Problem Solving By Searching

- ***Problem Solving Agents***
- Solutions and Performance
- Uninformed Search Strategies
- Avoiding Repeated States/Looping
- Partial Information
- Summary

Problem Solving Agent

Problem-solving agents: find sequence of actions that achieve goals.

Problem-Solving Steps:

1. *Goal Formulation*: where a goal is set of acceptable states.
2. *Problem Formulation:* choose the operators and state space.
3. *Search*
4. *Execute Found Solution*

Preliminaries

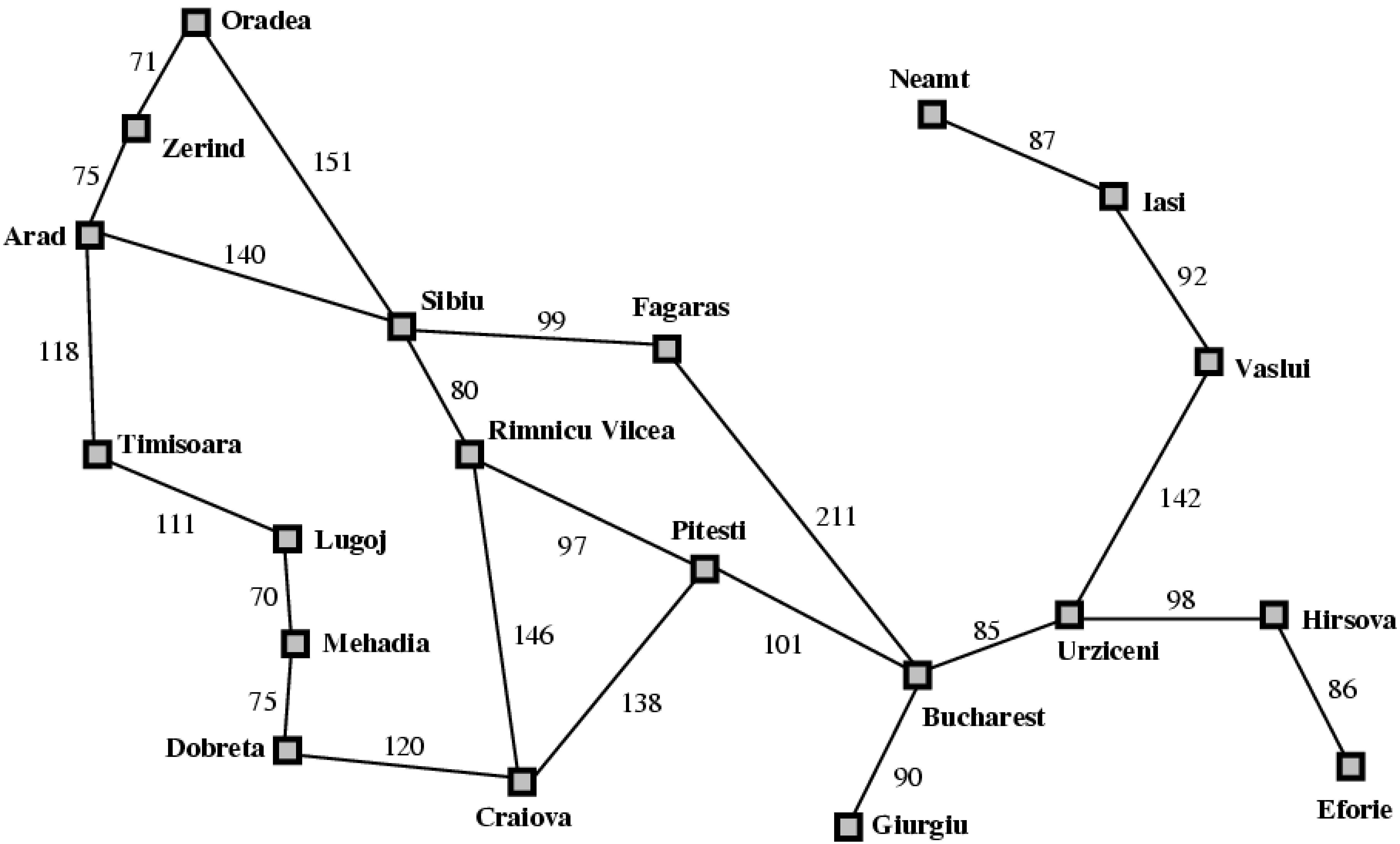
We need to define two things:

- Goal Formulation
  - ✓ Define objectives
- Problem Formulation
  - ✓ Define actions and states

Problem Formulation State Space Search

Four components:

1. The initial state
2. Actions (successor function)
3. Goal test
4. Path Cost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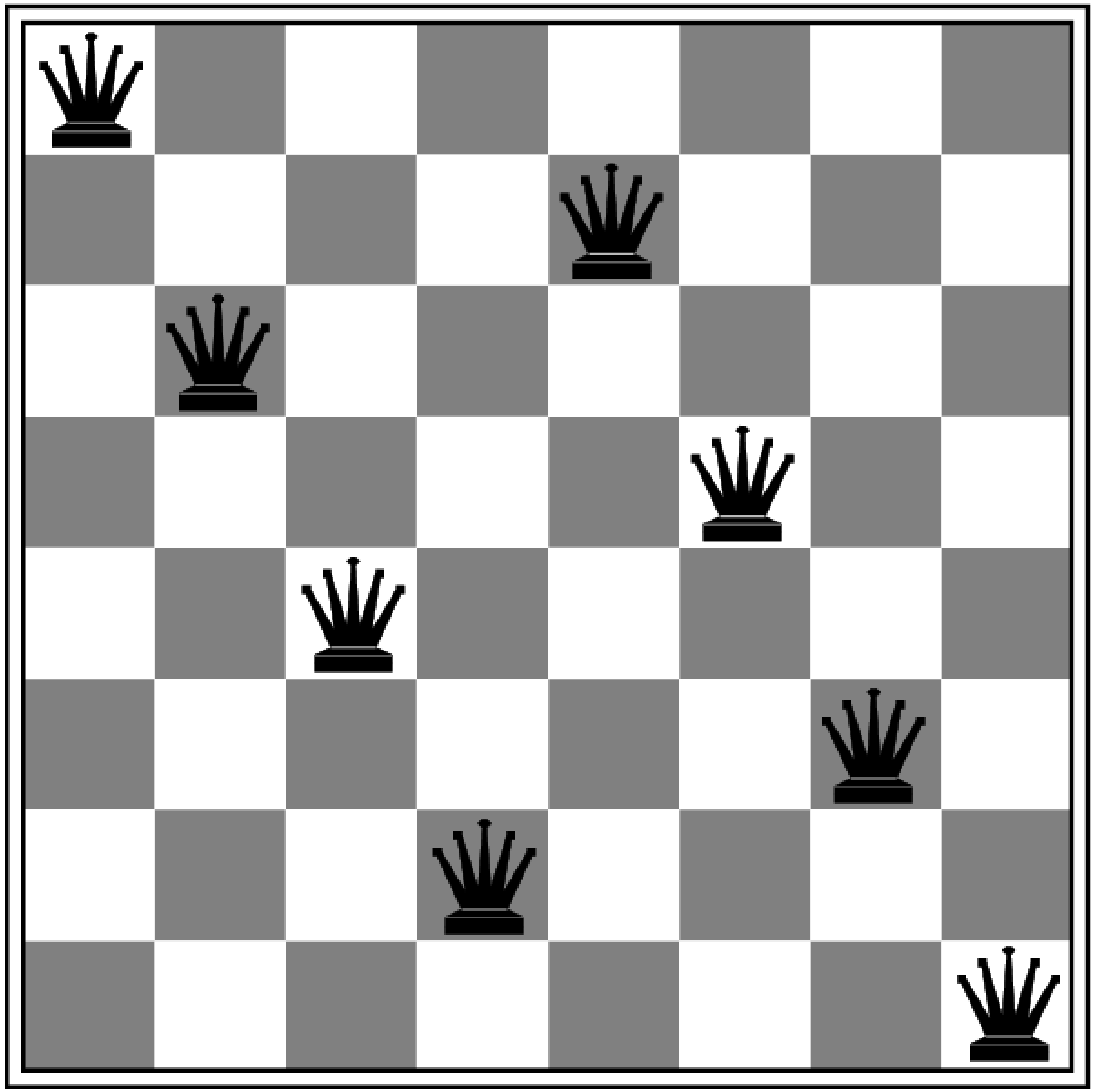
Other Examples

Toy Problems:

- ✓ Vacuum World
- ✓ 8-puzzle
- ✓ 8-queens problem



Other Examples

Real Problems

- ✓ Route-Finding Problem
- ✓ Robot Navigation
- ✓ Automatic Assembly Sequencing
- ✓ Protein Design
- ✓ Internet Searching

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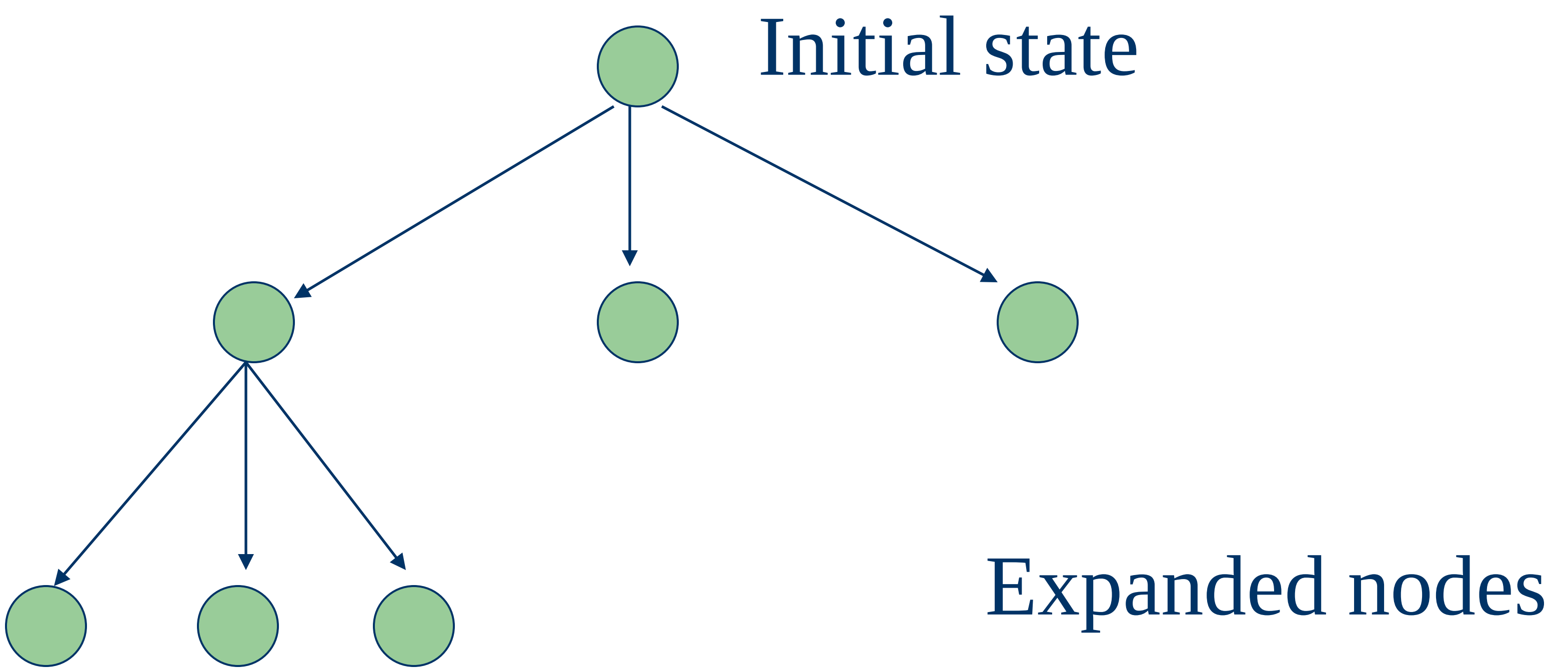
Solutions

- We search through a search tree
- We expand new nodes to grow the tree
- There are different search strategies
- Nodes contain the following:
  - ✓ state
  - ✓ parent node
  - ✓ action
  - ✓ path cost
  - ✓ *maybe* depth

Search Tree



Performance

Four elements of performance:

- Completeness (guaranteed to find solution)
- Optimality (optimal solution?)
- Time Complexity
- Space Complexity

Performance

Complexity requires three elements:

a. Branching factor **b**
b. Depth of the shallowest goal node **d**
c. Maximum length of any path **m** in the state space

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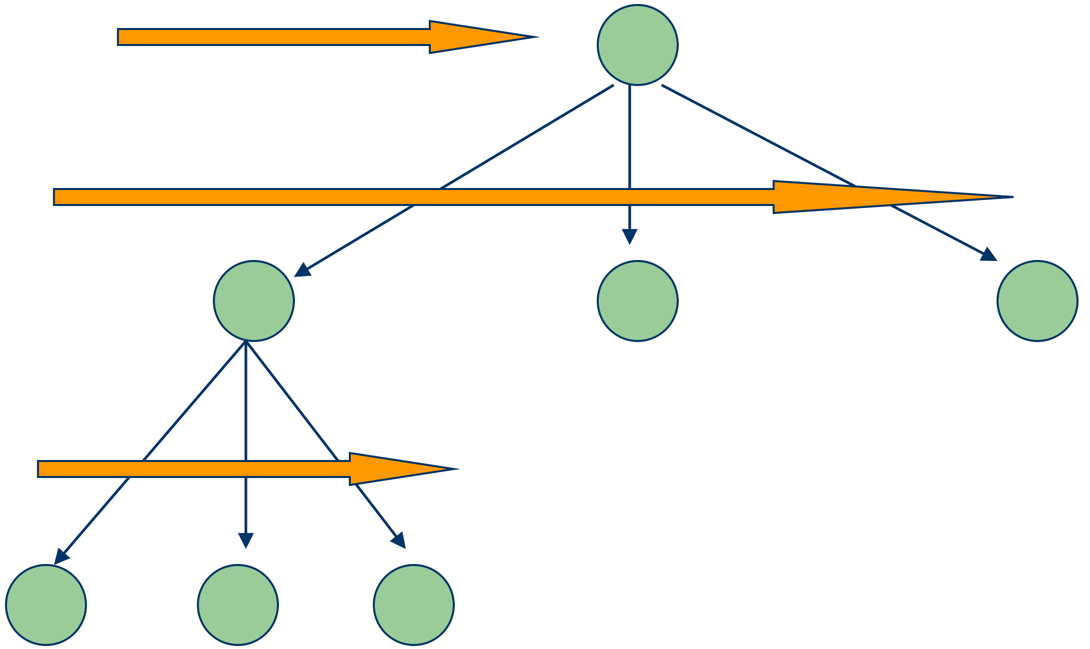
Breadth-First Search

- Root is expanded first
- Then all successors at level 2.
- Then all successors at level 3, etc.

Properties:

- Complete (if b and d are finite)
- Optimal (if path cost increases with depth)
- Cost is $O(b^{d+1})$
- Storage Let $n=b^{d+1}$: $O(n)$

Search



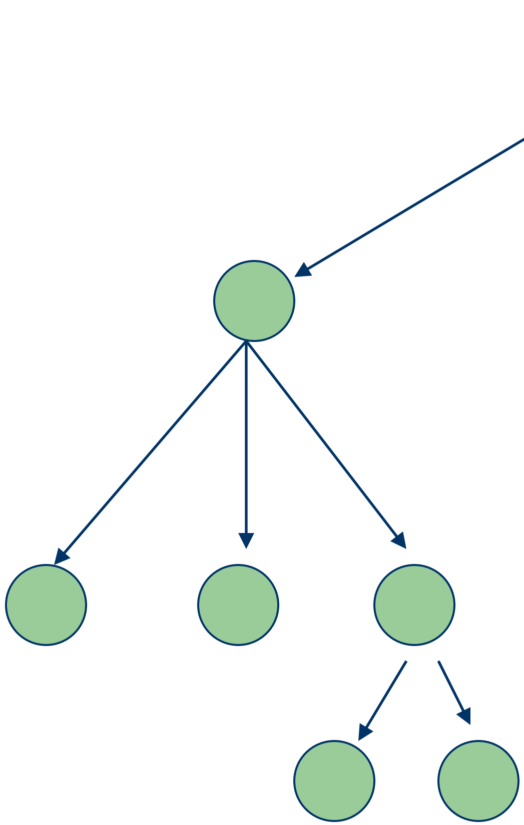
Uniform-Cost Search

- Expansion Approach---expands nodes completely
- Strategy: Expand node with lowest path cost.

Properties:

- Complete (if b and d are finite)
- Optimal (if path cost increases with depth)
- Cost: Similar to Breadth-first Search
- Could be worse than breadth first search

Search



Depth-First Search

- Expand the deepest node at the bottom of the tree.

Backtracking even does better space-wise: **O(d)**

Properties:

Only store the nodes on the current path including their unexpanded sibling nodes

- Incomplete
- suboptimal
- Space complexity is only O(**bd**)

Tree Depth First Search with Depth Bound L

Space Complexity Backtracking: O(d)

Space Complexity Expansion Depth-first Search: O(b*d)

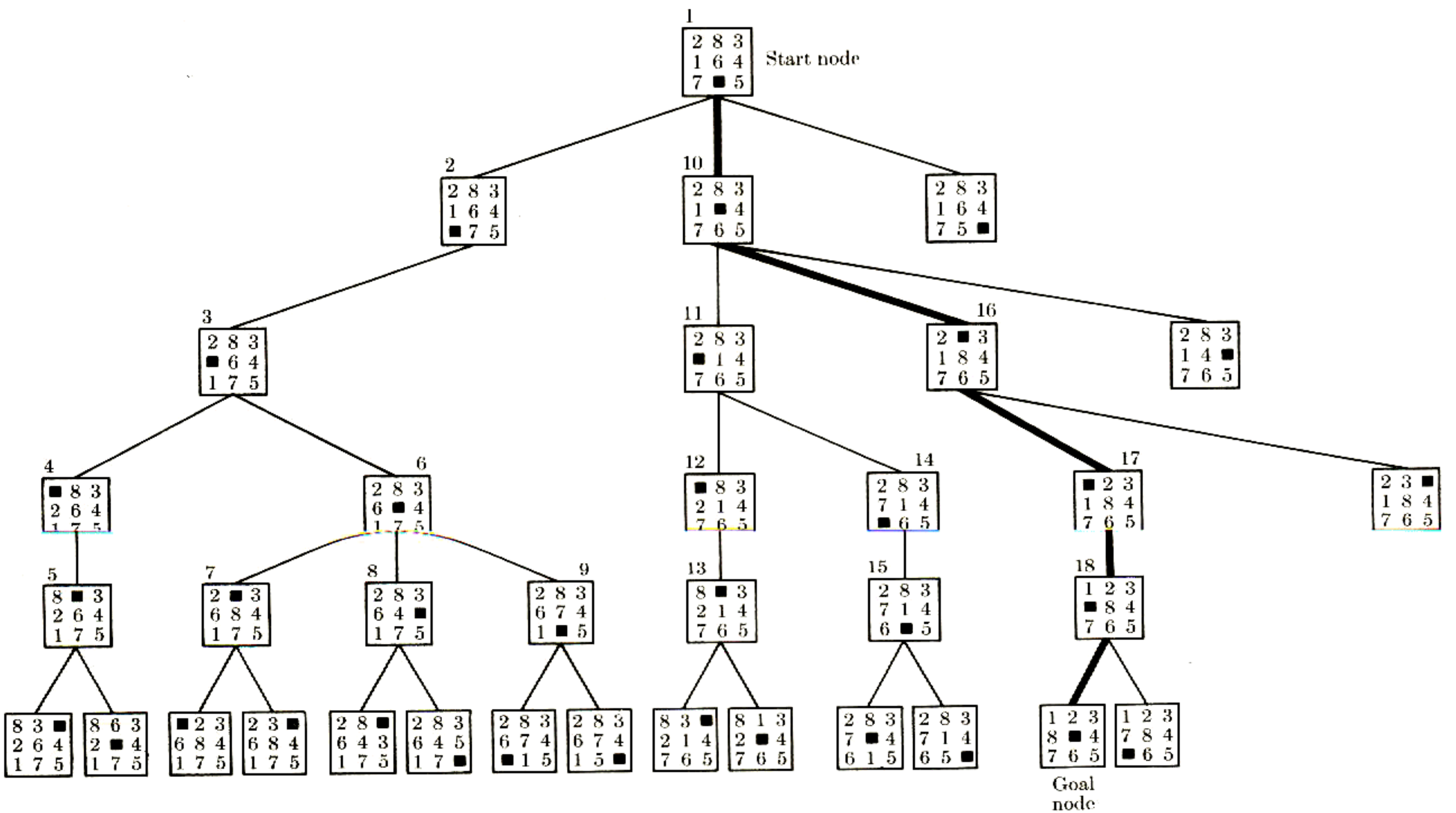
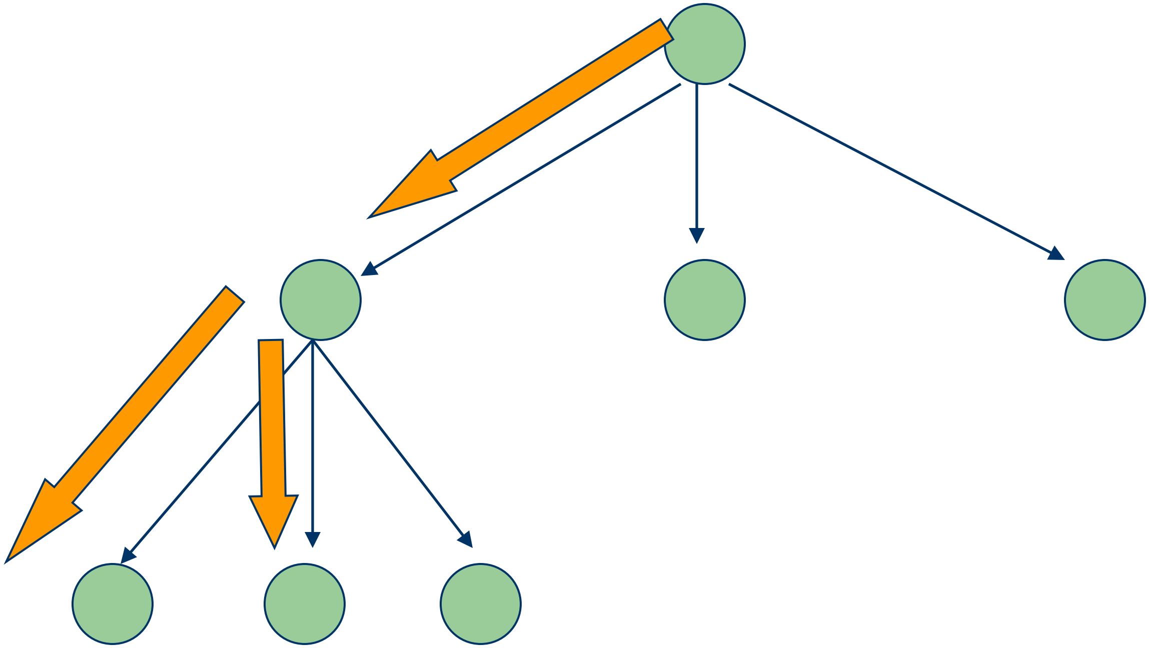


FIG. 3-5 *The tree produced by a depth-first search.*

Search



Depth-Limited

- Like depth-first search but with depth limit **L**.

Properties:

- Incomplete (if $\mathbf{L} < \mathbf{d}$)
- nonoptimal (if $\mathbf{L} > \mathbf{d}$)
- Time complexity is $O(\mathbf{b}^{L})$
- Space complexity is $O(\mathbf{bL})$

Iterative Deepening

- A combination of depth and breadth-first search.
- Gradually increases the limit **L**

Properties:

- Complete (if b and d are finite)
- Optimal if path cost increases with depth
- Time complexity is O($\mathbf{b}^{\mathbf{d}}$)

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Avoiding Looping & Repeated States (relates to expansion search)

- Use a list of expanded states; non-expanded states (*open* and *close list*)
- Use domain specific knowledge
- Use sophisticated data structures to find already visited states more quickly.
- Checking for repeated states can be quite expensive and slow down the search alg.

Remark: Non-expansion search strategies have to keep track of what operators have already been applied to avoid looping.

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Partial Information

Knowledge of states or actions is incomplete.

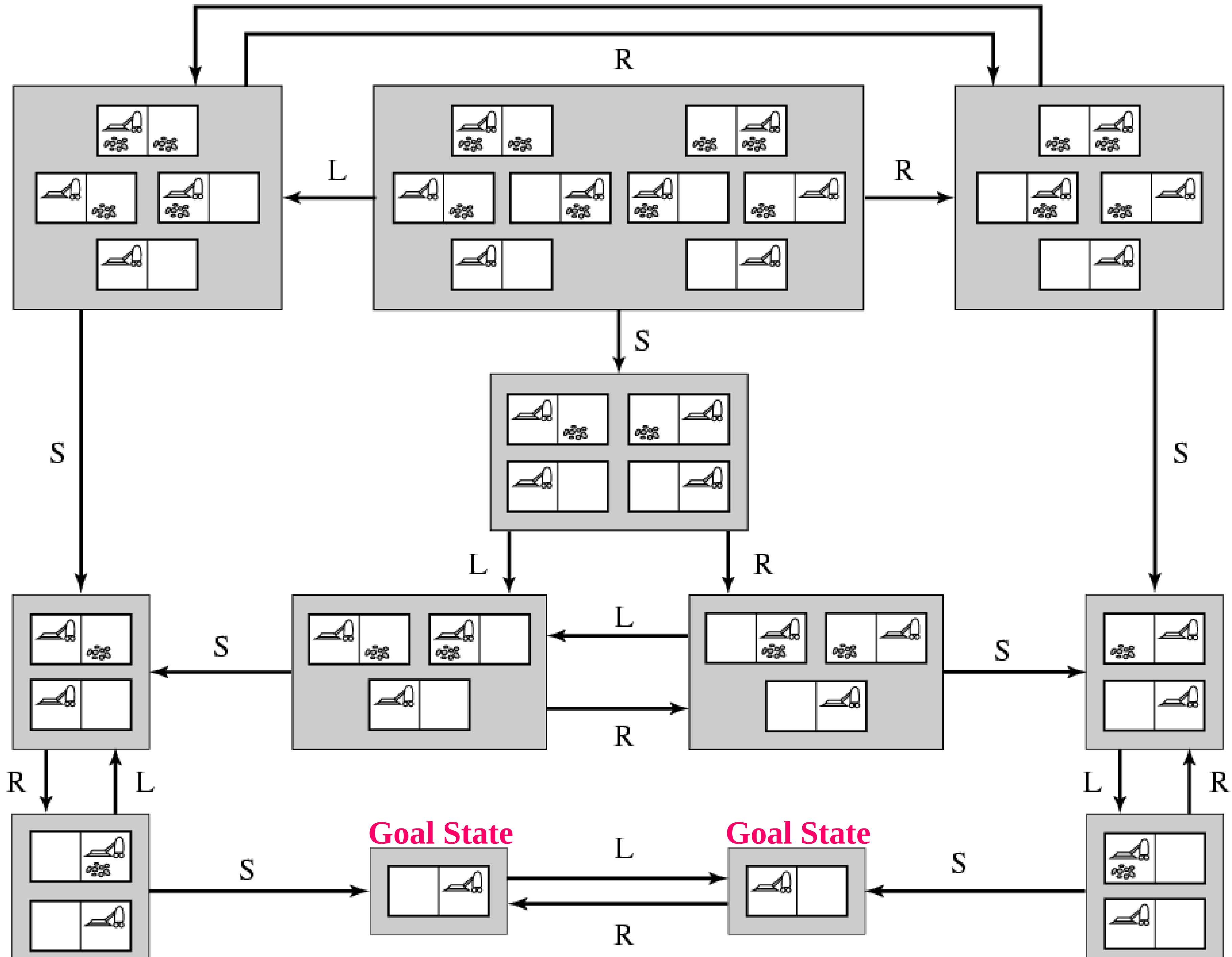
a. Sensorless problems
b. Contingency Problems
c. Exploration Problems

Problem types

Deterministic, accessible $\Longrightarrow$ *single-state problem*
Deterministic, inaccessible $\Longrightarrow$ *multiple-state problem*

Nondeterministic, inaccessible $\Longrightarrow$ *contingency problem*
must use sensors during execution
solution is a *tree* or *policy*
often *interleave* search, execution

Unknown state space $\Longrightarrow$ *exploration problem* ("online")



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Summary

- To search we need goal and problem formulation.
- A problem has initial state, actions, goal test, and path function.
- Performance measures: completeness, optimality, time and space complexity.

Summary

- Uninformed search has no additional domain specific knowledge: breadth and depth-first search, depth-limited, iterative deepening, bidirectional search.
- In partially observable environments, one must deal with uncertainty and incomplete knowledge.