CSC520 - Artificial Intelligence
Lecture 4

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Agenda

- Uninformed Search
  - Breadth First Search
  - Depth First Search
  - Iterative Deepening Search
  - Uniform Cost Search

Problem Recap

Agent

- Function
- Program
- Architecture

Task Environment

- Fully vs. Partially Observable
- Deterministic vs. Stochastic
- Episodic vs. Sequential
- Static vs. Dynamic
- Discrete vs. Continuous
- Known vs. Unknown
- Single vs. Multi-agent

Search Problem

- State Space
- Initial State
- Goal State
- Actions
- Transition Model
- Action Cost Function

Roadmap

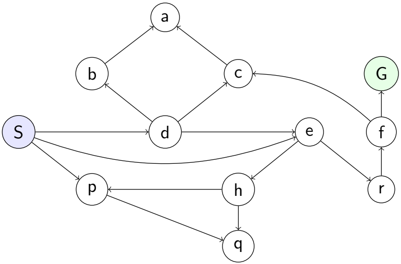
Ethics

Logic, Probability, Uncertainty, ...

Search

Problem

State Space vs Search Tree



State Space

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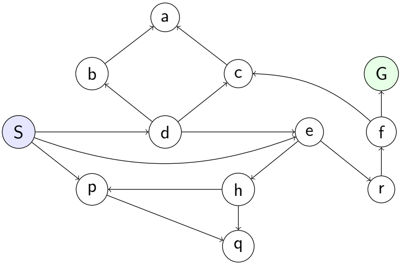

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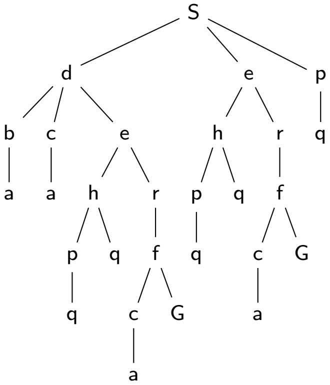

Search Tree

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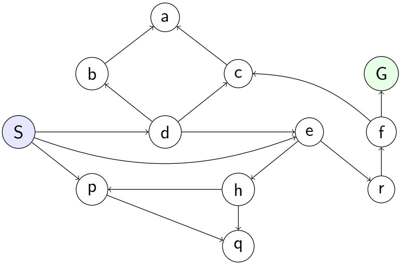

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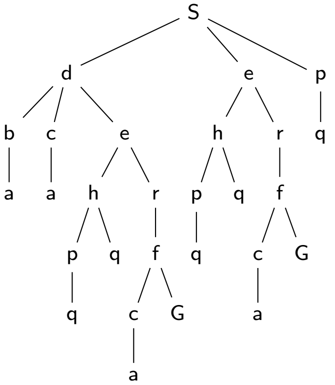

Search Tree

- What if the state space has a cycle?

Uninformed Search

- No knowledge of how close a state is to the goal state
- Systematically expand the nodes from the start node
  - A path is *redundant* if it contains a cycle OR if a lower cost path exists
  - *Tree* search does not check for redundant paths
  - *Graph* search checks for redundant paths
- Frontier is the set of unexpanded nodes
- Structure of a search tree node
  - State
  - Parent
  - Action
  - Path cost

General Tree Search Algorithm

function TREE-SEARCH(*problem*, *strategy*) **return** a solution or failure
    Add the initial state to *frontier*
    while true **do**
        if *frontier* is empty **then**
            return failure
        else
            Remove a *node* for expansion from *frontier* according to *strategy*
            if *node* is a goal state **then**
                return solution
            else
                Expand *node* and add the resulting nodes to the frontier

- *strategy* = Different search algorithms based on how a node is selected for expansion

Uninformed Search

- Breadth-first search
  - Expand shallowest node first (FIFO queue)

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  - Expand shallowest node first (FIFO queue)
- Depth-first search
  - Expand deepest node first (LIFO queue or stack)
- Uniform cost search (Dijkstra's algorithm)
  - Actions have different costs
  - Expand node with lowest path cost (priority queue)

Search Algorithm Properties

- Completeness
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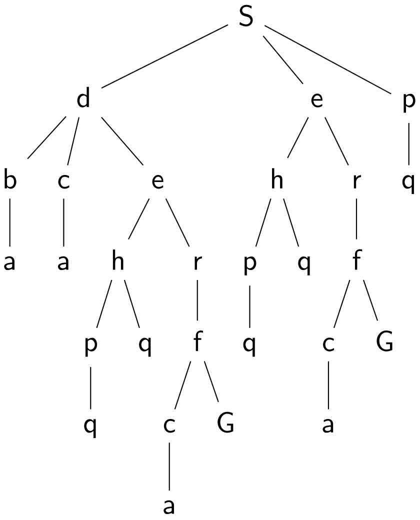
- Time complexity
  - Time taken by the algorithm measured in terms of states and actions
- Space complexity
  - Memory required by the algorithm measured in terms of states or nodes

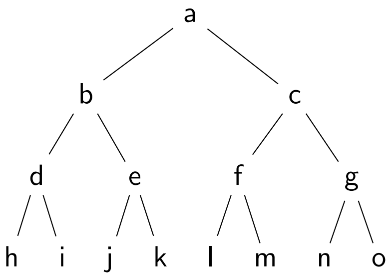
Breadth First Search



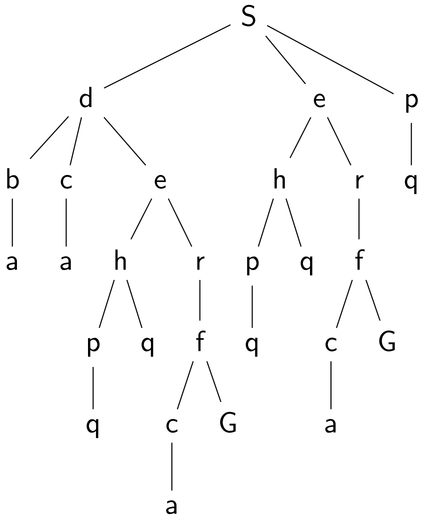
Expands shallowest node first

Breadth First Search Properties

- Completeness:
- Cost optimality:
- Time complexity
  - b is branching factor
  - d is depth of solution
  - $O(b^d)$
- Space complexity: $O(b^d)$



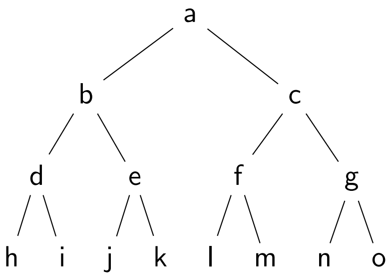
Depth First Search



Expands deepest node first

Depth First Search Properties

- Completeness:
- Cost optimality:
- Time complexity
  - b is branching factor
  - m is max depth
  - $O(b^m)$
- Space complexity: $O(bm)$



Iterative Deepening Search

- Combines benefits of BFS (completeness and optimality) and DFS (low space complexity)

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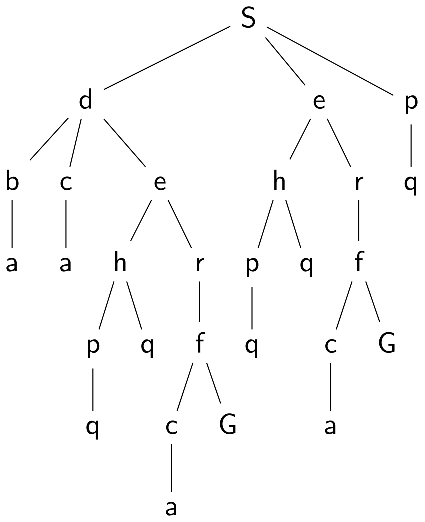
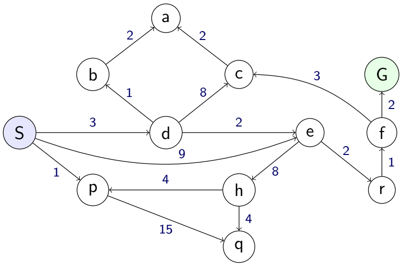
Iterative Deepening Search

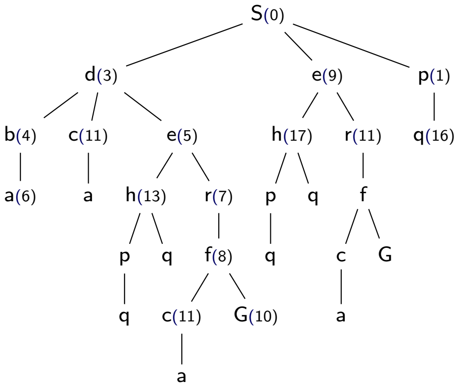
- Combines benefits of BFS (completeness and optimality) and DFS (low space complexity)
- Limit depth of DFS to prevent infinite paths
- Iterative deepening search, run DFS with depth limits $0, 1, 2, \ldots, L$
- L can be choosen based on the knowledge of the problem
  - For e.g., for the map of Romania, a suitable value of L is 19
- Completeness: Yes
- Cost Optimal: Yes
- Time complexity: $O(b^d)$
- Space complexity: $O(bd)$

Iterative Deepening Search



Uniform Cost Search





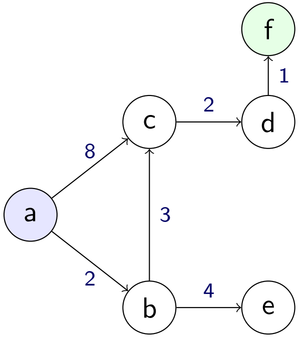
Expand node with lowest path cost

Uniform Cost Search Properties

- Expands nodes with cost less than cheapest solution
- Suppose C^* is the cheapest cost and ϵ is the least action cost. Then the tree depth will roughly be C^*/ϵ
- Completeness: Yes
- Cost optimality: Yes
- Time complexity: $O(b^{C^*/\epsilon})$
- Space complexity: $O(b^{C^*/\epsilon})$

Class Exercise

- Find the solutions generated by DFS, BFS, and UCS algorithms on the following problem.



Start State: a, Goal State: f