Announcements

- To be released by tomorrow morning
  - Slides
  - Access to edX Edge
  - Project 0: Python Tutorial
  - Math self-diagnostic on web --- optional, but important to check your preparedness for second half
  - Make sure you join the class on Piazza (so far … 28 enrolled)

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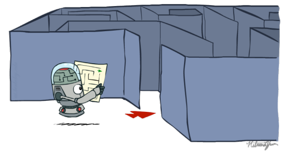
CSC 481: Artificial Intelligence

Search, DFS



Instructor: Marco Alvarez

University of Rhode Island

[These slides were 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.]

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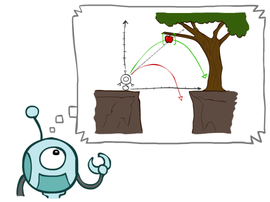
Today

- Agents that Plan Ahead
- Search Problems
- Uninformed Search Methods
  - Depth-First Search



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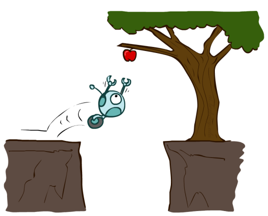
Reflex Agents

- 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



[Demo: reflex optimal (L2D1)]
[Demo: reflex optimal (L2D2)]

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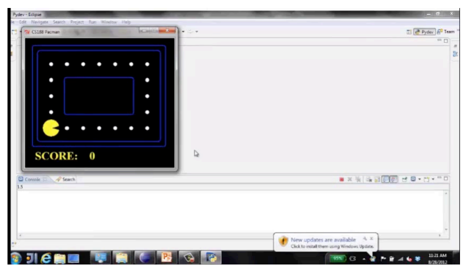
Video of Demo Reflex Optimal



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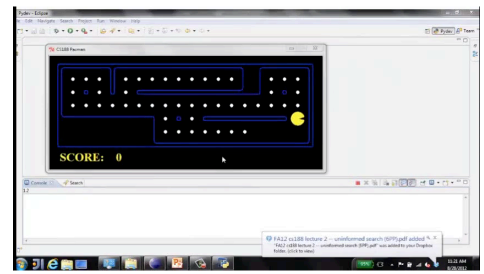
Video of Demo Reflex Odd



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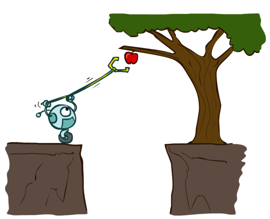
Planning Agents

- 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



[Demo: replanning (L2D3)]
[Demo: mastermind (L2D4)]

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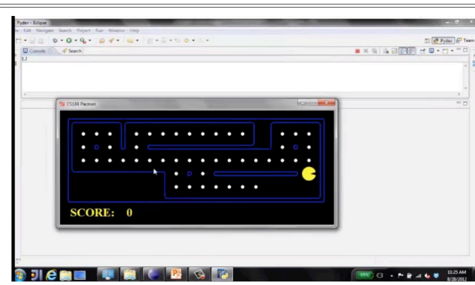
Video of Demo Mastermind



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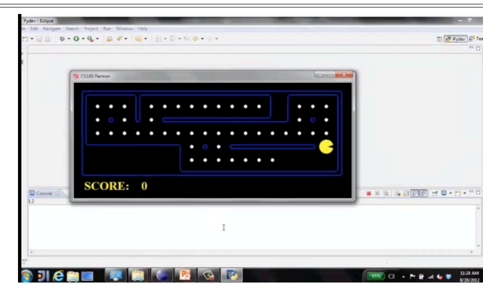
Video of Demo Replanning



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Search Problems

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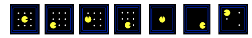
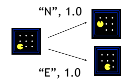
Search Problems

- 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

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Search Problems Are Models

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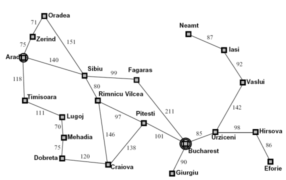
Example: Traveling in Romania



- State space:
  - Cities
- Successor function/Action:
  - Roads: Go to adjacent city with **cost** = distance
- Start state:
  - Arad
- Goal test:
  - Is state == Bucharest?
- Solution?

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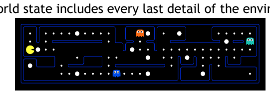
What's in a State Space?

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

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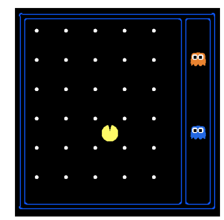
State Space Sizes?

- World state:
  - Agent positions: 120
  - Food count: 30
  - Ghost positions: 12
  - Agent facing: NSEW
- How many
  - World states?
    $120 \mathrm{x}(2^{30}) \mathrm{x}(12^2) \mathrm{x}4$
  - States for pathing?
    120
  - States for eat-all-dots?
    $120 \mathrm{x}(2^{30})$



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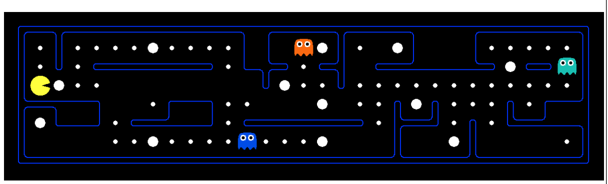
Quiz: Safe Passage



- 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)

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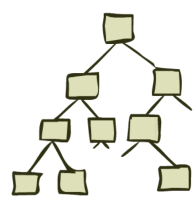
State Space Graphs and Search Trees



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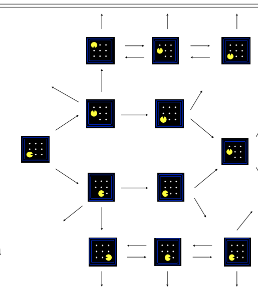
State Space Graphs

- 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



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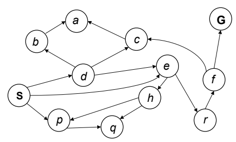

Tiny search graph for a tiny search problem

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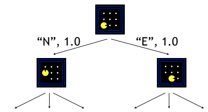
Search Trees



This is now / start

Possible futures

- 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

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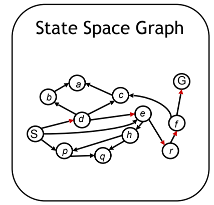
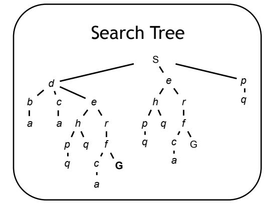
State Space Graphs vs. Search Trees



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.



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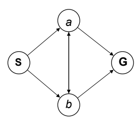
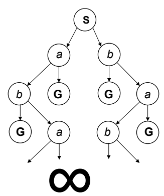
Quiz: State Space Graphs vs. Search Trees

Consider this 4-state graph:



How big is its search tree (from S)?



Important: Lots of repeated structure in the search tree!

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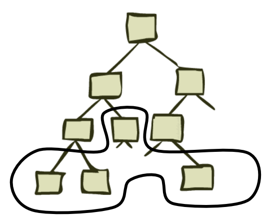
Tree Search



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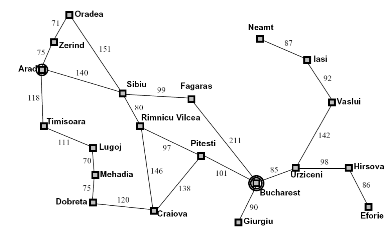
Search Example: Romania



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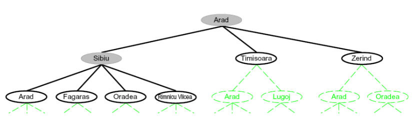
Searching with a Search Tree



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

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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?

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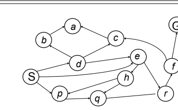
Example: Tree Search



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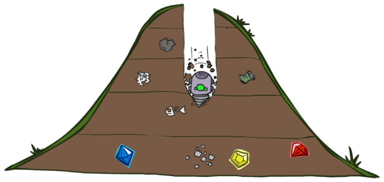
Depth-First Search



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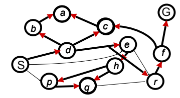
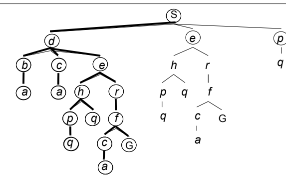
Depth-First Search

Strategy: expand a deepest node first

Implementation: Fringe is a LIFO stack





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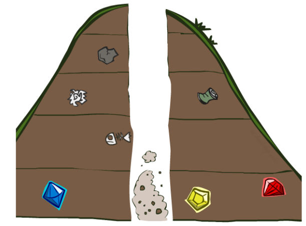
Search Algorithm Properties



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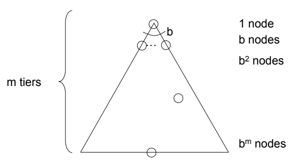
Search Algorithm Properties

- Complete: Guaranteed to find a solution if one exists?
- Optimal: Guaranteed to find the least cost path?
- Time complexity?
- Space complexity?

- Cartoon of search tree:
  - b is the branching factor
  - m is the maximum depth
  - solutions at various depths

- Number of nodes in entire tree?
  - $1 + b + b^2 + \ldots. b^m = O(b^m)$



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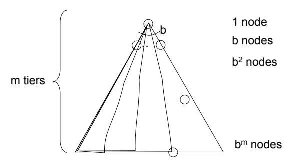
Depth-First Search (DFS) Properties

- What nodes DFS expand?
  - Some left prefix of the tree.
  - Could process the whole tree!
  - If m is finite, takes time $O(b^m)$
- How much space does the fringe take?
  - Only has siblings on path to root, so O(bm)
- Is it complete?
  - m could be infinite, so only if we prevent cycles (more later)
- Is it optimal?
  - No, it finds the "leftmost" solution, regardless of depth or cost



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