# Hybrid Algorithm for Risk Conscious Chemical Batch Scheduling under Uncertainty

**T. Tometzki**[1] **and S. Engell**[2]

**Abstract:** This contribution deals with the solution of two-stage mixed-integer programs with discrete scenarios that arise in real-time chemical batch scheduling under uncertainty. Real world two-stage decision problems usually give rise to large scale programs which cannot be solved in real time without incorporating decomposition methods. A stage decomposition-based hybrid solution algorithm is proposed that employs an evolutionary algorithm to determine the here-and-now (first-stage) decisions and mathematical programming to optimize the recourse (second-stage) decisions. The hybrid algorithm requires linear time in the number of scenarios, whereas the computation time of an exact algorithm grows significantly stronger than linear in the number of scenarios. For two-stage mixed-integer programs with a high number of scenarios, or when good solutions are needed quickly, the hybrid approach provides better results.

In many real world problems, the solution space of the evolutionary algorithm consists of many small polyhedral subsets (islands), leading to a feasible search space which is disconnected. Generic evolutionary algorithms are not suitable for search spaces with disjoint subsets of feasible solutions that are separated by large infeasible regions. To overcome this problem, the overall first-stage problem is decomposed into a finite number of smaller subproblems with connected feasible solution sets. The subproblems are solved independently by evolutionary algorithms, leading to parallel evolutions based on multiple populations. After each generation, the number of subproblems is reduced by comparing the current best global solution and lower bounds for the subproblems. The lower bounds are calculated by solving the corresponding integer relaxed two-stage linear programs.

For the incorporation of risk, the two-stage problem is extended by a second objective. The multiobjective problem is solved by a multiobjective evolutionary algorithm which is based on the elitist non-dominated sorting concept. The multiobjective algorithm generates a set of solution alternatives with regard to different risk aversion levels. The hybrid evolutionary algorithm and its extensions are applied to a real world batch scheduling problem from the polymer industry.

[1,2] Process Dynamics and Operations Group,
Department of Biochemical and Chemical Engineering,
Technische Universität Dortmund, 44221 Dortmund, Germany
{*thomas.tometzki, sebastian.engell*}*@bci.tu-dortmund.de*