Foundations of Artificial Intelligence

33. Automated Planning: Introduction

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Classification

classification:

Automated Planning

environment:

- static vs. dynamic
- deterministic vs. non-deterministic vs. stochastic
- fully vs. partially vs. not observable
- discrete vs. continuous
- single-agent vs. multi-agent

problem solving method:

- problem-specific vs. general vs. learning

33.1 Introduction

Automated Planning

What is Automated Planning?
"Planning is the art and practice of thinking before acting."
— P. Haslum

⇝ finding plans (sequences of actions)
that lead from an initial state to a goal state

our topic in this course: classical planning

- general approach to finding solutions for state-space search problems (Chapters 5–19)
- classical = static, deterministic, fully observable
- variants: probabilistic planning, planning under partial observability, online planning, ...

Planning: Informally

given:

- state space description in terms of suitable problem description language (planning formalism)

required:

- a plan, i.e., a solution for the described state space (sequence of actions from initial state to goal)
- or a proof that no plan exists

distinguish between

- optimal planning: guarantee that returned plans are optimal, i.e., have minimal overall cost
- suboptimal planning (satisficing): suboptimal plans are allowed

What is New?

Many previously encountered problems are planning tasks:

- blocks world
- missionaries and cannibals
- 15-puzzle

New: we are now interested in general algorithms, i.e., the developer of the search algorithm does not know the tasks that the algorithm needs to solve.

⇝ no problem-specific heuristics!

⇝ input language to model the planning task

Automated Planning: Overview

Chapter overview: automated planning

33.2 Repetition: State Spaces

About This Section

Nothing New Here!

This section is a repetition of Section 5.2
of the chapter "State-Space Search: State Spaces".

State Spaces

To cleanly study search problems we need a formal model.

Definition (state space)

A state space or transition system is a
6-tuple $\mathcal{S} = \langle S, A, cost, T, s_I, S_\star \rangle$ with

- finite set of states S
- finite set of actions A
- action costs $cost : A \to \mathbb{R}_0^+$
- transition relation $T \subseteq S \times A \times S$ that is deterministic in $\langle s, a \rangle$ (see next slide)
- initial state $s_I \in S$
- set of goal states $S_\star \subseteq S$

State Spaces: Terminology & Notation

Definition (transition, deterministic)

Let $\mathcal{S} = \langle S, A, cost, T, s_I, S_\star \rangle$ be a state space.

The triples $\langle s, a, s' \rangle \in T$ are called (state) transitions.

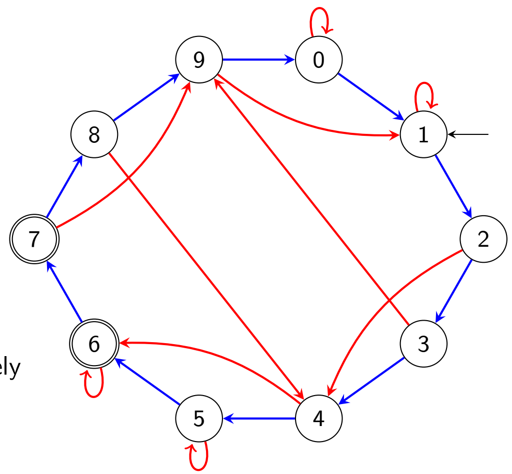
We say $\mathcal{S}$ has the transition $\langle s, a, s' \rangle$ if $\langle s, a, s' \rangle \in T$.
We write this as $s \xrightarrow{a} s'$, or $s \to s'$ when a does not matter.

Transitions are deterministic in $\langle s, a \rangle$: it is forbidden to have
both $s \xrightarrow{a} s_1$ and $s \xrightarrow{a} s_2$ with $s_1 \neq s_2$.

Graph Interpretation

state spaces are often depicted as directed, labeled graphs

- states: graph vertices
- transitions: labeled arcs
  (here: colors instead of labels)
- initial state: incoming arrow
- goal states: double circles
- actions: the arc labels
- action costs: described separately
  (or implicitly $= 1$)



State Spaces: Terminology

terminology:
- predecessor, successor
- applicable action
- path, length, costs
- reachable
- solution, optimal solution

33.3 Compact Descriptions

State Spaces with Declarative Representations

How do we represent state spaces in the computer?

previously: as black box

now: as declarative description

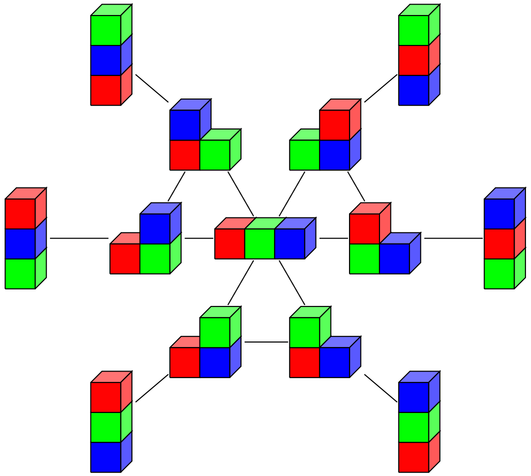
reminder: Chapter 6

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.

Reminder: Blocks World



problem: n blocks $\rightsquigarrow$ more than $n!$ states

Compact Description of State Spaces

How to describe state spaces compactly?

Compact Description of Several States

- introduce state variables
- states: assignments to state variables
- $\rightsquigarrow$ e.g., n binary state variables can describe 2^n states
- transitions and goal are compactly described with a logic-based formalism

different variants: different planning formalisms

33.4 Summary

Summary

- planning: search in general state spaces
- input: compact, declarative description of state space