Combining Complementary Scheduling Approaches into an Enhanced Modular Software

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Abstract
Detailed scheduling of batch plants requires taking into account a big amount of operational constraints that are not easy to introduce in optimization approaches. In this way heuristic/simulation approaches as those encountered in APS systems (Advanced Planning and Scheduling) are often utilized. Recipe representation is also an issue since frequently operational details do not fit in the aggregated representations used in the literature.

These facts have lead to the development of MOPP, a planning and scheduling environment in the form of a flexible modeling framework implemented into a basic general scheduling tool for producing practical solutions in complex industrial applications. Thus, the basis to assist process modeling (simulation and simple optimization procedures) are provided by MOPP as well as an open framework capable to be easily customized (implementation of particular constraints, rules, exceptions, etc.).

This approach and tool have been especially addressed to the modeling and optimization of complex manufacturing systems (batch chemical processes, pharmaceutical, fine chemicals, etc.). Thus, the kind of recipes considered require a detailed description of tasks and subtasks and of the hard time and storage constraints implicated (simultaneous activities, unstable intermediates, product synthesis and other concurrent processes...).

MOPP techniques include planning and scheduling capabilities based on heuristic approaches and stochastic optimization. Moreover, the MOPP package has been designed in a modular way following the CAPE-Open standards that allow using additional components in a distributed way.

This work describes the introduction (plug in) of a complementary module aimed to obtaining batches processing time windows utilizing constraints propagation mechanisms. This additional module has been developed independently by a second research group working in Constraint Based Search scheduling techniques for short term scheduling. One of the main questions addressed is due dates feasibility, and the analysis of different scenarios where some due dates are relaxed. Once processing time windows calculated by PCPIP are transferred to MOPP this information becomes a
useful tool that gives the user (or a software application) a measure of the remaining flexibility in batches allocation. This information aids in selecting appropriate timing procedures and/or manual modifications in the MOPP Gantt chart. Batches processing time windows are obtained initially from the planning phase. For each batch its time window is a time interval starting at the time instant where raw materials and equipment unit are available (\textit{est} – earliest starting time) and finishing at its due date (\textit{lft} – latest finishing time). Material balances and resources capacity limits (equipment units and cumulative resources) put constraints in these bounds since they imply in forced orderings among batches, reducing time windows duration through increases in \textit{est} and/or reductions in \textit{lft}. These constraint propagation mechanisms are utilized in commercial softwares implementing Constraint Based Search techniques such as ILOG Solver and Scheduler. In this work those mechanisms have been implemented in an independent module which has been plugged to MOPP system. This work also describes the software architecture adopted and the communication established between both systems. Finally, an illustrative case study is presented to discuss the interest of having different sources of information in the scheduling decision-making process.

\textbf{Keywords:} Scheduling, Constraint Based Search, information sharing