Planning and Optimization

A2. What is Planning?

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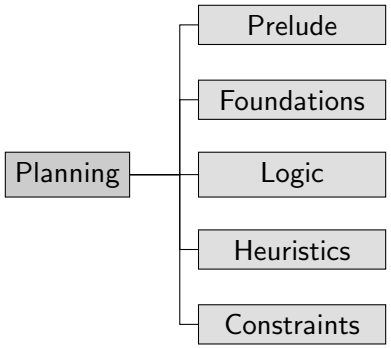
Content of this Course



Before We Start...

Prelude (Chapters A1–A3): very high-level intro to planning

- our goal: give you a little feeling what planning is about
- preface to the actual course

⇝ main course content (beginning with Chapter B1) will be mathematically formal and rigorous

- You can ignore the prelude 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).

$\rightsquigarrow$ these days called "domain-independent automated planning"
$\rightsquigarrow$ 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)

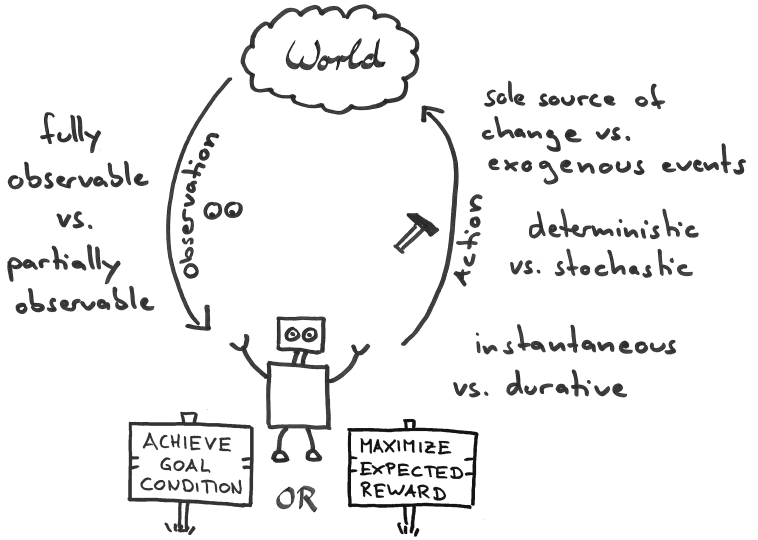
"Selecting a goal-leading course of action based on a high-level description of the world."

— Jörg Hoffmann

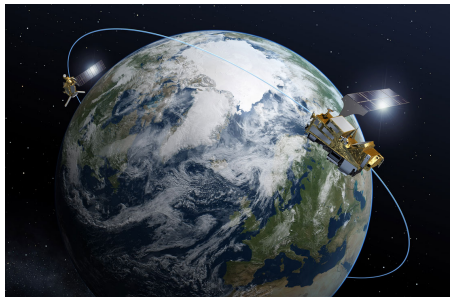
Domain-Independence of Automated Planning

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

General Perspective on Planning

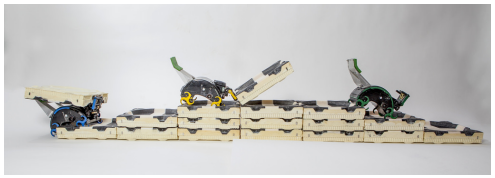


Example: Earth Observation



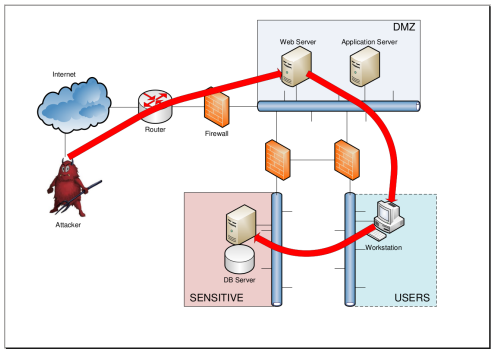
- satellite takes images of patches on Earth
- use weather forecast to optimize probability of high-quality images

Example: Termes



Harvard TERMES robots, based on termites

Example: Cybersecurity

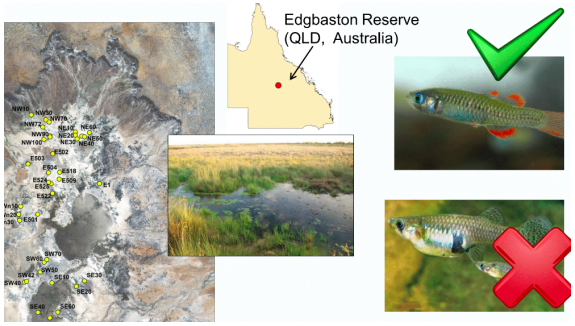


CALDERA automated adversary emulation system

Example: Intelligent Greenhouse

photo © LemnaTec GmbH

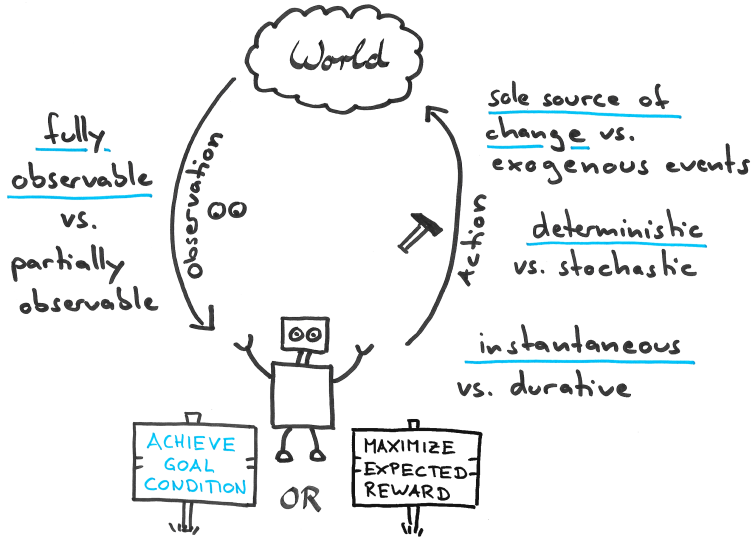
Example: Red-finned Blue-eye



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



Model-based vs. Data-driven Approaches

Model-based approaches know
the "inner workings" of the world
$\rightsquigarrow$ reasoning

Data-driven approaches rely only
on collected data from a black-box world
$\rightsquigarrow$ 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: sequence of actions taking initial state to a goal state
- or confirmation that no plan exists

$\rightsquigarrow$ 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 ($\approx$ 250 participants)
- major journals: general AI journals (AIJ, JAIR)

A2.2 Planning Task Examples

Example: The Seven Bridges of Königsberg

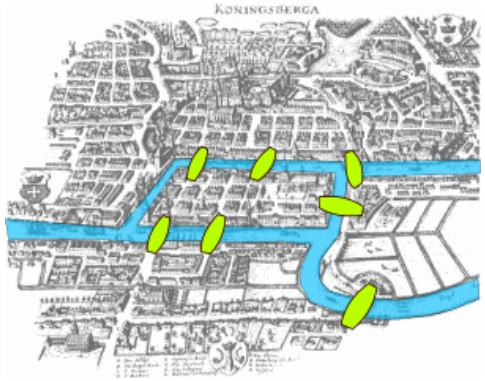


image credits: Bogdan Giuşcă (public domain)

Demo

```
$ ls demo/koenigsberg
```


Example: Intelligent Greenhouse

photo © LemnaTec GmbH

Demo

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

Example: FreeCell

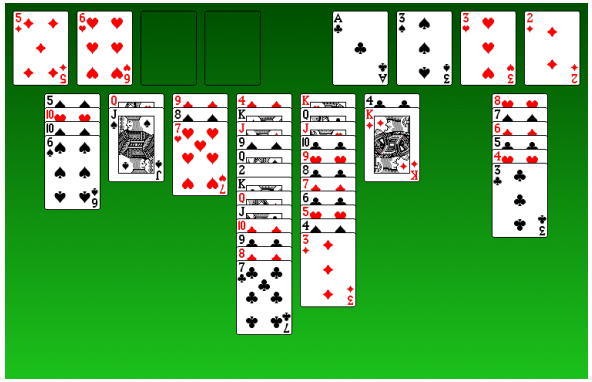


image credits: GNOME Project (GNU General Public License)

Demo Material

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


Many More Examples

Demo

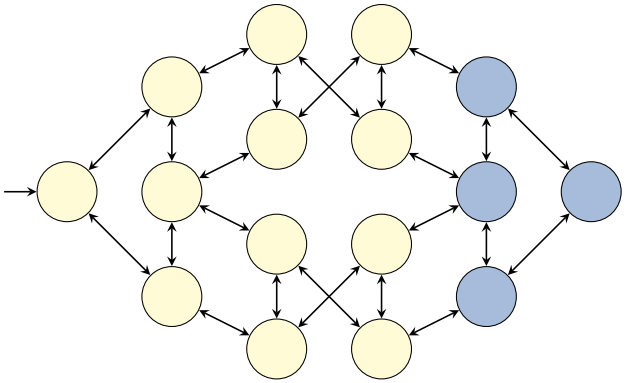
```
$ ls demo/ipc
agricola-opt18-strips
agricola-sat18-strips
airport
airport-adl
assembly
barman-mco14-strips
barman-opt11-strips
barman-opt14-strips
...
```

$\rightsquigarrow$ (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:



$\rightsquigarrow$ 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)

$\rightsquigarrow$ 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
  $\rightsquigarrow$ consider 2 billion/second $\rightsquigarrow$ 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!
  $\rightsquigarrow$ PSPACE-complete because of huge number of states
- often solved by state-space search
- number of states grows exponentially with input size