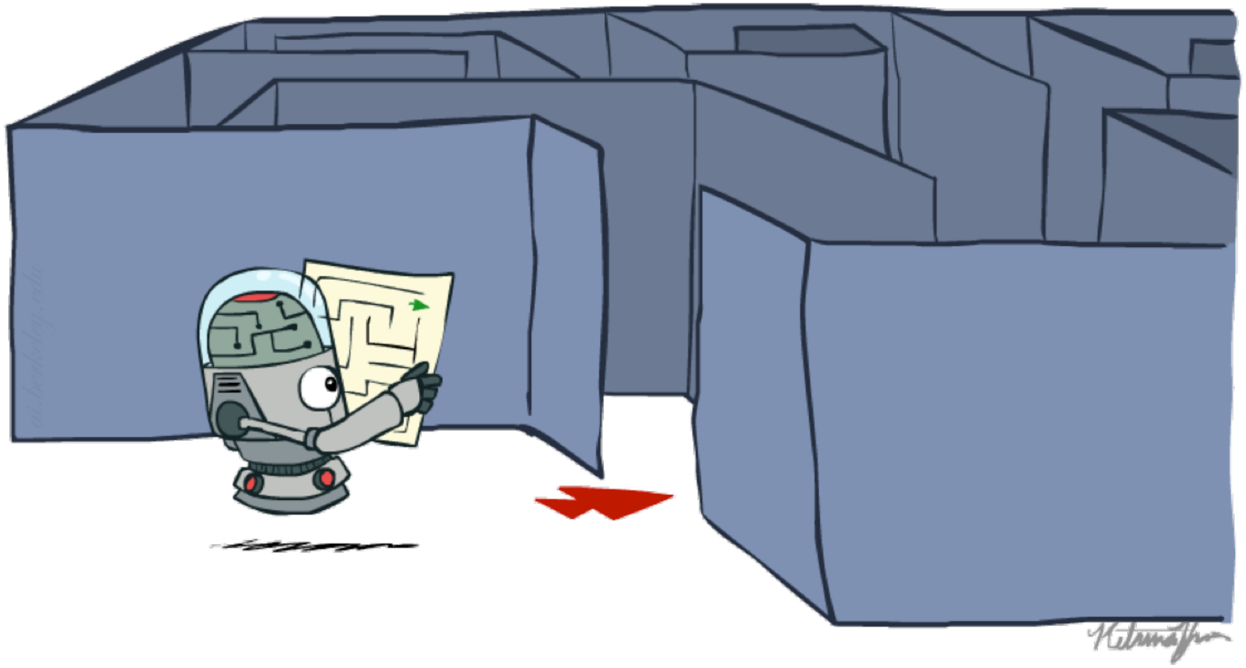
CS 343: Artificial Intelligence

Search



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[These slides are based on slides created by Dan Klein and Pieter Abbeel for CS188 Intro to AI at UC Berkeley. All CS188 materials are available at http://ai.berkeley.edu.]

Good morning colleagues!

- Past due:
  - Python tutorial
  - 3 reading responses: AI100 report; Chapters 1,2; Chapter 3
- HW1: Search
  - Due Monday 2/8 at 11:59 pm
- P1: Search
  - Due Wednesday 2/10 at 11:59 pm
  - Pair work allowed
- Readings: Constraint Satisfaction and Local Search
  - **NOT** just Chapter 4
  - Due Monday 2/1 at 9:30 am

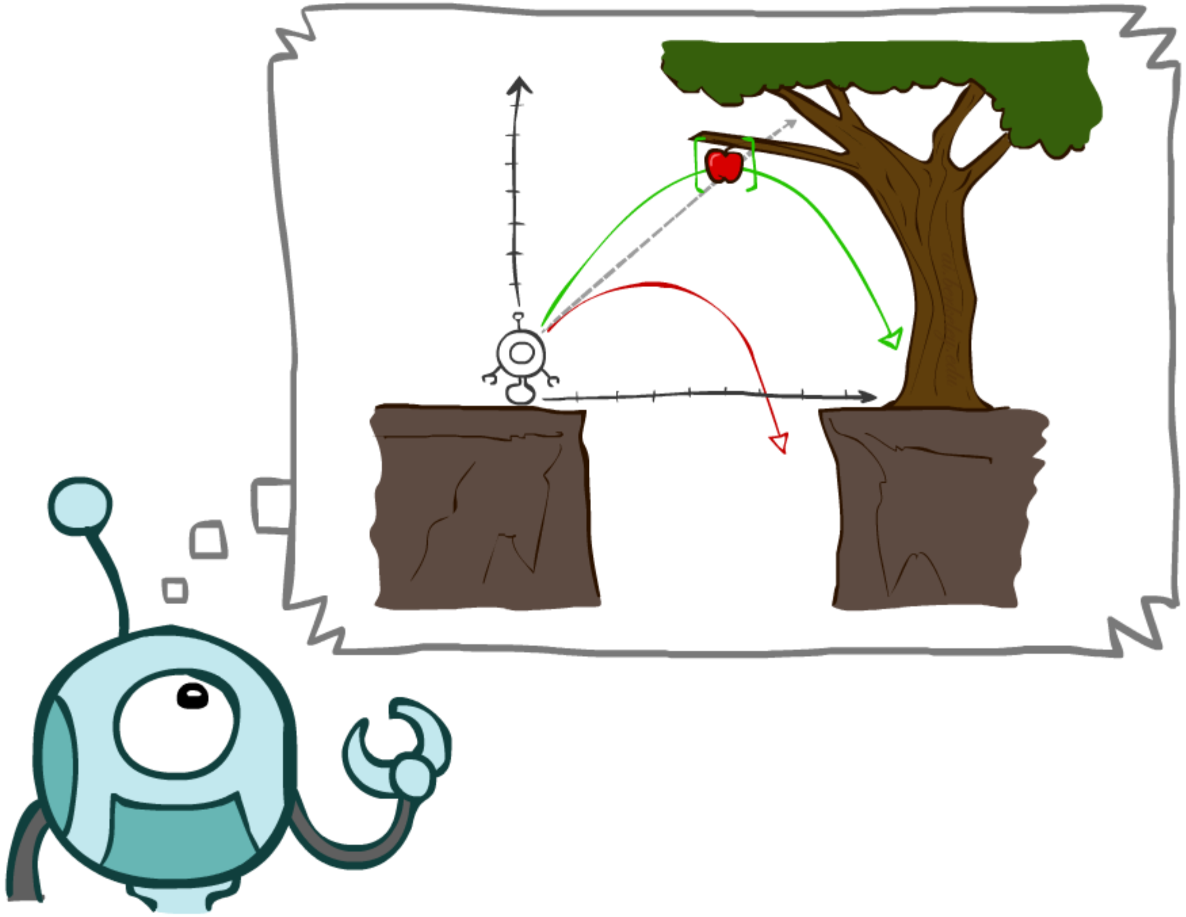
Programming Assignment 1

- P1: Search
  - Due Wednesday 2/10 at 11:59 pm
  - Pair work allowed

Textbook and other Resources

- Take your cue from how detailed things are
  - Important: heuristics for A* search; the concept of memory-bounded search
  - Just high-level ideas: IDA*, learning to search better
- Pseudocode can be useful
  - If something’s not clear, ask!
- Your reading responses were great!
- Monitor the class resources page
  - Links to more complete slide decks and lecture videos

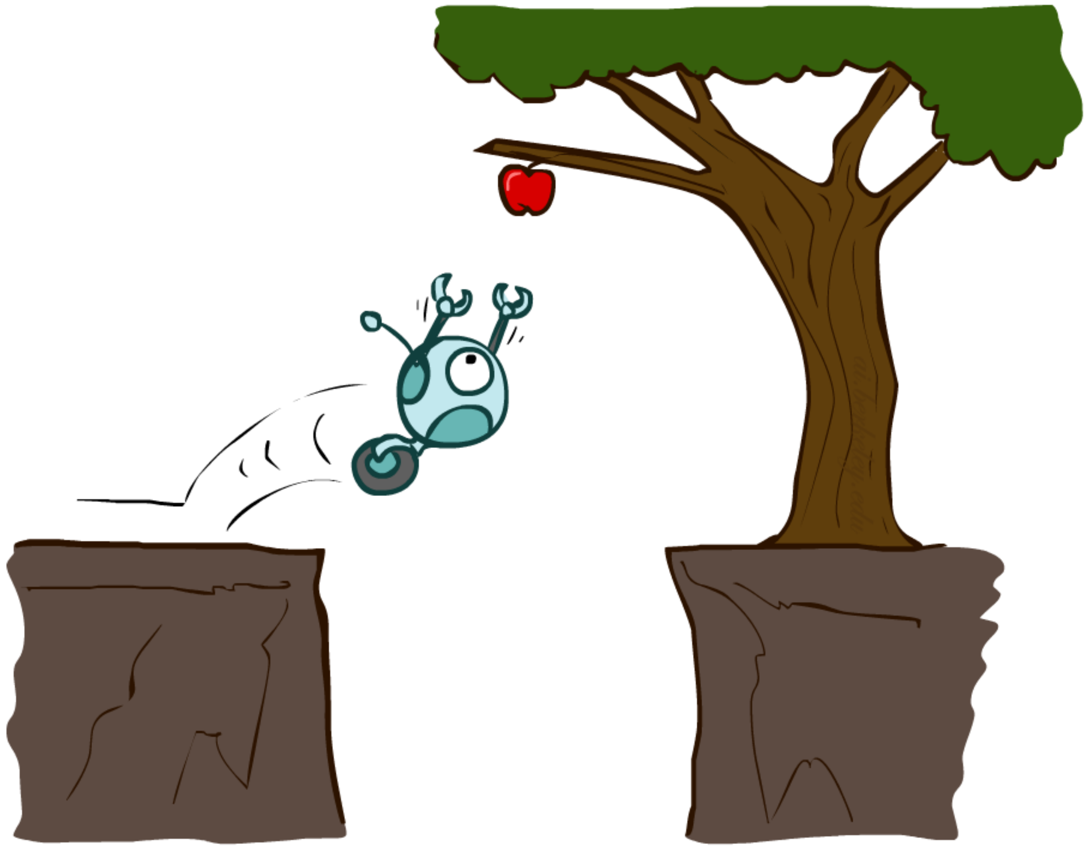
Agents that Plan



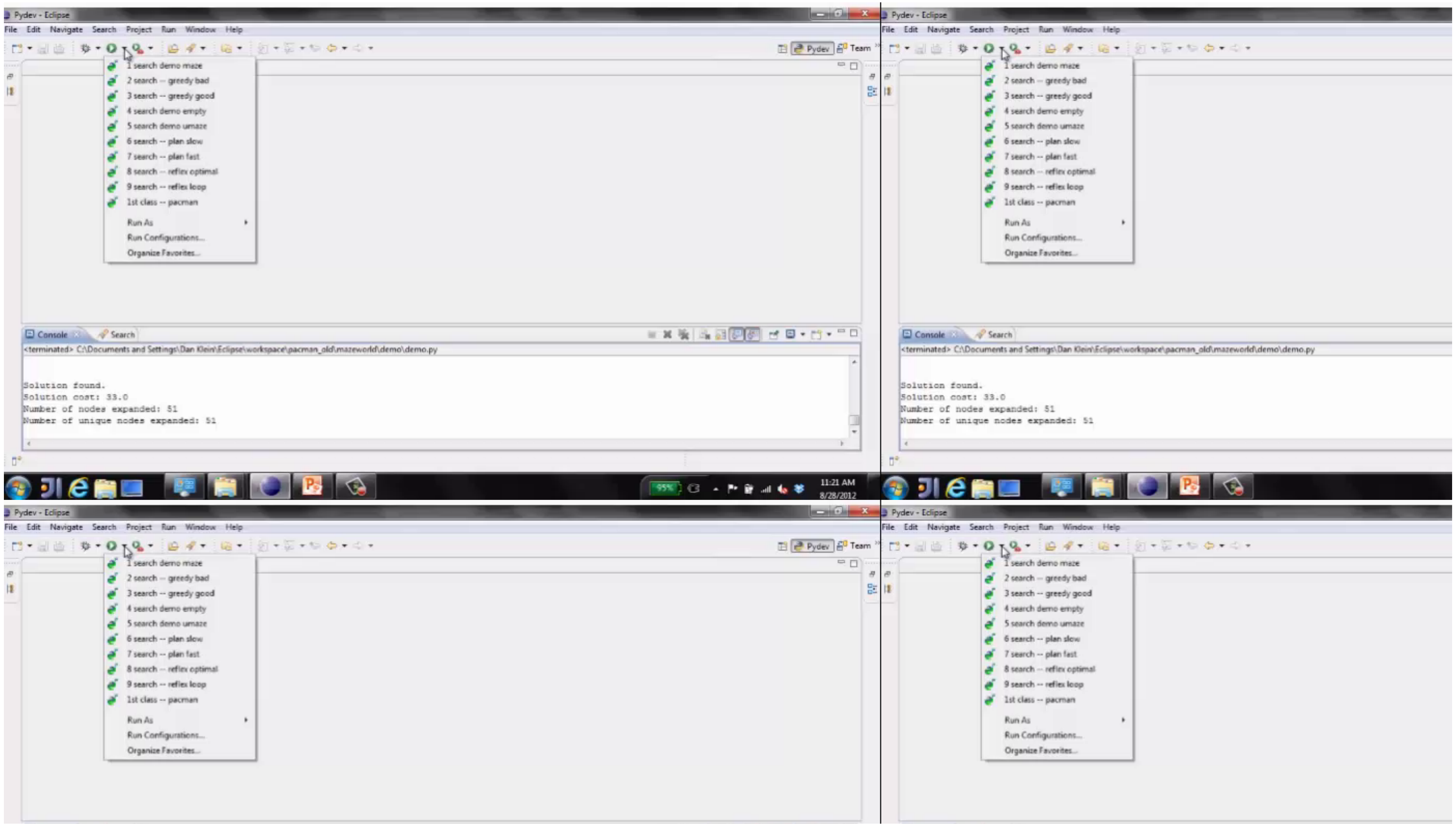
Reflex Agents

- Reflex agents:
  - Choose action based on current percept (and maybe memory)
  - May have memory or a model of the world's current state
  - Do not consider the future consequences of their actions
  - Consider how the world IS

- Can a reflex agent be rational?



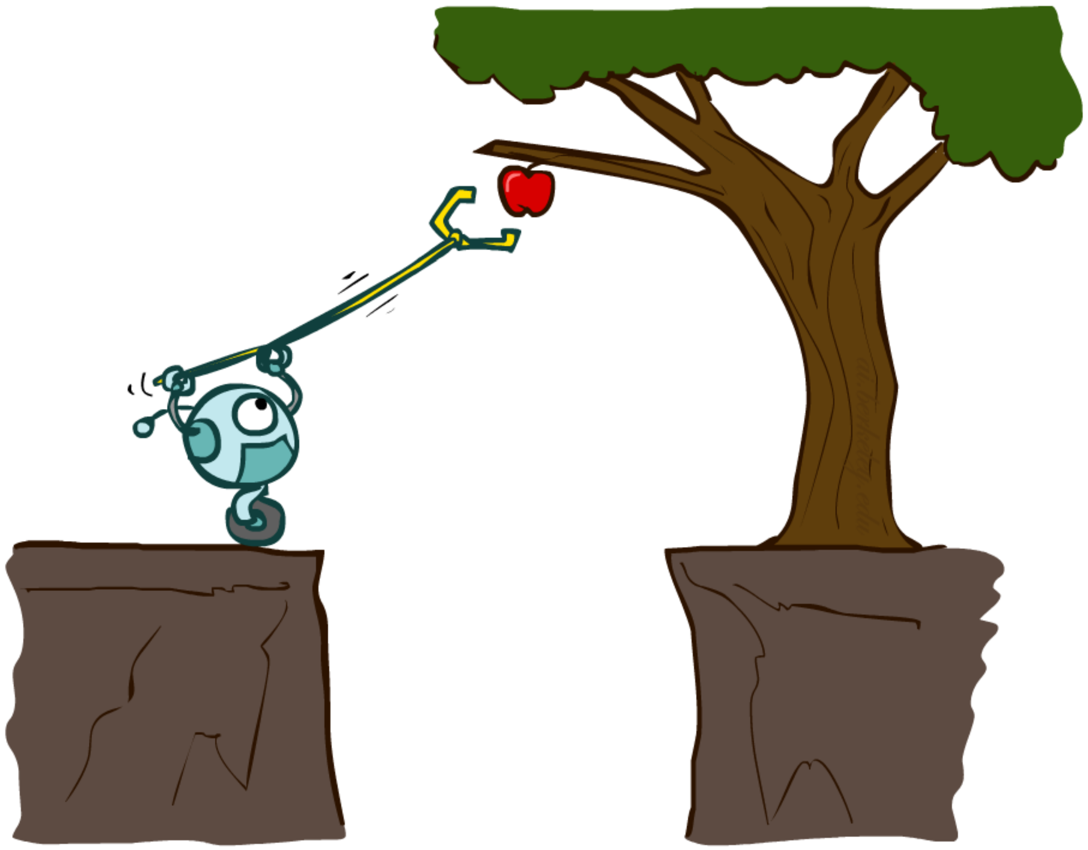
Video of Demo Reflex — Success



Planning Agents

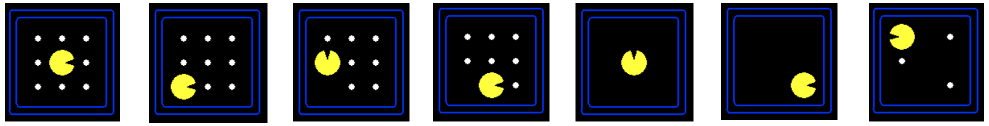
- Planning agents:
  - Ask “what if”
  - Decisions based on (hypothesized) consequences of actions
  - Must have a model of how the world evolves in response to actions
  - Must formulate a goal (test)
  - Consider how the world WOULD BE

- Optimal vs. complete planning
- Planning vs. replanning
- Planning vs. learning

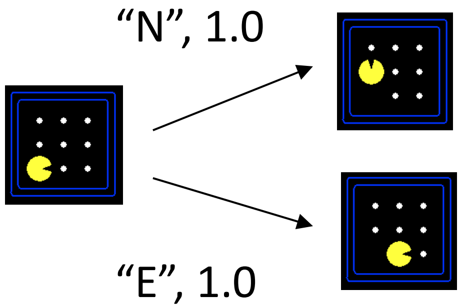


Search Problems

- A search problem consists of:
  - A state space



  - A successor function (with actions, costs)

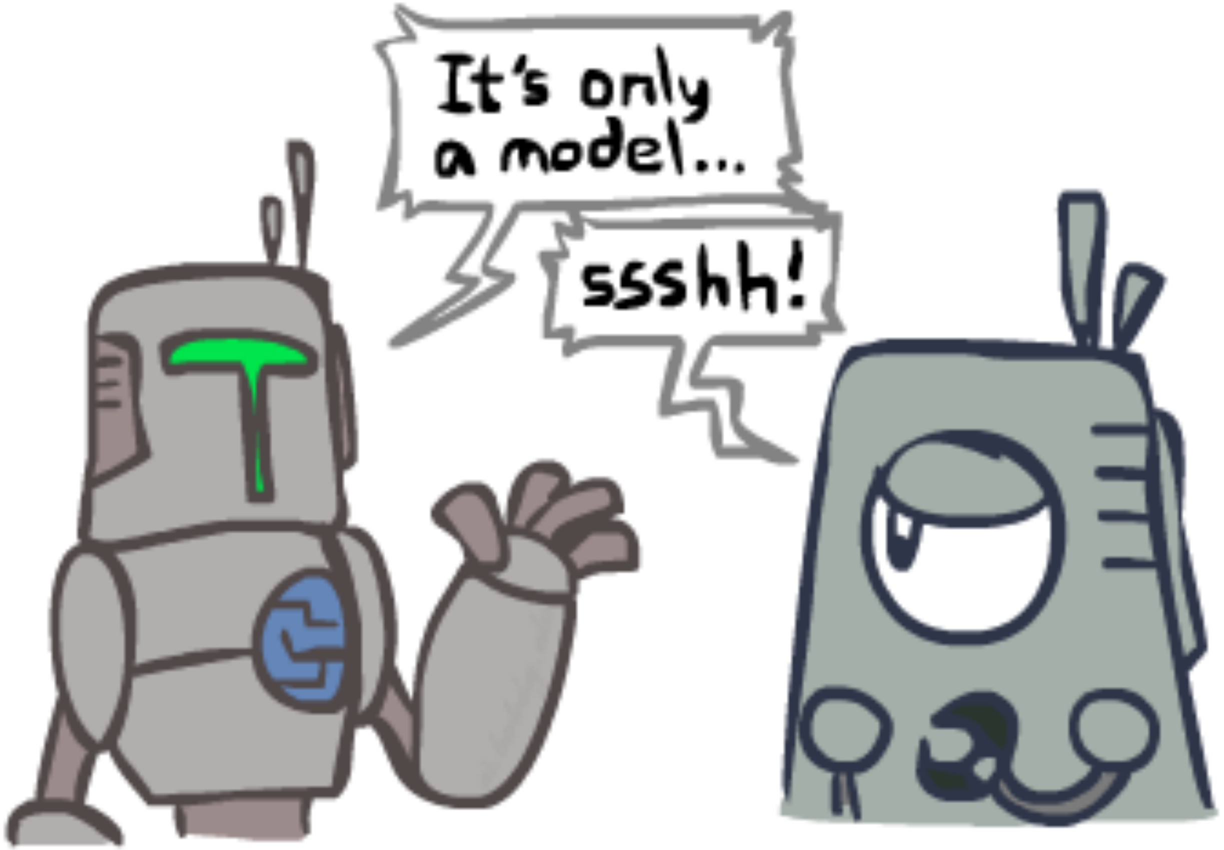


  - A start state and a goal test

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

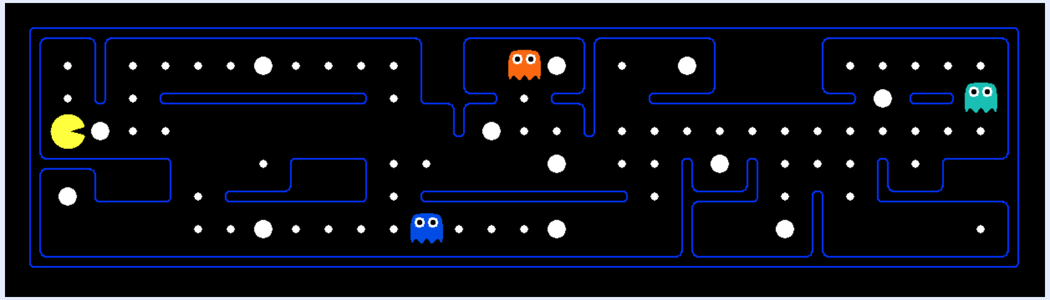
Search and Models

- Search operates over models of the world
  - The agent doesn't actually try all the plans out in the real world!
  - Planning is all "in simulation"
  - Your search is only as good as your models…
- This week:
  - Discrete
  - Deterministic
  - Fully observable



What's in a State Space?

The world state includes every last detail of the environment



A search state keeps only the details needed for planning (abstraction)

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

- Problem: Eat-All-Dots
  - States: {(x,y), dot booleans}
  - Actions: NSEW
  - Successor: update location and possibly a dot boolean
  - 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?

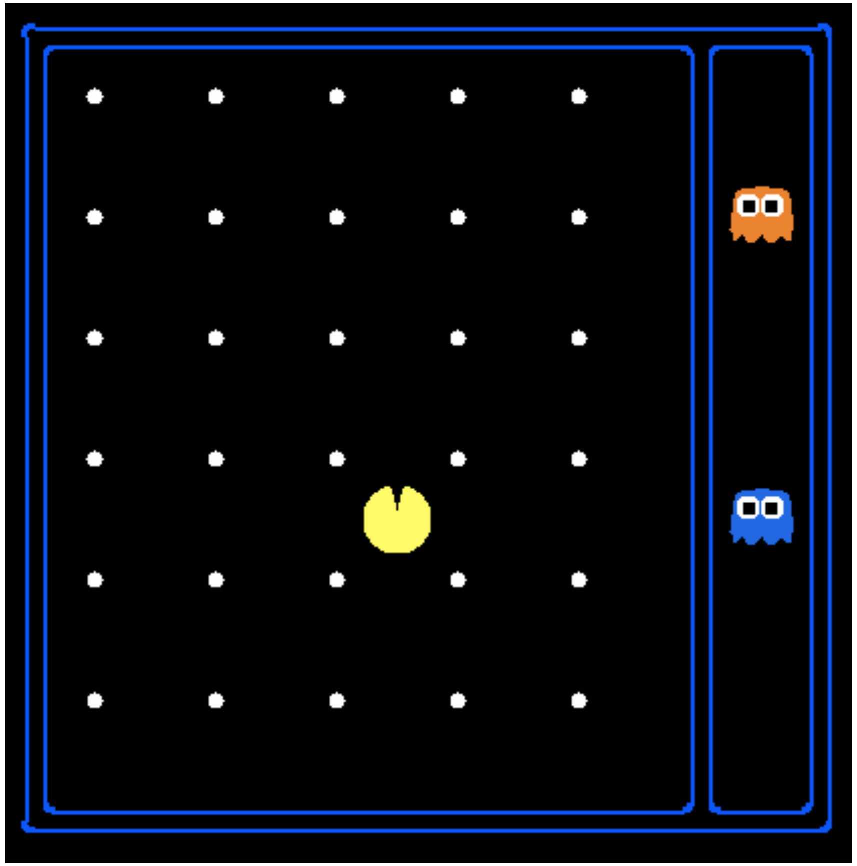
    $120 \times (2^{30}) \times (12^{2}) \times 4$ (> 74 trillion!)

    States for pathing?

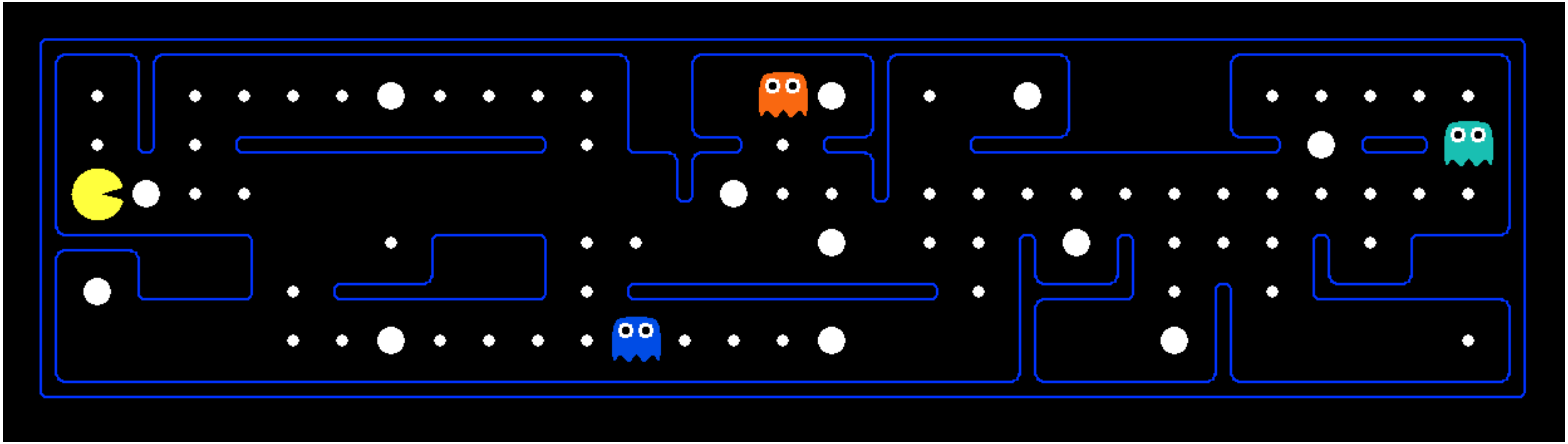
    120

    States for eat-all-dots?

    $120 \times (2^{30})$ (> 128 billion)

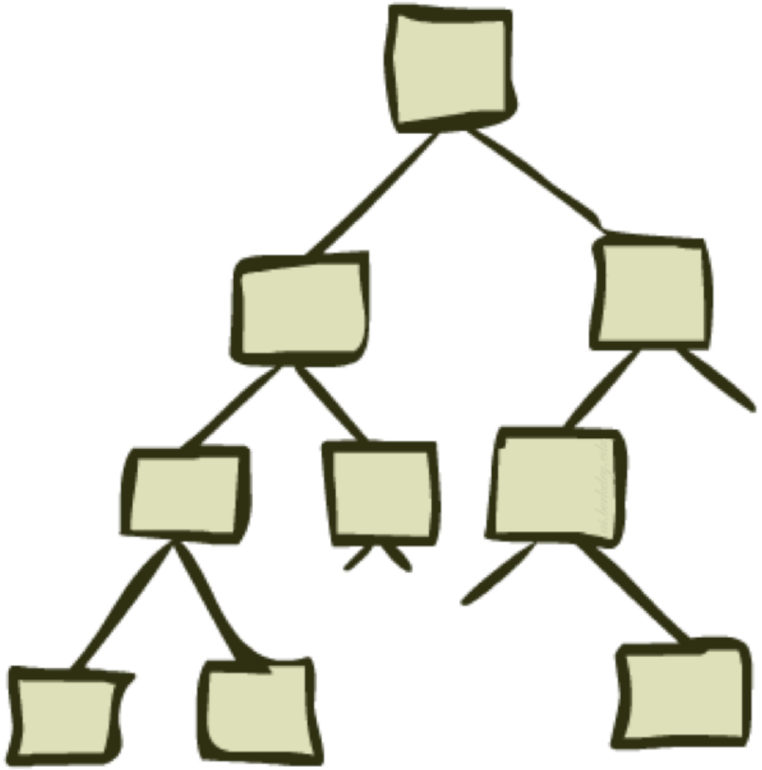


Quiz: Safe Passage



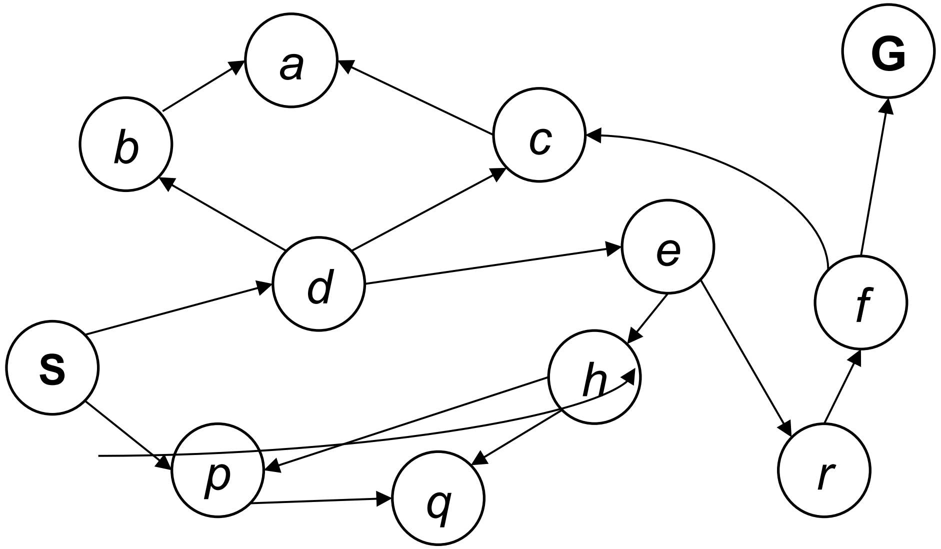
- Problem: eat all dots while keeping the ghosts perma-scared
- What does the state space have to specify?
  - (agent position, dot booleans, power pellet booleans, remaining scared time)

State Space Graphs and Search Trees



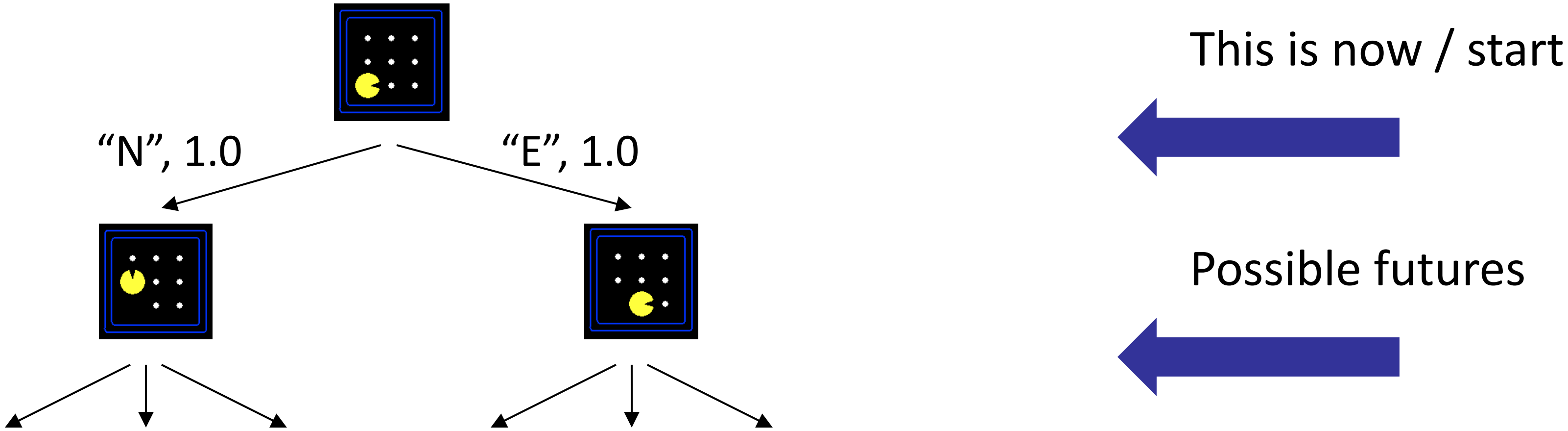
State Space Graphs

- State space graph: A mathematical representation of a search problem
  - Nodes are (abstracted) world configurations
  - Arcs represent successors (action results)
  - The goal test is a set of goal nodes (maybe only one)
- In a state space graph, each state occurs only once!
- We can rarely build this full graph in memory (it's too big), but it's a useful idea



Tiny search graph for a tiny search problem

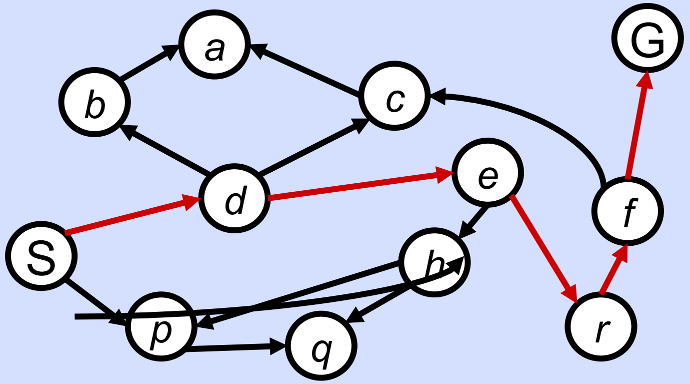
Search Trees



- A search tree:
  - A "what if" tree of plans and their outcomes
  - The start state is the root node
  - Children correspond to successors
  - Nodes show states, but correspond to PLANS that achieve those states
  - For most problems, we can never actually build the whole tree

State Space Graphs vs. Search Trees

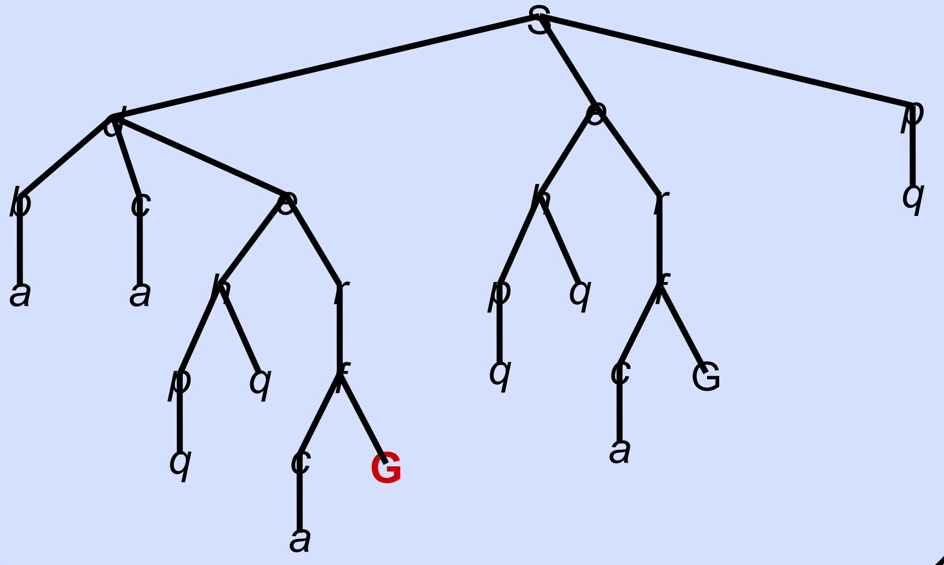
State Space Graph



Each NODE in in the search tree is an entire PATH in the state space graph.

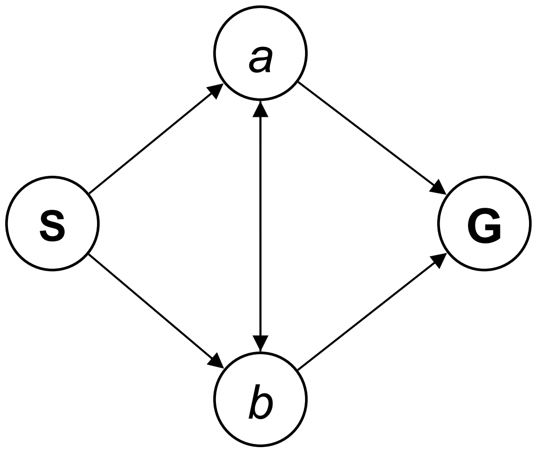
We construct both on demand – and we construct as little as possible.

Search Tree



Quiz: State Space Graphs vs. Search Trees

Consider this 4-state graph:



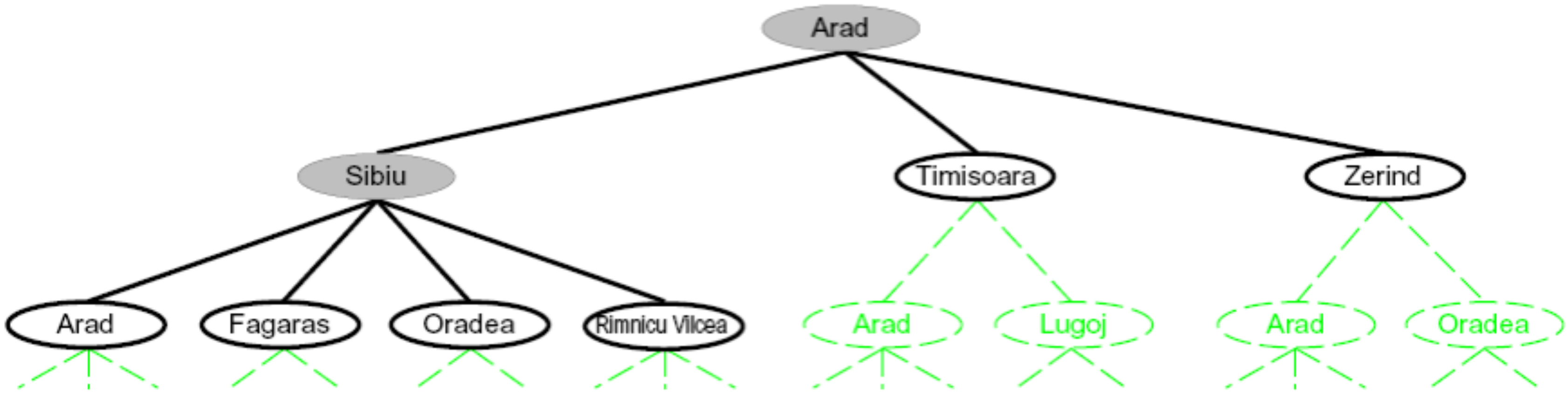
How big is its search tree (from S)?

Important: Lots of repeated structure in the search tree!

So why would we ever use a search tree?

1) Cannot store “closed list” (previously visited nodes)
2) Graph happens to be a tree, so no reason to store closed list

Searching with a Search Tree



- Search:
  - Expand out potential plans (tree nodes)
  - Maintain a fringe of partial plans under consideration
  - Try to expand as few tree nodes as possible

General Tree Search

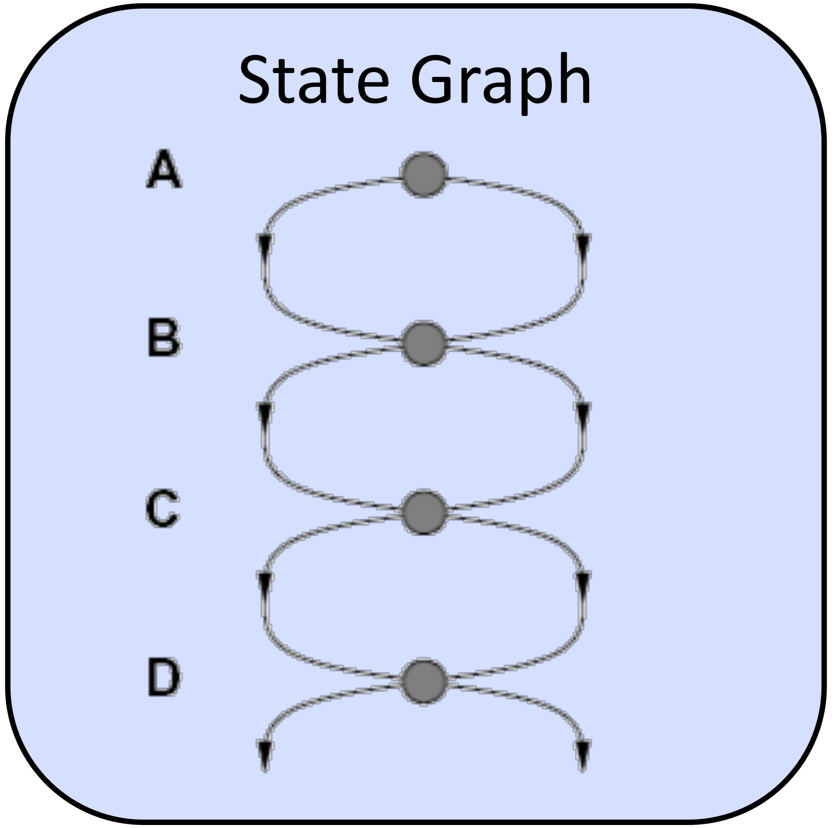
```
function TREE-SEARCH( problem, strategy) returns a solution, or failure
    initialize the search tree using the initial state of problem
    loop do
        if there are no candidates for expansion then return failure
        choose a leaf node for expansion according to strategy
        if the node contains a goal state then return the corresponding solution
        else expand the node and add the resulting nodes to the search tree
    end
```

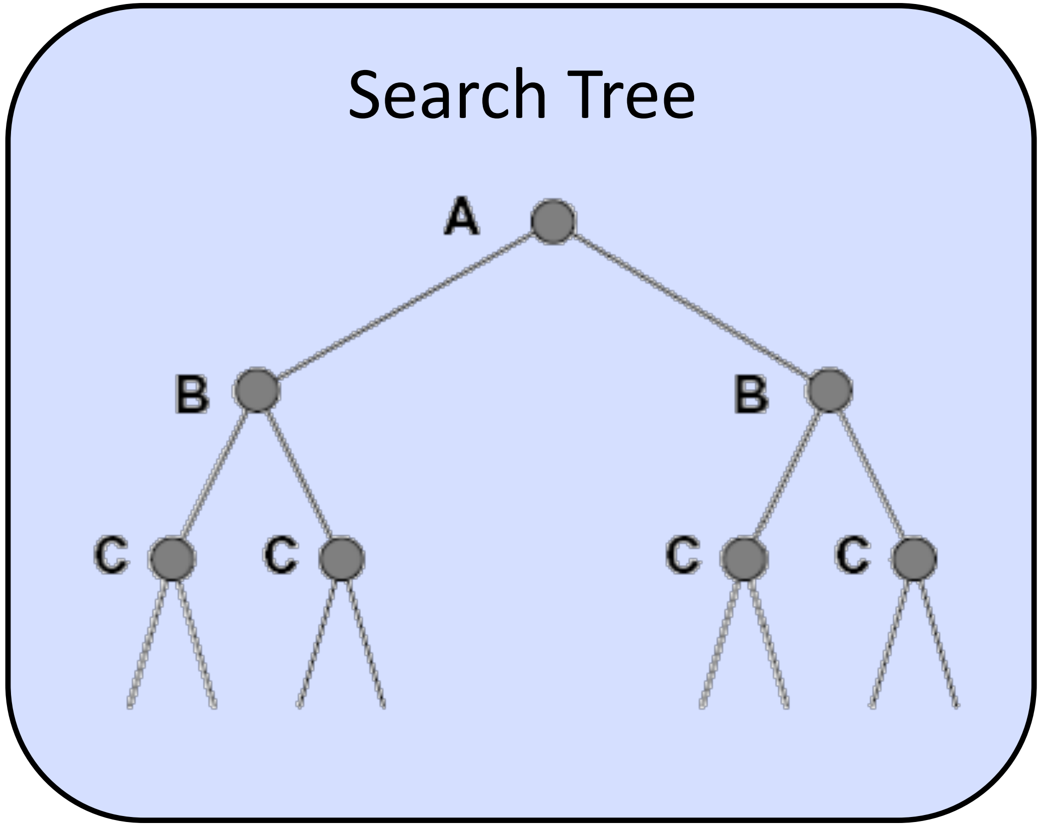
- Important ideas:
  - Fringe
  - Expansion
  - Exploration strategy

- Main question: which fringe nodes to explore?

Tree Search: Extra Work!

- Failure to detect repeated states can cause exponentially more work.





Graph Search

- Idea: never expand a state twice
- How to implement:
  - Tree search + set of expanded states ("closed set")
  - Expand the search tree node-by-node, but…
  - Before expanding a node, check to make sure its state has never been expanded before
  - If not new, skip it, if new add to closed set
- Important: store the closed set as a set, not a list
- Can graph search wreck completeness? Why/why not?
- How about optimality?

The Main Search Algorithms

- Uninformed Search:
  - Breadth First Search (BFS)
  - Depth First Search (DFS)
  - Uniform Cost Search (UCS) ~ [Dijkstra’s Algorithm]
- Informed Search:
  - Greedy Search ~ [Best First Search]
  - A* Search
- Test your understanding!