

Foundations of Artificial Intelligence

B2. State-Space Search: Representation of State Spaces

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B2.1 Representation of State Spaces

B2.2 Explicit Graphs

B2.3 Declarative Representations

B2.4 Black Box

B2.5 Summary

State-Space Search: Overview

Chapter overview: state-space search

- ▶ B1–B3. Foundations
 - ▶ B1. State Spaces
 - ▶ B2. Representation of State Spaces
 - ▶ B3. Examples of State Spaces
- ▶ B4–B8. Basic Algorithms
- ▶ B9–B15. Heuristic Algorithms

B2.1 Representation of State Spaces

Representation of State Spaces

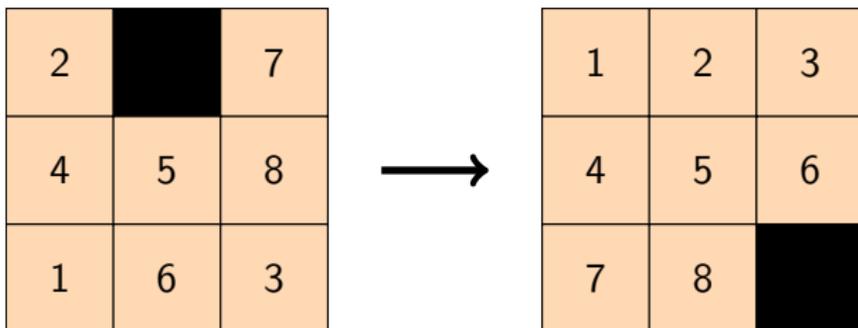
- ▶ practically interesting state spaces are often **huge** (10^{10} , 10^{20} , 10^{100} states)
- ▶ How do we **represent** them, so that we can efficiently deal with them algorithmically?

three main options:

- 1 as **explicit** (directed) graphs
- 2 with **declarative** representations
- 3 as a **black box**

German: explizit, deklarativ, Black Box

Example: 8-Puzzle



B2.2 Explicit Graphs

State Spaces as Explicit Graphs

State Spaces as Explicit Graphs

represent state spaces as **explicit directed graphs**:

- ▶ vertices = states
- ▶ directed arcs = transitions

↔ represented as **adjacency list** or **adjacency matrix**

German: Adjazenzliste, Adjazenzmatrix

Example (explicit graph for bounded inc-and-square)

`ai-b02-bounded-inc-and-square.graph`

State Spaces as Explicit Graphs

State Spaces as Explicit Graphs

represent state spaces as **explicit directed graphs**:

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↔ represented as **adjacency list** or **adjacency matrix**

German: Adjazenzliste, Adjazenzmatrix

Example (explicit graph for 8-puzzle)

ai-b02-puzzle8.graph

State Spaces as Explicit Graphs: Discussion

discussion:

- ▶ **impossible** for **large** state spaces (too much space required)
- ▶ if spaces small enough for explicit representations, solutions easy to compute: **Dijkstra's algorithm**
 $O(|S| \log |S| + |T|)$
- ▶ interesting for time-critical **all-pairs-shortest-path** queries
(examples: route planning, path planning in video games)

B2.3 Declarative Representations

State Spaces with Declarative Representations

State Spaces with Declarative Representations

represent state spaces **declaratively**:

- ▶ **compact** description of state space as input to algorithms
 \rightsquigarrow state spaces **exponentially larger** than the input
- ▶ algorithms directly operate on compact description
- \rightsquigarrow allows automatic reasoning about problem:
 reformulation, simplification, abstraction, etc.

Example (declarative representation for 8-puzzle)

`puzzle8-domain.pddl + puzzle8-problem.pddl`

B2.4 Black Box

State Spaces as Black Boxes

State Spaces as Black Boxes

Define an **abstract interface** for state spaces.

For state space $\mathcal{S} = \langle S, A, cost, T, s_1, S_G \rangle$

we need these methods:

- ▶ **init()**: generate initial state
result: state s_1
- ▶ **is_goal(s)**: test if s is a goal state
result: **true** if $s \in S_G$; **false** otherwise
- ▶ **succ(s)**: generate applicable actions and successors of s
result: sequence of pairs $\langle a, s' \rangle$ with $s \xrightarrow{a} s'$
- ▶ **cost(a)**: gives cost of action a
result: $cost(a) (\in \mathbb{N}_0)$

Remark: we will extend the interface later
in a small but important way

State Spaces as Black Boxes: Example and Discussion

Example (Black Box Representation for 8-Puzzle)

demo: `puzzle8.py`

- ▶ in the following: focus on black box model
- ▶ explicit graphs only as illustrating examples
- ▶ near end of semester: declarative state spaces
(classical planning)

B2.5 Summary

Summary

- ▶ state spaces often **huge** ($> 10^{10}$ states)
 \rightsquigarrow **how to represent?**
- ▶ **explicit graphs**: adjacency lists or matrices;
 only suitable for small problems
- ▶ **declaratively**: compact description as input
 to search algorithms
- ▶ **black box**: implement an abstract interface