# Constraint Systems

Lab 3 - Reminders
from the Last Lecture

# Optimization in or-tools (reminder)

**Branch and Bound in or-tools works via a search monitor**

In detail:

```
m = slv.Minimize(<variable>, <step>) # Minimization
m = slv.Maximize(<variable>, <step>) # Maximization
...
slv.NewSearch(<dec builder>, [m, <other mon.>])
```

Instead of a cost function, we have a cost variable

- Cost function implemented by posting a constraint

The **<step>** parameter represents the required improvement

- Bounding constraint (minimization): $z \leq zbest - step$

# Meta-constraints in or-tools (reminder)

## Reified constraints in or-tools

- Not all constraints can be reified!
- But many of them can

We just need to use the constraint as a term in an expression

- Usually, this requires adding brackets

```
expr = 2 * (x <= y)
```

- `(x <= y)` represents the feasibility state of $x \leq y$
- It can be used like any other expression

# Max/Min operators in or-tools (reminder)

**Just a word of warning:**

The **`sum`** function in python repeatedl applies **+**

- Since **+** is redefined in or-tools…
- …we can use **`sum`** to build expressions

In python **`min`** and **`max`** are functions, not operators

- Hence, they are not redefined in or-tools
- Istead, we have ad-hoc functions in the solver API

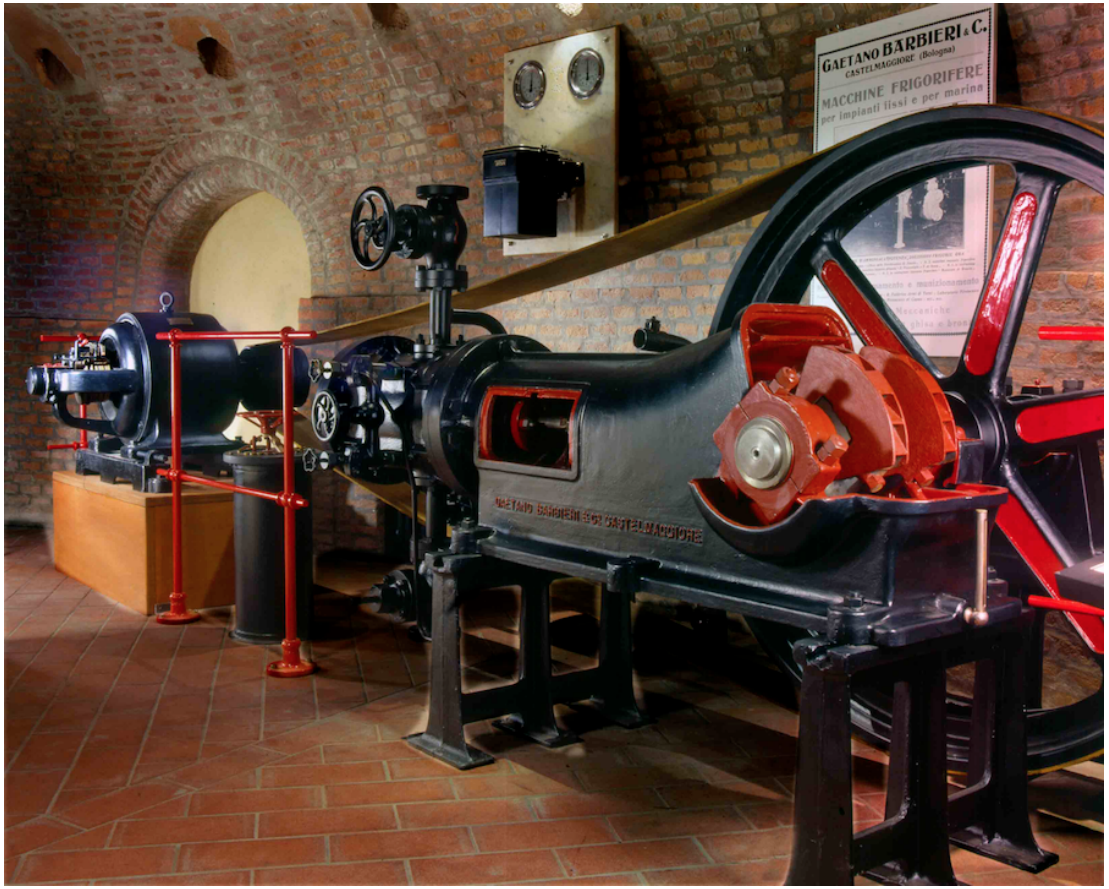
```
slv.Min(<expr/var>, <expr/var>) # Binary min
slv.Min(<list of vars>) # Min with many terms
slv.Max(<expr/var>, <expr/var>) # Binary max
slv.Max(<list of vars>) # Max with many terms
```

# Constraint Systems

## Lab 3 - A Production Scheduling Problem

# Production Line Scheduling

A small company can produce a number of product types



# Production Line Scheduling

**A small company can produce a number of product types**

- Every time unit, only a single product unit can be manufactured

The company has received a number of orders

- Each order refers to a single product type
- Each order requires a certain number of product units
- Each order has a deadline, which cannot be exceeded

Some pairs of products $\langle p1, p2 \rangle$ are associated to a setup time:

- After manufacturing a unit of $p1$, before switching to $p2$
- We need to wait 1 time unit, or to manufacture another product type

# Production Line Scheduling

**A small company can produce a number of product types**

**Goal:**

- Model & solve the problem using CP
- Satisfy all constraints
- Minimize the makespan