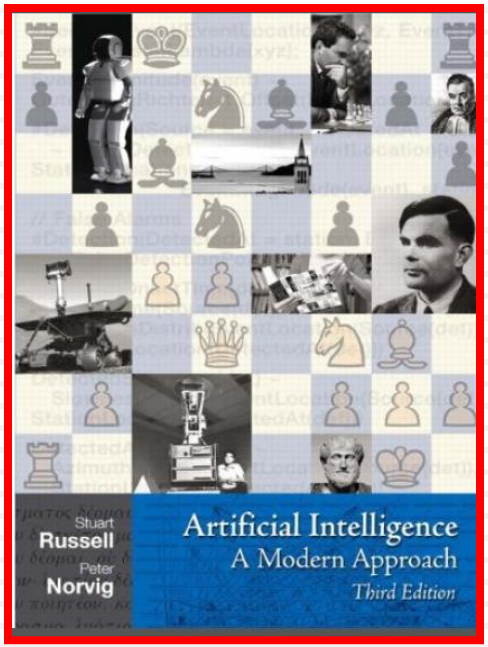
Princess Nora University
Faculty of Computer & Information Systems

ARTIFICIAL INTELLIGENCE

(CS 370D)

Computer Science
Department

جامعة الأميرة نورة بنت عبد الرحمن
Princess Nora Bint Abdul Rahman University



College of Computer and Information Sciences

(CHAPTER-3-PART2)

PROBLEM SOLVING AND SEARCH

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(Course coordinator)

Searching algorithm

Uninformed Search Algorithms(Blind Search)

3.1 Breadth first Search
3.2 Depth First Search
3.3 Depth limited Search
3.4 Iterative Deeping Search
3. 5 Bidirectional Search

Informed Search (Heuristic Search)

Best First Search
Greedy Search
Perfect Information Search
A* Search
Iterative Deepening A* Search
A* with PathMax

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Uninformed Search Algorithms(Blind Search)

1. Breadth first Search
2. Uniform Cost Search (UCS)
3. Depth First Search
4. Depth limited Search
5. Iterative Deeping Search
6. Bidirectional Search

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Blind Searches - Characteristics

- Simply searches the State Space

- Can only distinguish between a **goal state** and **a non-goal state**

- Blind Searches have no **preference** as to which state (node) that is expanded next.

- The different types of blind searches are characterised by the **order** in which they **expand the nodes**.

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1-Breadth first Search

- Use a queuing function that adds nodes to the end of the queue (**FIFO**)
- Expand Root Node First
- Expand all nodes at level **1** before expanding level **2**

OR

- Expand all nodes at level **d** before expanding nodes at level **d+1**
- Assuming all nodes that are visited **first** will be expanded **first**

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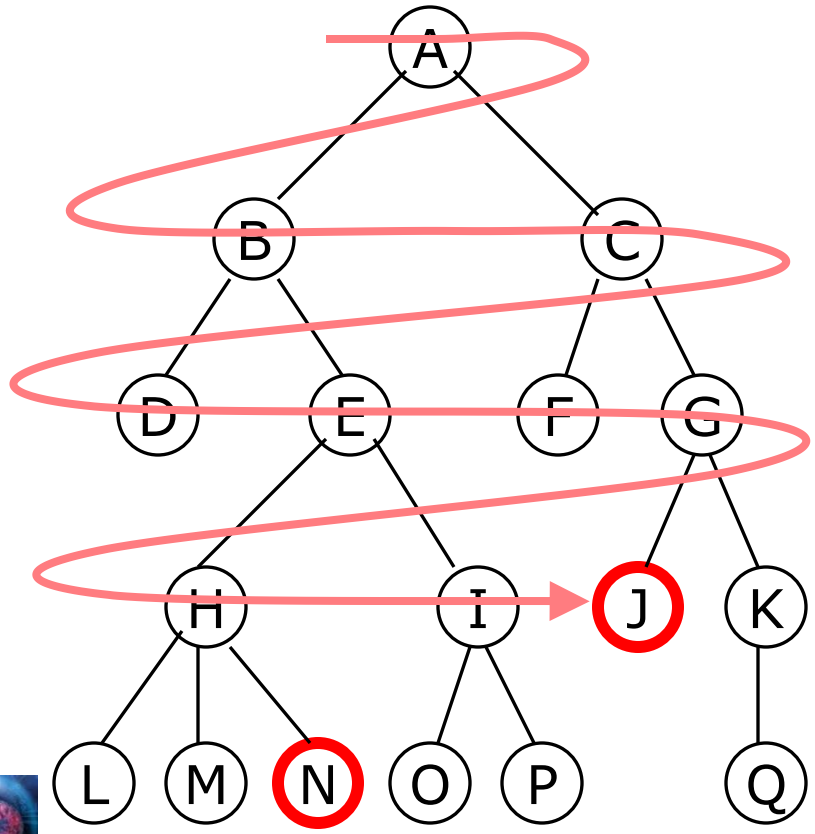
1-Breadth-first searching



- A breadth-first search (BFS) explores nodes nearest the root before exploring nodes further away
- For example, after searching A, then B, then C, the search proceeds with D, E, F, G
- Node are explored in the order A B C D E F G H I J K L M N O P Q
- J will be found before N

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Evaluating Breadth First Search

- **Observations**
  - Very systematic
  - **If** there is a solution breadth first search is guaranteed to find it
  - **If** there are several solutions then breadth first search will always find the shallowest (having little depth) goal state first and
  - **if** the cost of a solution is a non-decreasing function of the depth then it will always find the cheapest solution

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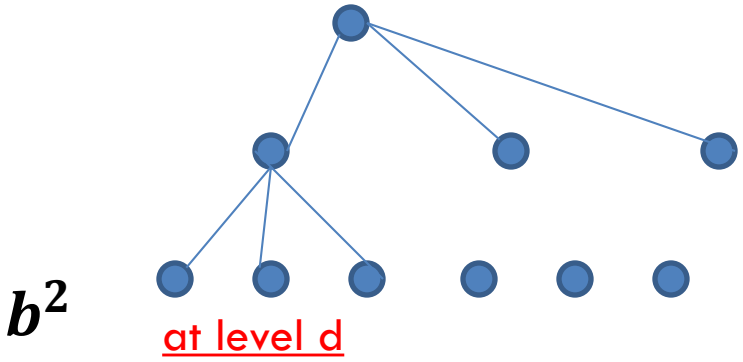
Evaluating Breadth First Search



- Space Complexity : $1 + b + b^2 + b^3 + \ldots + b^d$ i.e $O(b^d)$
- Time Complexity : $1 + b + b^2 + b^3 + \ldots + b^d$ i.e. $O(b^d)$

- Where **b** is the branching factor and **d** is the depth of the search tree

- Note : The space/time complexity could be less as the solution could be found anywhere on the **d^{th}** level.

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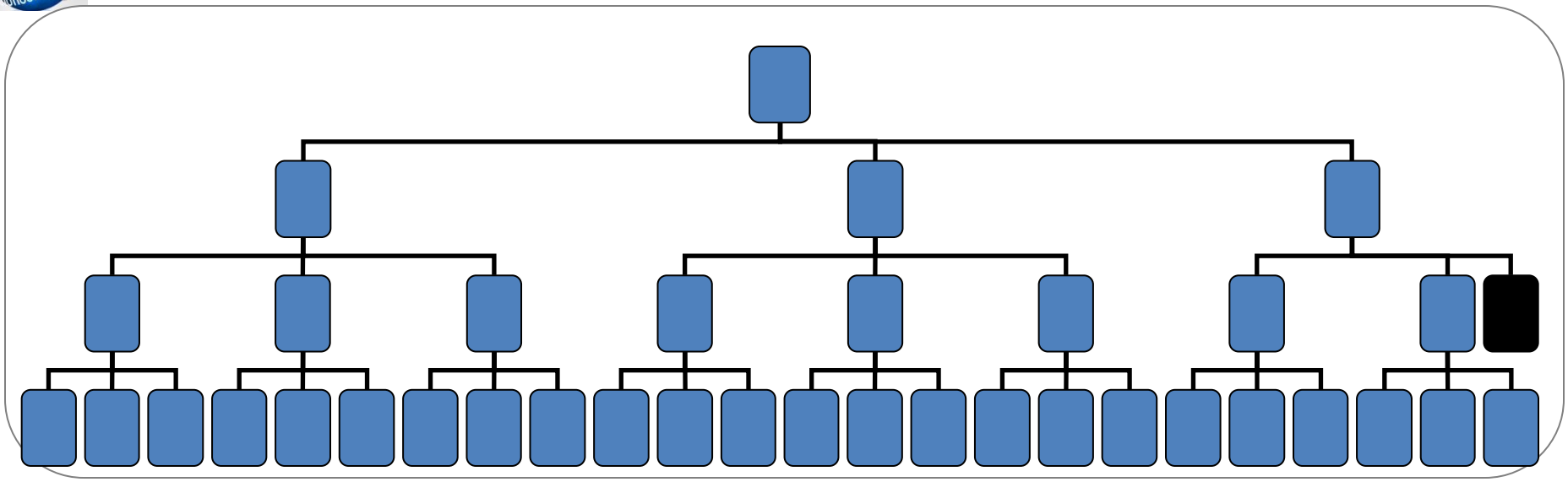
Evaluating Breadth First Search



- Every node that is generated must remain in memory so space complexity is therefore as time complexity
- Memory requirements are a bigger problem for breadth first search than is the execution

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2-Uniform Cost Search (UCS)

- Expand the **cheapest** node.
- **Main idea**: Expand the cheapest node. Where the cost is the path cost g(n).
- **Implementation**: Enqueue nodes in order of cost g(n) in the queue **frontier**(insert in order of increasing path cost).

  - **If a node n already exists in Frontier and a new path to n is found with a smaller cost, remove the node n from Frontier and insert the new node n with the new cost into Frontier**

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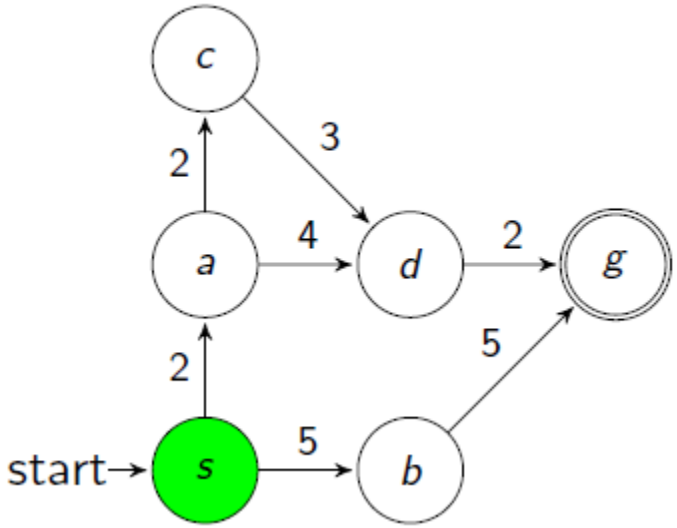
Uniform Cost Search (UCS)

Q:

path	cost
$\langle s \rangle$	0



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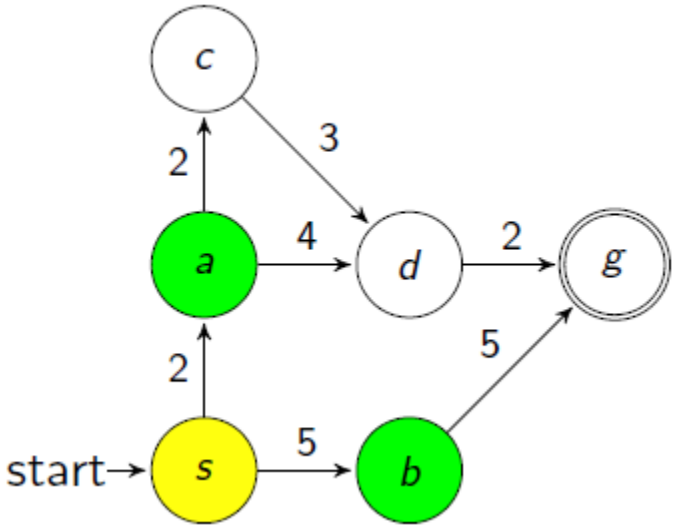
Uniform Cost Search (UCS)

Q:

path	cost
$\langle a, s \rangle$	2
$\langle b, s \rangle$	5



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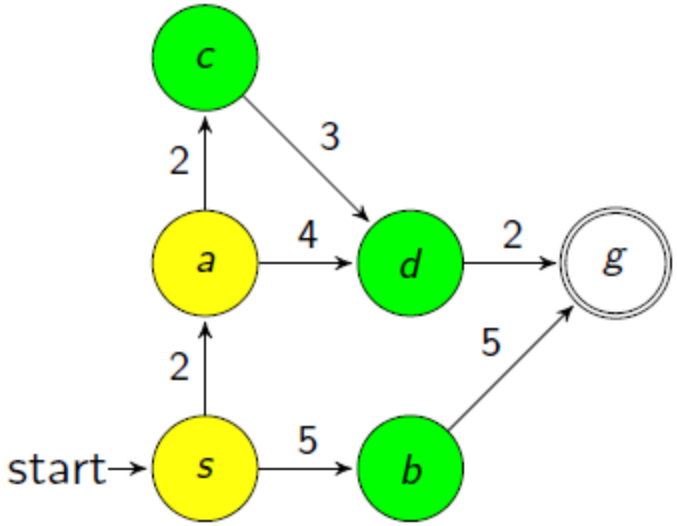
Uniform Cost Search (UCS)

Q:

state	cost
$\langle c, a, s \rangle$	4
$\langle b, s \rangle$	5
$\langle d, a, s \rangle$	6



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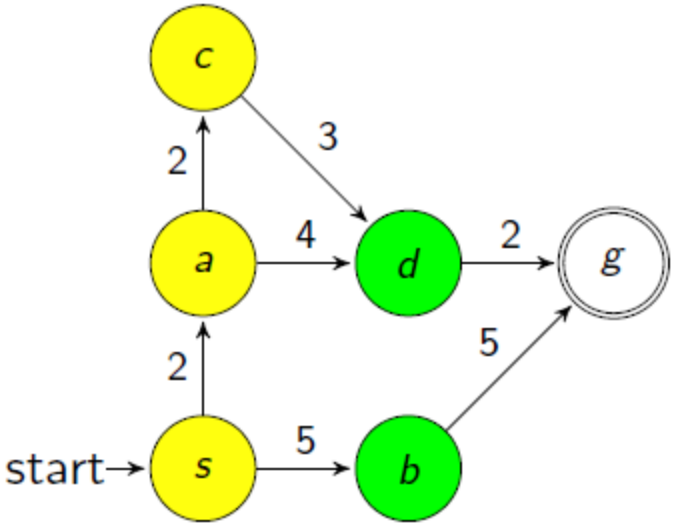
Uniform Cost Search (UCS)

Q:

state	cost
$\langle b, s \rangle$	5
$\langle d, a, s \rangle$	6
$\langle d, c, a, s \rangle$	7



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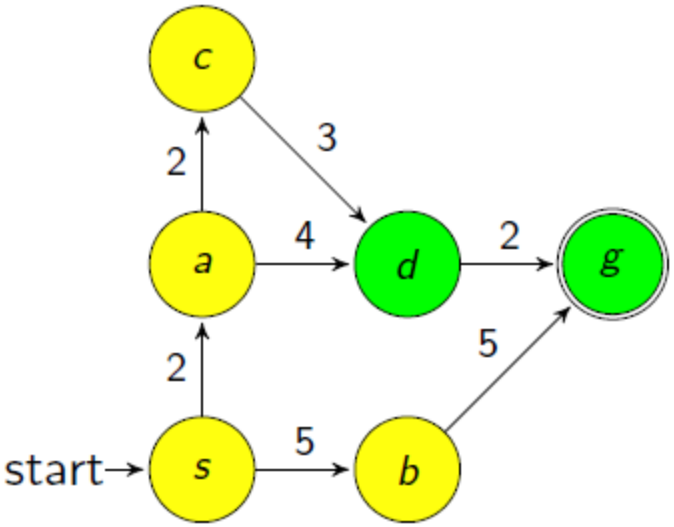
Uniform Cost Search (UCS)

Q:

state	cost
$\langle d, a, s \rangle$	6
$\langle d, c, a, s \rangle$	7
$\langle g, b, s \rangle$	10



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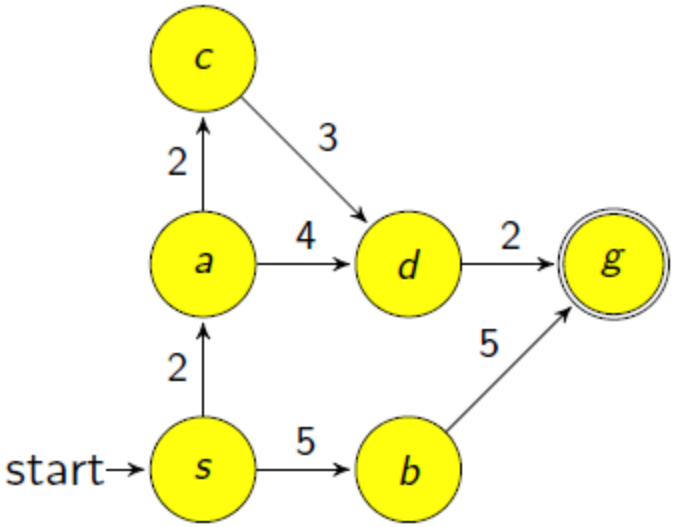
Uniform Cost Search (UCS)

Q:

state	cost
$\langle d, c, a, s \rangle$	7
$\langle g, d, a, s \rangle$	8
$\langle g, b, s \rangle$	10



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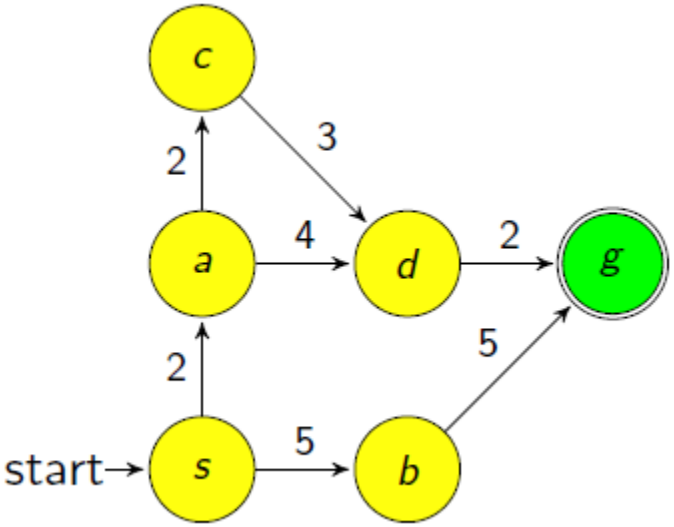
Q:

state	cost
$\langle g, d, a, s \rangle$	8
$\langle g, d, c, a, s \rangle$	9
$\langle g, b, s \rangle$	10



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Uniform Cost Search (UCS)

- UCS is an extension of BFS to the weighted-graph case
- (UCS = BFS if all edges have the same cost).

Complete? Yes

Time? $O(b^d)$

Space? : $O(b^d)$, note that every node in the fringe keep in the queue.

Optimal? Yes

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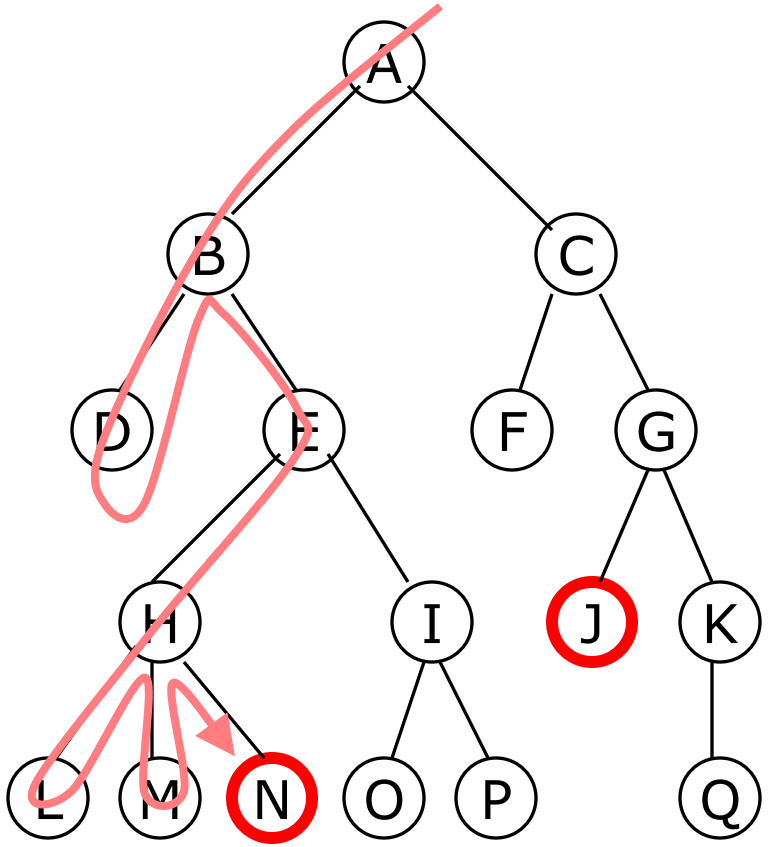
3-Depth-first searching



- A depth-first search (DFS) explores a path all the way to a leaf before backtracking and exploring another path
- For example, after searching A, then B, then D, the search **backtracks** and tries another path from B
- Node are explored in the order A B D B E H L H M H N H E I O I P I E B A C F C G J G K Q
- N will be found before J

- Always expands the **deepest** node in the current fringe
- The search proceeds immediately to deepest level of search tree , where nodes have no successors
- As those nodes are expanded they are dropped from fringe
- Can be implemented by **LIFO** queue (stack)
- For memory , this algorithm need only to store one path

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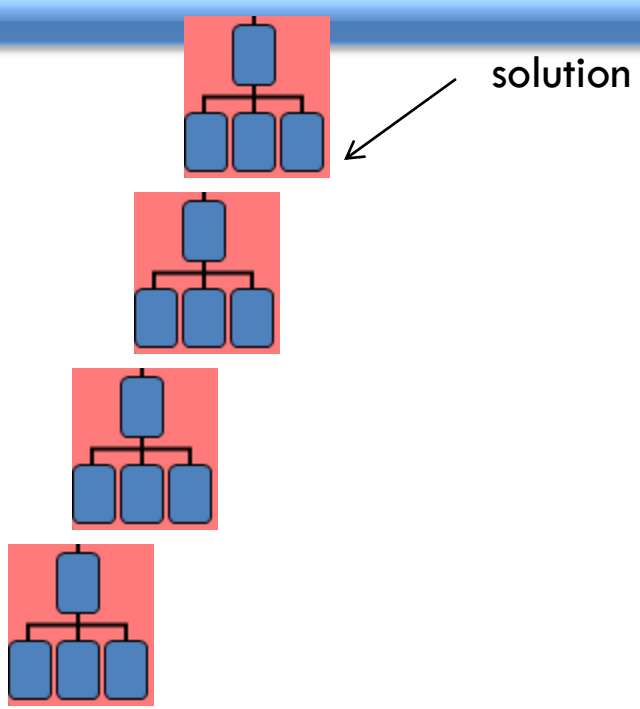
4-Depth-limited search



- The depth first search disadvantage is that the algorithm go deep and deep while solution may be near root
- It is depth-first search with an imposed **limit** on the depth of exploration, to guarantee that the algorithm ends.

Depth-limited search

= depth-first search with depth limit *l*,

i.e., nodes at depth *l* have no successors

- Recursive implementation:

```
function DEPTH-LIMITED-SEARCH( problem, limit) returns soln/fail/cutoff
    RECURSIVE-DLS(MAKE-NODE(INITIAL-STATE[problem]), problem, limit)

function RECURSIVE-DLS(node, problem, limit) returns soln/fail/cutoff
    cutoff-occurred? ← false
    if GOAL-TEST[problem](STATE[node]) then return SOLUTION(node)
    else if DEPTH[node] = limit then return cutoff
    else for each successor in EXPAND(node, problem) do
        result ← RECURSIVE-DLS(successor, problem, limit)
        if result = cutoff then cutoff-occurred? ← true
        else if result ≠ failure then return result
    if cutoff-occurred? then return cutoff else return failure
```

5-Iterative Deeping Search

- The algorithm consists of iterative, depth-first searches, with a maximum depth that increases at each iteration. Maximum depth at the beginning is 1.
- Only the actual path is kept in memory; nodes are regenerated at each iteration.
- DFS problems related to infinite branches are avoided.
- To guarantee that the algorithm ends if there is no solution, a general maximum depth of exploration can be defined.

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5-Iterative Deeping Search

- Depth-limited search, with
  - depth = 0
  - then again with depth = 1
  - then again with depth = 2
  - ... until you find a solution

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5-Iterative Deeping Search

Depth = 0

Depth Limit = 0

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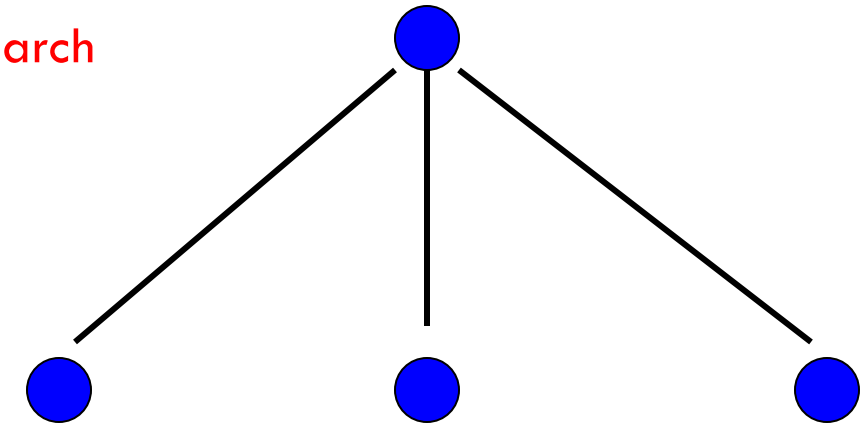
5-Iterative Deeping Search

Depth = 0

Depth Limit = 1



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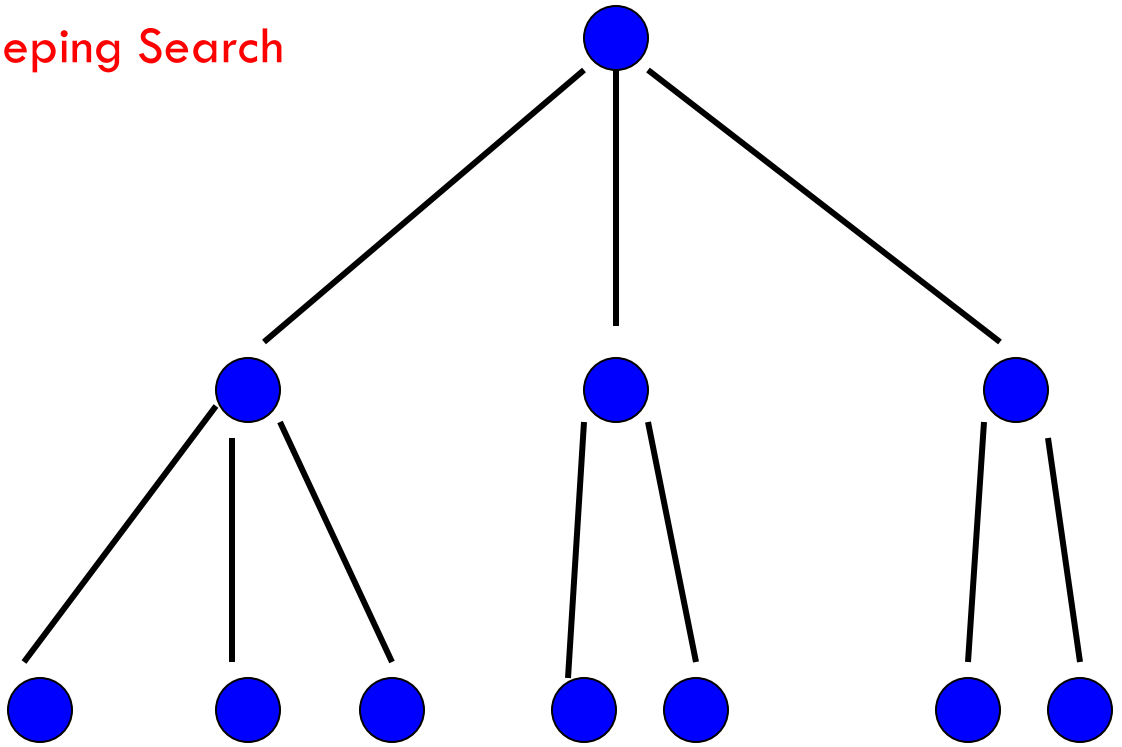
5-Iterative Deeping Search

Depth Limit = 2



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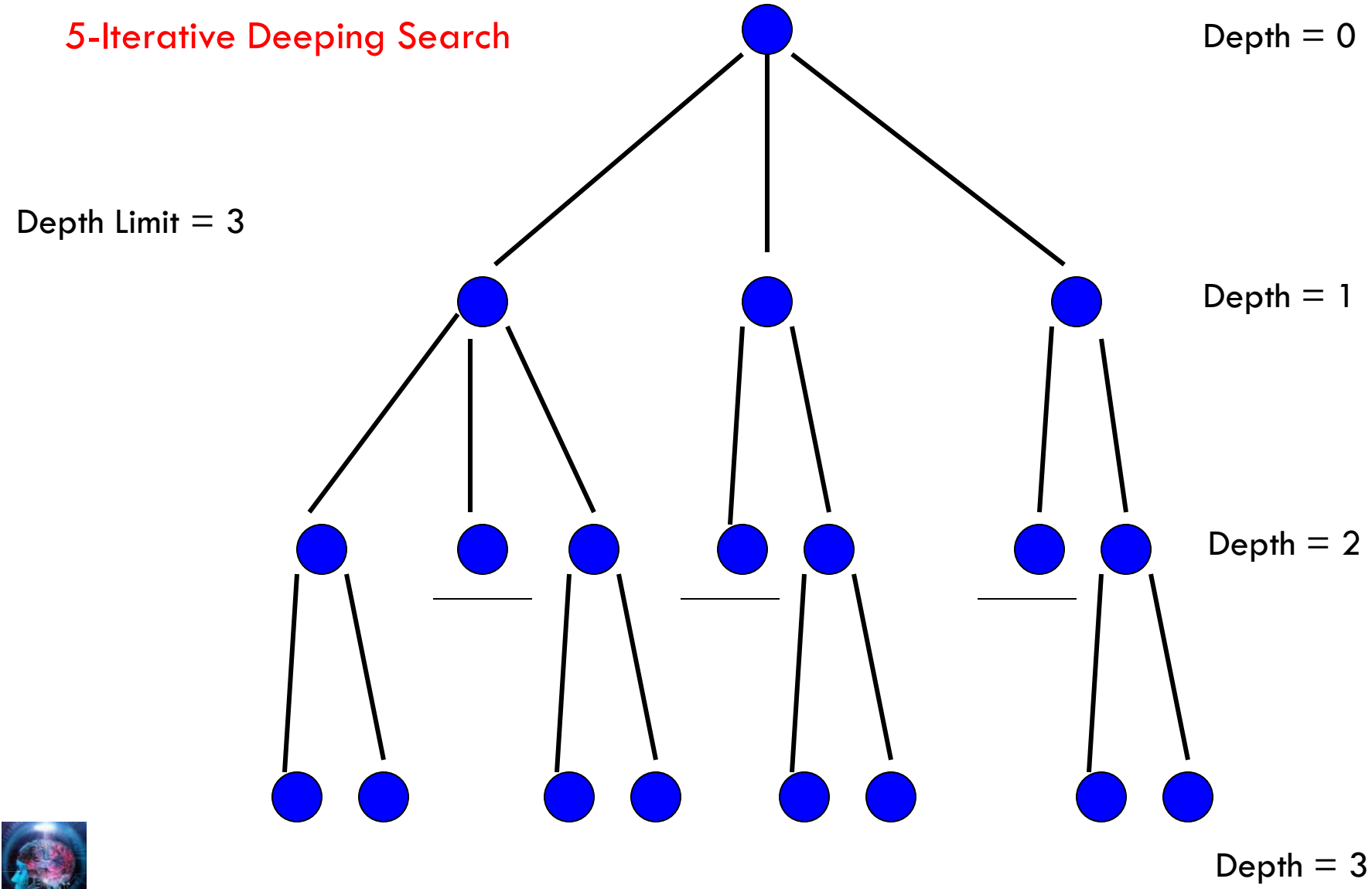
5-Iterative Deeping Search



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6-Bidirectional Search

- Start searching forward from initial state and backwards from goal, and try to meet in the middle

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Thank you

End of Chapter 3-Part2

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