CIS 471/571(Fall 2020): Introduction to Artificial Intelligence

Lecture 2: Uninformed Search

Thanh H. Nguyen

Most slides are by Pieter Abbeel, Dan Klein, Luke Zettlemoyer, John DeNero, Stuart Russell, Andrew Moore, or Daniel Lowd
Source: http://ai.berkeley.edu/home.html

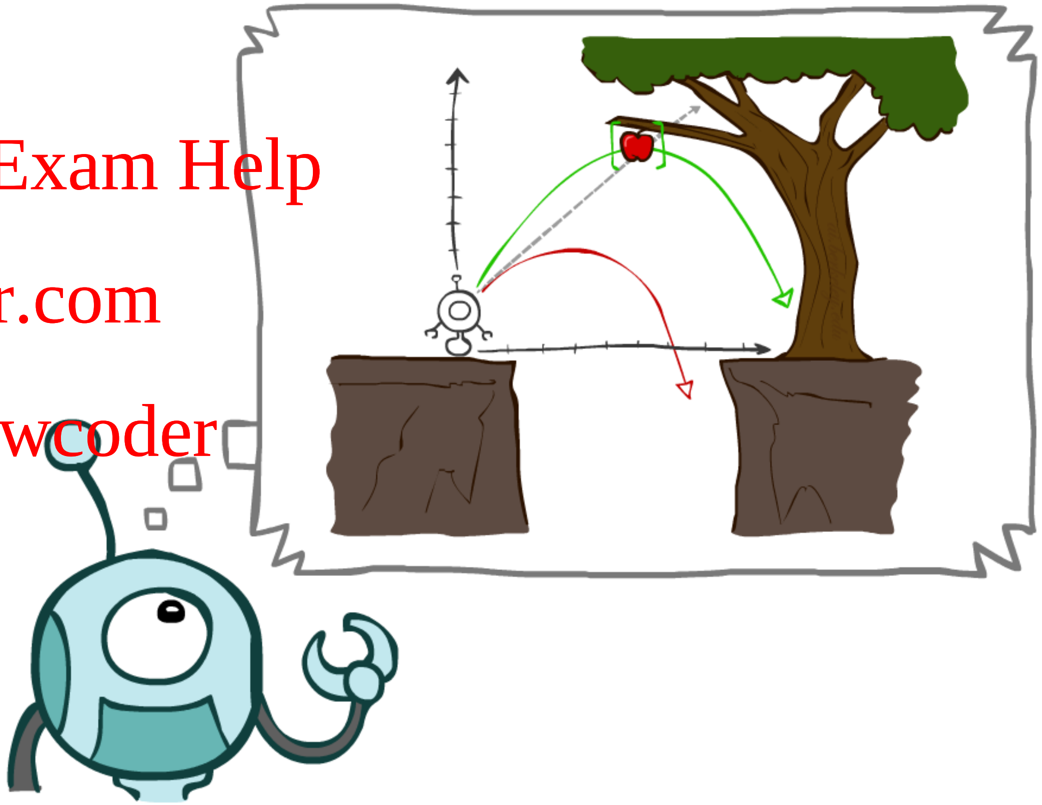
Announcement

- Project 1
  - Deadline: Oct 13th, 2020

- Written Assignment 1
  - Will be posted today
  - Deadline: Oct 10th, 2020

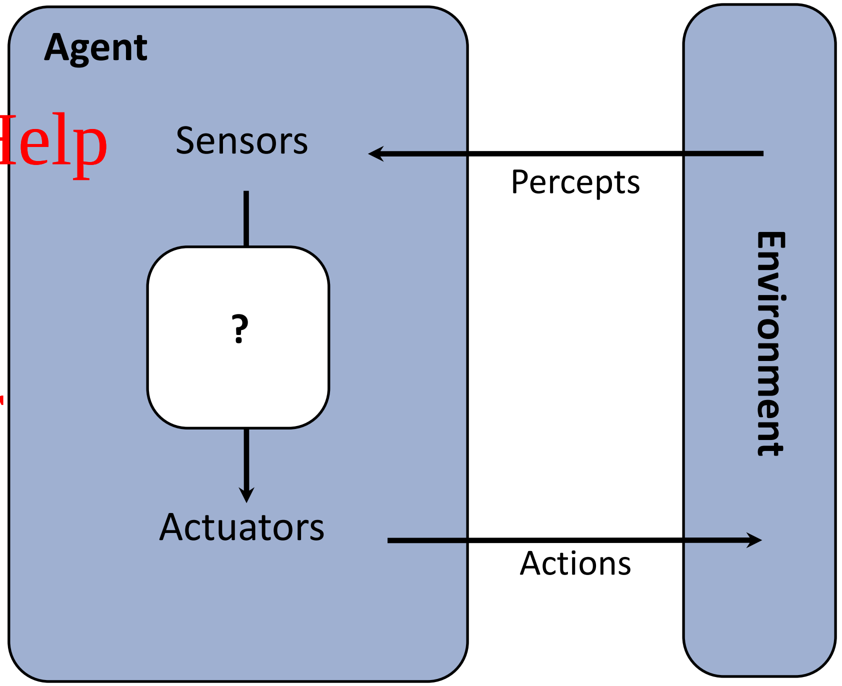
Today

- Agents that Plan Ahead
- Search Problems
- Uninformed Search Methods
  - Depth-First Search
  - Breadth-First Search
  - Uniform-Cost Search



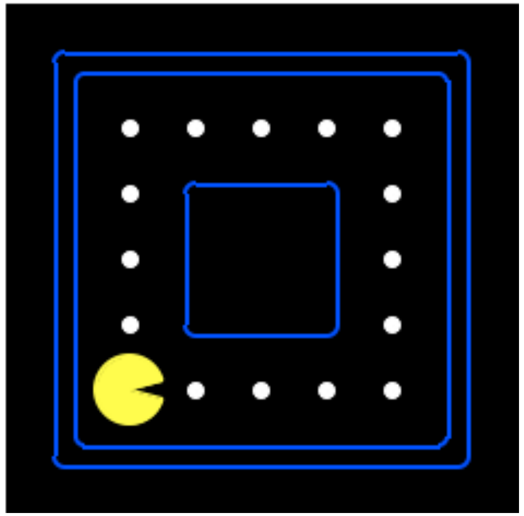
Rational Agents

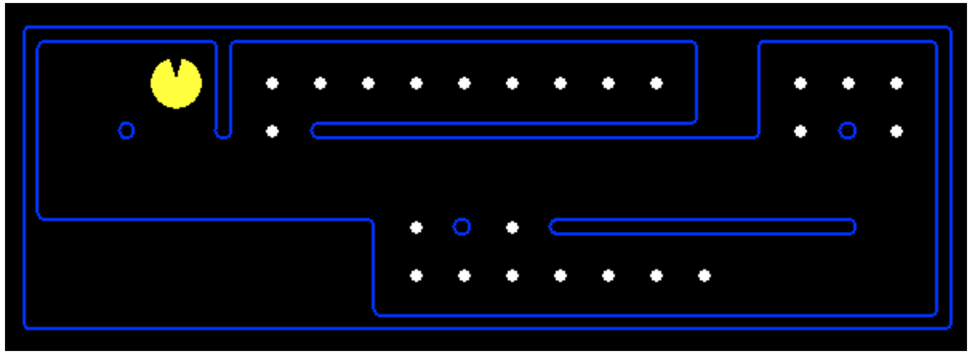
- An **agent** is an entity that *perceives* and *acts*.
- A **rational agent** selects actions that maximize its **utility function**.
- Characteristics of the **percepts, environment,** and **action space** dictate techniques for selecting rational actions.



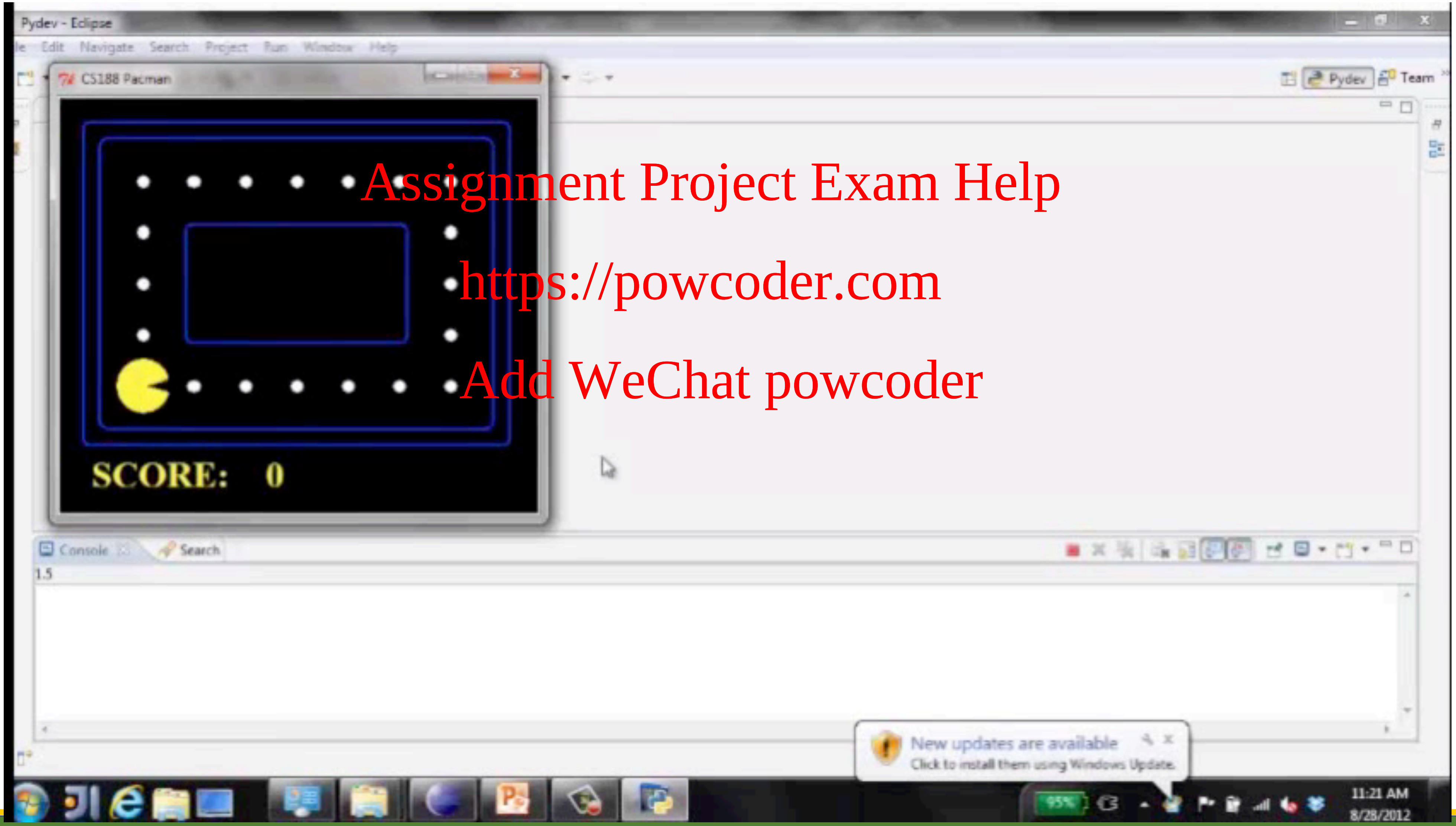
Reflex Agents

- Reflex agents:
  - Choose action based on current percept (and maybe memory)
  - Do not consider future consequences of their actions
  - Consider how the world IS
- Can a reflex agent be rational?

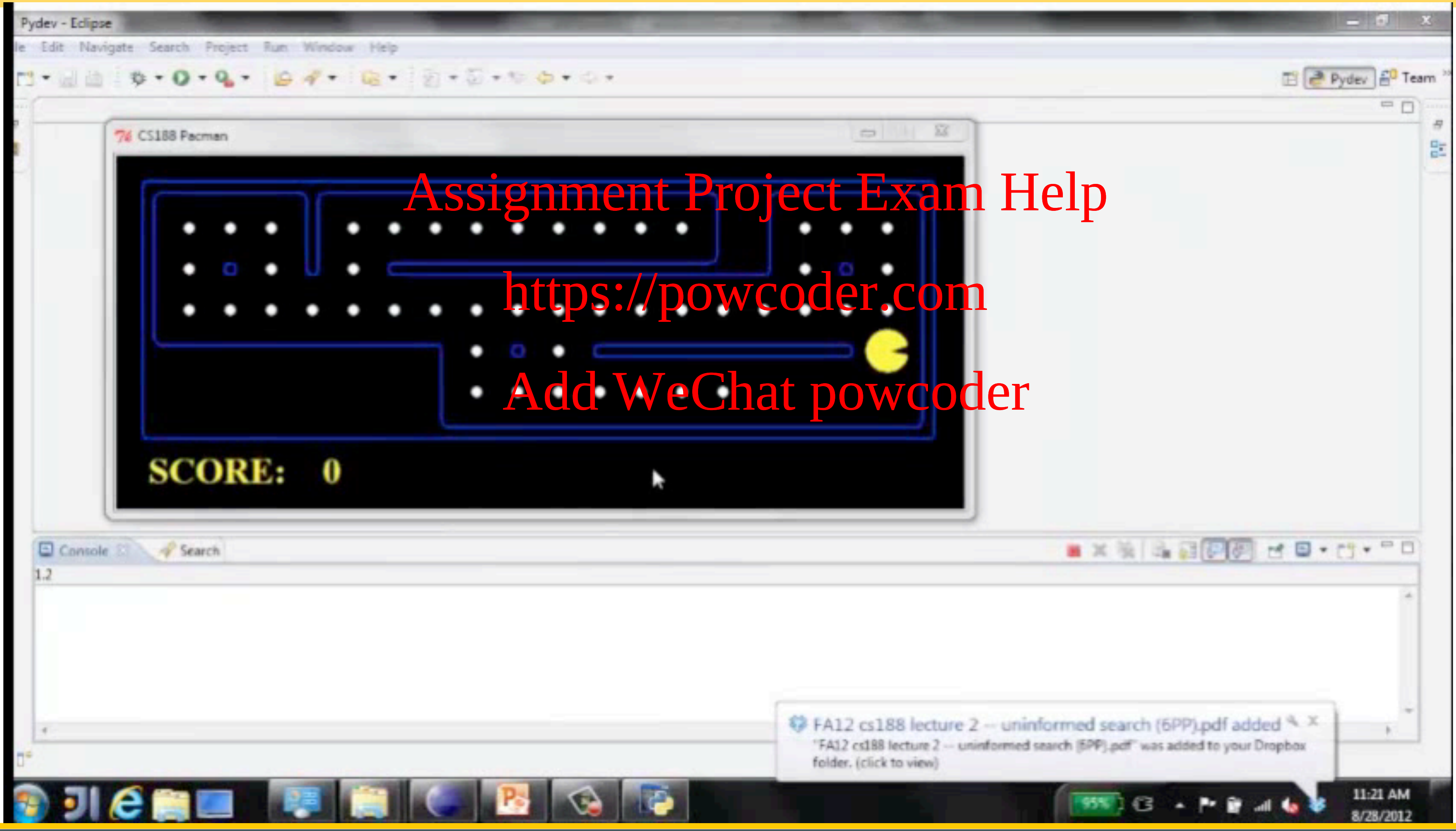




Video of Demo Reflex Optimal

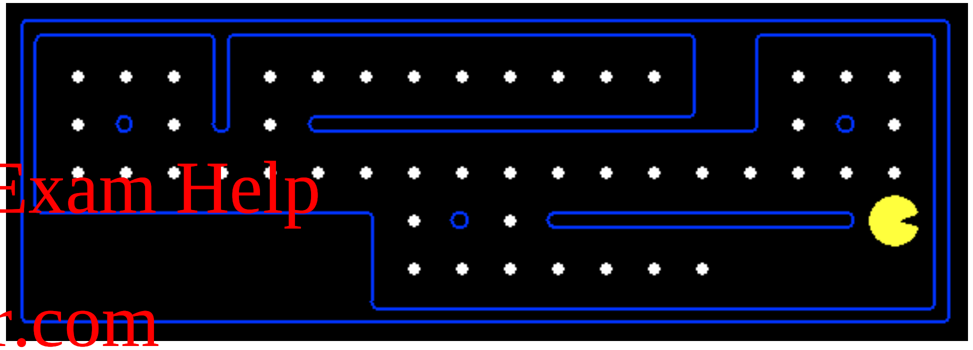


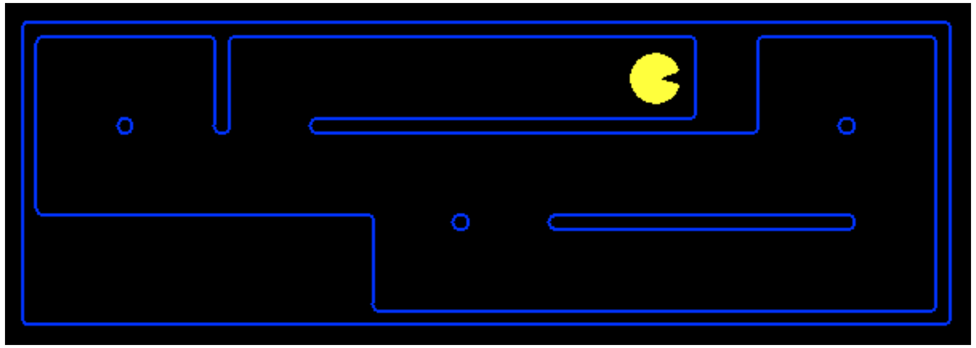
Video of Demo Reflex Odd



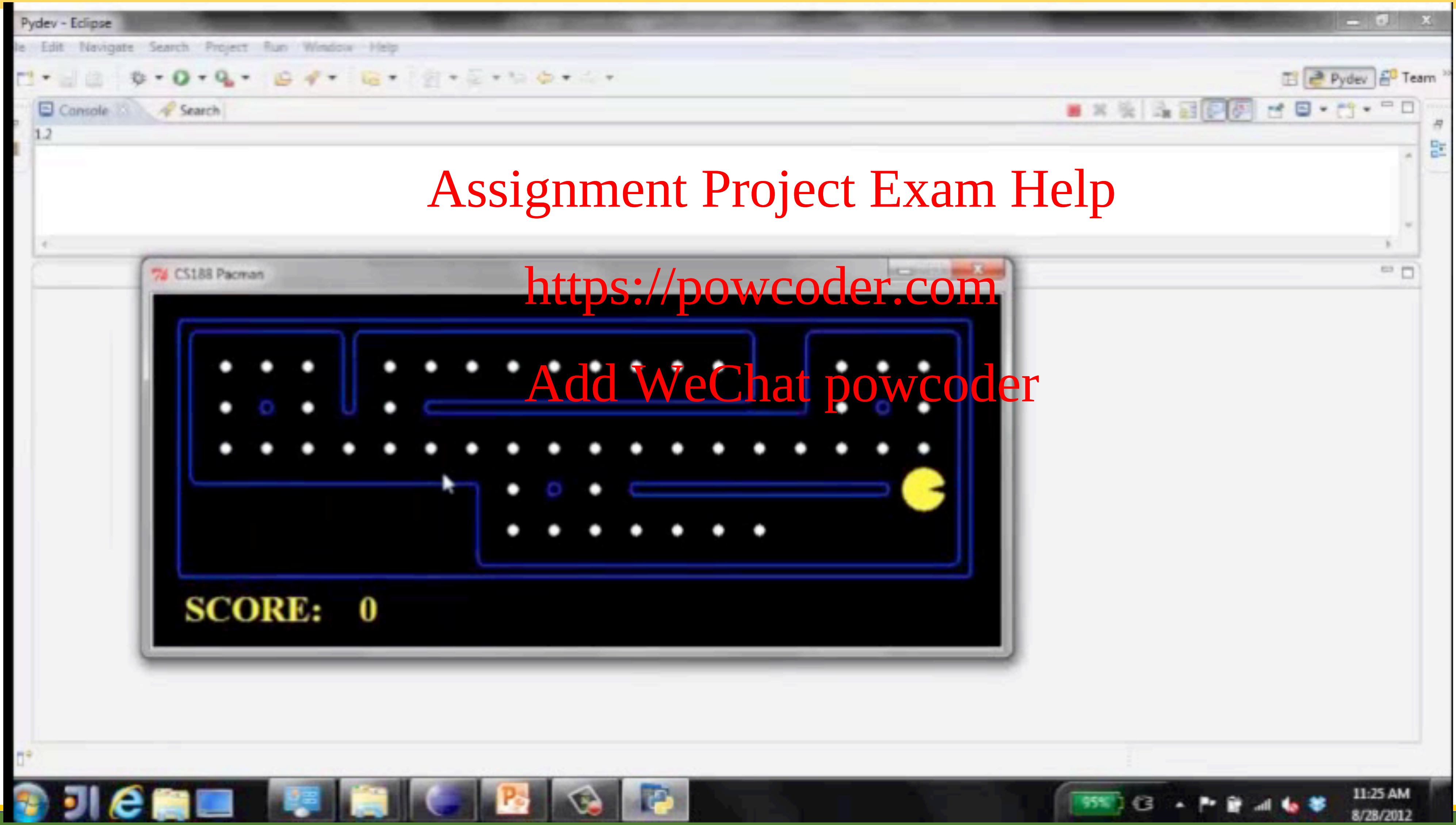
Goal-based Agents

- Goal-based agents:
  - Plan ahead
  - Ask “what if”
  - Decisions based on (hypothesized) consequences of actions
  - Must have a model of how the world evolves in response to actions
  - Act on how the world WOULD BE



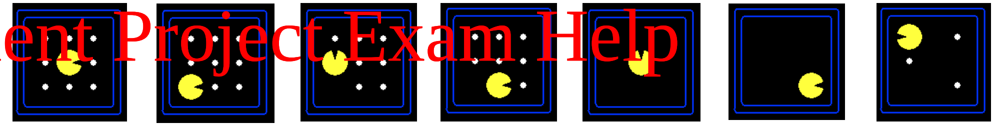


Video of Demo Mastermind

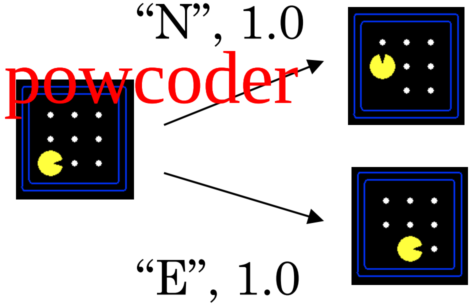


Search Problem

- A search problem consists of:
  - A state space



  - A successor function (with actions, costs)

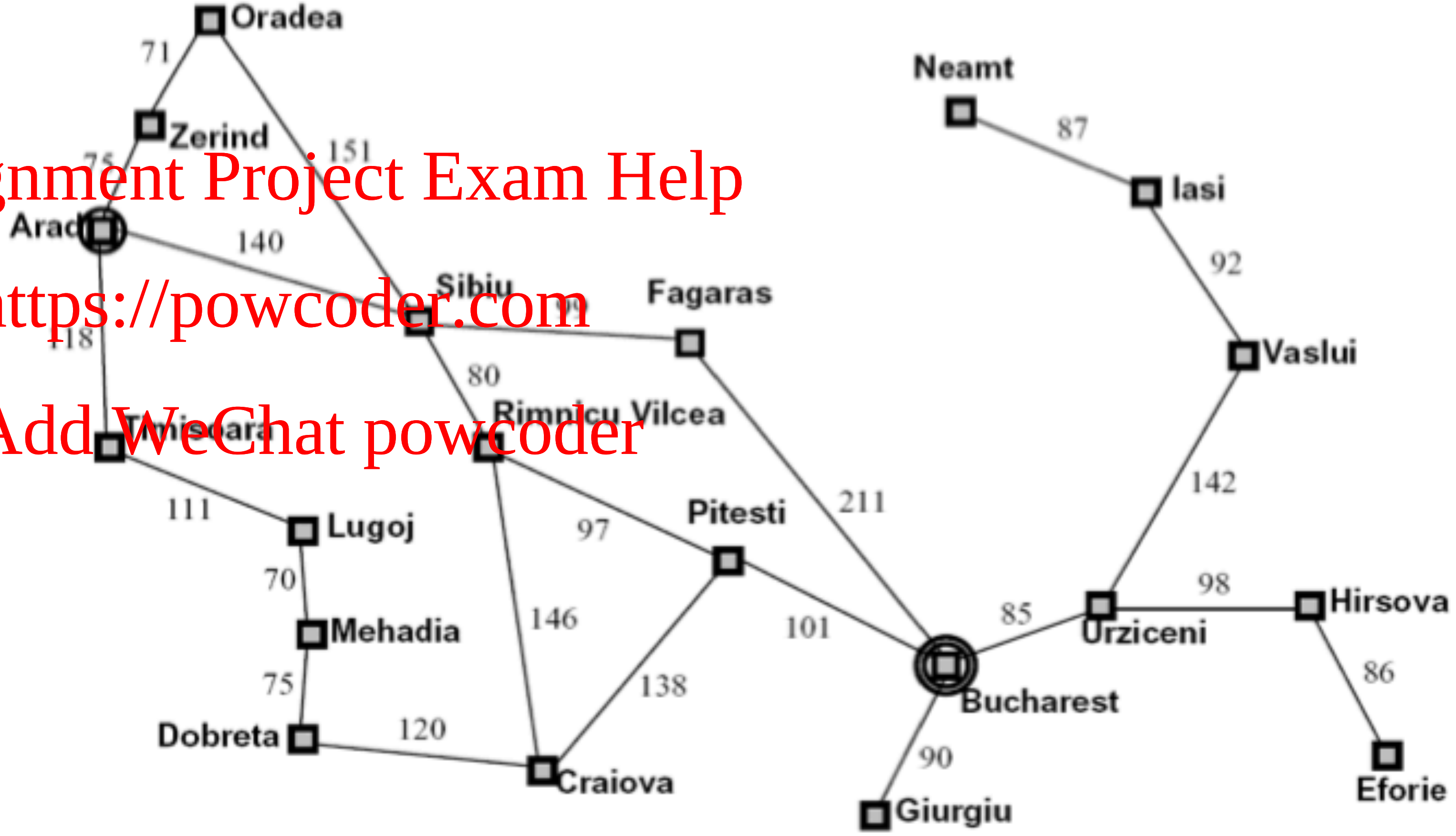


  - A start state and a goal test

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

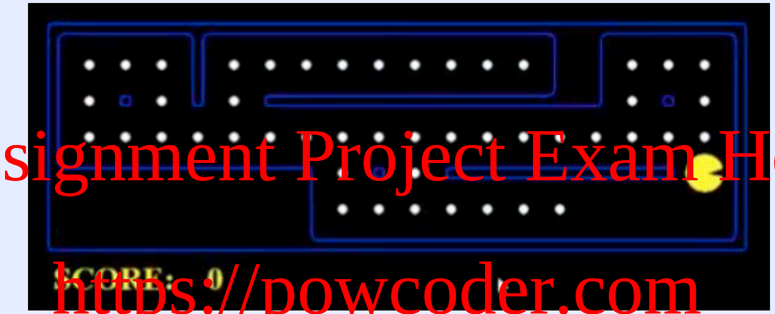
Example: Romania

- State space:
  - Cities
- Successor function:
  - Go to adj city with cost = dist
- Start state:
  - Arad
- Goal test:
  - Is state == Bucharest?
- Solution?



What is in State Space

The world state includes every last detail of the environment



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

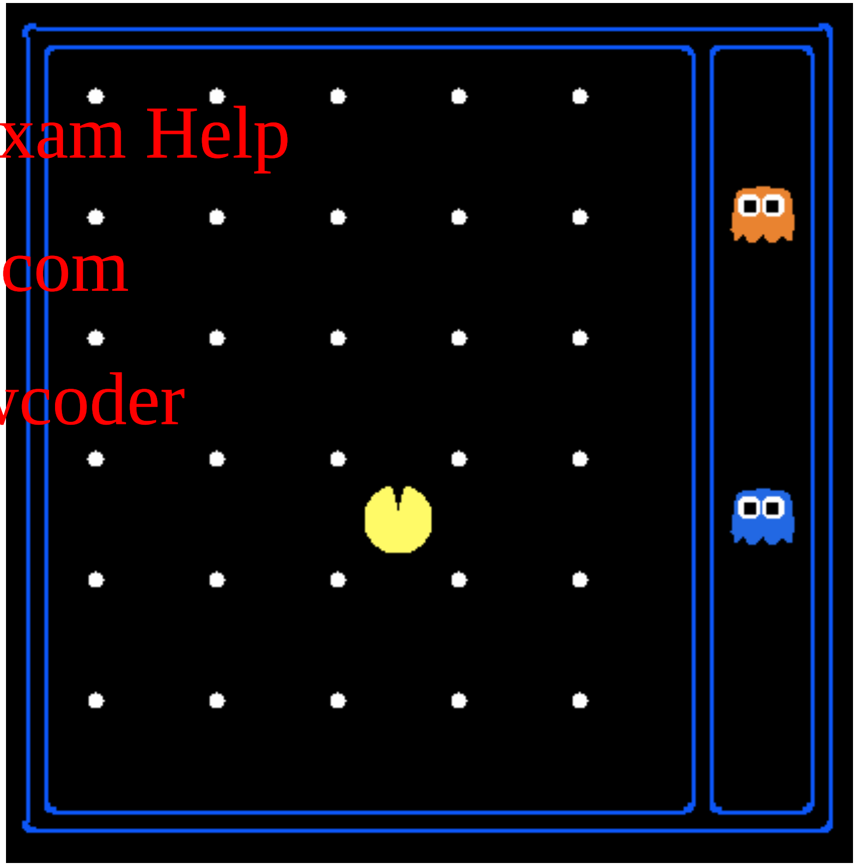
- Problem: Eat-All-Dots
  - States: {(x,y), dot booleans}
  - Actions: NSEW
  - Successor: update location and possibly a dot boolean
  - Goal test: dots all false

State Space Size

- Search Problem:
  Eat all of the food

- Pacman positions: 10 x 12 = 120
- Pacman facing: up, down, left, right
- Food Count: 30
- Ghost positions: 12

- How many
- World states? $120*(2^{30})*(12^2)*4$
- States for pathing? 120
- States for eat-all-dots? $120*(2^{30})$

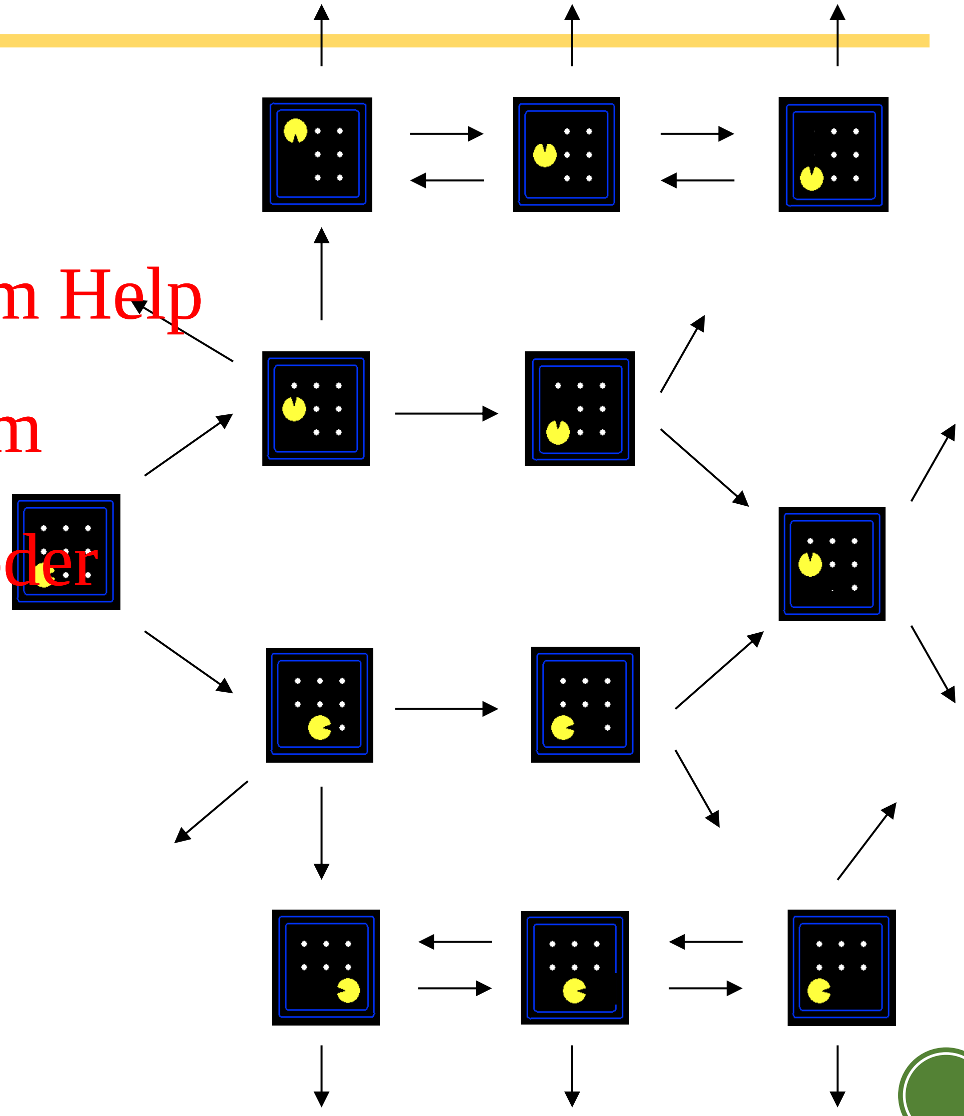


State Space Graphs

- 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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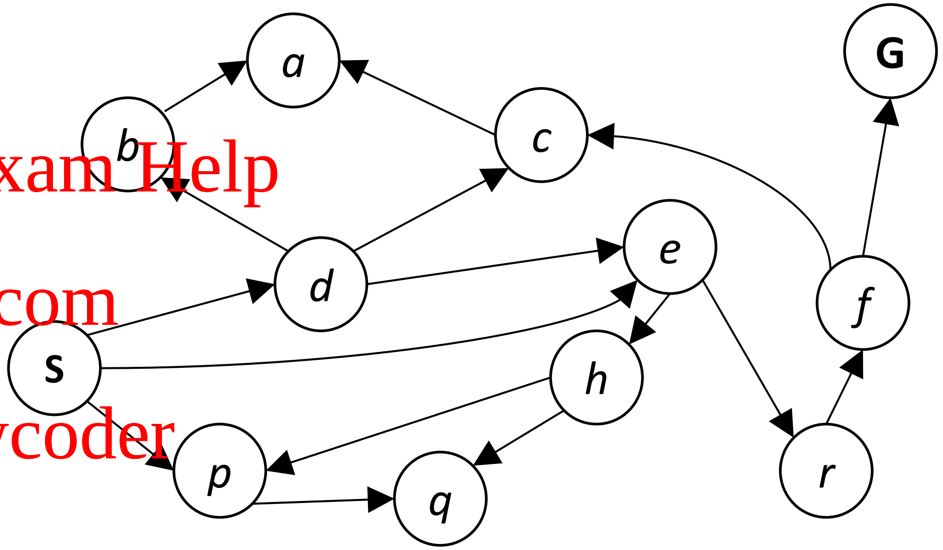
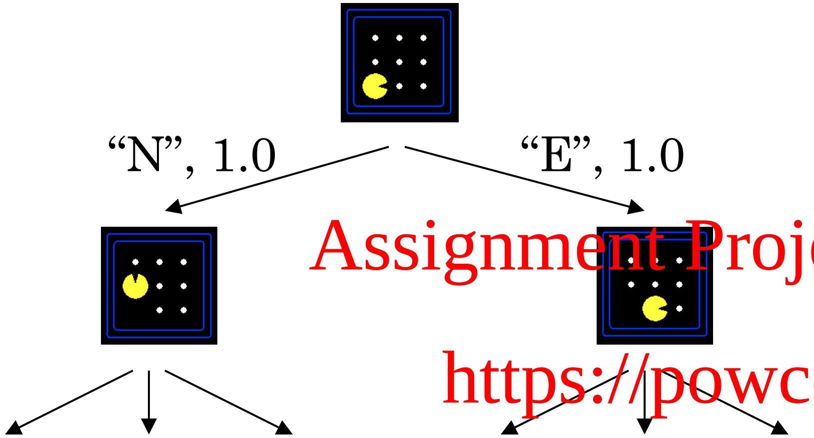


Tiny state space graph for a tiny search problem

Search Trees



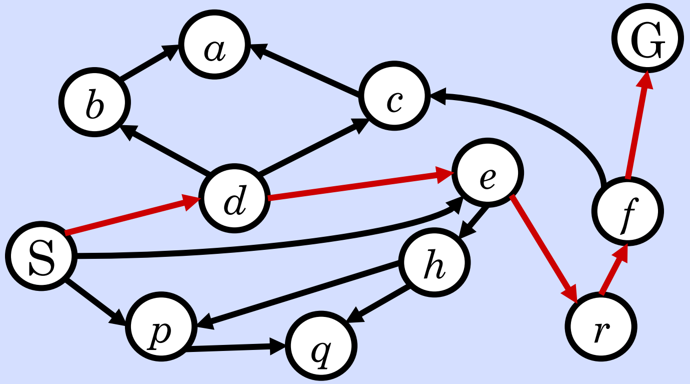
This is now / start

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

State Space Graphs vs. Search Trees

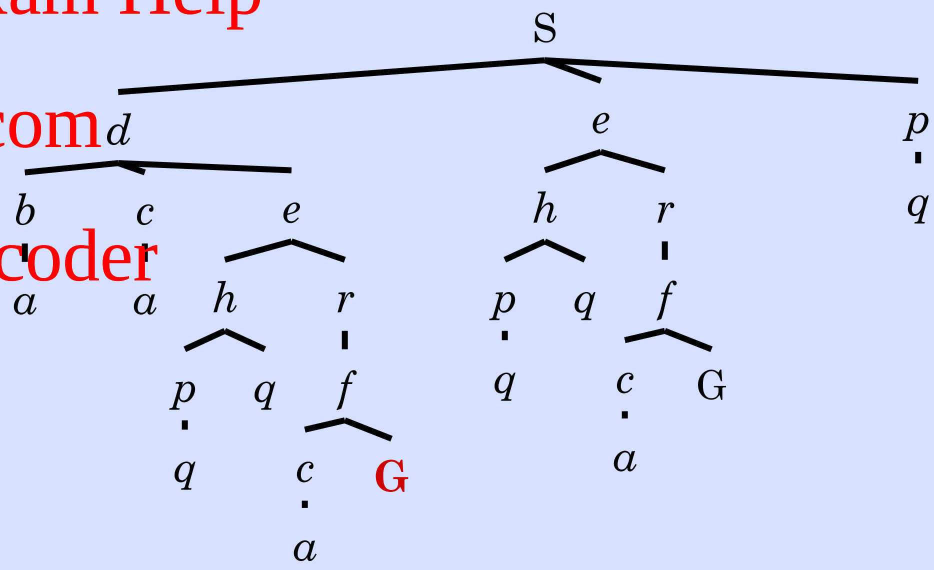
State Space Graph



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

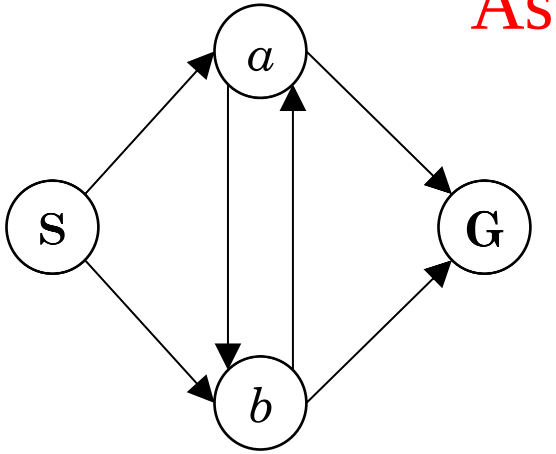
We construct both on demand – and we construct as little as possible.

Search Tree



Quiz: State Space Graphs vs. Search Trees

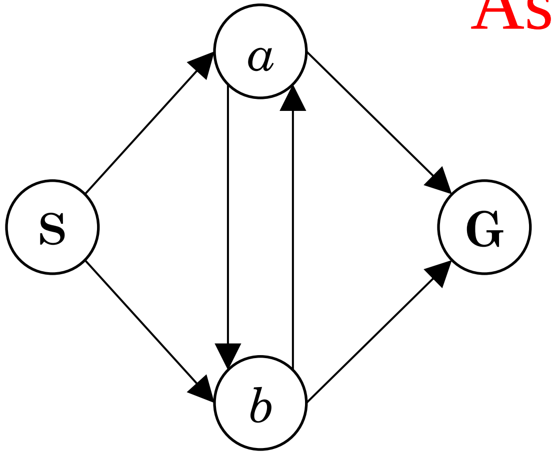
Consider this 4-state graph:



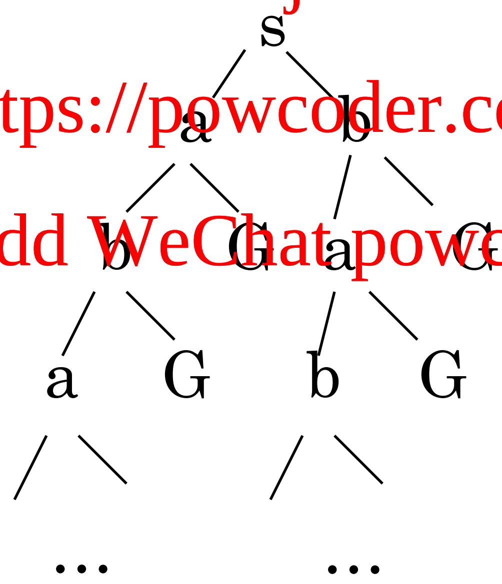
How big is its search tree (from S)?

Quiz: State Space Graphs vs. Search Trees

Consider this 4-state graph:

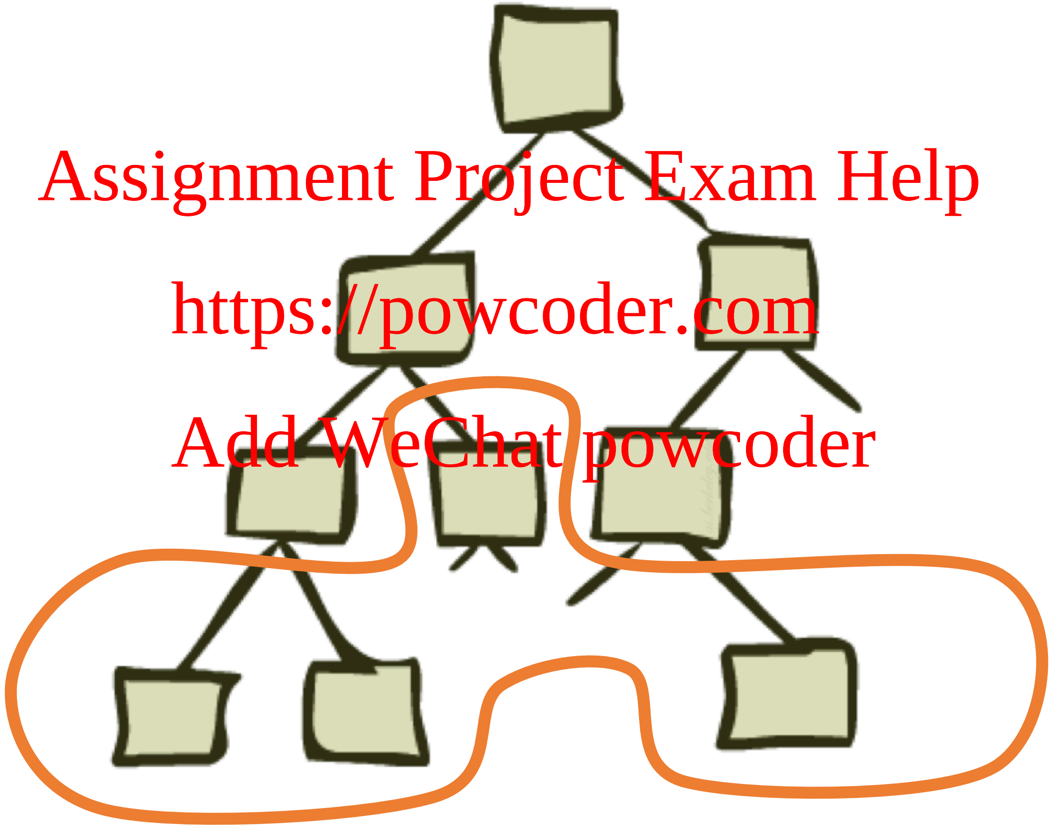


How big is its search tree (from S)?

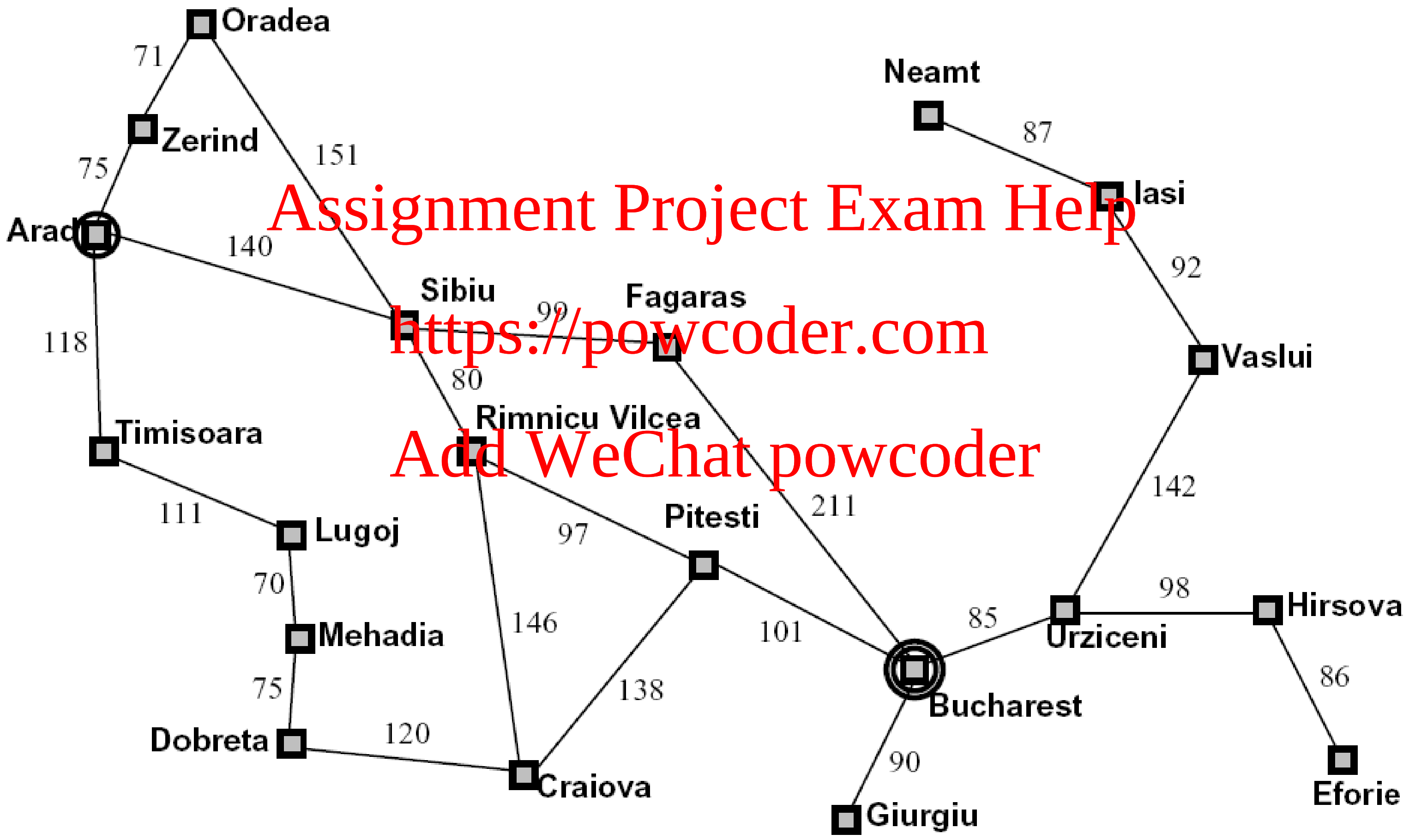


Important: Lots of repeated structure in the search tree!

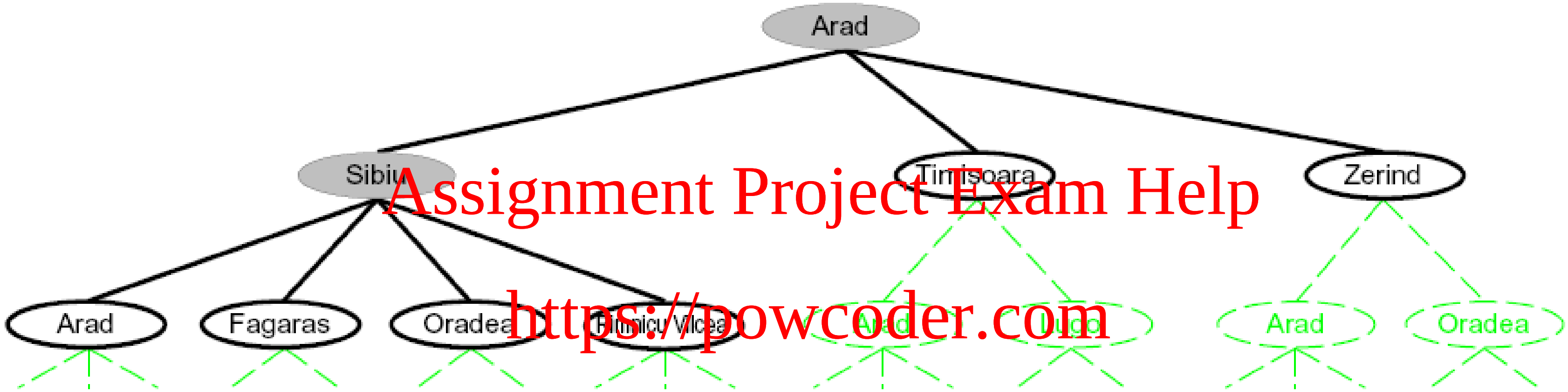
Tree Search



Search Example: Romania



Searching with a Search Tree

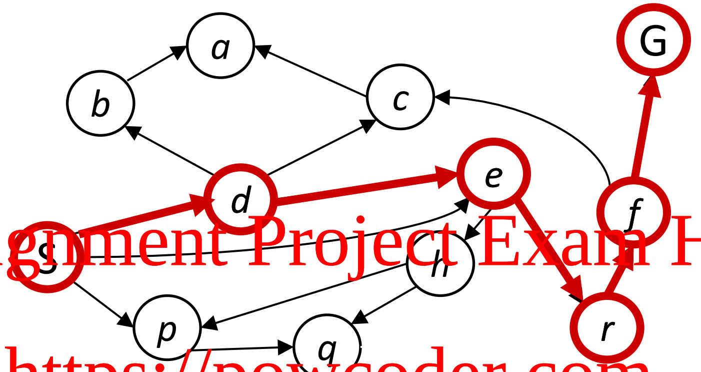


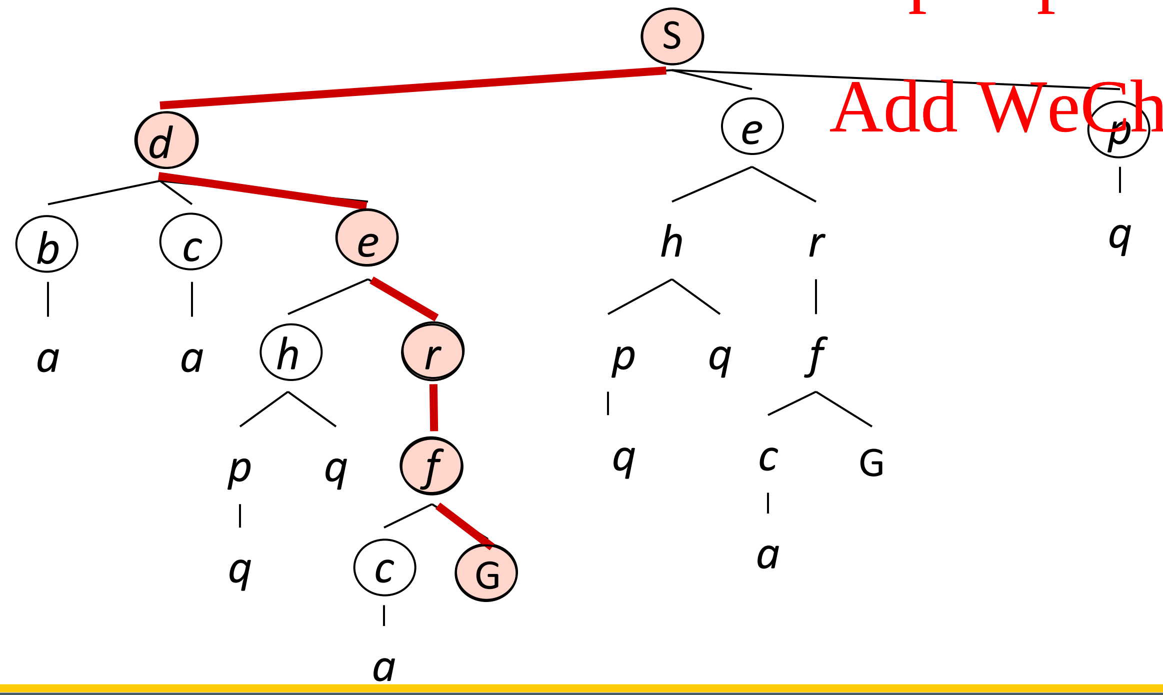
- Search:
  - Expand out potential plans (tree nodes)
  - Maintain a fringe of partial plans under consideration
  - Try to expand as few tree nodes as possible

General Tree Search

- Tree Search
  - Initialize the *root node* of the search tree with the *start state*
  - While there are unexpanded leaf nodes (fringe):
    - Choose a leaf node (strategy)
    - If the node contains a goal state:
      return the corresponding solution
    - Else: expand the node and add its children to the tree
- Important ideas:
  - Fringe
  - Expansion
- Strategy: which fringe nodes to explore?

Example: Tree Search





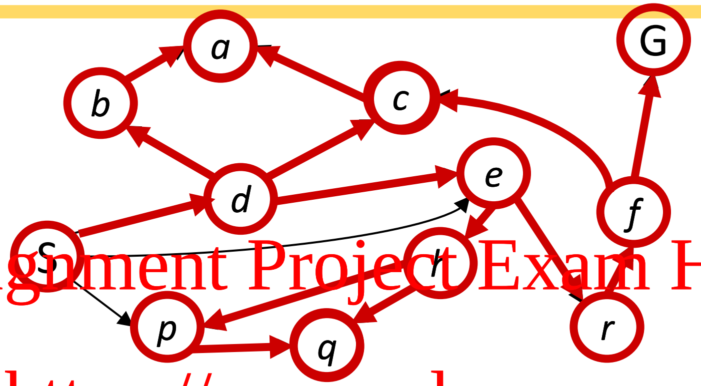
~~s~~
~~s → d~~
s → e
s → p
s → d → b
s → d → c
~~s → d → e~~
s → d → e → h
~~s → d → e → r~~
~~s → d → e → r → f~~
s → d → e → r → f → c
~~s → d → e → r → f → G~~

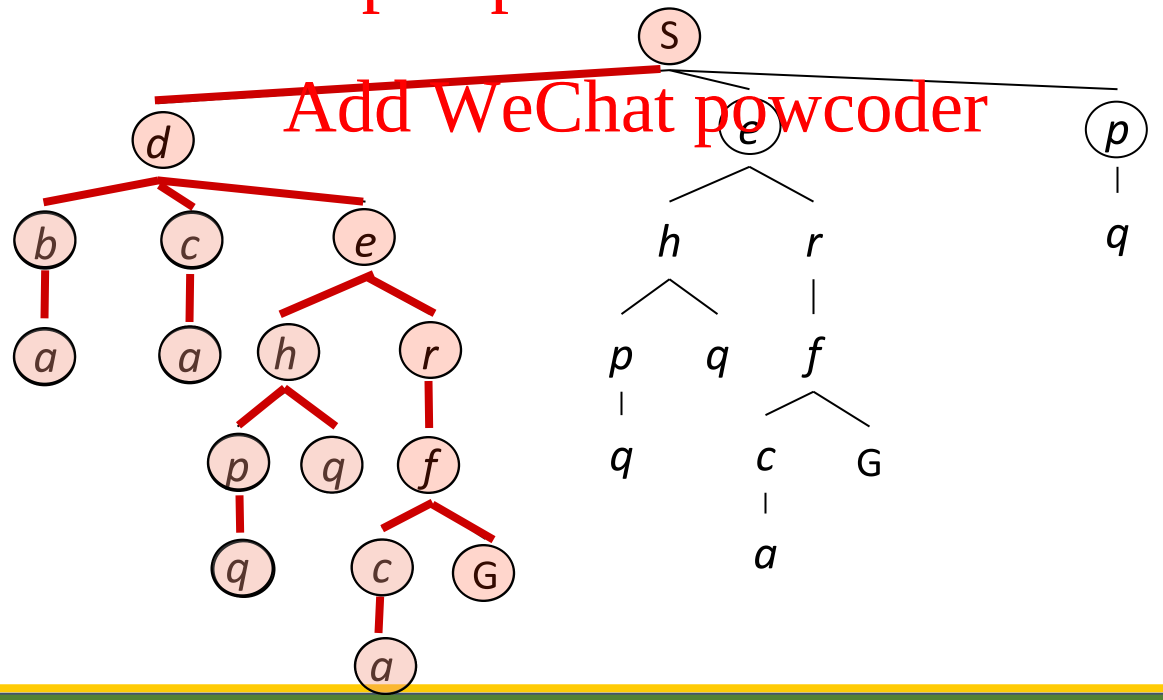
Depth-First Search (DFS)

Depth-First Search (DFS)

Strategy: expand a deepest node first

Implementation: Fringe is a LIFO stack

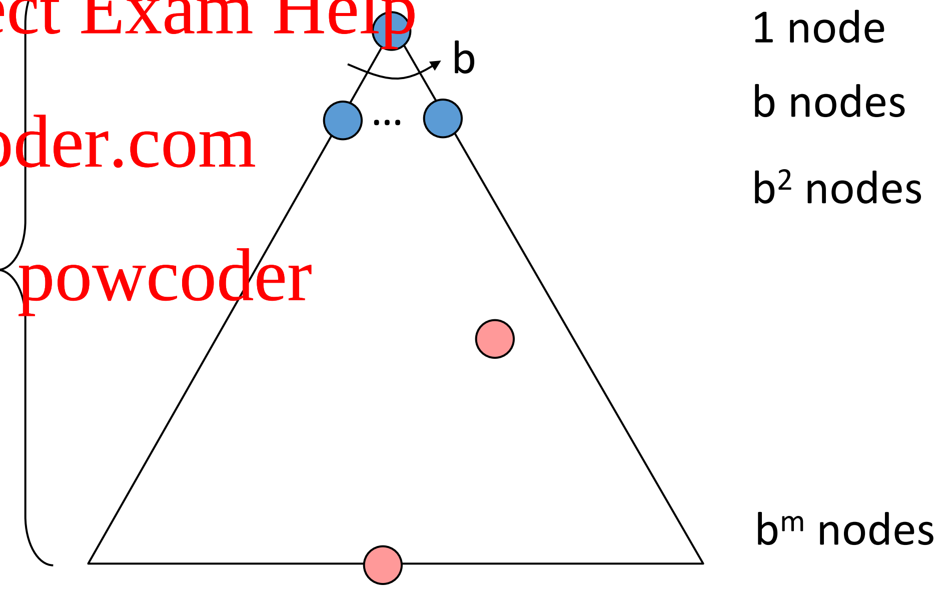




Search Algorithm Properties

- 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?
  - $1 + b + b^2 + \ldots.\ b^m = O(b^m)$

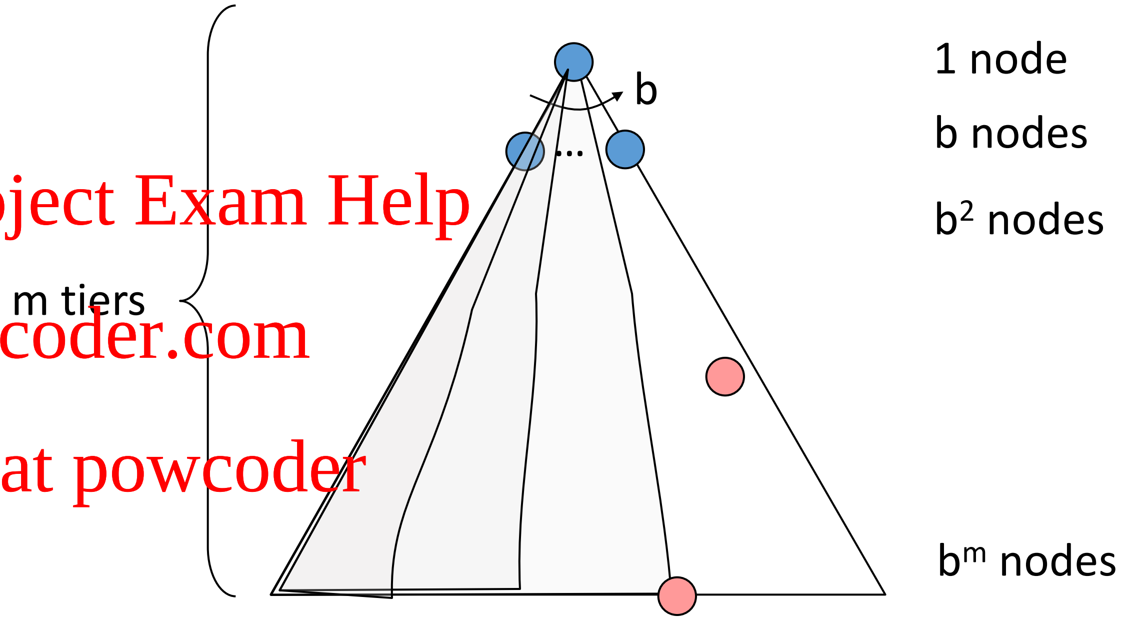
DFS Properties

- 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

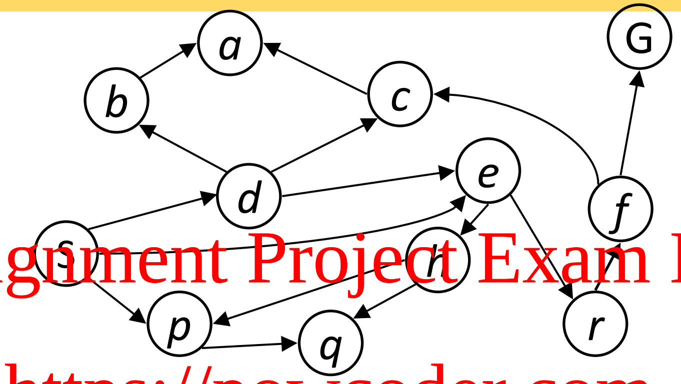


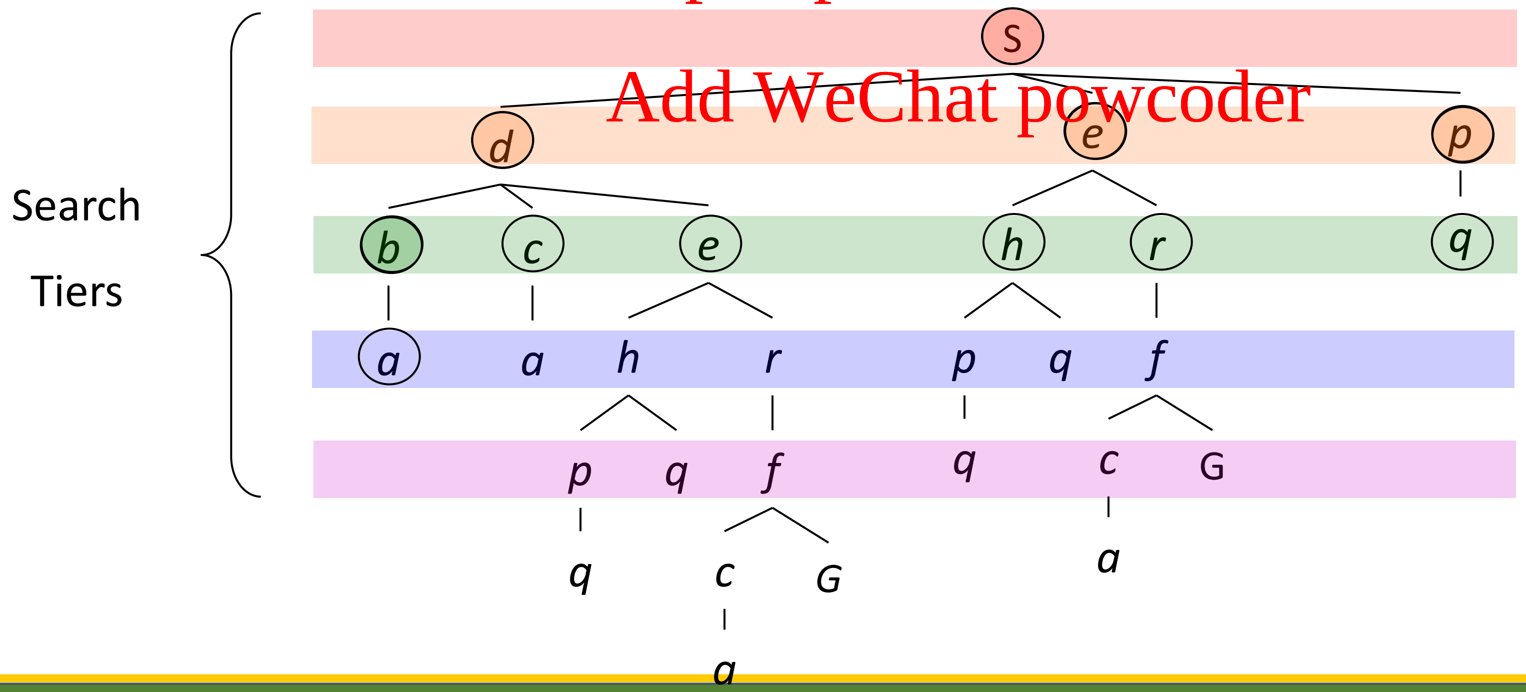
Breadth-First Search (BFS)

Breadth-First Search (BFS)

Strategy: expand a shallowest node first

Implementation: Fringe is a FIFO queue



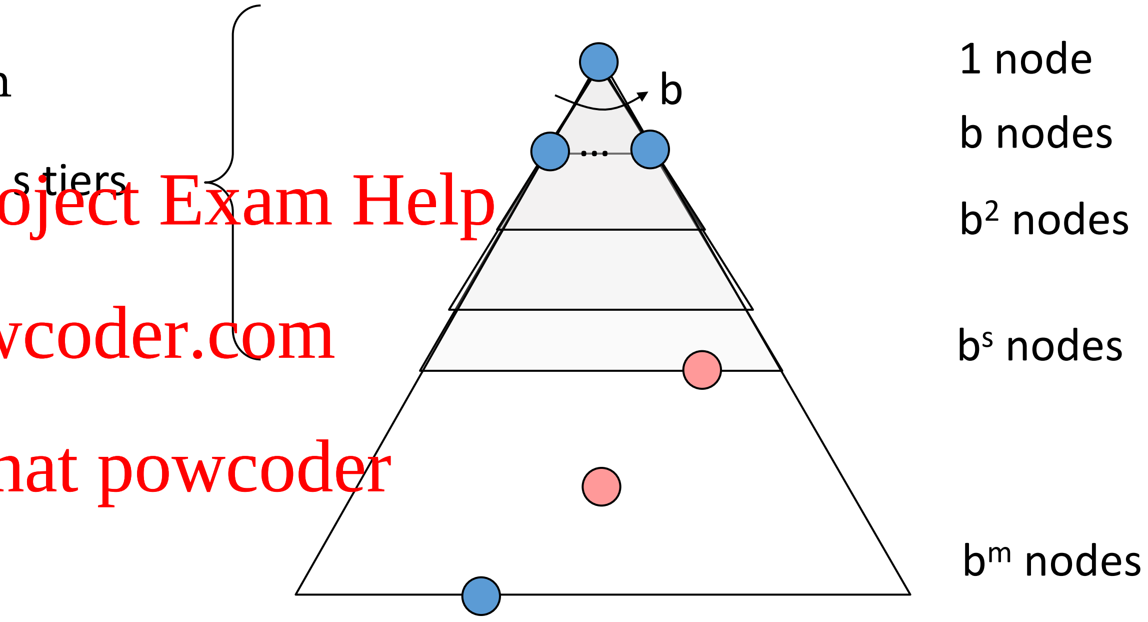


BFS Properties

- What nodes does BFS expand?
  - Processes all nodes above shallowest solution
  - Let depth of shallowest solution be s
  - Search takes time $O(b^s)$

- How much space does the fringe take?
  - $O(b^{s+1})$

- Is it complete?
  - s must be finite if a solution exists, so yes!
- Is it optimal?
  - Only if costs are all 1 (more on costs later)



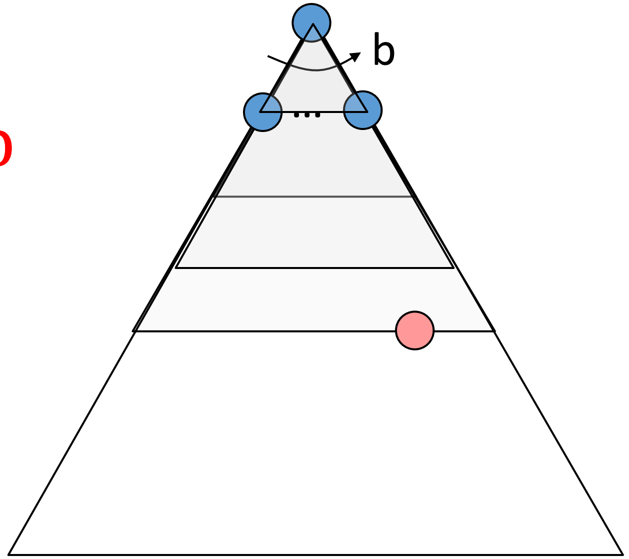
DFS vs BFS

- When will BFS outperform DFS?

- When will DFS outperform BFS?

Iterative Deepening

- Idea: get DFS's space advantage with BFS's time / shallow-solution advantages
  - Run a DFS with depth limit 1. If no solution…
  - Run a DFS with depth limit 2. If no solution…
  - Run a DFS with depth limit 3. …..



- Isn't that wastefully redundant?
  - Generally most work happens in the lowest level searched, so not so bad!