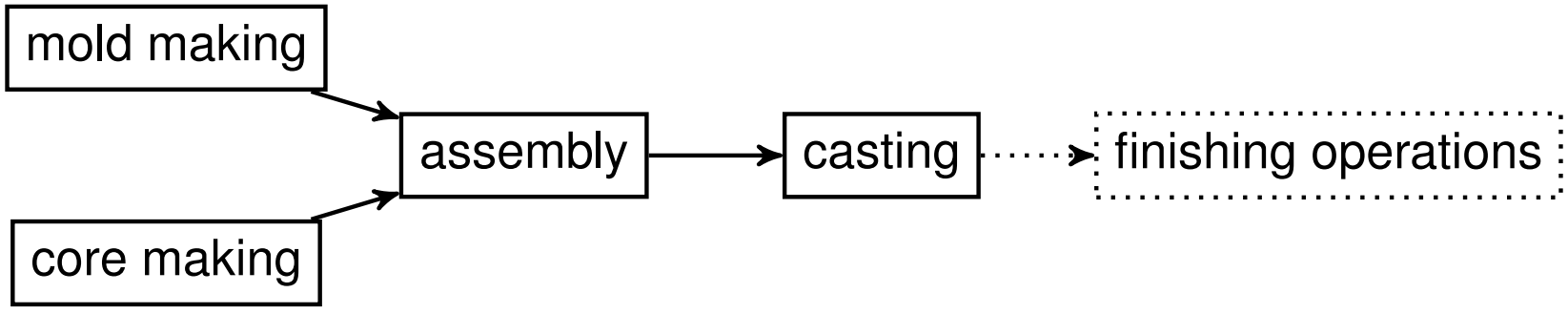
Optimization of foundry production processes

Kelemen Anna
Supervisor: Jüttner Alpár

Eötvös Loránd Tudományegyetem
January 9, 2025

Foundry processes

- casting: shaping molten metal by pouring it into molds



Properties

- objects
  - deadline
  - weight
  - metal type
  - mold making-, core making-, assembly- and waiting times
- shifts
  - casting/assembly
  - start, end
- goal: minimizing the total waiting time (between tasks + between finishing the object and its deadline)

IP model

- decision variables
  - z_{ijk} - assigning the objects to casting rounds
  - $X^m_{ijk}, X^c_{ijk}, X^a_{ijk}$ - assigning the tasks to shifts
- integer variables
  - $Y^m_i, Y^c_i, Y^a_i, S_{jk}$ - start times of the tasks
  - T_{jk} - duration of the tasks

Inequalities 1

- all objects are finished before their deadline

$$\sum_{j=1}^{d_i} \sum_{k=1}^{K} z_{ijk} = 1 \qquad \forall i \in I$$

- the tasks related to the same object are done in the correct order

$$Y_i^m + m_i + mw_i \leq Y_i^a \qquad \forall i \in I$$
$$Y_i^c + c_i + cw_i \leq Y_i^a \qquad \forall i \in I$$
$$Y_i^a + a_i + aw_i \leq D_i \qquad \forall i \in I$$

Inequalities 2

- the casting rounds don't exceed their capacity

$$\sum_{i=1}^{n} z_{ijk} \cdot w_i \leq 4000 \qquad \forall j \in J_1, \forall k \in \kappa_1$$

- in one round only one type of metal is cast

$$mt_{jk} \leq t_i + (1 - z_{ijk}) \qquad \forall j \in J_1, k \in \kappa_1, i \in I$$
$$mt_{jk} \geq t_i - (1 - z_{ijk}) \qquad \forall j \in J_1, k \in \kappa_1, i \in I$$

- each task starts and finishes during a shift

$$S_{jk} \geq AS_j \qquad \forall j \in J_2, k \in \kappa_2$$
$$S_{jk} + T_{jk} \leq AE_j \qquad \forall j \in J_2, k \in \kappa_2$$
$$S_{jk} + T_{jk} \leq S_{j(k+1)} \qquad \forall j \in J_2, k \in \kappa_2$$

Inequalities 3

- the tasks are assigned to tasks in shifts
- if a task of an object is assigned to a task in a shift, then they have the same start time and duration

$$Y_i^a - S_{jk} \leq N \cdot (1 - X_{ijk}^a) \qquad \forall i \in I, j \in J_2, k \in \kappa_2$$
$$S_{jk} - Y_i^a \leq N \cdot (1 - X_{ijk}^a) \qquad \forall i \in I, j \in J_2, k \in \kappa_2$$
$$a_i - T_{jk} \leq N \cdot (1 - X_{ijk}^a) \qquad \forall i \in I, j \in J_2, k \in \kappa_2$$
$$T_{jk} - a_i \leq N \cdot (1 - X_{ijk}^a) \qquad \forall i \in I, j \in J_2, k \in \kappa_2$$

Implementation and future goals

- Python
- Google OR-Tools library
  - CP-SAT solver
- slow running time for larger amounts of data

- **goal:** speed up the IP-solving algorithm
  - 2-phase optimization
  - relaxation, cutting plane or heuristic methods, etc.

Thank you for your attention!