# Uninformed Search (Ch. 3-3.4)

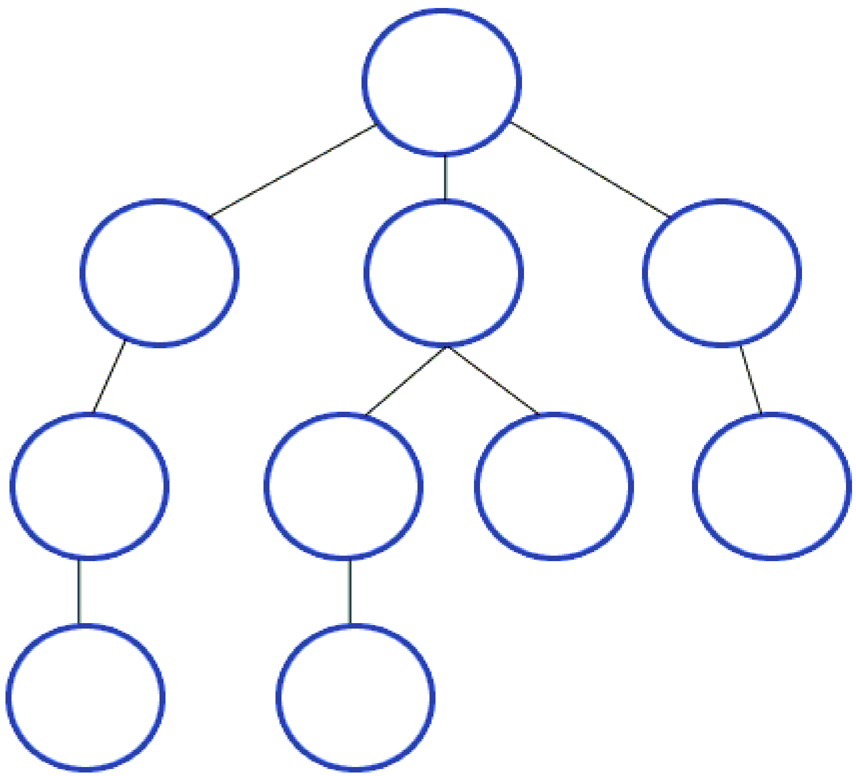
# Announcements

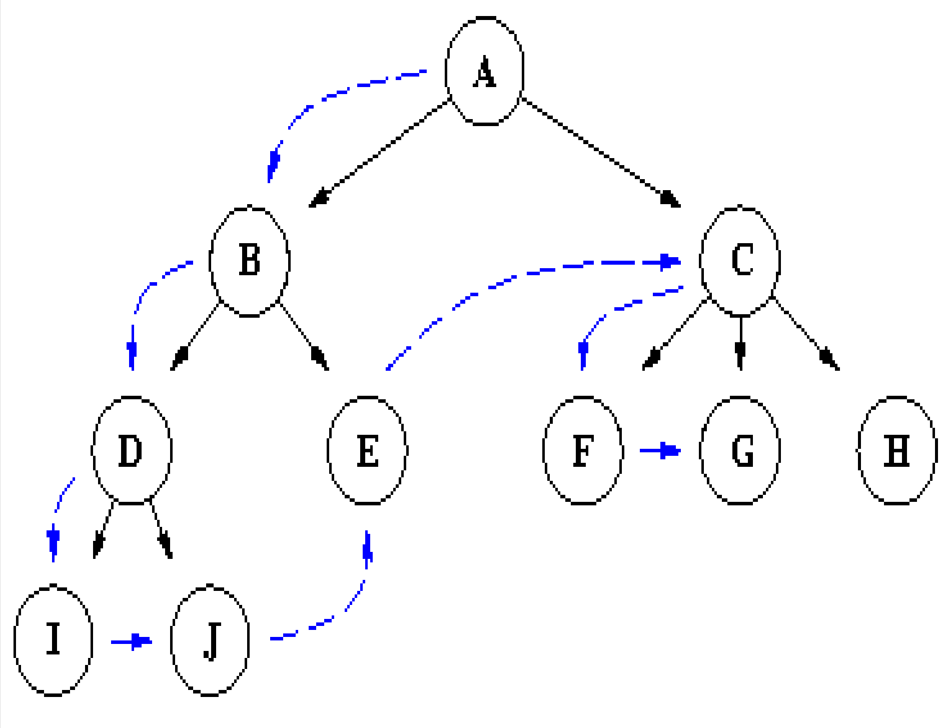
Writing 1 due tonight

Homework 2 posted tonight

# Depth first search

DFS is same as BFS except with a FILO (or LIFO) instead of a FIFO queue





# Depth first search

Metrics:

1. Might not terminate (not complete) (e.g. in vacuum world, if first expand is action L)
2. Non-optimal (just... no)
3. Time complexity = $O(b^m)$
4. Space complexity = $O(b*m)$

Only way this is better than BFS is the space complexity...

# Depth limited search

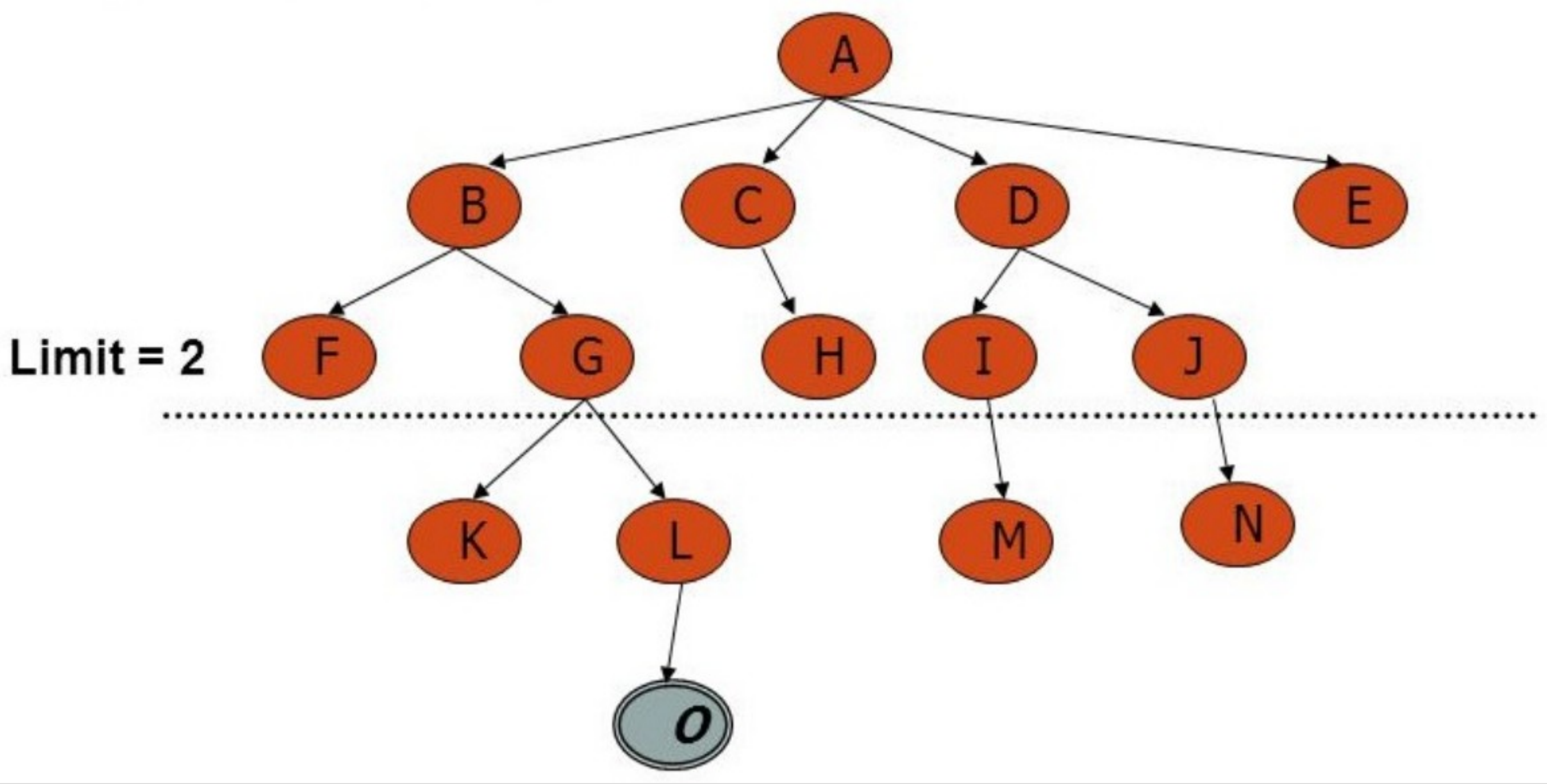
DFS by itself is not great, but it has two (very) useful modifications

Depth limited search runs normal DFS, but if it is at a specified depth limit, you cannot have children (i.e. take another action)

Typically with a little more knowledge, you can create a reasonable limit and makes the algorithm correct

# Depth limited search

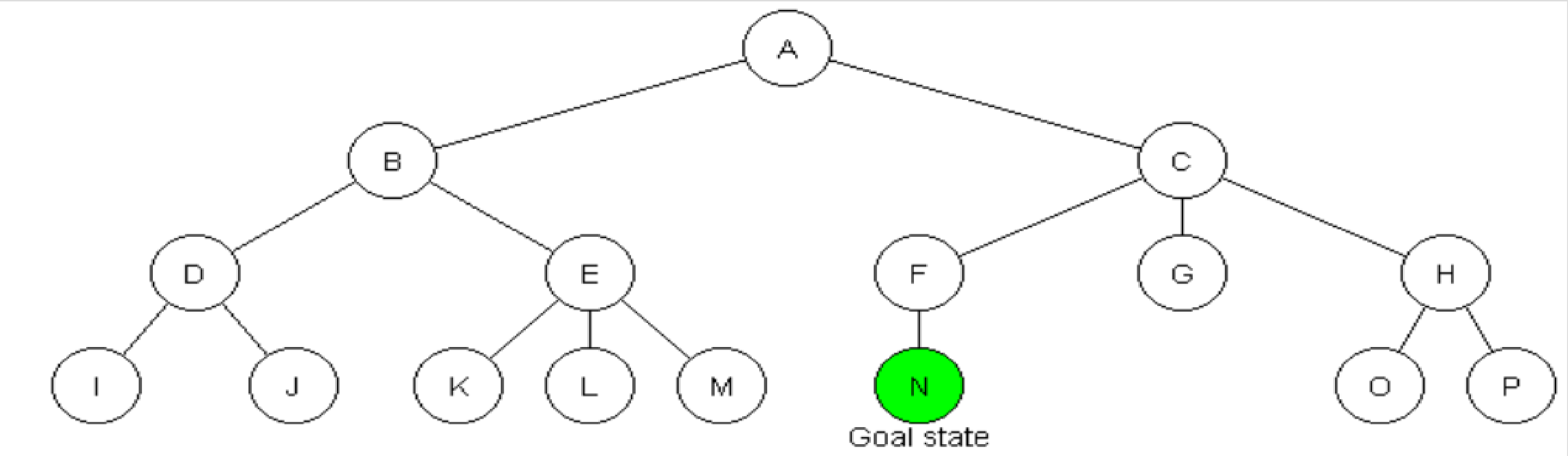
However, if you pick the depth limit before d, you will not find a solution (not correct, but will terminate)



# Iterative deepening DFS

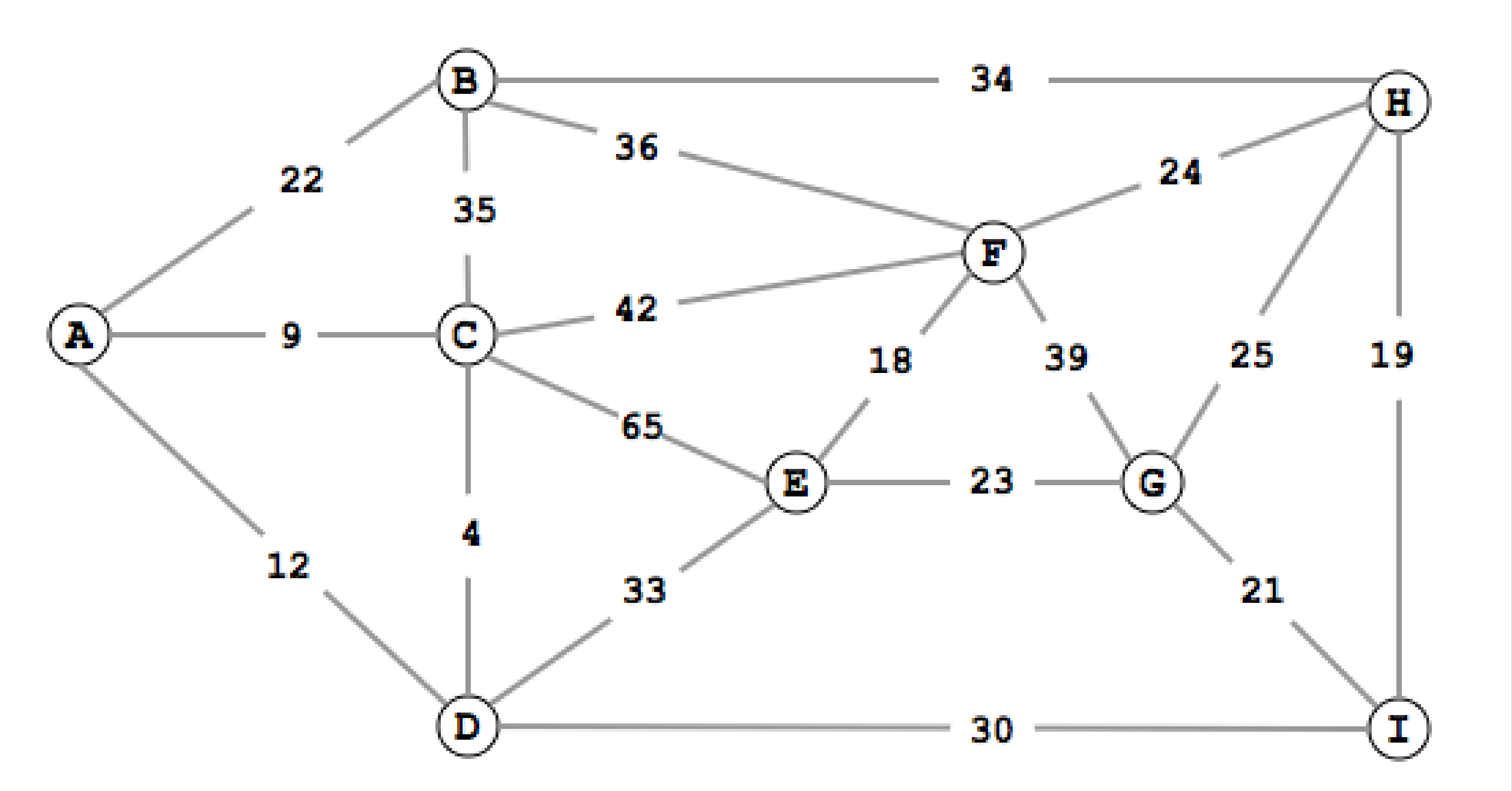
Probably the most useful uninformed search is iterative deepening DFS

This search performs depth limited search with maximum depth 1, then maximum depth 2, then 3... until it finds a solution

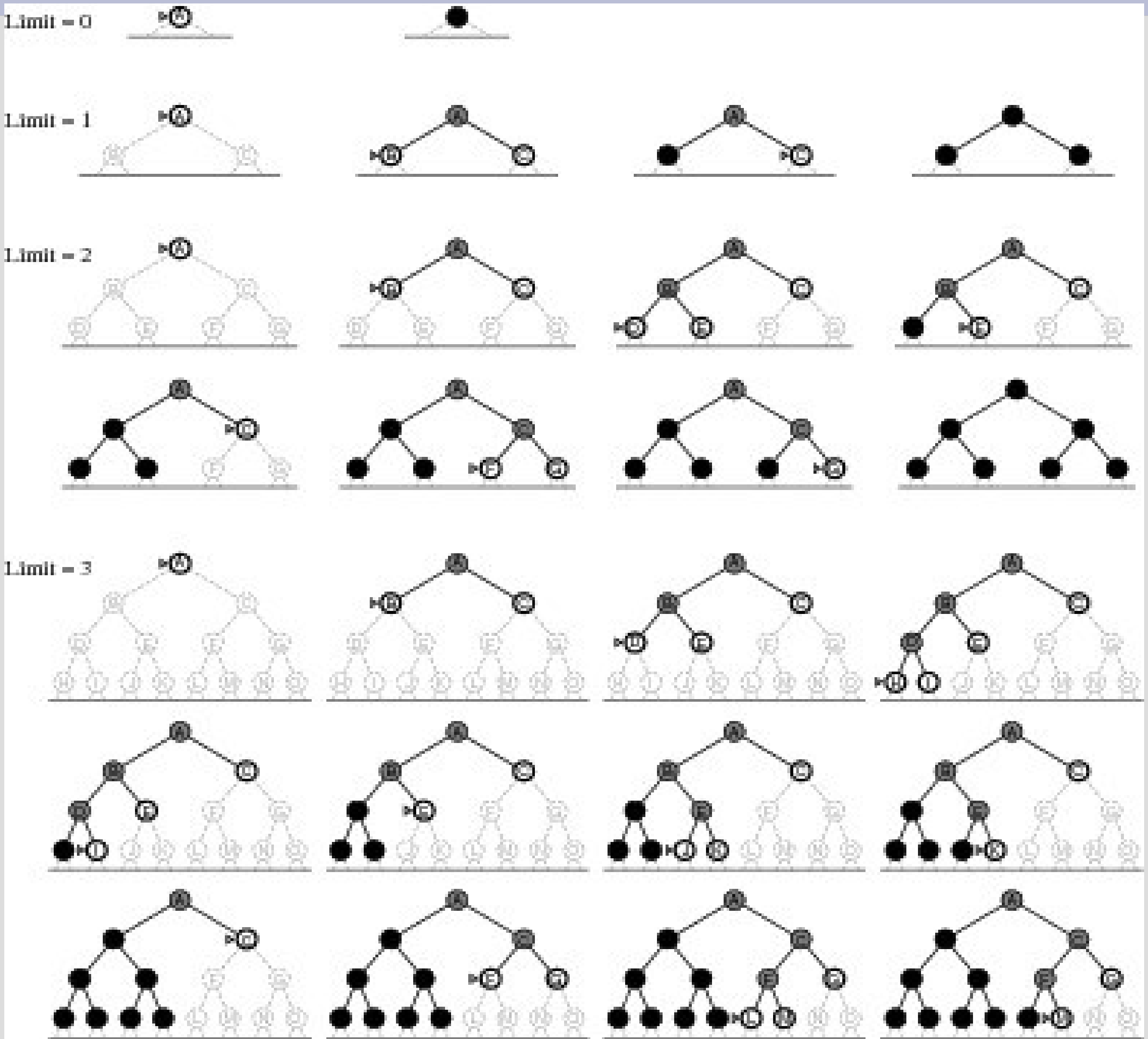


# Iterative deepening DFS

Try to use iterative deepening DFS on this:
Initial=A, Goal=G



# Iterative deepening DFS



# Iterative deepening DFS

The first few states do get re-checked multiple times in IDS, however it is not too many

When you find the solution at depth d, depth 1 is expanded d times (at most b of them)

The second depth are expanded d-1 times (at most $b^2$ of them)

Thus $(d+1)\cdot 1 + d\cdot b + (d-1)\cdot b^2 + ... + 1\cdot b^d = O(b^d)$

# Iterative deepening DFS

Metrics:
1. Complete
2. Non-optimal (unless uniform cost)
3. $O(b^d)$
4. $O(b*d)$

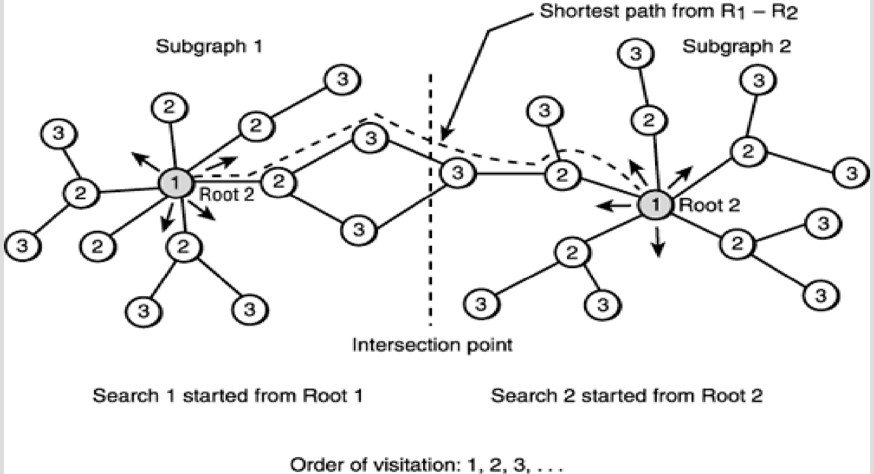
Thus IDS is better in every way than BFS (asymptotically)

One of the best uninformed searches

# Bidirectional search

Bidirectional search starts from both the goal and start (using BFS) until the trees meet

This is better as $2*(b^{d/2}) < b^d$
(the space is much worse than IDS, so only applicable to smaller problems)



# Bidirectional search

| 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.

# Summary of algorithms
# Fig. 3.21, p. 91

| Criterion | Breadth-First | Uniform-Cost | Depth-First | Depth-Limited | Iterative Deepening DLS | Bidirectional (if applicable) |
|---|---|---|---|---|---|---|
| Complete? | Yes[a] | Yes[a,b] | No | No | Yes[a] | Yes[a,d] |
| Time | $O(b^d)$ | $O(b^{\lfloor 1+C^*/\varepsilon \rfloor})$ | $O(b^m)$ | $O(b^l)$ | $O(b^d)$ | $O(b^{d/2})$ |
| Space | $O(b^d)$ | $O(b^{\lfloor 1+C^*/\varepsilon \rfloor})$ | $O(bm)$ | $O(bl)$ | $O(bd)$ | $O(b^{d/2})$ |
| Optimal? | Yes[c] | Yes | No | No | Yes[c] | Yes[c,d] |

Generally the preferred uninformed search strategy

There are a number of footnotes, caveats, and assumptions.
See Fig. 3.21, p. 91.
[a] complete if b is finite
[b] complete if step costs $\geq \varepsilon > 0$
[c] optimal if step costs are all identical
(also if path cost non-decreasing function of depth only)
[d] if both directions use breadth-first search
(also if both directions use uniform-cost search with step costs $\geq \varepsilon > 0$)