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.

Dynamic Problems
Ideal case, perfect knowledge of the future.
- Reactive: adapt once the changes happened.
- Proactive: prepare before the changes happen.
Worst case, no knowledge of the future.

Multi-Objective Optimization
- Optimize several objectives instead of one.
- Solutions can be incomparable.
- Solutions cannot be compared.
- Solutions (5, 7) ≻ (2, 4)
- Solutions (5, 7) ≻ (6, 6)
- Solutions (5, 7) ≻ (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

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

Optimal reward = 25

Sensor Network
Sensors (variables) can track different targets (values).
Different configurations offer different quality of observation (rewards).
Information about rewards are represented using constraints:

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Reward</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>17</td>
</tr>
<tr>
<td>S2</td>
<td>15</td>
</tr>
<tr>
<td>S3</td>
<td>15</td>
</tr>
</tbody>
</table>

Optimal reward = 25

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.