Applied Stochastic Integer Programming: Scheduling in the Processing Industries

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Abstract: In the processing industries multiproduct batch plants are widespread production facilities for small amounts of high-valued products. These plants usually consist of various stages comprising several processing units each, which are predominately driven in batch mode. To operate these plants efficiently, limited resources have to be assigned to certain processing tasks in order to optimize the economic return under various constraints. These scheduling problems have to be solved under real-time conditions, i.e. in relatively short computing time with incomplete information. They are addressed by a number of approaches from the mathematical programming domain, but only few of them contain explicit representation of uncertain data. Uncertainty conscious algorithms usually generate single staged schedules, which optimize flexibility indices and/or certain expectation values.

Our approach is conceptually different from those above inasmuch as the possibility of recourse actions is modeled by means of two-stage stochastic integer programs. Deterministic equivalents can be formulated as large MILPs with a block-angular matrix structure; they are solved by a dual decomposition approach based on Lagrangian relaxation of the non-anticipativity constraints. We will present a production process from the polymer industries as a real-world benchmark problem. The scheduling task is dominated by the strong coupling of substances and units and the significant uncertainties of demands and the process itself. The focus of the presentation is on the master scheduling problem as part of a two-layer cascade-like feedback structure. It is stated as a large-scale multiperiod model with accurately formulated capacity constraints and realistic production goals.

The program with integer first and second stages and 1,000 scenarios of right hand-side uncertainties consists of 140,022 integer variables, 448,000 continuous variables and 736,009 constraints. It is solved within 4 hours CPU time with optimality gaps of some 5%, which proves the real-time applicability of the proposed approach.

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