

Planning and Optimization

A2. What is Planning?

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— A2. What is Planning?

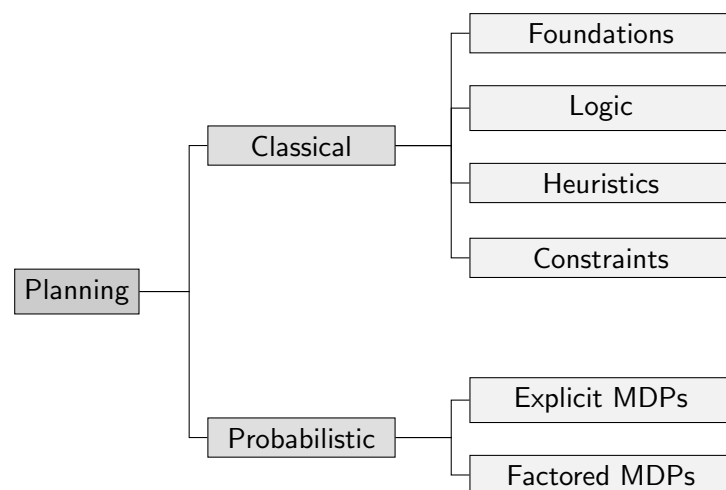
A2.1 Planning

A2.2 Planning Task Examples

A2.3 How Hard is Planning?

A2.4 Summary

Content of this Course



Before We Start. . .

today: a very high-level introduction to planning

- ▶ our goal: give you a little feeling what planning is about
- ▶ **preface** to the actual course
- ↪ main course content (beginning with Chapter A3) will be mathematically formal and rigorous
- ▶ You can ignore this chapter when preparing for the exam.

A2.1 Planning

General Problem Solving

Wikipedia: General Problem Solver

General Problem Solver (GPS) was a computer program created in 1959 by Herbert Simon, J.C. Shaw, and Allen Newell intended to work as a universal problem solver machine.

Any formalized symbolic problem can be solved, in principle, by GPS. [...]

GPS was the first computer program which separated its knowledge of problems (rules represented as input data) from its strategy of how to solve problems (a generic solver engine).

⇒ these days called “domain-independent automated **planning**”

⇒ this is what the course is about

So What is Domain-Independent Automated Planning?

Automated Planning (Pithy Definition)

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

— Patrik Haslum

Automated Planning (More Technical Definition)

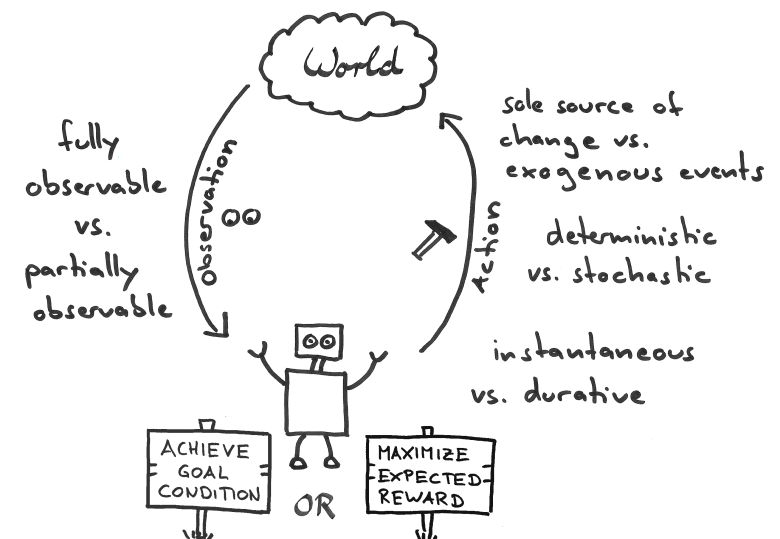
“Selecting a goal-leading course of action based on a high-level description of the world.”

— Jörg Hoffmann

Domain-Independence of Automated Planning

Create **one** planning algorithm that performs sufficiently well on **many** application domains (including future ones).

General Perspective on Planning

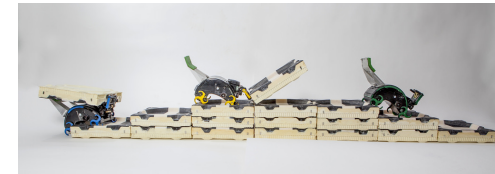


Example: Earth Observation



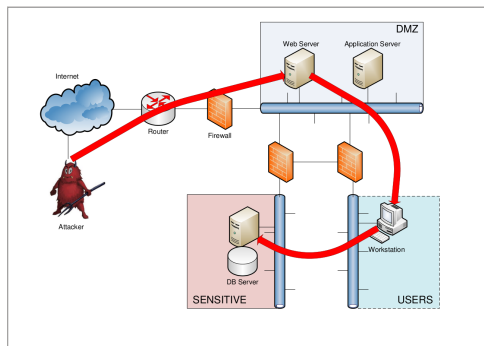
- ▶ satellite takes images of patches on Earth
- ▶ use [weather forecast](#) to optimize probability of high-quality images

Example: Termes



Harvard TERMES robots, based on termites

Example: Cybersecurity



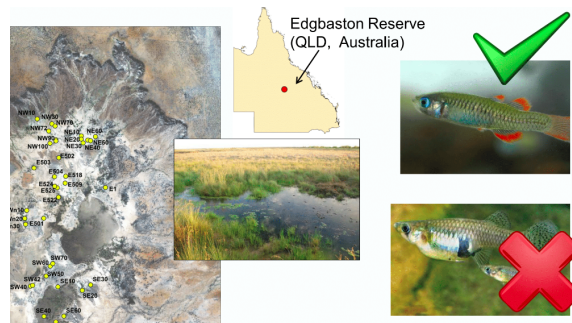
CALDERA automated adversary emulation system

Example: Intelligent Greenhouse



photo © LemnaTec GmbH

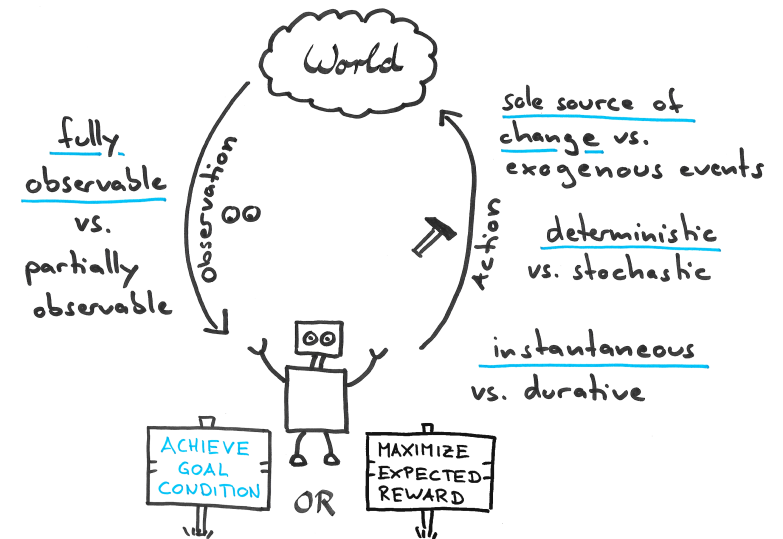
Example: Red-finned Blue-eye



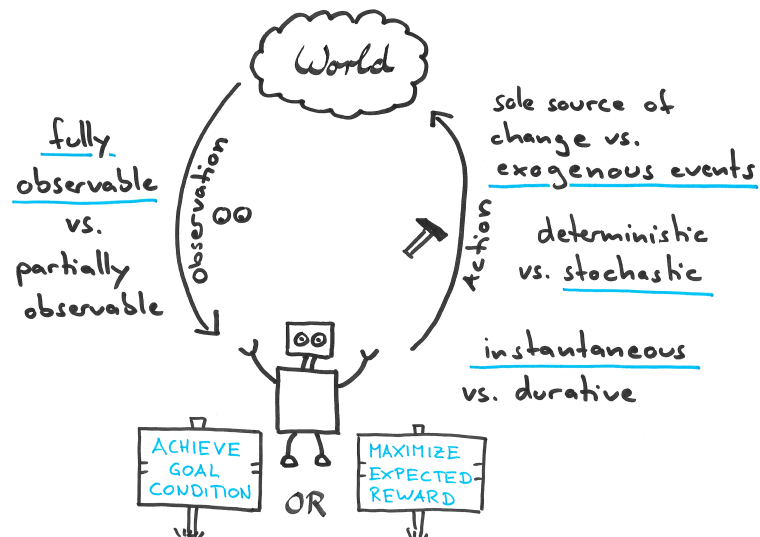
Picture by Iadine Chadès

- ▶ red-finned blue-eye population threatened by gambusia
- ▶ springs connected probabilistically during rain season
- ▶ find strategy to save red-finned blue-eye from extinction

Classical Planning



Probabilistic Planning



Model-based vs. Data-driven Approaches



Model-based approaches know the "inner workings" of the world
 ~ reasoning



Data-driven approaches rely only on collected data from a black-box world
 ~ learning

We focus on model-based approaches.

Planning Tasks

input to a planning algorithm: **planning task**

- ▶ initial state of the world
- ▶ actions that change the state
- ▶ goal to be achieved

output of a planning algorithm:

- ▶ **plan** (classical setting)
 - ▶ sequence of actions that takes initial state to a goal state
- ▶ **policy** (probabilistic setting)
 - ▶ function that returns for each state the action to take
- ▶ Why different concepts?

⇒ formal definitions later in the course

The Planning Research Landscape

- ▶ one of the major subfields of Artificial Intelligence (AI)
- ▶ represented at major AI conferences (IJCAI, AAAI, ECAI)
- ▶ annual specialized conference ICAPS (≈ 250 participants)
- ▶ major journals: general AI journals (AIJ, JAIR)

A2.2 Planning Task Examples

Example: The Seven Bridges of Königsberg

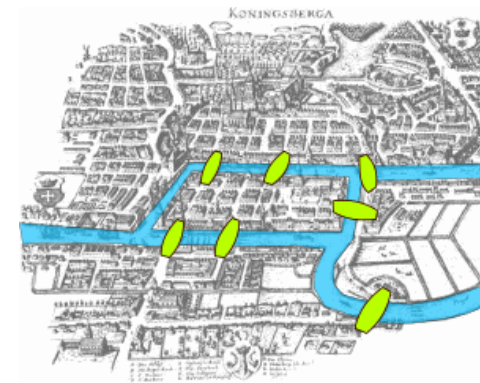


image credits: Bogdan Giuscă (public domain)

Demo

\$ ls demo/koenigsberg

Example: Intelligent Greenhouse



photo © LemnaTec GmbH

Demo

```
$ ls demo/ipc/scanalyzer-08-strips
```

Example: FreeCell

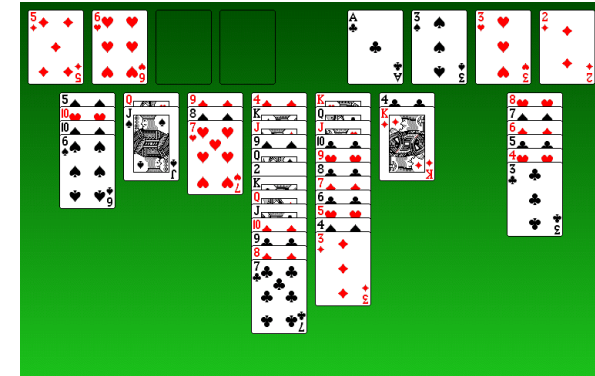


image credits: GNOME Project (GNU General Public License)

Demo Material

```
$ ls demo/ipc/freecell
```

Many More Examples

Demo

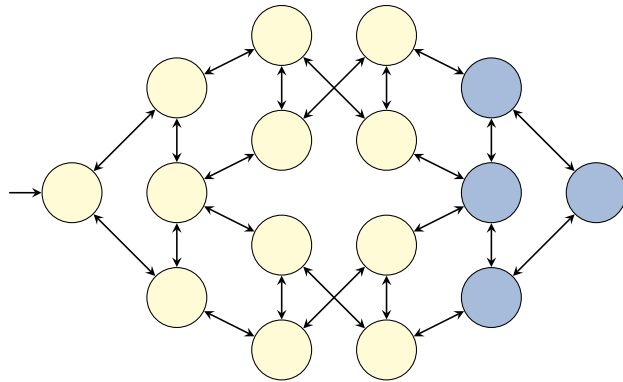
```
$ ls demo/ipc
agricola-opt18-strips
agricola-sat18-strips
airport
airport-adl
assembly
barman-mco14-strips
barman-opt11-strips
barman-opt14-strips
...
```

⇒ (most) benchmarks of planning competitions IPC 1998–2018

A2.3 How Hard is Planning?

Classical Planning as State-Space Search

classical planning as **state-space search**:



↪ much more on this later in the course

Is Planning Difficult?

Classical planning is computationally challenging:

- ▶ number of states grows **exponentially** with description size when using (propositional) logic-based representations
- ▶ **provably hard** (PSPACE-complete)

↪ we prove this later in the course

Problem sizes:

- ▶ Seven Bridges of Königsberg: **64** reachable states
- ▶ Rubik's Cube: **$4.325 \cdot 10^{19}$** reachable states
↪ consider 2 billion/second ↪ 1 billion years
- ▶ standard benchmarks: some with **$> 10^{200}$** reachable states

A2.4 Summary

Summary

- ▶ **planning** = thinking before acting
- ▶ major subarea of Artificial Intelligence
- ▶ **domain-independent** planning = general problem solving
- ▶ **classical planning** = the “easy case” (deterministic, fully observable etc.)
- ▶ still hard enough!
↪ PSPACE-complete because of huge number of states
- ▶ **probabilistic planning** considers stochastic action outcomes and exogenous events.