Foundations of Artificial Intelligence

33. Automated Planning: Introduction

Malte Helmert and Gabriele Röger

University of Basel

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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

Introduction

Automated Planning

What is Automated Planning?

"Planning is the art and practice of thinking before acting."

— P. Haslum

$\rightsquigarrow$ 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 5–21)
- 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.

- $\rightsquigarrow$ no problem-specific heuristics!
- $\rightsquigarrow$ input language to model the planning task

Planning: Overview

Chapter overview: planning

- 33. Introduction
- 34. Planning Formalisms
- 35.–39. Planning Heuristics

Repetition: State Spaces

About Section

Nothing New Here!

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

Formalization of State Spaces

preliminary remarks:

- To properly handle search problems algorithmically, we need a formal definition.
- basic semantic concept: state spaces
- state spaces are (annotated) graphs
- paths to goal states correspond to solutions

State Spaces

Definition (state space)

A state space is a 6-tuple $\mathcal{S} = \langle S, A, cost, T, s_0, S_\star \rangle$ with

- S finite set of states
- A finite set of actions
- $cost : A \to \mathbb{R}_0^+$ action costs
- $T \subseteq S \times A \times S$ transition relation; deterministic in $\langle s, a \rangle$ (see next slide)
- $s_0 \in S$ initial state
- $S_\star \subseteq S$ set of goal states

- also: transition system
- German: Zustandsraum, Zustand, Aktion, Aktionskosten, Übergangsrelation (Transitionsrelation), Anfangszustand, Zielzustände

State Spaces: Transitions, Determinism

Definition (transition, deterministic)

Let $\mathcal{S} = \langle S, A, cost, T, s_0, S_\star \rangle$ be a state space.

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

We say "$\mathcal{S}$ has the transition $\langle s, a, s' \rangle$" if $\langle s, a, s' \rangle \in T$,
and we write $s \xrightarrow{a} s'$, or $s \to s'$ if not interested in a.

Transitions are deterministic in $\langle s, a \rangle$:
$s \xrightarrow{a} s_1$ and $s \xrightarrow{a} s_2$ with $s_1 \neq s_2$ is not allowed.

State Spaces: Terminology

terminology:

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

German: Vorgänger, Nachfolger, anwendbare Aktion, Pfad, Länge, Kosten, erreichbar, Lösung, optimale Lösung

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

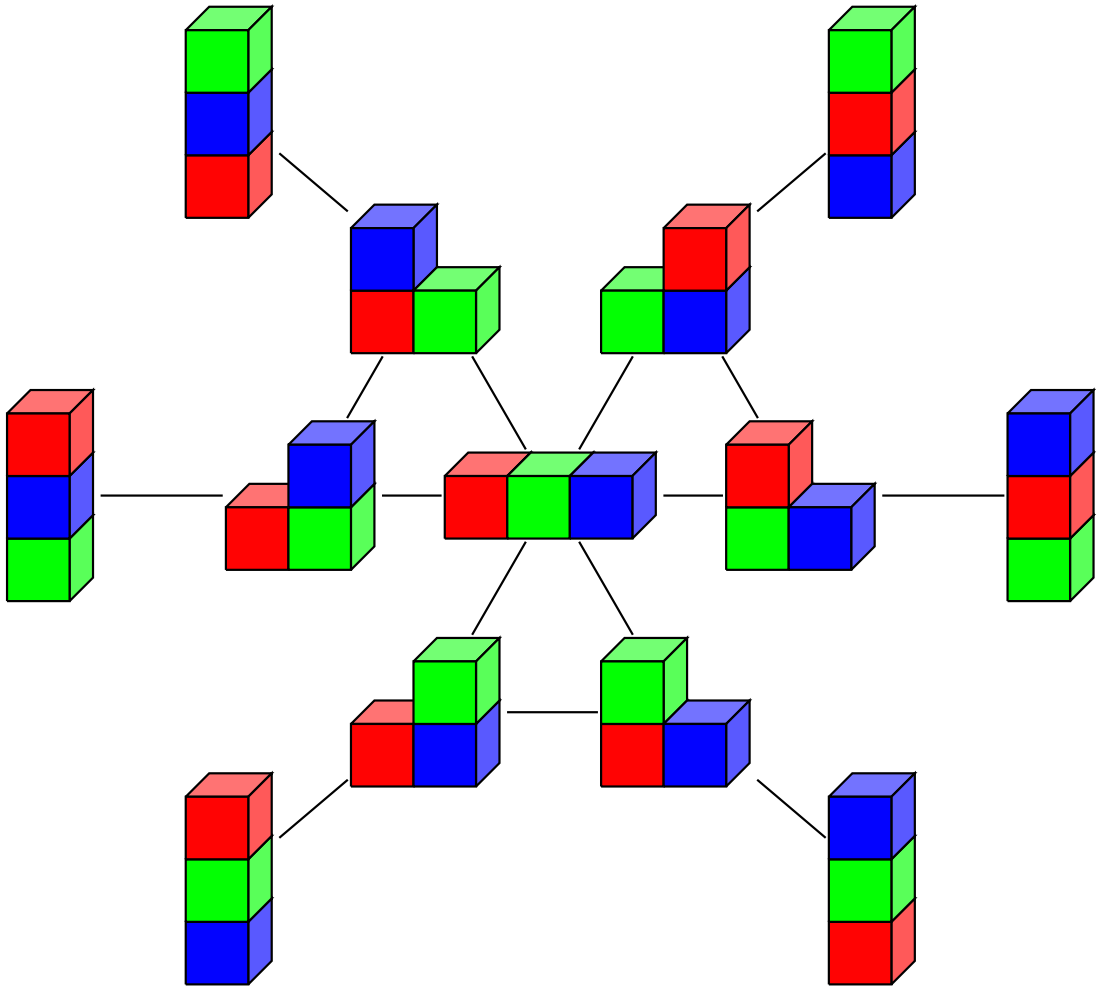
State Spaces with Declarative Representations

represent state spaces declaratively:

- compact description of state space as input for algorithms
  $\rightsquigarrow$ state space exponentially larger than input
- algorithms work directly on compact description

$\rightsquigarrow$ allows for automatic problem reformulation, simplification, abstraction, ...

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

Summary

Summary

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