Artificial Intelligence

3.4: Solving Problem by Searching

Today’s Topic

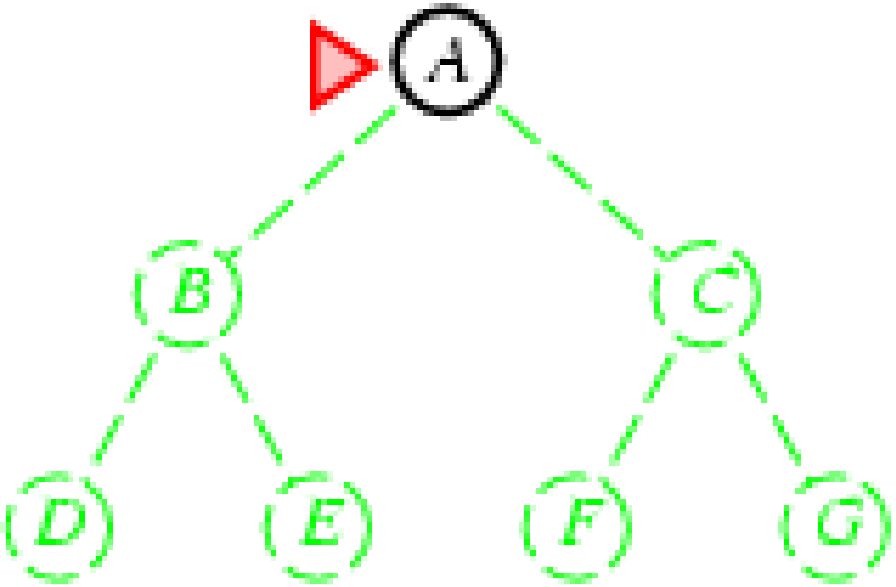
- Uninformed Search Strategies
  - BFS,DFS,UCS
  - DPL, ID

Uninformed search strategies

- Uninformed search strategies use only the information available in the problem definition
  - Breadth-first search
  - Uniform-cost search
  - Depth-first search
  - Depth-limited search
  - Iterative deepening search

Breadth-first search

- Expand shallowest unexpanded node
- Implementation:
  - QUEUE : FIFO Implementation



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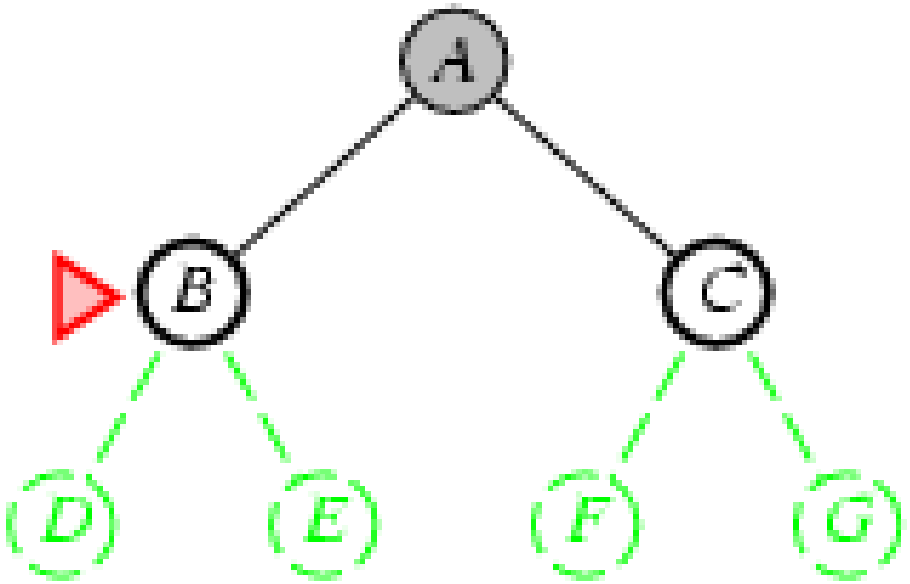

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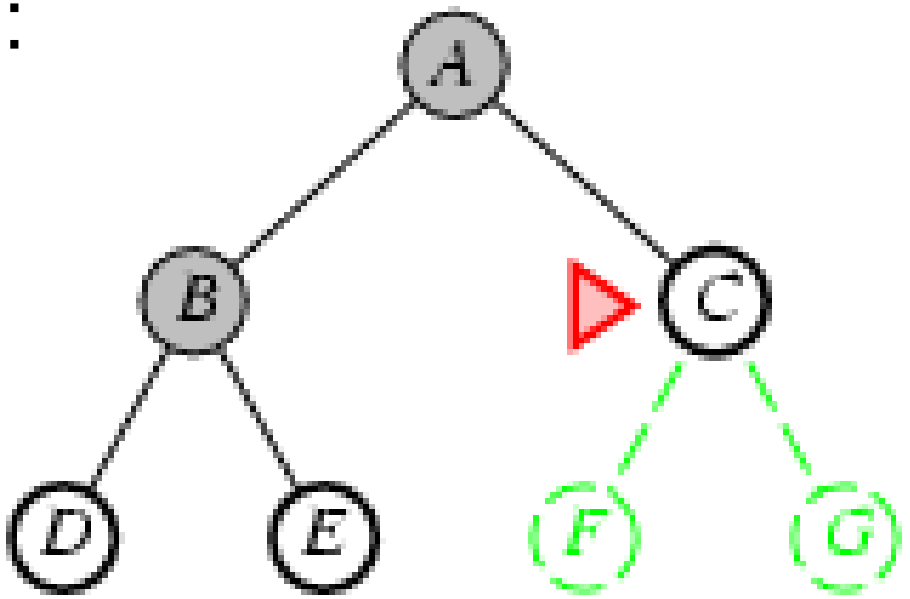

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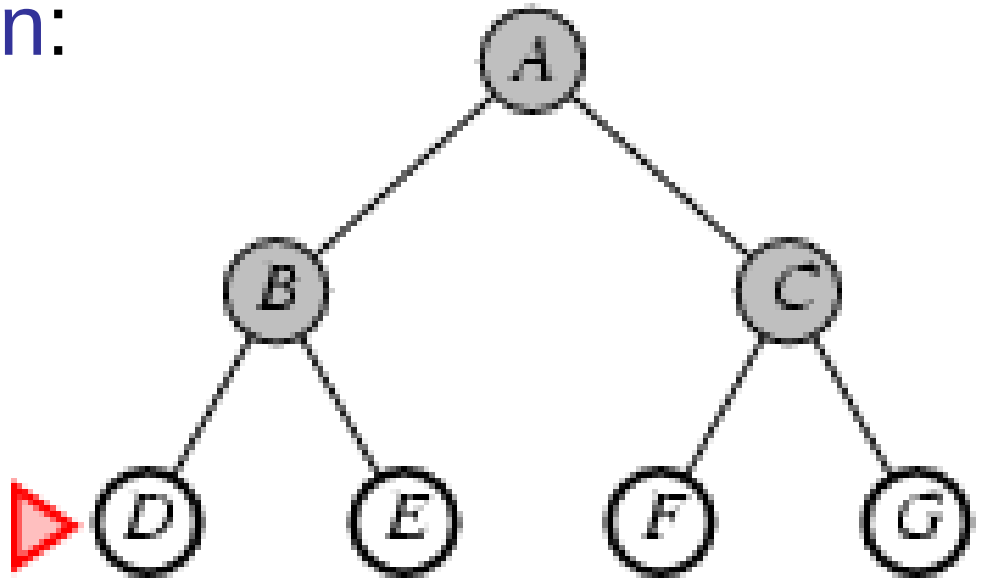


Breadth-first search

```
function BREADTH-FIRST-SEARCH(problem) returns a solution, or failure
    node ← a node with STATE = problem.INITIAL-STATE, PATH-COST = 0
    if problem.GOAL-TEST(node.STATE) then return SOLUTION(node)
    frontier ← a FIFO queue with node as the only element
    explored ← an empty set
    loop do
        if EMPTY?(frontier) then return failure
        node ← POP(frontier)  /* chooses the shallowest node in frontier */
        add node.STATE to explored
        for each action in problem.ACTIONS(node.STATE) do
            child ← CHILD-NODE(problem, node, action)
            if child.STATE is not in explored or frontier then
                if problem.GOAL-TEST(child.STATE) then return SOLUTION(child)
                frontier ← INSERT(child, frontier)
```

Figure 3.11 Breadth-first search on a graph.

Breadth-first Search: Analysis of BFS

- Time complexity: Assume a state space where every state has b successors
  - Assume solution is at depth d
  - Worst case: expand all but the last node at depth d
  - Total number of nodes generated:
    - $b + b^2 + b^3 + \ldots + b^d = 0(b^d)$
- Space Complexity: Every node generated must remain in memory so it will be same as time complexity

Properties of breadth-first search

- Complete? Yes (if b is finite)
- Time? $b+b^2+b^3+\ldots+b^d = O(b^d)$
- Space? $O(b^d)$ (keeps every node in memory)
- Optimal? Yes (if cost = 1 per step)
- Space is the bigger problem (more than time)

Using Breadth-first Search

- When is BFS appropriate?
  - space is not a problem
  - it's necessary to find the solution with the fewest arcs
  - although all solutions may not be shallow, at least some are

- When is BFS inappropriate?
  - space is limited
  - all solutions tend to be located deep in the tree
  - the branching factor is very large

Exponential Growth

- **Exponential growth quickly makes complete state space searches unrealistic**

- **If the branch factor was 10, by level 5 we would need to search 100,000 nodes (i.e. 10^5)**

Exponential Growth

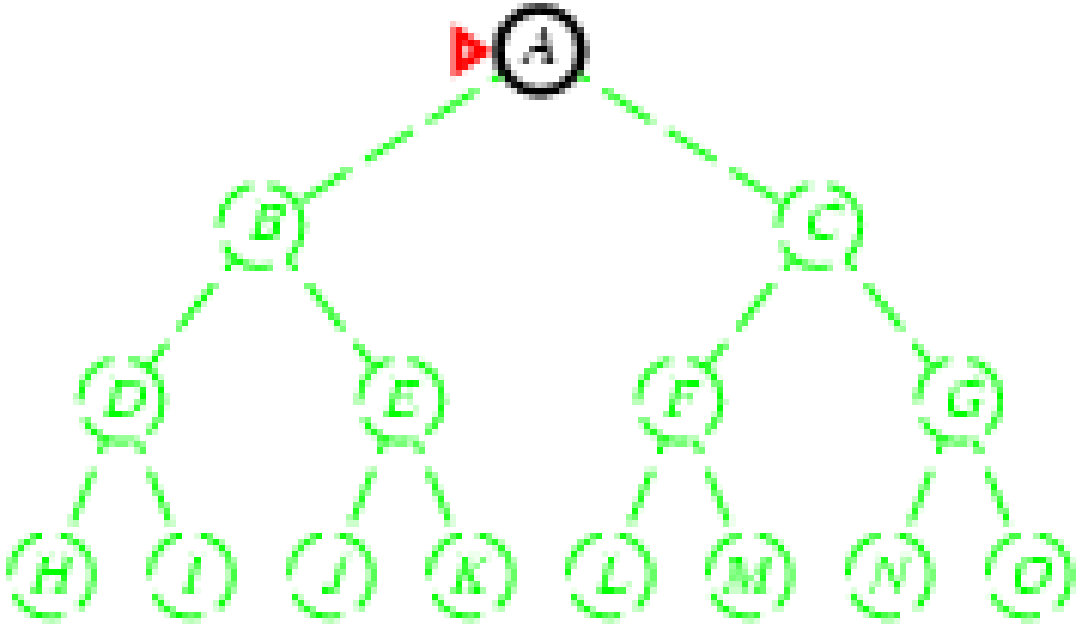
Depth	Nodes	Time	Memory
2	110	.11 milliseconds	107 kilobytes
4	11,110	11 milliseconds	10.6 megabytes
6	10^6	1.1 seconds	1 gigabyte
8	10^8	2 minutes	103 gigabytes
10	10^{10}	3 hours	10 terabytes
12	10^{12}	13 days	1 petabyte
14	10^{14}	3.5 years	99 petabytes
16	10^{16}	350 years	10 exabytes

Figure 3.13 Time and memory requirements for breadth-first search. The numbers shown assume branching factor $b = 10$; 1 million nodes/second; 1000 bytes/node.

Time and memory requirements for breadth-first search, assuming a branching factor of 10, 100 bytes per node and searching 1000 nodes/second

Depth-first search

- Expand deepest unexpanded node in the current fringe
- LIFO-Stack
- Implementation:



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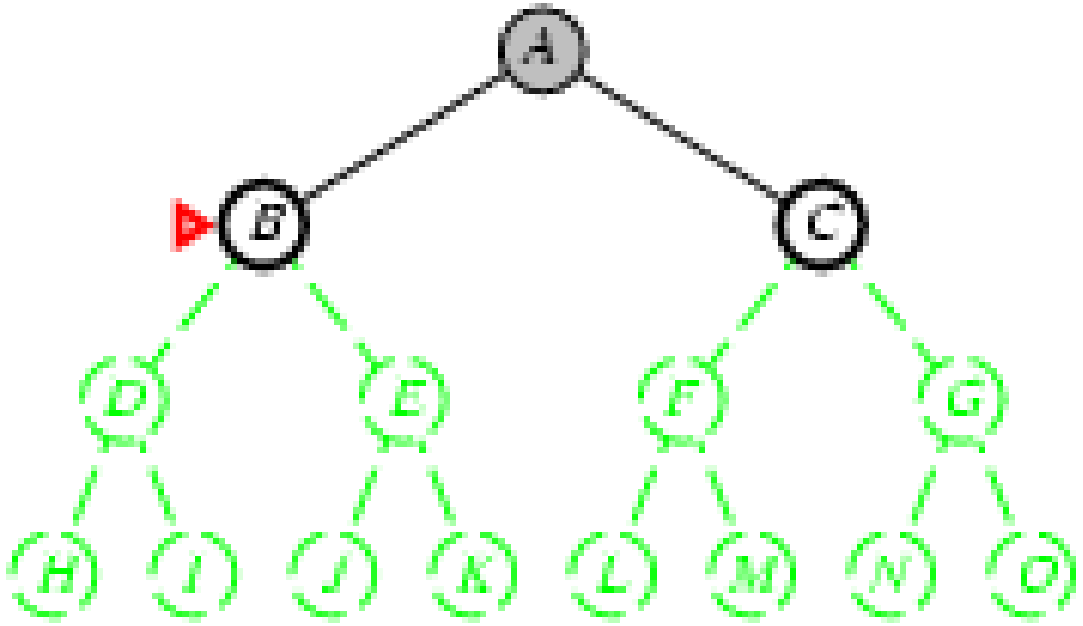

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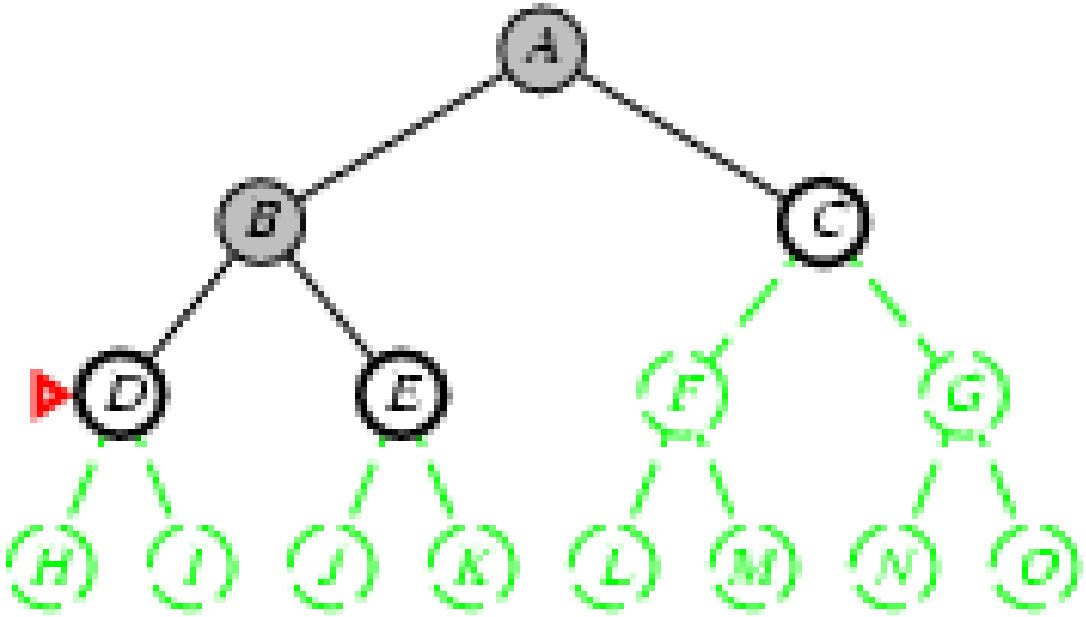

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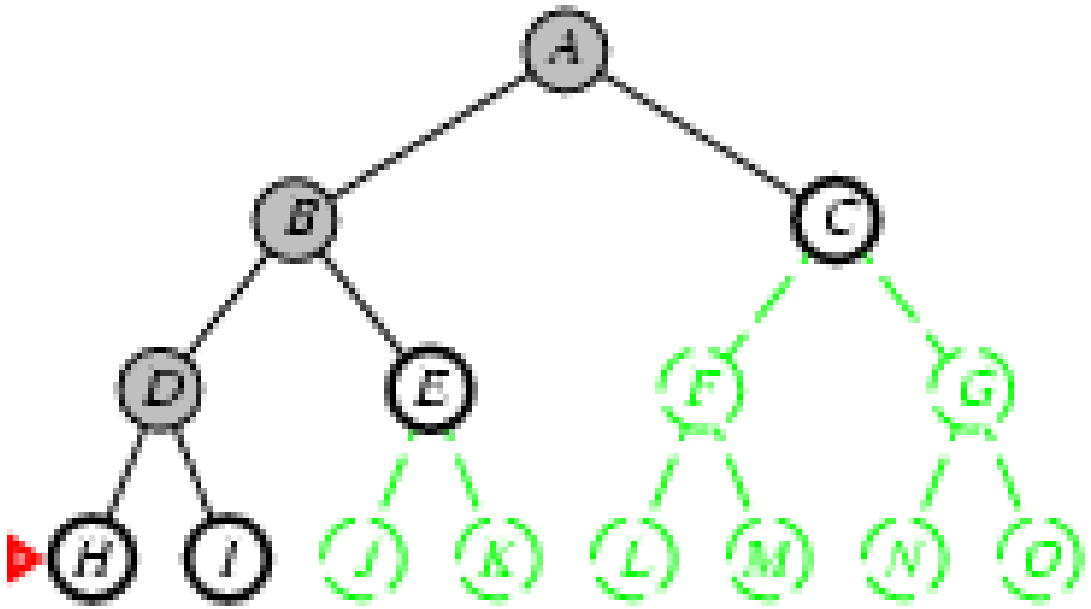

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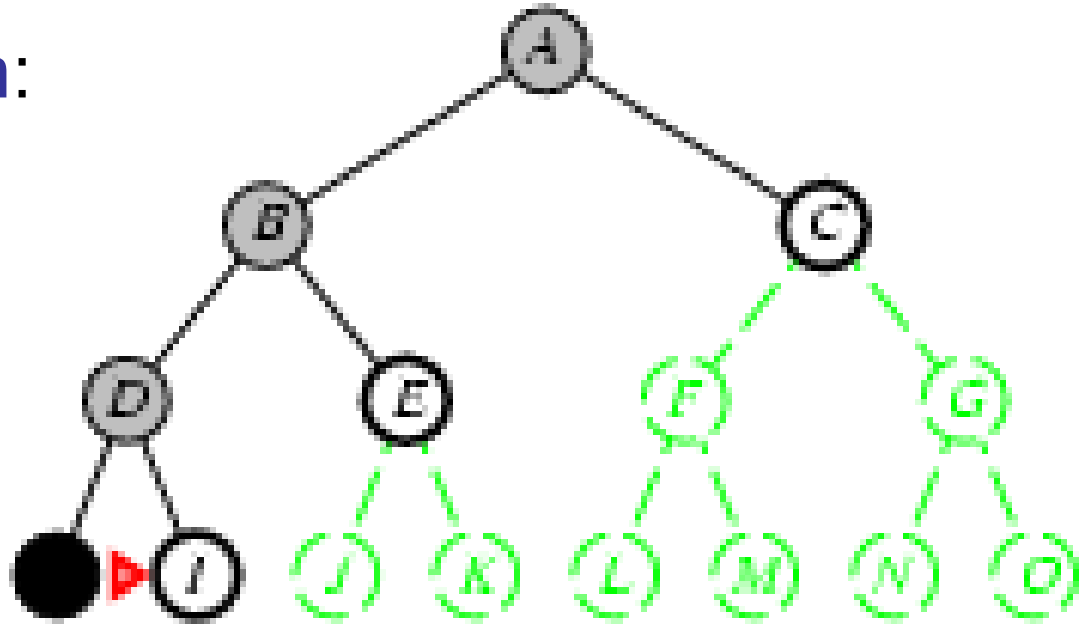

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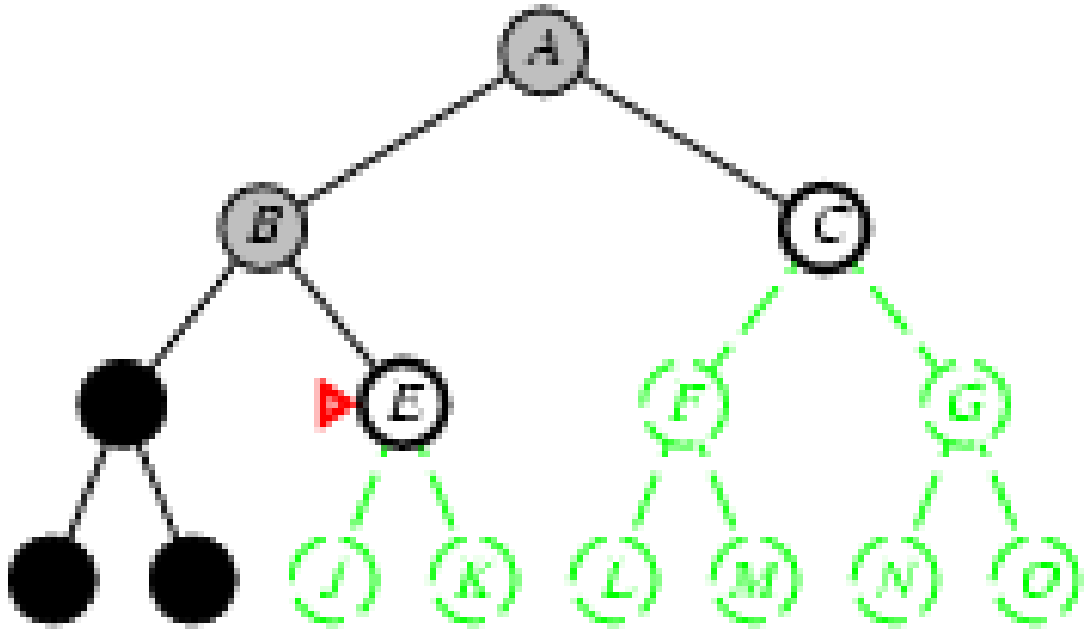
- Expand deepest unexpanded node
- Implementation:
  - *fringe* = LIFO queue, i.e., put successors at front



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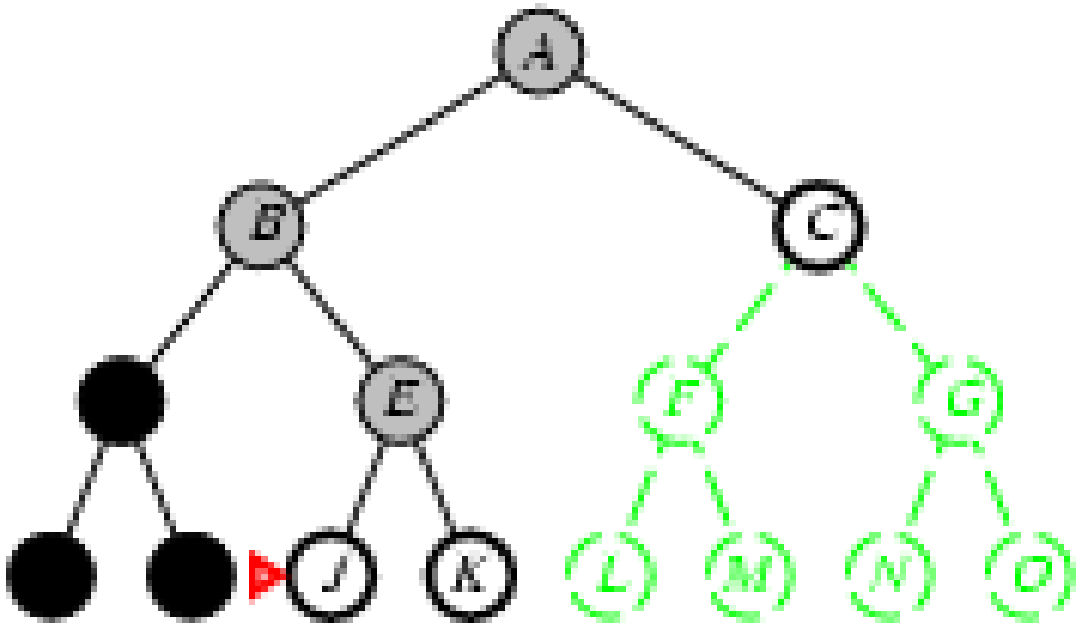

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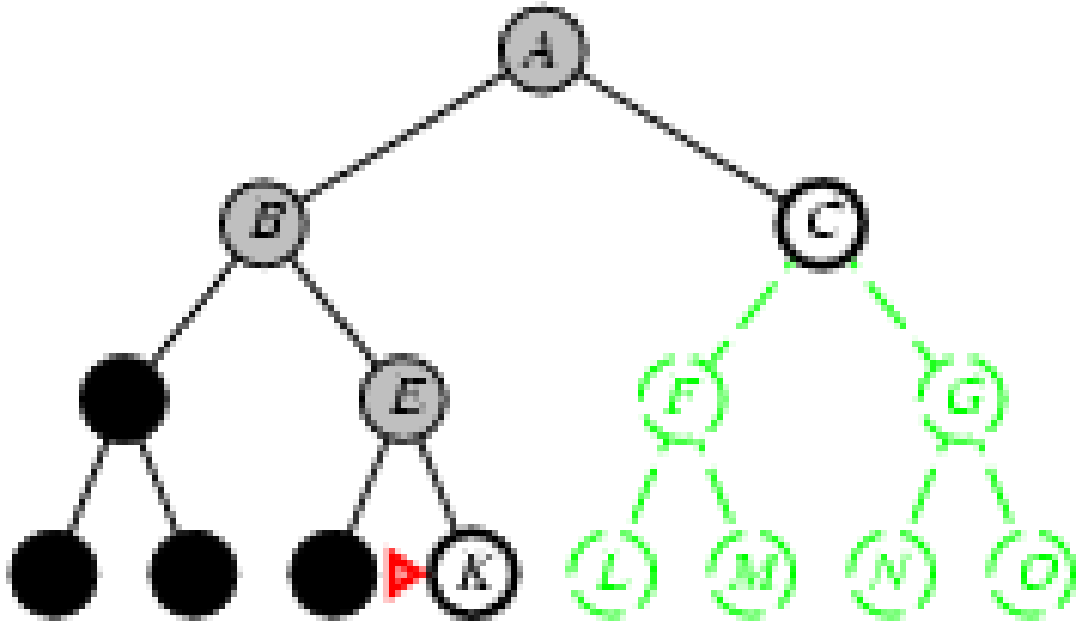

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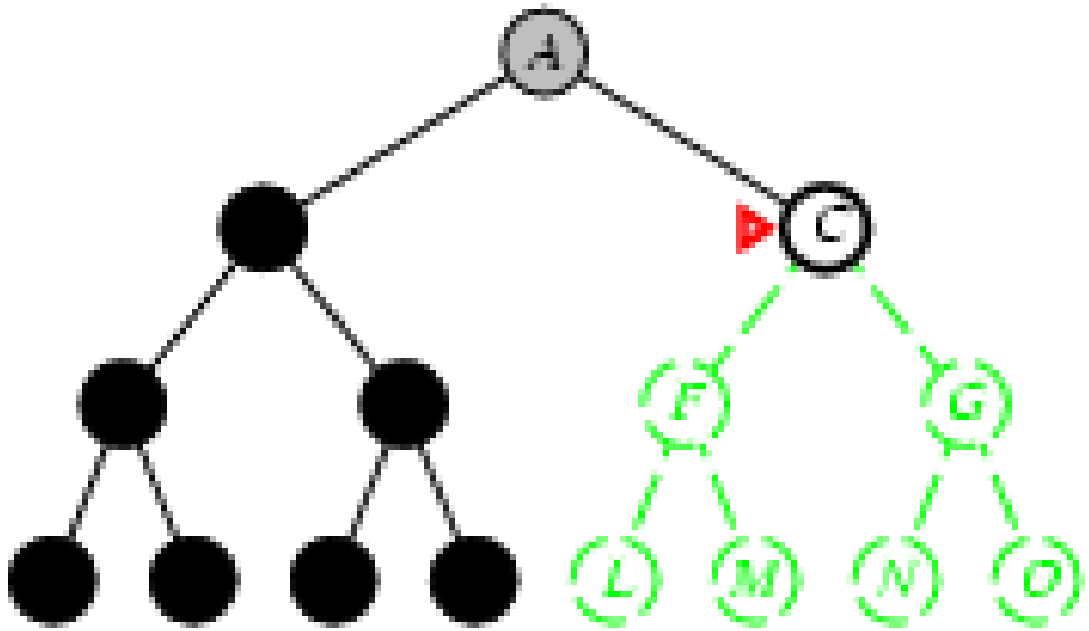

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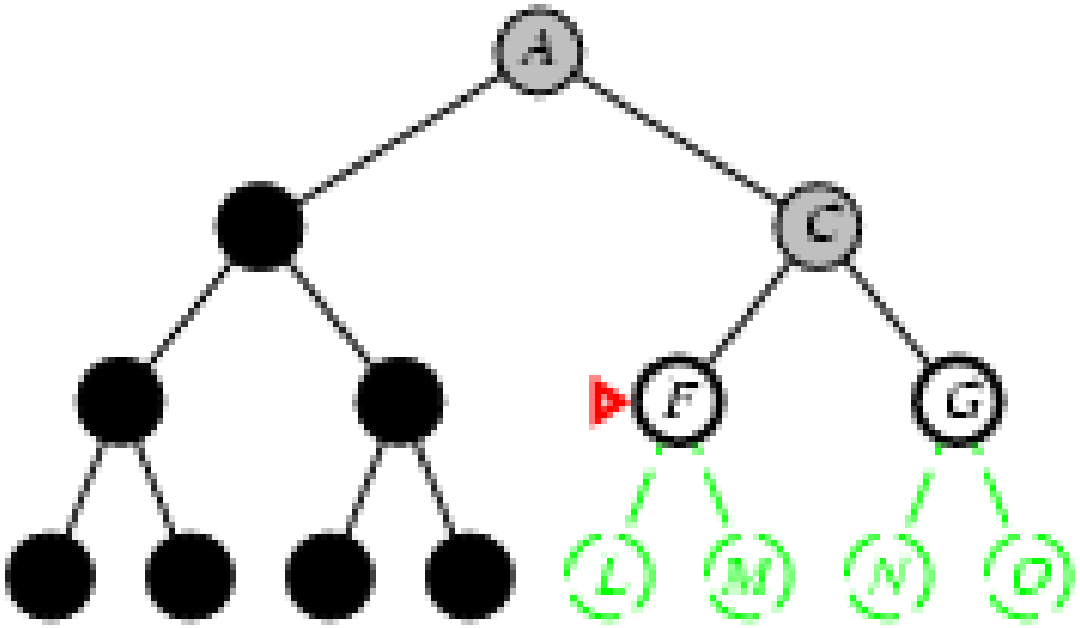

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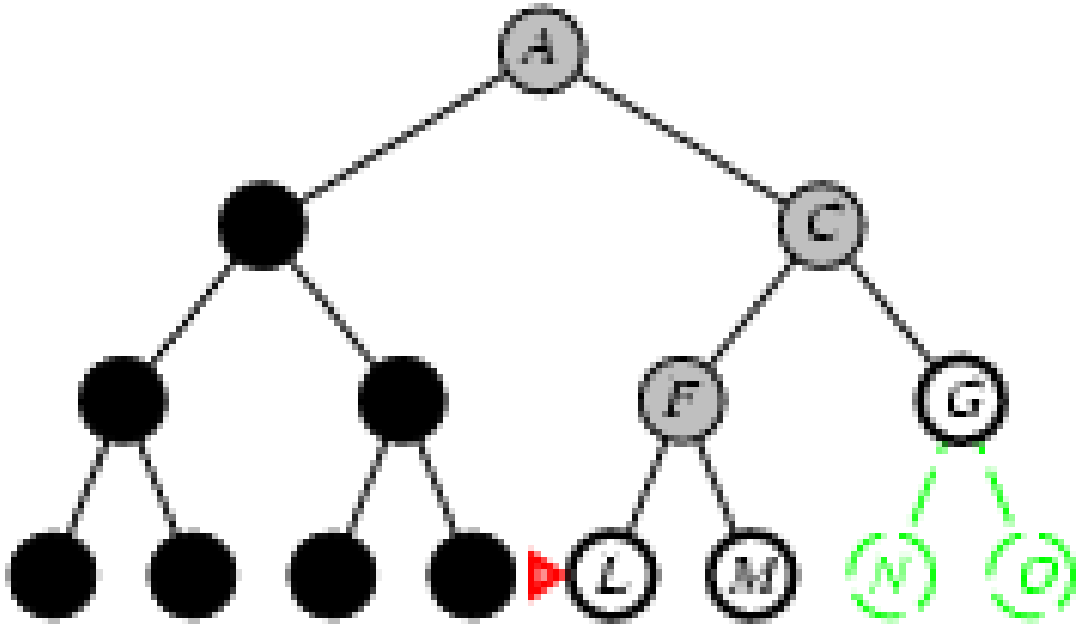

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