CS 232: Artificial Intelligence

Fall 2026

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Homework 3: Pacman versus the world

The UC Berkeley AI course has a set of projects that revolve around the classic Pacman arcade game.

In this assignment, your goal is to fill in some of the functions related to search, which help Pacman find food pellets. This version of Pacman won't have any ghosts yet.

Recap

Graph Search

function **GraphSearch**(problem, strategy) return solution or failure

Initialize frontier to start state of problem

Initialize *explored set* to be empty

do

- if the frontier is empty then return failure
- choose leaf for expansion according to strategy and remove from frontier
- if node contains goal state then return solution
- *else:*
  - *add node to the explored set*
  - expand the node and add resulting nodes to the frontier *only if* not already in the **explored** set

***Question**: do we ever need to add duplicate nodes to the frontier?*

Uninformed Search

function **UISearch**(problem, strategy) return solution or failure

Initialize frontier to start state of problem

Initialize *explored set* to be empty

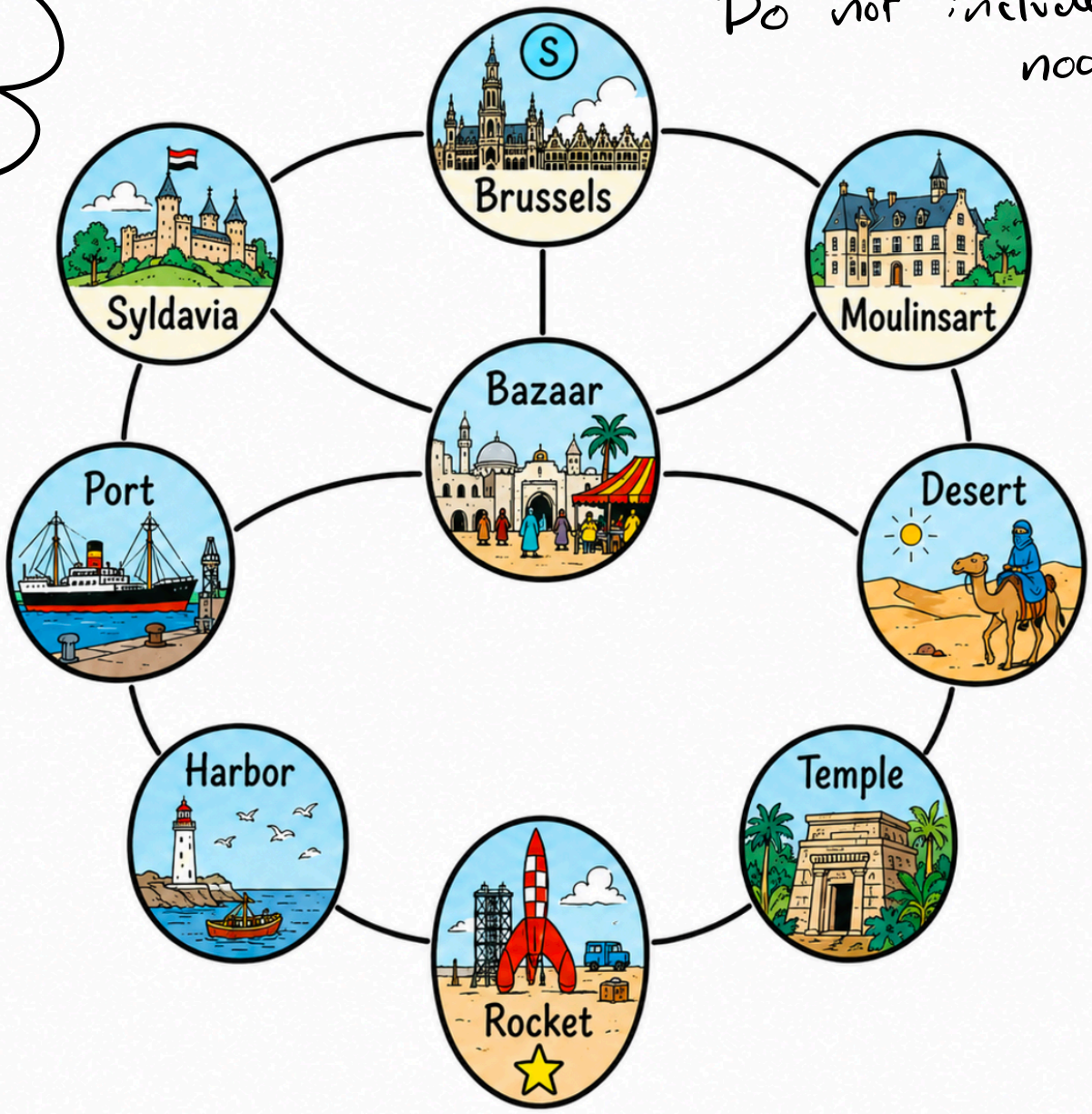
do

- if the frontier is empty then return failure
- choose leaf for expansion according to strategy and remove from frontier
- if node contains goal state then return solution
- *else:*
  - *add node to the explored set*
  - expand the node and add resulting nodes to the frontier *only if* not already in the **frontier** (or explored set)

Uninformed Search Practice

BFS

Do not include duplicate nodes in frontier!



Frontier

~~Brussels~~
~~Bazaar~~
~~Moulinsart~~
~~Syldavia~~
~~Desert~~
~~Port~~
~~Temple~~
~~Harbor~~
Rocket ★

Visited

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Bazaar
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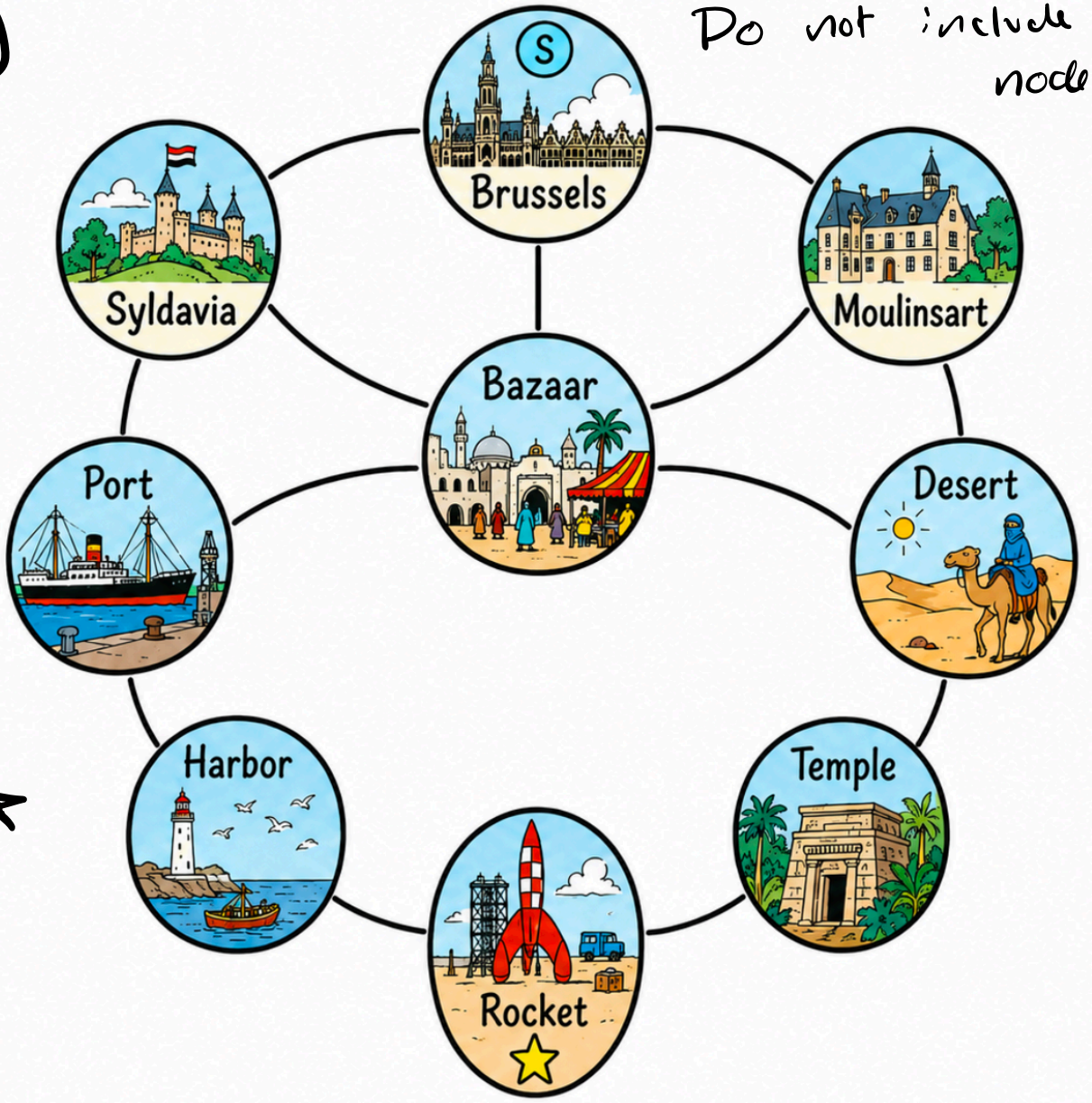
Uninformed Search Practice

DFS

Do not include duplicate nodes in frontier!



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Search Conundrum

Breadth-first

- ☑ Complete,
- ☑ Optimal
- ☒ *but* uses $O(b^d)$ space

Depth-first

- ☒ Not complete *unless m is bounded*
- ☒ Not optimal
- ☒ Uses $O(b^m)$ time; terrible if m >> d
- ☑ *but* only uses ***O(b*m) space***

Slides adapted from Chris Callison-Burch

Depth-Limited Search

Depth-First search *but with depth limit l.*

- i.e. nodes at depth *l* *have no successors.*
- No infinite-path problem!

If $l = d$ (by luck!), then optimal

- But:
  - **If $l < d$ then incomplete** ☹
  - **If $l > d$ then not optimal** ☹

Time complexity: $O(b^l)$

Space complexity: $O(bl)$

Slides adapted from Chris Callison-Burch

Iterative Deepening

Key Idea: Use depth-limited search, but keep increasing the depth limit.

- ☑ Complete
- ☑ Optimal *(if depth limit increased by 1 each time)*

If our search space is tractable, then BFS is optimal & we should use it.

But, in other cases, we can use iterative deepening.

Summary of algorithms

Criterion	Breadth-First	Depth-First	Depth-limited	Iterative deepening
Complete?	YES	NO	NO	YES
Time	b^d	b^m	b^l	b^d
Space	b^d	bm	bl	bd
Optimal?	YES	NO	NO	YES

d = depth of nearest goal state
m = maximum depth of search space
l = depth limit
b = branching factor.

Slides adapted from Chris Callison-Burch

Informed Search

Uninformed Search

Uses only information available in problem definition

Informally:

Uninformed search: All non-goal nodes in frontier look equally good

Informed search: Some non-goal nodes can be ranked above others.

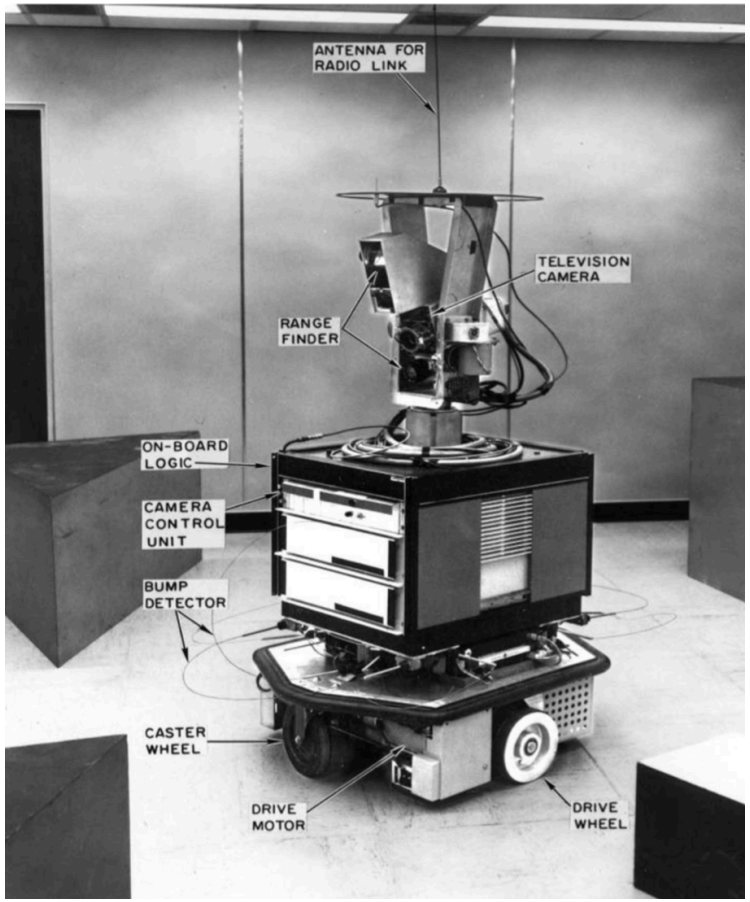
Informed Search

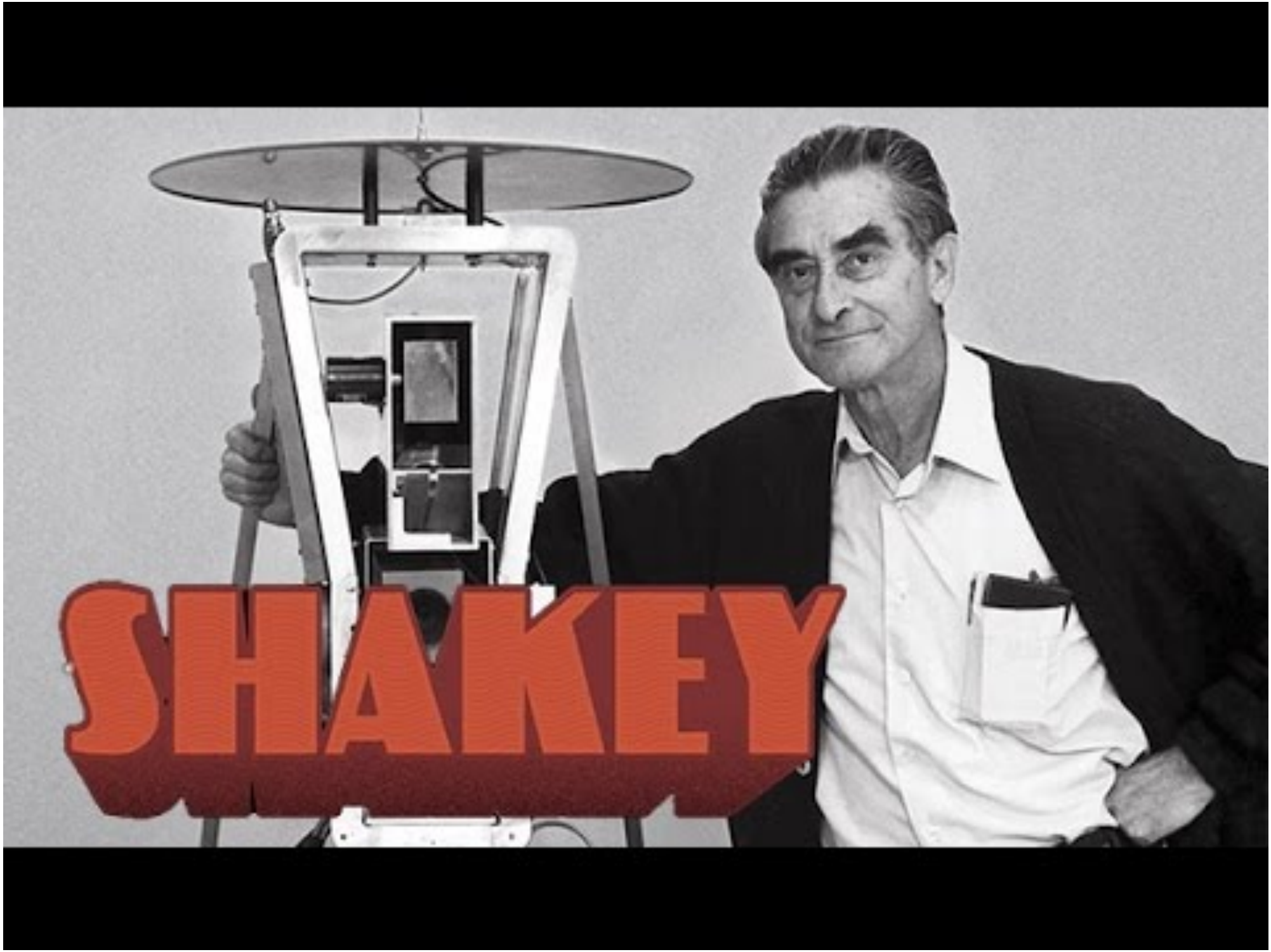
An **informed search** strategy uses **domain-specific information** about the location of the goals in order to find a solution **more efficiently** than uninformed search.

Hints will come as part of a **heuristic function** denoted h(n).

One of the most famous informed search algorithms is **A*** which was developed for **robot navigation**.

Shakey the robot was developed at the Stanford Research Institute from 1966 to 1972.

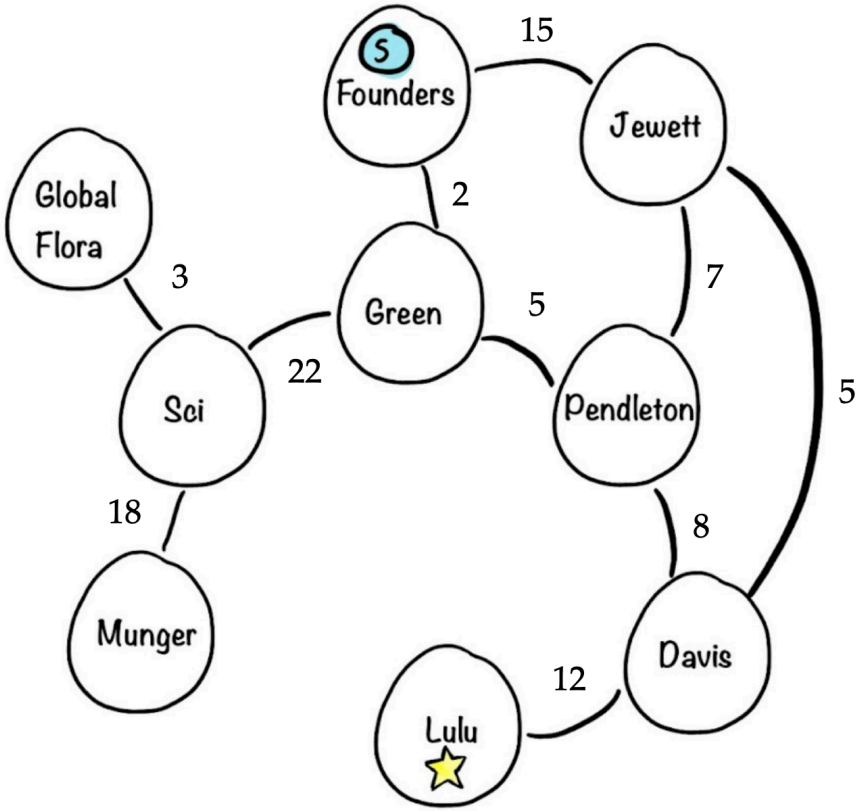



SHAKEY

Motivation: Navigation Tasks

So far, we have assumed that all actions have the same cost.

But this isn't true for many applications.



Some of these buildings are much closer than others!

g(N): the Path Cost Function

- **Our assumption so far: All moves equal in cost**
  - Cost = # of nodes in path-1
  - *g(N) = depth(N)* in the search tree

N_0, N_1, N_2 = nodes visited on path between N_0 & N_2

$C(i,j)$: Cost of going from N_i to N_j

If N_0 is the start state:

$$g(N_3) = C(N_0, N_1) + C(N_1, N_2) + C(N_2, N_3)$$

Uniform-Cost Search

Use BFS (ish):

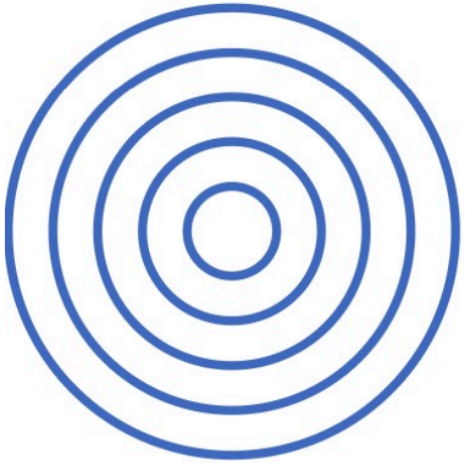
BUT: expand the node w/ lowest path cost first.

Frontier = priority queue ordered by $g(n)$

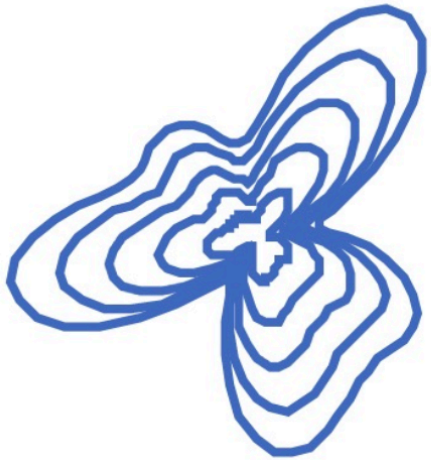
When a new path to a node is discovered, we may need to update its cost!

Key point: apply goal test only when node is visited.

Shape of Search



- **Breadth First Search** explores equally in all directions. Its frontier is implemented as a FIFO queue. This results in smooth contours or "plys".



- **Uniform Cost Search** lets us prioritize which paths to explore. Instead of exploring all possible paths equally, it favors lower cost paths. Its frontier is a priority queue. This results in "cost contours".

A Better Idea

- Node expansion based on an **estimate** which includes distance to the goal.
- General approach of informed search:
  - Best-first search: node selected for expansion based on an **evaluation function f(n)**
  - f(n) includes an estimate of the distance to the goal