

Foundations of Artificial Intelligence

6. State-Space Search: Representation of State Spaces

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6.1 Representation of State Spaces

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6.3 Declarative Representations

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6.5 Summary

State-Space Search: Overview

Chapter overview: state-space search

- ▶ 5.–7. Foundations
 - ▶ 5. State Spaces
 - ▶ 6. Representation of State Spaces
 - ▶ 7. Examples of State Spaces
- ▶ 8.–12. Basic Algorithms
- ▶ 13.–19. Heuristic Algorithms

6.1 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: explizite Graphen, deklarative Repräsentationen, Black Box

6.2 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: Adjazenliste, Adjazenzmatrix

Example (explicit graph for 8-puzzle)

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)

6.3 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
 ↪ state spaces **exponentially larger** than the input
- ▶ algorithms directly operate on compact description
- ↪ allows automatic reasoning about problem:
 reformulation, simplification, abstraction, etc.

Example (declarative representation for 8-puzzle)

puzzle8-domain.pddl + puzzle8-problem.pddl

6.4 Black Box

State Spaces as Black Boxes

State Spaces as Black Boxes

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

For state space $\mathcal{S} = \langle S, A, cost, T, s_0, S_* \rangle$

we need these methods:

- ▶ **init()**: generate initial state
 result: state s_0
- ▶ **is_goal(s)**: test if s is a goal state
 result: **true** if $s \in S_*$; **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)

6.5 Summary

Summary

- ▶ state spaces often huge ($> 10^{10}$ states)
~> 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