A Simulation-Optimization approach for the short-term scheduling of a sugarhouse

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In process systems engineering, the short-term scheduling of industrial processes involves to find the optimal series of actions to carry out when operating the process equipment in order to comply with a determinate objective (maximization of profit, minimization of makespan, et cetera). In many cases this is done with deterministic optimization models with fixed values for parameters. But, this leads often to sub-optimal or infeasible solutions for the real-world cases, because many of the assumed parameters' values are, in fact, uncertain. Although this is acknowledged since long time, the increase in complexity when these uncertainties are considered in scheduling problems has hindered their study to very recent years.

To account for uncertainties, one of the procedures is to apply partially the resulting schedule until it is considered that it is no longer optimal due to the uncertainties. Reached this point, a new deterministic schedule, considering the new state of the model, is done, a technique that is called rescheduling. However, there is a trade-off in the frequency this rescheduling is done. While more frequent is the rescheduling the better is the handling of uncertainties, but also the more is the total amount of computational workload required.

Subramanian et al. (2001, 2003) proposed a simulation-optimization approach (Sim-Opt), for tackling the uncertainties in portfolio selection for R&D pharmaceutical projects. This approach proposes the combination of discrete-event simulation with deterministic optimization and stochastic optimization in two levels. In the inner level a deterministic optimization algorithm ignores all the random elements present in the problem and obtains a deterministic optimal solution for it, then the discrete-events simulation implements it handling uncertainties while respecting the guidelines given by the optimization algorithm. This level is within an outer level where a stochastic optimization technique utilizes the information from the simulation to search the decision space systematically, trying to improve the performance of the problem. The election of the problem variables that will be controlled by each level, and the optimization and simulation algorithms, depends of the study case.

The Sim-Opt approach has two key characteristics:

- It is a very flexible scheme, a feature that has leaded to applications with purposes different from the original one, e.g.: industrial supply chain optimization (Jung et al., 2004, Mele et al., 2006) or life-support system design for manned missions to Mars (Aydogan et al., 2005).
- The use of a subjacent simulation model allows to include as many details as desired. In optimization models there is often the need to downsize the detail level in order to not create a large optimization problem unsolvable even with large computing power.

The objective of this work is to develop a technique based on the Sim-Opt approach to determinate the optimal rescheduling frequency for short-term scheduling of an industrial real-world size problem, a sugarhouse.

A sugarhouse is the final concentration and crystallization stage of the industrial sugar production (from cane or beet). It consists of several large (in the order of tens of tons of material holding) vacuum pans that receive the sugar/water/impurities juice from upstream processes and evaporate the remaining water to crystallize the sugar, which is then sent to packaging. These pans work in batch mode, but the upstream and downstream processes are continuous, so, in order to avoid accumulation problems, they have to work in parallel and out-of-phase crystallization cycles, with intermediate storage tanks between the continuous and batch units. The operation of this house is complex and difficult, not only it is necessary to comply with the several set-points in each stage, but also there is the transition from continuous to batch operation and vice versa, leading to potential accumulation problems. In addition, the existence of long recycles within the sugarhouse makes necessary to plan (schedule) the house operation with several hours in advance.

The optimal scheduling of a sugarhouse has many uncertain parameters and non-linearities that cannot be fully represented with deterministic short-term scheduling techniques without increasing to impracticality the computational workload required to solve the problem. This is when rescheduling is used to account for them.

For this case we propose that the decision variables handled by the inner level of the Sim-Opt approach are those usually considered in a deterministic short-term scheduling problem, those being quantity, starting and duration of the crystallization cycles for each vacuum pan, mass processed in each cycle and mass stored in the intermediate tanks. And, for the outer stochastic algorithm, the decision variable to be handled is the frequency on which the rescheduling is done. For this study case, the source of uncertainty considered in the problem is random deviation from the required flow of sugar/water/impurities juice delivered to each crystallizer, as it has been found that impacts greatly in the total amount of sugar produced in a span of 24 hours.

The Sim-Opt/rescheduling technique proposed will be used to find the optimal rescheduling frequency need to maximize the sugar production of the sugarhouse.

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