Inf2D 02: Problem Solving by Searching

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Outline

- Problem-solving agents
- Problem types
- Problem formulation
- Example problems
- Basic search algorithms

Problem-solving agents

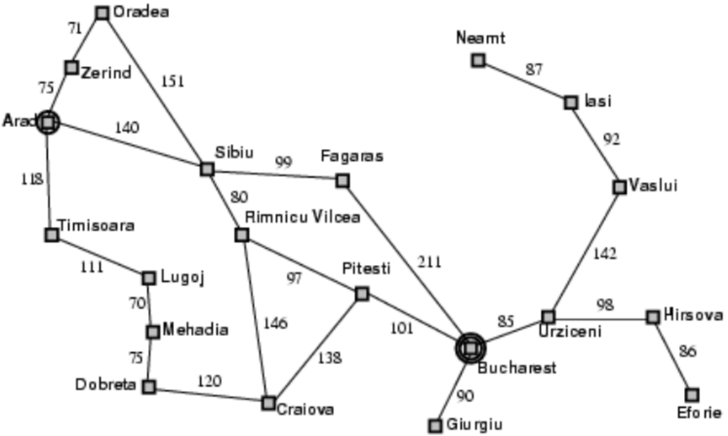
```
function SIMPLE-PROBLEM-SOLVING-AGENT(percept) returns an action
    persistent: seq, an action sequence, initially empty
                state, some description of the current world state
                goal, a goal, initially null
                problem, a problem formulation
  state ← UPDATE-STATE(state, percept)
  if seq is empty then do
    goal ← FORMULATE-GOAL(state)
    problem ← FORMULATE-PROBLEM(state, goal)
    seq ← SEARCH(problem)
    if seq = failure then return a null action
  action ← FIRST(seq)
  seq ← REST(seq)
  return action
```

Agent has a " Formulate, Search, Execute"

Example: Romania

- On holiday in Romania; currently in Arad.
- Flight leaves tomorrow from Bucharest
- Formulate goal:
  - be in Bucharest
- Formulate problem:
  - states: various cities
  - actions: drive between cities
- Find solution:
  - sequence of cities, e.g., Arad, Sibiu, Fagaras, Bucharest

Example: Romania



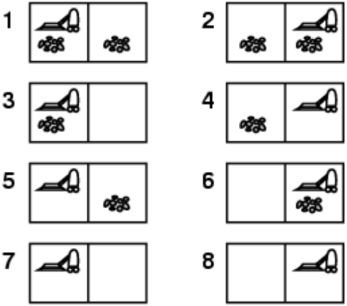
Problem types

- Deterministic, fully observable $\rightarrow$ single-state problem
  - Agent knows exactly which state it will be in; solution is a sequence
- Non-observable $\rightarrow$ sensorless problem (conformant problem)
  - Agent may have no idea where it is; solution is a sequence
- Nondeterministic and/or partially observable $\rightarrow$ contingency problem –
  - percepts provide new information about current state
  - often interleave search, execution
- Unknown state space $\rightarrow$ exploration problem

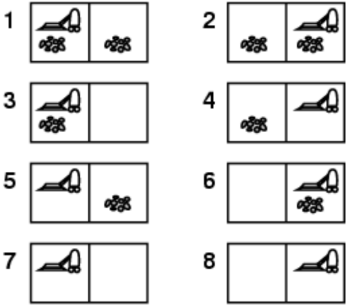
Example: vacuum world

– Single-state, start in #5.

Solution?



Example: vacuum world



– Single-state, start in #5.

Solution: [*Right*, *Suck*]

– Sensorless, start in $\{1, 2, 3, 4, 5, 6, 7, 8\}$ e.g., Right goes to $\{2, 4, 6, 8\}$

Solution?

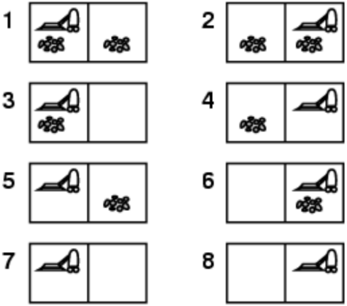
Example: vacuum world

- Sensorless, start in $\{1, 2, 3, 4, 5, 6, 7, 8\}$ e.g., Right goes to $\{2, 4, 6, 8\}$

  Solution: [*Right, Suck, Left, Suck*]

- Contingency
  - Nondeterministic: Suck may dirty a clean carpet
  - Partially observable: location, dirt at current location.
  - Percept: [*L, Clean*], i.e., start in #5 or #7

  Solution?



Example: vacuum world

– Contingency
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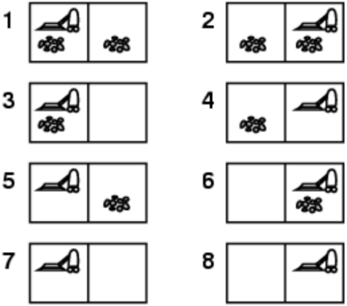


Solution: [*Right*, **if** *dirt* **then** *Suck*]

Single-state problem formulation

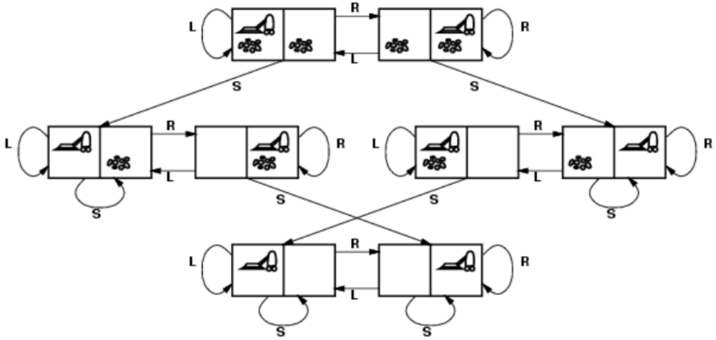
A problem is defined by four items:

- initial state e.g., "in Arad"
- actions or successor function $S(x)$ =set of action–state pairs
  - e.g., $S(\text{Arad}) = \{\langle \text{Arad} \rightarrow \text{Zerind},\ \text{Zerind} \rangle, \ldots\}$
- goal test, can be
  - explicit, e.g., $x =$ "in Bucharest"
  - implicit, e.g., $Checkmate(x)$
- path cost (additive)
  - e.g., sum of distances, number of actions executed, etc.
  - $c(x, a, y)$ is the step cost of taking action a in state x to reach state y, assumed to be ≥ 0
- A solution is a sequence of actions leading from the initial state to a goal state

Selecting a state space

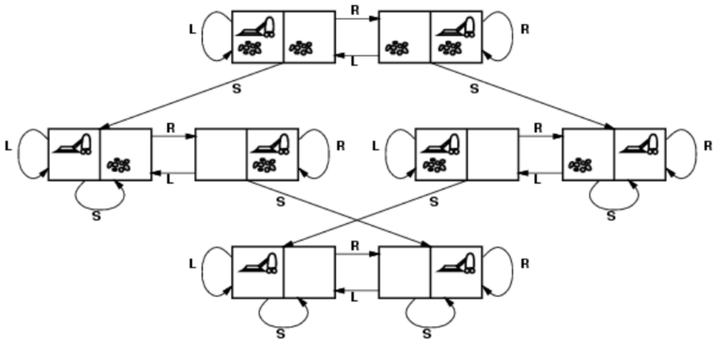
- Real world is absurdly complex $\rightarrow$ state space must be abstracted for problem solving
- (Abstract) state = set of real states
- (Abstract) action = complex combination of real actions
  - e.g., "Arad $\rightarrow$ Zerind" represents a complex set of possible routes, detours, rest stops, etc.
- For guaranteed realizability, any real state "in Arad" must get to some real state "in Zerind"
- (Abstract) solution =
  - set of real paths that are solutions in the real world
- Each abstract action should be "easier" than the original problem

Vacuum world state space graph



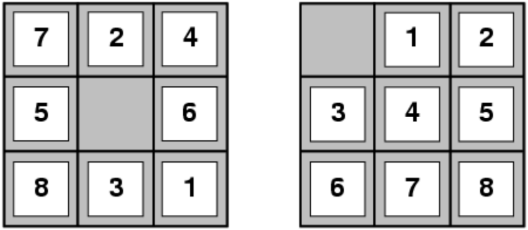
– states?
– actions?
– goal test?
– path cost?

Vacuum world state space graph



– states? Pair of dirt and robot locations
– actions? Left, Right, Suck
– goal test? no dirt at any location
– path cost? 1 per action

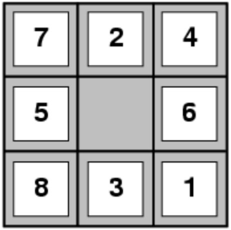
Example: The 8-puzzle



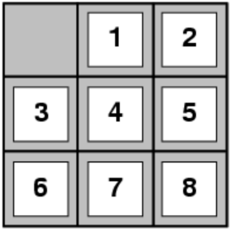
Start State Goal State

- states?
- actions?
- goal test?
- path cost?

Example: The 8-puzzle



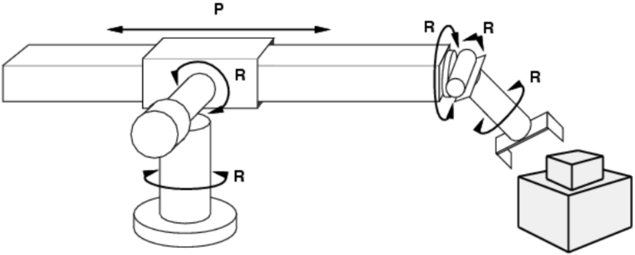
Start State



Goal State

– states? locations of tiles
– actions? move blank left, right, up, down
– goal test? $=$ goal state (given)
– path cost? 1 per move

Example: robotic assembly



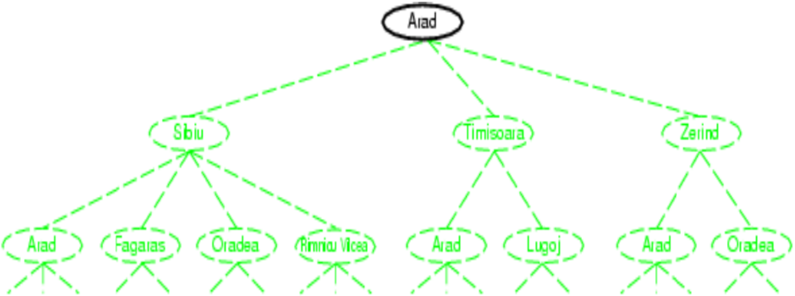
- states?: real-valued coordinates of robot joint angles & parts of the object to be assembled
- actions?: continuous motions of robot joints
- goal test?: complete assembly
- path cost?: time to execute

Tree search algorithms

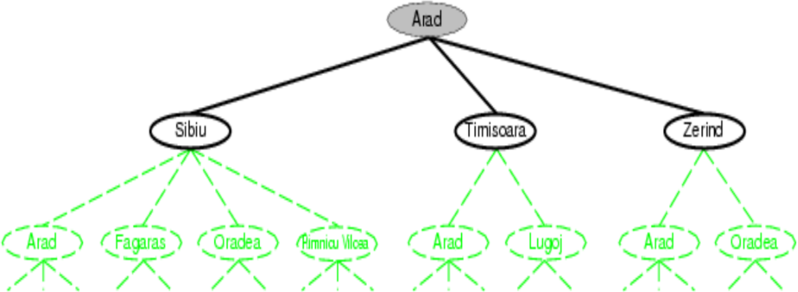
– Basic idea:
  - offline, simulated exploration of state space by generating successors of already-explored states (a.k.a. expanding states)

```
function TREE-SEARCH(problem) returns a solution, or failure
  initialize the frontier using the initial state of problem
  loop do
    if the frontier is empty then return failure
    choose a leaf node and remove it from the frontier
    if the node contains a goal state then return the corresponding solution
    expand the chosen node, adding the resulting nodes to the frontier
```

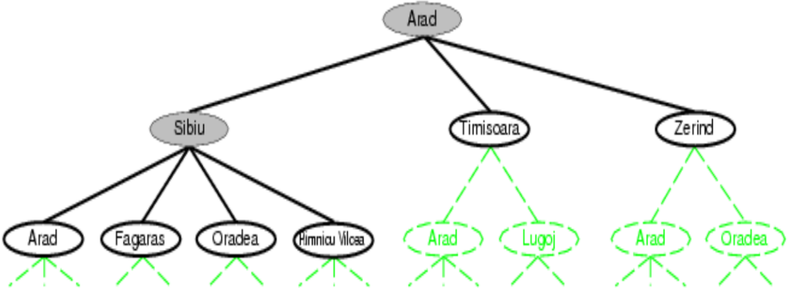
Tree search example



Tree search example



Tree search example



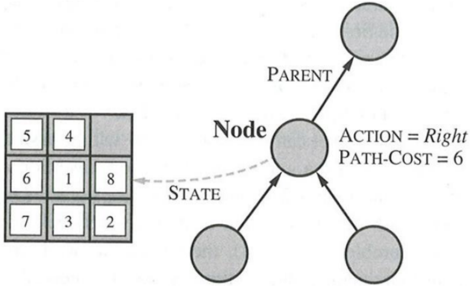
Implementation: general tree search

```
function TREE-SEARCH(problem) returns a solution, or failure
    initialize the frontier using the initial state of problem
    loop do
        if the frontier is empty then return failure
        choose a leaf node and remove it from the frontier
        if the node contains a goal state then return the corresponding solution
        expand the chosen node, adding the resulting nodes to the frontier
```

```
function CHILD-NODE(problem, parent, action) returns a node
    return a node with
        STATE = problem.RESULT(parent.STATE, action),
        PARENT = parent, ACTION = action,
        PATH-COST = parent.PATH-COST + problem.STEP-COST(parent.STATE,
                        action)
```

Implementation: states vs. nodes

- A state is a (representation of) a physical configuration
- A node is a book-keeping data structure constituting part of a search tree includes state, parent node, action, path cost



- Using these it is easy to compute the components for a child node. (The `CHILD-NODE` function)

Summary

– Problem formulation usually requires abstracting away real-world details to define a state space that can feasibly be explored.