

Principles of AI Planning

1. Introduction

Albert-Ludwigs-Universität Freiburg



Bernhard Nebel and Robert Mattmüller

October 22nd, 2014

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- Coordinates
- Rules

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People



Lecturers

Prof. Dr. Bernhard Nebel

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- **office:** room 052-00-029
- **consultation:** Tuesday, 12:15-13:00

Dr. Robert Mattmüller

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- **office:** room 052-00-045
- **consultation:** by appointment (email) or just drop by in the office

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Exercises

Robert Mattmüller

David Speck

- **email:** david.speck@pluto.uni-freiburg.de
- **consultation:** by appointment (email)

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Lectures

- **time:** Wednesday 14:15-16:00, Friday 14:15-15:00
- **place:** SR 101-00-010/14

Exercises

- **time:** Friday 15:15-16:00
- **place:** SR 101-00-010/14

Course web site

<http://gki.informatik.uni-freiburg.de/teaching/ws1415/aip/>

- **main page:** course description
- **lecture page:** slides
- **exercise page:** assignments, software
- **bibliography page:** literature references and papers

- no script, no recommended textbook (although two textbooks exist, but they are not necessary for this course)
 - Geffner and Bonet (2013), A Concise Introduction to Models and Methods for Automated Planning (comes closest to this course, includes relatively recent research results)
 - Nau, Ghallab, and Traverso (2004), Automated Planning: Theory and Practice (very different from this course, a bit outdated)
- slides handed out during lectures and available on the web
- additional resources: bibliography page on web + **ask us!**

Acknowledgments:

- slides based on earlier courses by Jussi Rintanen, Bernhard Nebel and Malte Helmert
- many figures by Gabi Röger

Target audience



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Students of Computer Science:

- Master of Science, any year
- Bachelor of Science, ~3rd year

Other students:

- advanced study period (~4th year)

Prerequisites



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Course prerequisites:

- **propositional logic**: syntax and semantics
- **foundations of AI**: search, heuristic search
- **computational complexity theory**: decision problems, reductions, NP-completeness

Credit points & exam



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- 6 ECTS points
- special lecture in specialization field
Cognitive Technical Systems
- **oral exam** of about 30 minutes for B.Sc. students
- **written or oral exam** for M.Sc. students
(depending on their number)

Exercises



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Exercises (written assignments):

- handed out once a week
- due one week later, before the lecture
- discussed in the next exercise session
- may be solved in groups of two students ($2 \neq 3$)
- successful participation prerequisite for exam admission

- points can be earned for “reasonable” solutions to exercises.
- at least 50% of points prerequisite for admission to final exam.

What is plagiarism?

- passing off solutions as your own that are not based on your ideas (work of other students, Internet, books, ...)
- <http://en.wikipedia.org/wiki/Plagiarism> is a good intro

Consequence: no admission to the final exam.

- We may (!) be generous on first offense.
- Don't tell us “We did the work together.”
- Don't tell us “I did not know this was not allowed.”

- What is planning?
- Problem classes
- Dynamics
- Observability
- Objectives
- Planning vs. game theory
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Planning

“Planning is the art and practice of thinking before acting.”
— Patrik Haslum

- intelligent decision making: What actions to take?
- general-purpose problem representation
- algorithms for solving any problem expressible in the representation
- application areas:
 - high-level planning for intelligent robots
 - autonomous systems: NASA Deep Space One, ...
 - problem solving (single-agent games like Rubik's cube)

Why is planning difficult?



- solutions to classical planning problems are **paths from an initial state to a goal state** in the **transition graph**
 - efficiently solvable by Dijkstra's algorithm in $O(|V| \log |V| + |E|)$ time
 - Why don't we solve all planning problems this way?
- state spaces may be **huge**: $10^{10}, 10^{100}, 10^{1000}, \dots$ states
 - constructing the transition graph is infeasible!
 - planning algorithms try to **avoid constructing whole graph**
- planning algorithms are often much more efficient than obvious solution methods constructing the transition graph and using e.g. Dijkstra's algorithm

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Different classes of problems



- **dynamics**: deterministic, nondeterministic or probabilistic
 - **observability**: full, partial or none
 - **horizon**: finite or infinite
 - ...
- 1 classical planning
 - 2 conditional planning with full observability
 - 3 conditional planning with partial observability
 - 4 conformant planning
 - 5 Markov decision processes (MDP)
 - 6 partially observable MDPs (POMDP)

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Properties of the world: dynamics

Deterministic dynamics

Action + current state **uniquely** determine successor state.

Nondeterministic dynamics

For each action and current state there may be **several possible** successor states.

Probabilistic dynamics

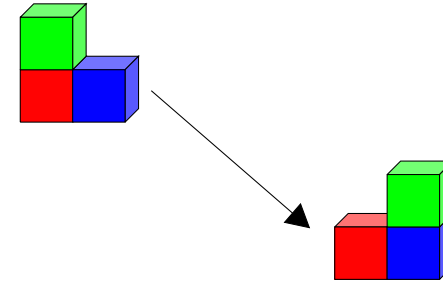
For each action and current state there is a **probability distribution** over possible successor states.

Analogy: deterministic versus nondeterministic automata

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Deterministic dynamics example

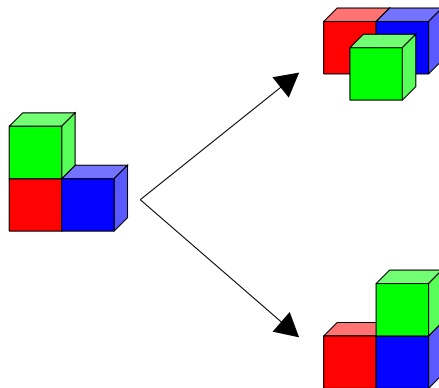
Moving objects with a robotic hand:
move the green block onto the blue block.



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Nondeterministic dynamics example

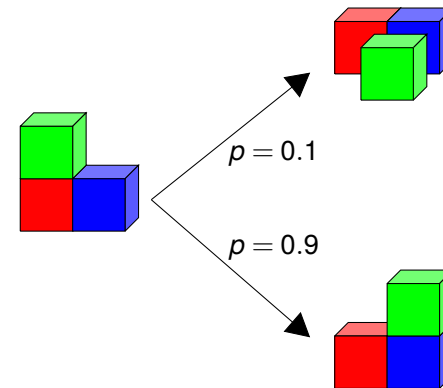
Moving objects with an **unreliable** robotic hand:
move the green block onto the blue block.



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Probabilistic dynamics example

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Properties of the world: observability

Full observability

Observations determine current world state **uniquely**.

Partial observability

Observations determine current world state **only partially**: we only know that current state is one of several possible ones.

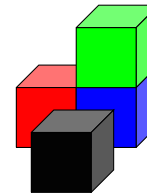
No observability

There are **no observations** to narrow down possible current states. However, can use knowledge of **action dynamics** to deduce which states we might be in.

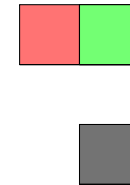
Consequence: If observability is not full, must represent the **knowledge** an agent has.

What difference does observability make?

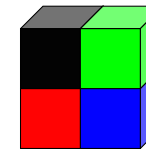
Camera A



Camera B



Goal



Different objectives

- 1 Reach a goal state.
 - **Example**: Earn 500 Euro.
- 2 Stay in goal states indefinitely (infinite horizon).
 - **Example**: Never allow bank account balance to be negative.
- 3 Maximize the probability of reaching a goal state.
 - **Example**: To be able to finance buying a house by 2024 study hard and save money.
- 4 Collect the maximal **expected** rewards/minimal expected costs (infinite horizon).
 - **Example**: Maximize your future income.
- 5 ...

Relation to games and game theory

- Game theory addresses decision making in multi-agent setting: "Assuming that the other agents are rational, what do I have to do to achieve my goals?"
- Game theory is related to **multi-agent planning**.
- In this course we concentrate on **single-agent planning**.
- Some of the techniques are also applicable to special cases of multi-agent planning.
 - **Example**: Finding a **winning strategy** of a game like chess. In this case it is not necessary to distinguish between an **intelligent opponent** and a **randomly behaving opponent**.
- Game theory in general is about **optimal strategies** which do not necessarily guarantee winning. For example card games like poker do not have a winning strategy.

What do you learn in this course?



- emphasis on **classical** planning (“simplest” case)
- brief digression to **nondeterministic** planning
- **theoretical background** for planning
 - formal **problem definition**
 - basic **theoretical notions**
(e. g., normal forms, progression, regression)
 - **computational complexity** of planning
- **algorithms** for planning:
 - based on **heuristic search**

Many of these techniques are applicable to problems outside AI as well.

- **hands-on experience** with a classical planner (probably)

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