Challenges for Constraint Optimization in AI

Dealing with Dynamical Changes and Multiple Objectives

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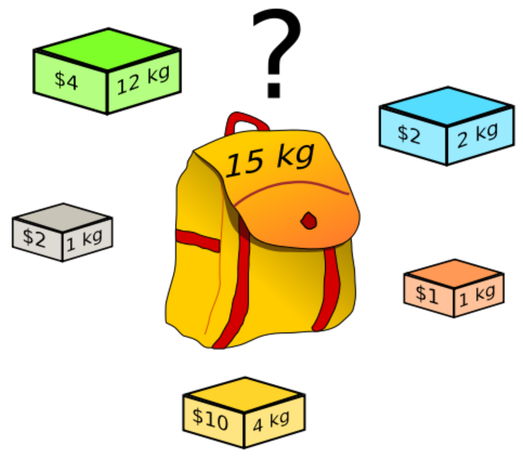
What is Optimization ?

Optimization is the search for the *best* solution of a problem.

- In Mathematics, find the parameters that maximize/minimize a function.
- In games (checkers, chess, go, ...), find a strategy to maximize winning chances.
- In logistics, find the fastest way to deliver products to clients.
- ...

Helps us get the most out of some limited resources (time, money, energy, ...).



Constraint Optimization

- Represent problems with variables and constraints.
- The goal is to find an assignment of values to the variables that optimizes the constraints.
- Can model many Artificial Intelligence problems.
- Simple graph representation.
- Easy to distribute between agents or processors.

Sensor Network

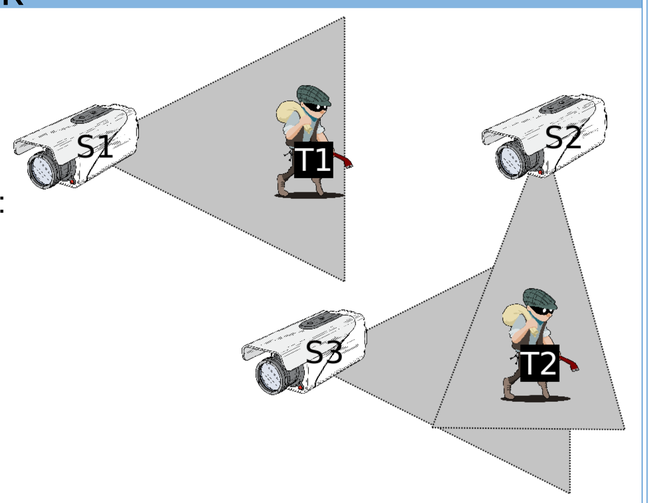
Sensors (variables) can track different targets (values).
Different configurations offer different quality of observation (rewards).

- Information about rewards are represented using constraints:

S1	S2	S3	Reward
T1	T1	T1	17
T1	T1	T2	15
T1	T2	T1	15
T1	T2	T2	10

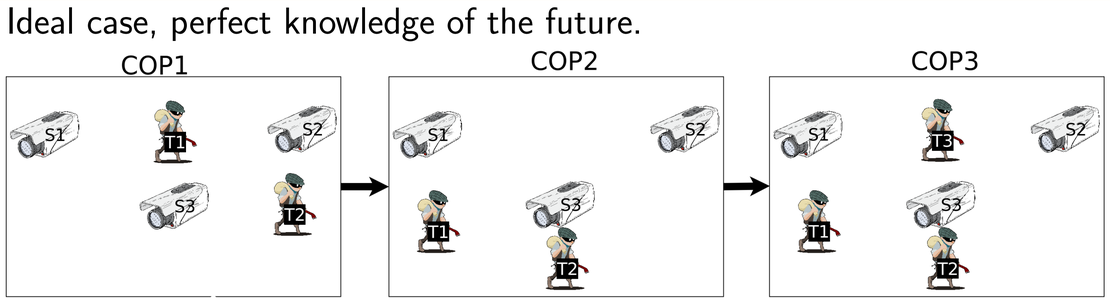
S2	S3	Reward
T1	T1	0
T1	T2	10
T2	T1	10
T2	T2	15

Optimal reward = 25

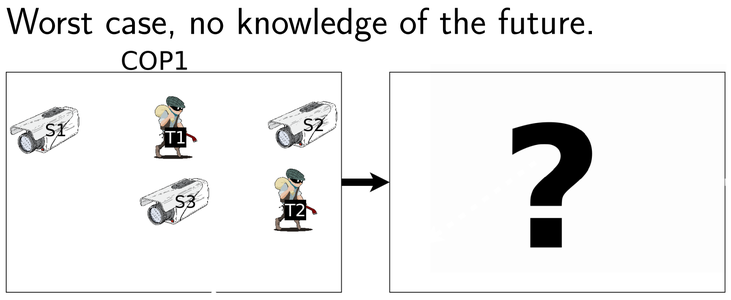


Dynamic Problems

Ideal case, perfect knowledge of the future.



Worst case, no knowledge of the future.



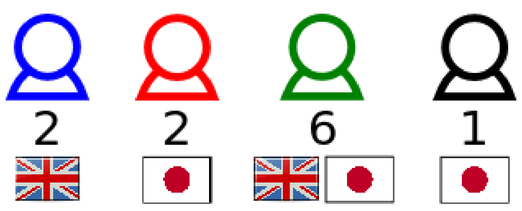
Two complementary approaches to dynamic problems:

- Reactive: adapt once the changes happened.
- Proactive: prepare before the changes happen.

Team Formation

- Creating a team of people with complementary skills.
  - Rescue teams in case of earthquake.
  - Experts to build a big building.
- Robust: team is still good if someone leaves.
  - Important for sensitive applications.
  - Higher initial investment.
- Recoverable: team can be easily fixed if someone leaves.
  - Flexible to changes.
  - Depend on the evolution of the cost of the agents.

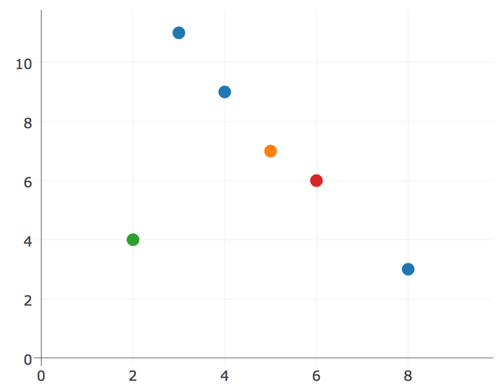
Team that can speak English and Japanese



Cost	Property	Team
3	Optimal	
9	1-Robust	

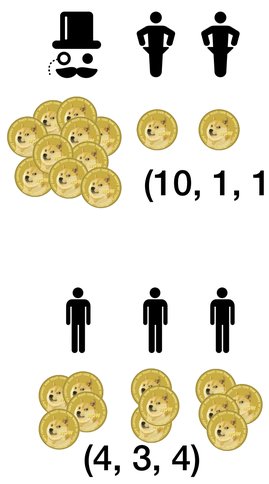
Multi-Objective Optimization

- Optimize several objectives instead of one.
- Solutions can be incomparable.
- $(5,7) \succ (2,4)$
- $(5,7) \not\prec (6,6)$
- $(5,7) \not\succ (6,6)$
- Incomparable solutions make the **Pareto Front**.



Trade-off selection

- How to choose a solution ?
- Multiple methods :
  - Utilitarian : focus on the total sum.
  - Egalitarian : fair repartition
  - Weighted-sum : degree of preference per objective
- Examples :
  - $(10,1,1)$ maximize the sum
  - $(4,3,4)$ focus on a fair distribution



Timetabling and Scheduling

- Many fields require complex schedules or timetables.
- Schools (University, High-School), Transportation (Bus, Airplanes), Delivery (Trucks, Drones), ...
- Complex problems with many constraints and objectives.