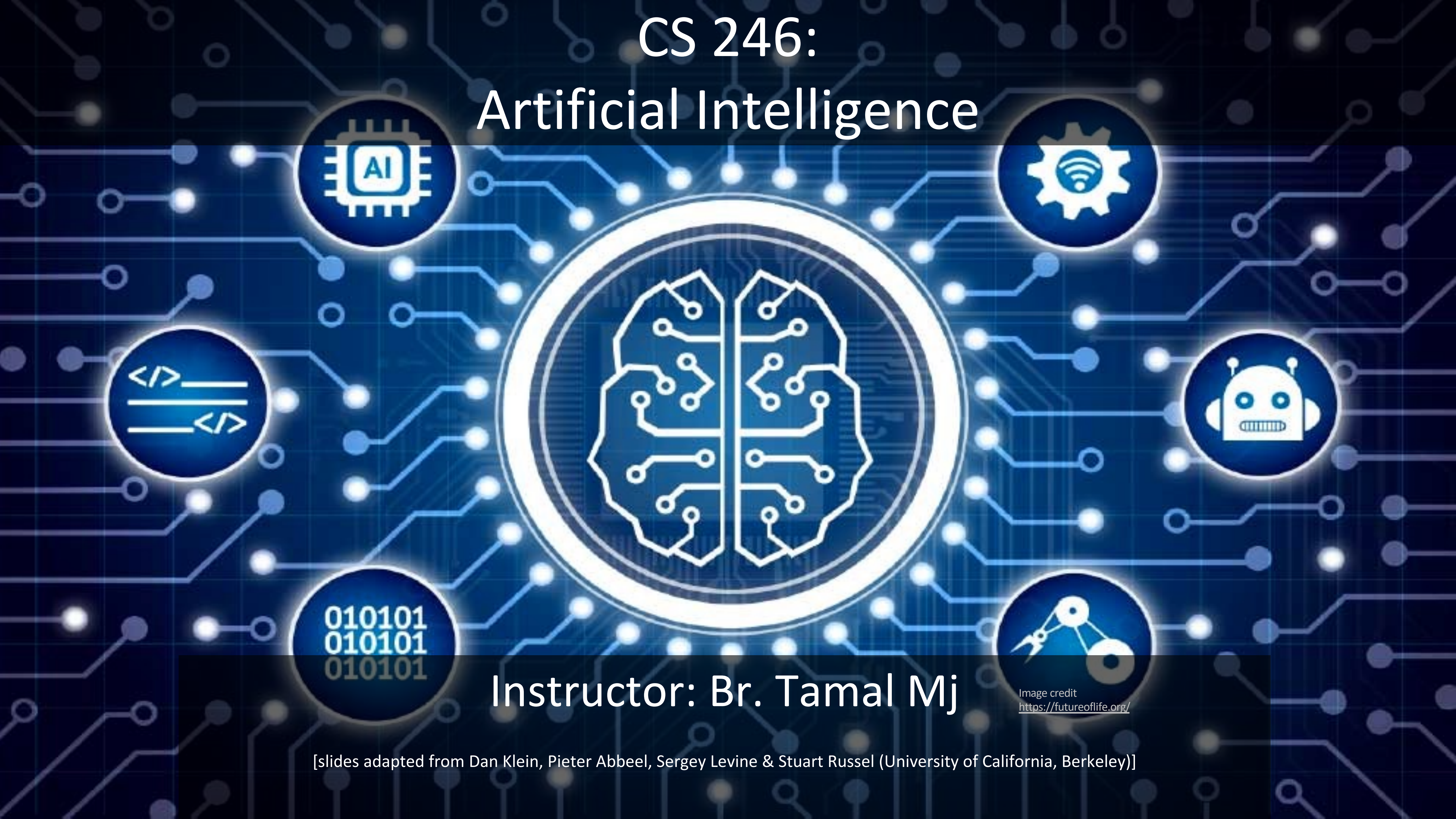
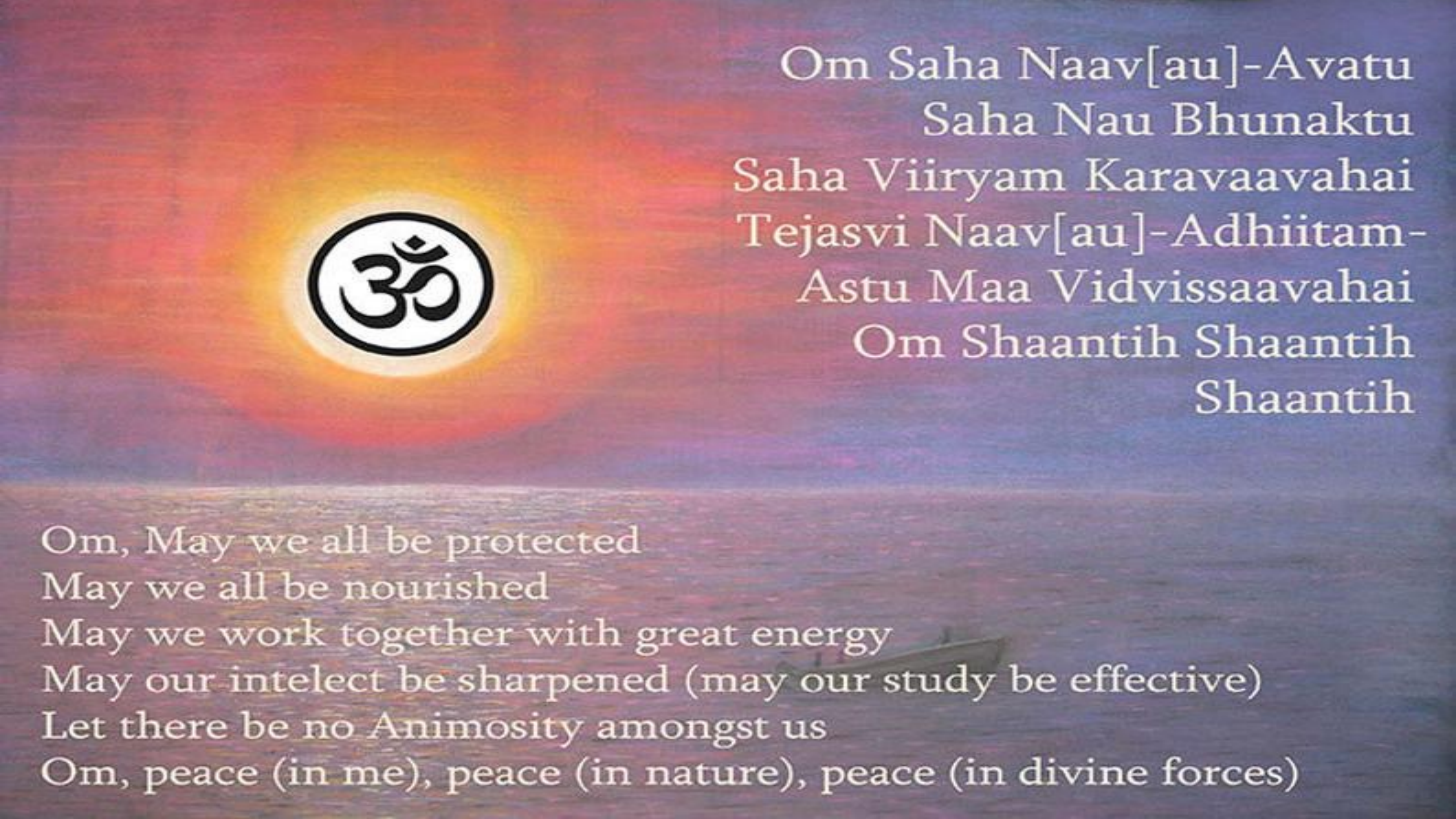
CS 246: Artificial Intelligence



Instructor: Br. Tamal Mj

Image credit
https://futureoflife.org/

[slides adapted from Dan Klein, Pieter Abbeel, Sergey Levine & Stuart Russel (University of California, Berkeley)]

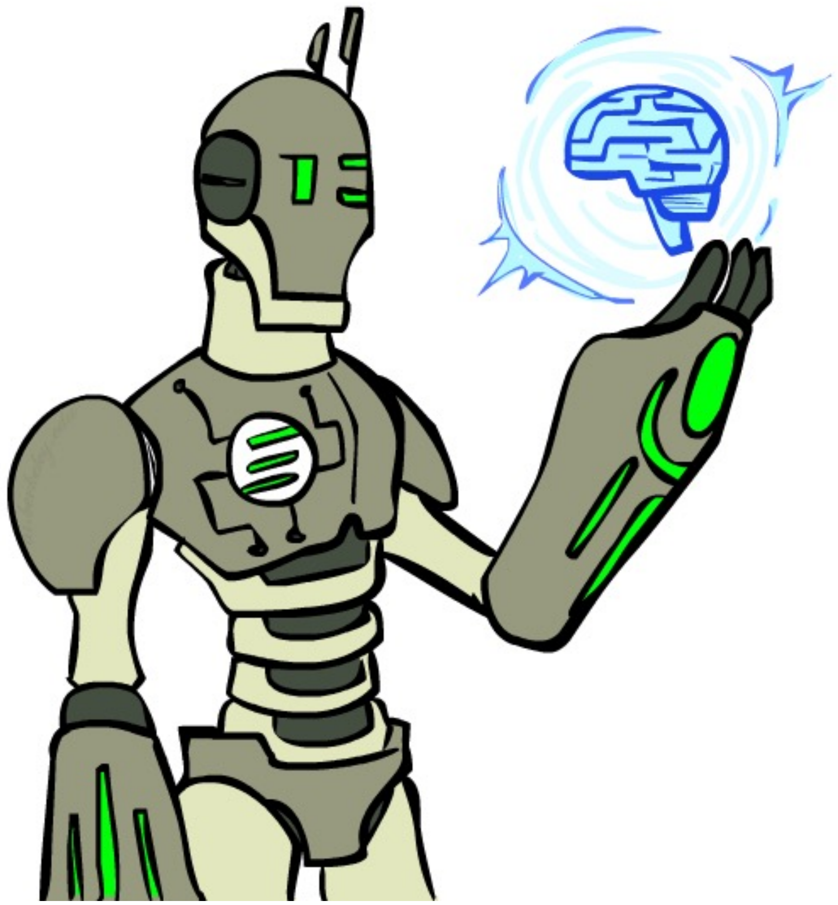


Om Saha Naav[au]-Avatu
Saha Nau Bhunaktu
Saha Viiryam Karavaavahai
Tejasvi Naav[au]-Adhiitam-
Astu Maa Vidvissaavahai
Om Shaantih Shaantih
Shaantih

Om, May we all be protected
May we all be nourished
May we work together with great energy
May our intelect be sharpened (may our study be effective)
Let there be no Animosity amongst us
Om, peace (in me), peace (in nature), peace (in divine forces)

Today

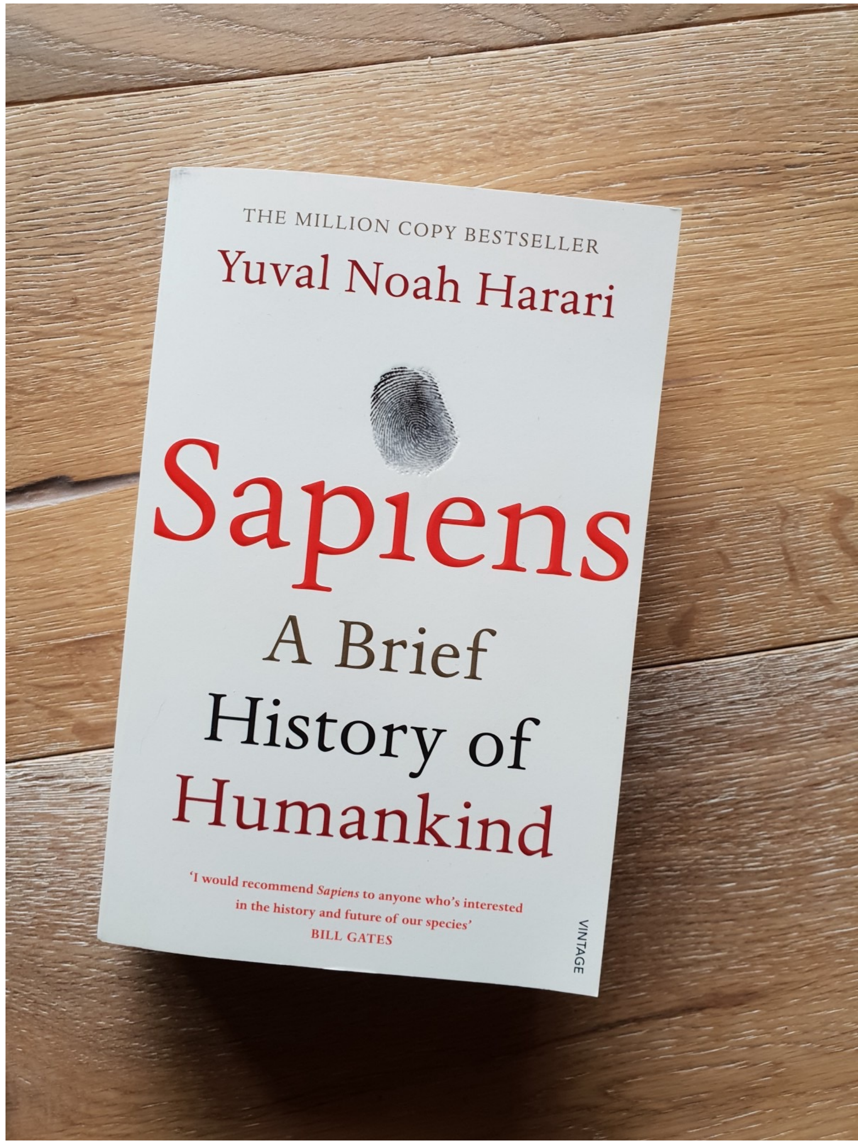
- What is artificial intelligence?
- What can AI do?



Homo Sapiens

- Homo Sapiens Man the wise – man the wise – because of our intelligence
- Understanding how we think?
  - Perceive
  - Understand
  - Predict
  - Manipulate

AI goes beyond: Not only understanding but also building *intelligent* entities


THE MILLION COPY BESTSELLER
Yuval Noah Harari
Sapiens
A Brief History of Humankind
'I would recommend Sapiens to anyone who's interested in the history and future of our species' BILL GATES
VINTAGE

What is AI?

The science of making machines that:

Rational Decisions

We'll use the term **rational** in a very specific, technical way:

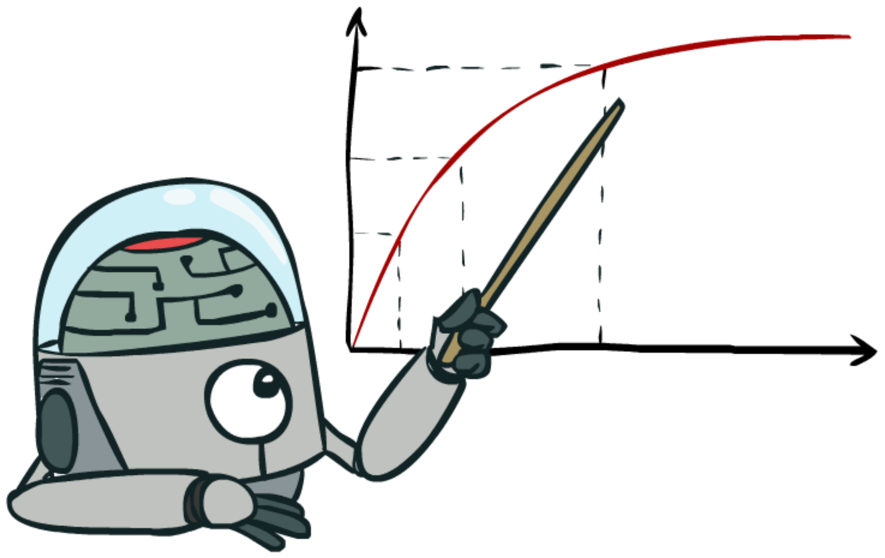
- Rational: maximally achieving pre-defined goals
- Rationality only concerns what decisions are made

  (not the thought process behind them)
- Goals are expressed in terms of the **utility** of outcomes
- Being rational means **maximizing your expected utility**

A better title for this course would be:

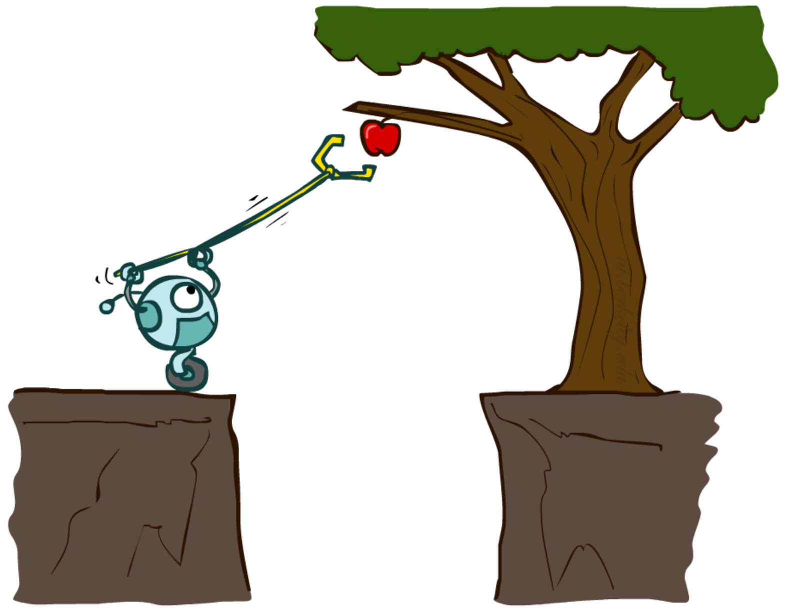
Computational Rationality

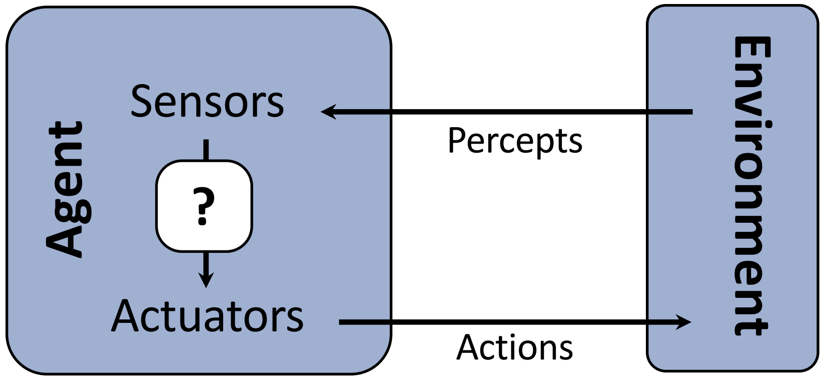
Maximize Your Expected Utility



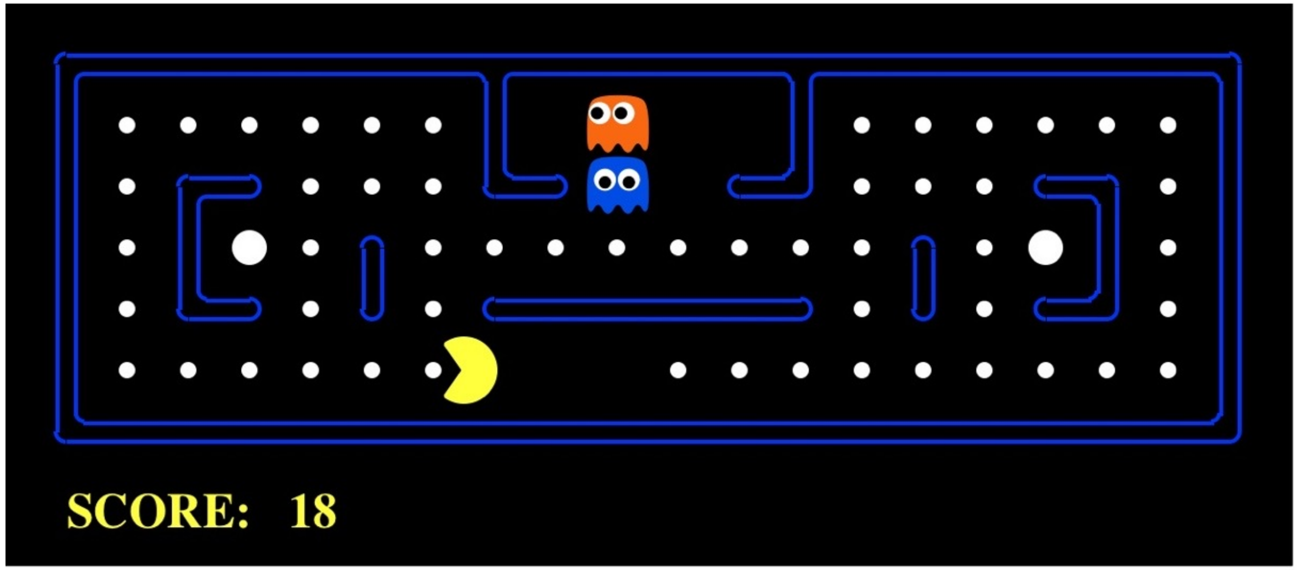
Designing Rational Agents

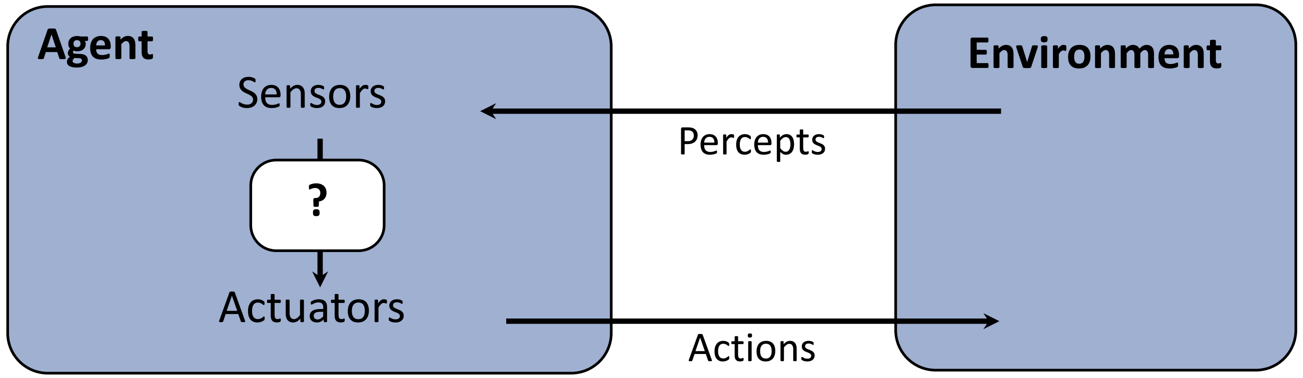
- An **agent** is an entity that *perceives* and *acts*.
- A **rational agent** selects actions that maximize its (expected) **utility**.
- Characteristics of the **percepts, environment,** and **action space** dictate techniques for selecting rational actions
- **This course** is about:
  - General AI techniques for a variety of problem types
  - Learning to recognize when and how a new problem can be solved with an existing technique





Pac-Man as an Agent



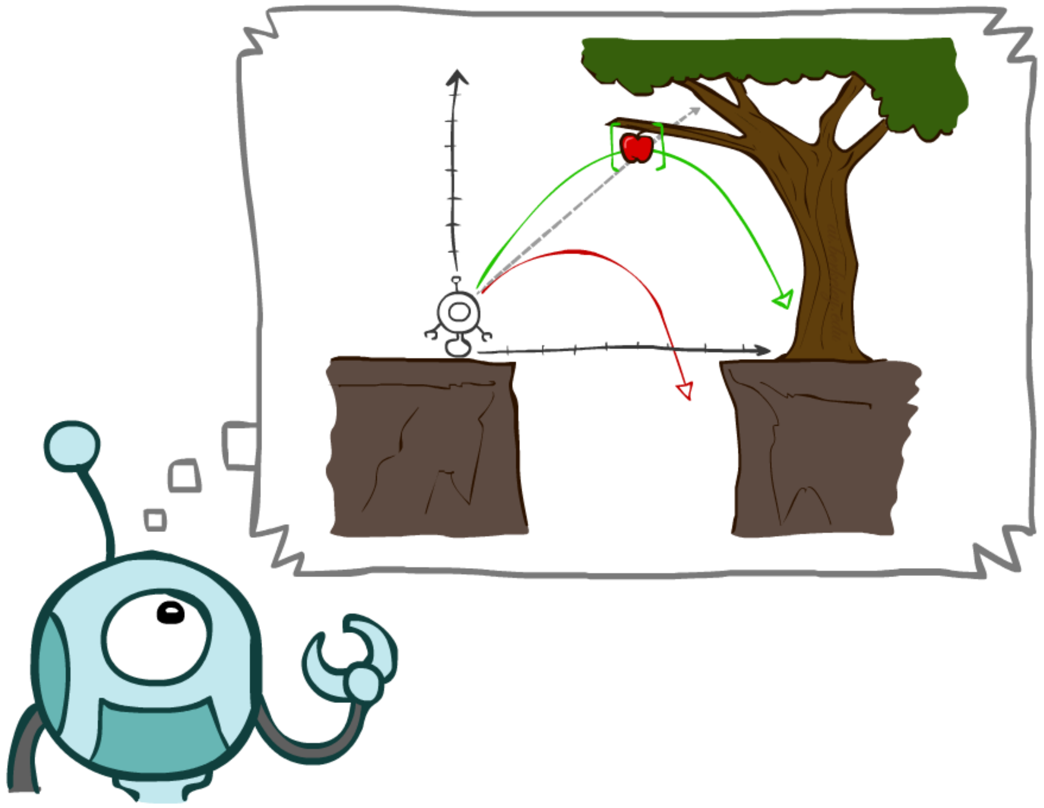


Pac-Man is a registered trademark of Namco-Bandai Games, used here for educational purposes

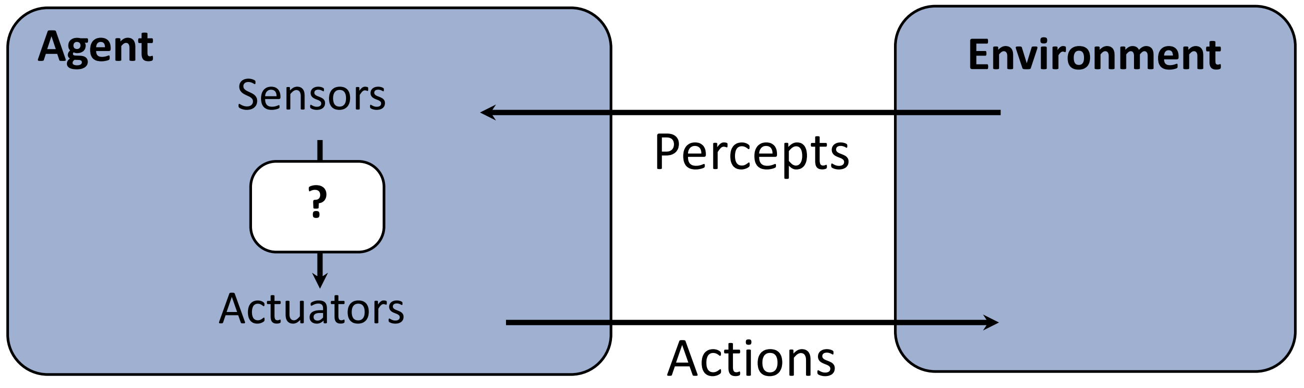
Demo1: pacman-l1.mp4 or L1D2

Next

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



Agents and environments



- An agent ***perceives*** its environment through ***sensors*** and ***acts*** upon it through ***actuators***

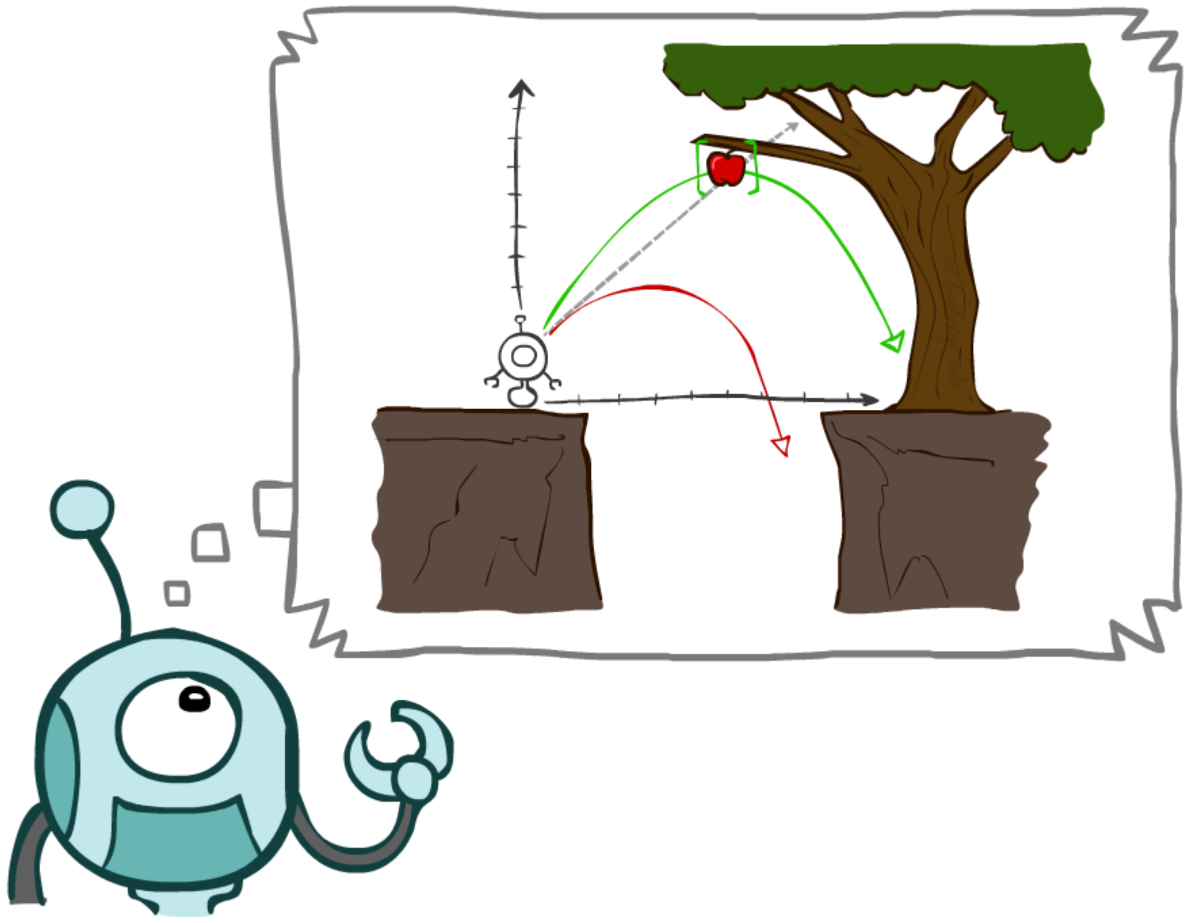
Rationality

- A ***rational agent*** chooses actions maximize the ***expected*** utility
  - Today: agents that have a goal, and a cost
    - E.g., reach goal with lowest cost
  - Later: agents that have numerical utilities, rewards, etc.
    - E.g., take actions that maximize total reward over time (e.g., largest profit in $)

Agent design

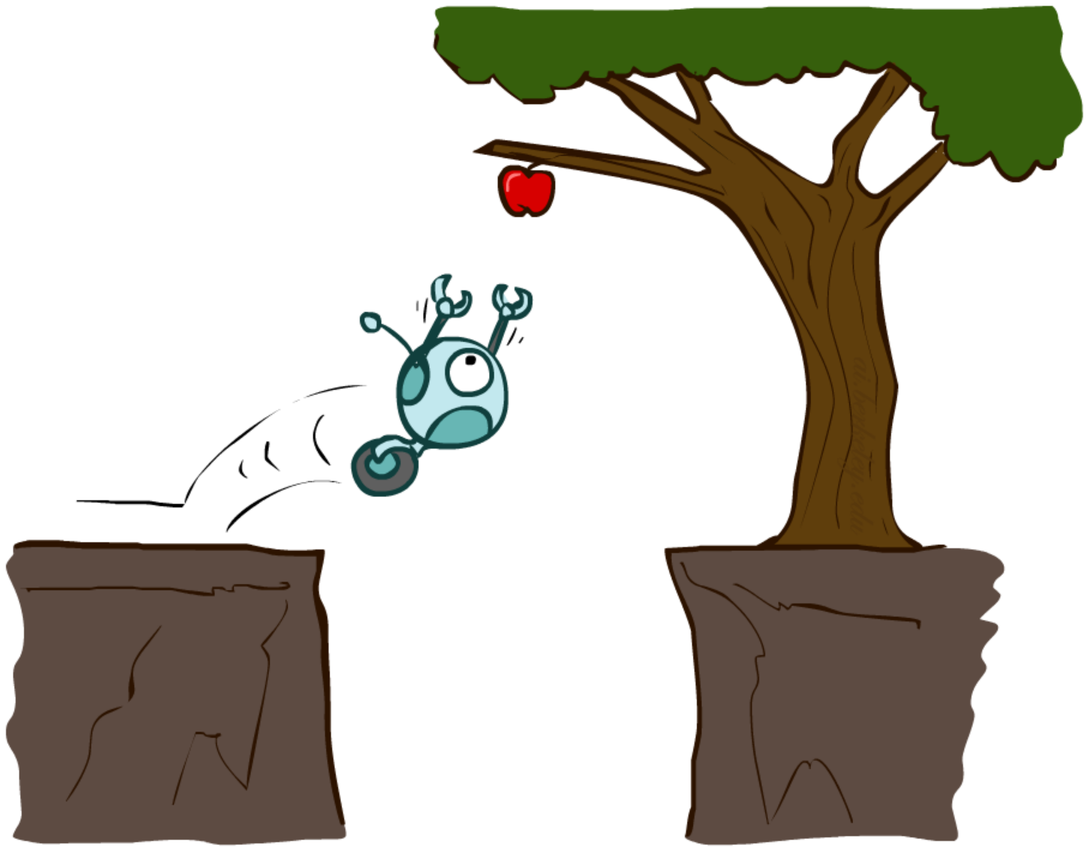
- **The environment type largely determines the agent design**
  - ***Fully/partially observable*** => agent requires ***memory*** (internal state)
  - ***Discrete/continuous*** => agent may not be able to enumerate ***all states***
  - ***Stochastic/deterministic*** => agent may have to prepare for ***contingencies***
  - ***Single-agent/multi-agent*** => agent may need to behave ***randomly***

Agents that Plan



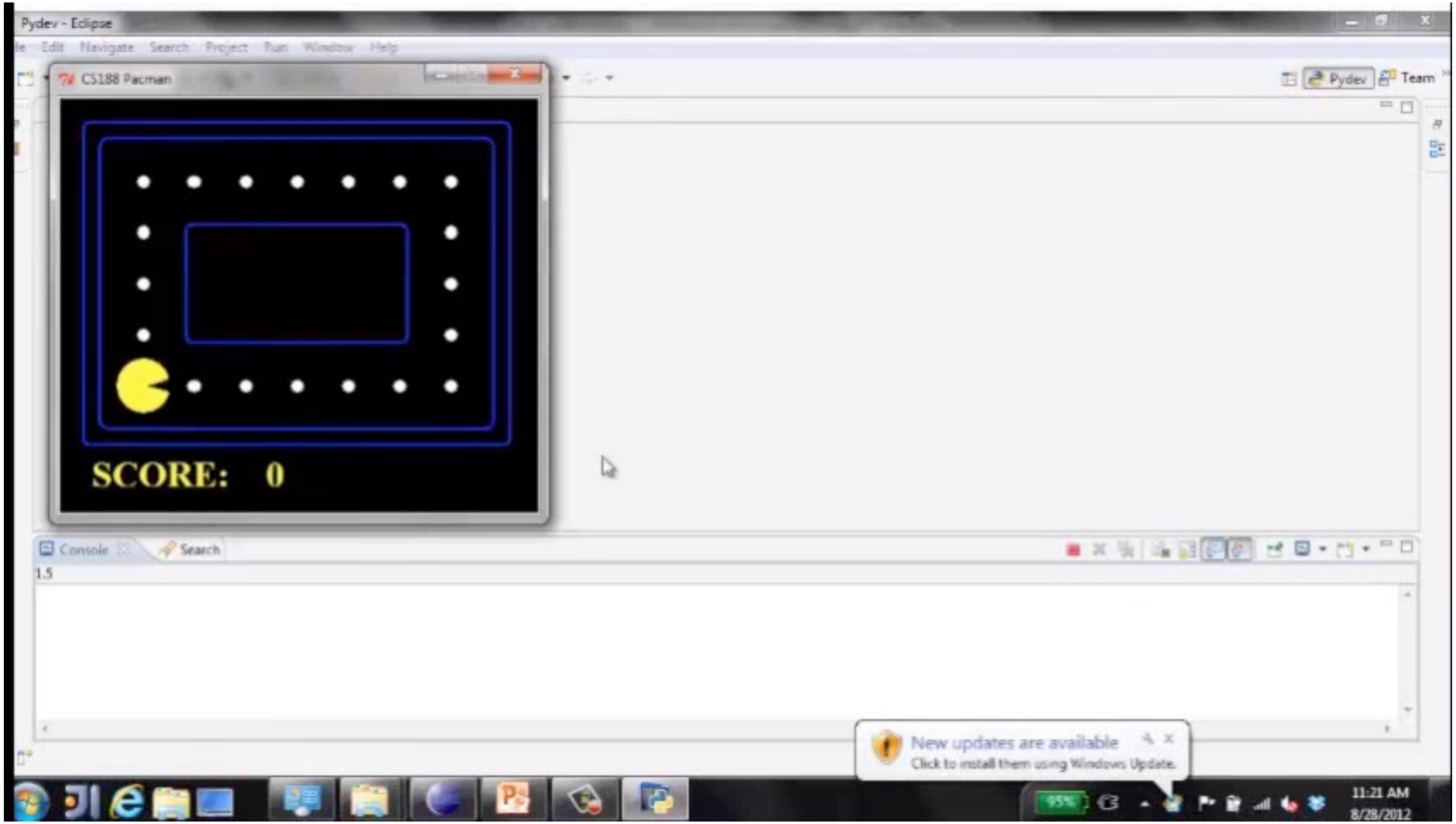
Reflex Agents

- 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?



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

Video of Demo Reflex Optimal


Pydev - Eclipse
File Edit Navigate Search Project Run Window Help
CS188 Pacman
SCORE: 0
Pydev
Team
Console
Search
New updates are available
Click to install them using Windows Update.
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1.5
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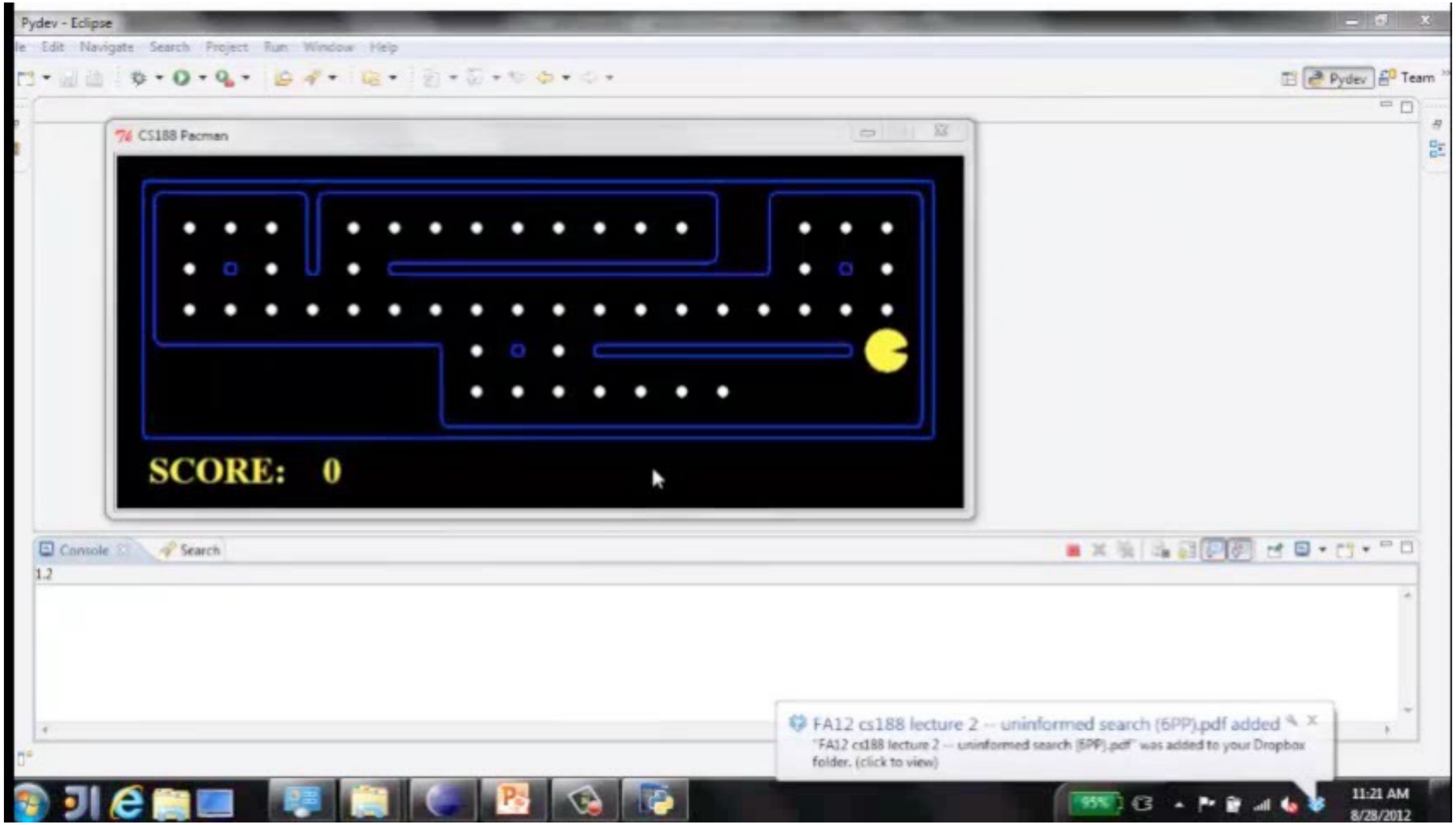
Video of Demo Reflex Odd



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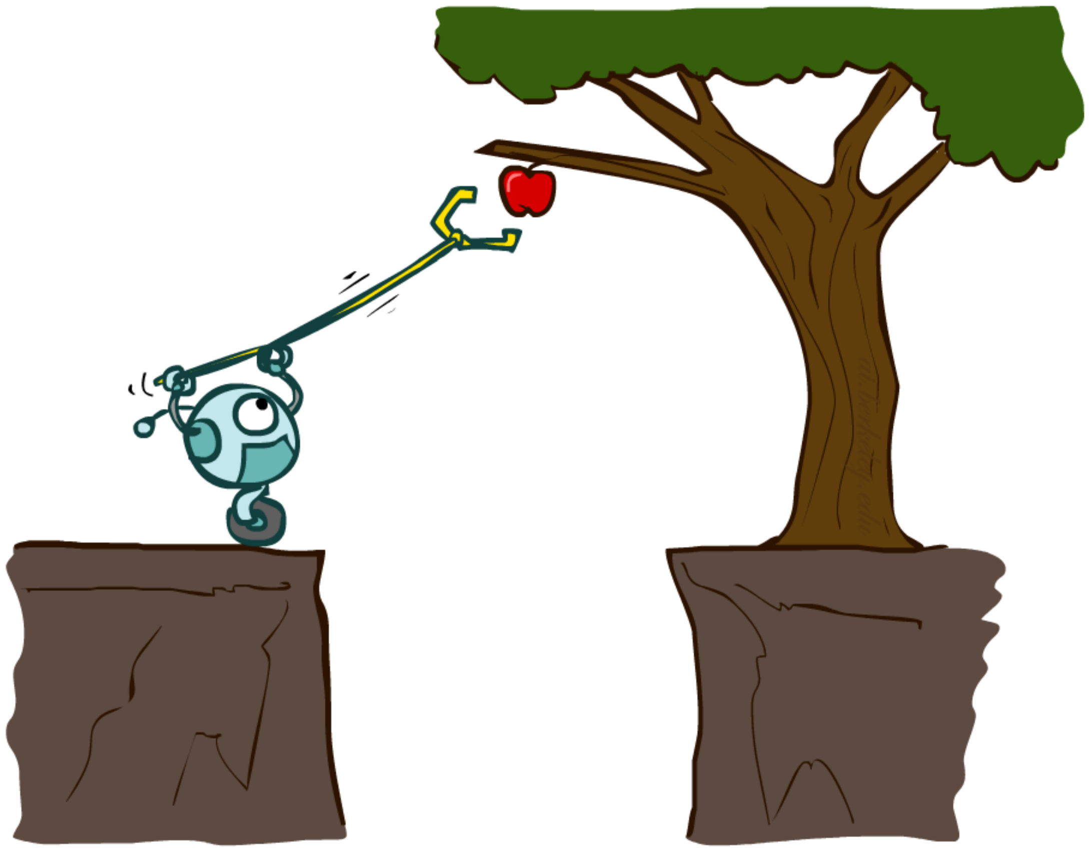
1.2
```

FA12 cs188 lecture 2 -- uninformed search (6PP).pdf added
"FA12 cs188 lecture 2 -- uninformed search (6PP).pdf" was added to your Dropbox folder. (click to view)

Planning Agents

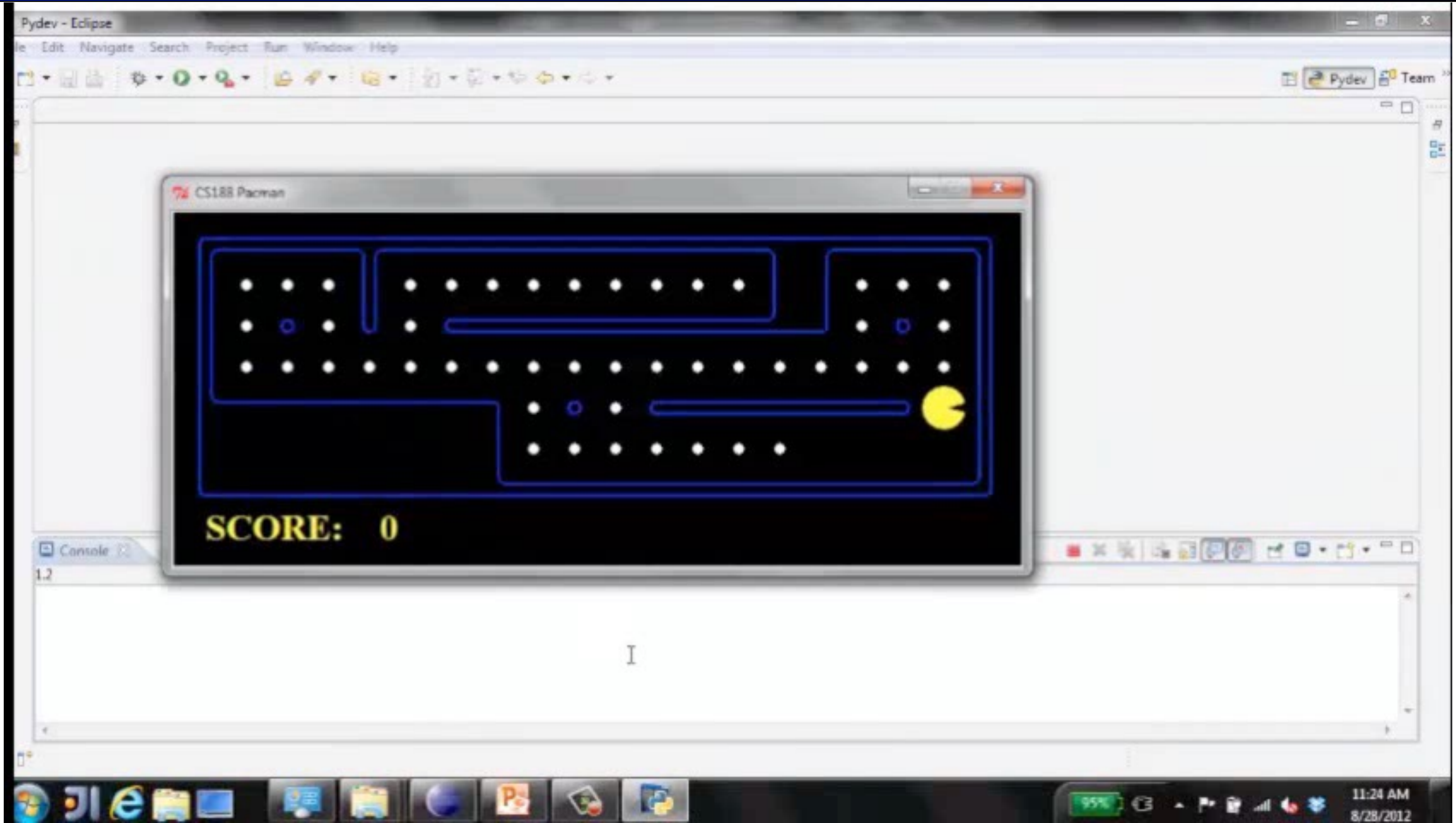
- Planning agents:
  - Ask “what if”
  - Decisions based on (hypothesized) consequences of actions
  - Must have a model of how the world evolves in response to actions
  - Must formulate a goal (test)
  - Consider how the world WOULD BE
- Optimal vs. complete planning
- Planning vs. replanning



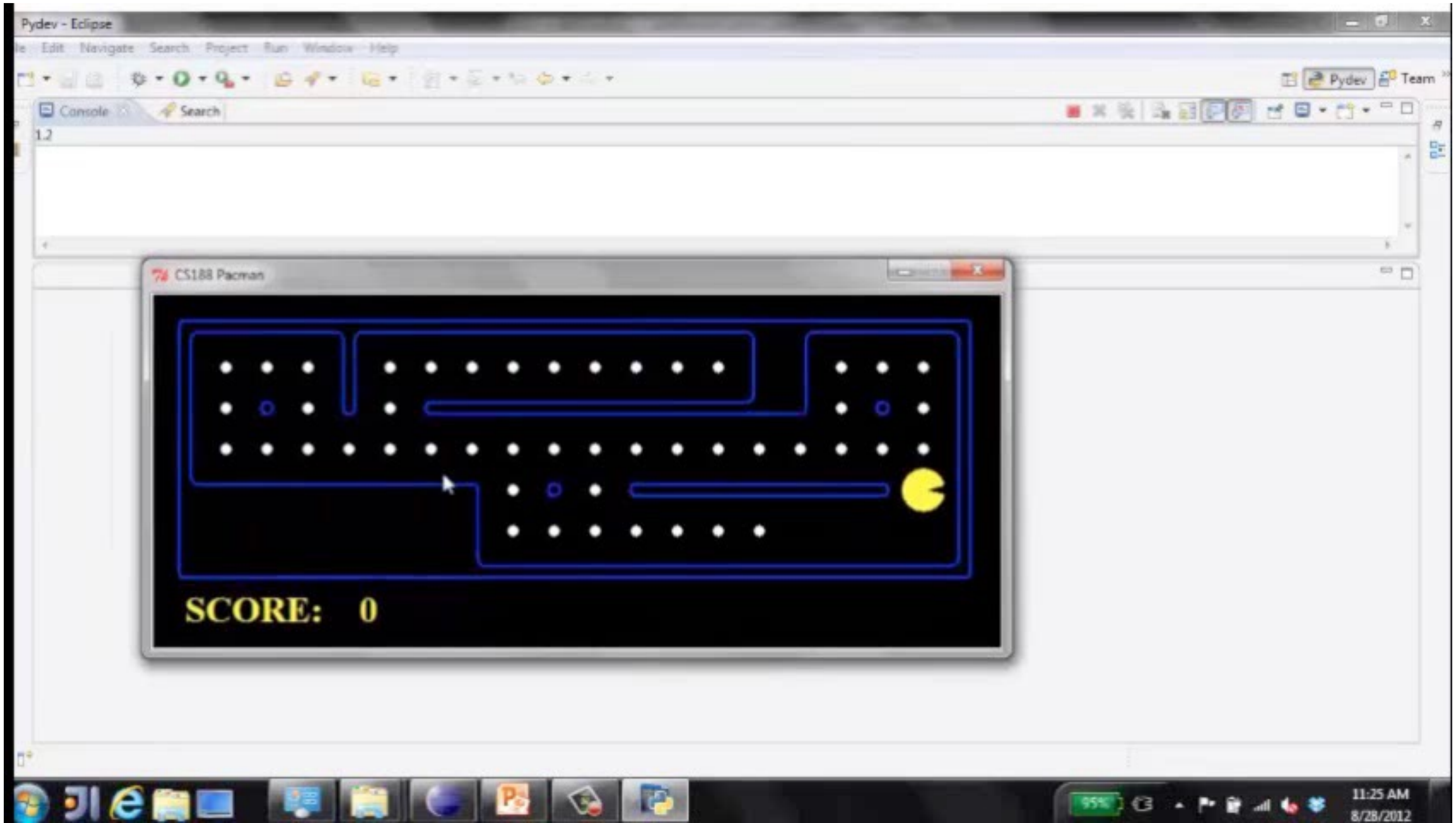
[Demo: re-planning (L2D3)]

[Demo: mastermind (L2D4)]

Video of Demo Replanning



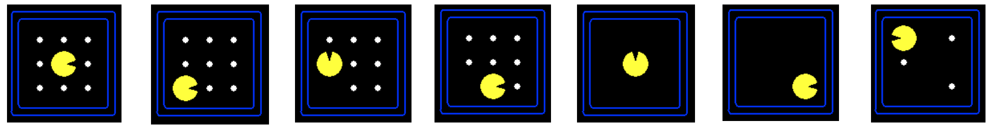
Video of Demo Mastermind



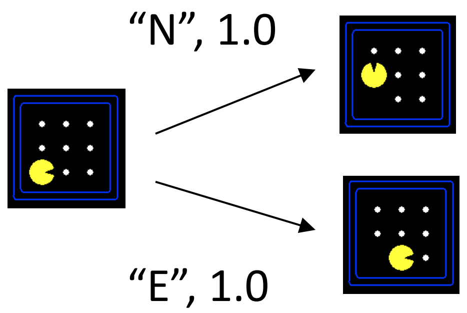
Search Problems

Search Problems

- A search problem consists of:
  - A state space



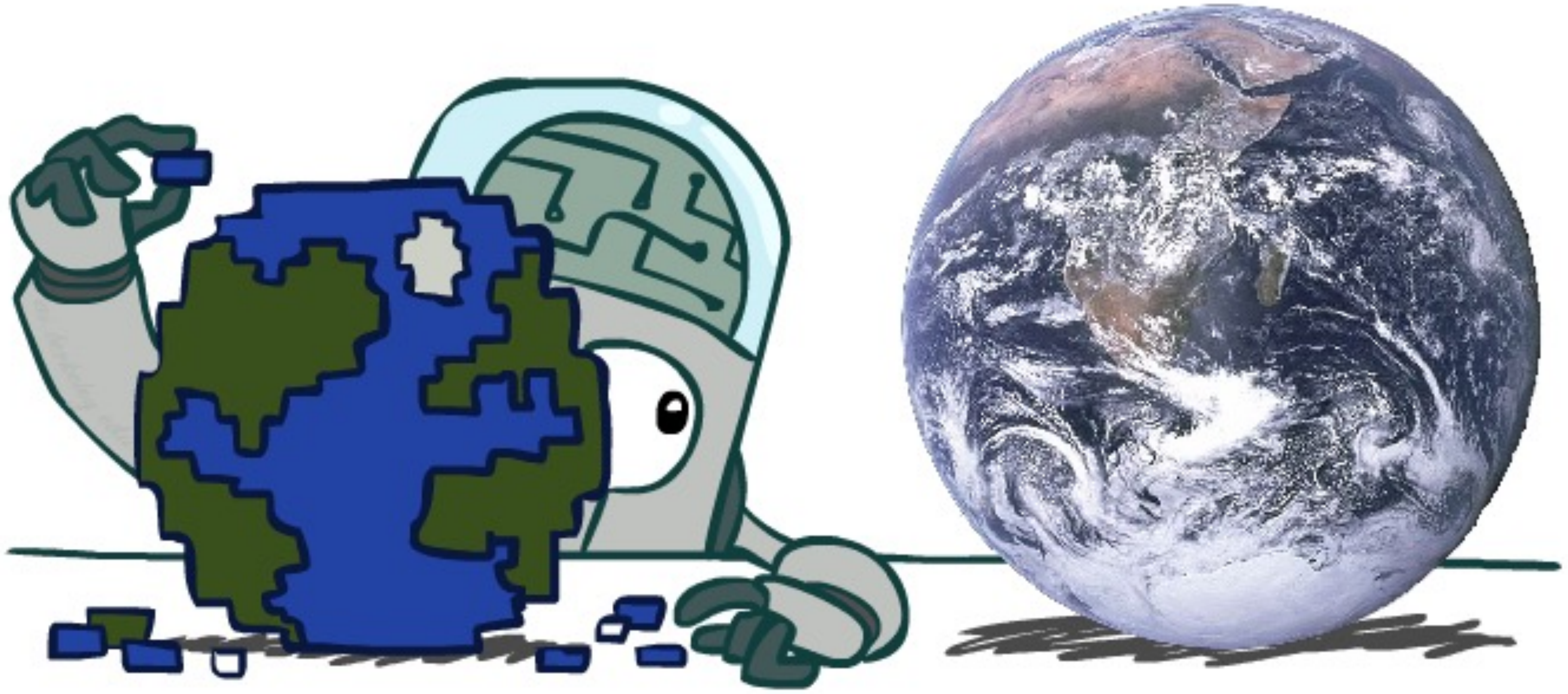
  - A successor function (with actions, costs)



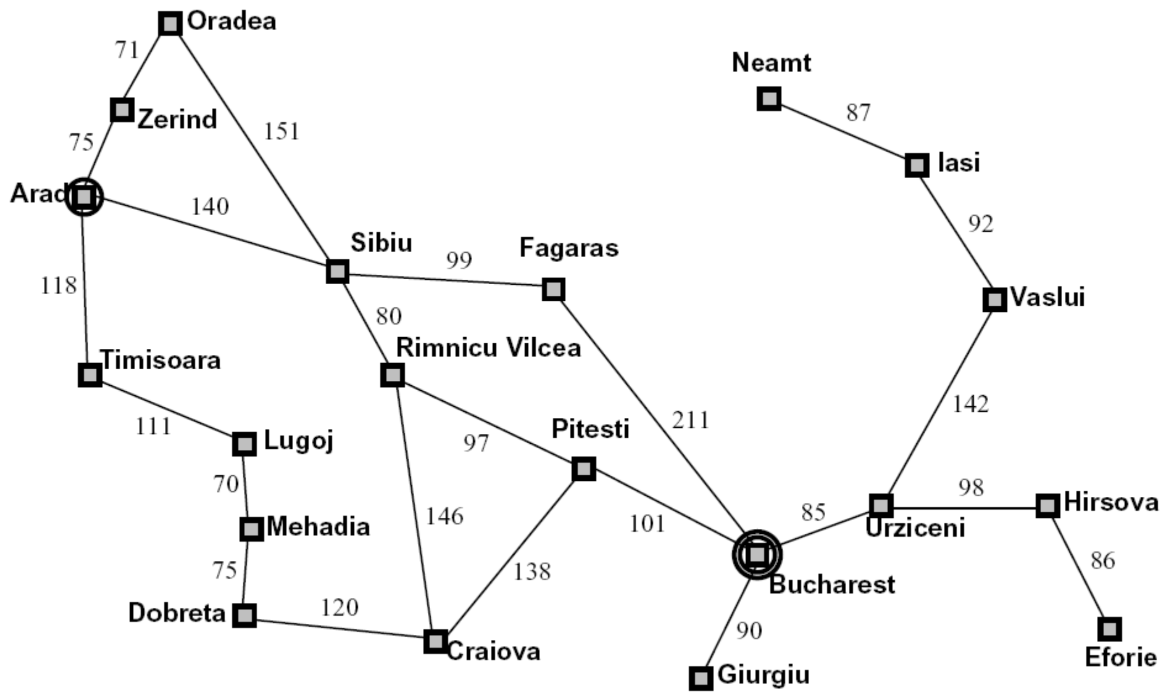
  - A start state and a goal test

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

Search Problems Are Models



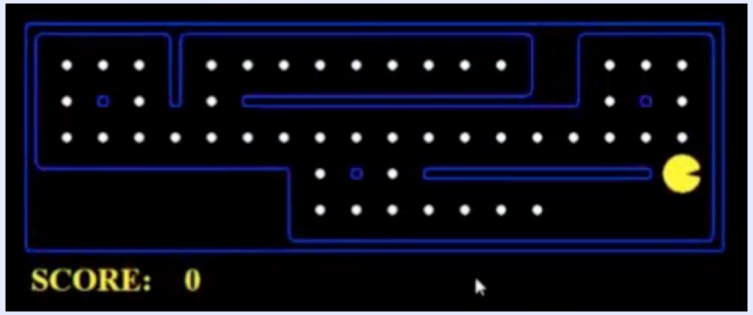
Example: Traveling in Romania



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

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?

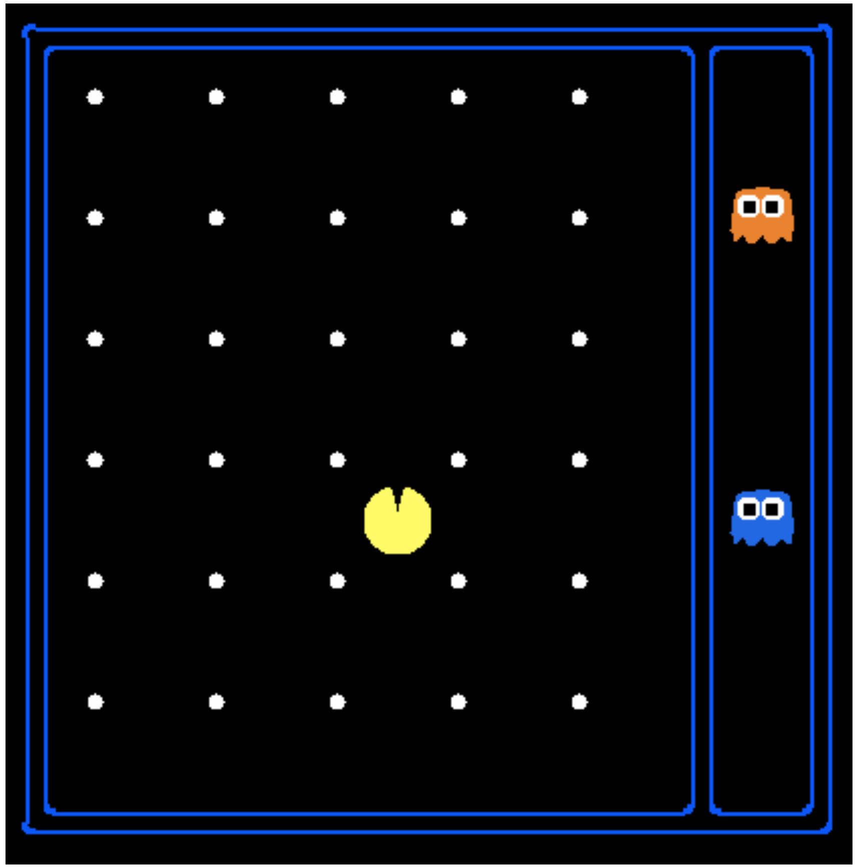
- World state:
  - Agent positions: 120
  - Food count: 30
  - Ghost positions: 12
  - Agent facing: NSEW

- How many
  - World states?

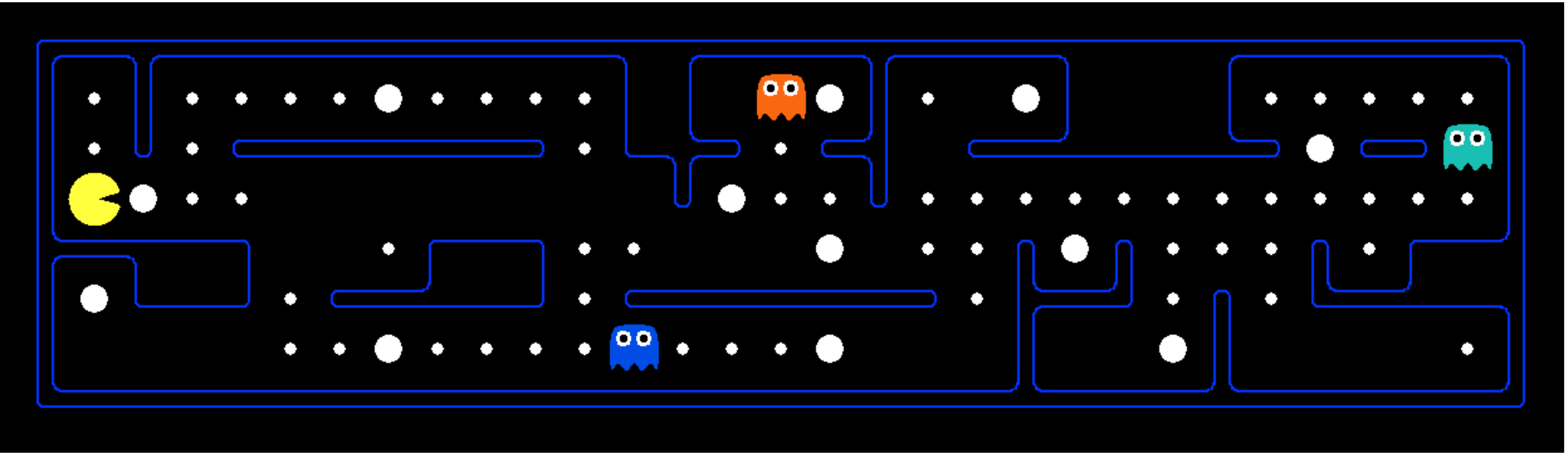
    $120 \times (2^{30}) \times (12^2) \times 4$
  - States for pathing?

    120
  - States for eat-all-dots?

    $120 \times (2^{30})$

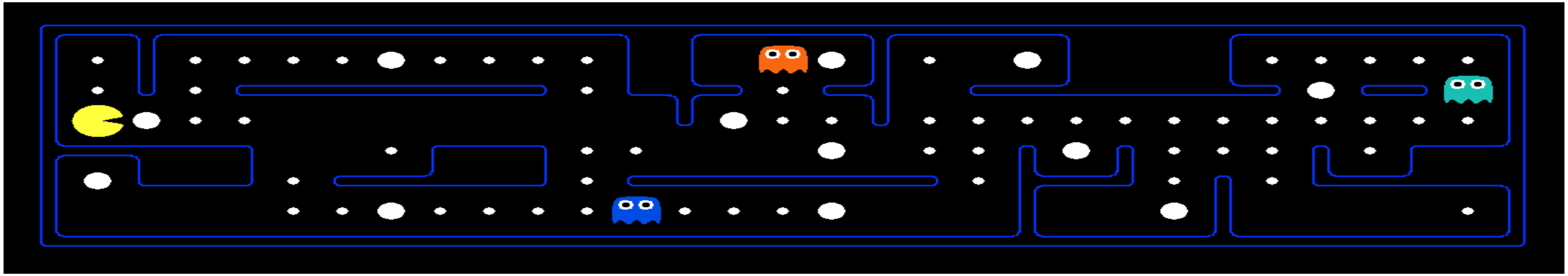


Quiz: Safe Passage



- Problem: eat all dots while keeping the ghosts perma-scared
- What does the state space have to specify?

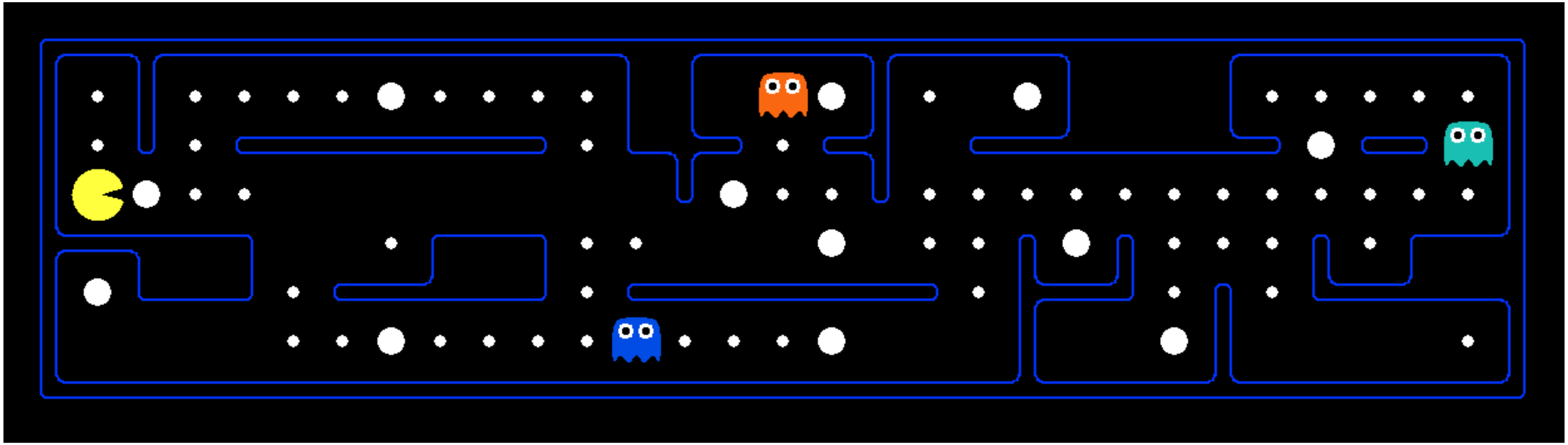
Options



- Problem: eat all dots while keeping the ghosts perma-scared
- What does the state space have to specify? Pick from the list:

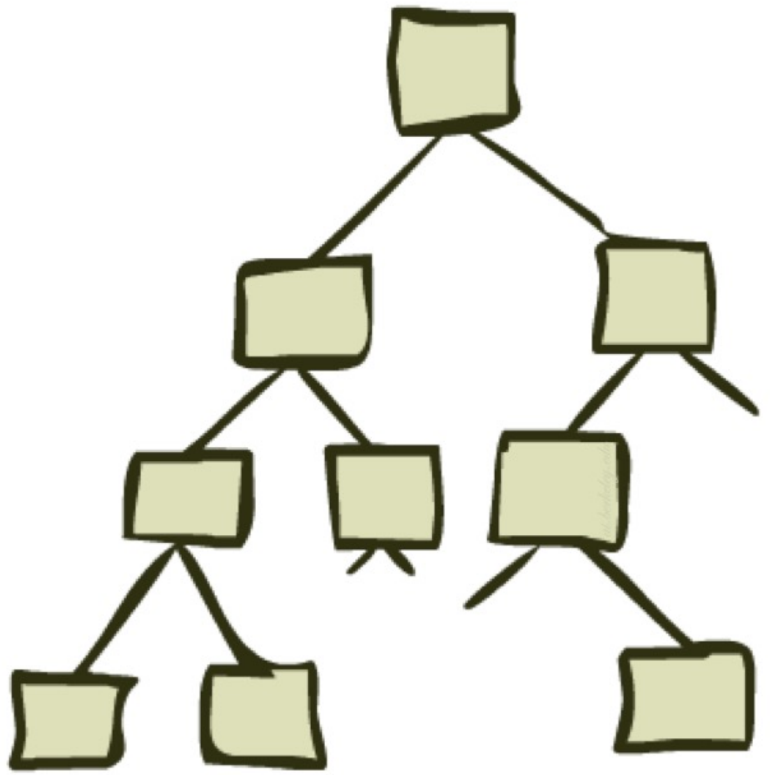
1. Pacman's position
2. Postion of each ghost
3. A boolean for each dot that represents whether it has been eaten
4. A boolean for each power pellet that represents whether it has been eaten
5. The remaining amount of time for which the ghosts will be

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

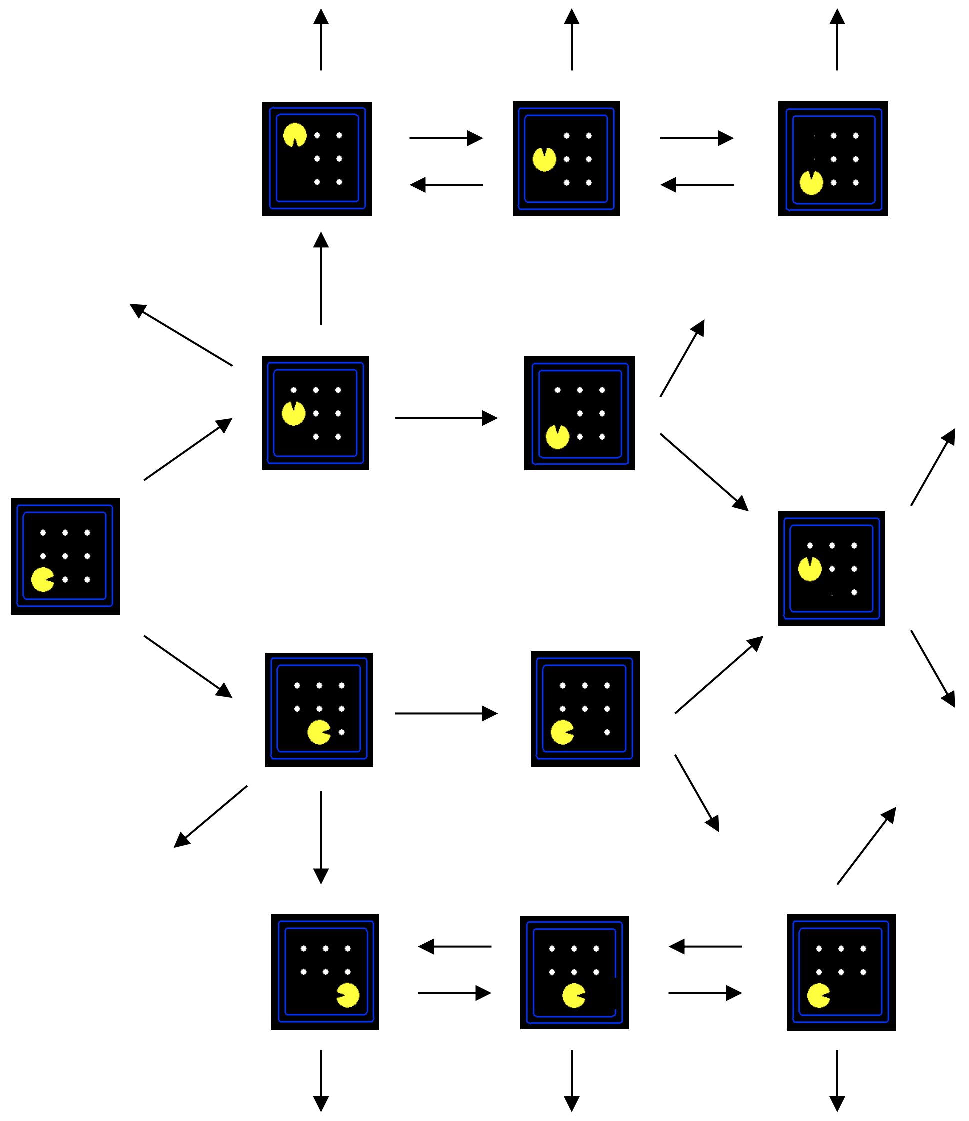


State Space Graphs

- 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



Legend of Chessboard

State Space Graphs

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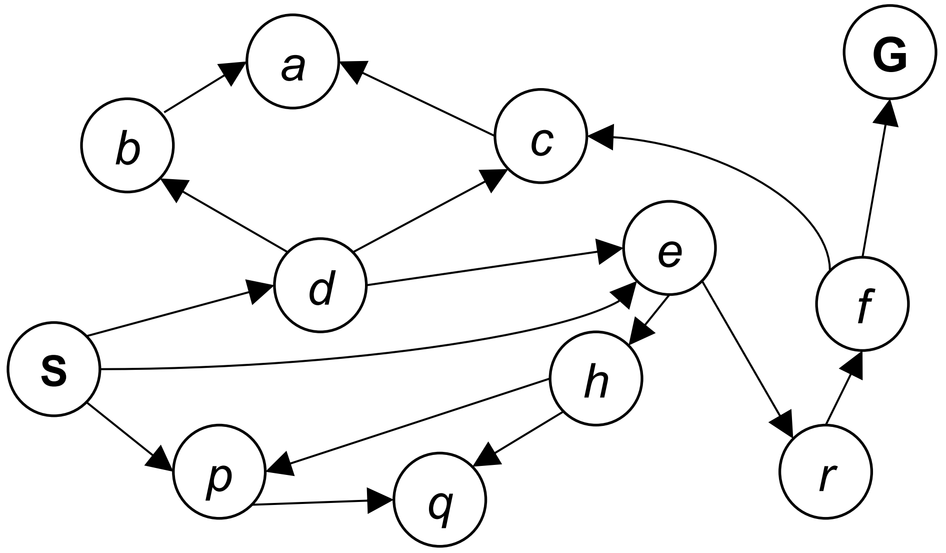
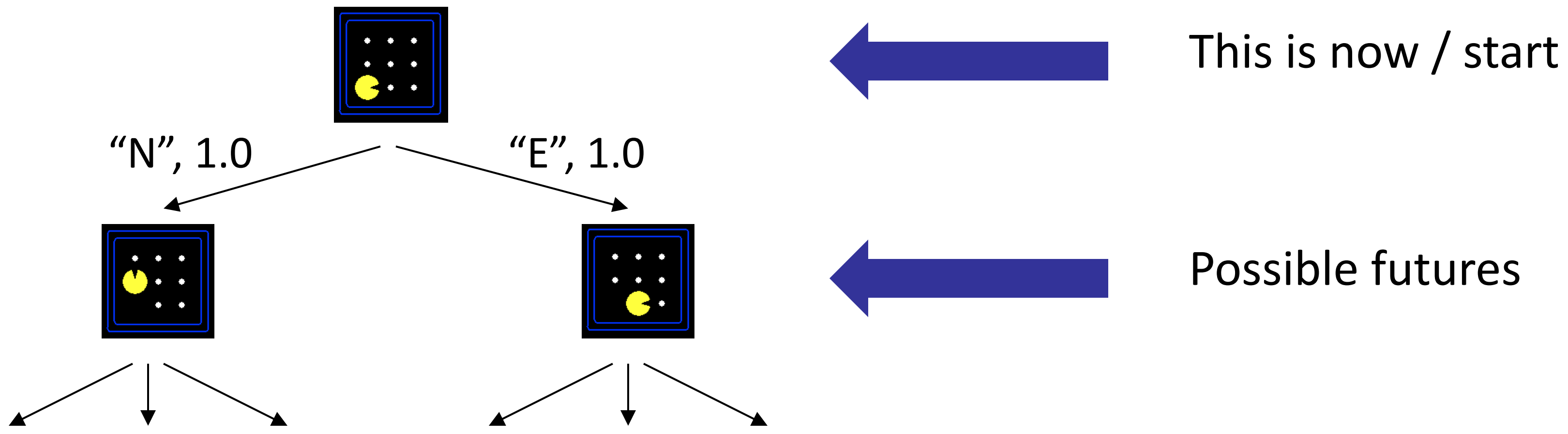


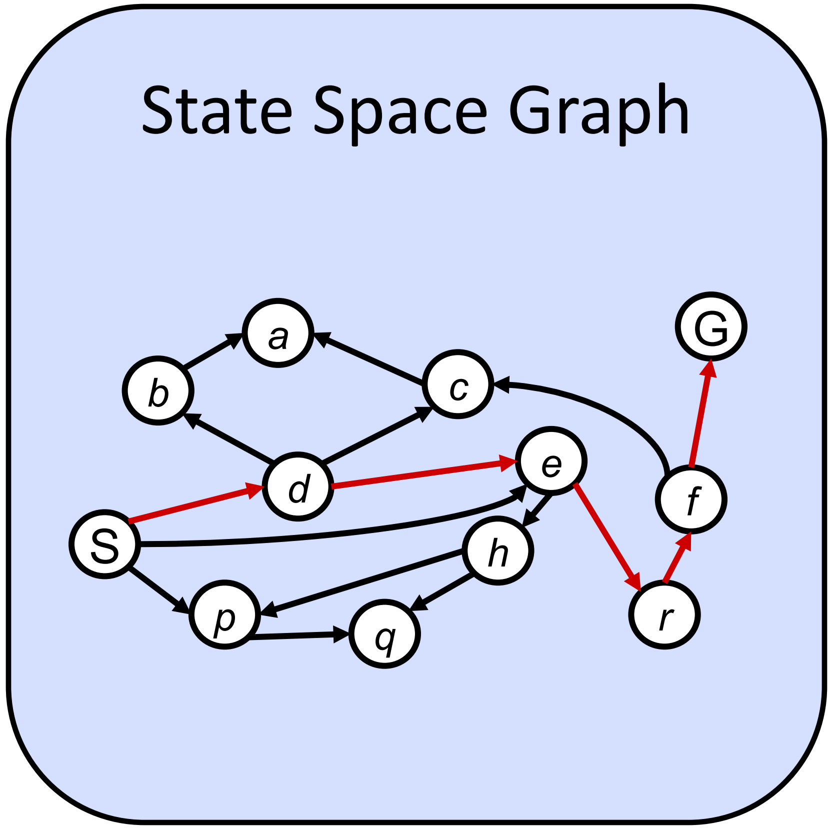
Tiny state space graph for a tiny search problem

Search Trees



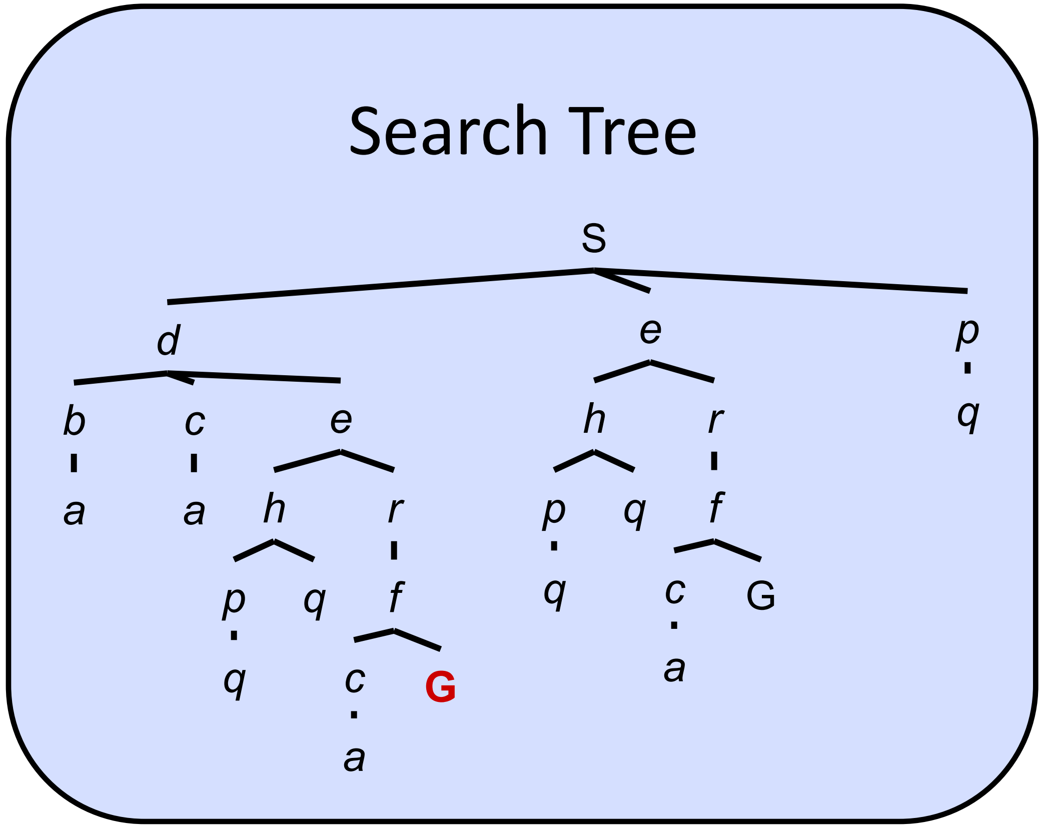
- A search tree:
  - A "what if" tree of plans and their outcomes
  - The start state is the root node
  - Children correspond to successors
  - Nodes show states, but correspond to PLANS that achieve those states
  - For most problems, we can never actually build the whole tree

State Space Graphs vs. Search Trees



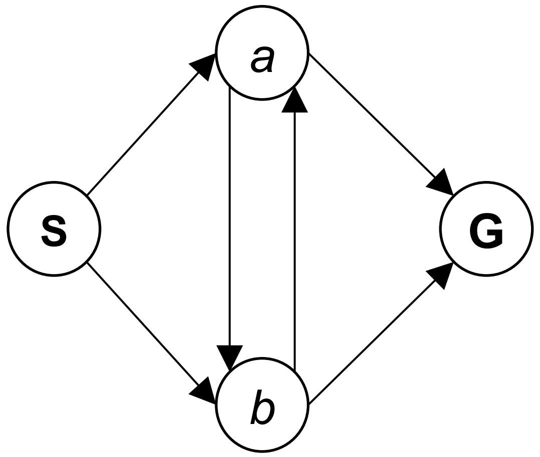
Each NODE in in the search tree is an entire PATH in the state space graph.

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

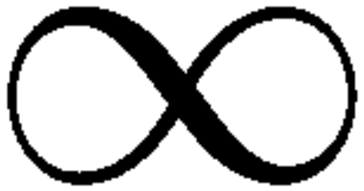


Quiz: State Space Graphs vs. Search Trees

Consider this 4-state graph:

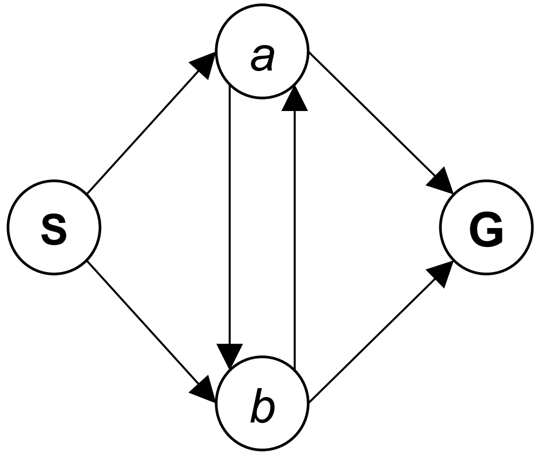


How big is its search tree (from S)?

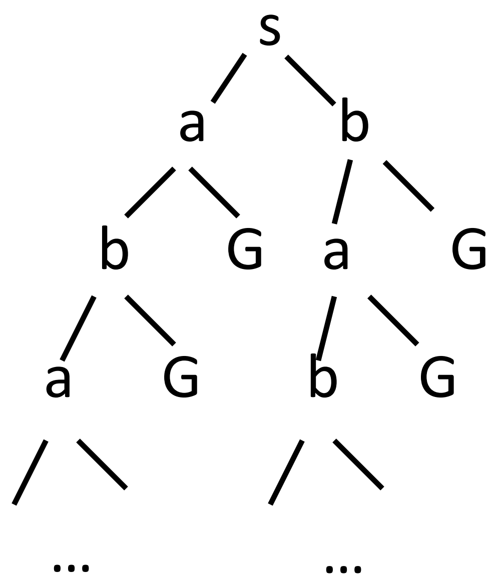


Quiz: State Space Graphs vs. Search Trees

Consider this 4-state graph:



How big is its search tree (from S)?



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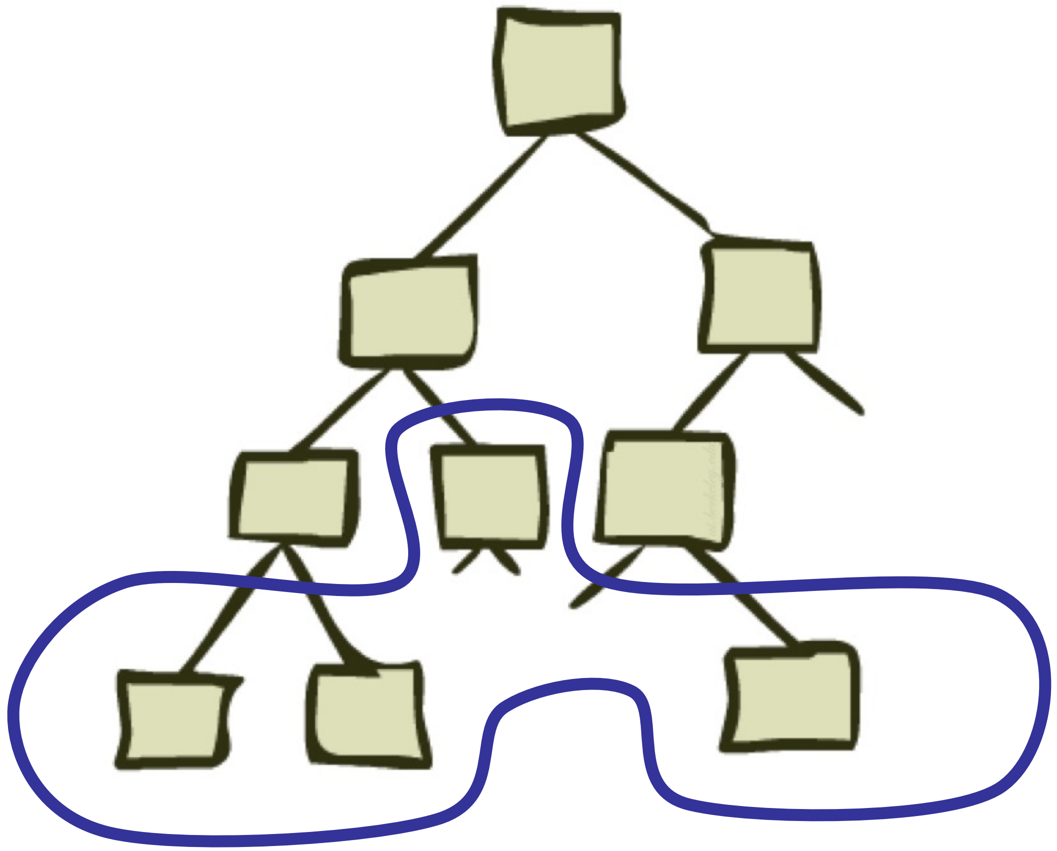
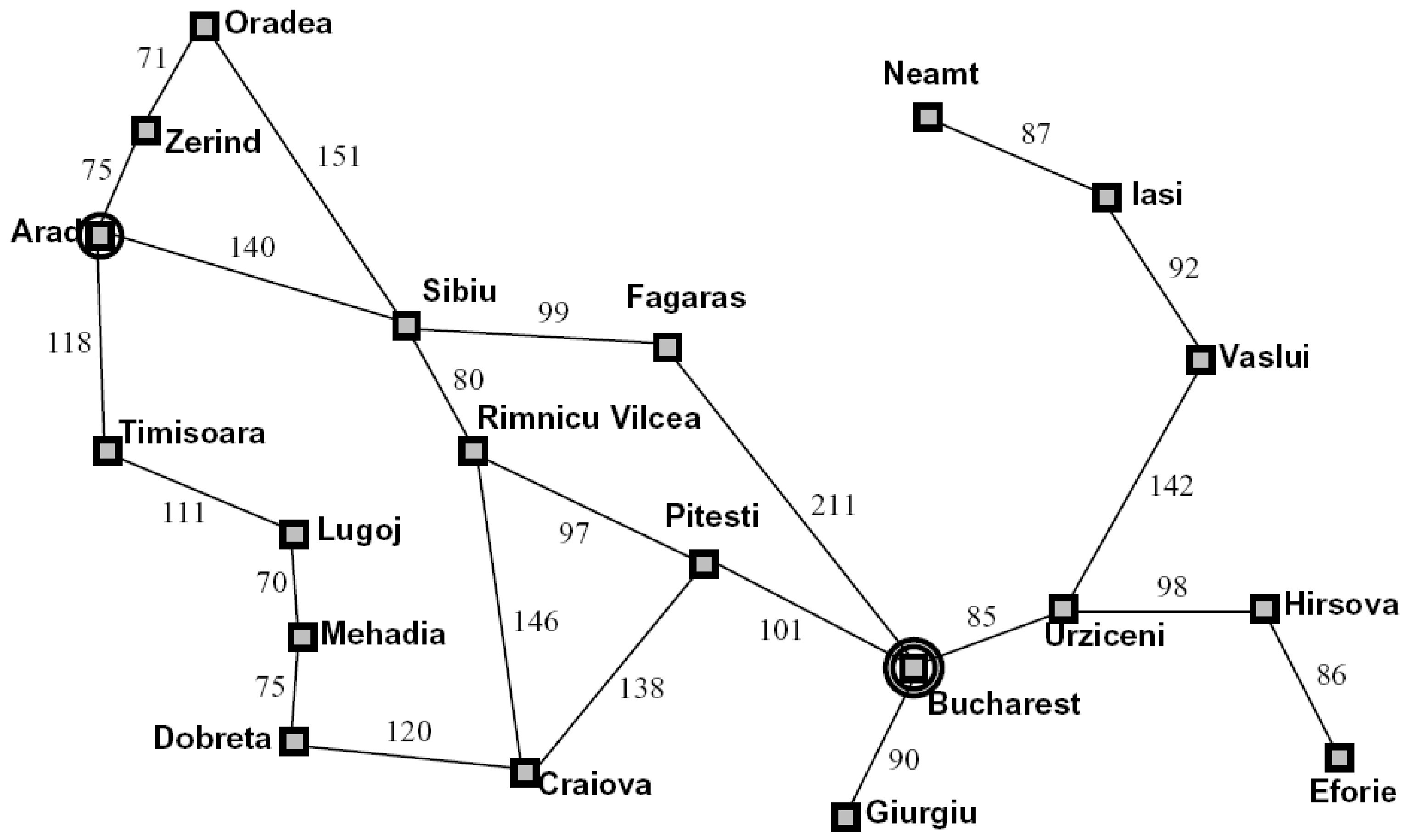
Important: Lots of repeated structure in the search tree!

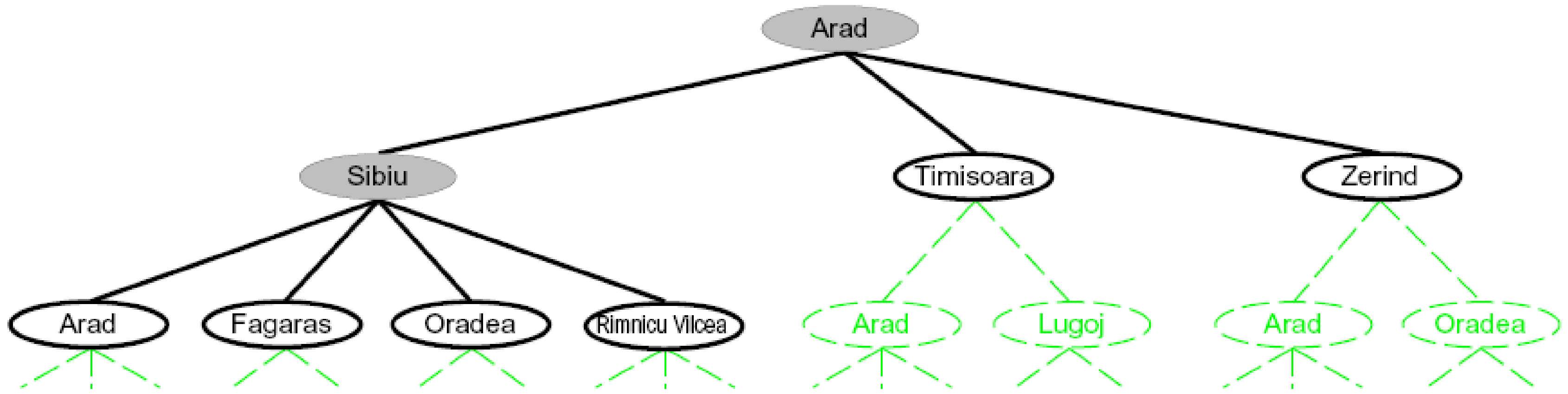
Tree Search



Search Example: Romania

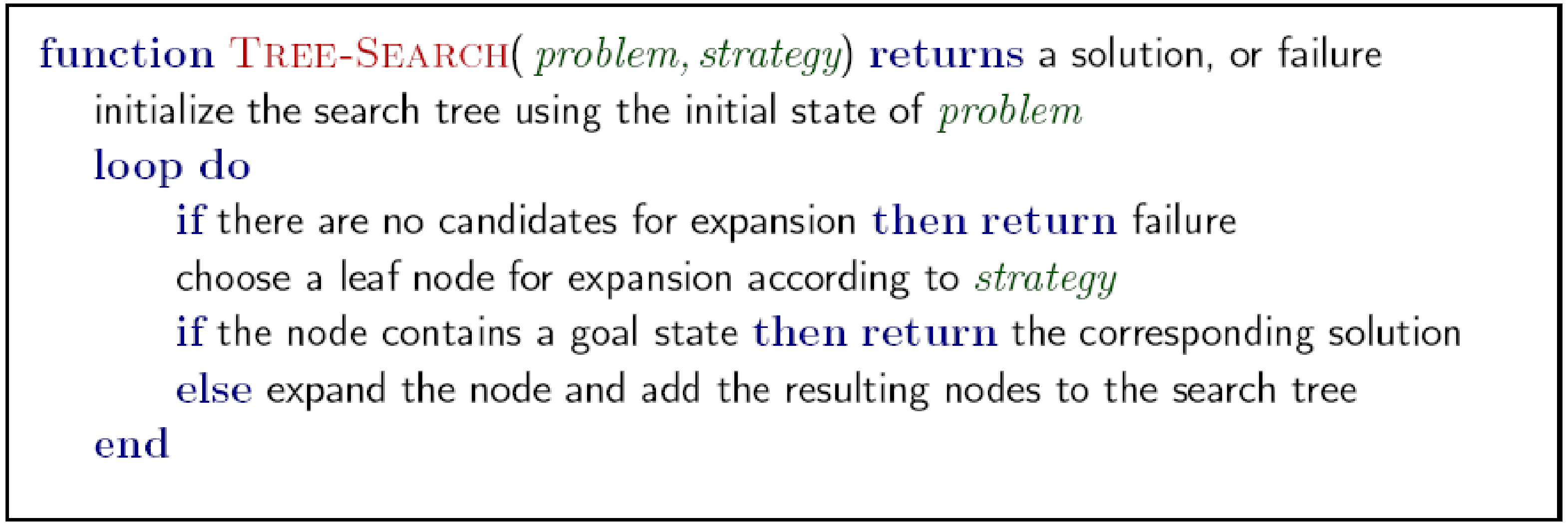


Searching with a Search Tree



- 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

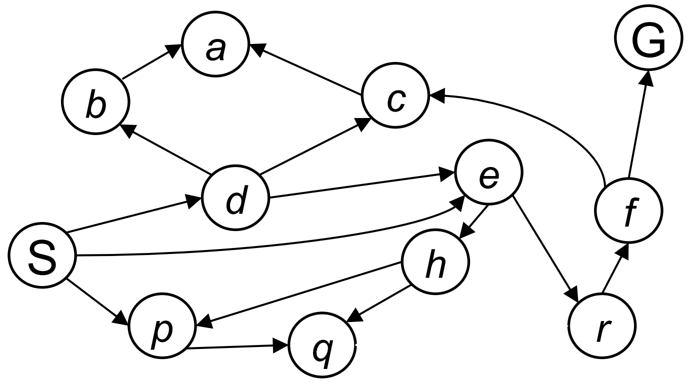


```
function TREE-SEARCH( problem, strategy) returns a solution, or failure
    initialize the search tree using the initial state of problem
    loop do
        if there are no candidates for expansion then return failure
        choose a leaf node for expansion according to strategy
        if the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

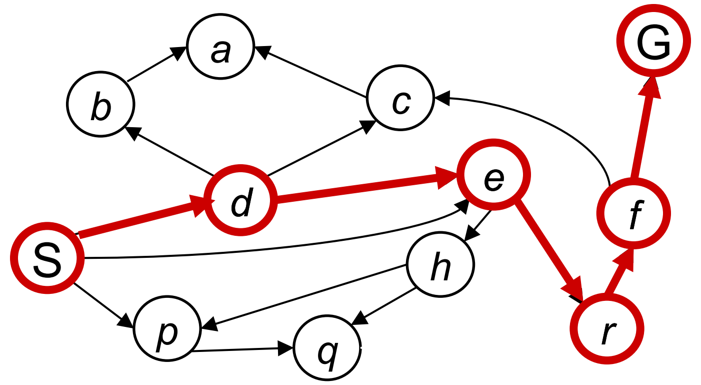
- Important ideas:
  - Fringe
  - Expansion
  - Exploration strategy

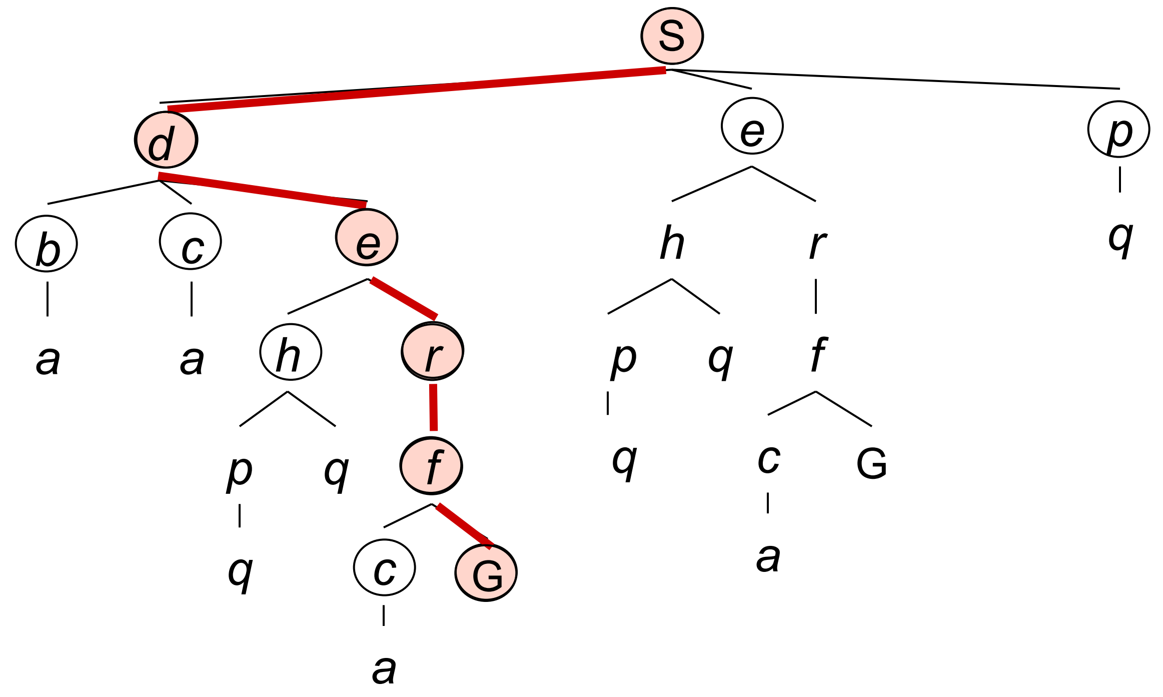
- Main question: which fringe nodes to explore?

Example: Tree Search



Example: Tree Search





~~s~~

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s → e

s → p

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s → d → e → h

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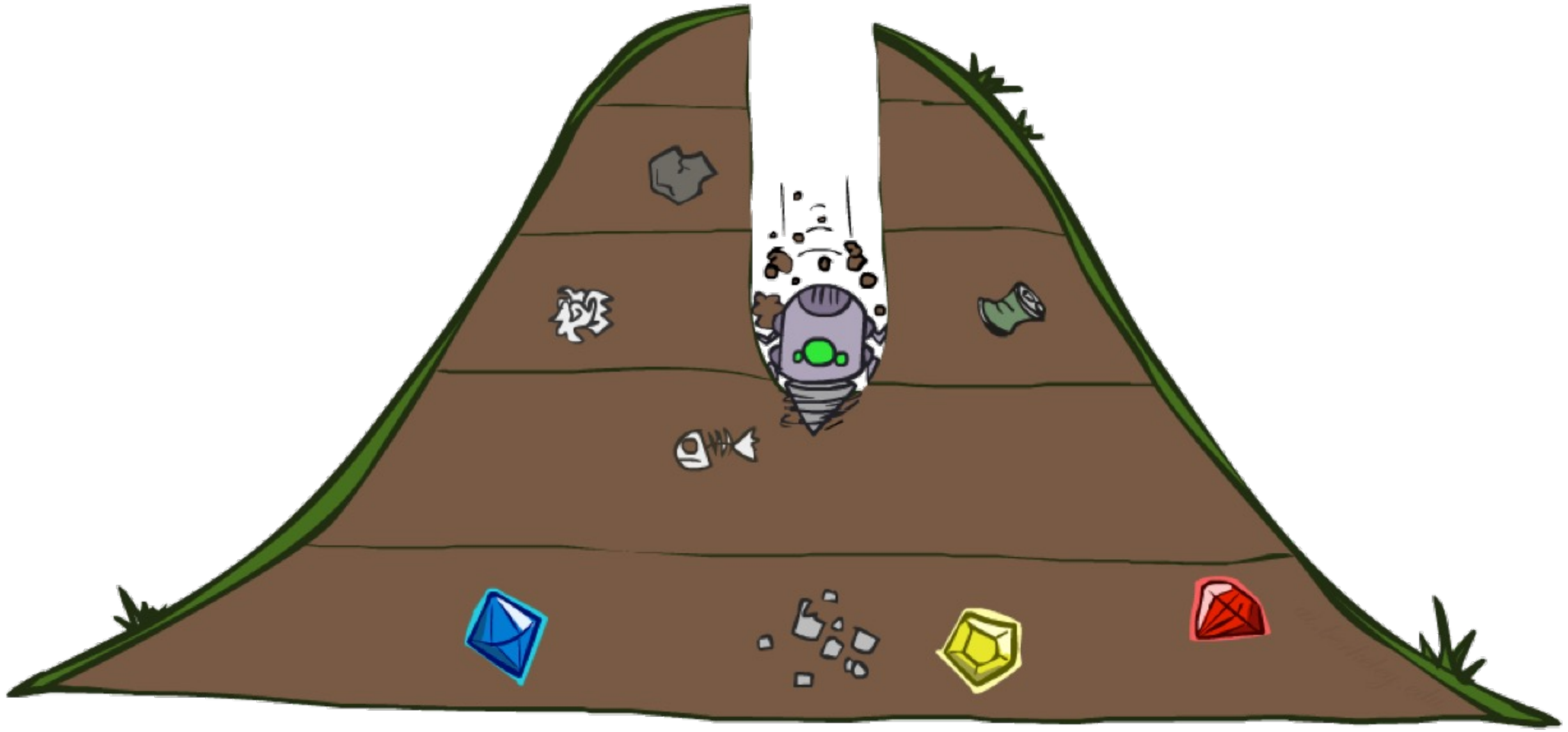
~~s → d → e → r → f~~

s → d → e → r → f → c

~~s → d → e → r → f → G~~

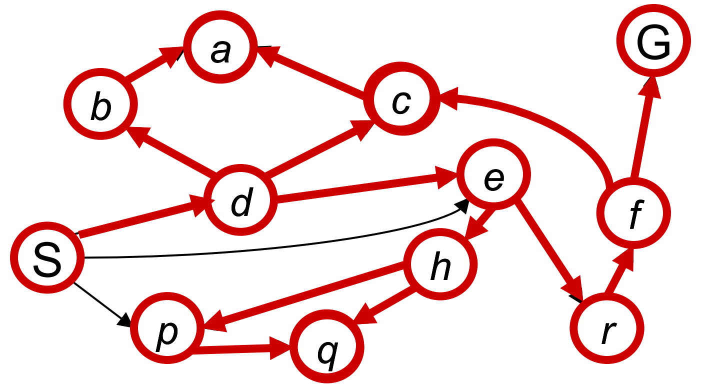
Depth-First Search

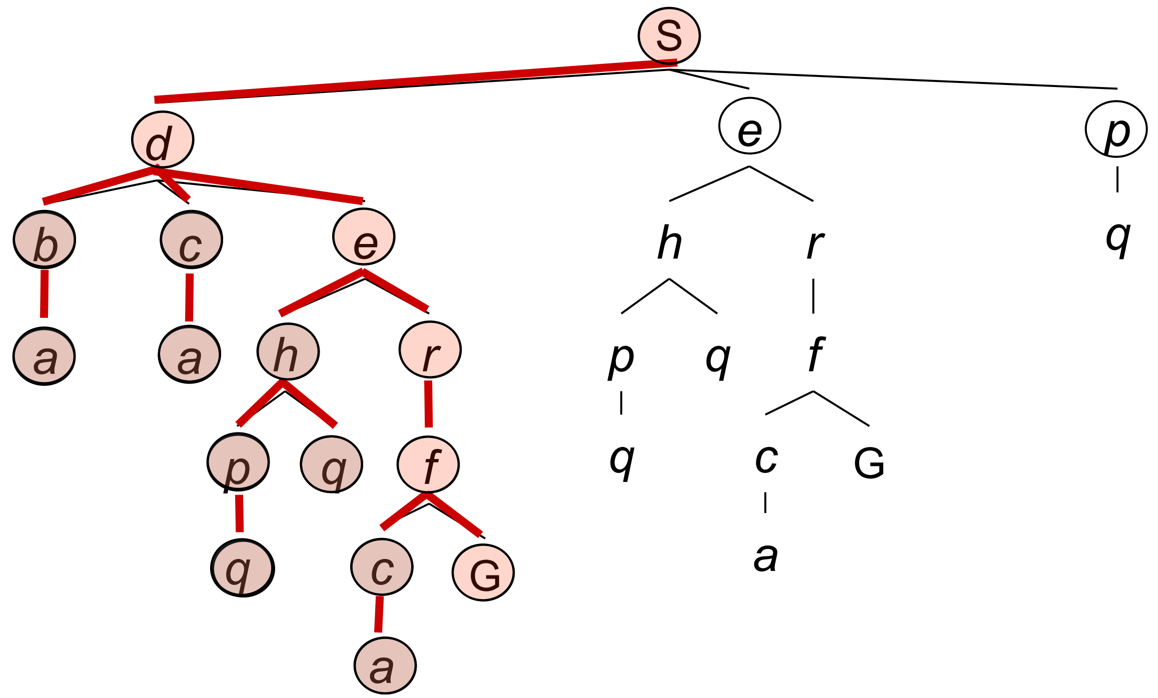


Depth-First Search

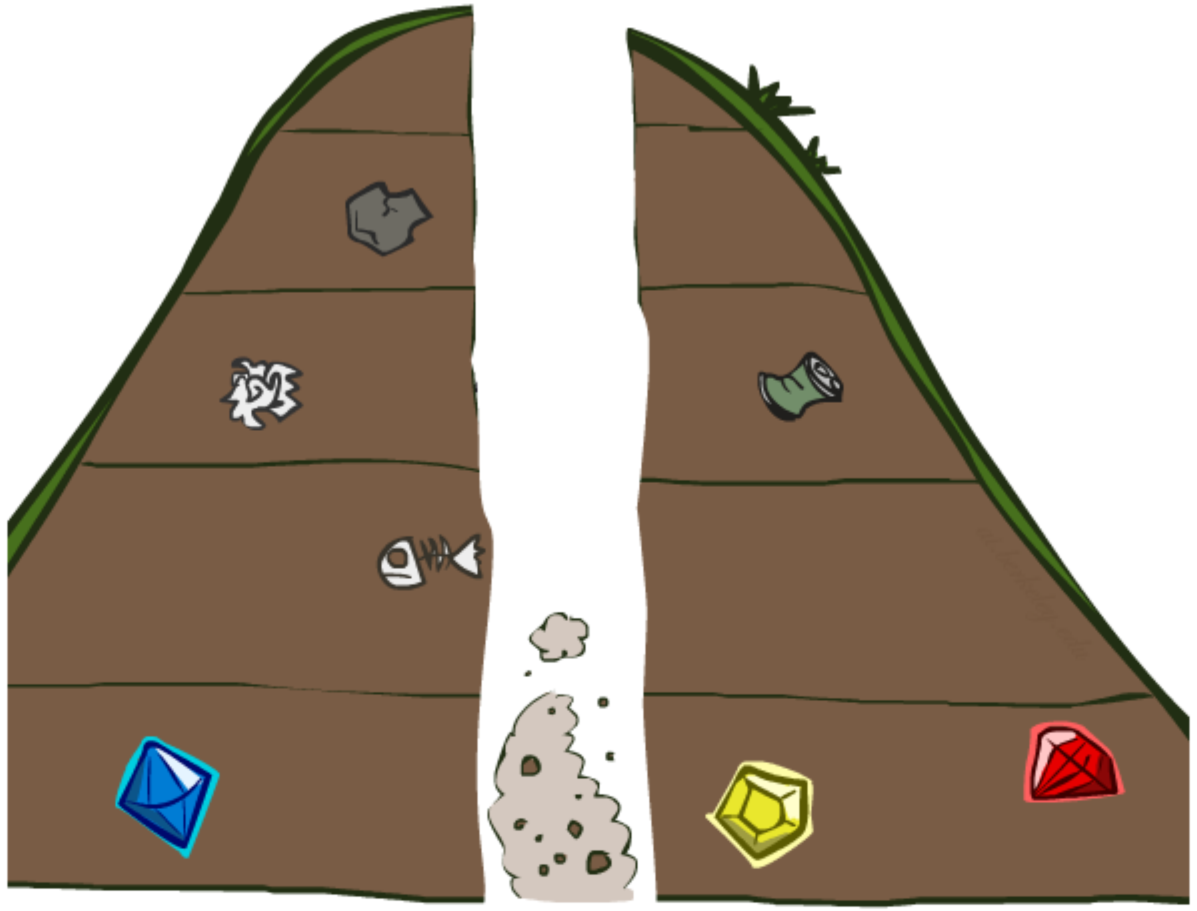
Strategy: expand a deepest node first

Implementation: Fringe is a LIFO stack





Search Algorithm Properties

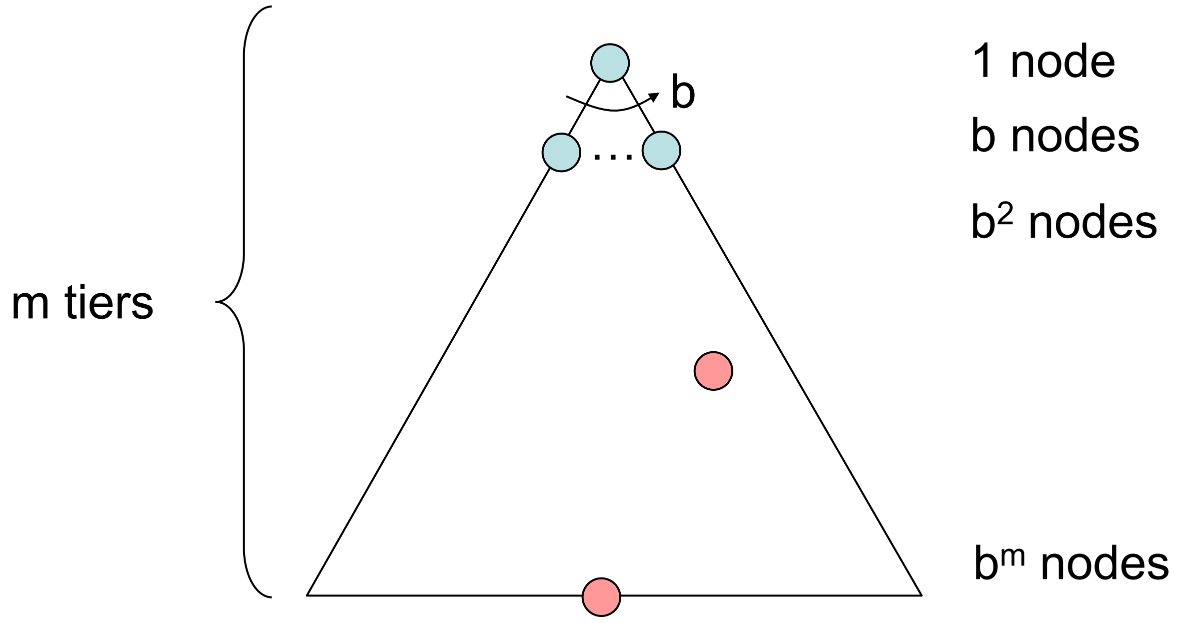


Search Algorithm Properties

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

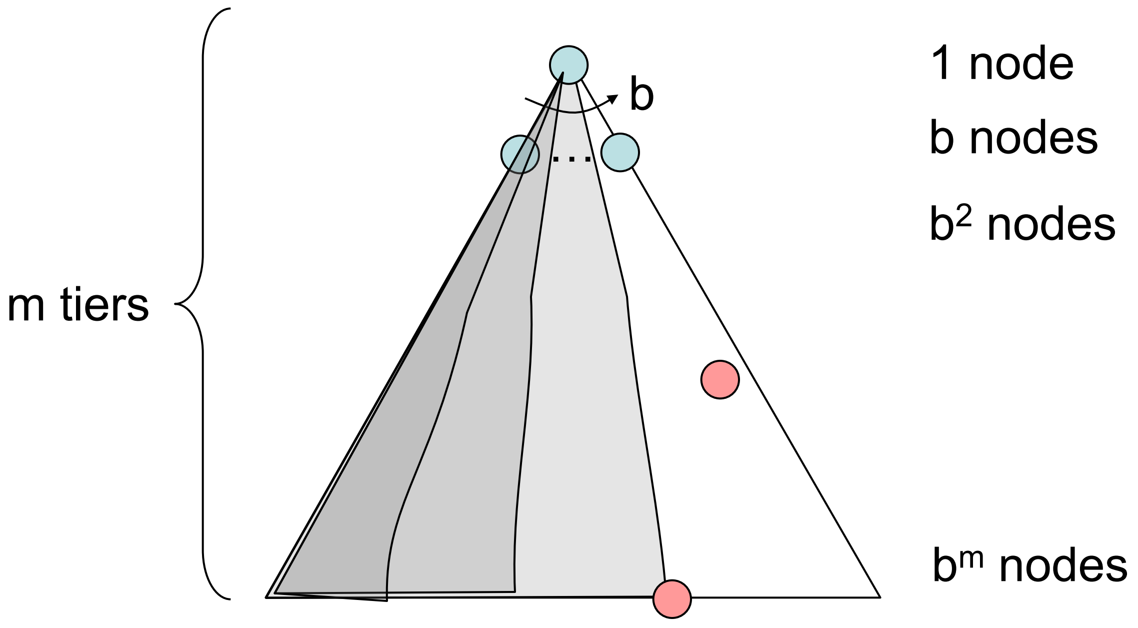
- Cartoon of search tree:
  - b is the branching factor
  - m is the maximum depth
  - solutions at various depths

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

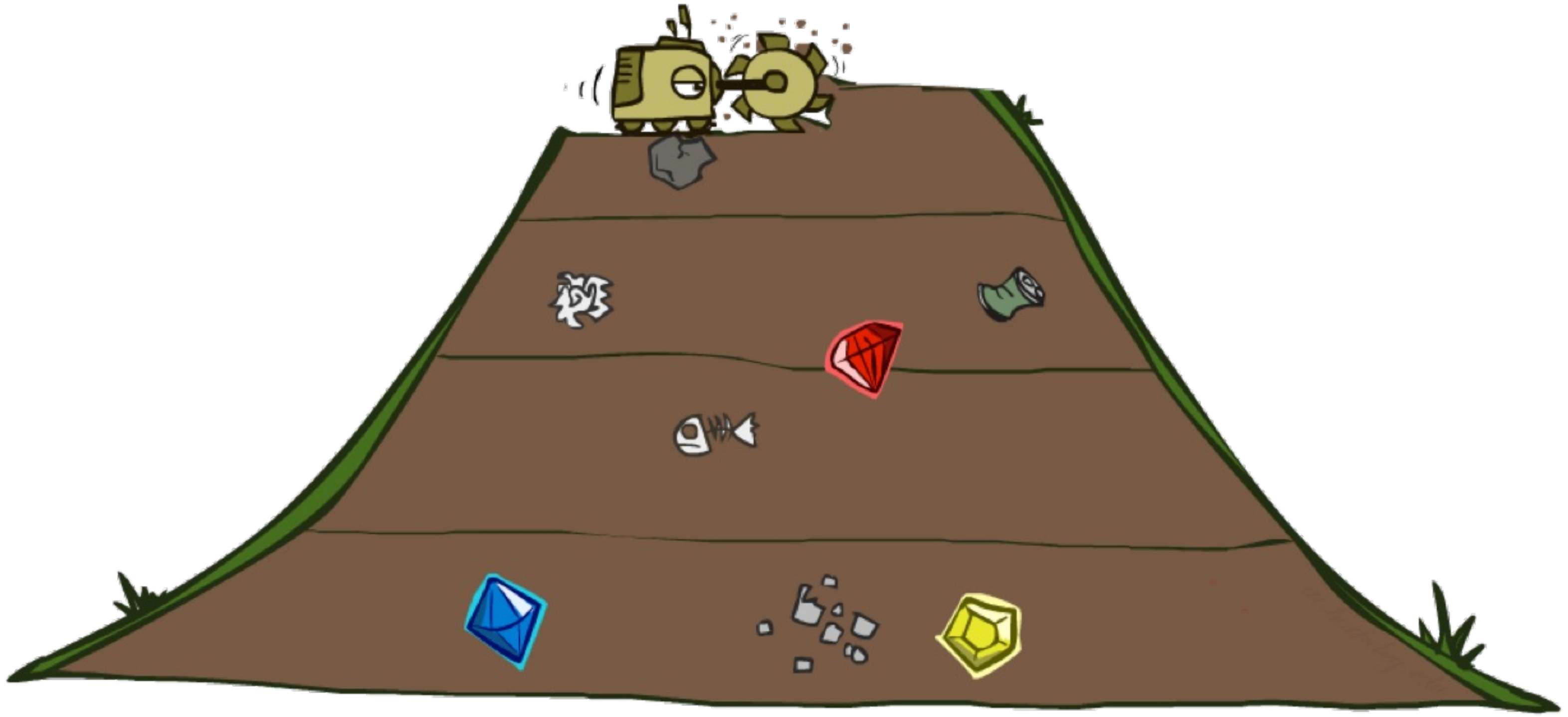


Depth-First Search (DFS) Properties

- 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



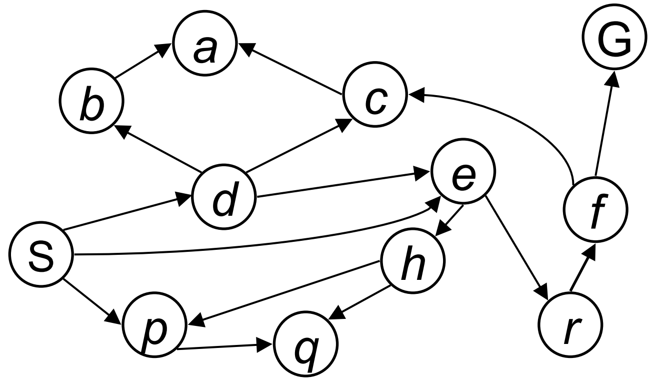
Breadth-First Search

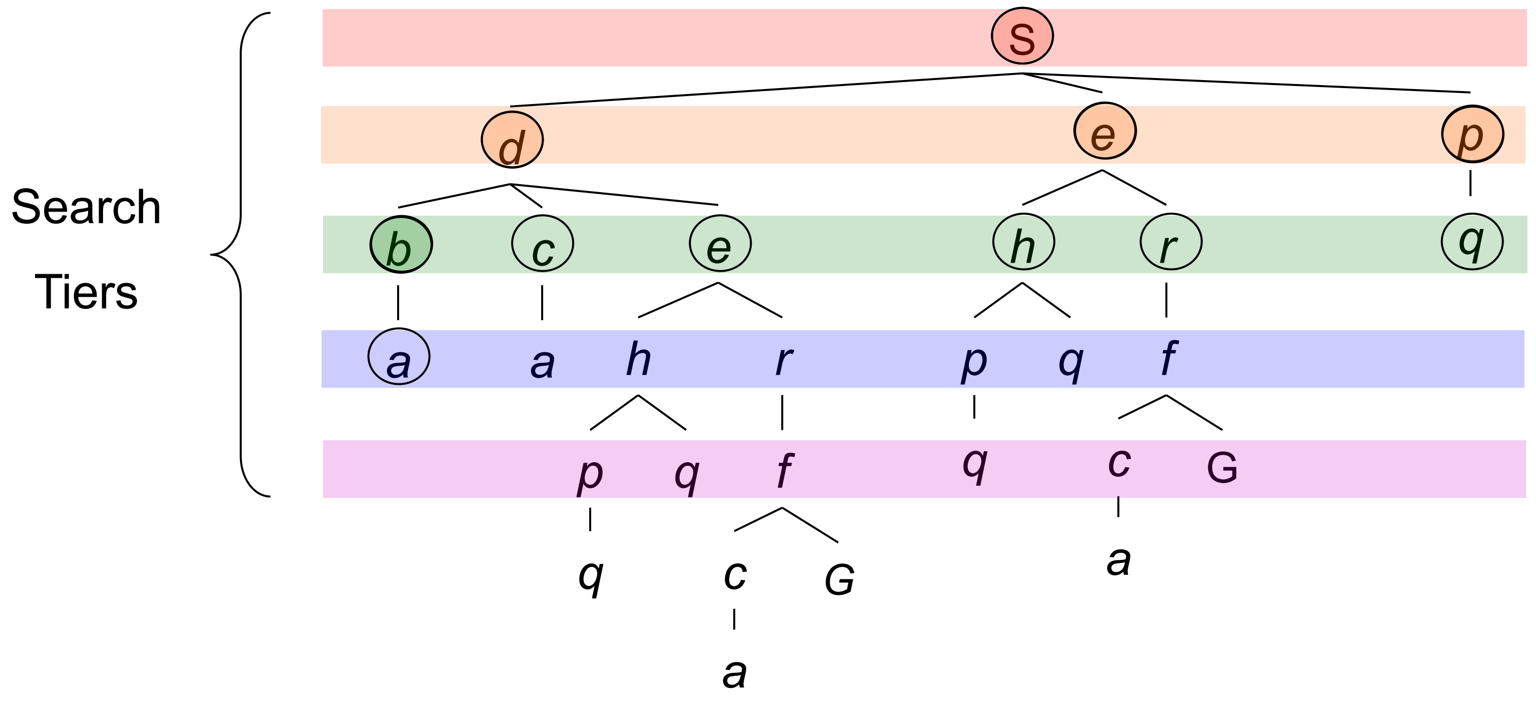


Breadth-First Search

Strategy: expand a shallowest node first

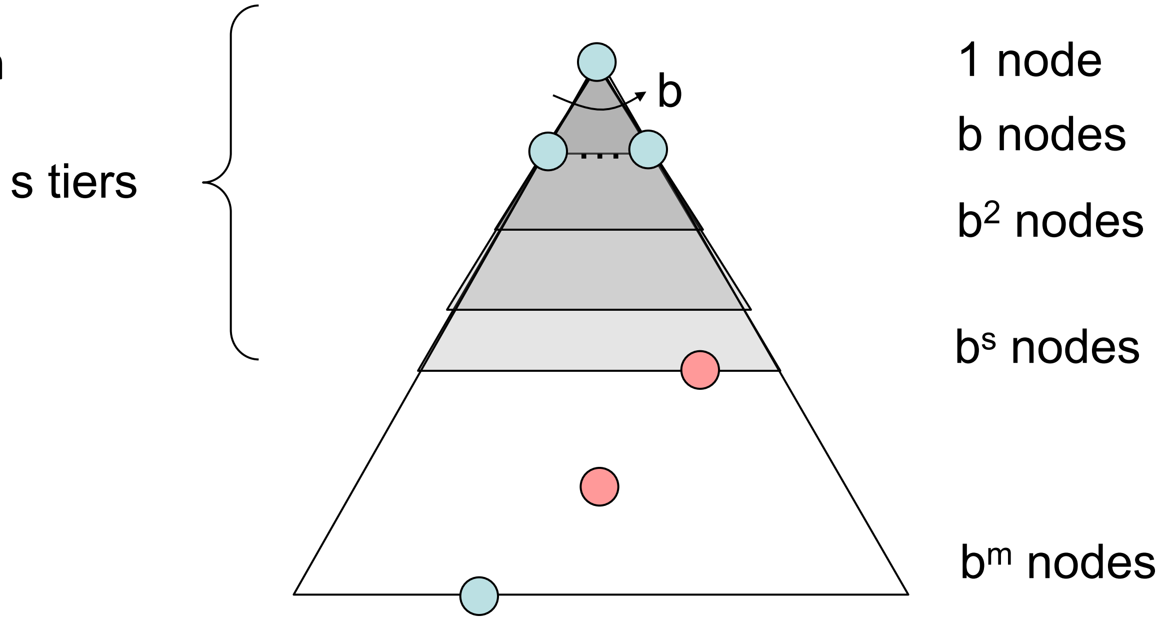
Implementation: Fringe is a FIFO queue



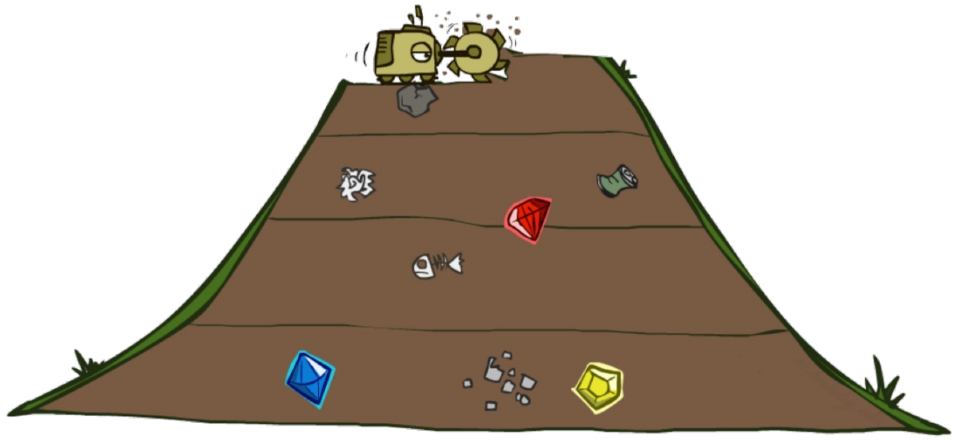


Breadth-First Search (BFS) Properties

- 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?
  - Has roughly the last tier, so $O(b^s)$
- 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)



Quiz: DFS vs BFS



Quiz: DFS vs BFS

- When will BFS outperform DFS?

- When will DFS outperform BFS?

[Demo: dfs/bfs maze water (L2D6)]

Video of Demo Maze Water DFS/BFS (part 1)

Video of Demo Maze Water DFS/BFS (part 2)