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Pinned Post: AI in the news!

Lecture Attendance Link

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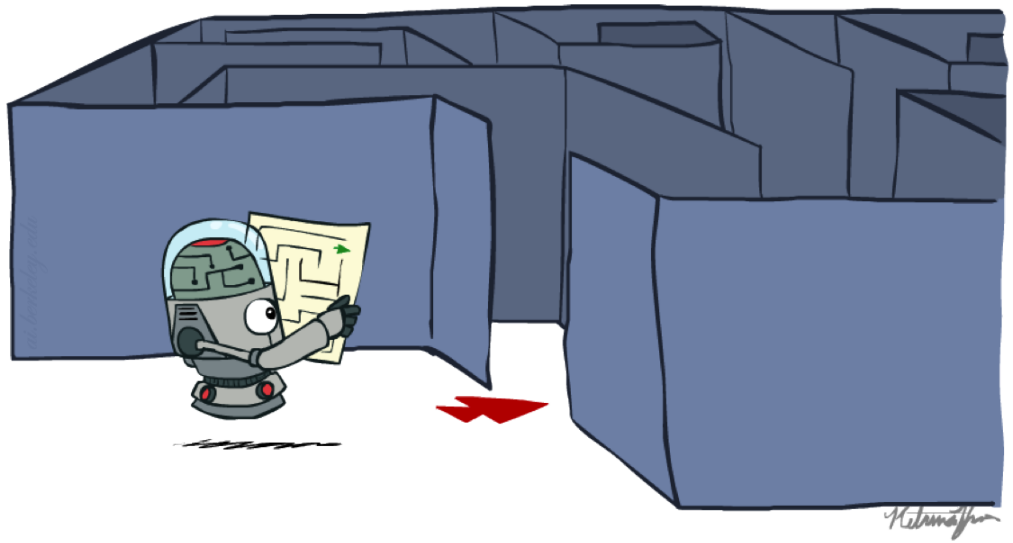
CS 188: Artificial Intelligence

Search.



Today.

Agents that Plan Ahead

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Search Problems.

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  - Model world with state space.

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Uninformed Search Methods:
- Depth-First Search
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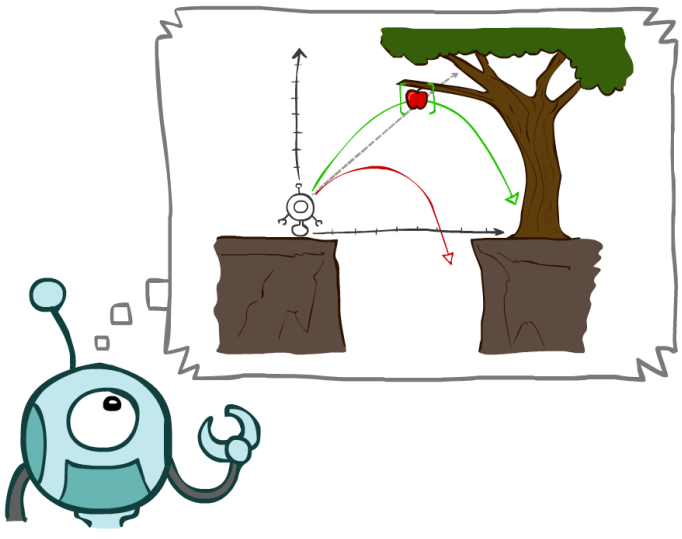
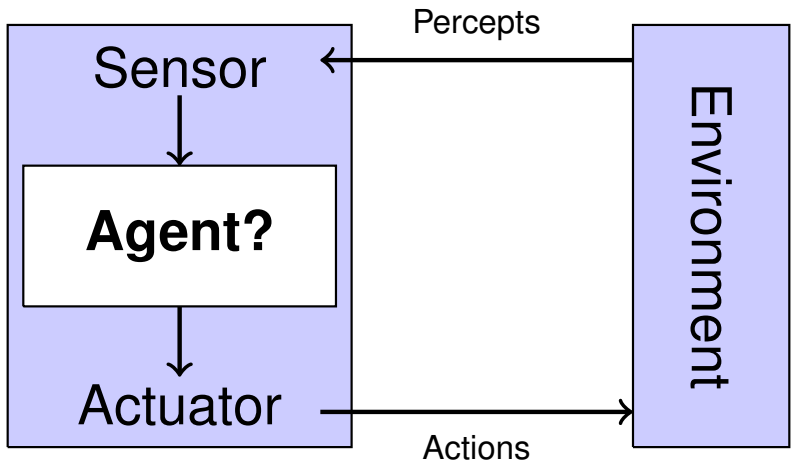
- Uniform-Cost Search



Frame of AI



An agent percieves its environment with sensors and acts on environment using actuators.

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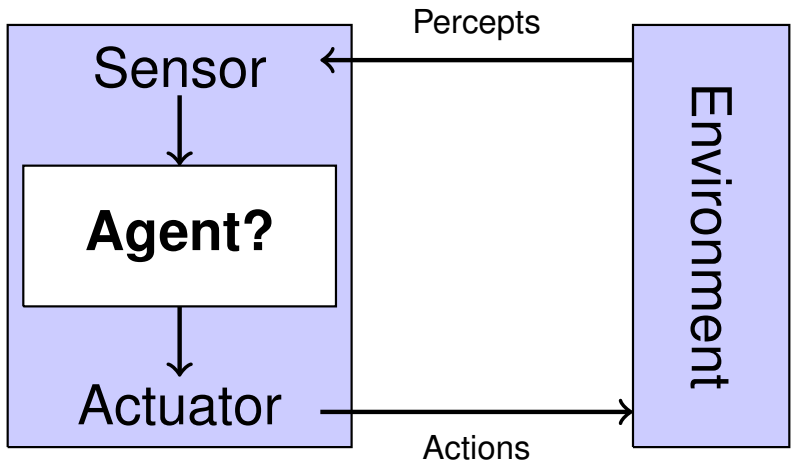

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Car:

Sensors:

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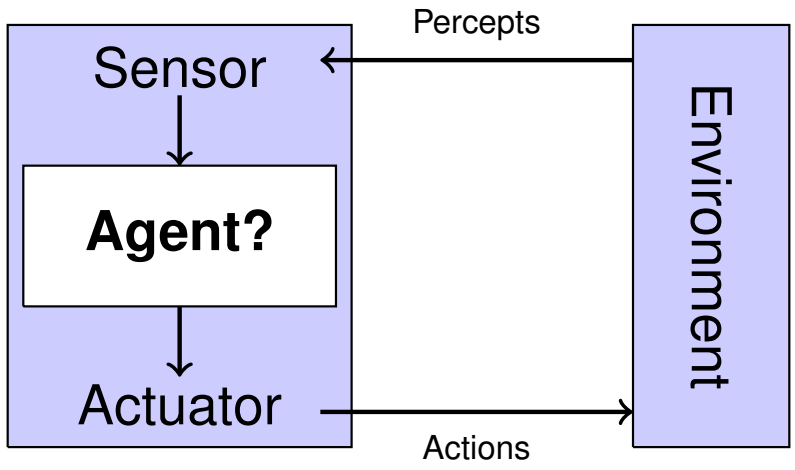

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Sensors: camera,

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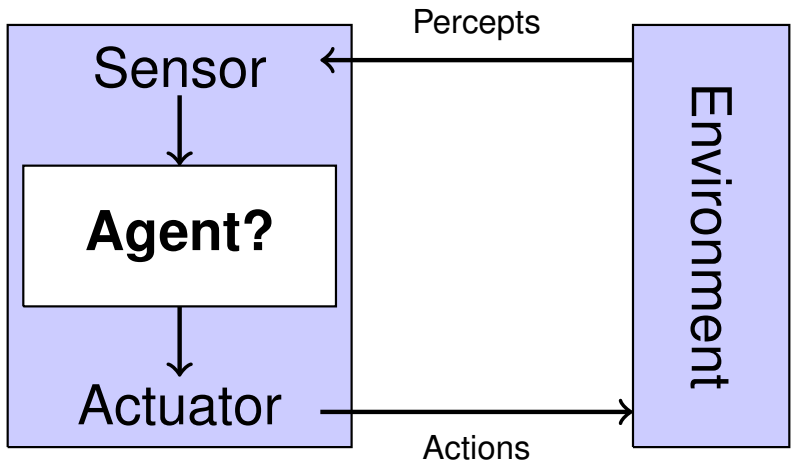

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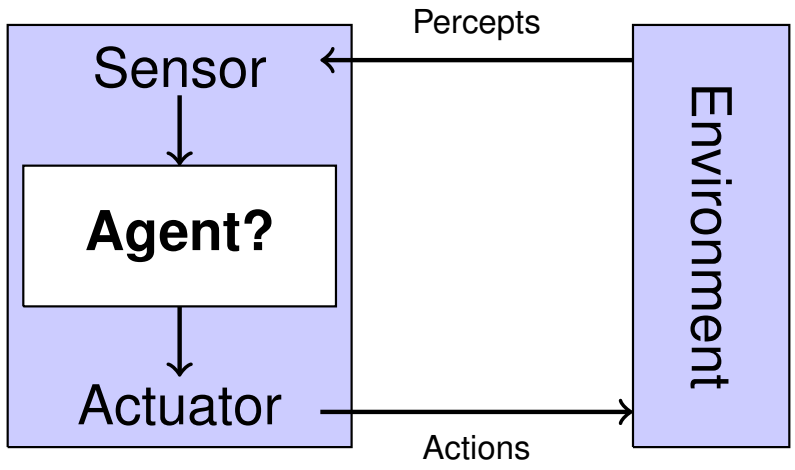

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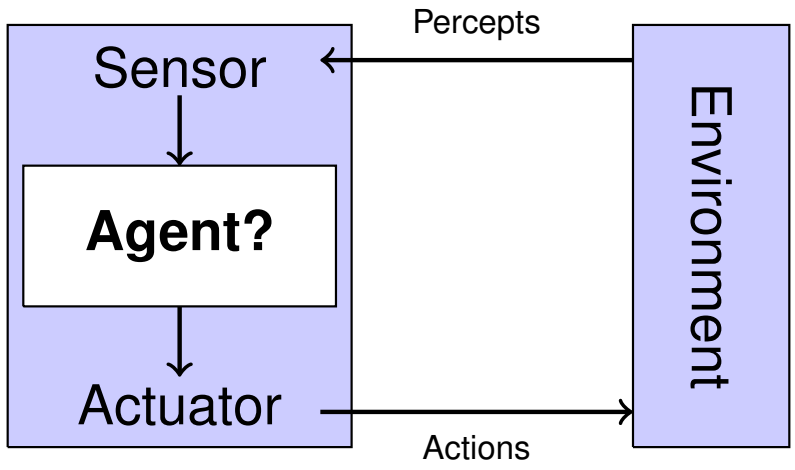

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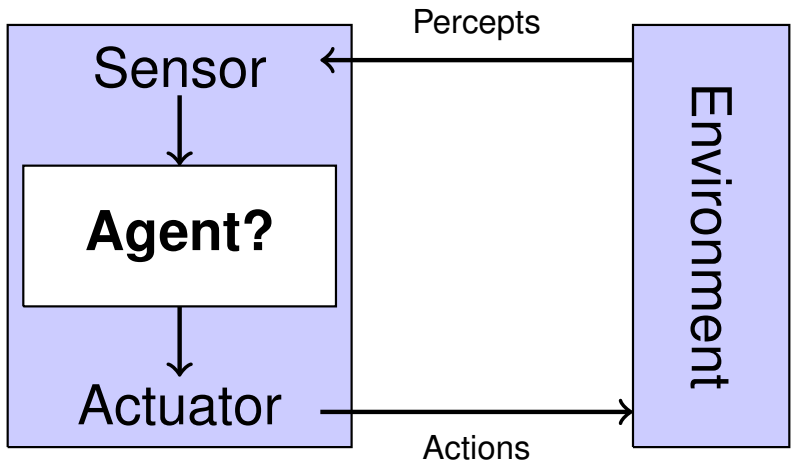

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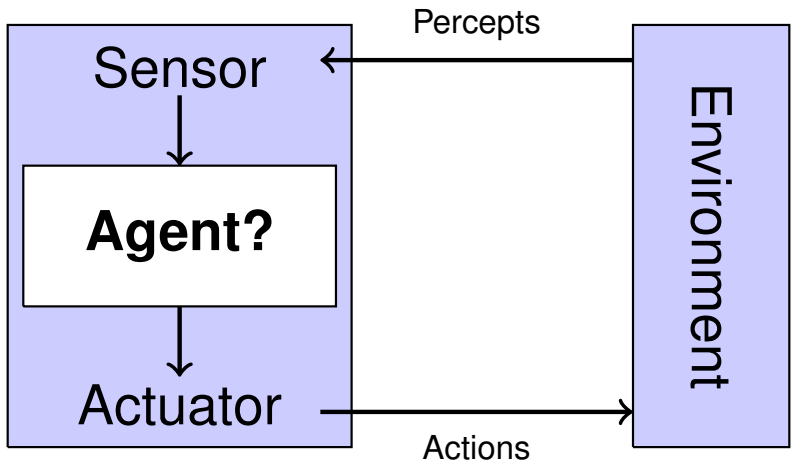

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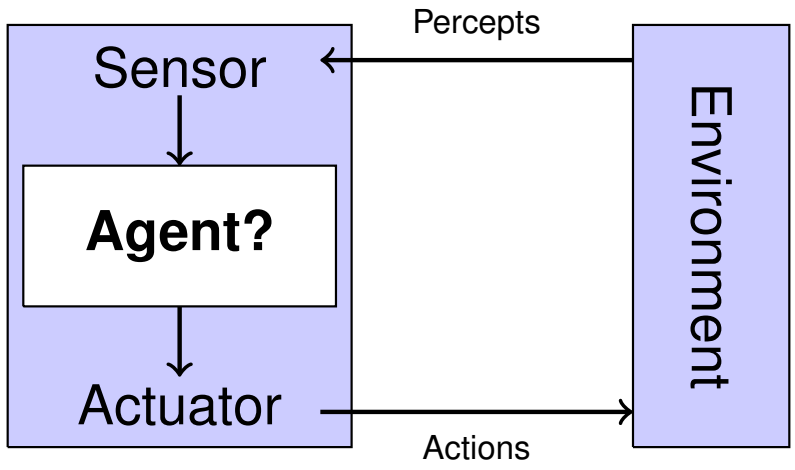

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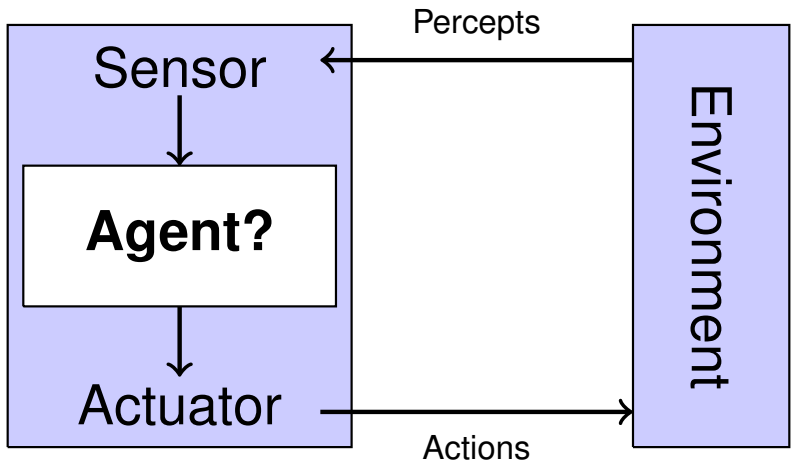

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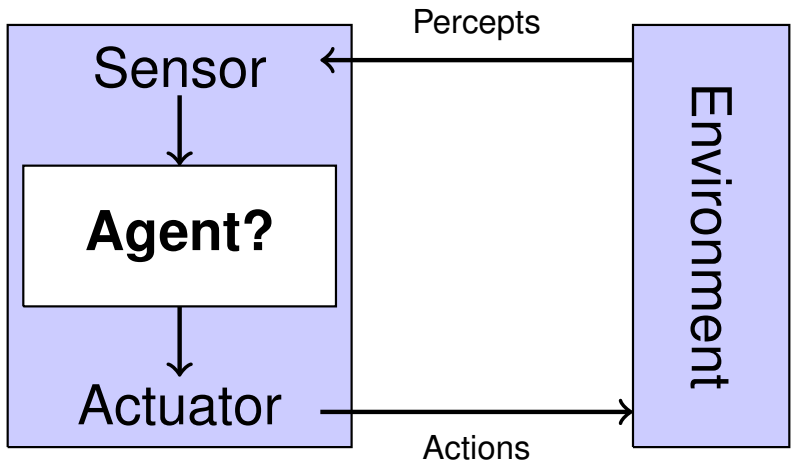

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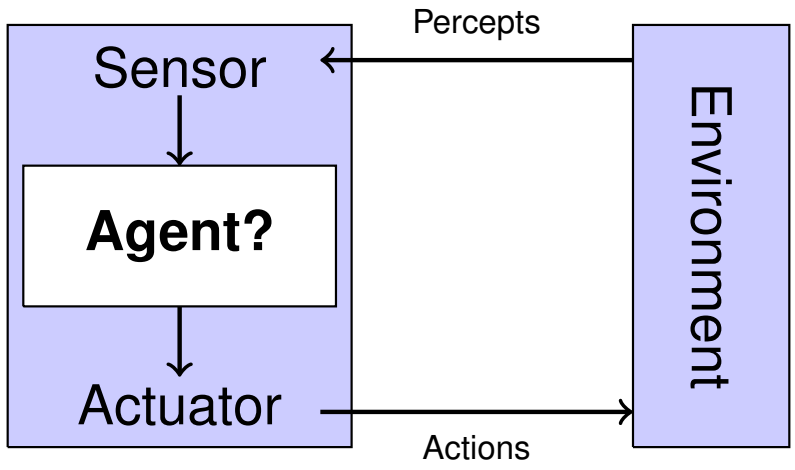

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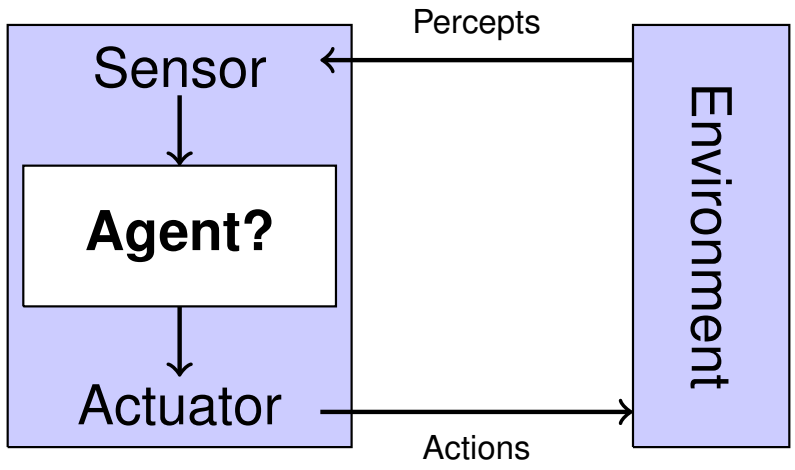

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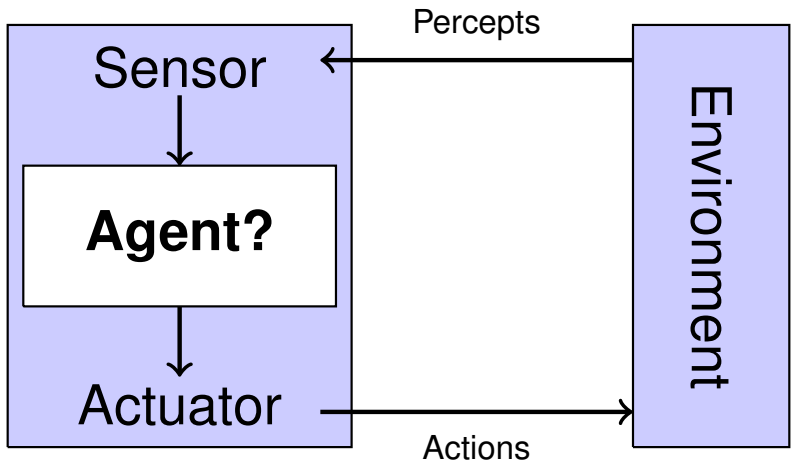

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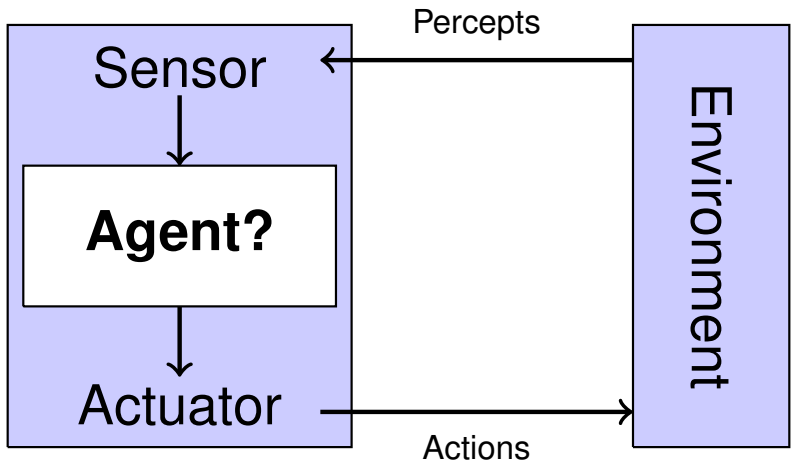

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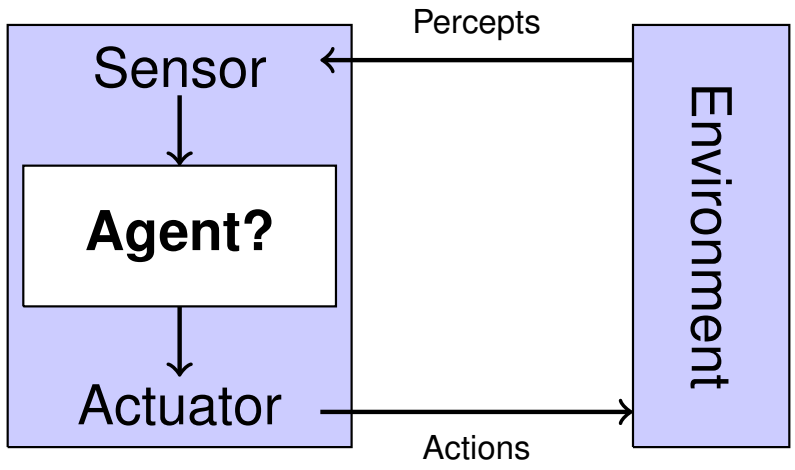

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E.g., reach goal with lowest cost.

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Later: agents have numerical utilities, rewards, etc.
E.g., takes action that maximizes total reward over time.
(Reward: largest total profit. or expected total profit.)

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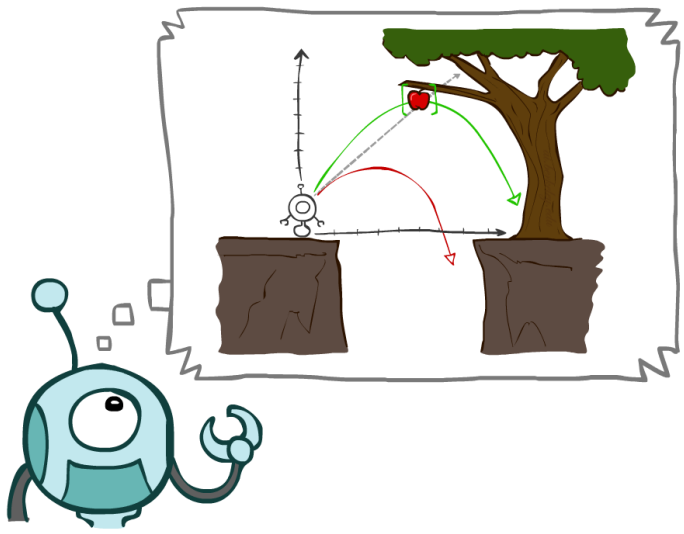
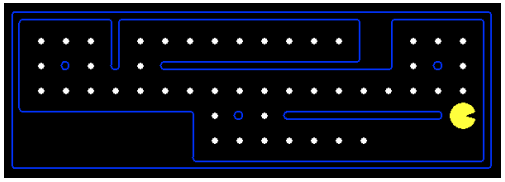
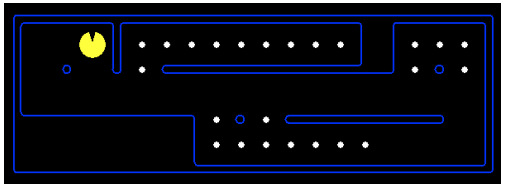
- Single-agent/multi-agent $\rightarrow$ agent may need to behave randomly.

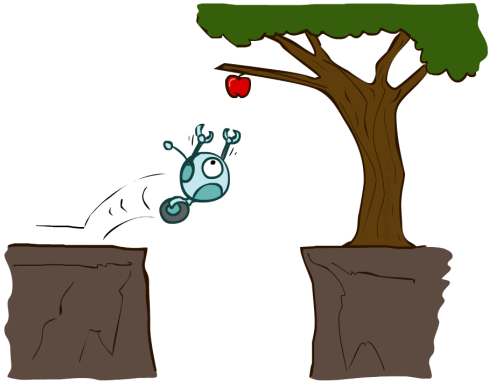
Agents that Plan



Reflex Agents







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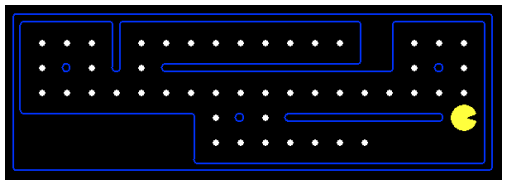

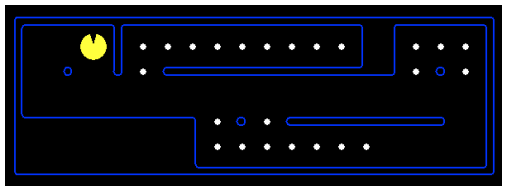

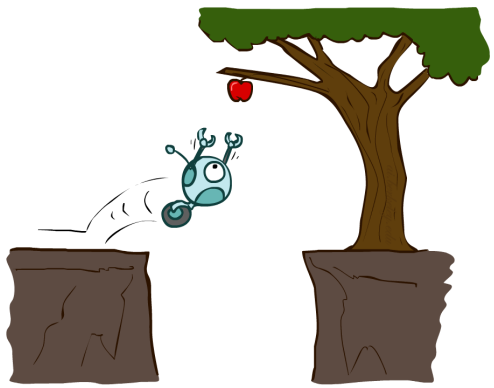

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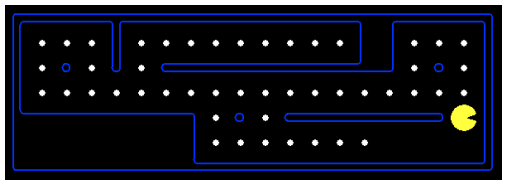

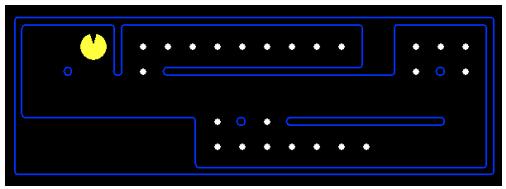

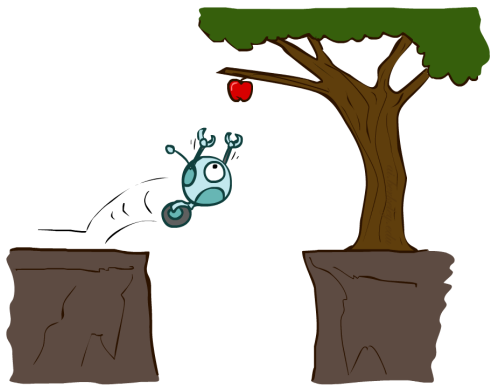

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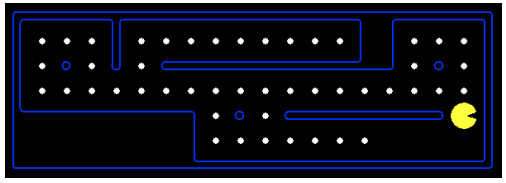

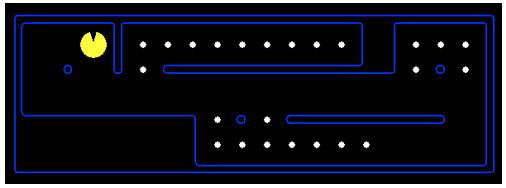

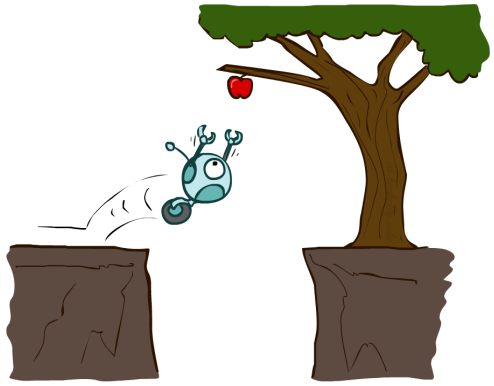

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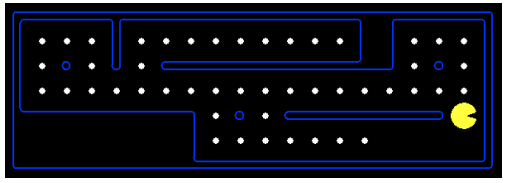

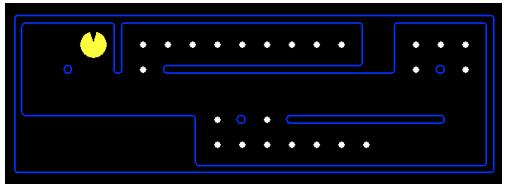

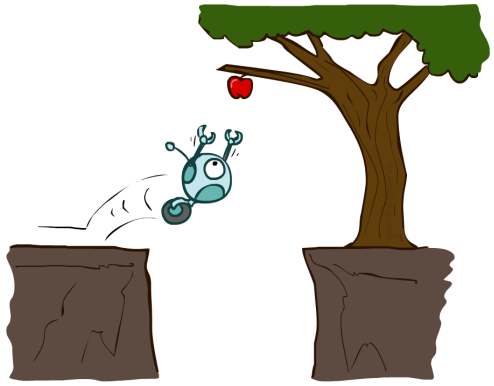

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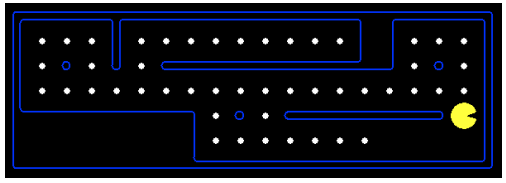

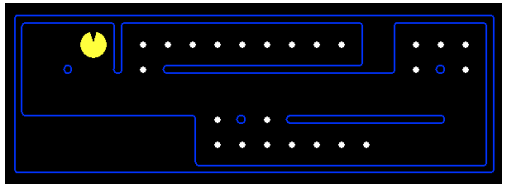

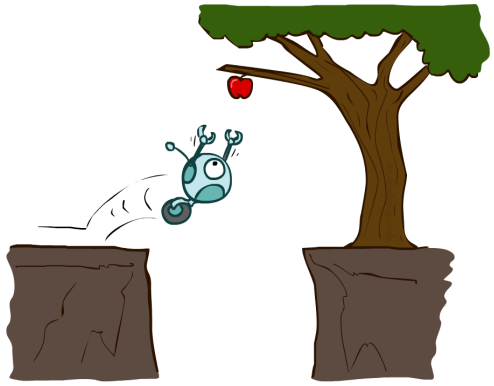

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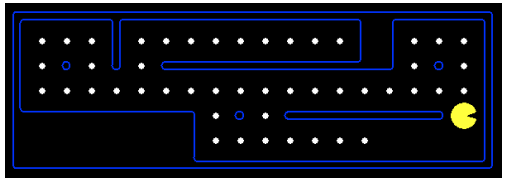

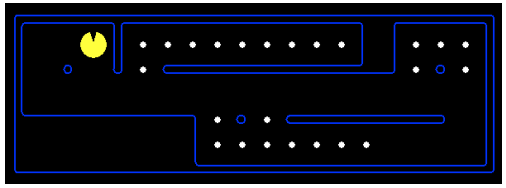

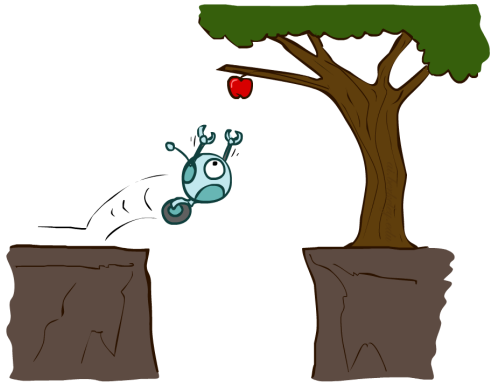

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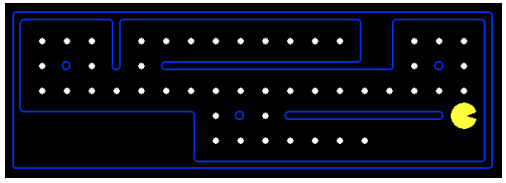

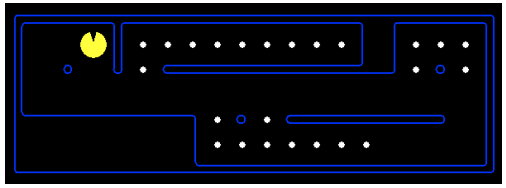

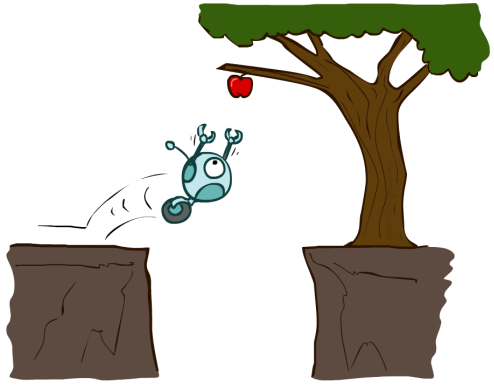

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- Choose action based on current percept (and maybe memory)
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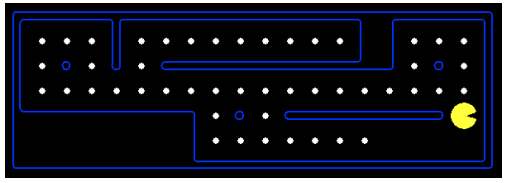
- Consider how the world IS.

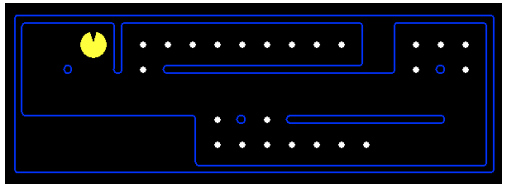
Can a reflex agent be rational?

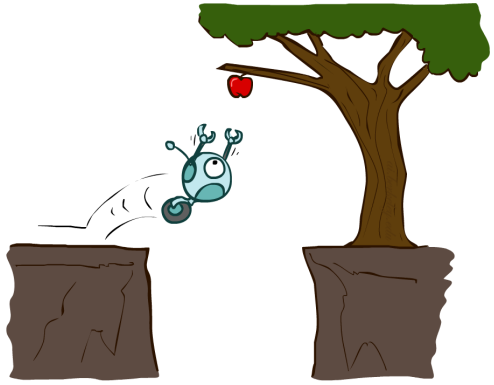
Examples:

Stove:

Reflex Agents







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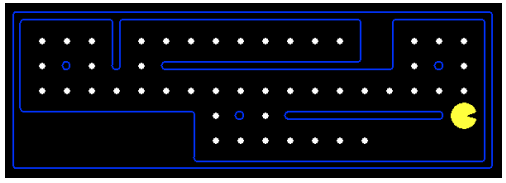

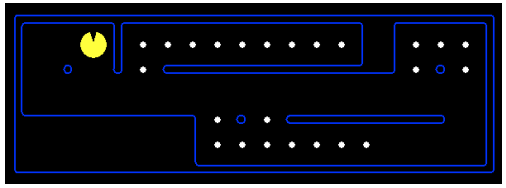

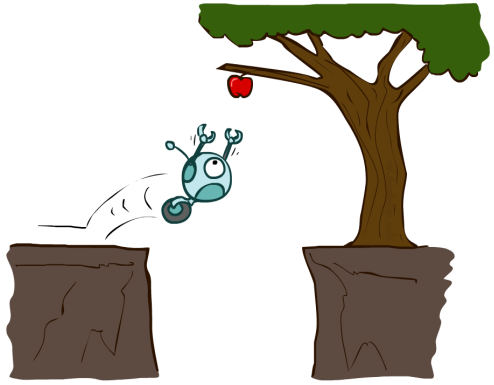

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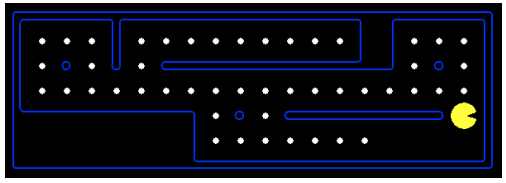

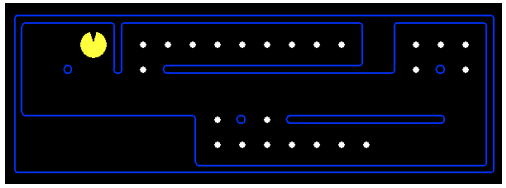

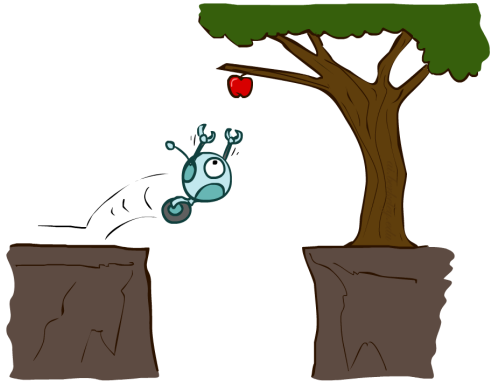

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Examples:

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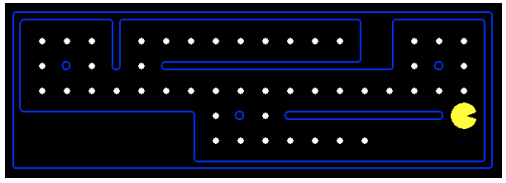
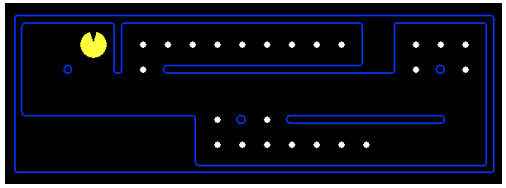
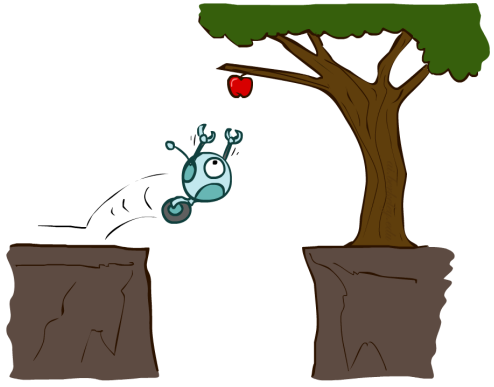
Reflex Agents







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Examples:

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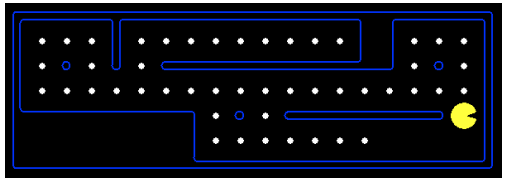

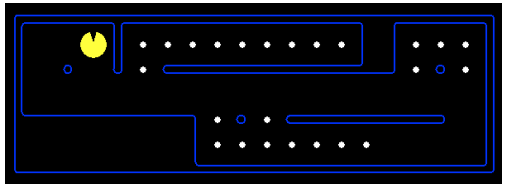

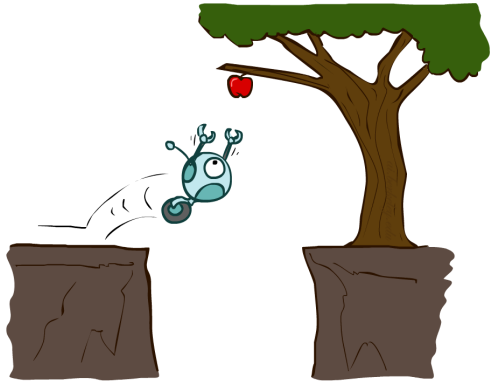

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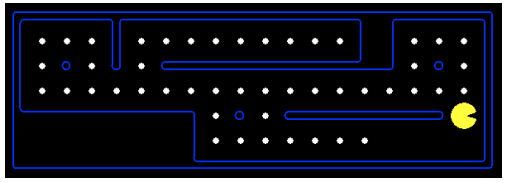

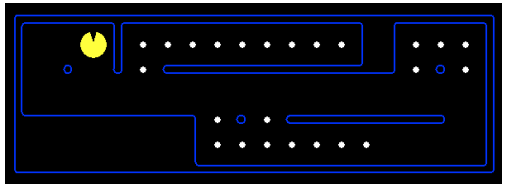

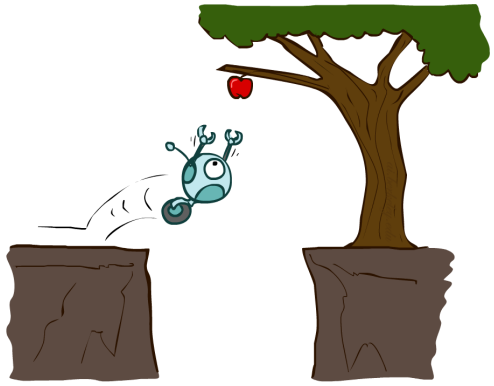

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Examples:

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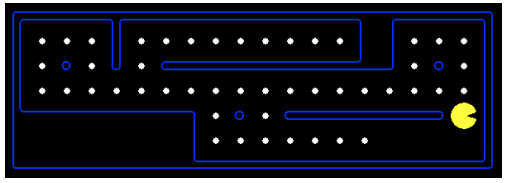
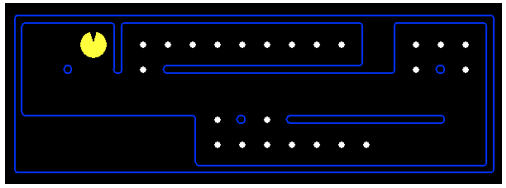
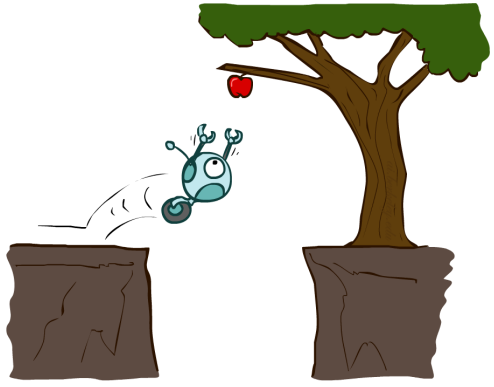
Go to Tahoe:

Reflex Agents







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Go to Tahoe: skid in snow,

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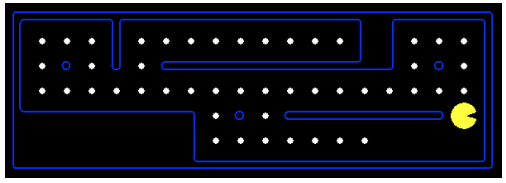

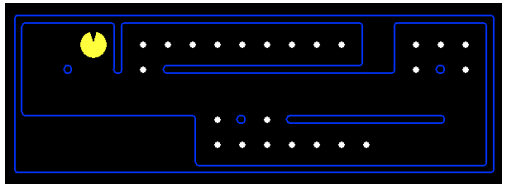

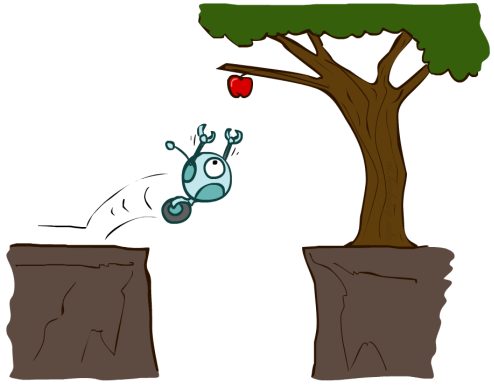

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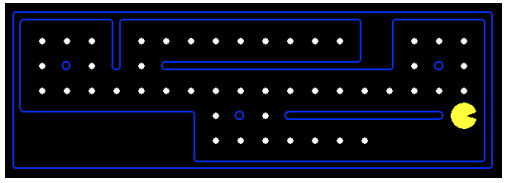

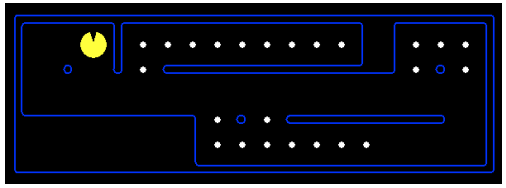

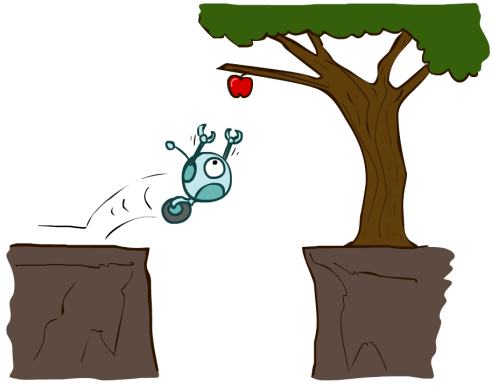

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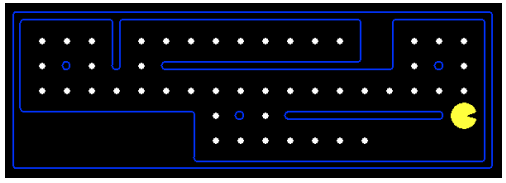

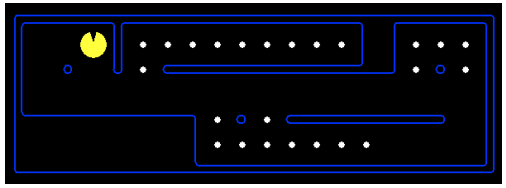

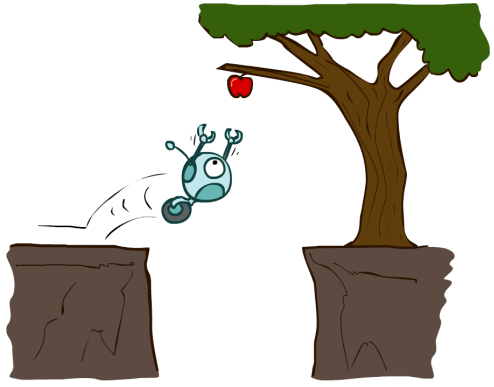

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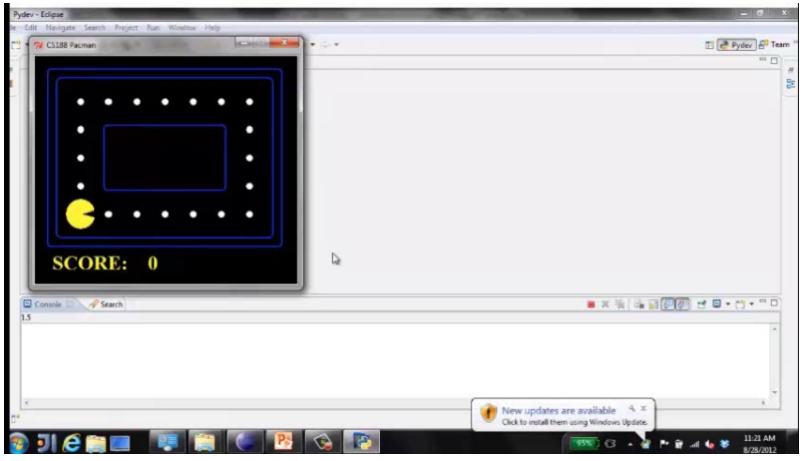
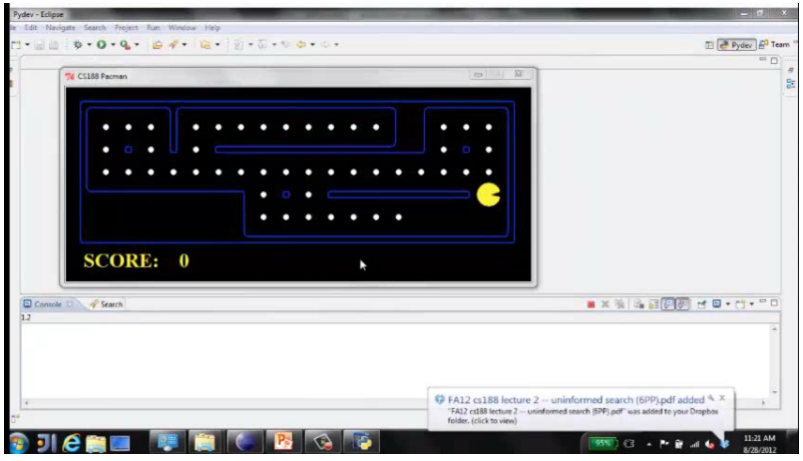
[Demo: reflex (L2D1 and L2D2)]

Video of Demo Reflex Optimal



Video of Demo Reflex Odd



Planning Agents

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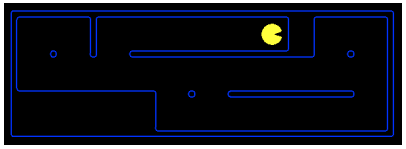

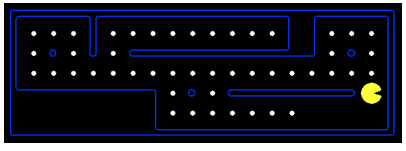

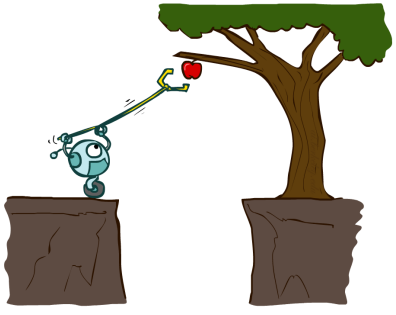

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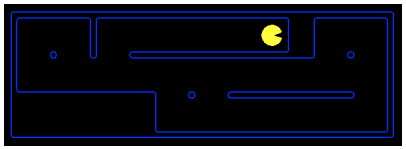
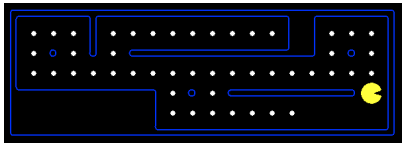
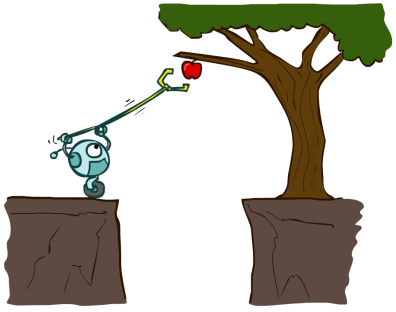


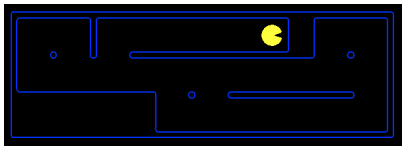


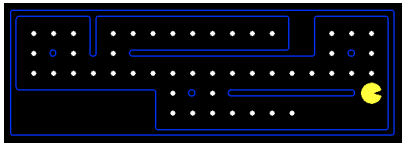


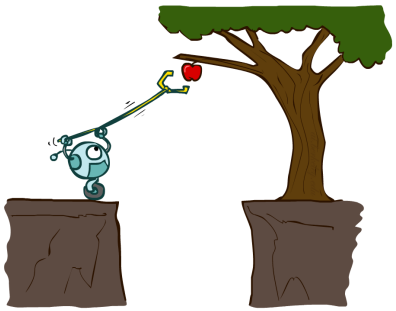
Planning agents:

Ask “what if?”

Planning Agents





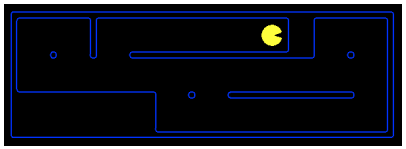


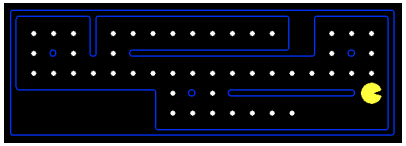
Planning agents:

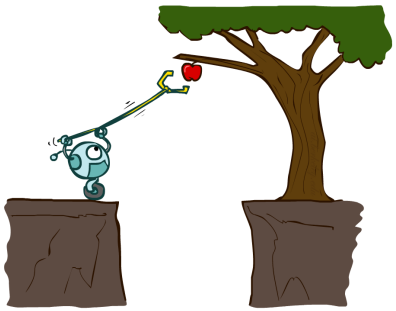
Ask “what if?”

Decisions based on (hypothesized) consequences of actions.

Planning Agents







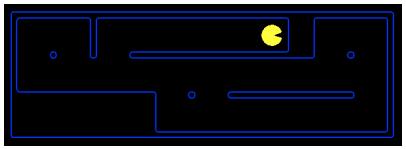
Planning agents:

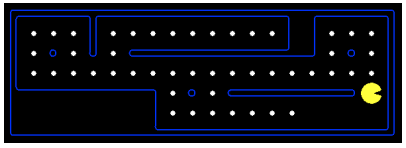
Ask “what if?”

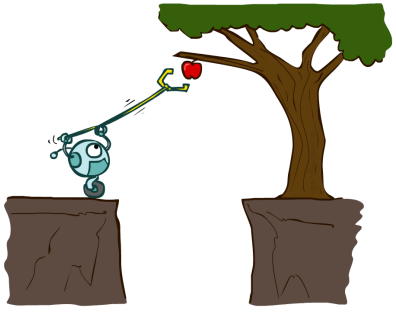
Decisions based on (hypothesized) consequences of actions.

Must have a model of how the world evolves in response to actions.

Planning Agents







Planning agents:

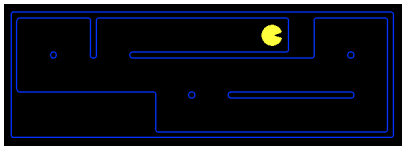
Ask “what if?”

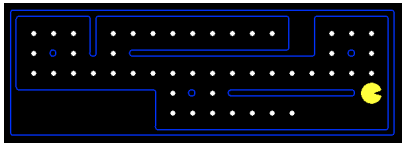
Decisions based on (hypothesized) consequences of actions.

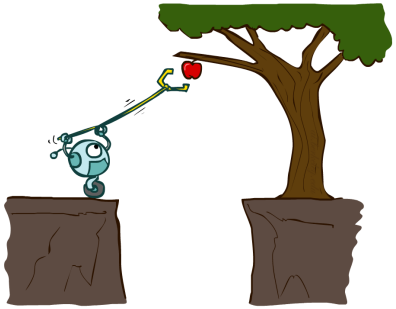
Must have a model of how the world evolves in response to actions.

Must formulate a goal (test).

Planning Agents







Planning agents:

Ask “what if?”

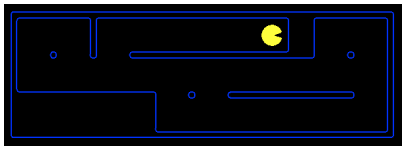
Decisions based on (hypothesized) consequences of actions.

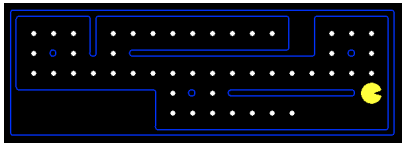
Must have a model of how the world evolves in response to actions.

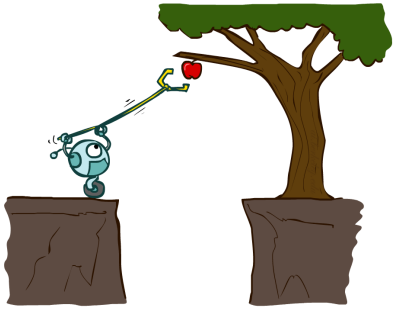
Must formulate a goal (test).

Consider how the world WOULD BE.

Planning Agents







Planning agents:

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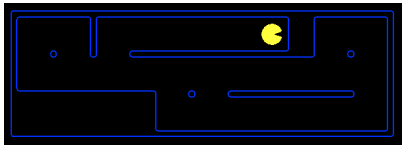
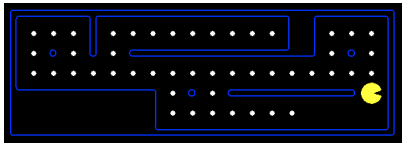
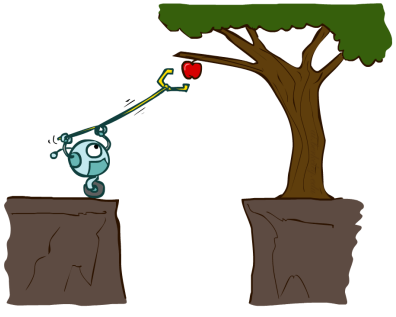
Planning Agents







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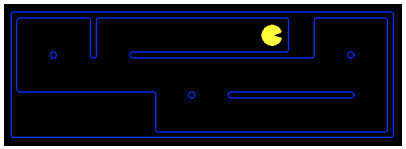
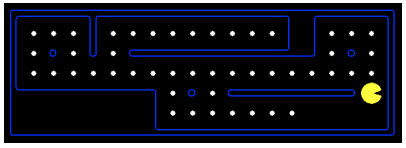
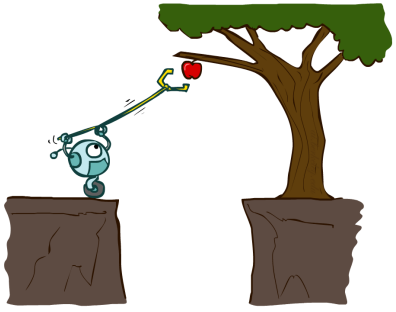
Planning Agents







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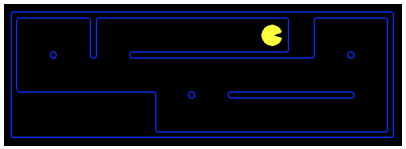
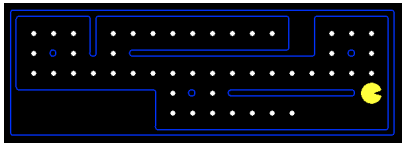
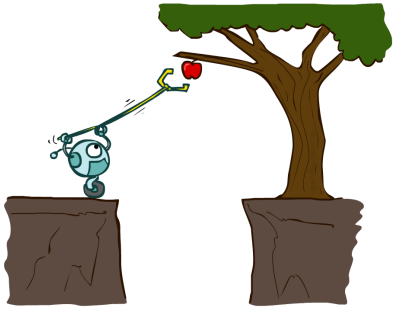
Planning Agents







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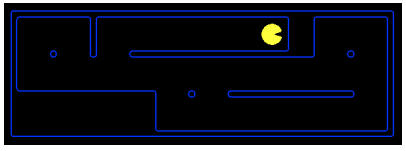
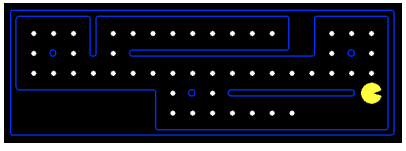
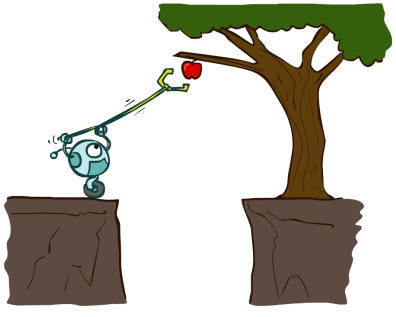
Planning Agents







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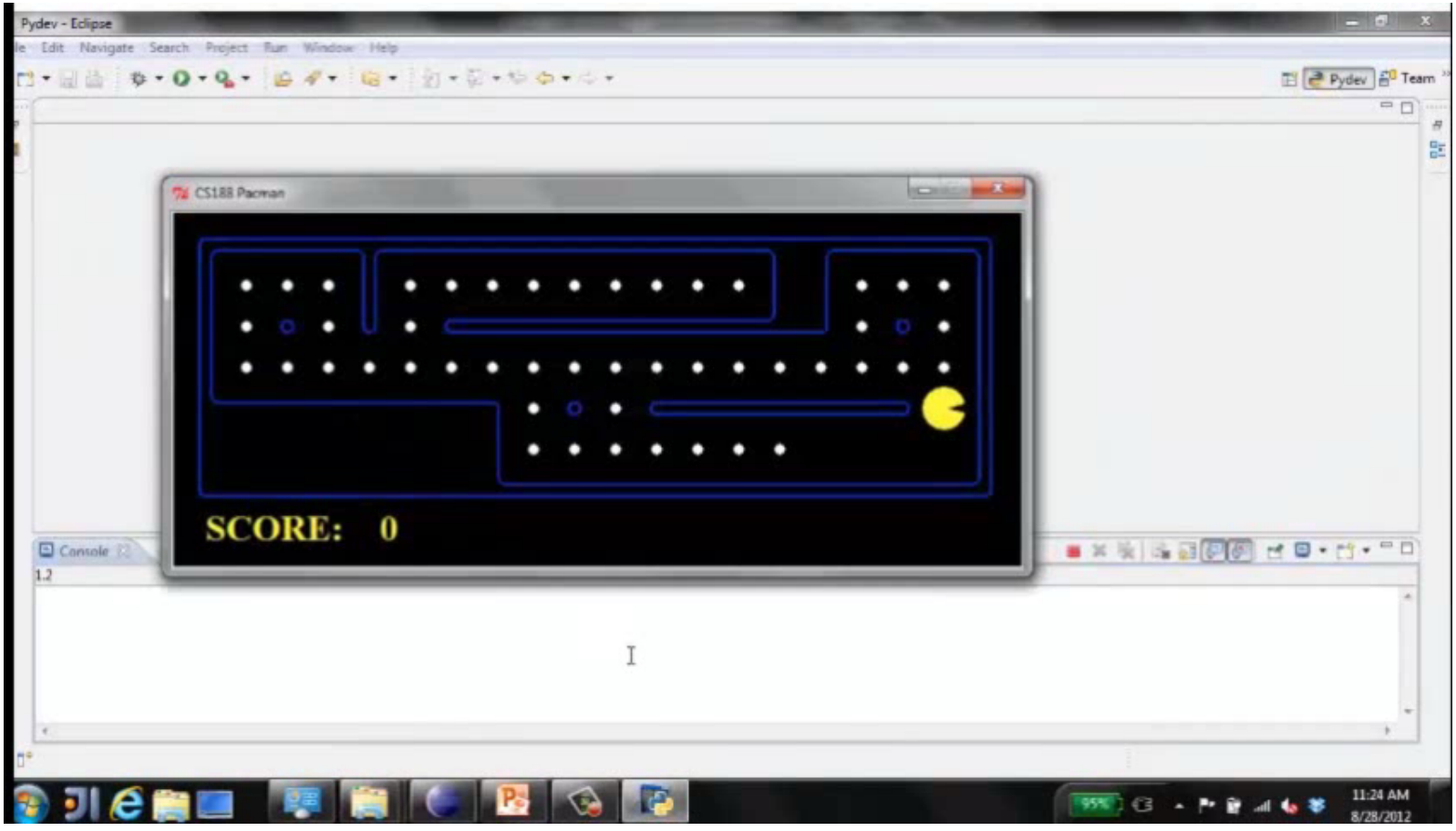
Planning vs. replanning

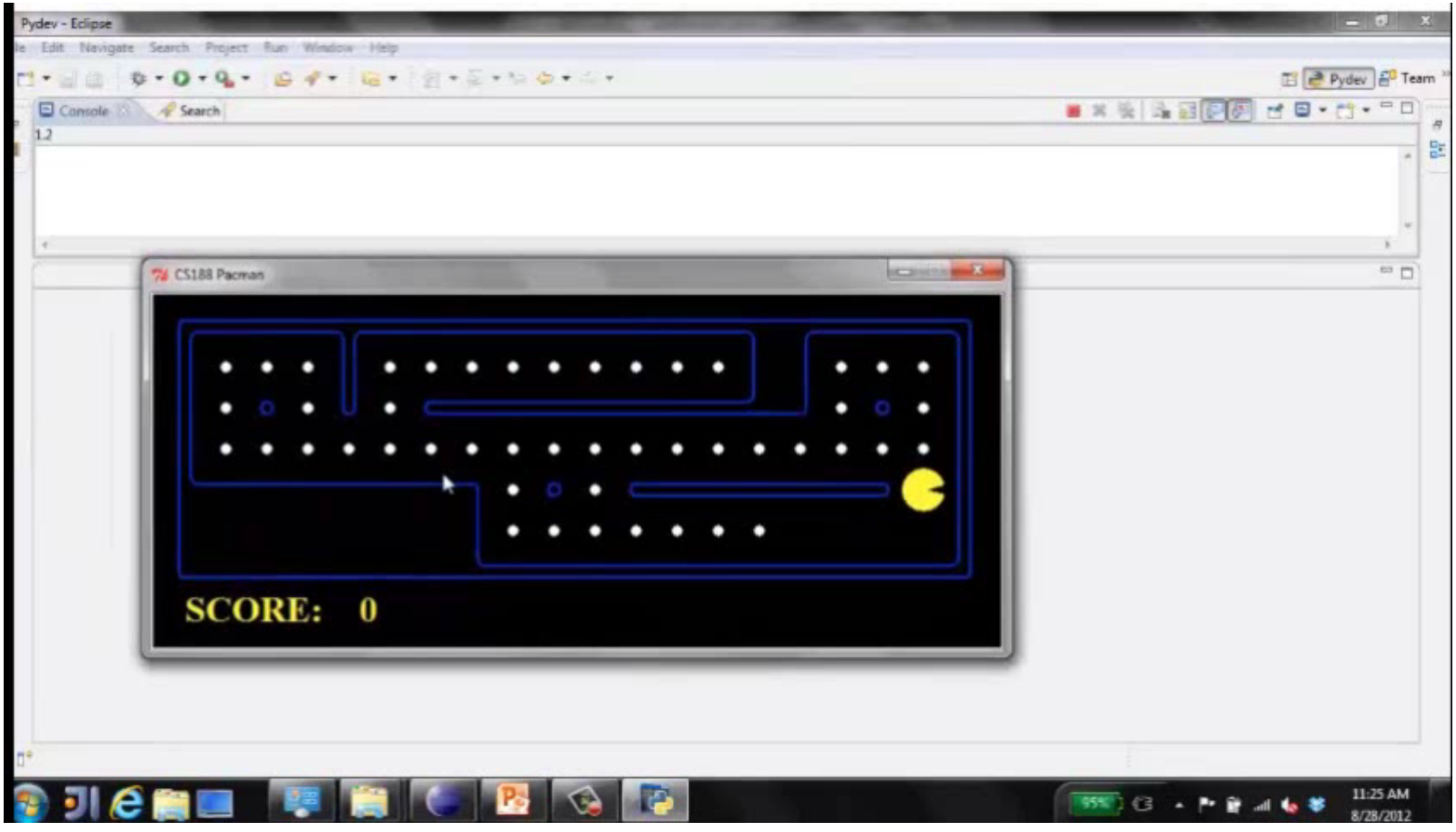
[Demo: nearest dot re-planning (L2D3), mastermind (L2D4)]

Video of Demo

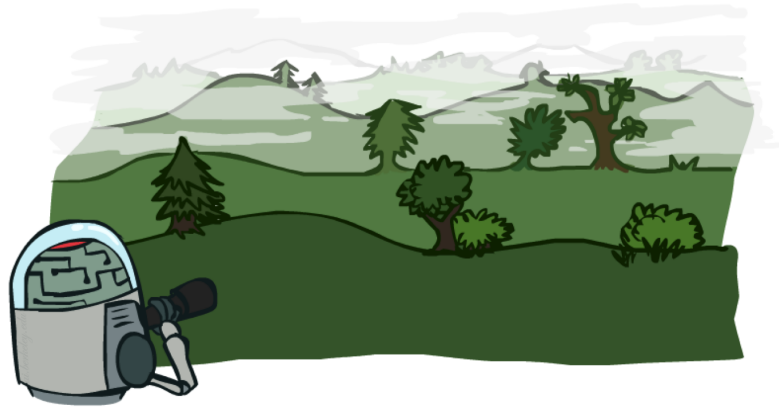
Replanning



Video of Demo Mastermind



Search Problems



Search Problems

A search problem consists of:

Search Problems

A search problem consists of:

A state space

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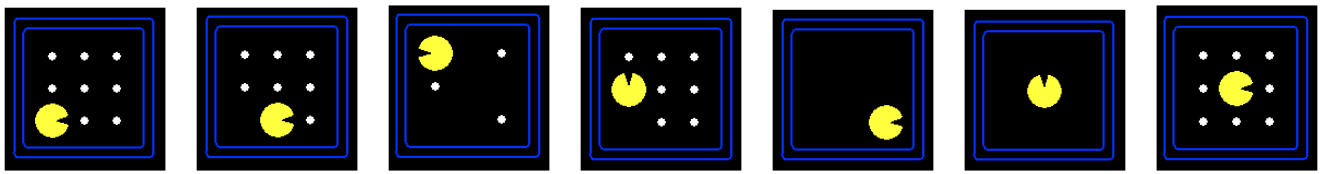

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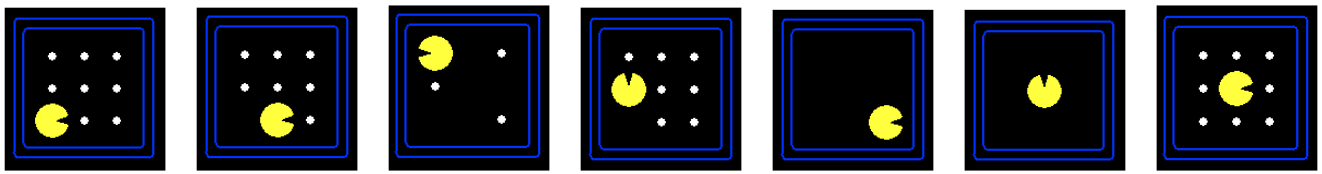

A successor function
(with actions, costs)

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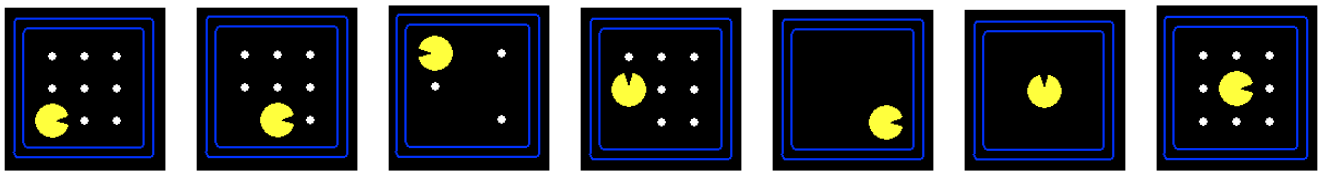

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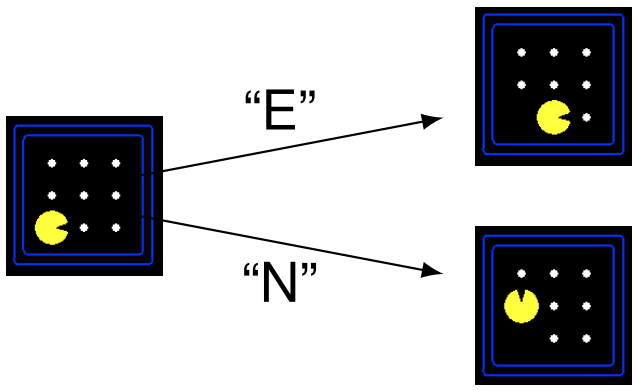

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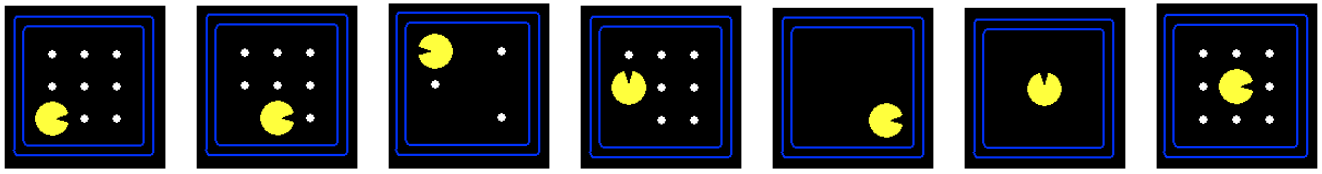

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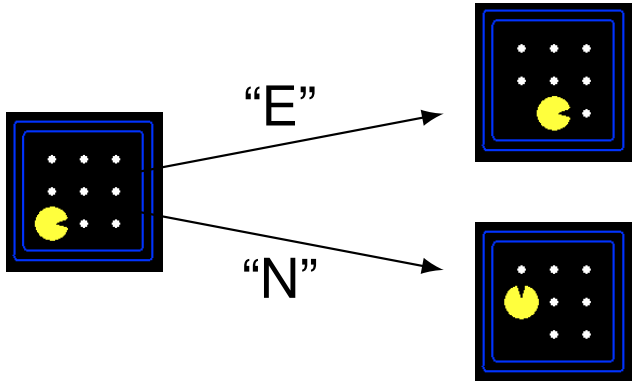

A start state and a goal test

Search Problems

A search problem consists of:

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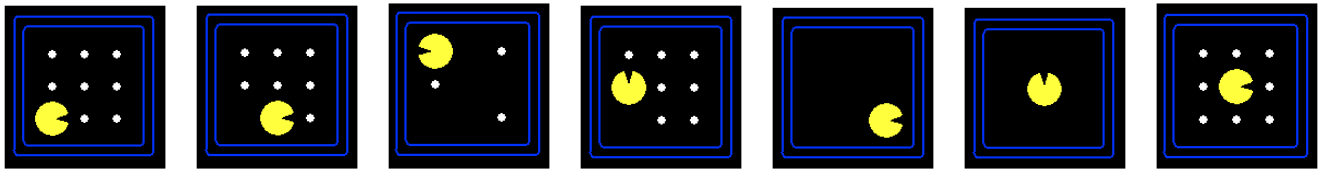

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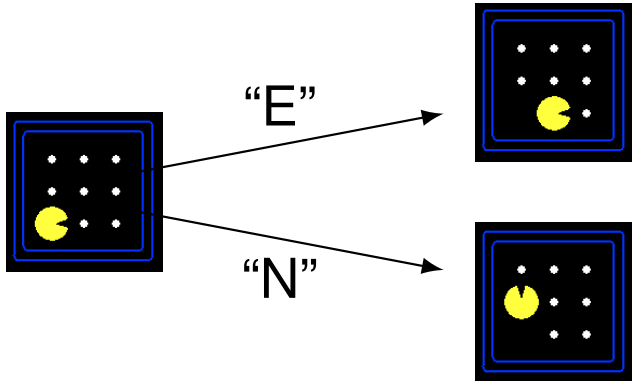
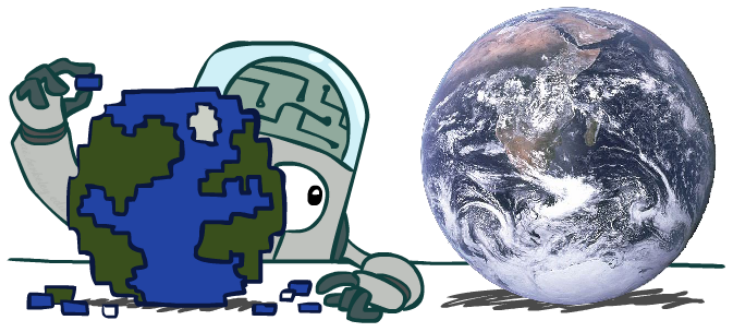


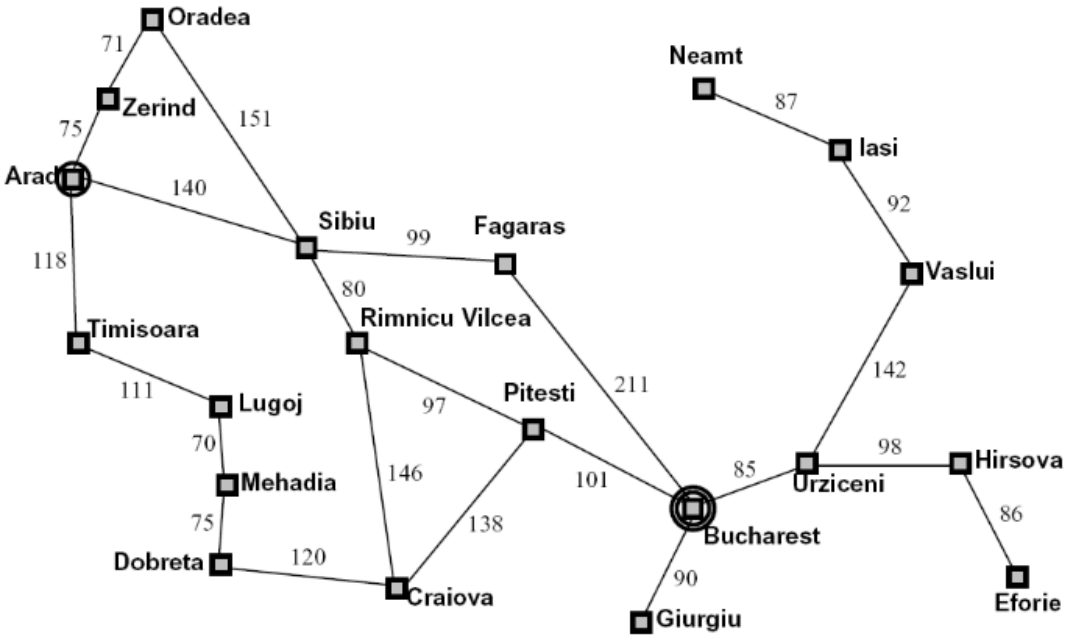
A start state and a goal test

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

Search Problems Are Models

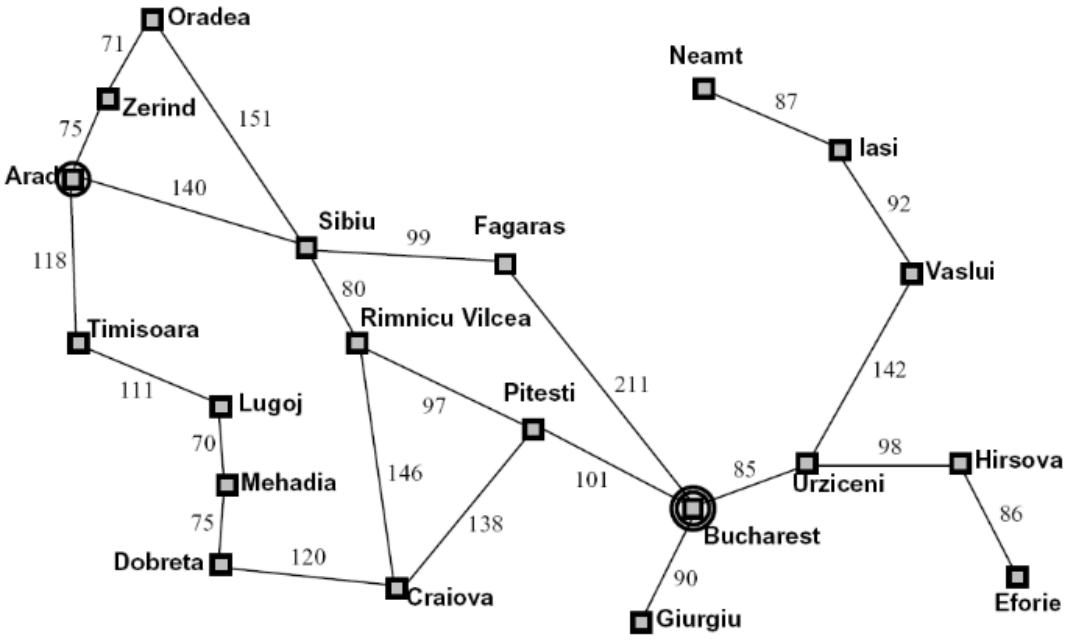


Example: Traveling in Romania



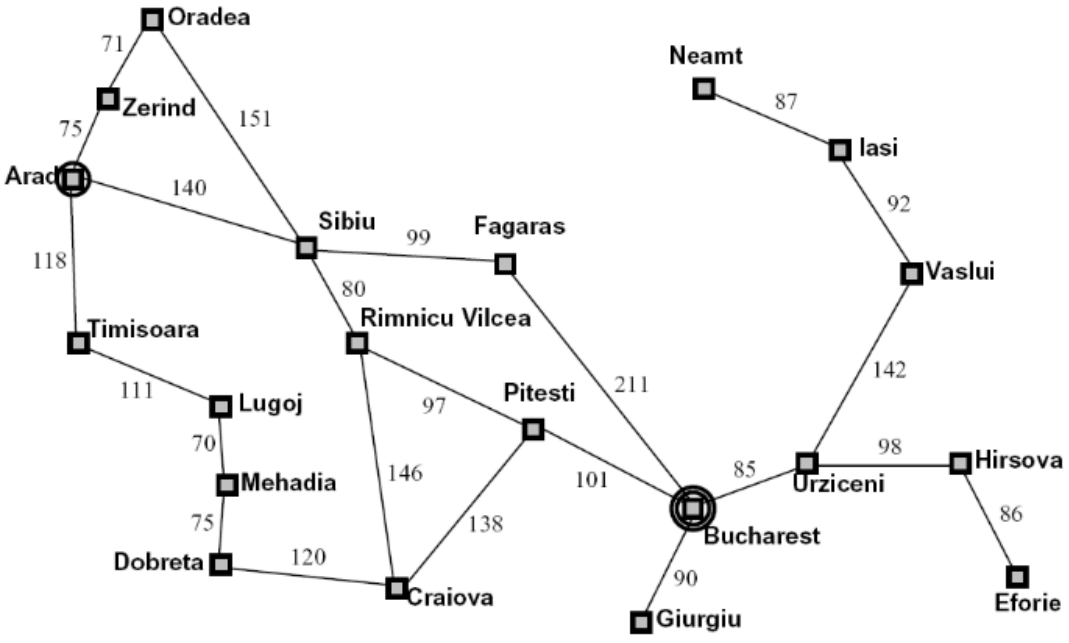
State space:

Example: Traveling in Romania



State space:
Cities

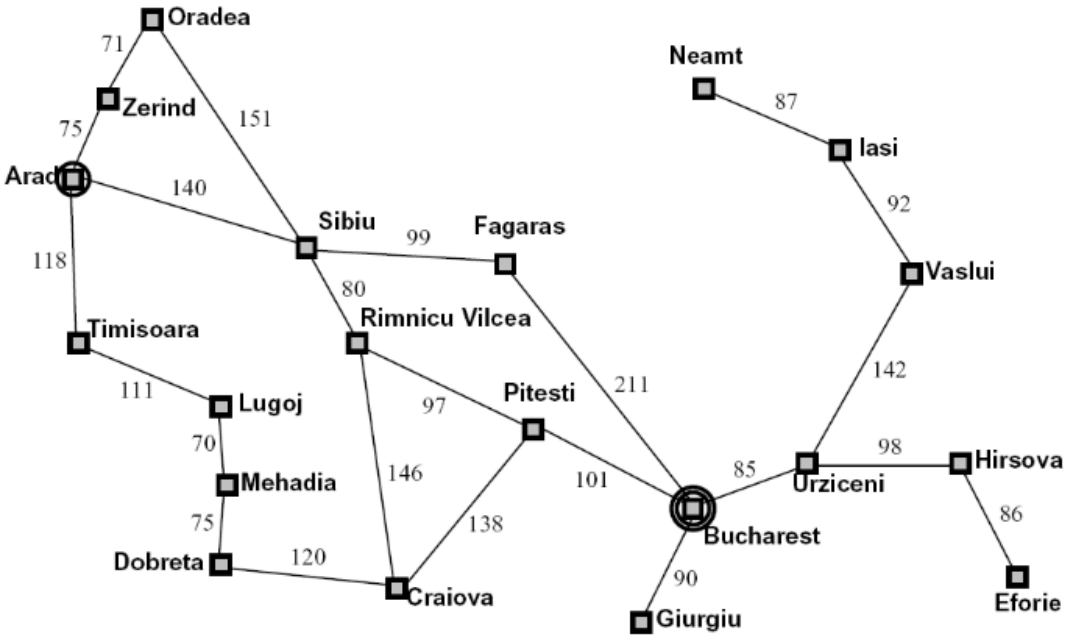
Example: Traveling in Romania



State space:
Cities

Successor function:

Example: Traveling in Romania



State space:
Cities

Successor function:
Roads: Neighboring city with cost = distance

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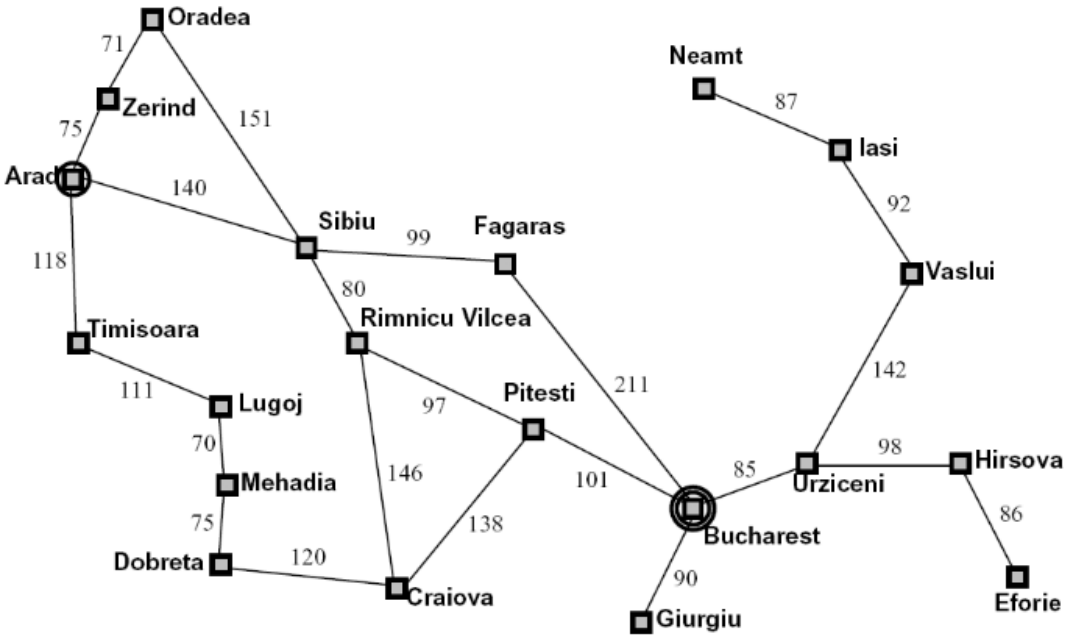

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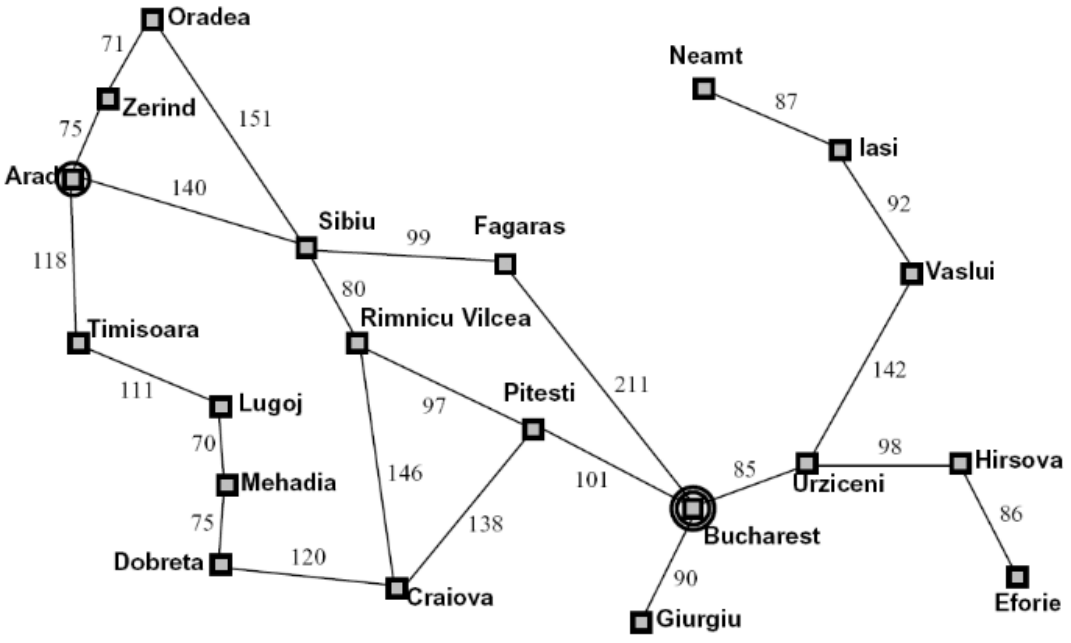

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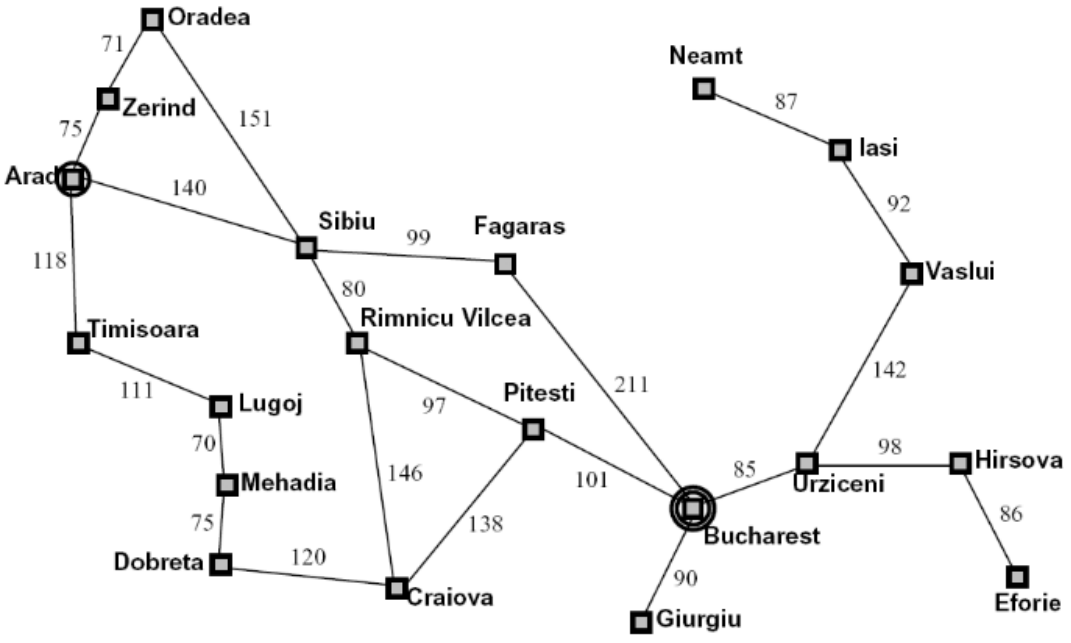
Start state:
Arad

Example: Traveling in Romania



State space:
Cities

Successor function:
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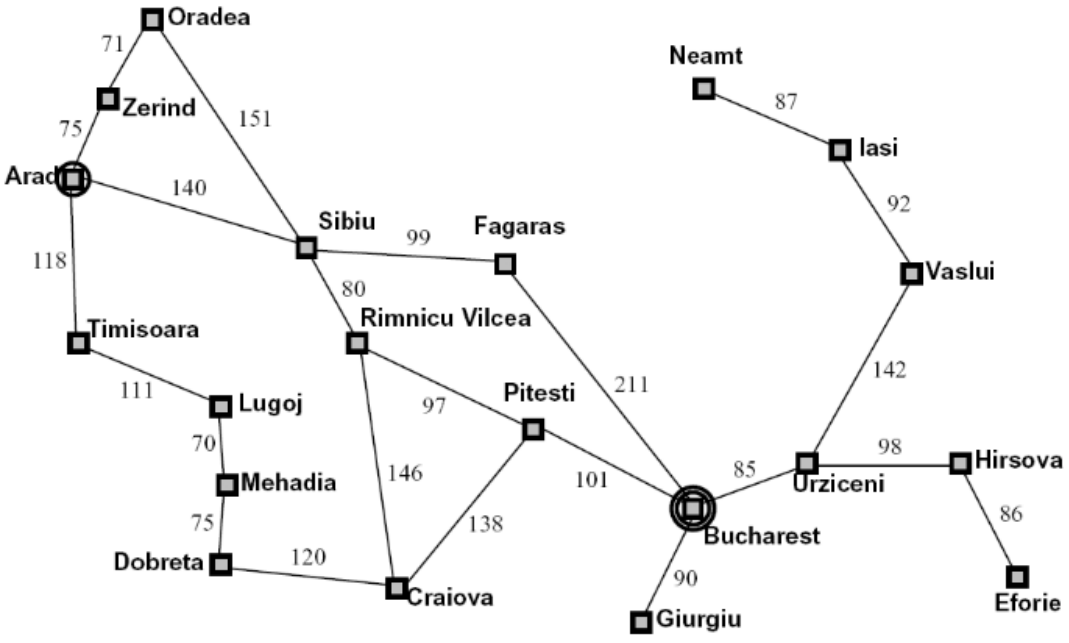
Start state:
Arad

Goal test:

Example: Traveling in Romania



State space:
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Start state:
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Goal test:
Is state == Bucharest?

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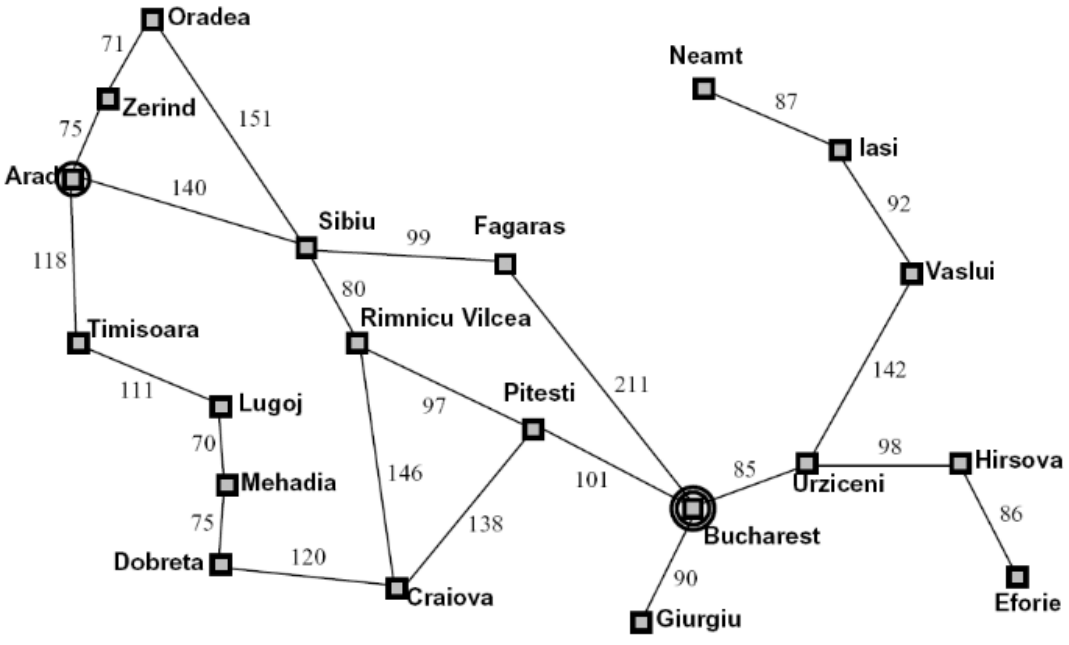

State space:
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Successor function:
Roads: Neighboring city with cost = distance

Start state:
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Goal test:
Is state == Bucharest?

Solution?

What's in a State Space?

The world state includes every last detail of the environment.

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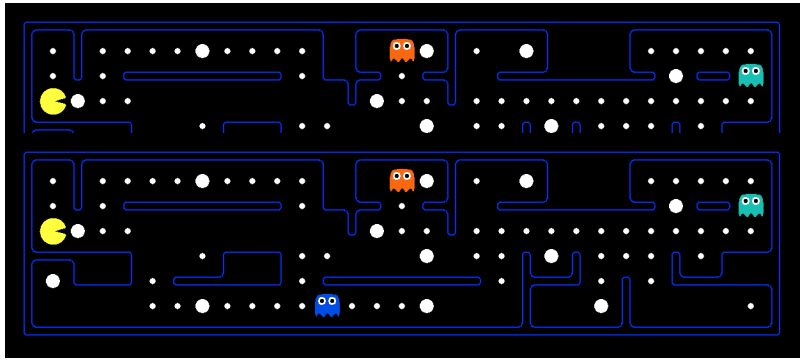

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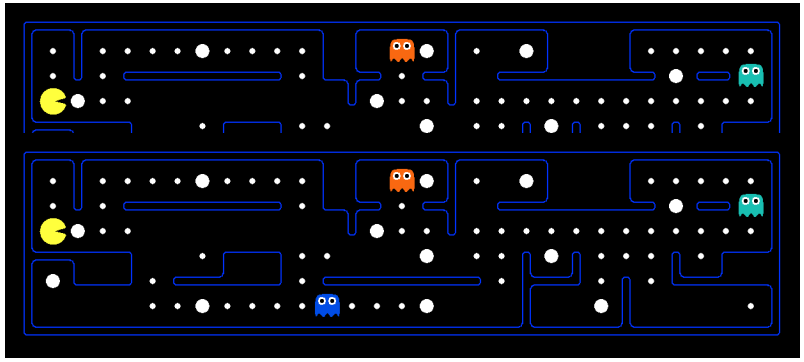

Search state keeps only details needed for planning (abstraction).

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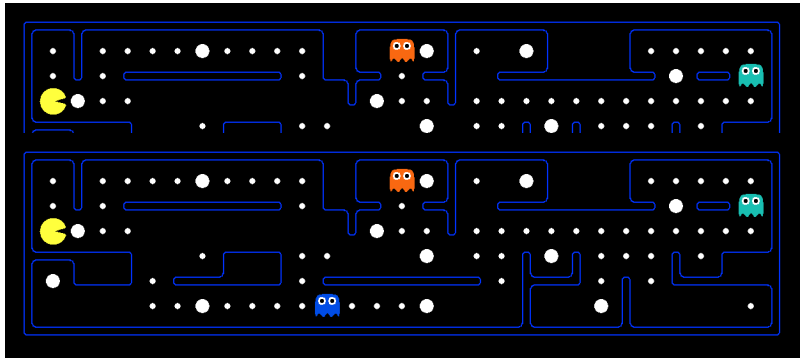

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Problem: Pathing

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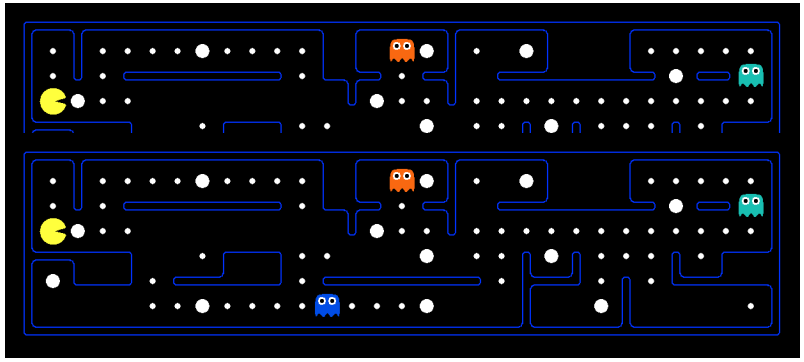

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States:

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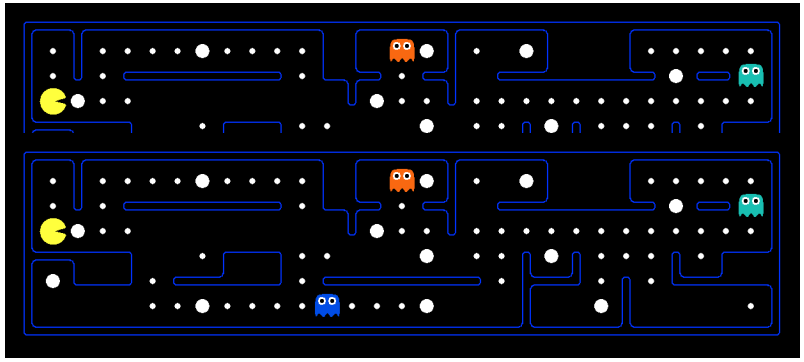

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Problem: Pathing

States: (x, y) location

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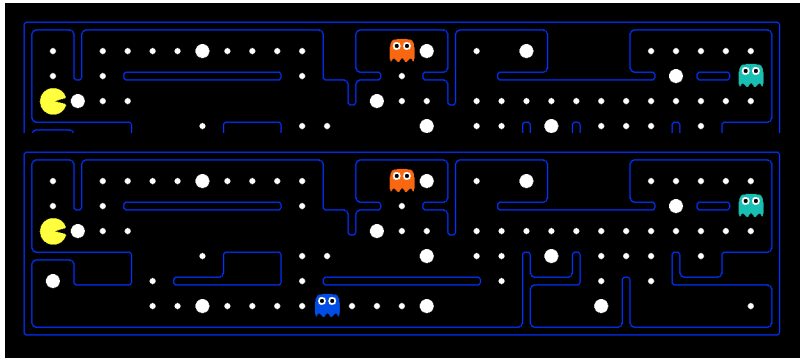

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Problem: Pathing

States: (x, y) location
Actions:

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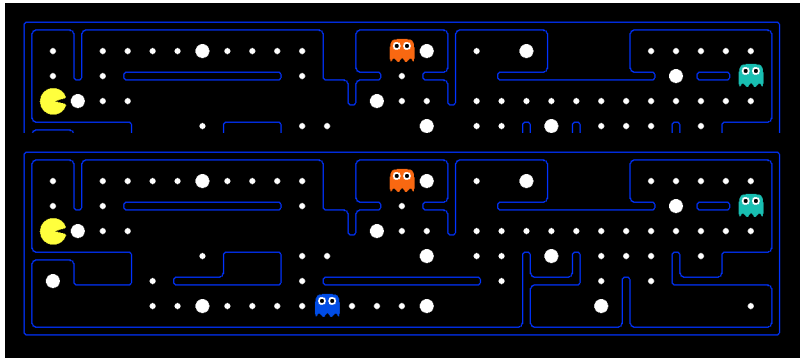

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Problem: Pathing

States: (x, y) location
Actions: NSEW

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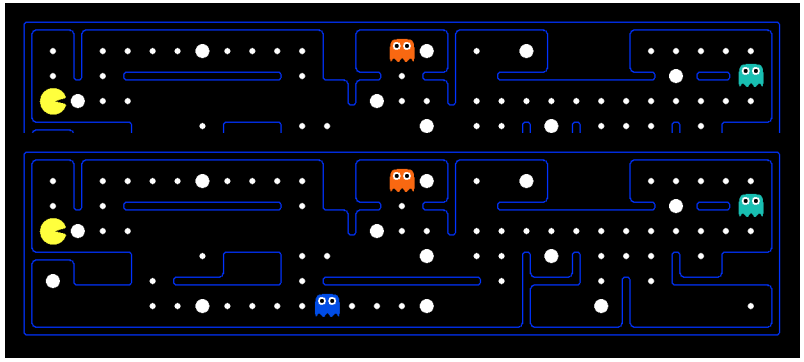

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Problem: Pathing

States: (x, y) location
Actions: NSEW
Successor:

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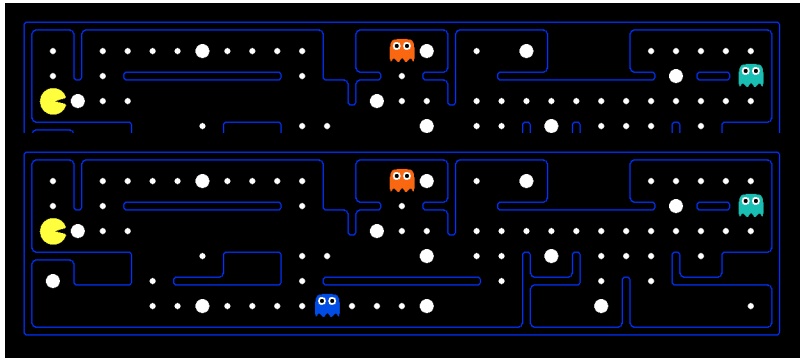

Search state keeps only details needed for planning (abstraction).

Problem: Pathing

States: (x, y) location
Actions: NSEW
Successor: update location only

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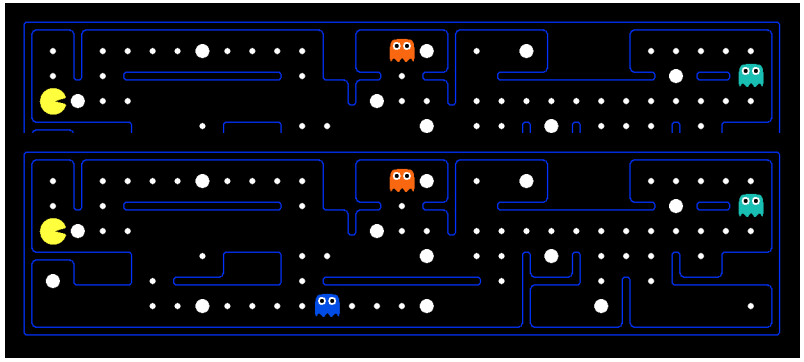

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Goal test:

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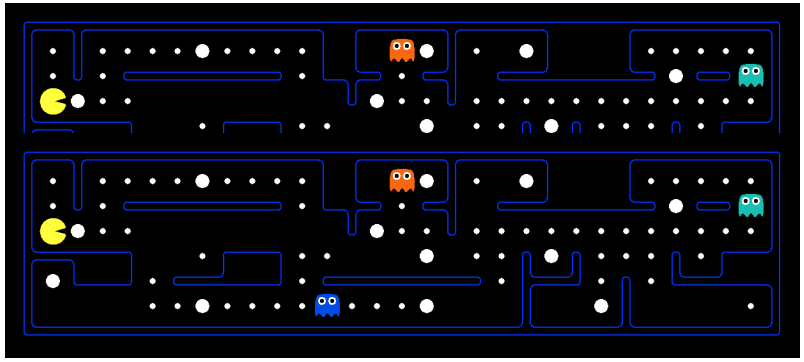

Search state keeps only details needed for planning (abstraction).

Problem: Pathing

States: (x, y) location
Actions: NSEW
Successor: update location only
Goal test: is $(x, y) =$END?

What's in a State Space?

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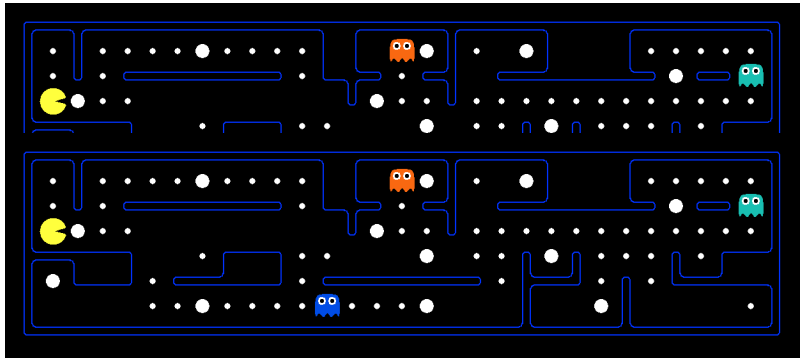

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Problem: Pathing

States: (x, y) location
Actions: NSEW
Successor: update location only
Goal test: is $(x, y) =$END?

Problem: Eat-All-Dots

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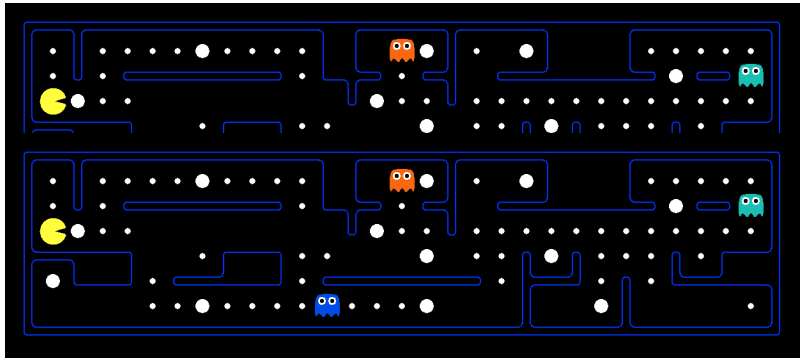

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Problem: Eat-All-Dots

States:

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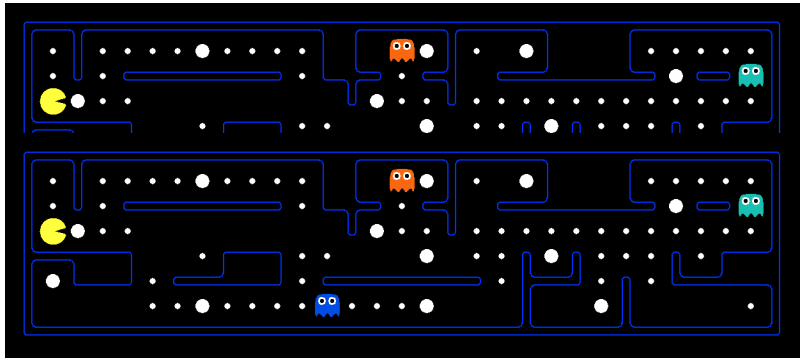

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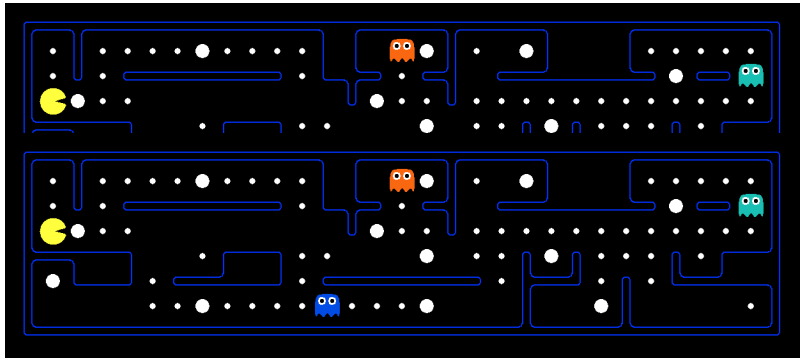

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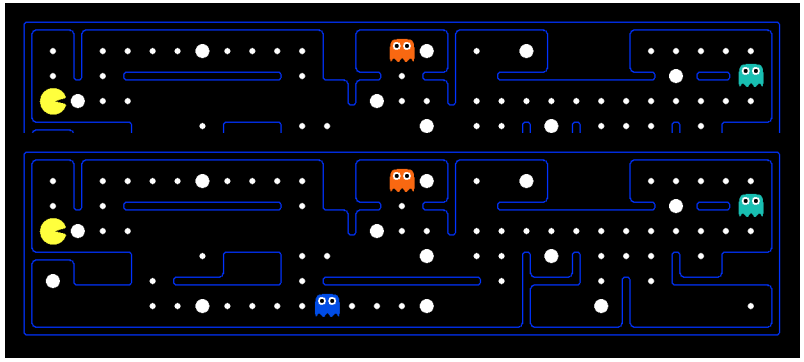

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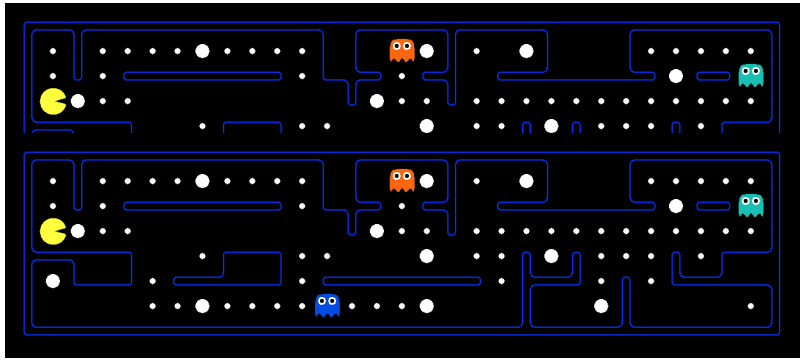

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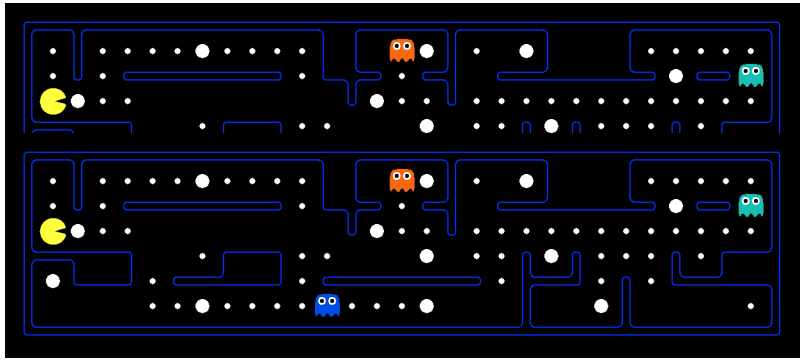

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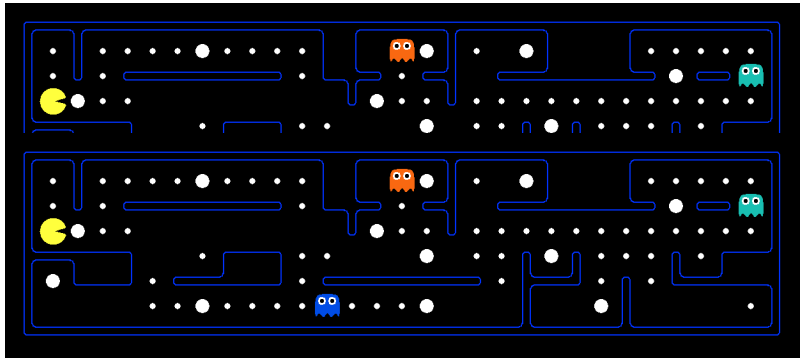

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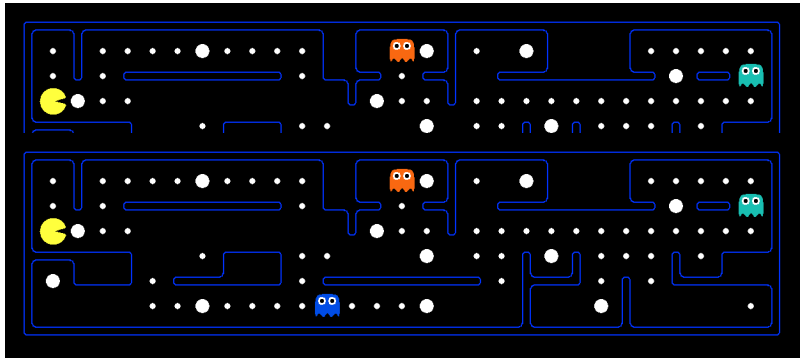

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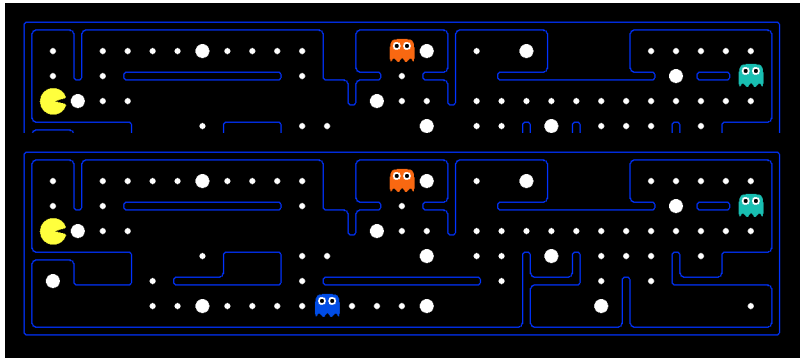

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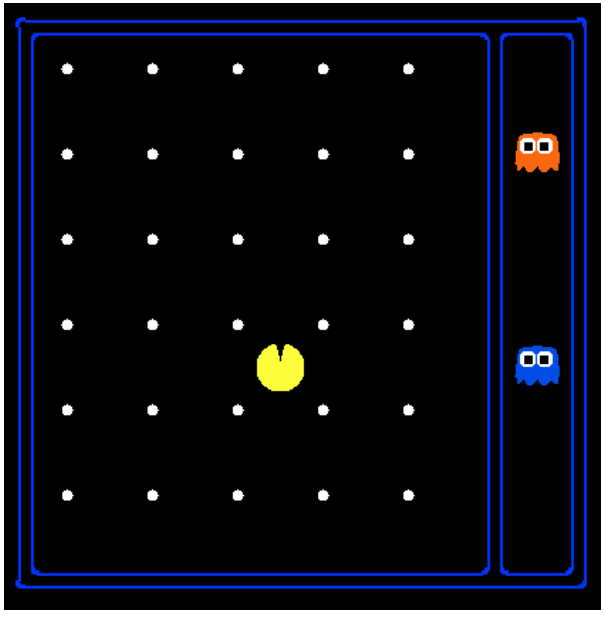

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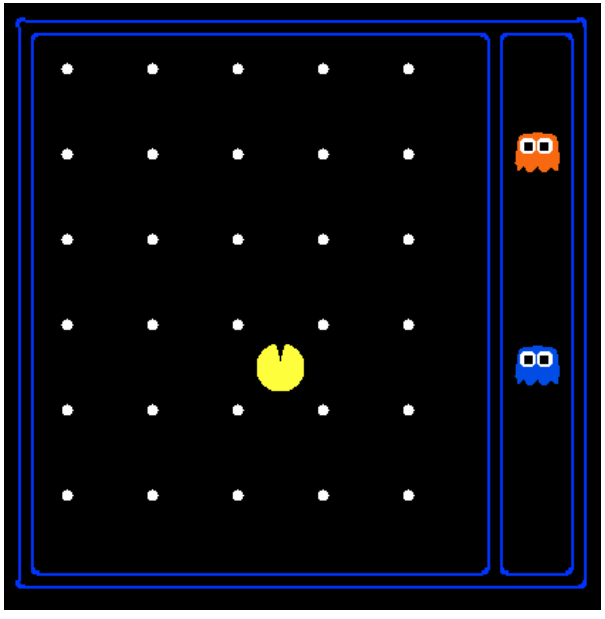

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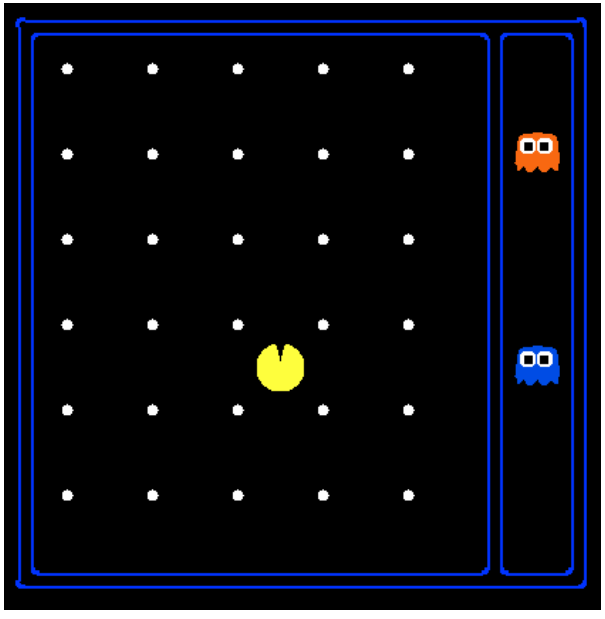

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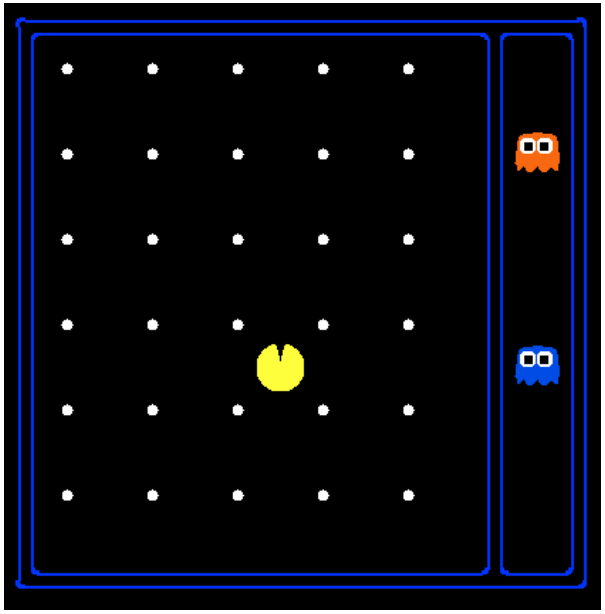

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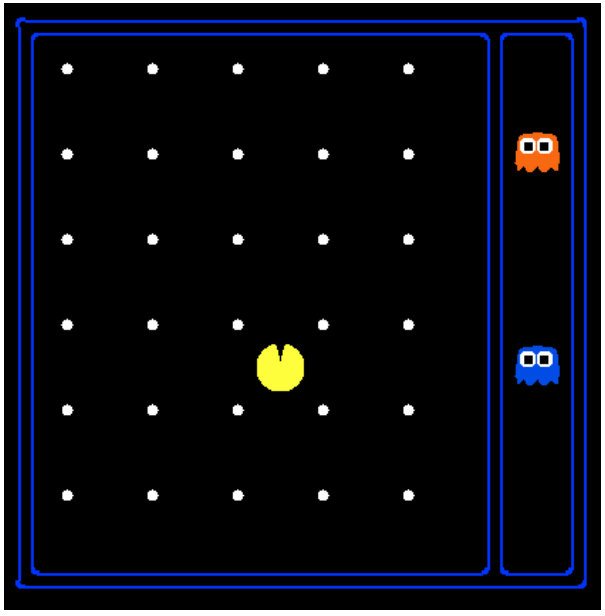

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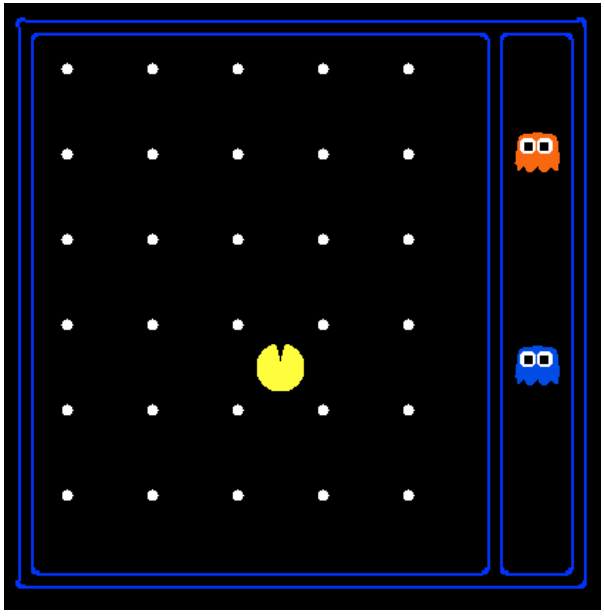

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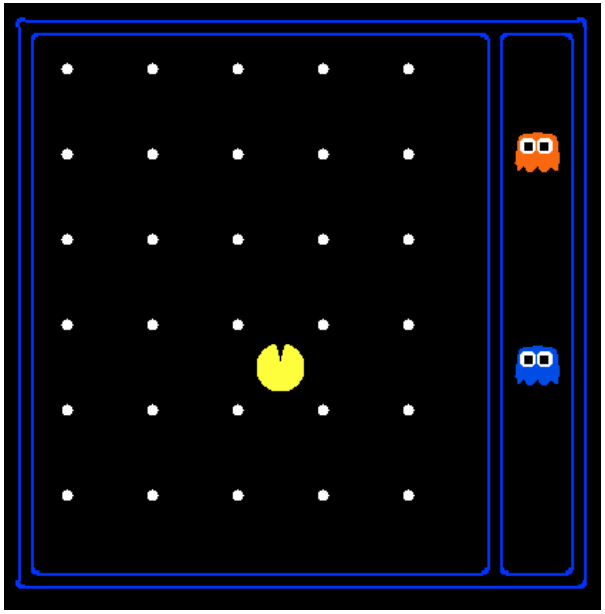

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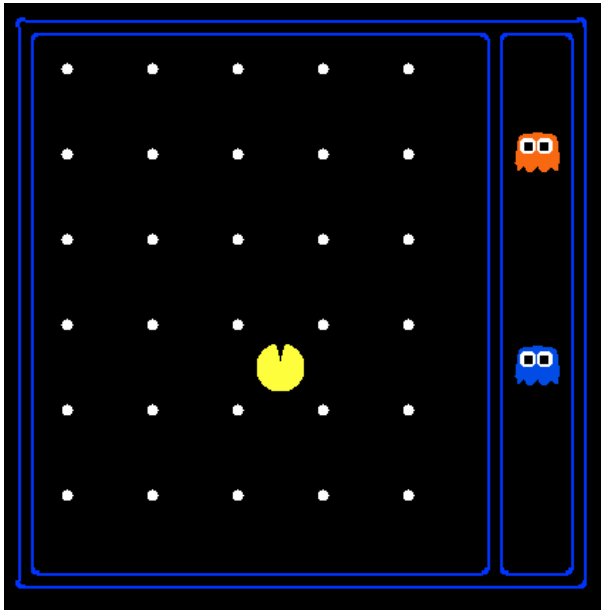

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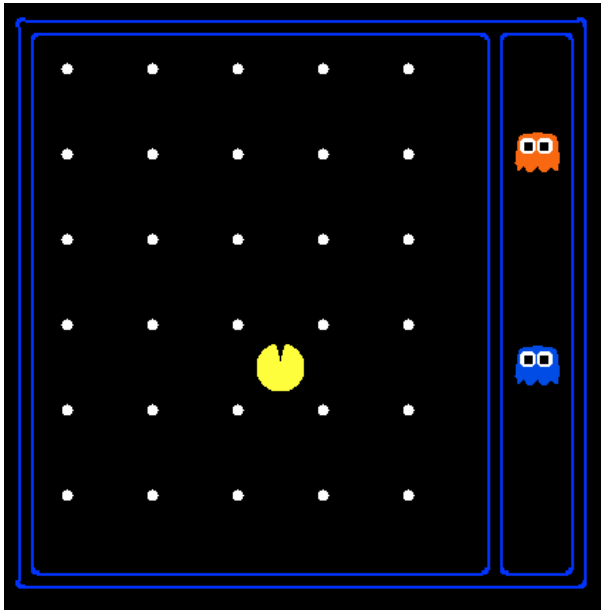

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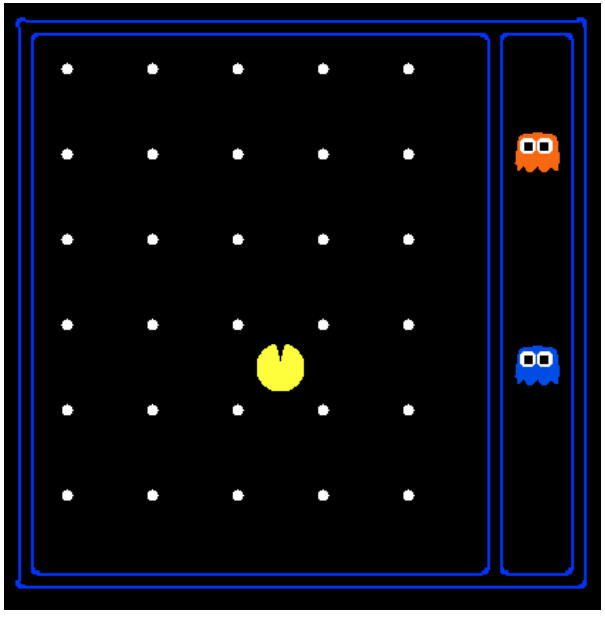

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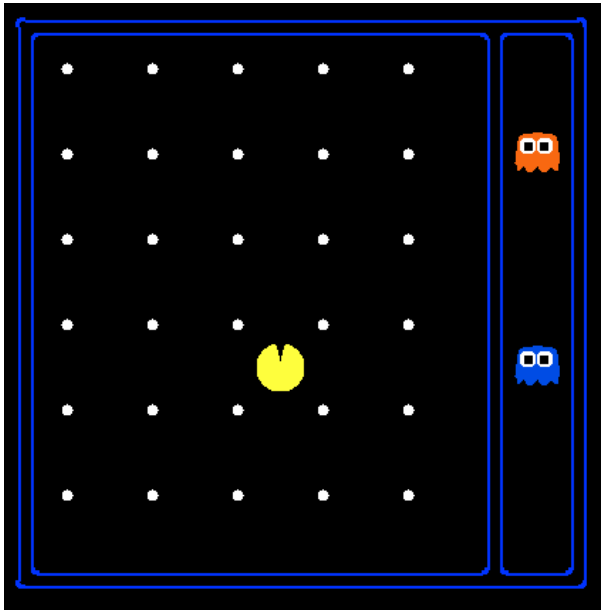

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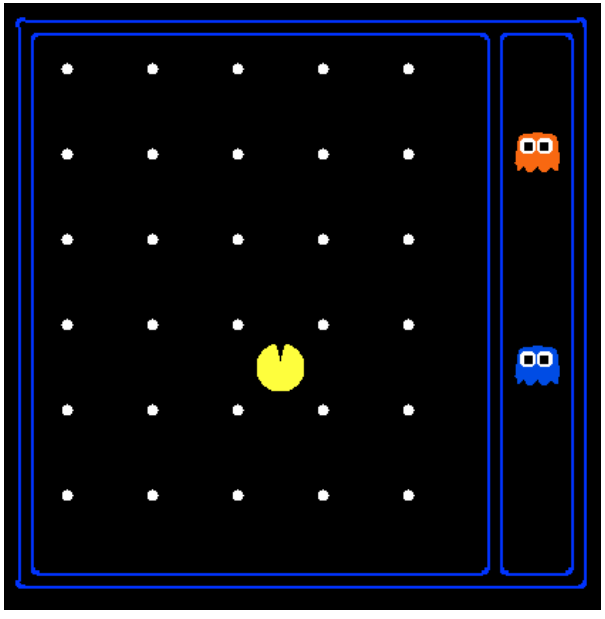

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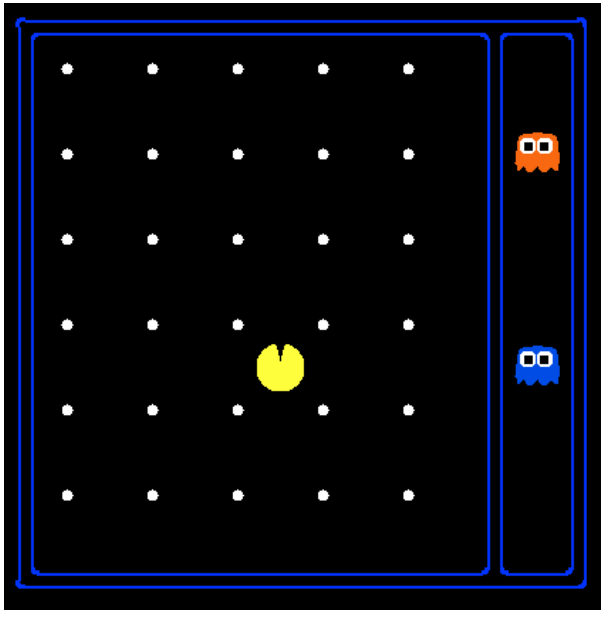

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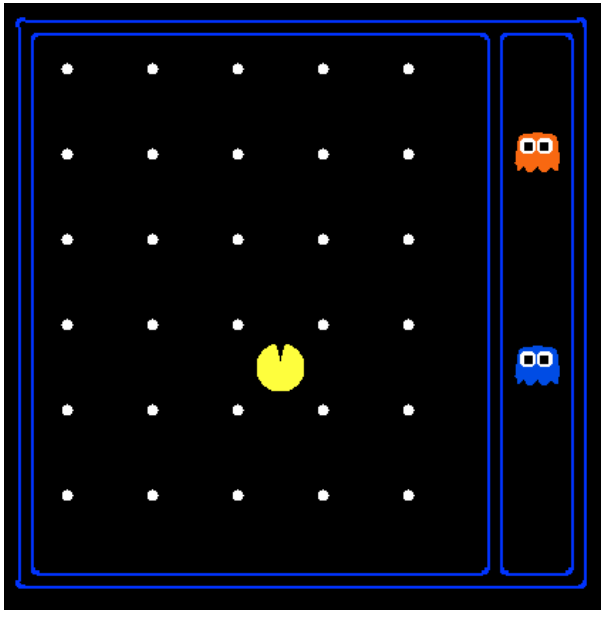

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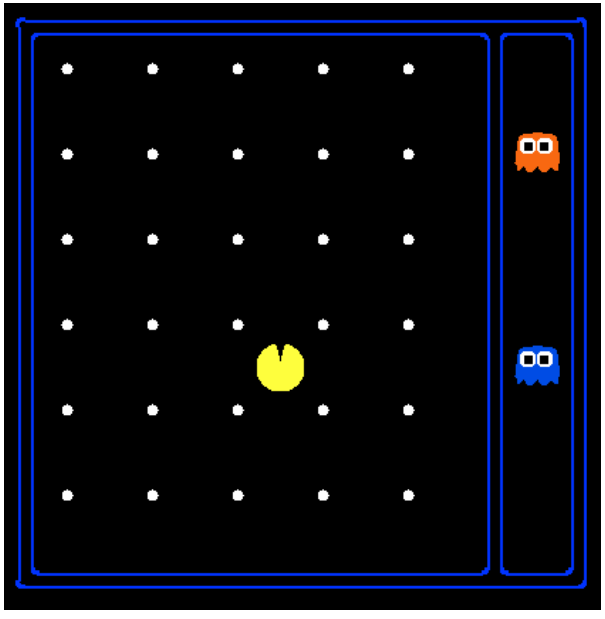

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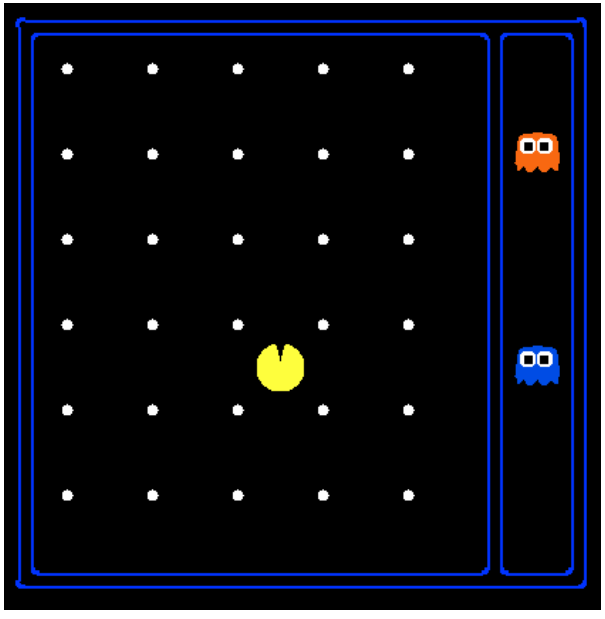

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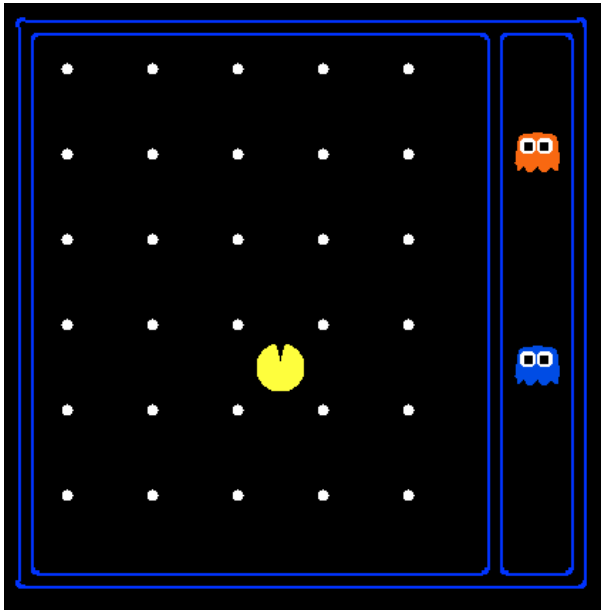

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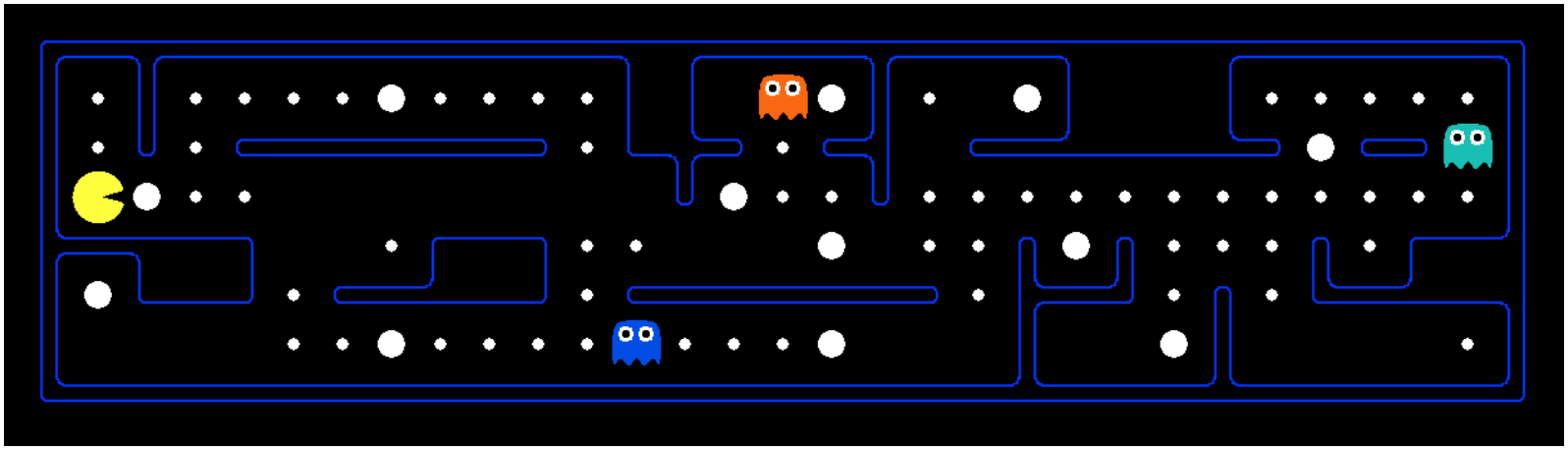

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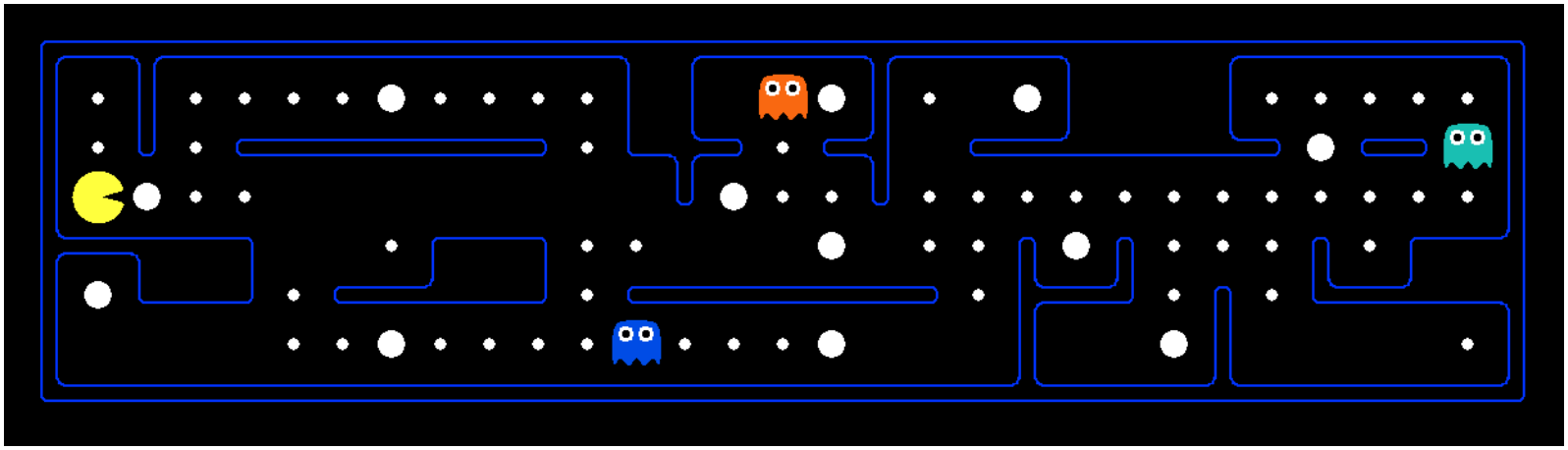

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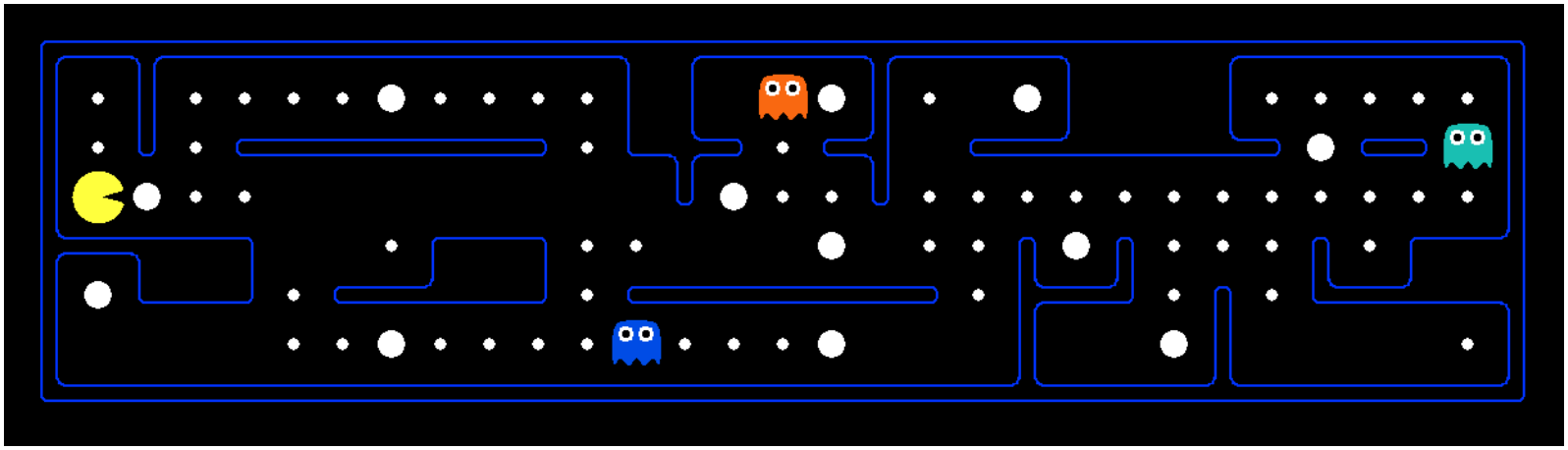

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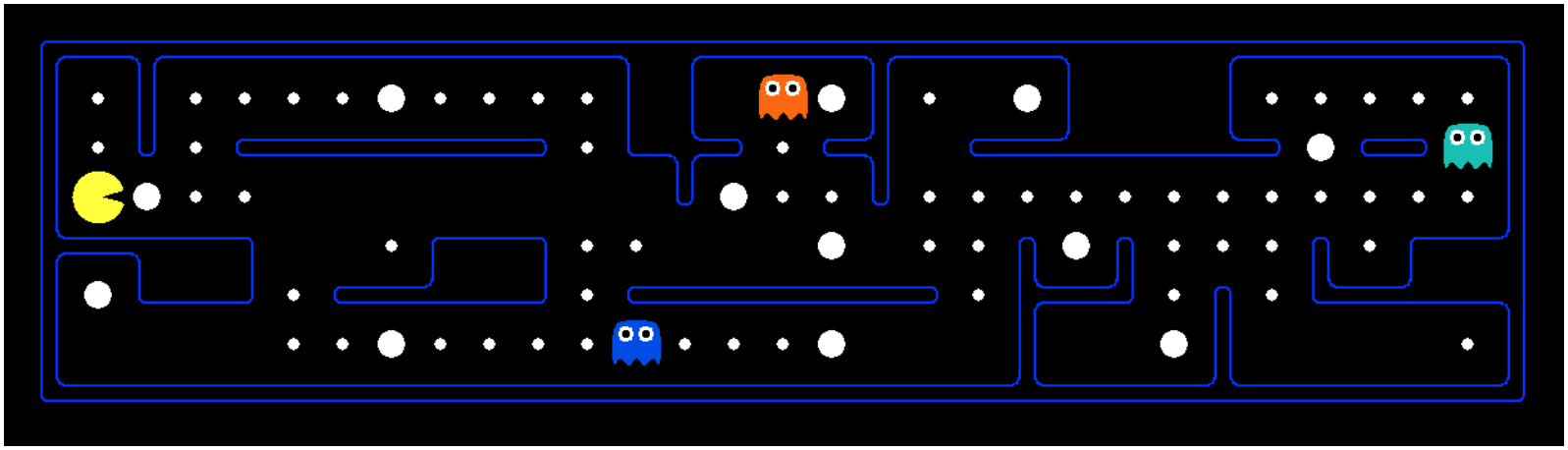

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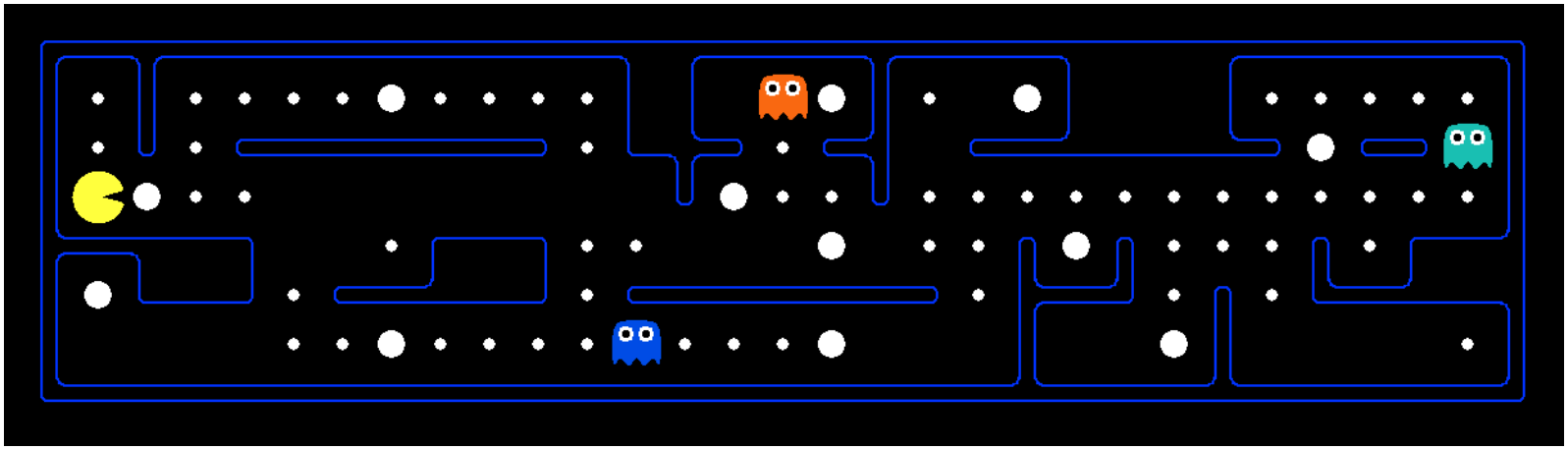

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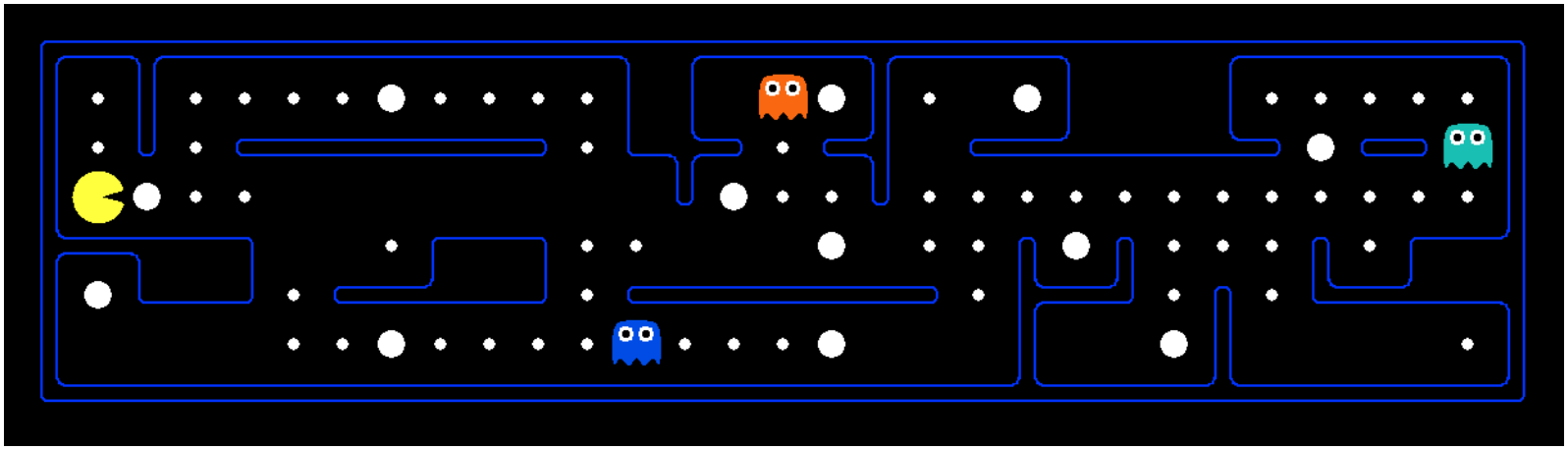

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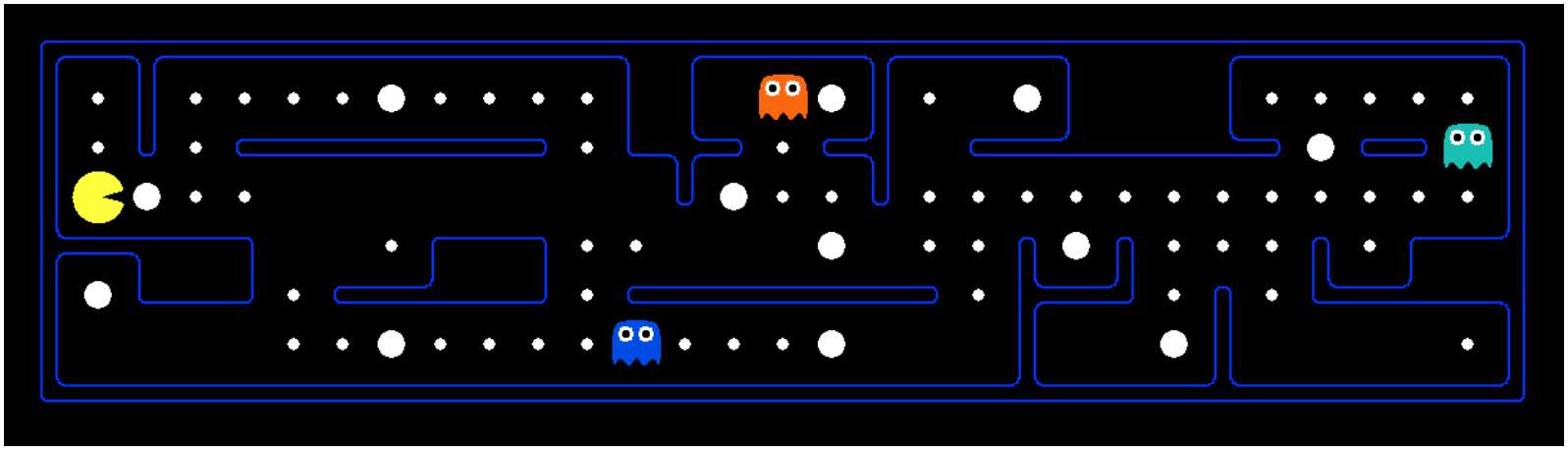

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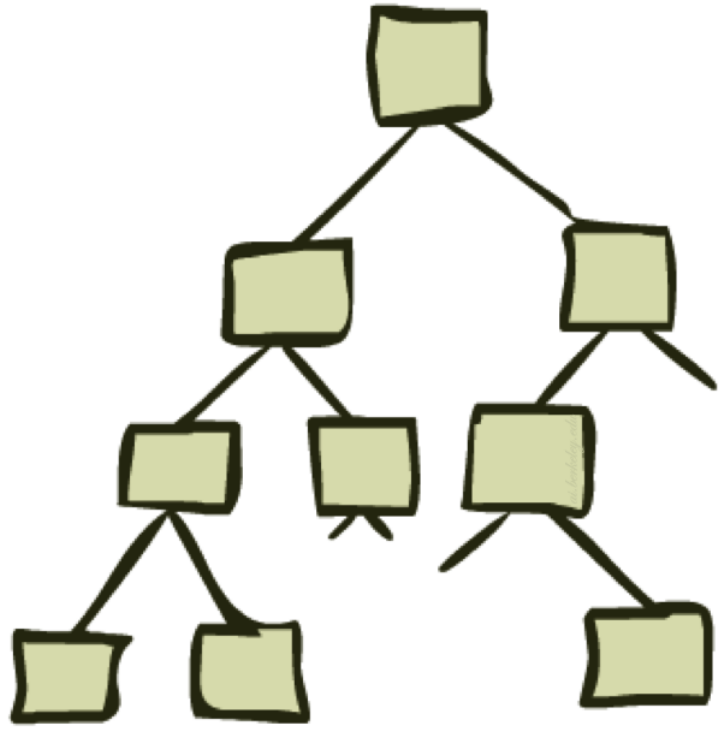
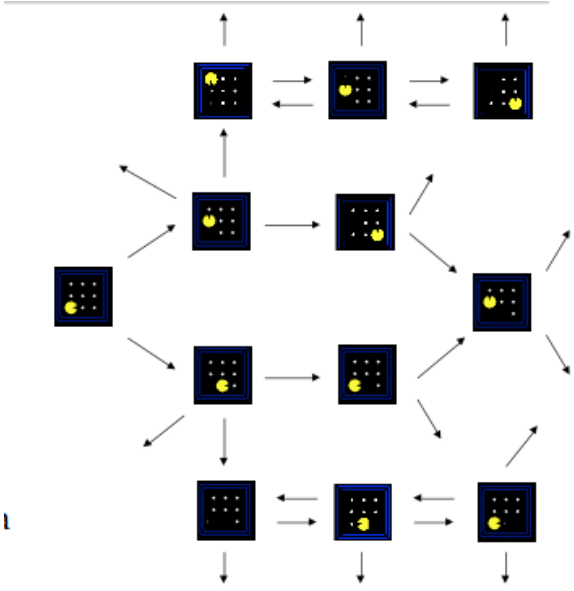
- Single-agent/multi-agent $\rightarrow$ agent may need to behave randomly.

State Space Graphs and Search Trees



State Space Graphs

State space graph: A mathematical representation of a search problem



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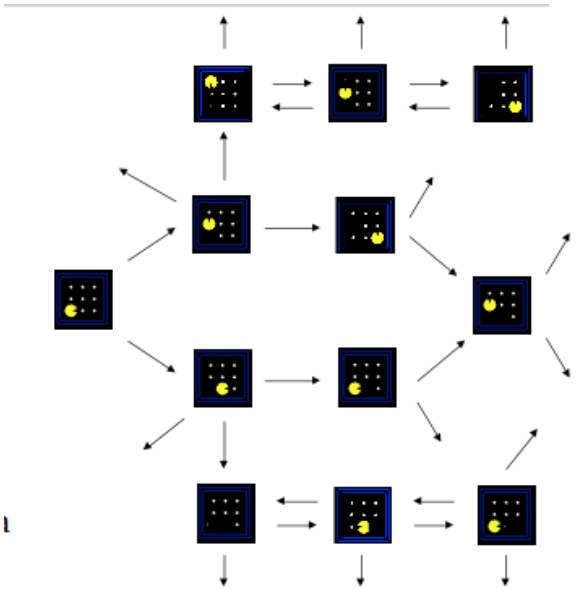

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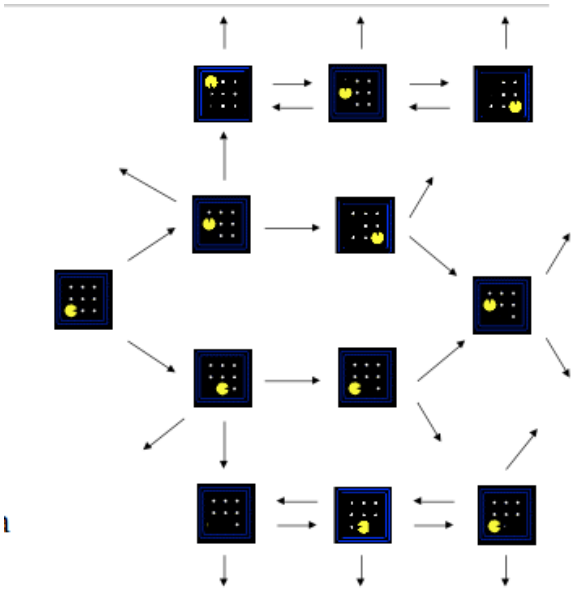

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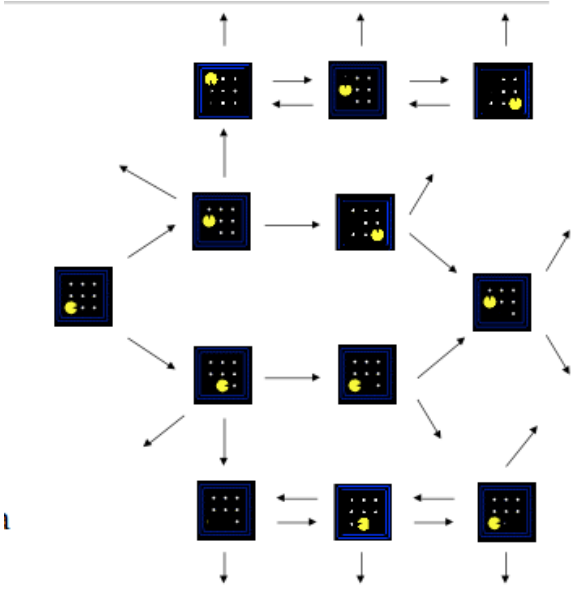

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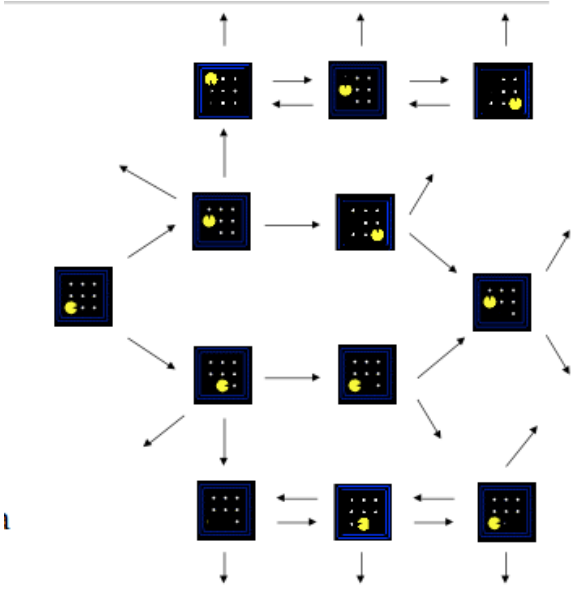

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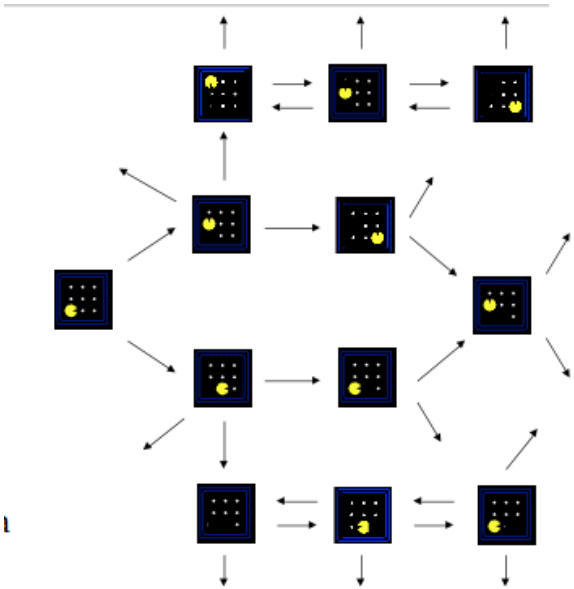

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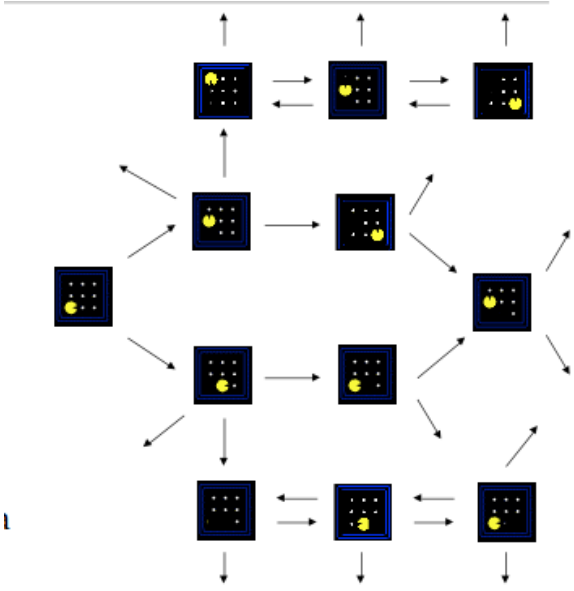

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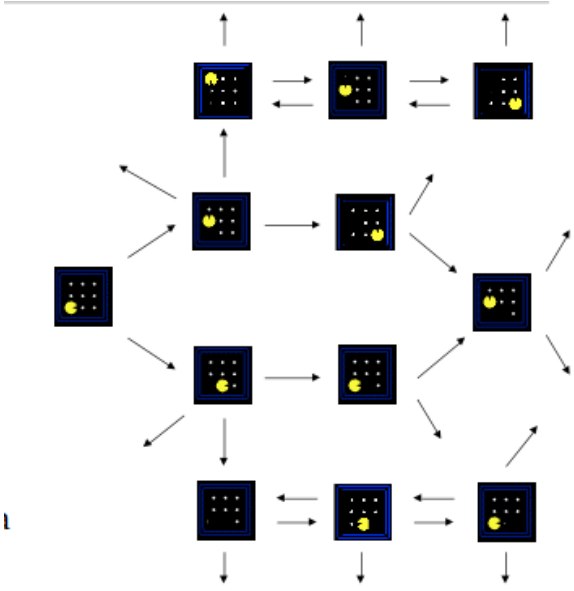

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E.g., replanning.

State Space Graphs

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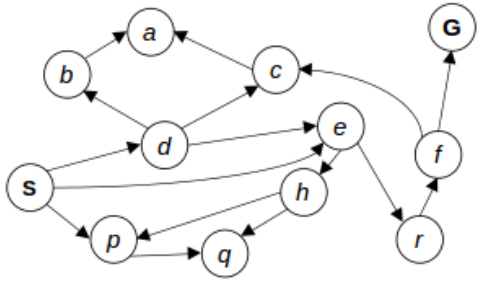

Tiny search graph for a tiny search problem

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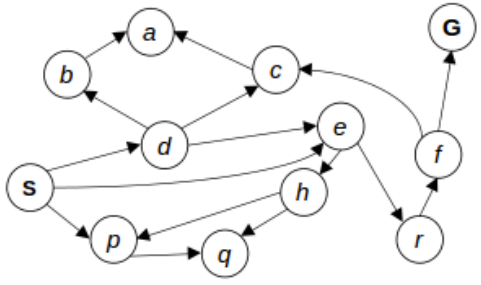

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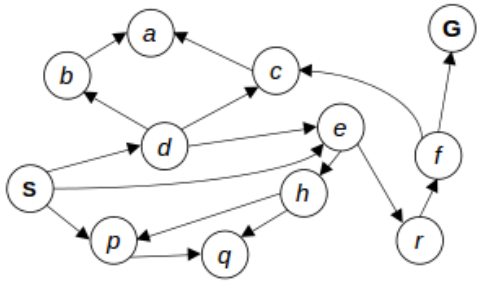

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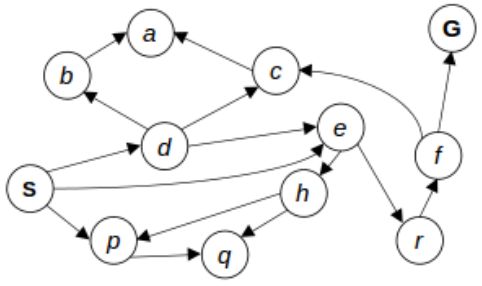

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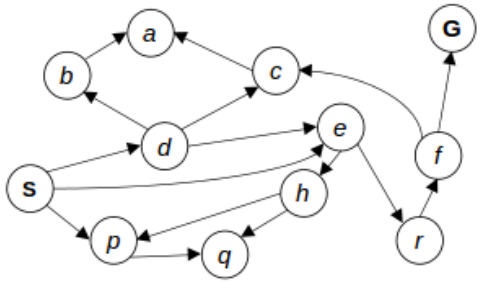

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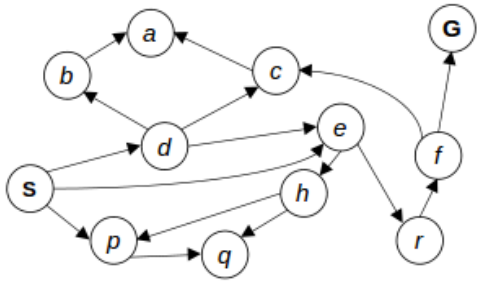

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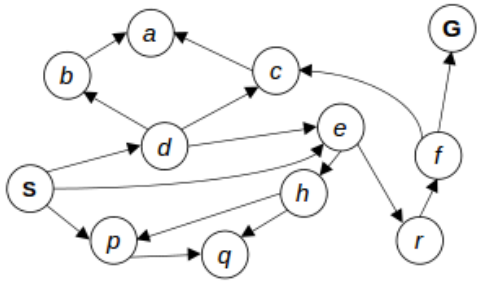

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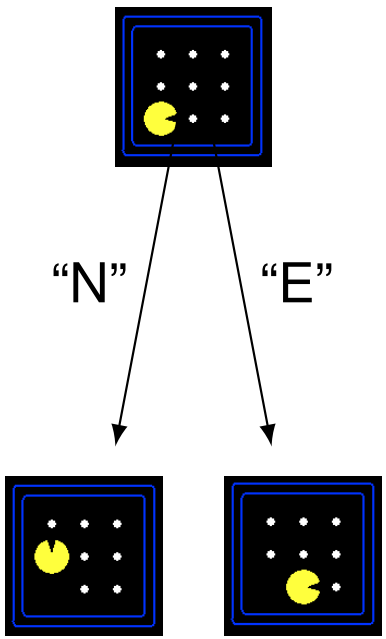
Search Trees

This is now / start



Possible futures.

A search tree:

Search Trees

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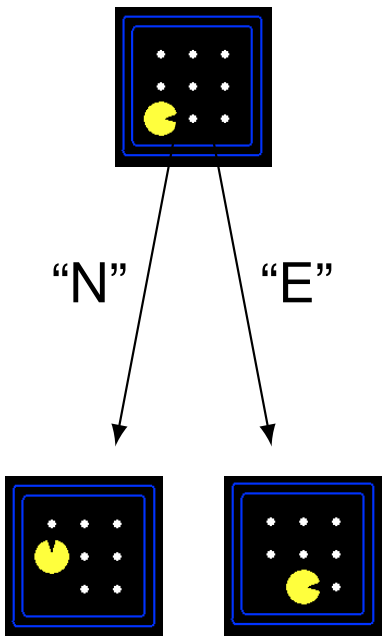

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A “what if” tree of plans and their outcomes

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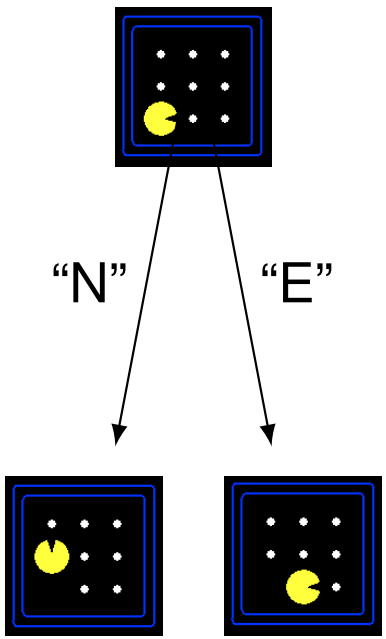

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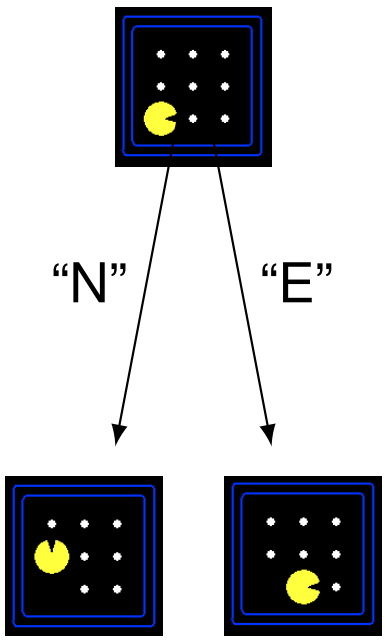

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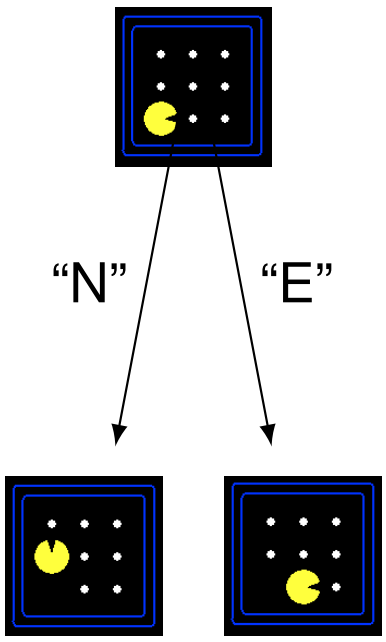

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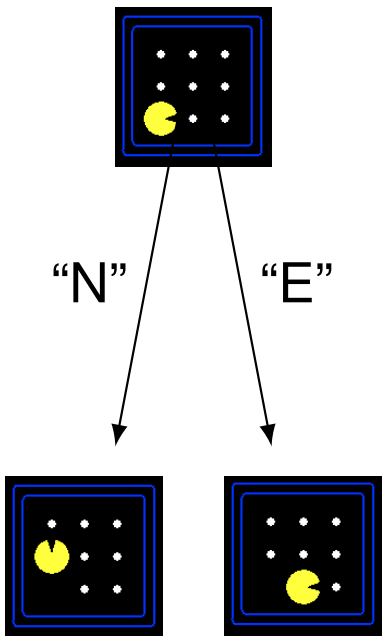

Possible futures.

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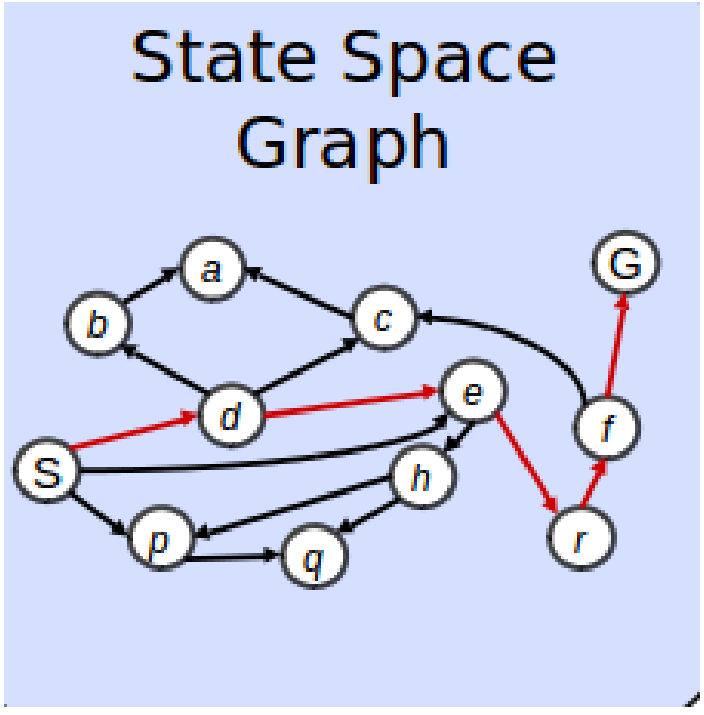
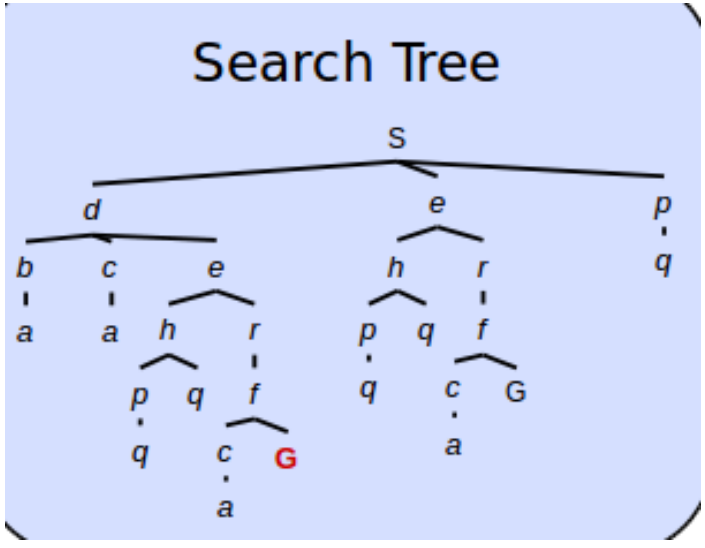
Nodes show states, but correspond to PLANS that achieve those states

For most problems, we can never actually build the whole tree

State Space Graphs vs. Search Trees





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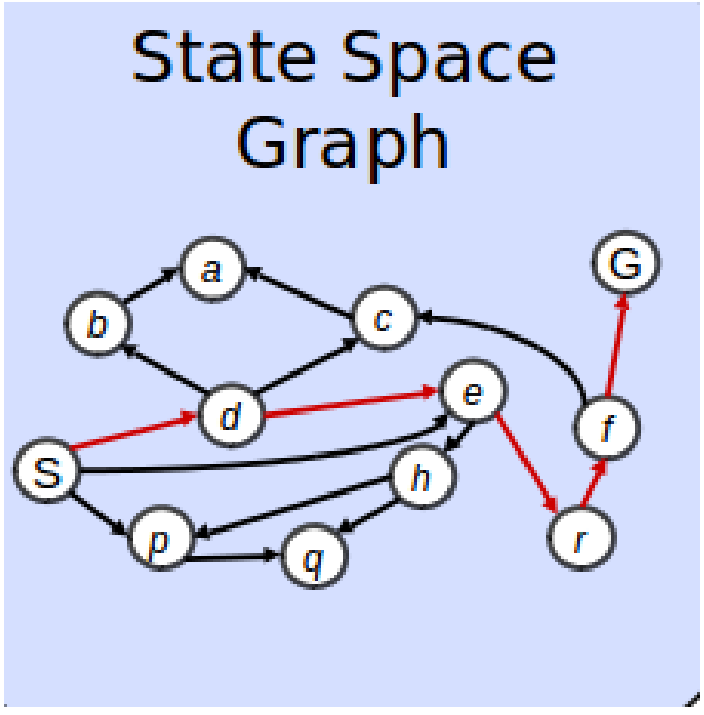

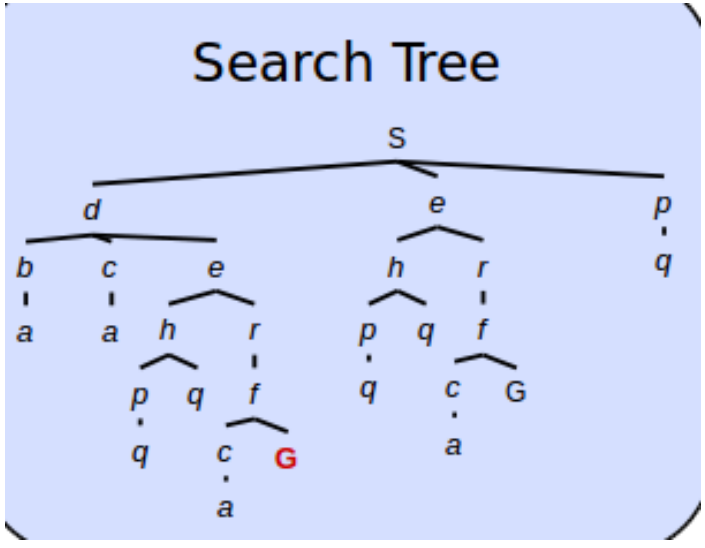

Each NODE in search tree is an entire PATH in state space graph.

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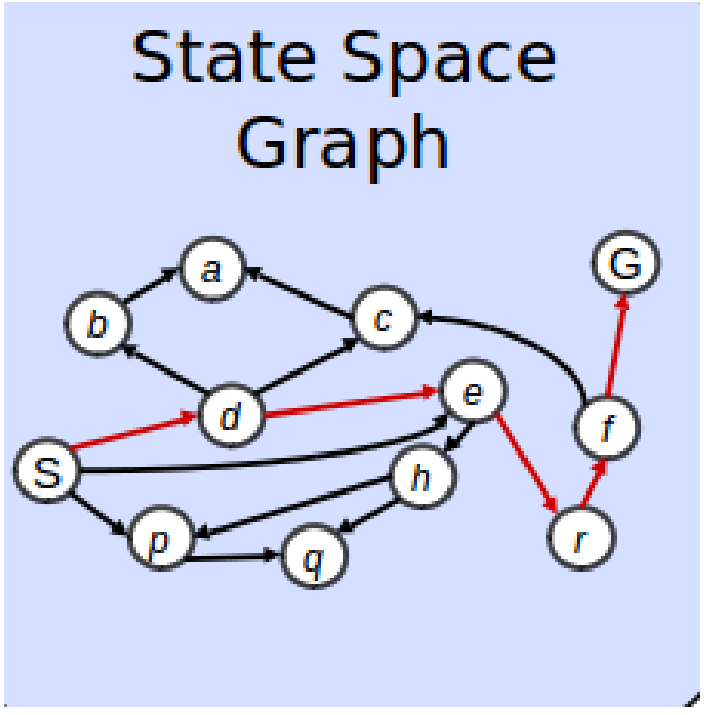
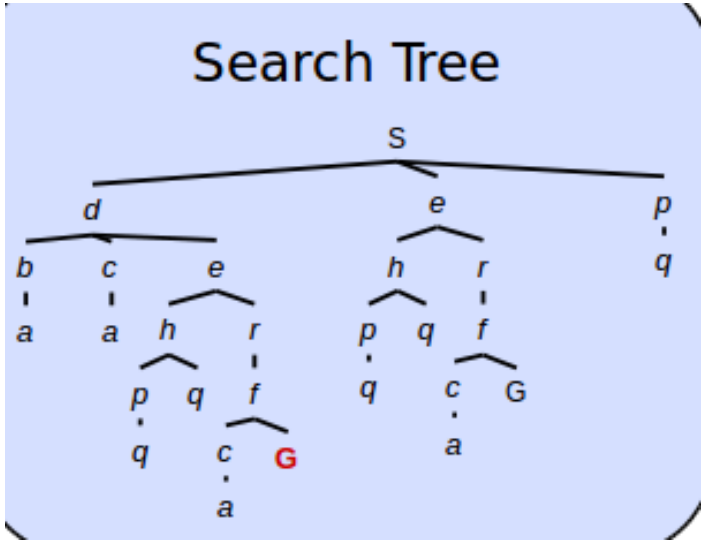


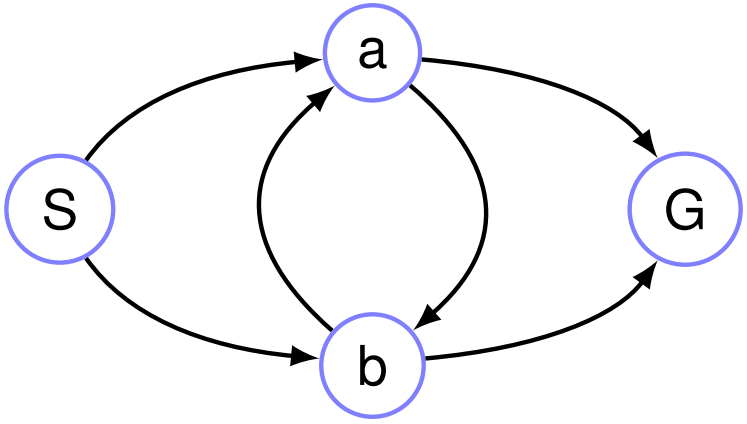


Each NODE in search tree is an entire PATH in state space graph.

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 large could search tree be?

Quiz:State Space Graphs vs. Search Trees

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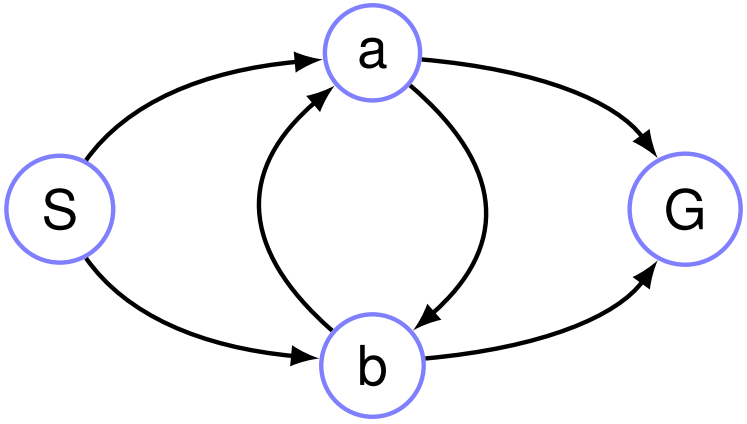

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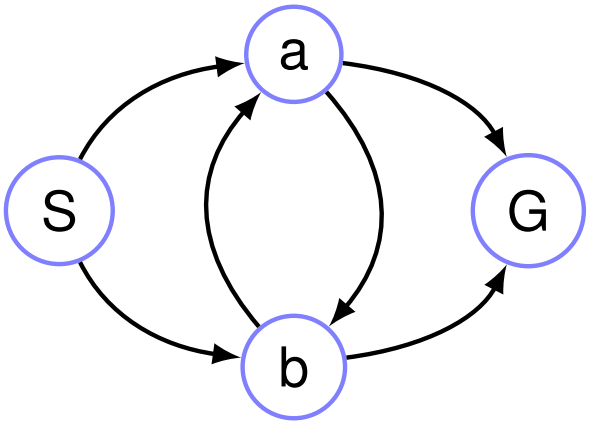

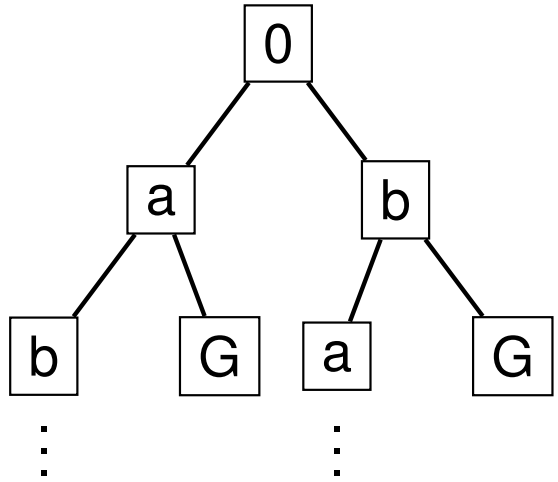

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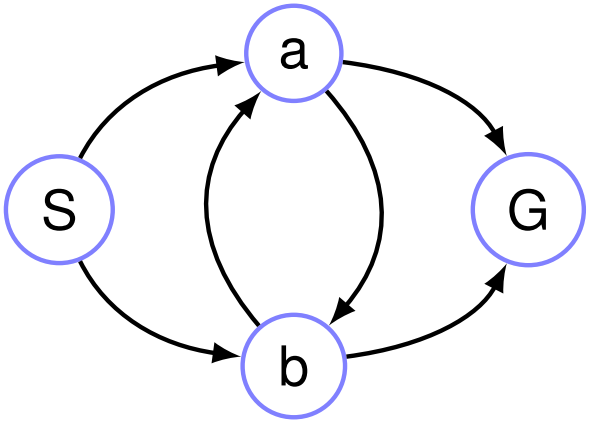

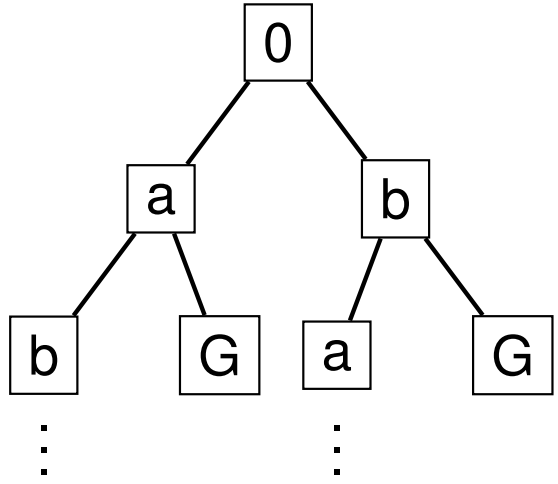

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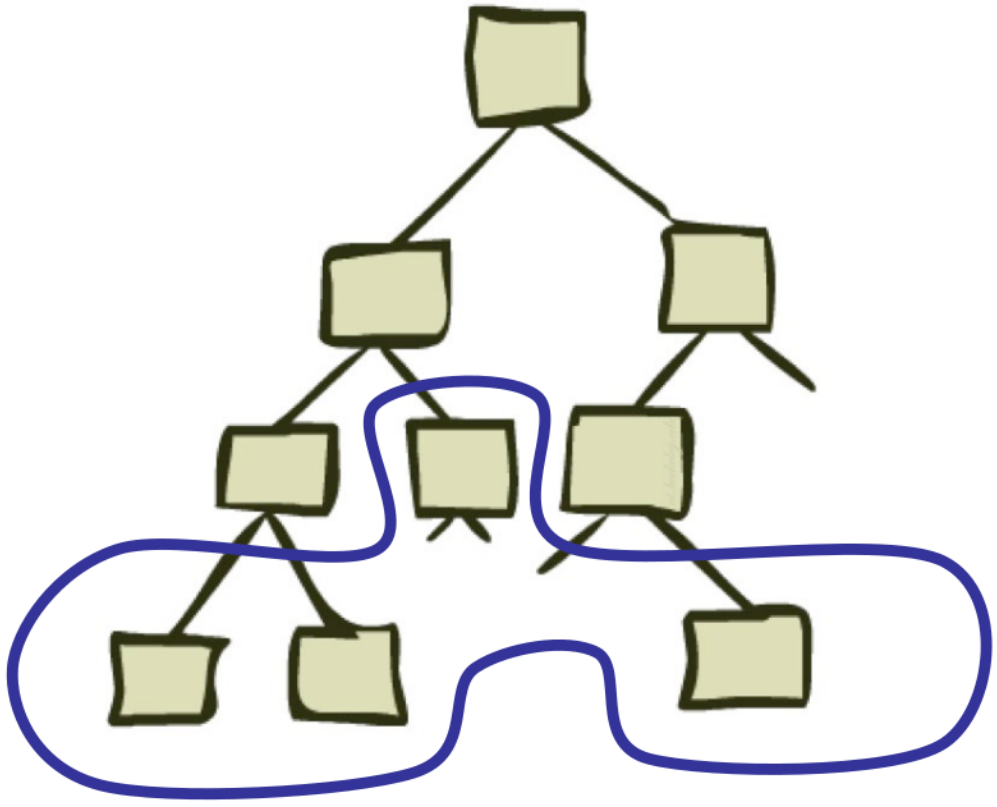
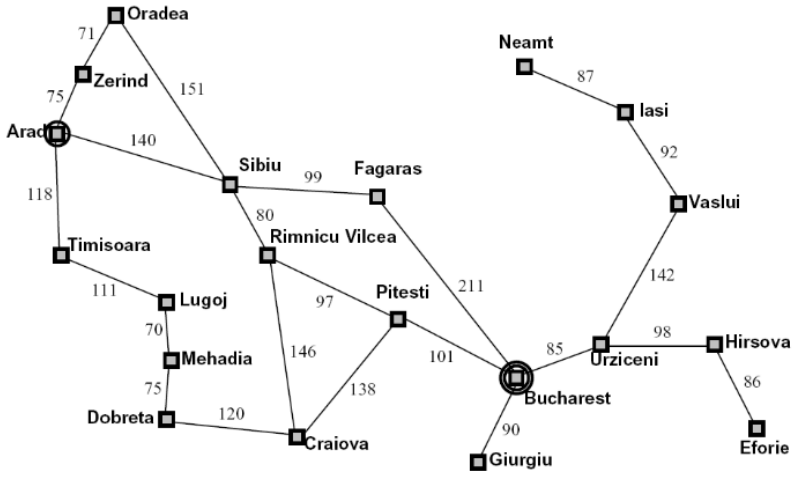
Tree Search



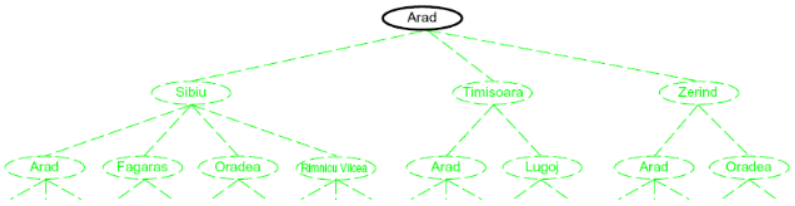
Search Example: Romania



Searching with a Search Tree

Search:

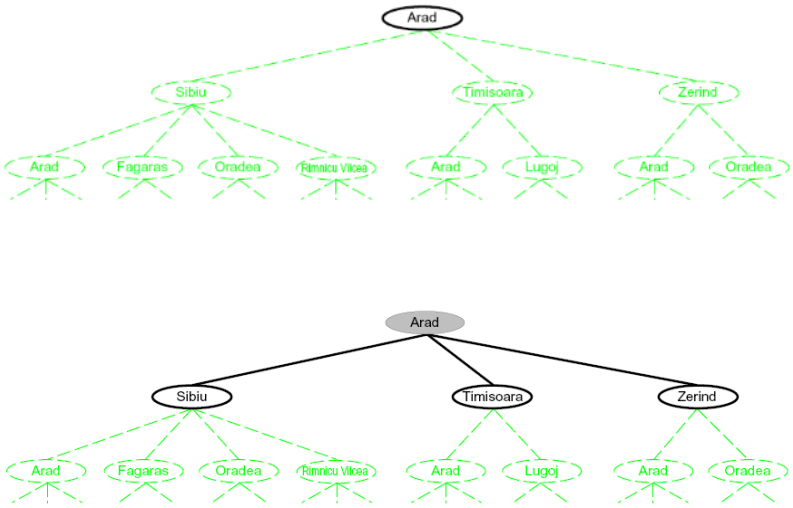
Searching with a Search Tree



Search:

(1) Expand out potential plans (tree nodes)

Searching with a Search Tree



Search:

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(2) Maintain a fringe of partial plans under consideration.

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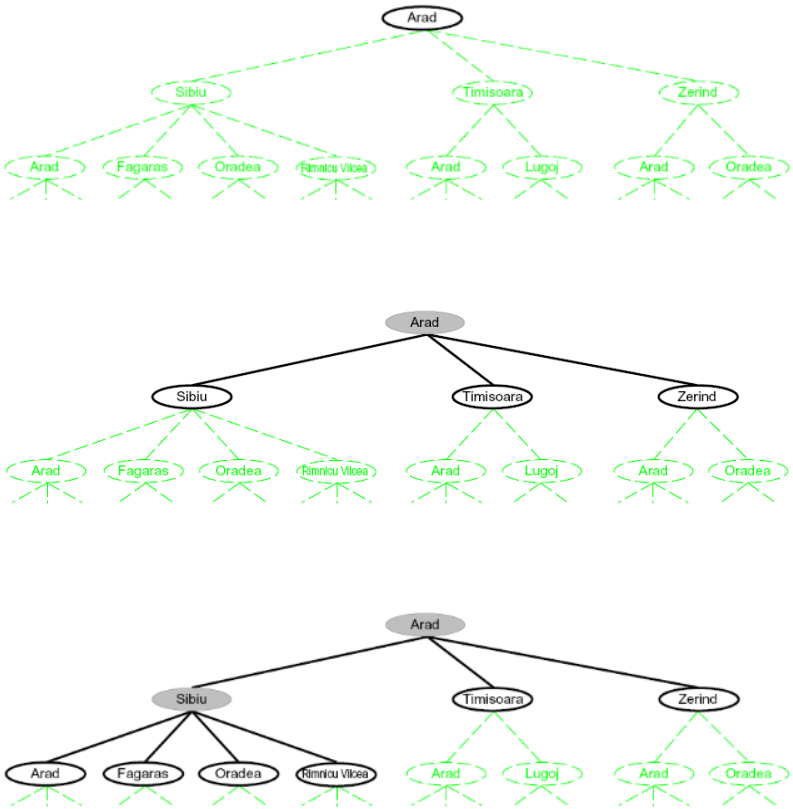

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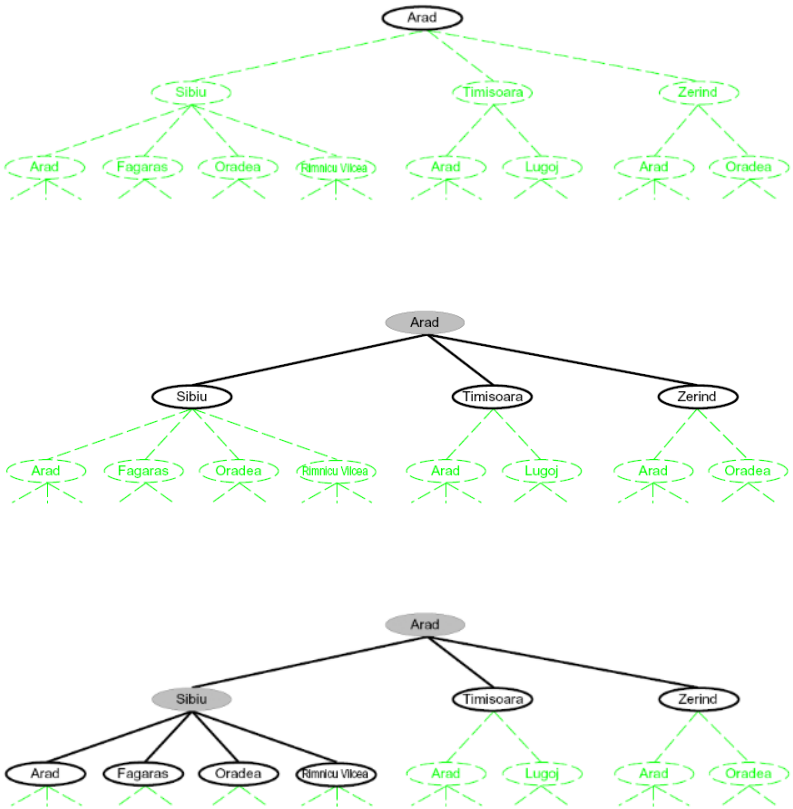

Search:

(1) Expand out potential plans (tree nodes)

(2) Maintain a fringe of partial plans under consideration.

(3) Try to expand as few tree nodes as possible

General Tree Search

Important ideas:

General Tree Search

Important ideas:

- Fringe

General Tree Search

Important ideas:

- Fringe
- Expansion

General Tree Search

Important ideas:

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Main question: which fringe nodes to explore?

General Tree Search

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Main question: which fringe nodes to explore?

```
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
```