A* AND AO* ALGORITHM

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INTRODUCTION TO A* ALGORITHM

- Some problems can be solved by representing the world in the initial state
- Then for each action we can perform on the world we generate states for what the world would be like if we did so

- If we do this until the world is in the state that we desire as a solution, then the route from the start to this goal state is the solution to our problem

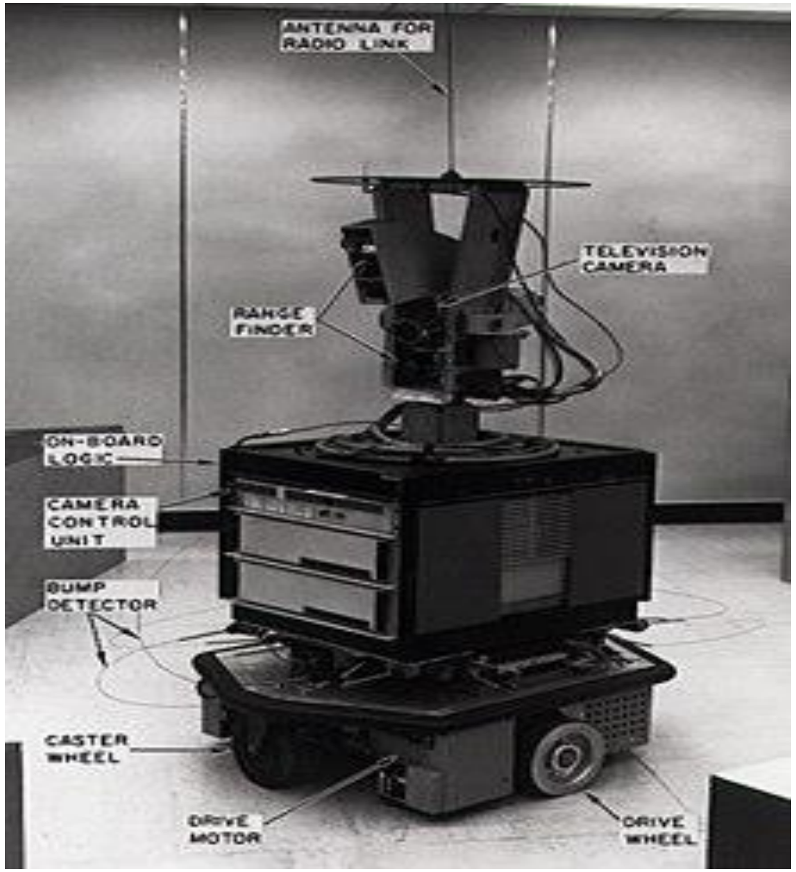
- Why A* is advantageous?
- As the A* algorithm will not only find a path, if there is one, but it will find the shortest path

BRIEF HISTORY

- Peter Hart, Nils Nilsson and Bertram Raphael of Stanford Research Institute (now SRI International) first published the algorithm in 1968

- A* was created as part of the Shakey project, which had the aim of building a mobile robot that could plan its own actions

- Nils Nilsson originally proposed using the Graph Traverser algorithm for Shakey's path planning

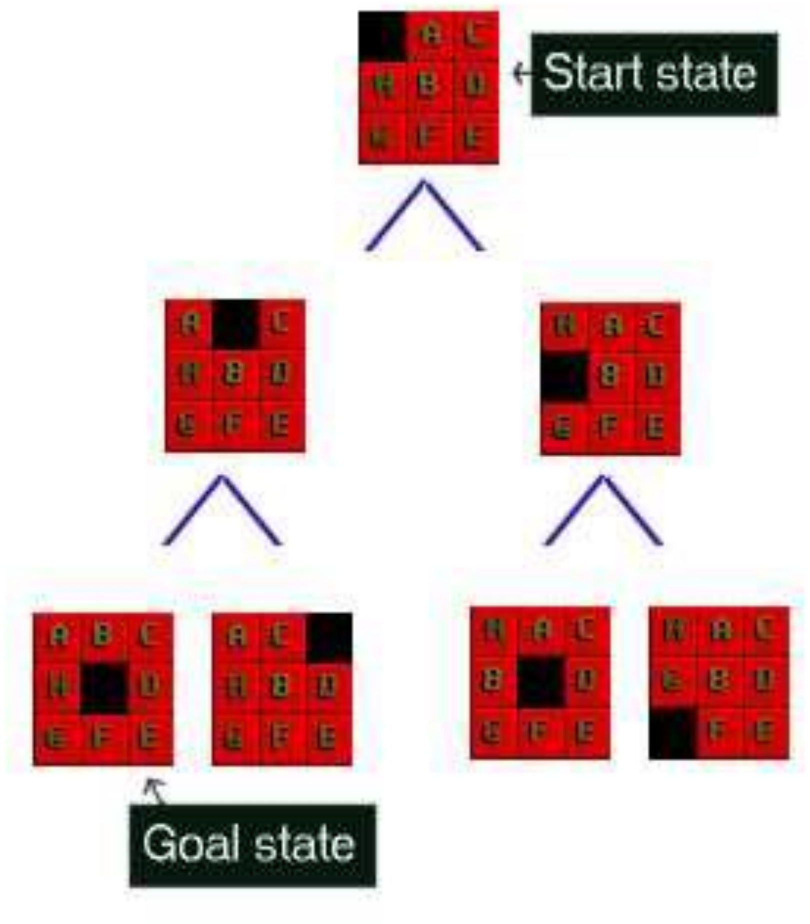


EXPLANATION WITH EXAMPLE

- We consider the 8 puzzle problem
- This is a simple sliding tile puzzle on a 3*3 grid, where one tile is missing and you can move the other tiles into the gap until you get the puzzle into the goal position
- There are 362,880 different states that the puzzle can be in, and to find a solution the search has to find a route through them.

- Here are two states for example;
- The first is a jumbled up example that you may start from.
  - Start state SPACE, A, C, H, B, D, G, F, E
- the last one is the GOAL state, at which point we've found the solution.
  - Goal state A, B, C, H, SPACE, D, G, F, E

- RULE: If there is a blank tile above, below, to the left or to the right of a given tile, then you can move that tile into the space



IMPLEMENTING A*

- What we need to do is start with the start state and then generate the graph downwards from there
- We ask how many moves can we make from the start state?
  - The answer is 2, there are two directions we can move the blank tile, and so our graph expands.
- If we were just to continue blindly generating successors to each node, we could potentially fill the computer's memory before we found the goal node
- Obviously we need to remember the best nodes and search those first
- We also need to remember the nodes that we have expanded already, so that we don't expand the same state repeatedly.

- Let's start with the OPEN list.
- This is where we will remember which nodes we haven't yet expanded.
- When the algorithm begins the start state is placed on the open list, it is the only state we know about and we have not expanded it.
- So we will expand the nodes from the start and put those on the OPEN list too.
- Now we are done with the start node and we will put that on the CLOSED list.
- The CLOSED list is a list of nodes that we have expanded.

- $f = g + h$

- Using the OPEN and CLOSED list lets us be more selective about what we look at next in the search.
- We want to look at the best nodes first.
- We will give each node a score on how good we think it is.
- This score should be thought of as the cost of getting from the node to the goal plus the cost of getting to where we are.
- Traditionally this has been represented by the letters f, g and h.
- 'g' is the sum of all the costs it took to get here,
- 'h' is our heuristic function, the estimate of what it will take to get to the goal.
- 'f' is the sum of these two.
- We will store each of these in our nodes.

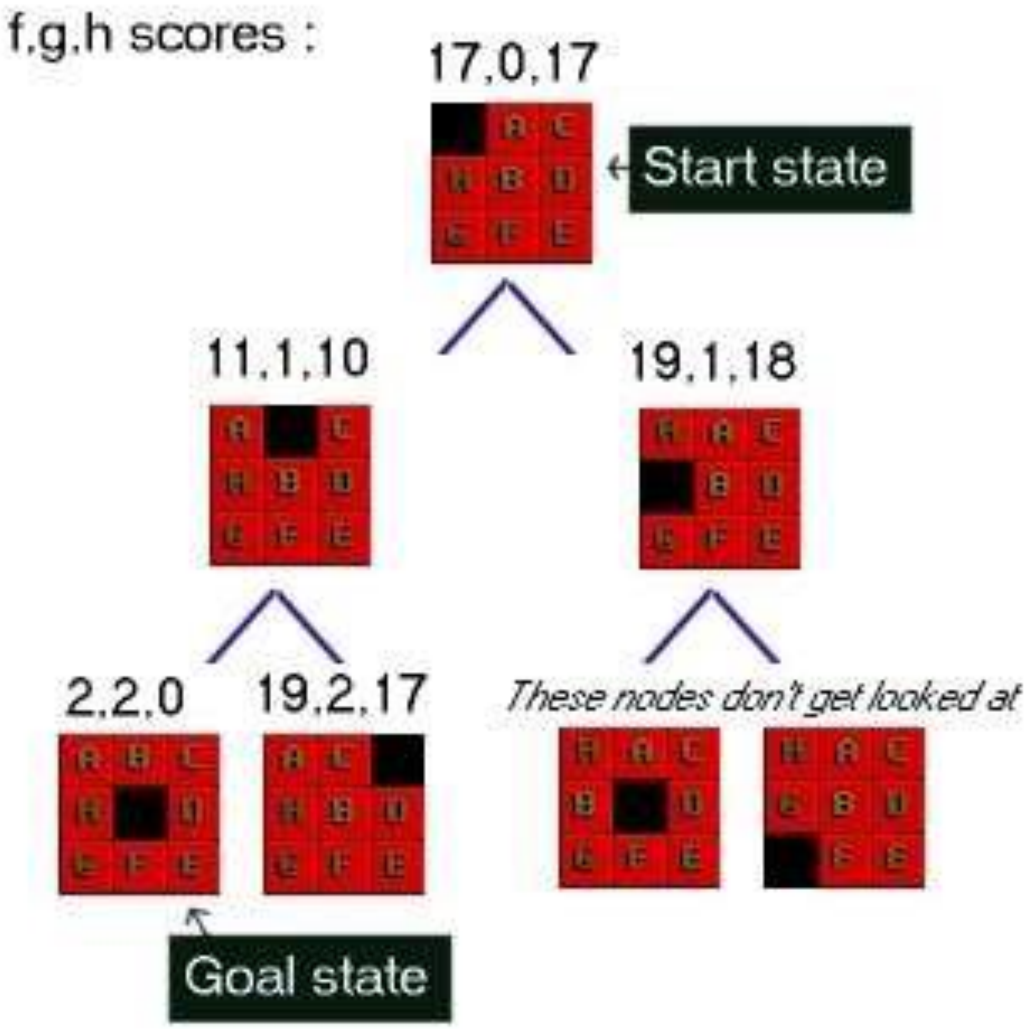
PSEUDOCODE OF A*

```
Create a node containing the goal state node_goal
Create a node containing the start state node_start
Put node_start on the open list
while the OPEN list is not empty
{
Get the node off the open list with the lowest f and call it node_current
if node_current is the same state as node_goal we have found the solution; break from the while loop
    Generate each state node_successor that can come after node_current
    for each node_successor of node_current
    {
        Set the cost of node_successor to be the cost of node_current plus the cost to get to node_successor from node_current
        find node_successor on the OPEN list
        if node_successor is on the OPEN list but the existing one is as good or better then discard this successor and continue
        if node_successor is on the CLOSED list but the existing one is as good or better then discard this successor and continue
        Remove occurences of node_successor from OPEN and CLOSED
        Set the parent of node_successor to node_current
        Set h to be the estimated distance to node_goal (Using the heuristic function)
         Add node_successor to the OPEN list
    }
    Add node_current to the CLOSED list
}
```

- First of all look at the g score for each node.
- This is the cost of what it took to get from the start to that node.
- So in the picture the center number is g, which increases by one at each level.

- Next look at the last number in each triple.
- This is h, the heuristic score, obtained by Nilsson's Sequence, which converges quickly to a correct solution

- **Nilsson's sequence score**
- **A** tile in the center scores 1 (since it should be empty)
- For each tile not in the center, if the tile clockwise to it is not the one that should be clockwise to it then score 2.
- Multiply this sequence by three and finally add the total distance you need to move each tile back to its correct position



ADVANTAGES AND DISADVANTAGES OF A*

- **Advantages:**
- It is complete and optimal.
- It is the best one from other techniques. It is used to solve very complex problems.
- It is optimally efficient, i.e. there is no other optimal algorithm guaranteed to expand fewer nodes than A*.

- **Disadvantages:**
- This algorithm is complete if the branching factor is finite and every action has fixed cost.
- The speed execution of A* search is highly dependent on the accuracy of the heuristic algorithm that is used to compute h (n).

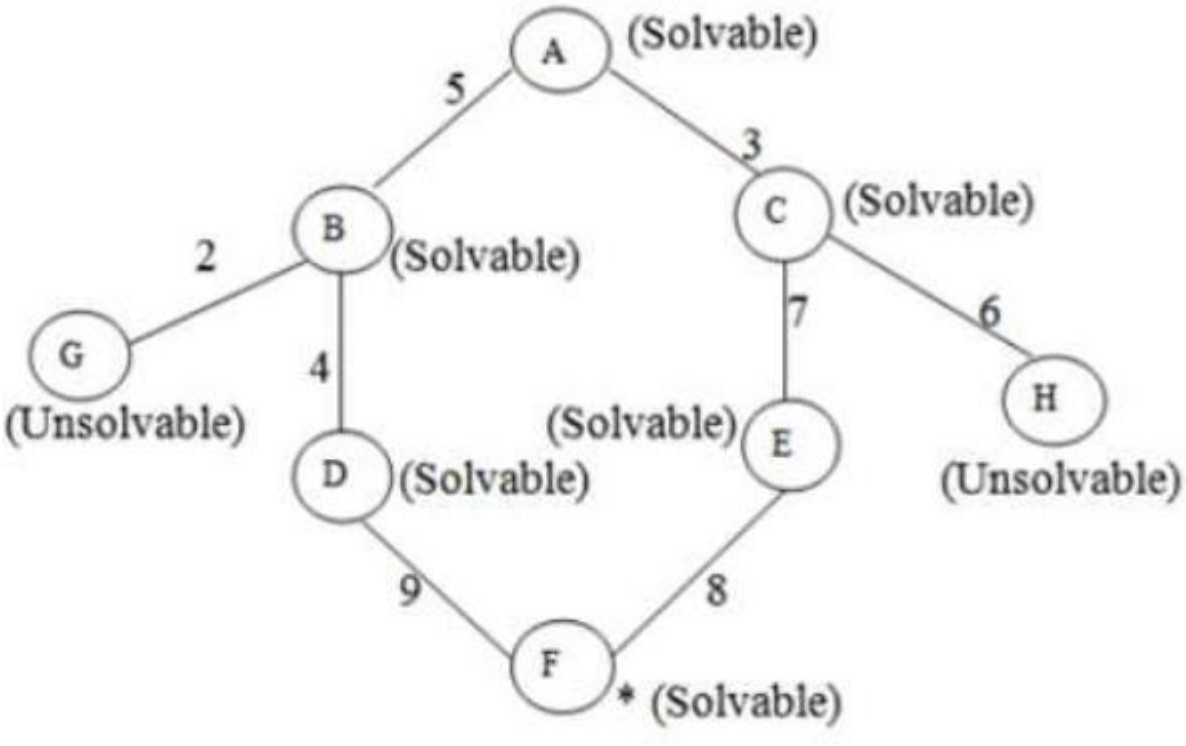
AO* GRAPH
AND-OR GRAPH

- The Depth first search and Breadth first search given earlier for OR trees or graphs can be easily adopted by AND-OR graph.
- The main difference lies in the way termination conditions are determined, since all goals following an AND nodes must be realized; whereas a single goal node following an OR node will do.
- So for this purpose we are using AO* algorithm.
- Like A* algorithm here we will use two arrays and one heuristic function.
- **OPEN:**
- It contains the nodes that has been traversed but yet not been marked solvable or unsolvable.
- **CLOSE**:
- It contains the nodes that have already been processed.

ALGORITHM

- **Step 1:** Place the starting node into OPEN.
- **Step 2:** Compute the most promising solution tree say T0.
- **Step 3:** Select a node n that is both on OPEN and a member of T0. Remove it from OPEN and place it in CLOSE
- **Step 4:** If n is the terminal goal node then level n as solved and level all the ancestors of n as solved.
  - If the starting node is marked as solved then success and exit.
- **Step 5:** If n is not a solvable node, then mark n as unsolvable.
  - If starting node is marked as unsolvable, then return failure and exit.
- **Step 6:** Expand n. Find all its successors and find their h (n) value, push them into OPEN.
- **Step 7:** Return to Step 2.
- **Step 8:** Exit.

EXAMPLE FOR IMPLEMENTATION



- Let us take the following example to implement the AO* algorithm

Step 1:

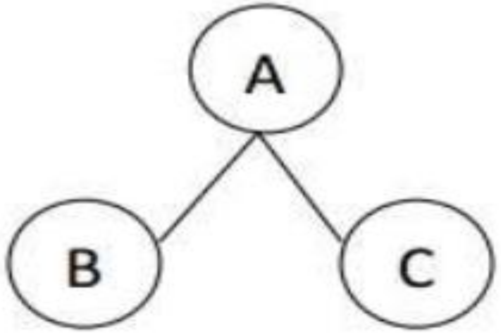
In the above graph, the solvable nodes are A, B, C, D, E, F and the unsolvable nodes are G, H. Take A as the starting node. So place A into OPEN.

i.e. OPEN = [A] CLOSE = (NULL) [ϕ]

Step 2:

The children of A are B and C which are solvable. So place them into OPEN and place A into the CLOSE.

i.e. OPEN = [B | C] CLOSE = [A]



Step 3:

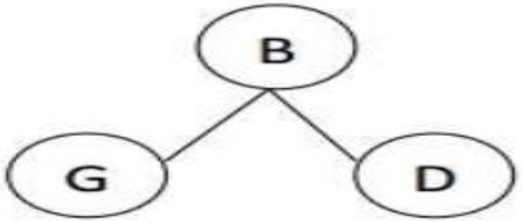
Now process the nodes B and C. The children of B and C are to be placed into OPEN. Also remove B and C from OPEN and place them into CLOSE.

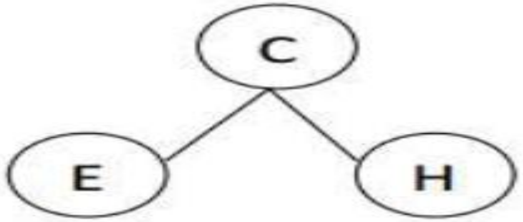
So OPEN =

G	D	E	

C

A	B	C





Step 4:

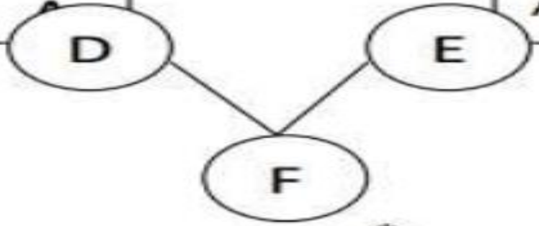
As the nodes G and H are unsolvable, so place them into CLOSE directly and process the nodes D and E.

i.e. OPEN =

A

CLOSE =

A	B	C		G (O)	D	E	H (O)



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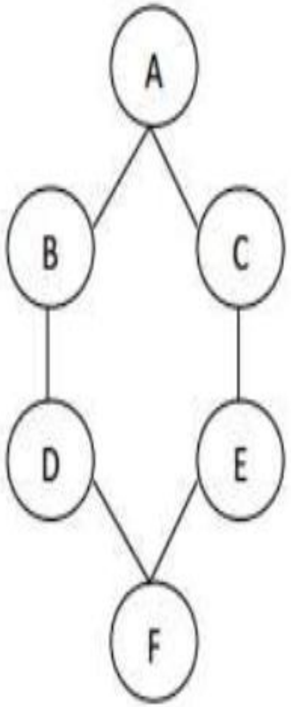
Step 5:

Now we have been reached at our goal state. So place F into CLOSE.

A	B C		G (O)	D E		H (O)	F

AO* Graph:



Step 6:

Success and Exit

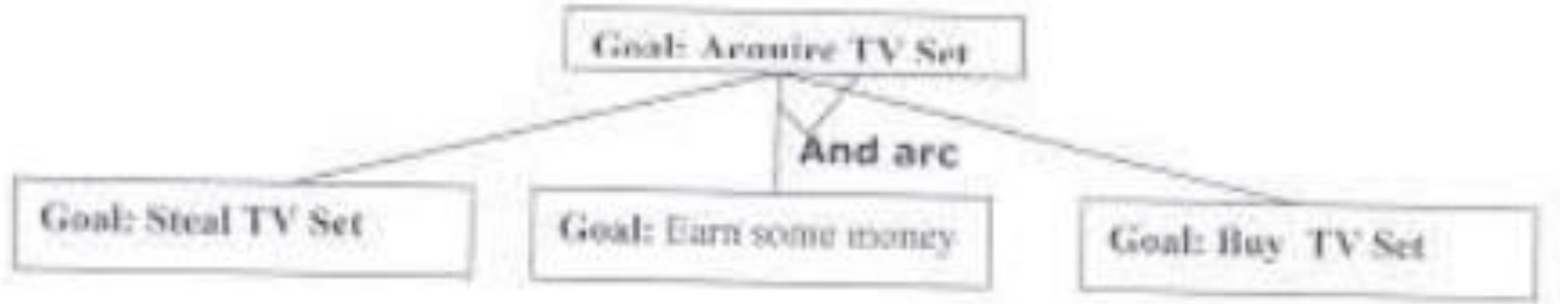
ADVANTAGES AND DISADVANTAGES OF AO*

- **Advantages:**
- It is an optimal algorithm.
- If traverse according to the ordering of nodes. It can be used for both OR and AND graph.

- **Disadvantages:**
- Sometimes for unsolvable nodes, it can’t find the optimal path.

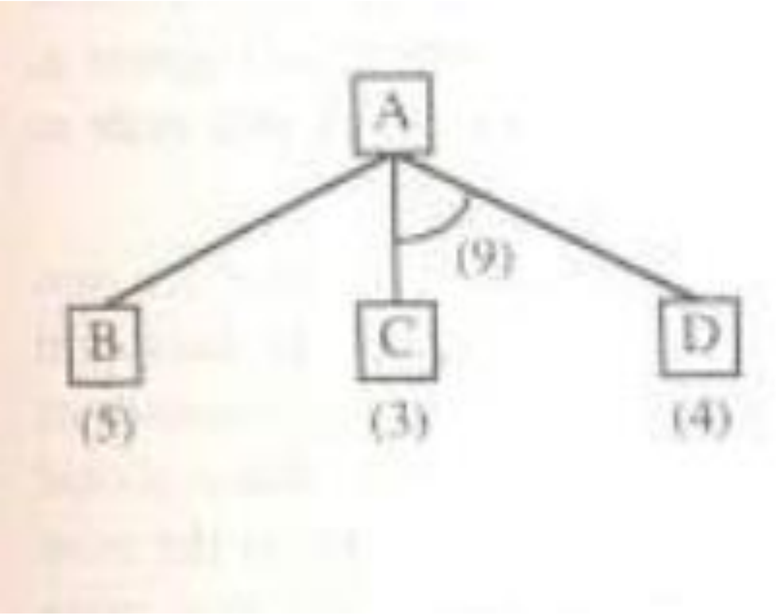
PROBLEM REDUCTION WITH AO*

- When a problem can be divided into a set of sub problems, where each sub problem can be solved separately and a combination of these will be a solution, AND-OR graphs or AND – OR trees are used for representing the solution
- The decomposition of the problem or problem reduction generates AND arcs.
- One AND arc may point to any number of successor nodes
- these must be solved so that the arc will rise to many arcs, indicating several possible solutions.
- Hence the graph is known as AND - OR instead of AND



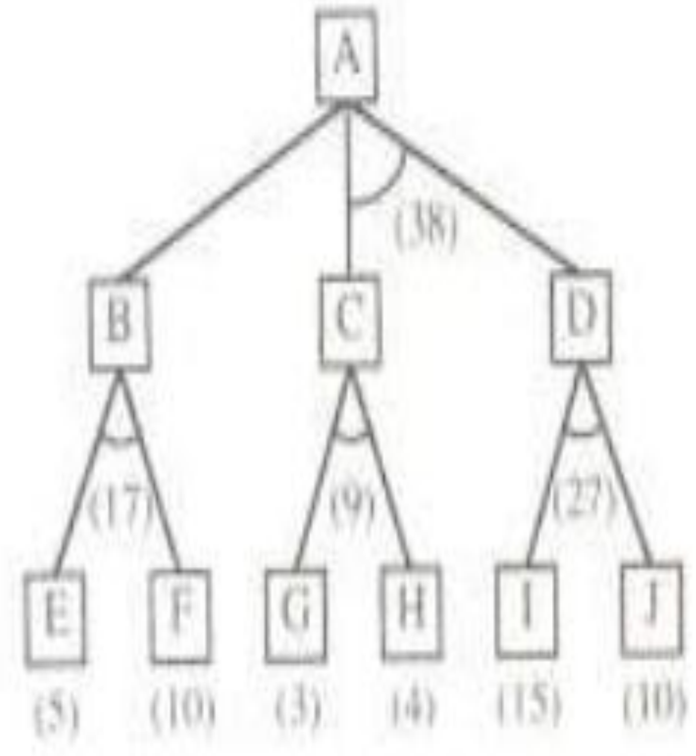
- An algorithm to find a solution in an AND - OR graph must handle AND area appropriately
- A* algorithm can not search AND - OR graphs efficiently

- In figure (a) the top node A has been expanded producing two area one leading to B and leading to C-D .
- the numbers at each node represent the value of f ' at that node (cost of getting to the goal state from current state).
- For simplicity, it is assumed that every operation(i.e. applying a rule) has unit cost, i.e., each are with single successor will have a cost of 1 and each of its components.
- With the available information till now , it appears that C is the most promising node to expand since its f ' = 3 , the lowest but going through B would be better since to use C we must also use D' and the cost would be 9(3+4+1+1). Through B it would be 6(5+1).

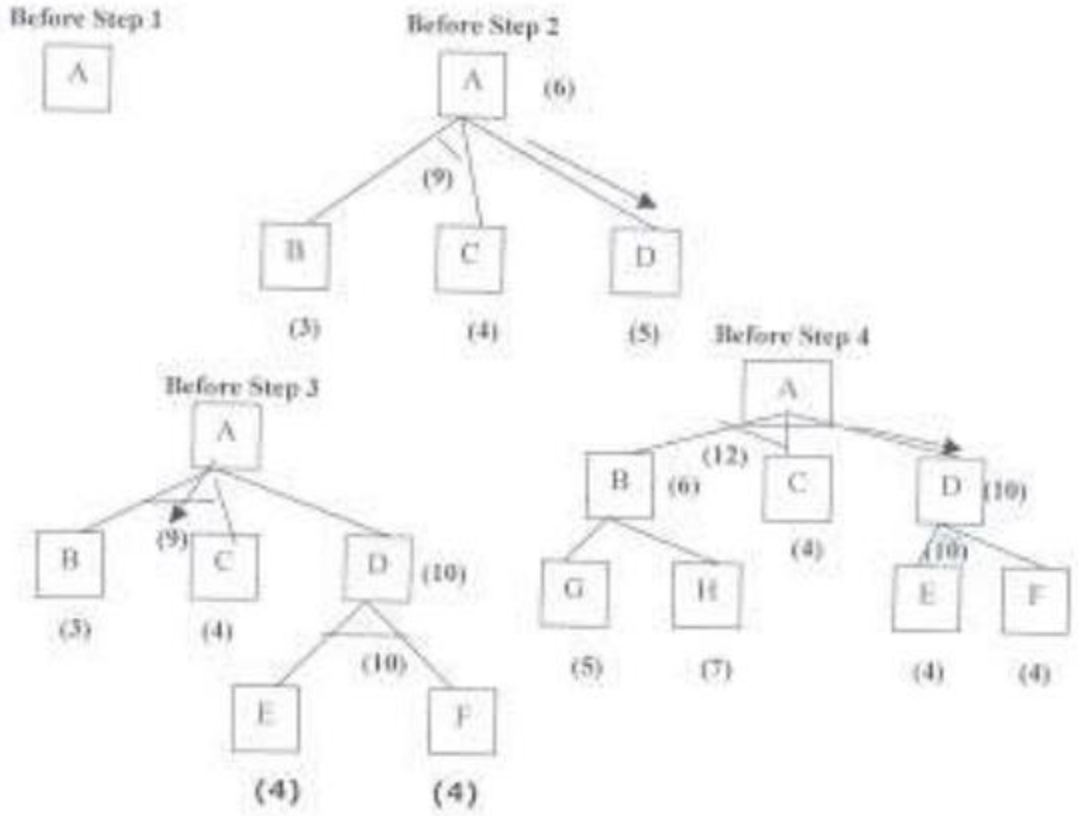


- Thus the choice of the next node to expand depends not only n a value but also on whether that node is part of the current best path form the initial mode

- the node G appears to be the most promising node, with the least f ' value. But G is not on the current best path, since to use G we must use GH with a cost of 9 and again this demands that arcs be used (with a cost of 27).
- The path from A through B, E-F is better with a total cost of (17+1=18).
- Thus we can see that to search an AND-OR graph, the following three things must be done
  - 1. traverse the graph starting at the initial node and following the current best path, accumulate the set of nodes that are on the path and have not yet been expanded.
  - 2. Pick one of these unexpanded nodes and expand it. Add its successors to the graph and compute f ' (cost of the remaining distance) for each of them
  - 3. Change the f ' estimate of the newly expanded node to reflect the new information produced by its successors. Propagate this change backward through the graph. Decide which of the current best path.



- The initial node is expanded and D is Marked initially as promising node.
- D is expanded producing an AND arc E-F.
- f ' value of D is updated to 10.
- Going backwards we can see that the AND arc B-C is better, it is now marked as current best path.
- B and C have to be expanded next. This process continues until a solution is found or all paths have led to dead ends, indicating that there is no solution.
- An A* algorithm the path from one node to the other is always that of the lowest cost and it is independent of the paths through other nodes




Thank
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Kia Ora
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Dank Je
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