جامعة الملك سعود
King Saud University

Problem Solving Using Search

IT426: Artificial Intelligence Systems

Information Technology Department

Topics in This Chapter

- Significance of search in AI
- Problem formulation
- Uninformed search
- Informed search and heuristics
- Local search and optimization
- Constraint Satisfaction Problems

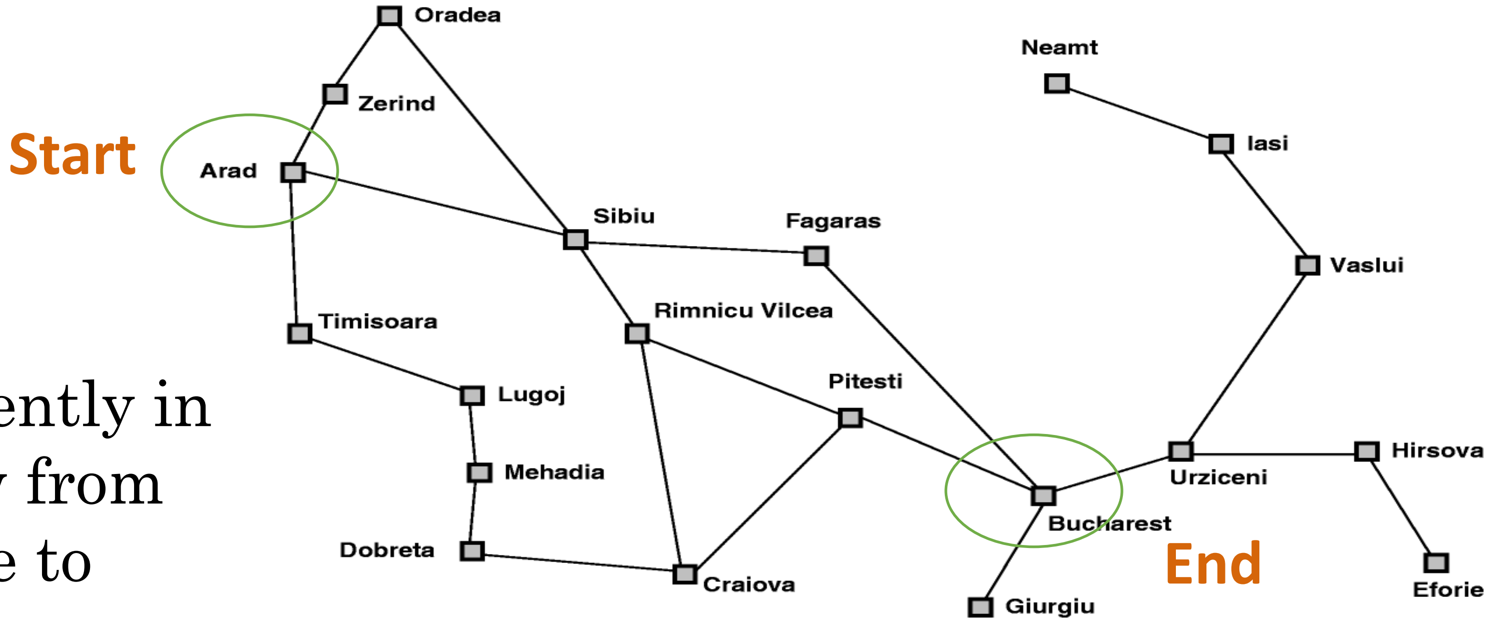
Revisiting Agents

- Simple reflex agents: Select actions based on the *current* percept
- Model-based reflex agent: Knowledge about "how the world works"
- **Goal-based agents:** "What will happen if I do such-and-such?" and "Will that make me happy?"
  - **Problem Solving Agents (use atomic rep. of state)**
  - Planning Agents (use factored/structured rep. of state)
- Utility-based agents: Exactly how happy
- Learning agents

Why do we study search in AI?

- Problems that seem to require intelligence usually require <u>exploring multiple alternatives</u>
- Search is a systematic way of exploring alternatives
- Search can be defined as: the process of looking for a sequence of actions that reaches the goal
- **Challenge:** How to find the goal as quickly as possible or without using too many resources.

Example search problem: holiday in Romania



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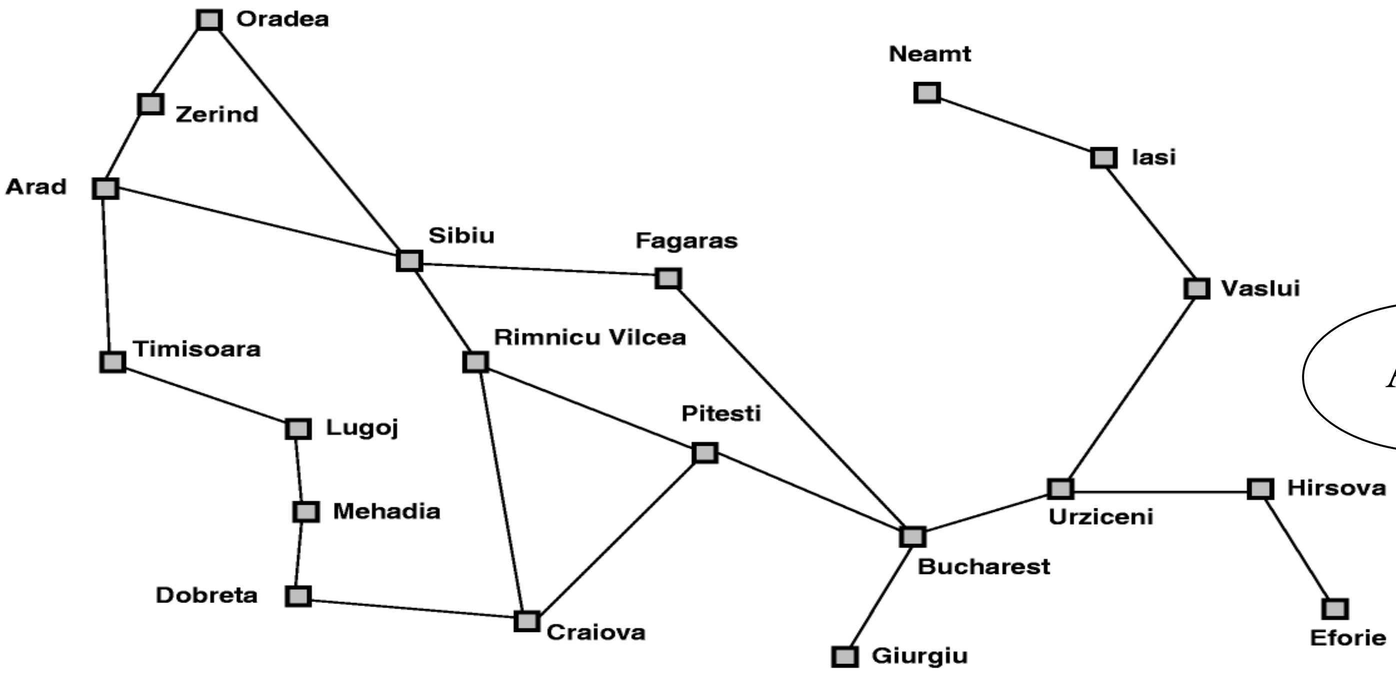
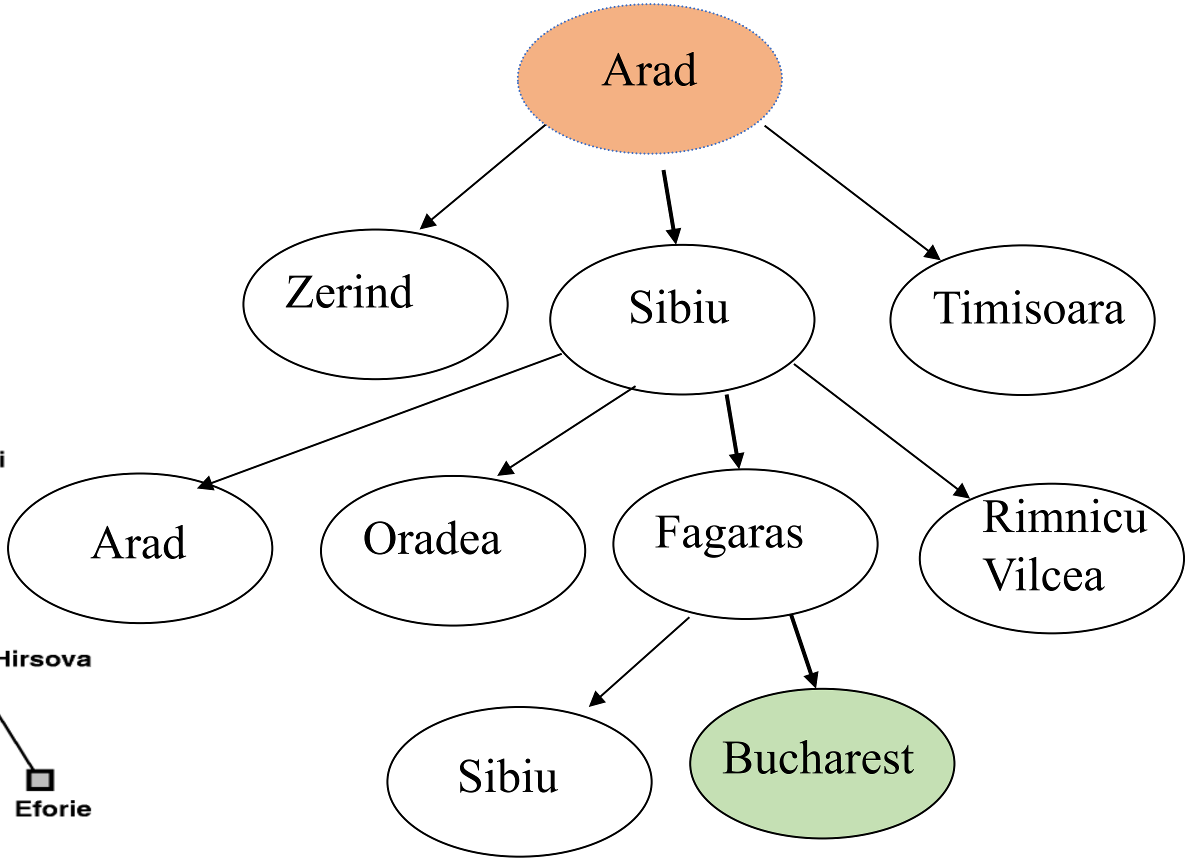
Example problem:
On holiday in Romania; currently in Arad. Flight leaves tomorrow from Bucharest. Find a short route to drive to Bucharest

Find A Short Route To Drive Form Arad To Bucharest





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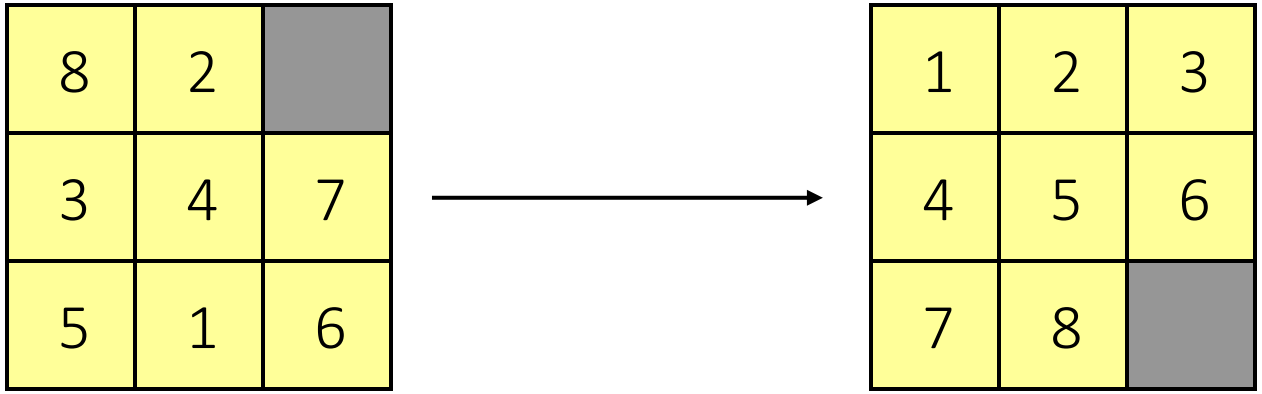
Another example search problem: 8-puzzle

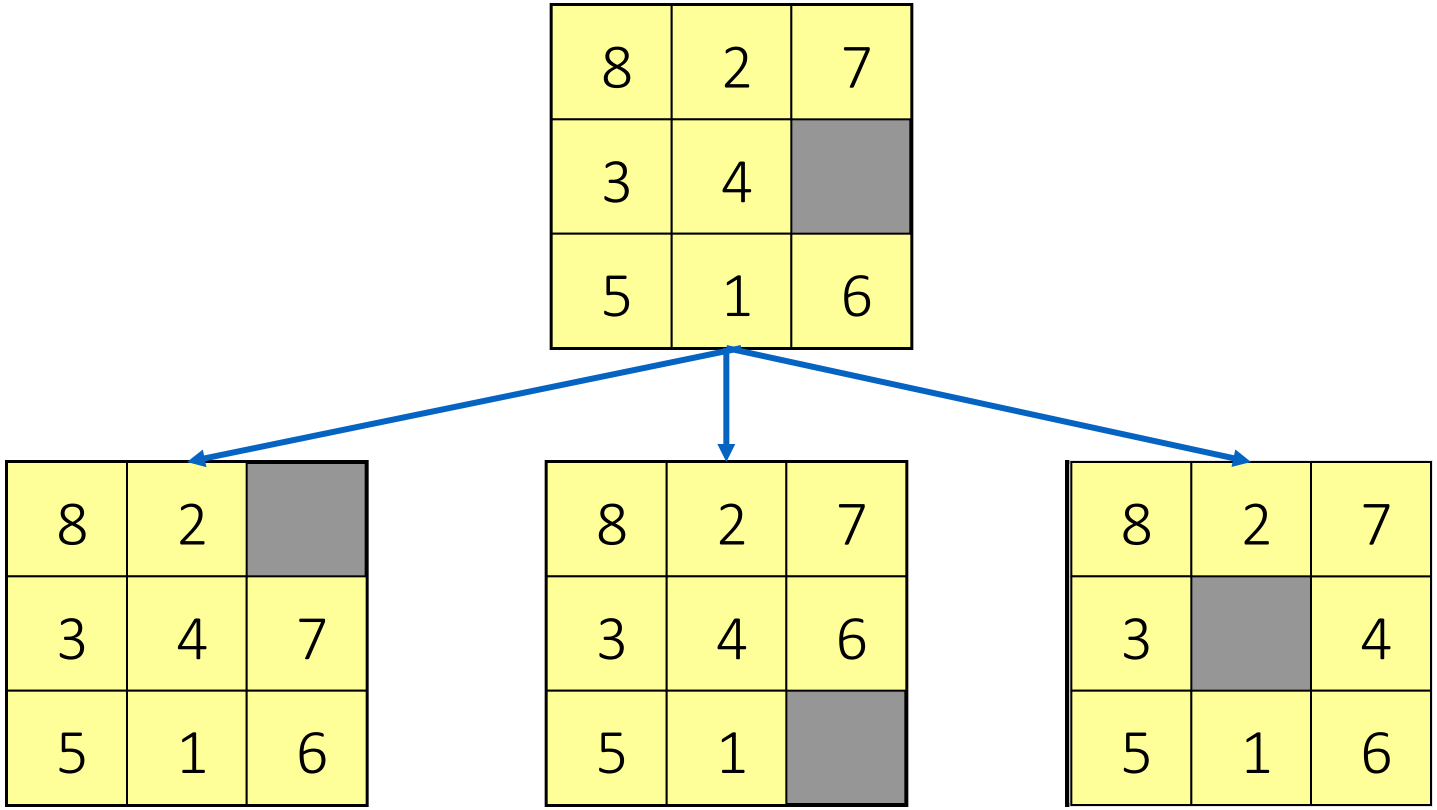


8	2	
3	4	7
5	1	6

1	2	3
4	5	6
7	8	

Find the sequence of minimum steps to solve the puzzle

8-Puzzle



8	2	7
3	4	
5	1	6

8	2	
3	4	7
5	1	6

8	2	7
3	4	6
5	1	

8	2	7
3		4
5	1	6

What is common among search problems?

- Goal is known (remember it’s goal-based agent)
- Solution is a sequence of actions that takes me from the initial step to the goal.
- There are multiple solutions
- Each solution has a cost
- Challenge: find the least cost solution

How can we solve such problems using search?

- Three main steps:
  1. Formulate the goal
  2. Formulate the search problem
  3. Find a solution using search

1st step: Goal formulation

- Decide which properties of the world we are interested in, and which can be ignored or abstracted away.

- A goal is a **state** that meets some characteristics. It can be:
  - A task to be accomplished
  - A situation to be reached
  - A set of properties to be acquired

Exercise

- What is the goal for the “holiday in Romania” problem?
- What is the goal for the “8-puzzle” problem?

2nd step: Problem Formulation

A **problem** can be defined formally by five components:

1. Initial state
2. Actions
3. Transition model
4. Goal test
5. Path cost

What is a State?

- A ***state representation*** is an important aspect of problem formulation.
- Contains all of the information necessary to predict the effects of an action and to determine if it is a goal state
- Ask yourself: which properties matter & how to represent them?
- **A state does:**
  - Represent all information meaningful to the problem at a given “instant in time” – usually in the future
  - Exist in an ***abstract***, ***mathematical*** sense
- **A state DOES NOT:**
  - Tell the computer how it arrived at the state
  - Tell the computer how to choose the next action

EXERCISES

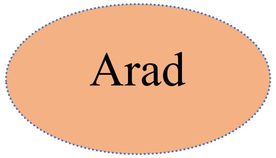
- What is the state representation for the following problems:
  - Holiday in Romania
  - 8-Puzzle” problem
  - **Travelling salesman problem:** Given a set of n cities, visit each city exactly once starting and ending in the same city.

needs a list of all visited cities and which city salesman is in

Initial State

- The initial state that the agent starts in (starting point)

- E.g.
  - initial state: In(Arad)

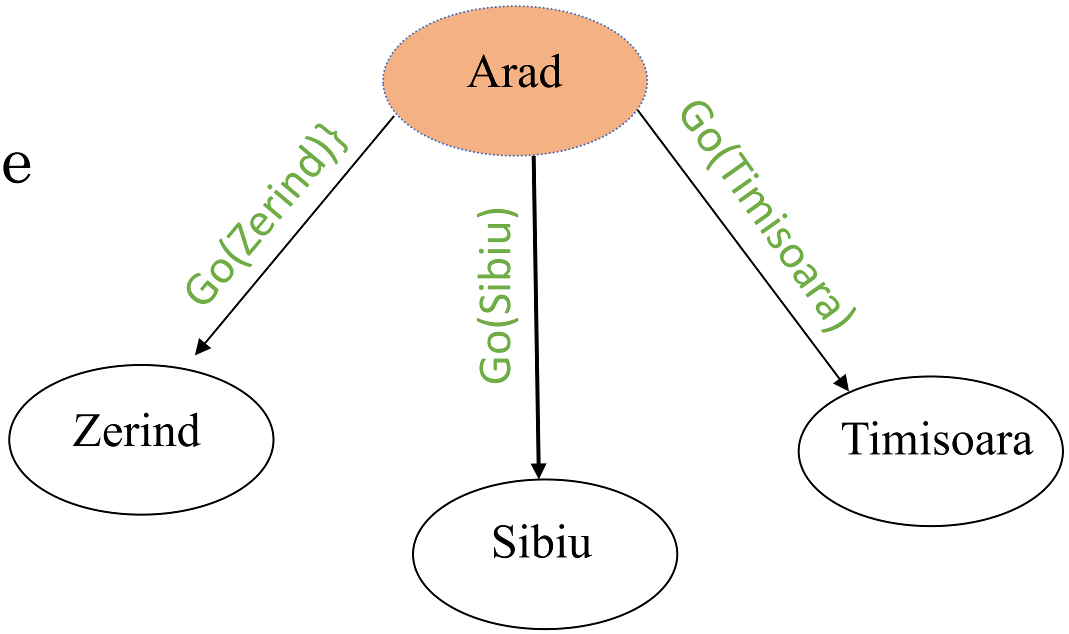


Arad

Actions

- A description of the possible **actions** available to the agent at a given state.

- E.g.
  - from the state In(Arad), the actions are {Go(Sibiu),Go(Timisoara),Go(Zerind)}



Transition Model

- A successor function:

Given a particular state x,

fsuccessor(x) = {(<action, new state>) }

where:

action is one of the legal actions in state *x*

new state is the successor state that can be reached from *x* by applying *action*.

Definitions related to transition model

- **Successor** refers to the state that results from doing action *a* in state *s*
    - E.g. Generates the next city to visit according to the current state.
- The *successor function* allows together **with** the *initial state* to define the ***state space***
- **State space** is the set of all states reachable from the initial state by any sequence of actions.
- The state space forms a directed network or **graph** in which the nodes are states and the links between nodes are actions
- A **path** in the state space is a sequence of states connected by a sequence of actions.

Goal Test

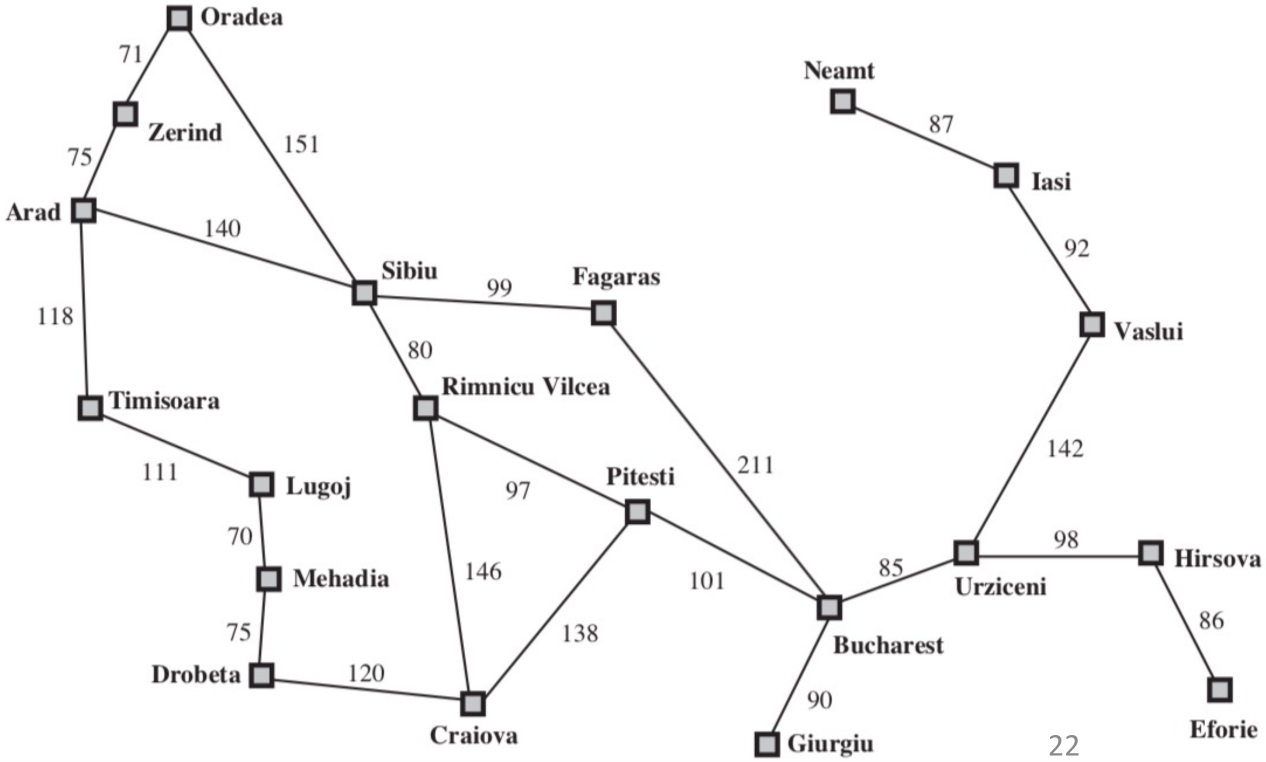
- Determines whether a given state is a goal state

- E.g.
  - Goal test: {In(Bucharest)}

Path Cost

- A function that assigns a numeric cost to each path
- The problem-solving agent chooses a cost function that reflects its own performance measure.

- E.g.
  - path cost= total length in km.



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Solution

- A **solution** to a problem is an action sequence that leads from the initial state to a goal state.

- Solution quality is measured by the path cost function, and an **optimal solution** has the lowest path cost among all solutions.

Problem formulation

The Touring problem: Given a set of n cities, the touring problem consists of visiting cities at least once starting and ending in the same city.

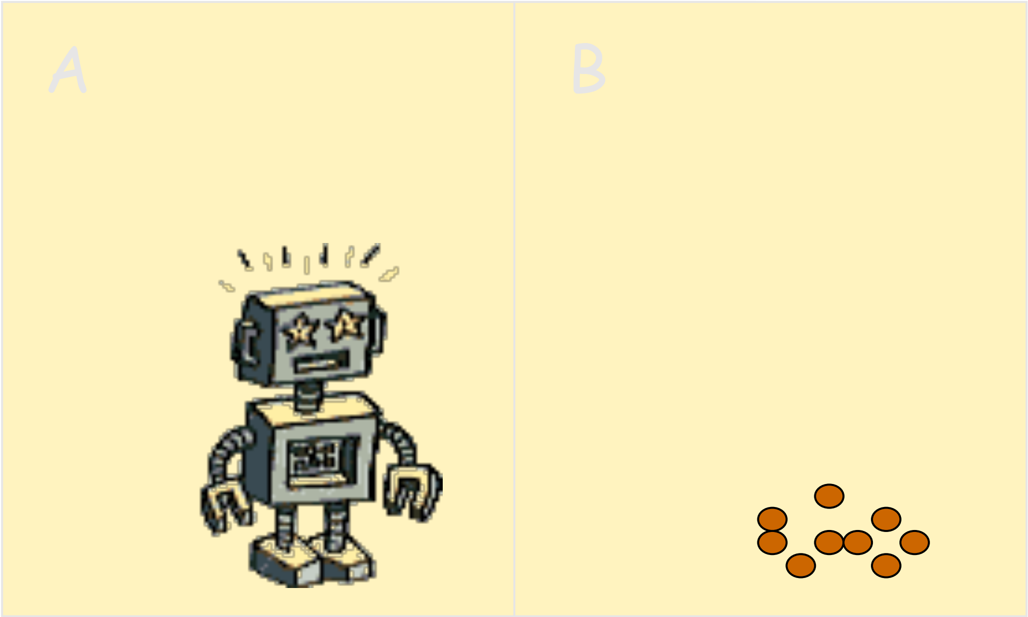
- **States:** Specified by the current city and the set of cities already visited.
- **Initial state:** Any state can be designed as the initial state.
- **Actions**: take a trip between adjacent cities.
- **Transition model (Successor function):** Generates the next city to visit according to the current state.
- **Goal test:** Ending city reached and all cities have been visited.
- **Path cost:** Sum of all step costs.

Problem Formulation Example

The vacuum world

Problem Formulation: Vacuum World

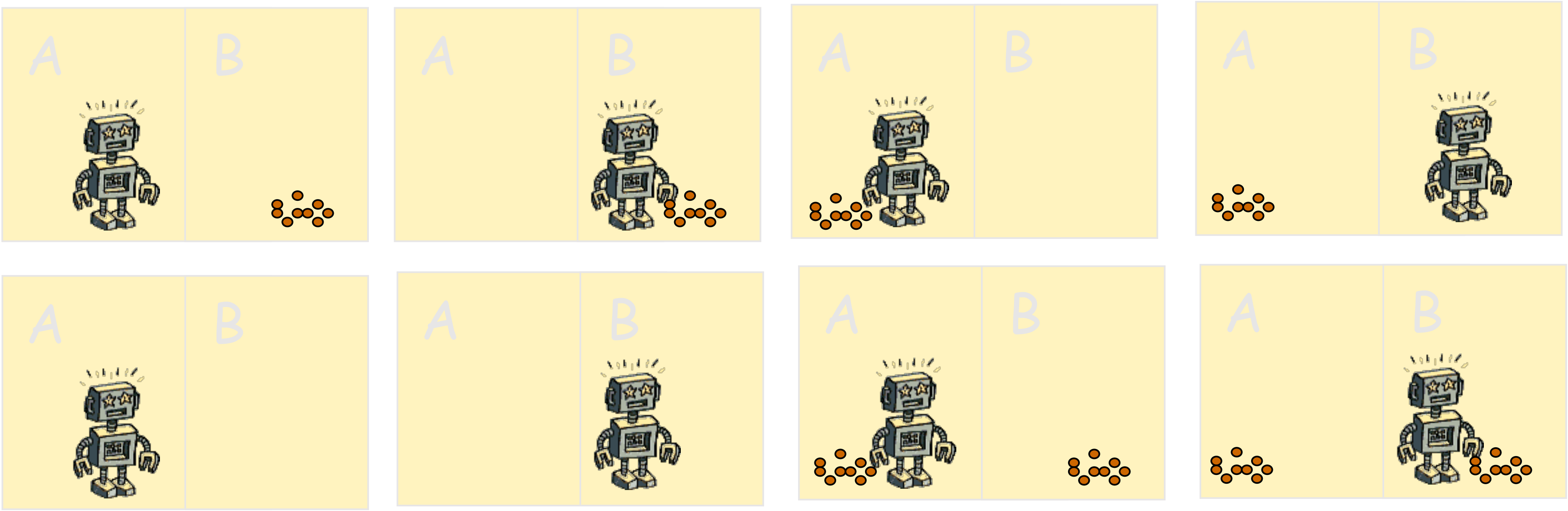
- State representation?
- Initial state?
- Actions?
- Transition Model?
- Goal test?
- Path cost function?



State Representation

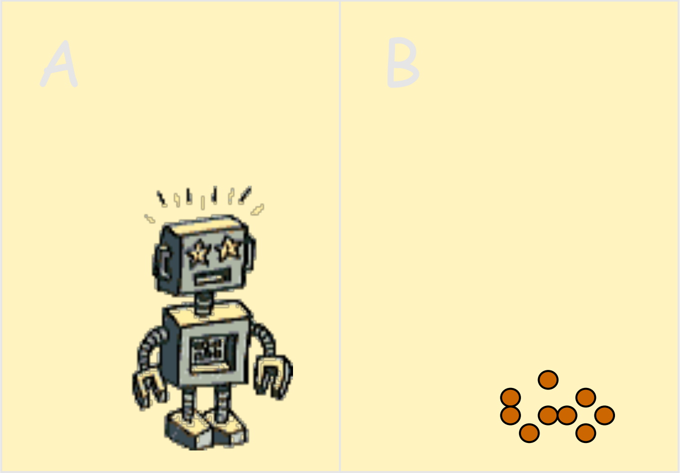
- The agent is on one of two locations, each of which might or might not contain dirt. Thus, there are 2 x 2x 2 = 8 possible world states.

A clean, A dirty
B clean, B dirty
in A, in B
2 x 2 x 2 = 8



Initial state & Actions

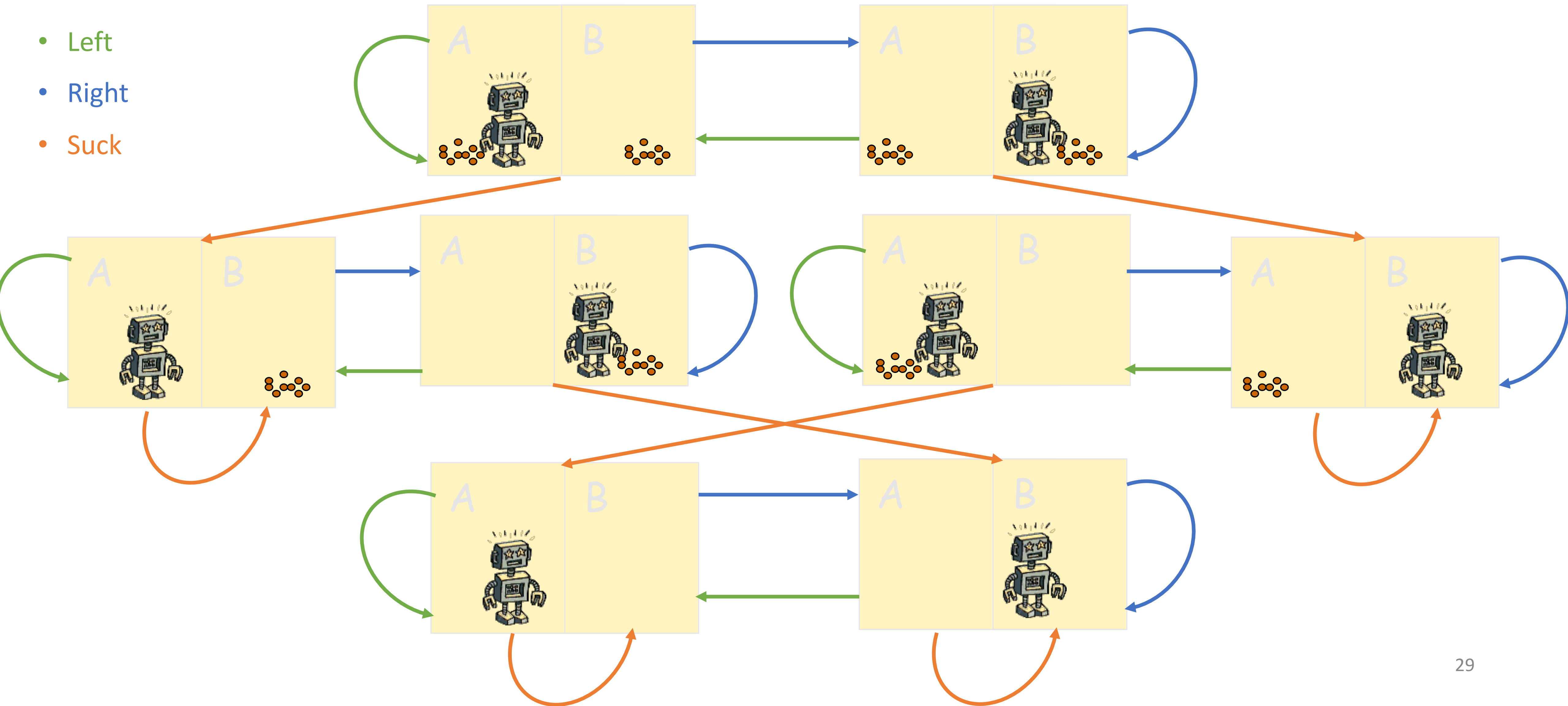
- **Initial state:** Any state can be designated as the initial state



- **Actions**: each state has just 3 actions (Left, Right, and Suck)

Transition Model

- Left
- Right
- Suck



Goal Test & Path Cost

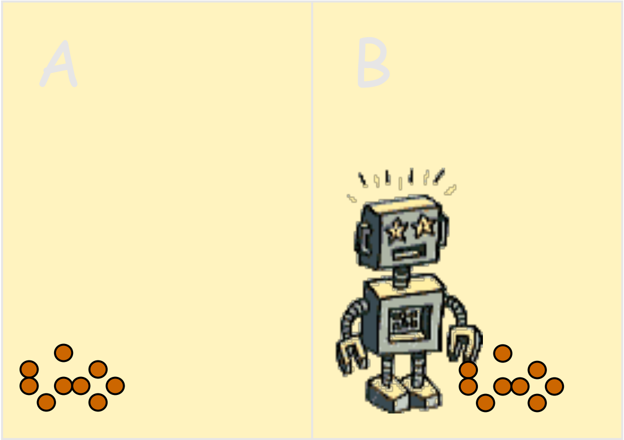
- **Goal test:** Check whether all the squares are clean.

- **Path cost function:** Each step costs 1. So the path cost is the number of steps.

Graphs into Trees

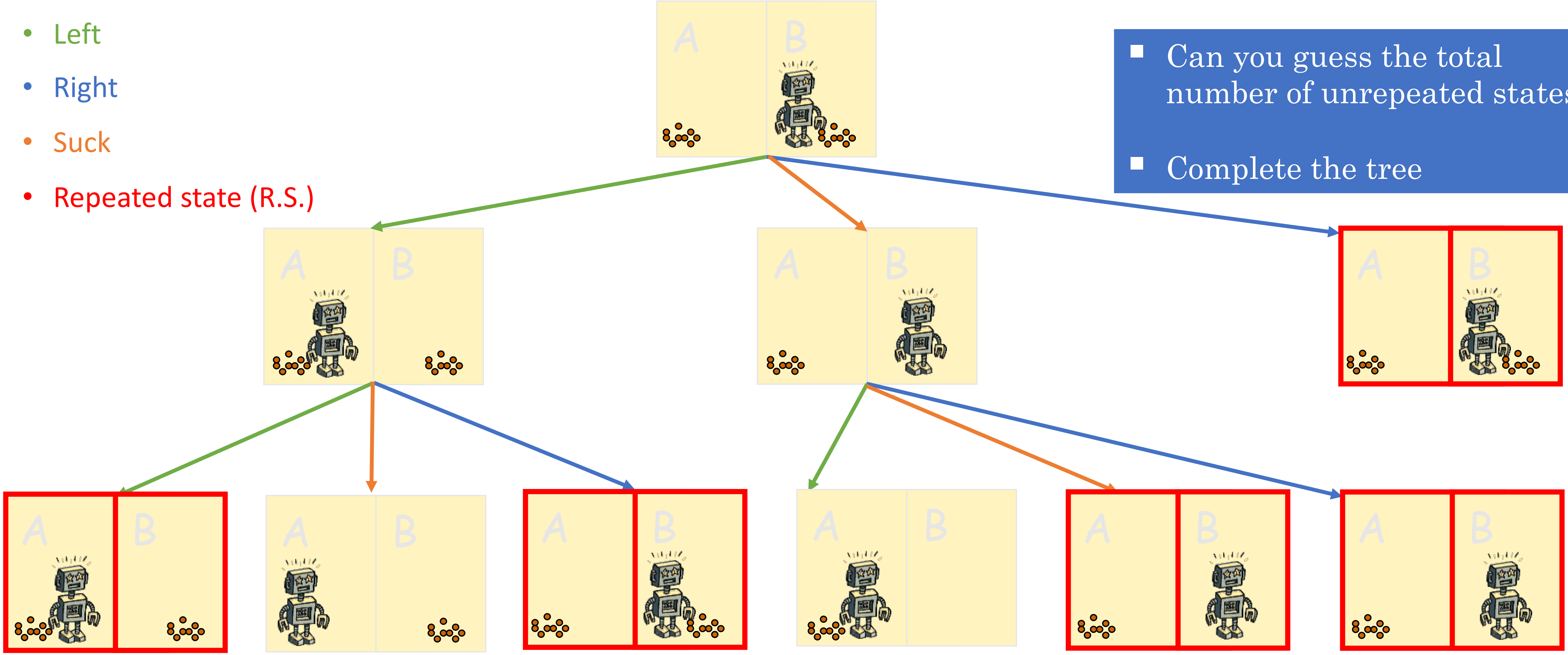
- If the initial state is known, for simplicity, the **state space** can also be drawn as a **tree**.

- We designate an initial state for the vacuum world:



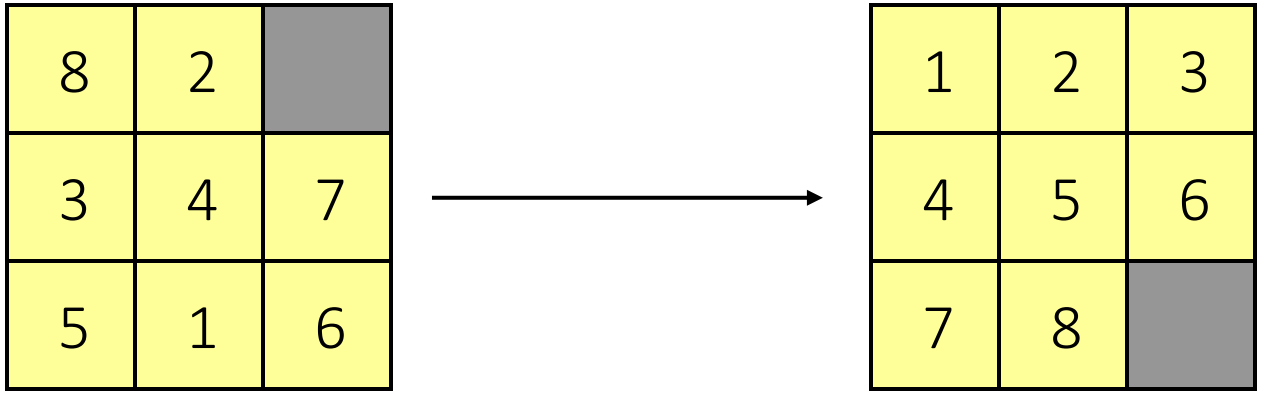
Vacuum World State Space: A Tree

- Left
- Right
- Suck
- Repeated state (R.S.)



- Can you guess the total number of unrepeated states?
- Complete the tree

Exercise: Formulate the search problem: 8-puzzle



- State representation? position of numbers
- Initial state? any
- Actions? moving adjacent cells LEFT RIGHT UP DOWN
- Transition Model?
- Goal test? ordered
- Path cost sum of actions

More Examples:

Text book, Section 3.2, P (69-75)