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Combination of optimization with multiple resources and energy constraints

Optimisation sous contraintes de ressources énergétiques multiples (OREM)

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Introduction

The integration of energy constraints in deterministic scheduling models, such as job-shop scheduling or resource-constrained project scheduling, yields a combinatorial optimization challenge. It follows that the literature on this subject is sparse. In the OREM project, we focus on a scheduling problem where activities must fit into time windows and require an energetic resource. Each activity has an energy demand. The energetic resource has a limited instantaneous availability (maximum available power). As soon as it is started and not completed, the activity must be assigned, at every time point, a power lying within an interval. For each activity, the total energy brought must fulfill its demand. At every time point, the power consumed by all activities cannot reach the resource availability.

Some applications

- Hybrid Electric Vehicles
- Smart grids in smart buildings
- The smart building ADREAM of the LAAS

Problem with a single resource

For each task \( i \in A \), find a feasible curve \( h_i(t), \ T \in T \).

Parameters
- \( A \) : a set of tasks \( A = \{1, 2, \ldots, n\} \)
- \( A \) : resource availability \( R \in R \) to respect
- \( A \) : a set of tasks \( A = \{1, 2, \ldots, n\} \)
- Minimum instantaneous consumption (demand) \( b_{i, k} \in N \)
- Maximum instantaneous consumption (demand) \( b_{i, k} \in N \)
- Energy required \( W_i \)
- Release date \( r_i \in N \)
- Due date \( d_i \in N \)
- Time domain \( T \), Demand domain \( B \)

Conceptual model and illustration

\[
egin{array}{l}
\forall i \in A, \ t \in T :\\
\forall i \in A, t \in \mathbb{T} :\\
\sum_{i=1}^{n} h_i(t) \leq B\\
\sum_{i=1}^{n} h_i(t) \leq B\\
\sum_{i=1}^{n} h_i(t) \leq B\\
\sum_{i=1}^{n} h_i(t) \leq B\\
\end{array}
\]

Mathematical formulation for the single-resource case

Variables
- Demand curves \( h_i(t), \ T \rightarrow \mathbb{R}, i \in A \)
- Indicator of task started \( x_i \)
- Indicator of task ended \( y_i \)

4 variants

- Continuous time horizon \( T \subseteq \mathbb{R} \) or Discrete time horizon \( T \subseteq \mathbb{N} \)
- Continuous demands \( B \subseteq \mathbb{R} \) or Discrete demands \( B \subseteq \mathbb{N} \)

Discrete-time mathematical model (26)

\[
\begin{align*}
\text{max} & \quad \sum_{i \in A} \sum_{t \in T} x_i h_i(t) \\
\text{s.t.} & \quad \sum_{i \in A} x_i h_i(t) = \sum_{i \in A} y_i h_i(t) = 1 \quad \forall i \in A, w \in [t_i, d_i] \cap T \\
& \quad \sum_{i \in A} x_i h_i(t) = W_i \quad \forall i \in A, w \in T \\
& \quad \sum_{i \in A} b_i h_i(t) = B \quad \forall i \in T \\
& \quad \sum_{i \in A} b_i h_i(t) + d_i h_i(t) \leq k_{i, j} \quad \forall i \in [t_i, d_i - 1] \cap T, \forall i \in A \\
& \quad \sum_{i \in A} x_i h_i(t) \leq d_i h_i(t) \quad \forall i \in [t_i, d_i - 1] \cap T, \forall i \in A \\
& \quad \sum_{i \in A} x_i h_i(t) \leq d_i h_i(t) \quad \forall i \in [t_i, d_i - 1] \cap T, \forall i \in A \\
& \quad \sum_{i \in A} x_i h_i(t) \leq d_i h_i(t) \quad \forall i \in [t_i, d_i - 1] \cap T, \forall i \in A \\
& \quad x_i, y_i \in \{0, 1\} \quad \forall i \in A, w \in T \\
\end{align*}
\]

Methodology and Contributions expected

Phase 1 : Solving the single-resource case
- Mathematical formulation of the different variants
- Identification of valid inequalities and dedicated separation procedures

Phase 2 : Solving the multi-resource case
- Extension of the mathematical model and the valid inequalities to the multi-resource case
- Definition of patterns of resource consumption and procedure for feasible patterns generation with regard to predefined constraints
- Development of a column-generation-based algorithm to exploit the feasible patterns identified

Phase 3 : Experimental Validation
- Introduction of more realistic consumption/production curves
- Tests on data sets of realistic power profiles for hybrid electric vehicles and mission profiles provided by the researchers in Electrical Engineering from LAPLACE
- Experiments on the smart building ADREAM of the LAAS (http://www.laas.fr/ADREAM/)

Expected Contributions
- Integration of energy sources selection in scheduling, taking into account constraints related to the efficiency of technological equipments and their dynamics, both related to the characteristics of each energy source.
- New hybridization of techniques and solution methods : combination of patterns generation (including dual solutions-based filtering) and propagation of resource constraints for the scheduling problem considered.

References