Attendance

- If you registered late, please listen to Week 1's lecture on iCampus by the end of Week 2 (Sunday) to get attendance approved
- All holiday replacement pre-recorded lectures will be automatically ticked for attendance on iCampus – listen before deadline
- Your offline class attendance will be manually ticked on iCampus by the end of the week – please wait one week before informing me if your attendance was not ticked for a particular class that you had attended the week before
- If you are going to be absent due to medical or other official reasons, please inform me **before** the class or within 24 hours
  - The date(s) of absence
  - The reason for absence: provide substantial evidence containing your name and date (e.g. medical certificate)
  - Aesthetic surgeries are **not** accepted as valid reasons for missing a quiz or exam (unless there is a proper justification for it)

Problem-solving Agents:
2.1 Formulating Problems

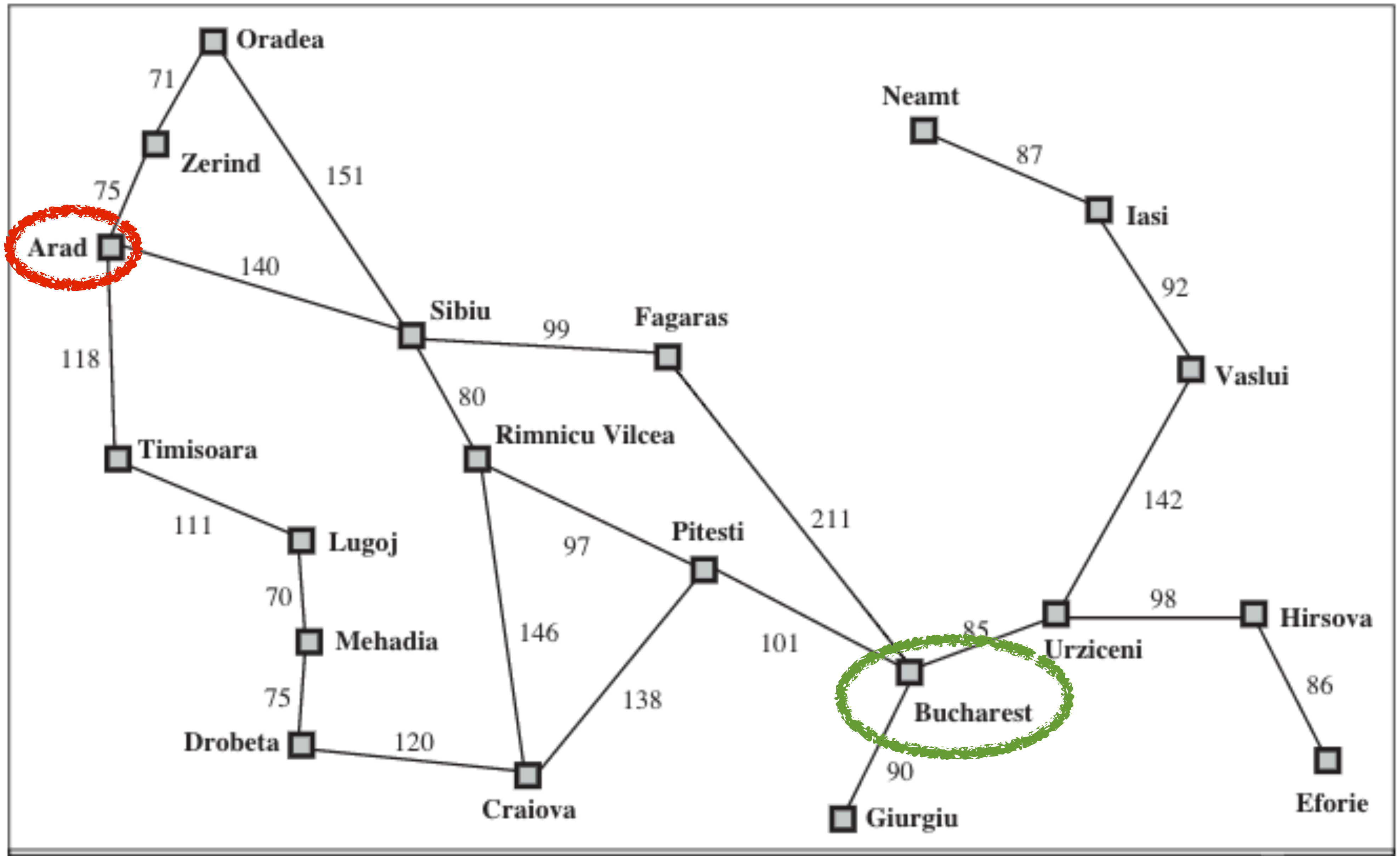
Outline

- Goal and Problem formulation
- Search
- Well-defined Problems
- Example Problems

Goals & Problem Formulation

- State – a representation of a physical configuration; a snapshot of the world at a given time step
- A state is a summary of all past actions sufficient to choose future actions optimally
- Goal – a set of world states, exactly in which the goal is satisfied
    - Be in Busan
- Problem formulation – process of deciding what actions and states to consider, given a goal
    - Action of driving from one city to another

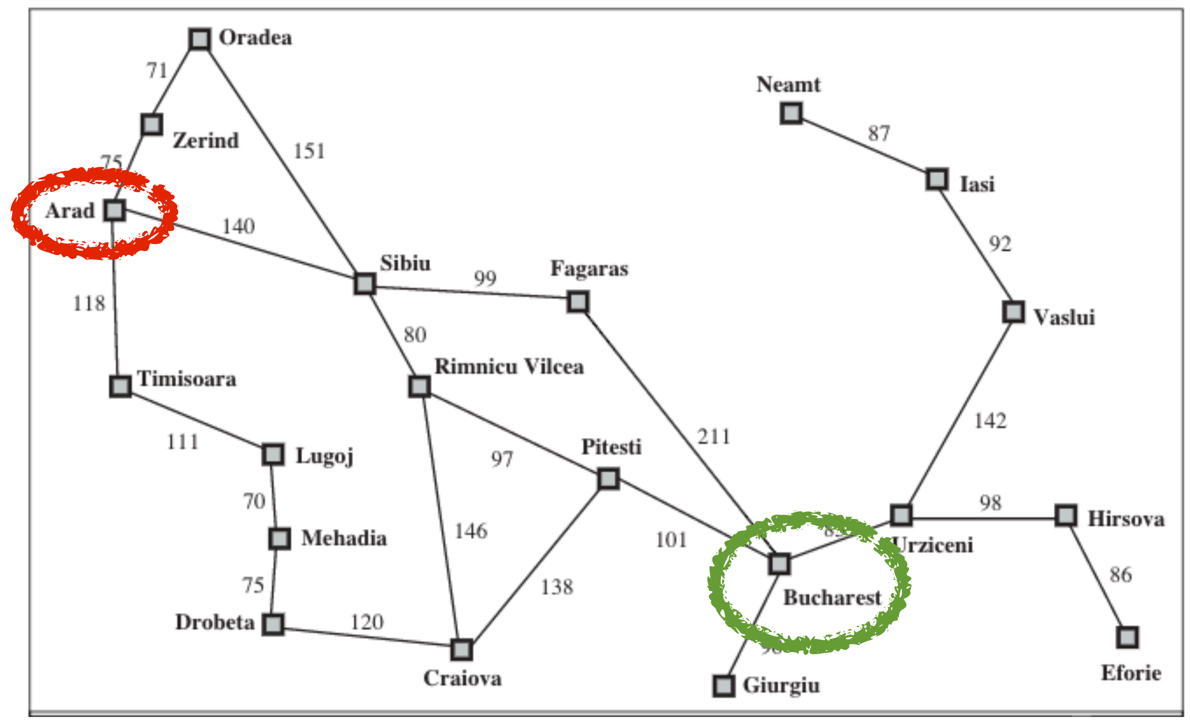
Romania



Initial state: current location is Arad

Problem-solving Sequence

- Initial state:
  - Arad
- Formulate goal:
  - Be in Bucharest
- Formulate problem:
  - states: cities
  - actions: drive between cities
- Formulate solution:
  - Sequence of cities: Arad, Sibiu, Fagaras, Bucharest



➡ Solution is a fixed sequence of actions if environment is observable, discrete, known(map), deterministic

Search

- The process of looking for a sequence of actions that reaches the goal
- A search algorithm takes a problem as input and returns a solution in the form of a sequence of actions
- Once a solution is found, the sequence of actions can be carried out or executed
- formulate ➔ search ➔ execute
- More details on search in the next few lectures

Well-defined Problems

- Goal test – check that a given (current) *state* is the goal state, e.g. $In(Bucharest)$
- Sometimes goal is an *abstract property*, e.g. “checkmate” in Chess
- Transition model is a description of what each action does – $Result(s, a)$ returns the successor state from doing action a in state s

$$Result(In(Arad), Go(Zerind)) = In(Zerind)$$

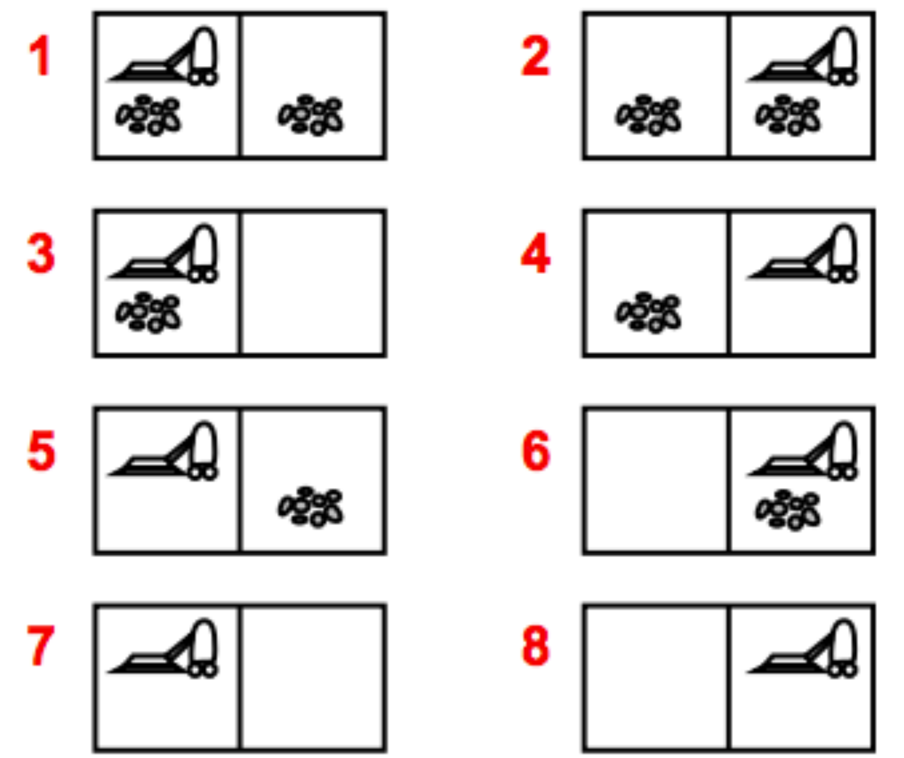
- Path cost function assigns *numeric* cost to each path, the agent chooses a cost function that reflects its own performance measure, e.g. in vacuum world: the number of steps in the path
- An optimal solution is a solution (action sequence) that has the lowest path cost among all solutions

Problem Types

- Deterministic, fully observable → single-state problem
  - agent knows exactly which state it will be in
  - solution is a sequence
- Non-observable → conformant problem
  - agent may have no idea where it is
  - solution (if any) is a sequence
- Nondeterministic and/or partially observable → contingency problem
  - percepts provide new information about current state
  - solution is contingent plan or policy, often interleave search and execution
- Unknown state space → exploration problem (“online”)

Vacuum World Problem Types

- Single-state: start in #5. Solution?
  - *[Right, Suck]*
- Conformant: start anywhere {1, 2, 3, 4, 5,... , 8}. Solution?
  - *[Right, Suck, Left, Suck]*
- Contingency: start in #5, Suck can make a clean carpet dirty. Solution?
  - *[Right,* if *Dirty* then *Suck]*



All the possible states for the vacuum world problem with 2 squares

Single-state Problem Formulation

- Problem definition

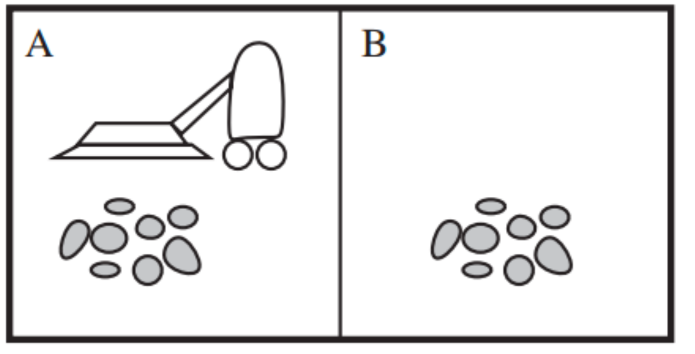
  1. Initial State, e.g. In Arad, In state #5
  2. Successor function, $S(x)$ = set of action-state pairs, e.g. $S(Arad) = \{<Arad \rightarrow Zerind, Zerind>, \ldots\}$
  3. Goal test, can be explicit e.g. "In Bucharest" or implicit e.g. $NoDirt(x)$
  4. Path cost (additive), e.g. sum of distances, number of actions executed, etc

- Solution is a sequence of actions leading from the initial state to the goal state

Example Problems

Toy Problem – Vacuum World

- States agent location, dirt locations. Agent can be in one of 2 locations and each location may contain dirt. $n \times 2^n = 2 \times 2^n = 8$ possible states

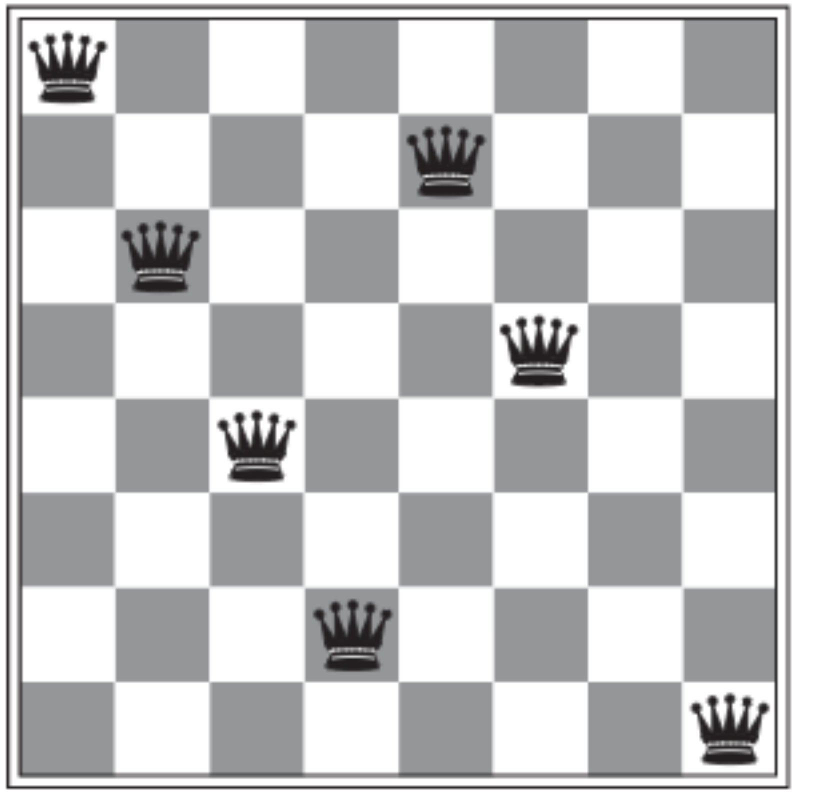


- Initial state Any one of the states
- Actions *Left*, *Right*, *Suck*, *NoOp*
- Transition model Actions should have their expected effects, except for moving left from the leftmost square, and right from the rightmost square. Sucking in a clean square has no effect.
- Goal test Check that all squares are clean
- Path cost Each step taken costs 1, so path cost is the number of steps in the path OR 1 per action (0 for *NoOp*)

Toy problem – 8-queens

- States any arrangement of 0 to 8 queens on the board
- Initial state no queens on the board
- Actions add/move a queen to an empty square
- Transition model returns the board with a queen added to the specified square
- Goal test 8 queens on the board, none attacked
- Improved formulation:
  - **States** all possible arrangements of n queens ($0 \leq n \leq 8$), one per column in the leftmost n columns, with no queen attacking another
  - **Actions** add a queen to any square in the leftmost empty column such that it is not attacked by any other queen

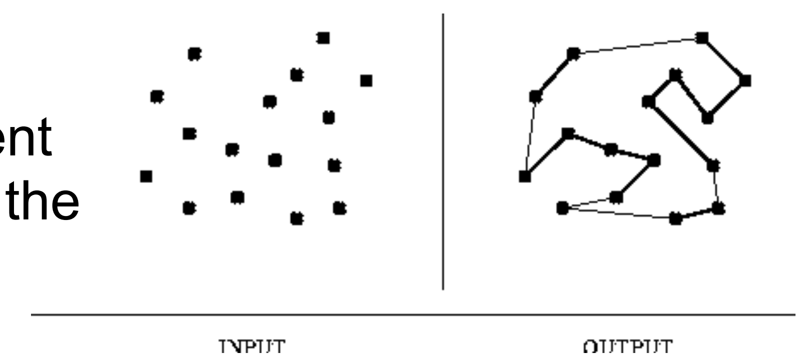
➡Reduces state space from 1.8×10^{14} to just 2,057



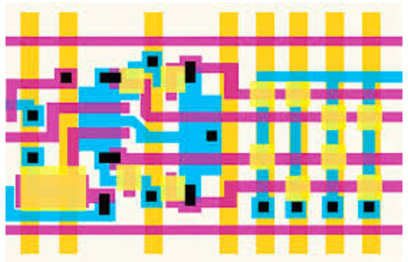
Goal: to place 8 queens on a chessboard such that no queen attacks any other. (A queen attacks any piece in the same row, column or diagonal)

Real World Problems

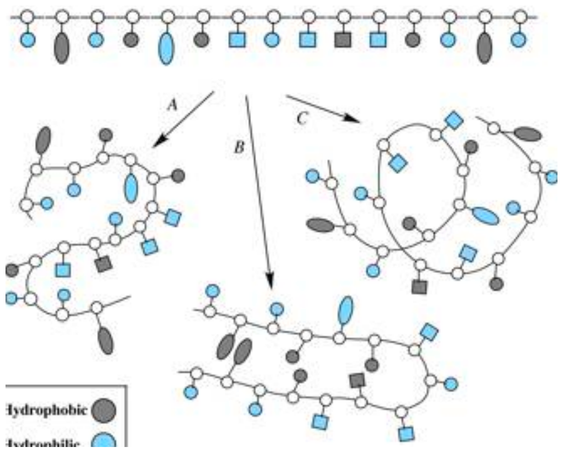
- Route-finding problem – airline travel-planning
- Touring problems – closely related to route-finding with different state space; each state must include the current location <u>and</u> the set of cities the agent has visited.
  - Travelling salesman problem (TSP) visit each city exactly once



- VLSI (Very large-scale integration) layout – positioning millions of components and connections on a chip to minimise area, circuit delays, minimise stray capacitances and maximise manufacturing yields. Split into cell layout and channel routing

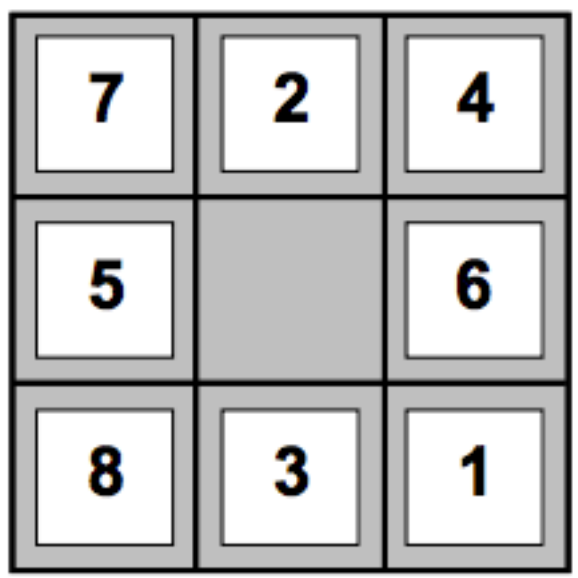


- Robot navigation – generalisation of route-finding problem; robot can move in a continuous space with an infinite set of possible actions and states
- Automatic assembly sequencing & protein design – aims are to find an order in which to assemble the parts of some object & to find a sequence of amino acids that will fold into a three-dimensional protein with the right properties to cure some disease

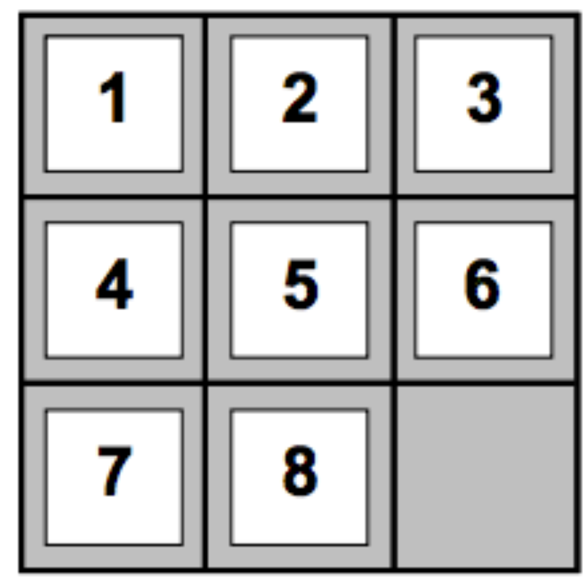


Exercise

* Define the 8-puzzle game in terms of states, actions, goal test and path cost



Start State



Goal State

* states??
* actions??
* goal test??
* path cost??

Summary

- Looked at problem-solving agent's goals, states and solution
- Defined the problem better with initial states, transition models and path cost for optimal solutions
- Introduced the notion of search as the process of get from an initial state to the goal state
- Different types of problems
  - Toy and real world examples

References

- Russel and Norvig, Chapter 3.1–3.2