Uninformed search

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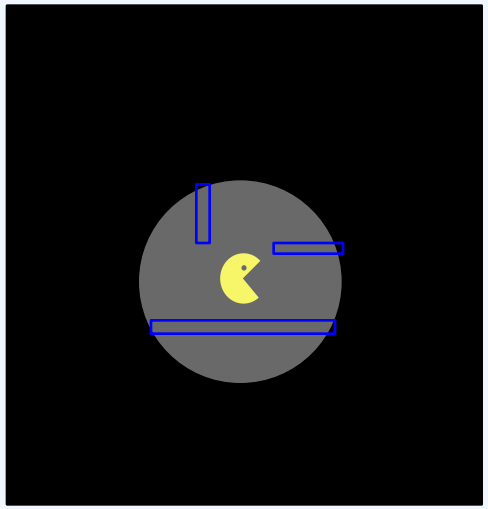
Today's schedule

- Rational agents
- Search problems
  - State space graph: modeling the problem
  - Search trees: scratch paper for solution
- Uninformed search
  - Depth first search (DFS) algorithm
  - Breadth first search (BFS) algorithm

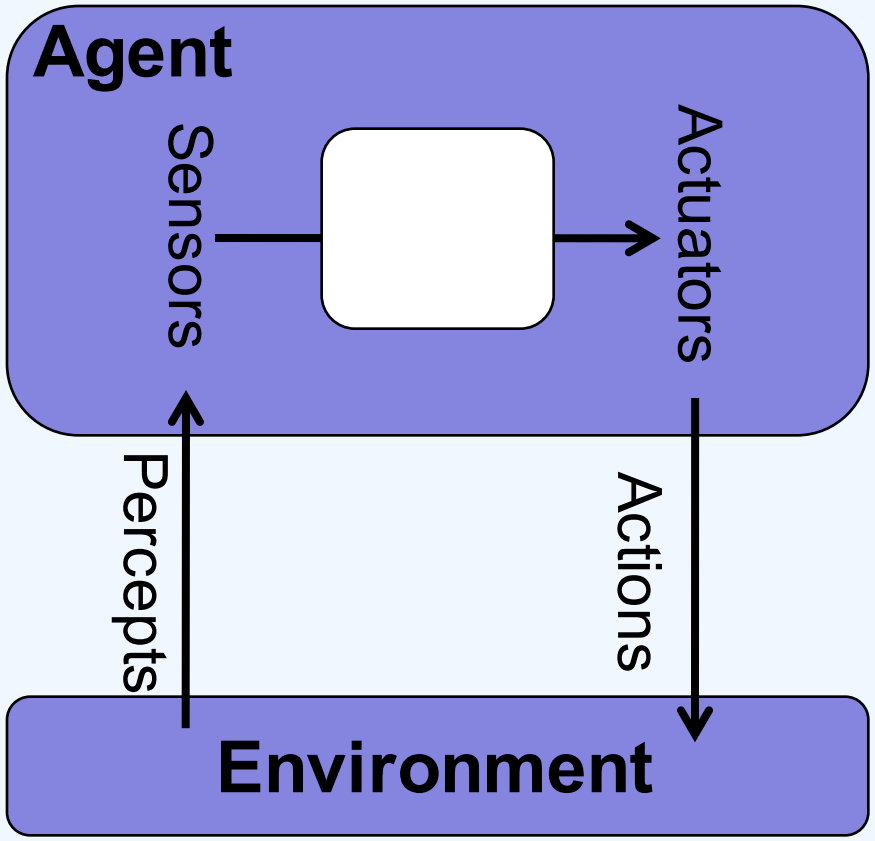
Example 0: Roguelike game



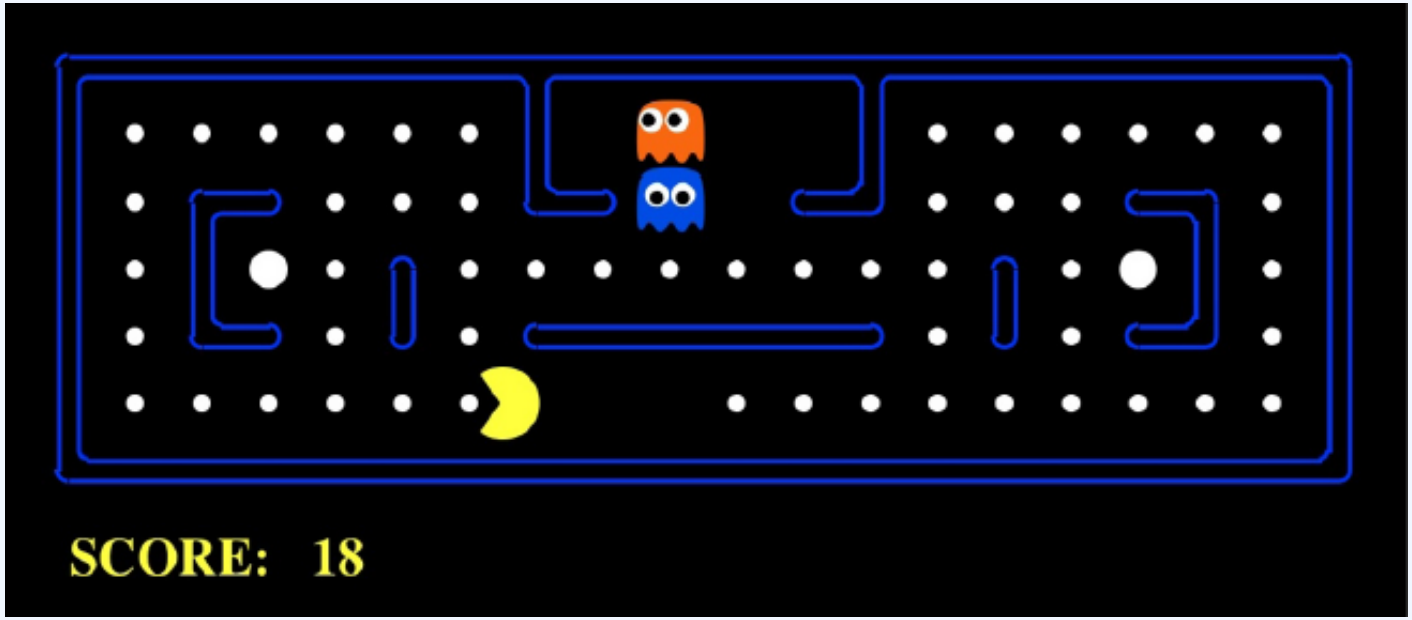
- You entered a maze in darkness
- No map but you build one as you explore
- Limited sight, only know which direction does not have a wall
  - know nothing about enemies, traps, etc.
  - you only see the exit when you step on it
- Goal: write a walkthrough to minimize the cost of reaching the next level
- How would you do it?

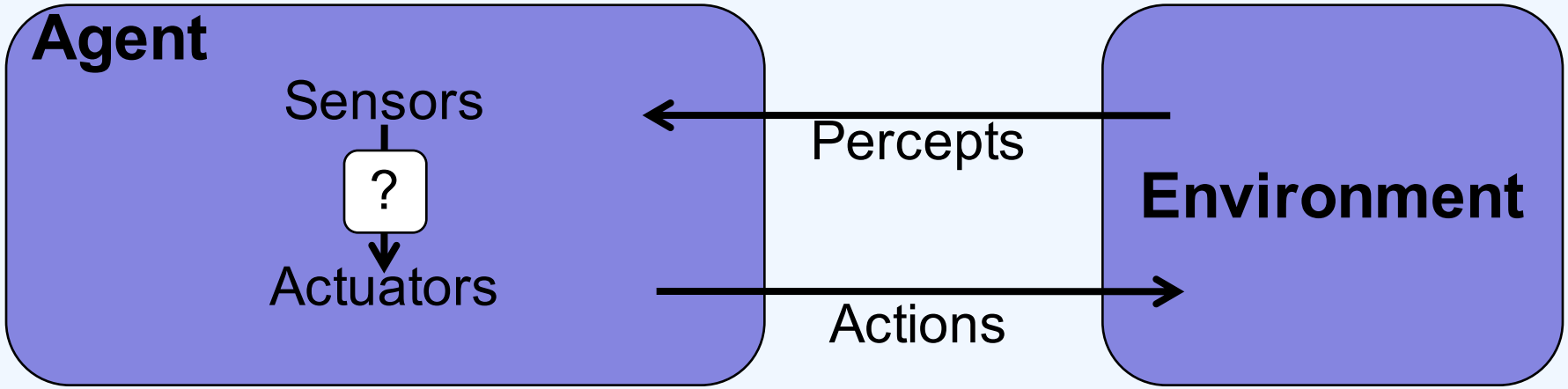
Rational Agents

- An agent is an entity that perceives and acts.
- A rational agent selects actions that maximize its utility function.
- Characteristics of the percepts, environment, and action space dictate techniques for selecting rational actions.

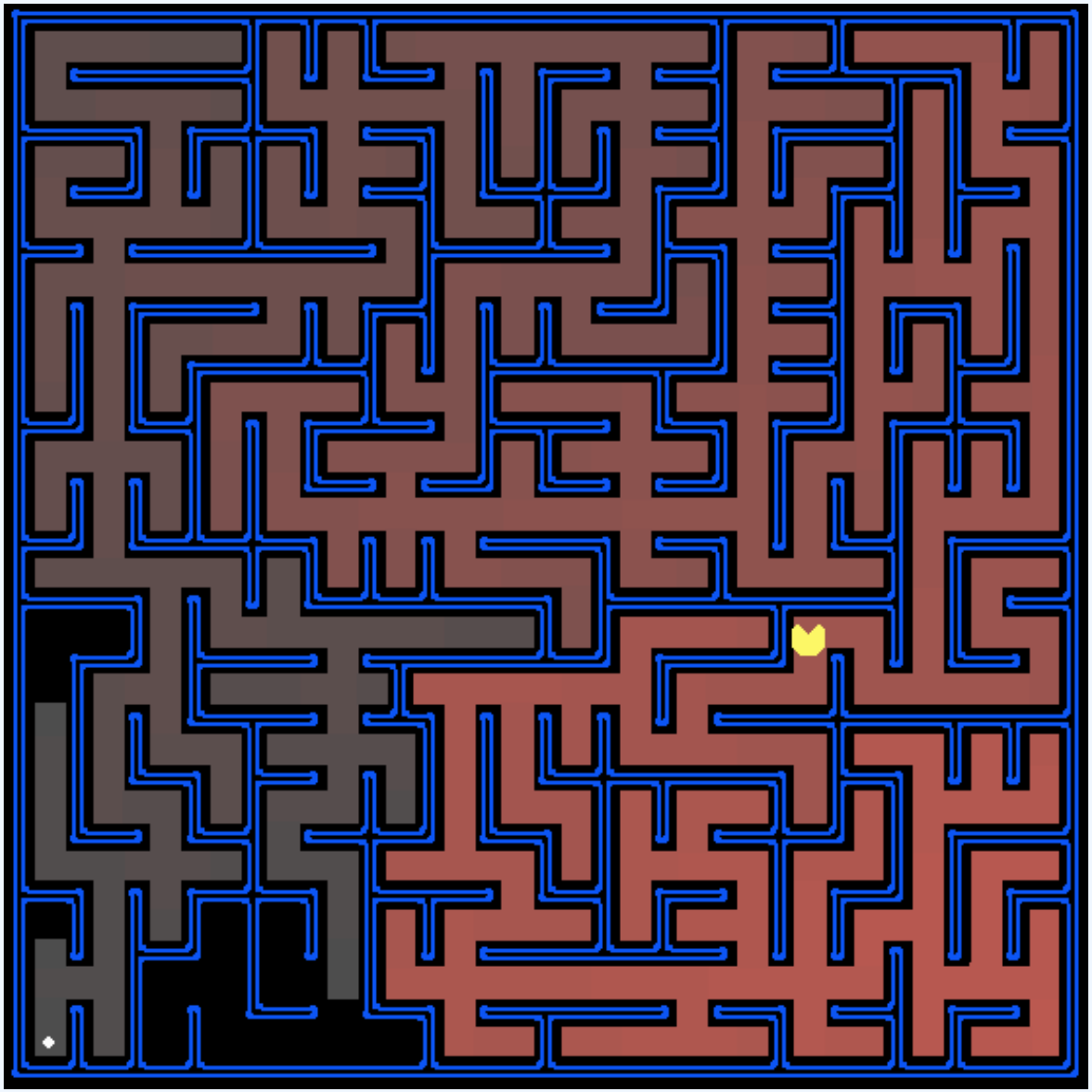


Example 1: Pacman as an Agent



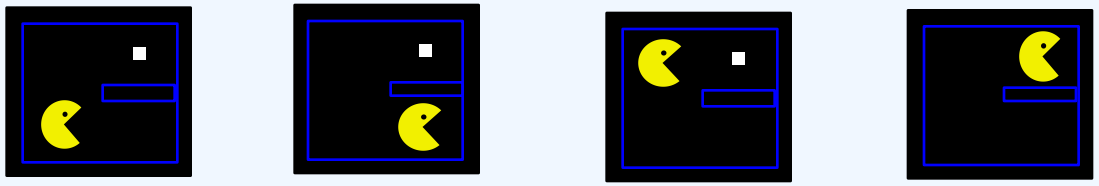


When goal = search for something (no cost yet)



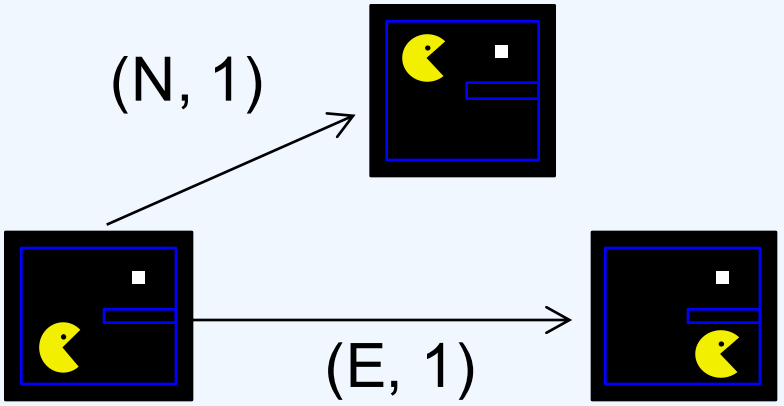
Search Problems

- A **search problem** consists of:
  - A state space



  - A successor function

    (with actions, costs)

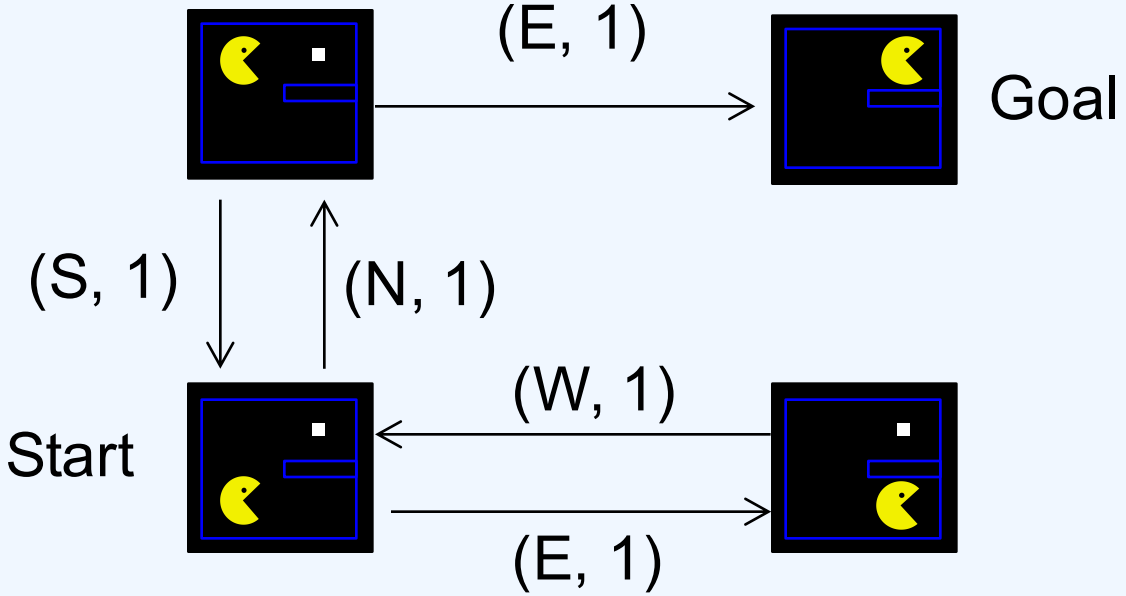


  - A start state and a goal test

- A **solution** is a sequence of actions (a plan) which transforms the start state to a goal state

State space graph: modeling the problem

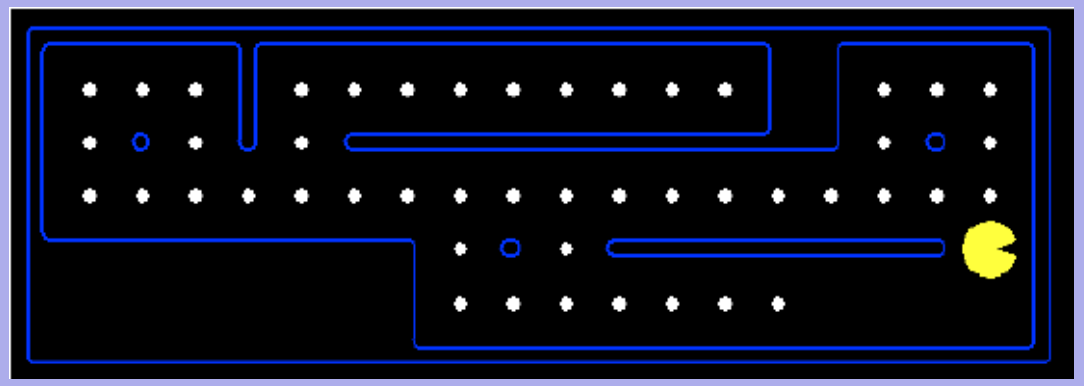
- A directed weighted graph of all states
  - a→b: b is a successor of a
  - weight(a→b): the cost of traveling from a to b



  - Note: just for analysis, usually the state space graph is not fully built

What's in a State Space?

The world state specifies every last detail of the environment



A search state keeps only the details needed (abstraction)

- Problem: Pathing
  - States: (x,y) location
  - Actions: NSEW
  - Successor: adjacent locations
  - Goal test: is (x,y) = END

- Problem: Eat-All-Dots
  - States: {(x,y), dot booleans}
  - Actions: NSEW
  - Successor: updated location and dot booleans
  - Goal test: dots all false

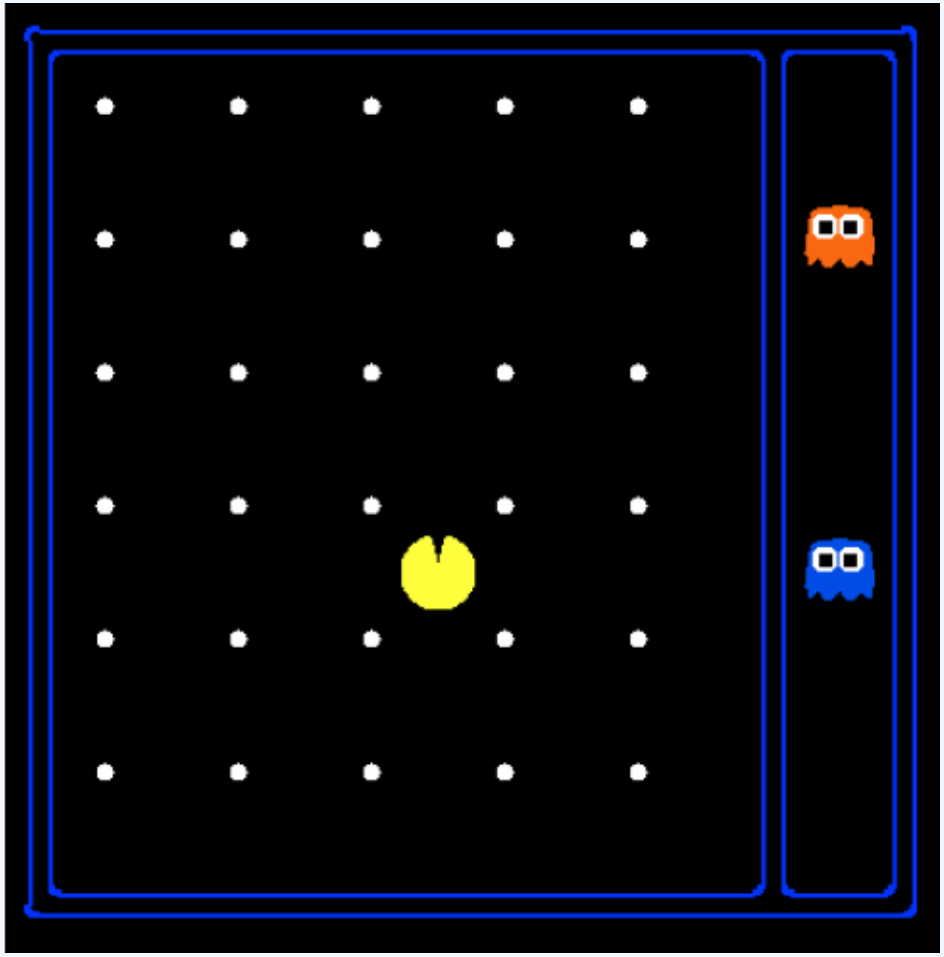
State Space Sizes?

- World state:
  - •Agent positions: 120
  - •Food count: 30
  - •Ghost positions: 12
  - •Agent facing: NSEW
- How many
  - • World states?

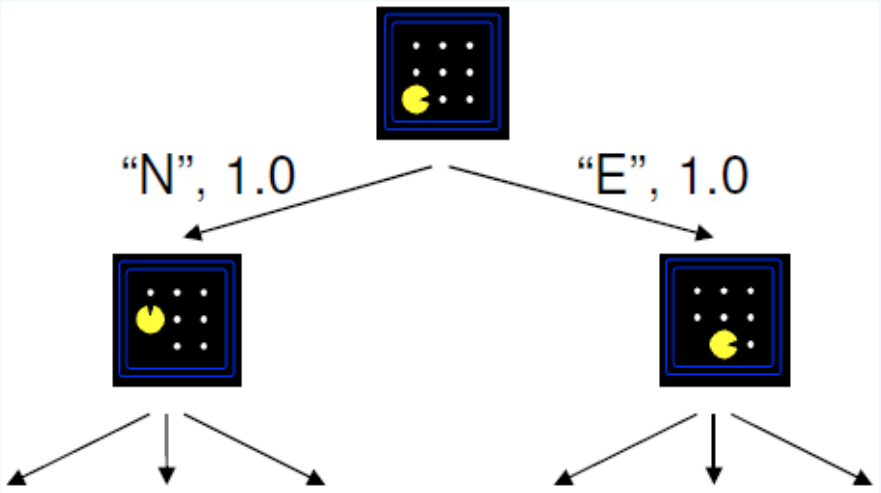
    $120 \times 2^{30} \times 12^2 \times 4$
  - • States for pathing?

    120
  - • States for eat-all-dots?

    120×2^{30}



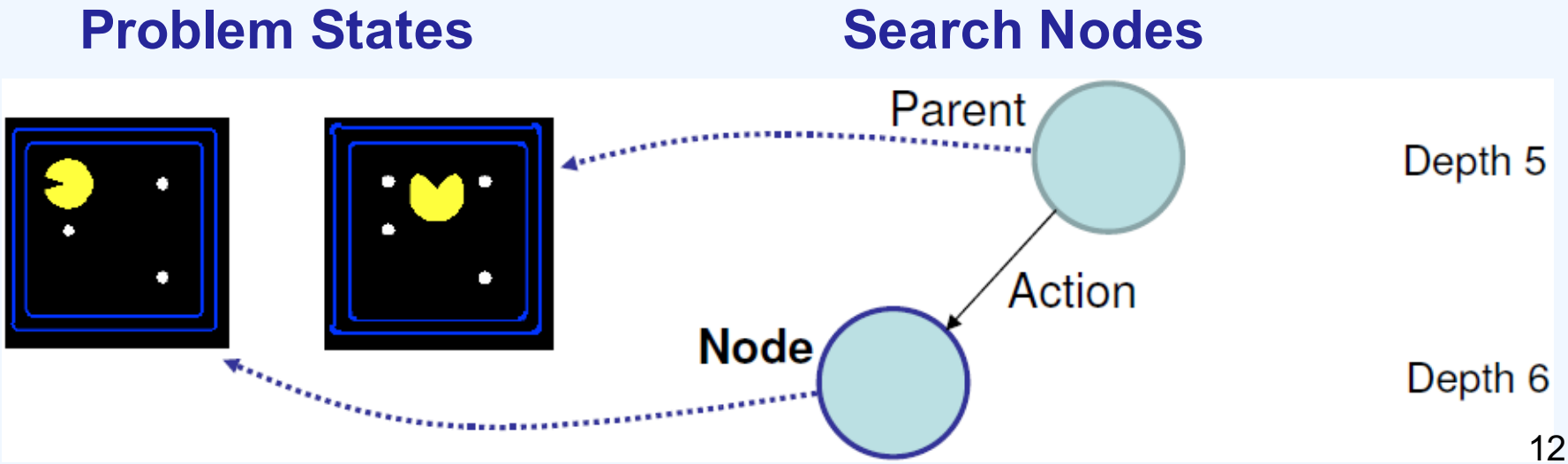
Search Trees: scratch paper for solution



- A **search tree**:
  - Start state at the root node
  - Children correspond to successors
  - Nodes contain states, correspond to PLANS to those states
  - For most problems, we can never actually build the whole tree

Space graph vs. search tree

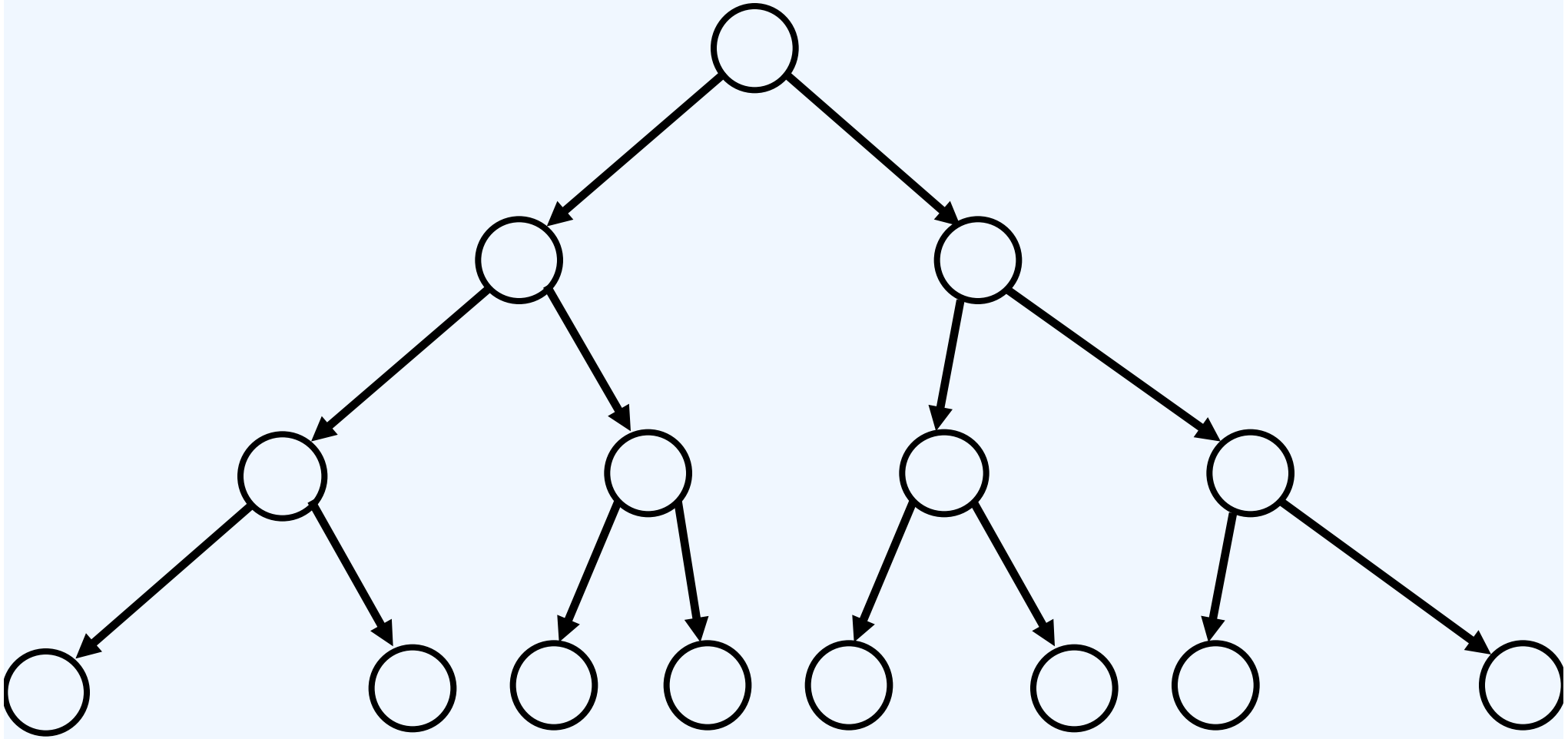
- Nodes in state space graphs are problem states:
  - Represent an abstracted state of the world
  - Have successors, can be goal/non-goal, have multiple predecessors
- Nodes in search trees are plans
  - Represent a plan (sequence of actions) which results in the node's state
  - Have a problem state and one parent, a path length, a depth and a cost
  - The same problem state may be achieved by multiple search tree nodes



Uninformed search

- Uninformed search: given a state, we only know whether it is a goal state or not
  - Cannot say one non-goal state looks better than another non-goal state
  - Can only traverse state space blindly in hope of somehow hitting a goal state at some point
- Also called blind search
  - Blind does **not** imply unsystematic!

Breadth-first search (search tree)



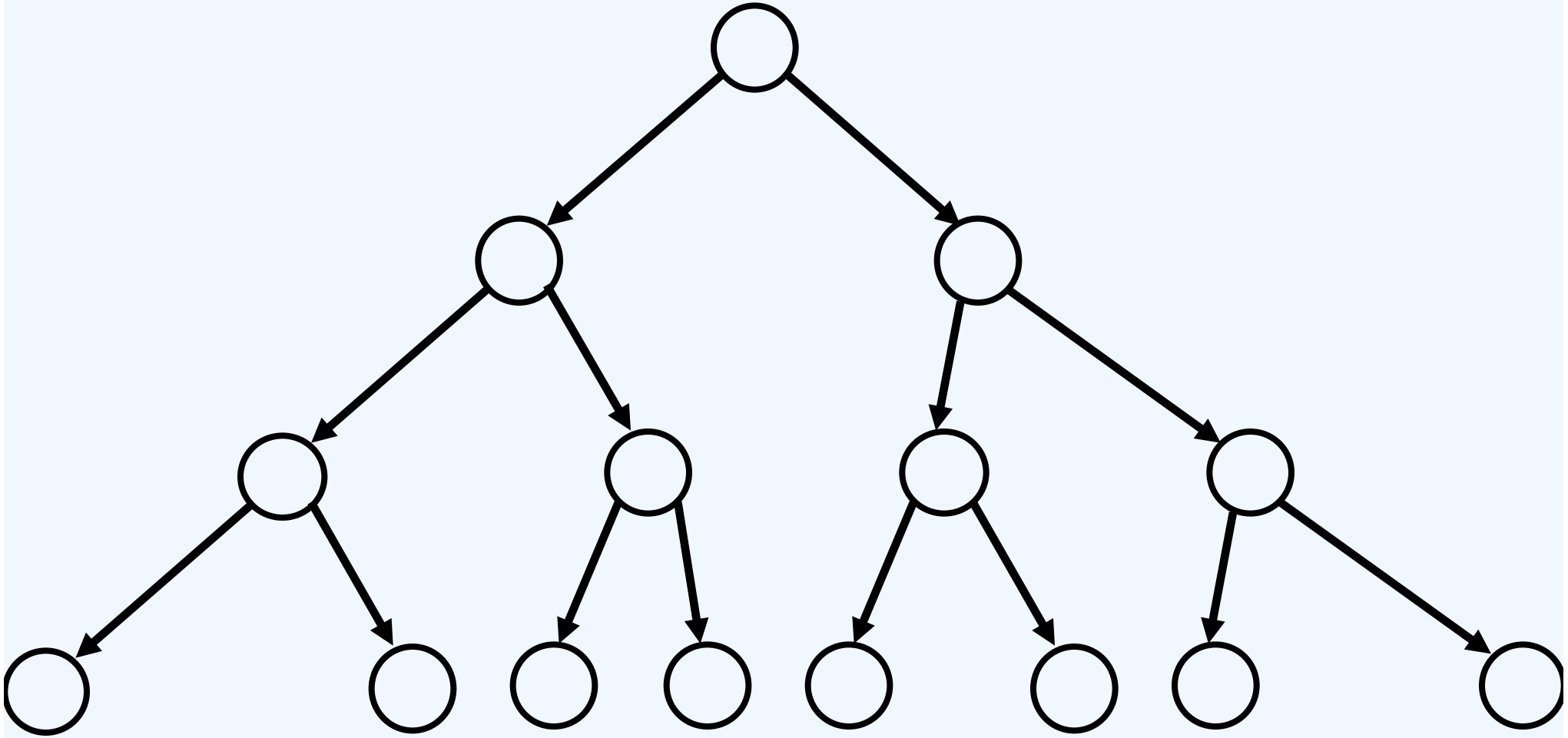
BFS

- Never expand a node whose state has been visited
- Fringe can be maintained as a First-In-First-Out (FIFO) queue (class Queue in util.py)
- Maintain a set of visited states
- *fringe := {node corresponding to initial state}*
- *loop:*
  - *if fringe empty, declare failure*
  - *choose and remove the top node v from fringe*
  - *check if v's state s is a goal state; if so, declare success*
  - *if v's state has been visited before, skip*
  - *if not, expand v, insert resulting nodes into fringe*
- This is the BFS you should implement in project 1

Properties of breadth-first search

- May expand more nodes than necessary
- BFS is complete: if a solution exists, one will be found
- BFS finds a shallowest solution
  - Not necessarily an optimal solution if the cost is non-uniform
- If every node has b successors (the branching factor), shallowest solution is at depth d, then fringe size will be at least b^d at some point
  - This much space (and time) required ☹

Depth-first search



Properties of depth-first search

- Not complete (might cycle through non-goal states)
- If solution found, generally not optimal/shallowest
- If every node has b successors (the branching factor), and we search to at most depth m, fringe is at most bm
  - Much better space requirement ☺
  - Saves even more space by recursion
- Time: still need to check every node
  - $b^m + b^{m-1} + \ldots + 1$ (for b>1, $O(b^m)$)
  - Inevitable for uninformed search methods…

If we keep a set of visited stages

- Never add a visited state to the fringe
- This version of DFS is complete (avoid cycling)
- Space requirement can be as bad as BFS

DFS

- Never expand a node whose state has been visited
- Fringe can be maintained as a Last-In-First-Out (LIFO) queue (class Stack in util.py)
- Maintain a set of visited states
- *fringe := {node corresponding to initial state}*
- *loop:*
  - *if fringe empty, declare failure*
  - *choose and remove the top node v from fringe*
  - *check if v's state s is a goal state; if so, declare success*
  - *if v's state has been visited before, skip*
  - *if not, expand v, insert resulting nodes into fringe*
- This is the DFS you should implement in project 1

You can start to work on Project 1 now

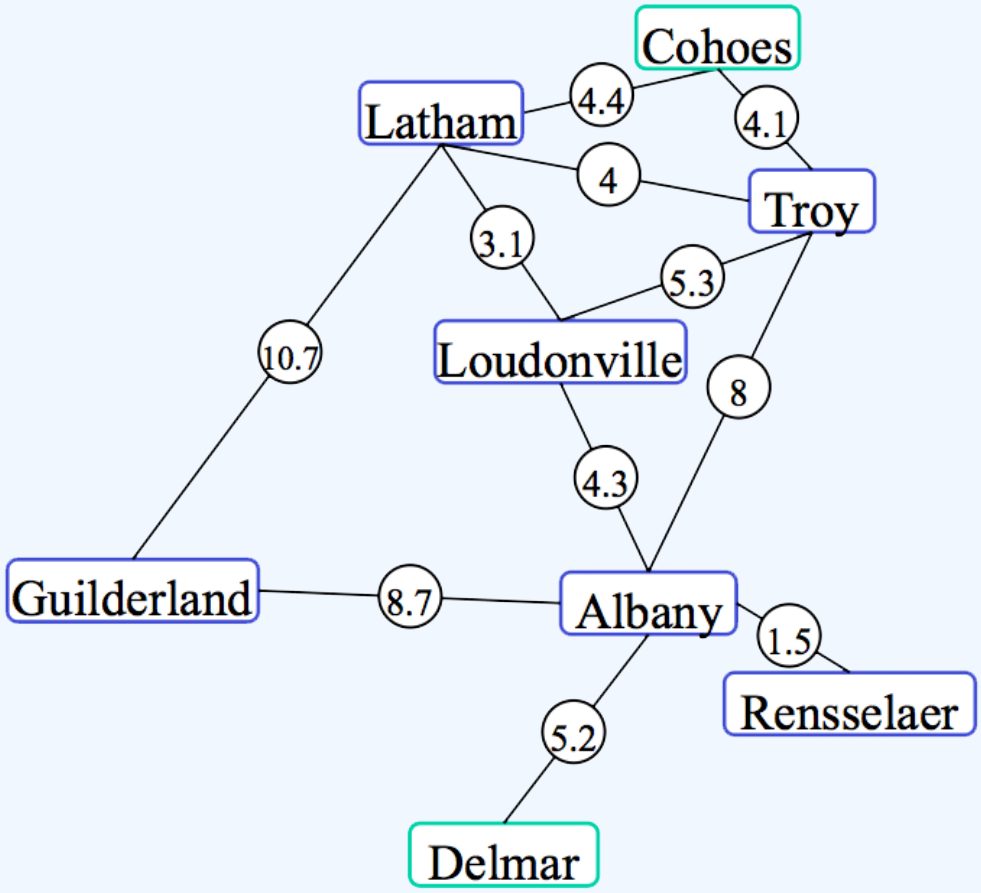
- Read the instructions on course website and the comments in search.py first
- Q1: DFS
  - LIFO
- Q2: BFS
  - FIFO
- Due in two weeks (Feb 3)
- Check util.py for LIFO and FIFO implementation
- Use piazza for Q/A

Dodging the bullets

- The auto-grader is very strict
  - 0 point for expanding more-than-needed states
  - no partial credit
- Hint 1: do not include *print "Start:", problem.getStartState()* in your formal submission
  - comment out all debuging commands
- Hint 2: remember to check if a state has been visited before
- Hint 3: return a path from start to goal. You should pass the local test before submission (details and instructions on project 1 website)

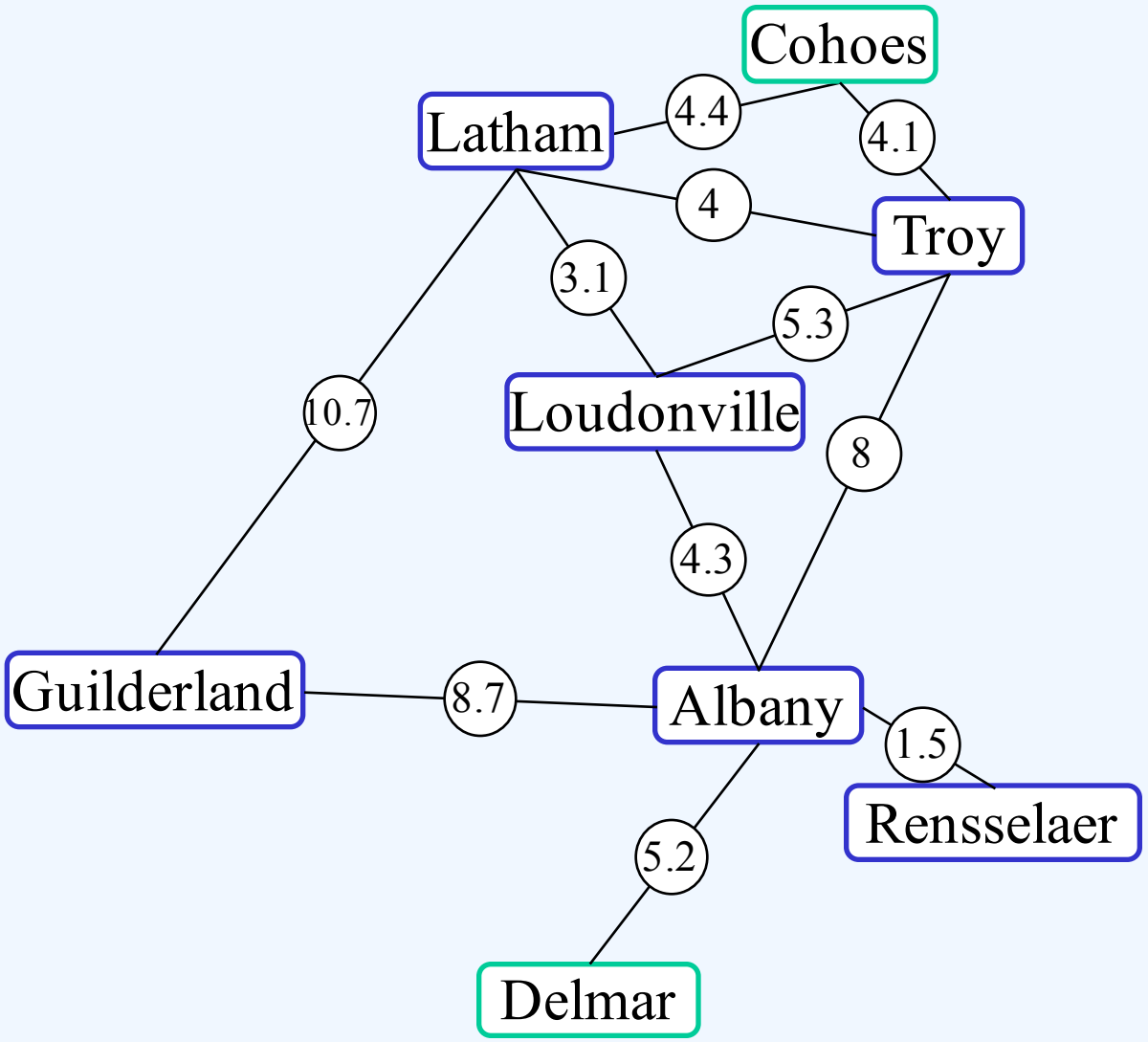
State Space Graphs

- State space graph: A mathematical representation of a search problem
  - For every search problem, there's a corresponding state space graph
  - The successor function is represented by arcs
- We can rarely build this graph is memory (so we don't)



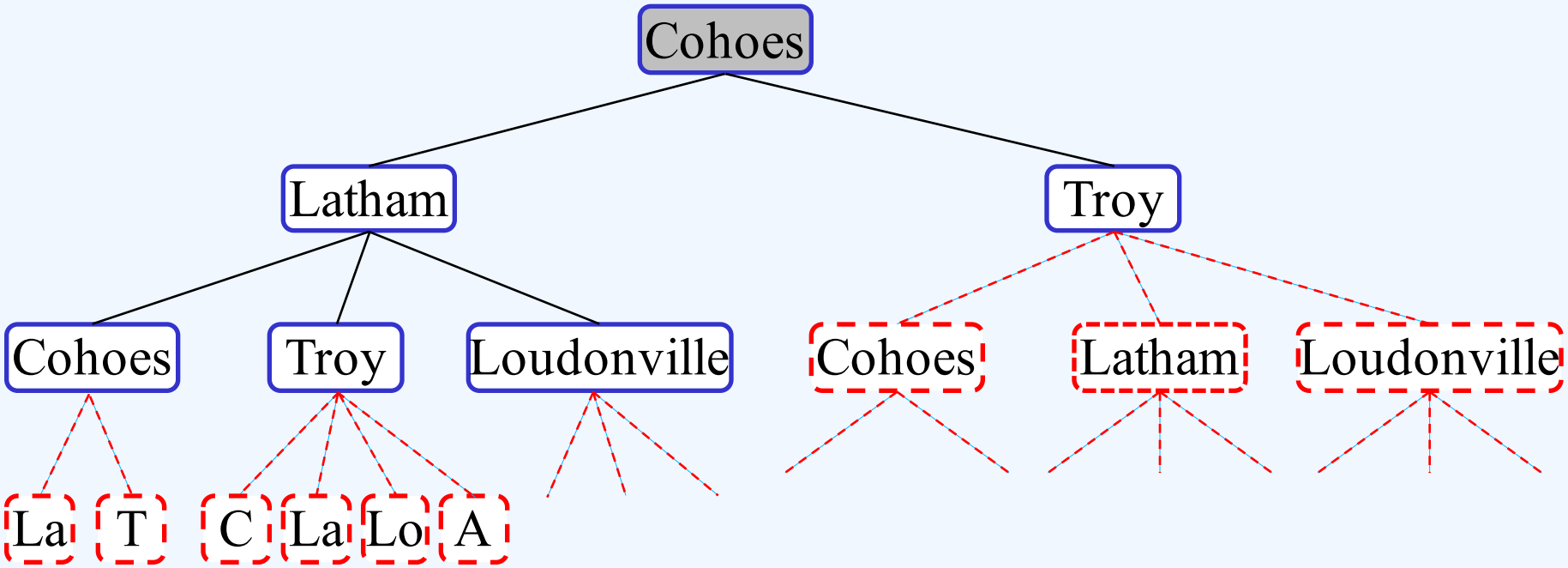
Ridiculously tiny search graph for a tiny search problem

Example 2: Capital Region



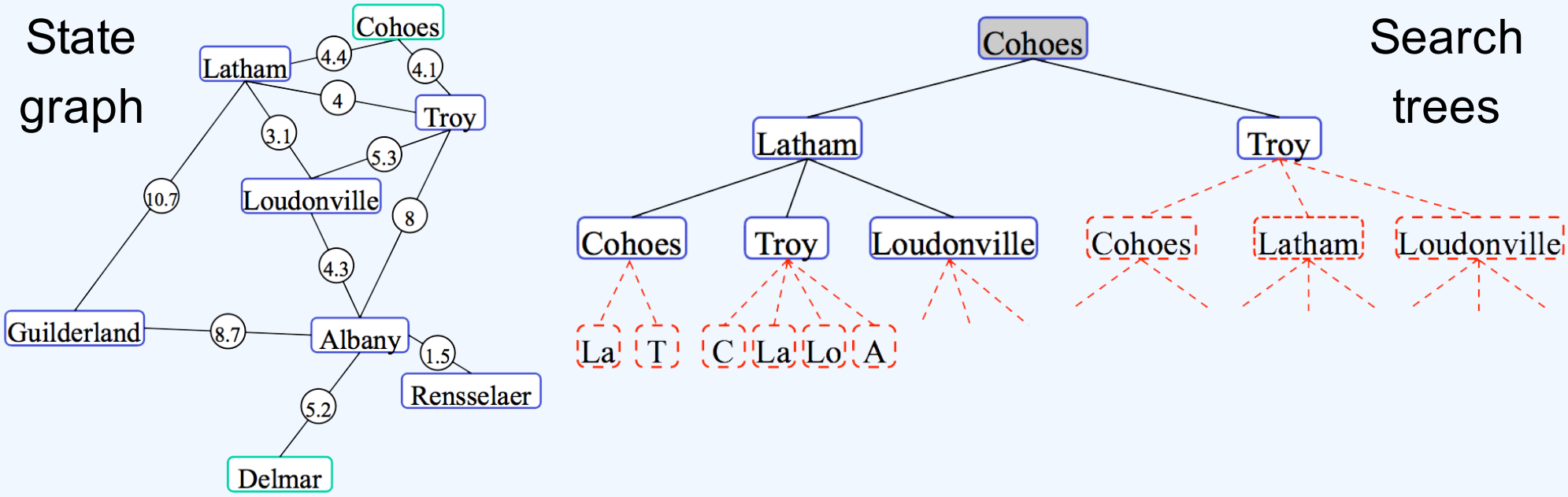
- State space:
  - Cities
- Successor function:
  - Roads: Go to adjacent city with cost = dist
- Start state:
  - Cohoes
- Goal test:
  - Is state == Delmar
- Solution?

Another Search Tree



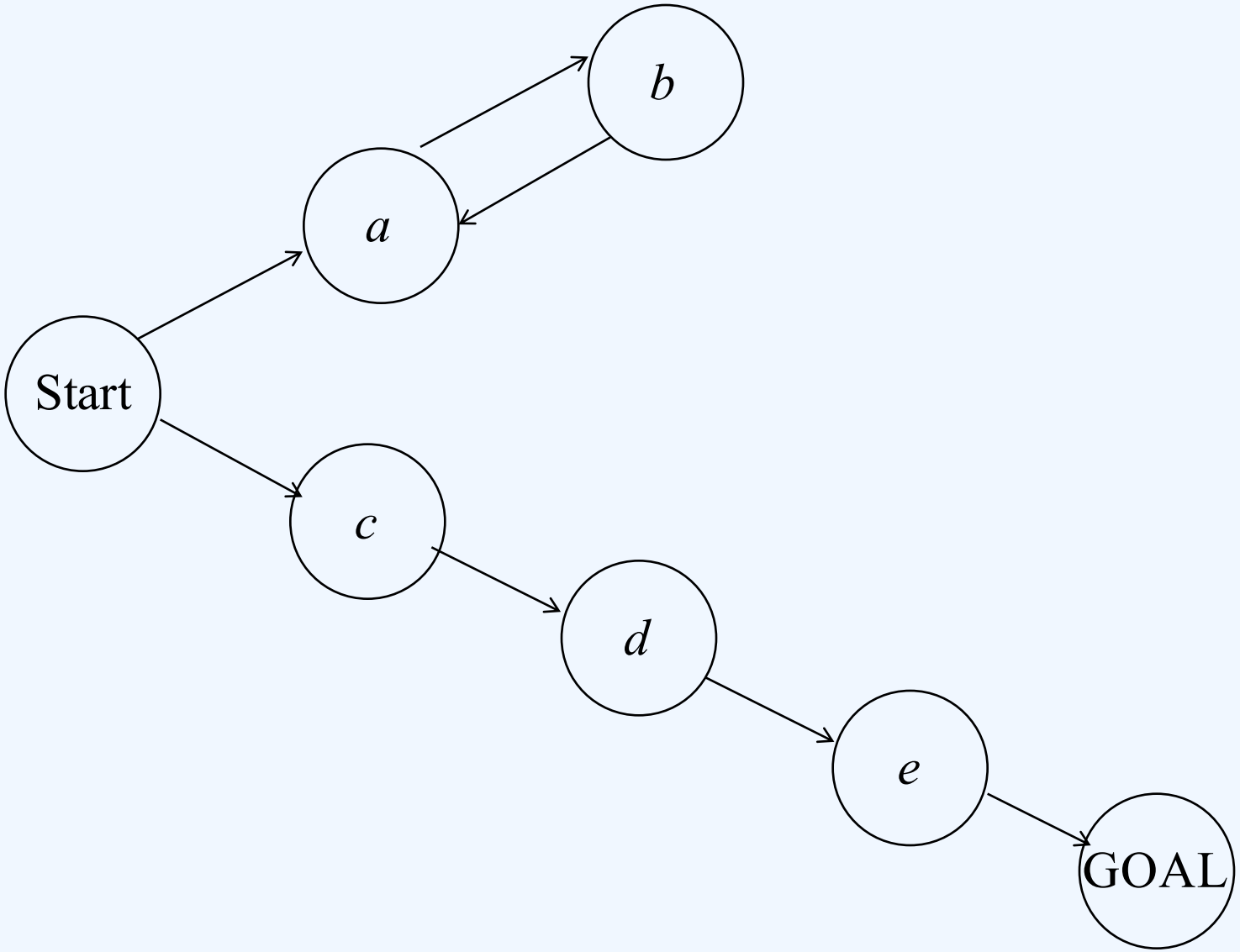
- Search:
  - Expand out possible plans
  - Maintain a fringe of unexpanded plans
  - Try to expand as few tree nodes as possible

State Graphs vs. Search Trees



- State graphs: a representation of the search problem
  - each node is an abstract of the state of the world
- Search tree: a tool that helps us to find the solution
  - each node represents an entire path in the graph
  - tree nodes are constructed on demand and we construct as little as possible

Example



Example