Structured-symmetry-breaking in ILP, applications to the Unit Commitment Problem

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Abstract: Symmetries arising in integer linear programs can impair the solution process, in particular when symmetric solutions lead to an excessively large Branch and Bound (B&B) search tree. Various techniques, so called *symmetry-breaking techniques*, are available to handle symmetries in integer linear programs (ILP) $\min\{cx \mid x \in \mathcal{X}\}$, with $\mathcal{X} \subseteq \mathcal{P}(m,n)$, where $\mathcal{P}(m,n)$ is the set of $m \times n$ binary matrices. A symmetry is defined as a permutation π of the indices $\{(i,j) \mid 1 \leq i \leq m,\ 1 \leq j \leq n\}$ such that for any solution $x \in \mathcal{X}$, $\pi(x)$ is also solution with the same cost, *i.e.*, $\pi(x) \in \mathcal{X}$ and $c(x) = c(\pi(x))$. The *symmetry group* $\mathcal{G}$ of (ILP) is the set of all such permutations. A *subproblem* is problem (ILP) restricted to a subset of $\mathcal{X}$. In [3], symmetries arising in solution subsets of (ILP) are called *sub-symmetries*. Such sub-symmetries may not exist in $\mathcal{G}$. In this presentation, we focus on *structured* (sub-)symmetries arising from (sub-)symmetry groups containing all sub-column permutations of a given solution submatrix. We will present various structured-symmetry-breaking techniques from the literature [7, 8, 5, 3, 4, 6]. An experimental comparison is proposed, on several variants of the Unit Commitment Problem (UCP). The first UCP variant considered features constraints on the minimum up and down times of each unit. This variant is called the Min-up/min-down Unit Commitment Problem (MUCP) as defined in [2], and is structurally close to French insular UCPs solved at EDF. When the MUCP is considered, the integer decomposition property [1] holds for the classical formulation and thus efficient aggregation techniques apply [6]. The second UCP variant considered is the *ramp-constrained MUCP*, featuring minimum and down times, as well as constraints limiting power variations, referred to as *ramp constraints*. The French continental UCP for thermal units is structurally close to this variant. When the ramp-constrained MUCP is considered, the integer decomposition property does not hold anymore for the classical formulation, then the corresponding aggregated solutions can no longer be disaggregated. We show that the sub-symmetry-breaking inequalities from [4] outperform other state-of-the-art symmetry-breaking techniques.

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