1 Arrowhead project and production optimization

Nowadays, a lot of research works are focused on internet of things and web-services to optimize everyday life. Part of this trend, the Arrowhead ARTEMIS European project aims to enable collaborative automation by networked embedded devices. Schneider Electric leads a Work Package about production pilots with ten different industrial contexts and the same goal: show that collaborative automation can improve performances.

This internship will be focused on a pilot aiming production flexibility and energy efficiency in a discrete manufacturing process: the production of electrical enclosures, cabinets and accessories at a Schneider Electric production site. The pilot consists of understanding the energy consumption of the manufacturing process and managing it in order to optimize the energy consumption expressed either in Wh, in €, or in CO_2 emissions. The amount of resources spent in the plant is significant: the annual costs of energy and water reaches more than 1.6 M€, out of which the major part (62%) is electricity, but the detailed split of this consumption is unknown.

2 Scheduling problem

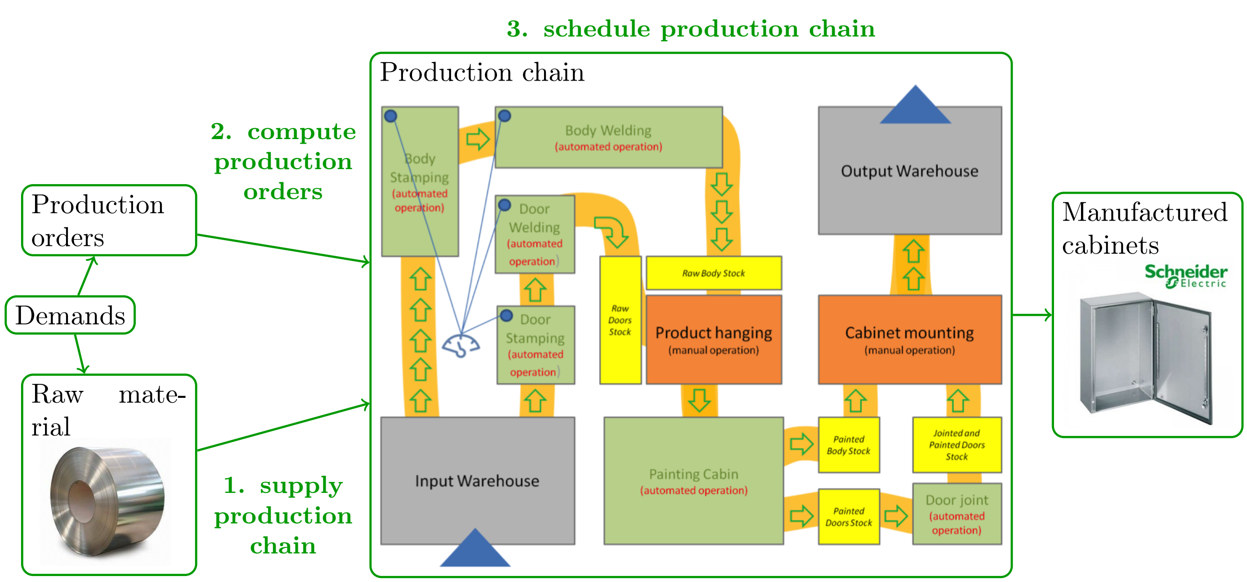

Figure 1: Optimization problems

In the pilot manufacturing plant, there are three optimization problems to schedule production. These problems are illustrated on Figure 1. The first one is to ensure that: given a set of product demands, and a set of raw materials, the initial stock has always material needed by the production chain. The second problem is to compute production orders (batch of intermediate of final references to be produced with a due date) from product demands. The problem we want to study during this internship is the third one: when do we need to schedule production order activities in order to produce cabinets on time and to minimize energy-related cost?

This scheduling problem is a job-shop problem that can be described according to the Graham notation: $J_m|d_j, prec|\sum_j \left[W_j^T T_j + W_j^E E_j + \mathcal{E}_j\right]$ where $\mathcal{E}_j$ is the energetic cost of the job j. A formal description of the scheduling problem is given below:

INSTANCE Number $m \in \mathbb{N}^*$ of machines, set J of jobs, each job $j \in J$ consisting of an ordered collection of tasks $t_k[j], 1 \leq k \leq n_j$.

A length $l(t) \in \mathbb{N}$, a minimum (resp. maximum) precedence delay $\delta_{min}(t) \in \mathbb{N}$ (resp. $\delta_{max}(t) \in \mathbb{N}$), a machine $p(t) \in \{1, 2, \ldots, m\}$ where $p(t_k[j]) \neq p(t_{k+1}[j])$ for each such task t.

A due date $d(j) \in \mathbb{N}$, an energy cost $\mathcal{E}_j$ (that depends on the starting dates of the tasks), a earliness cost W_j^E, and a tardiness cost W_j^T for all job $j \in J$ and a precedence graph $G = (J, A)$ between jobs.

A cost bound B.

QUESTION Is there a job-shop schedule for J, i.e., a collection of one-processor schedules σ_i mapping $\{t : p(t) = i\}$ into $\mathbb{N}$, $1 \leq i \leq m$, such that:

- $\sigma_i(t) \geq \sigma_i(t')$ implies $\sigma_i(t) \geq \sigma_i(t') + l(t')$,
- $\sigma(t_{k+1}[j]) \geq \sigma(t_k[j]) + l(t_k[j]) + \delta_{min}(t_k[j])$ (where the appropriate subscripts are to be assumed on σ) for all $j \in J$ and $1 \leq k < n_j$,
- $\sigma(t_{k+1}[j]) \leq \sigma(t_k[j]) + l(t_k[j]) + \delta_{max}(t_k[j])$ for all $j \in J$ and $1 \leq k < n_j$,
- $\forall (a, b) \in A, \sigma_b(t_1[b]) \geq \sigma_a(t_{n_a}[a]) + l(t_{n_a}[a]) + \delta_{min}(t_{n_a}[a])$
- $\sum_{\forall j \in J} (\mathcal{E}_j + W_j^T \times \max(\sigma(t_{n_j}[j]) - d(j), 0) + W_j^E \times \max(d(j) - \sigma(t_{n_j}[j]), 0)) \leq B$

3 Internship outline

Scheduling problems consist of finding starting dates for a set of tasks on different machines. Job-shop scheduling is a restricted case where tasks are grouped in several jobs, within a job, tasks are constrained by a chain-precedence graph, and only a given machine is available for each task. According to Garey et al. (1976), the basic job-shop scheduling problem $J_m||C_{max}$ is strongly NP-hard. Although small instances may be solved in a optimal way, real world instances must be handled with approximation techniques. According to Danna (2004), large-scale job-shop problems with just-in-time criterion are well handled by hybrid local search methods.

The first part of the internship will be dedicated to study the state of the art, beginning with the following references on: job-shop scheduling (Garey et al. (1976)), energy scheduling (Artigues et al. (2009)), just-in-time scheduling (Beck and Refalo (2003)) and local search operators (Vaessens et al. (1996); Balas and Vazacopoulos (1998)).

Then, the trainee will have to understand the method that have been previously developed during the project. This resolution method is illustrated on Figure 2 where a first feasible solution is generated by a CSP formulation to bootstrap a local search engine. This local search engine has several operators implemented: a swap activities operator, a shift operator and a MIP operator. The code is written in Java and was tested on a public benchmark. The first tests show that most of the best-known solutions were found for these instances.

Afterwards, more local search operators (new ones or those found in the literature) should be added in the existing Java code. The constraint formulation should also be improved, depending on the preferences of the candidate. Finally, new experiments will be done to quantify the efficiency of the improved method. A generic black-box local search solver could also be compared to the method developed from scratch.

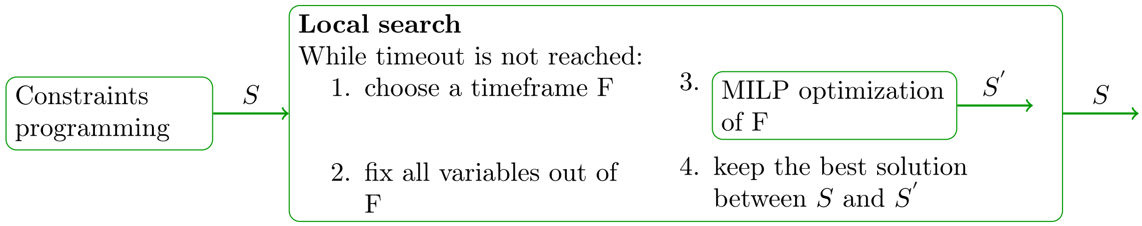

Figure 2: Local search resolution method

4 Practical information

This internship will be done in the MAORE team of the LIRMM (Montpellier) and/or in the Schneider Electric A4S team (38TEC, Grenoble) on a five of six months period. A gratification of about 1000€ per month will be provided by Schneider Electric. The internship will be supervised by Chloé Desdouits (PhD student), Rodolphe Giroudeau and Eric Bourreau (senior lecturers) and Claude Le Pape (PhD, engineer, manager).

References

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Balas, E. and Vazacopoulos, A. (1998). Guided local search with shifting bottleneck for job shop scheduling. *Management science*, 44(2):262–275.

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