,'Rimnicu':193,

'Sibiu':253,'Timisoara':329,'Urziceni':80,'Vaslui':199,'Zerind':374}

dict_gn=dict(
Arad=dict(Zerind=75,Timisoara=118,Sibiu=140),
Bucharest=dict(Urziceni=85,Giurgiu=90,Pitesti=101,Fagaras=211),
Craiova=dict(Drobeta=120,Pitesti=138,Rimnicu=146),
Drobeta=dict(Mehadia=75,Craiova=120),
Eforie=dict(Hirsova=86),
Fagaras=dict(Sibiu=99,Bucharest=211),
Giurgiu=dict(Bucharest=90),
Hirsova=dict(Eforie=86,Urziceni=98),
Iasi=dict(Neamt=87,Vaslui=92),
Lugoj=dict(Mehadia=70,Timisoara=111),
Mehadia=dict(Lugoj=70,Drobeta=75),
Neamt=dict(Iasi=87),
Oradea=dict(Zerind=71,Sibiu=151),
Pitesti=dict(Rimnicu=97,Bucharest=101,Craiova=138),
Rimnicu=dict(Sibiu=80,Pitesti=97,Craiova=146),
Sibiu=dict(Rimnicu=80,Fagaras=99,Arad=140,Oradea=151),
Timisoara=dict(Lugoj=111,Arad=118),
Urziceni=dict(Bucharest=85,Hirsova=98,Vaslui=142),
Vaslui=dict(Iasi=92,Urziceni=142),
Zerind=dict(Oradea=71,Arad=75)
)
import queue as Q


start='Arad'
goal='Bucharest'
result=''

def get_fn(citystr):
    cities=citystr.split(',')
```

```
    hn=gn=0
    for ctr in range(0,len(cities)-1):
        gn=gn+dict_gn[cities[ctr]][cities[ctr+1]]
    hn=dict_hn[cities[len(cities)-1]]
    return(hn+gn)

def printout(cityq):
    for i in range(0,cityq.qsize()):
        print(cityq.queue[i])

def expand(cityq):
    global result
    tot,citystr,thiscity=cityq.get()
    nexttot=999
    if not cityq.empty():
        nexttot,nextcitystr,nextthiscity=cityq.queue[0]
    if thiscity==goal and tot<nexttot:
        result=citystr+'::'+str(tot)
        return
    print("Expanded city------------------------------",thiscity)
    print("Second best f(n)------------------------------",nexttot)
    tempq=Q.PriorityQueue()
    for cty in dict_gn[thiscity]:
            tempq.put((get_fn(citystr+','+cty),citystr+','+cty,cty))
    for ctr in range(1,3):
        ctrtot,ctrcitystr,ctrthiscity=tempq.get()
        if ctrtot<nexttot:
            cityq.put((ctrtot,ctrcitystr,ctrthiscity))
        else:
            cityq.put((ctrtot,citystr,thiscity))
            break
    printout(cityq)
    expand(cityq)
def main():
    cityq=Q.PriorityQueue()
    thiscity=start
    cityq.put((999,"NA","NA"))
    cityq.put((get_fn(start),start,thiscity))
    expand(cityq)
    print(result)
main()
```



AWS Cloud9 File Edit Find View Go Run Tools Window Support Preview Run Last
A*problem.py
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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 the search algorithm
path = astar_search(graph, heuristics, 'Frankfurt', 'Zurich')
print("Path:", path)
171:21 Python Spaces: 4
BFS.py
dict_hn={'Arad':336,'Bucharest':0,'Craiova':160,'Drobeta':242,'Eforie':161,
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Lugoj=dict(Mehadia=70,Timisoara=111),
Mehadia=dict(Lugoj=70,Drobeta=75),
Neamt=dict(Iasi=87),
7:46 Python Spaces: 4
RA19110030106
Run Comm RA1911003010675/A*pr Runner: Python 3 CWD ENV
Path: ['Frankfurt: 0', 'Mannheim: 85', 'Karlsruhe: 152', 'Basel: 343', 'Zurich: 428']
Process exited with code: 0
RA191100301067
Run Comm RA1911003010675/BFS.p Runner: Python 3 CWD ENV
(450, 'Arad,Sibiu,Fagaras', 'Fagaras')
(526, 'Arad,Sibiu,Rimnicu', 'Rimnicu')
Expanded city----------------------------- Pitesti
Second best f(n)----------------------------- 447
(418, 'Arad,Sibiu,Rimnicu,Pitesti,Bucharest', 'Bucharest')
(447, 'Arad,Timisoara', 'Timisoara')
(607, 'Arad,Sibiu,Rimnicu,Pitesti', 'Pitesti')
(526, 'Arad,Sibiu,Rimnicu', 'Rimnicu')
(450, 'Arad,Sibiu,Fagaras', 'Fagaras')
(999, 'NA', 'NA')
Arad,Sibiu,Rimnicu,Pitesti,Bucharest::418
Process exited with code: 0