Online Scheduling via Simulation-Optimization for Multiproduct Batch Plants

# Abstract

Scheduling in the process industry determines the sequence and timing of operations to optimize objectives such as minimizing order tardiness and improving plant utilization. In research, scheduling problems are traditionally solved “batch-wise”, i.e. for an idle plant and a given set of orders, production recipes and due dates, optimal schedules are computed. However, this does not reflect reality of production planning and scheduling which is a continuous process, where new orders arrive periodically or at unknown instances, the real operations take longer or shorter periods of time than specified in the recipes, pieces or equipment break down, or operations cannot be executed as planned because resources are not available. All these aspects could be covered by infinitely fast re-computation of optimal schedules whenever an event happens or new information becomes available, but this is practically impossible for realistic problems due to the required computation time.

In online or real-time scheduling, a continuous exchange of information between the scheduling system and the control system of the production plant is necessary. The scheduling model must be updated frequently to reflect the current state of the production system and of the orders. The scheduling algorithm must react to events and disturbances fast, but also utilize the available computing power such that the schedule is near optimal.

We present an online iterative simulation-optimization approach which is tailored to handle these challenges. It builds on our previous work on simulation-optimization using evolutionary algorithms, as described in [1]. The evolutionary algorithm continuously searches for better schedules while the simulation model is updated with the latest information so that the evaluation of each generation of solutions reflects the current situation. After a pre-specified reaction time, a new solution is available after major disturbances. While the first operations of this solution are started, the schedule is further improved continuously and each assignment and timing of an operation that has not been started is based on the currently best solution.

We validate our approach using a multiproduct, multistage batch plant from the pharmaceutical industry, as in the work of Kopanos et al. [2], and demonstrate that it can generate high-quality solutions in the presence of new order arrivals and disturbances. The results are compared with those provided by an idealized clairvoyant scheduler which has access to the full information before the schedule is computed. The influence of the choice of the reaction time after a disturbance which involves a compromise between a fast reaction and better decisions in the immediate future is studied in detail.

# Introduction

Scheduling is a decision making process for the short to mid term production planning. By sequencing and timing operations of orders and allocating operations on machines it increase the productivity, reduces the operational costs, and provides the operators with production plans. During the execution of production plans disruptive events, parameter uncertainties, and changes in the plan necessitate to adjustments to the production plan to guarantee feasibility in the execution of the plan. These adjustments are usually performed on the fly by experienced plant operators

# Introduction

1. **Production Scheduling**

* Scheduling specify the order of activities in production processes
  + E.g., when and where which operation of orders is executed
* Environments with many degrees of freedom, e.g. a set of products with different recipes, parallel processing units, limited resources availability, in their production process benefit significantly from advanced scheduling methods
* It helps operators in their decision making process, increases productivity, and reduced operating costs
* Requirements of advanced scheduling systems
* The adaptation dilemma
  + The decisions made by the scheduling system are transferable to the plant
  + The scheduling model captures all relevant plant behaviors
  + The scheduling system can predict the outcome of decisions
  + The plant state is correctly captured in the scheduling system
  + The solution should be generated fast, or the solution might become obsolete
* Helps operators of a plant to coordinate operations to increase productivity and reduce operating costs
* The dynamic nature of production processes necessitate rescheduling procedures when the state of the system makes the production plan infeasible
* Rescheduling updates an existing schedule in response to disruptions and changes

1. **Context and importance:**

* Background Information:
  + Scheduling is a decision making process
  + In the process industry it is useful batch plants with multiple products
  + Combinatorial optimization problem that is hard to solve
  + Decides on sequencing, batching and allocation of operations
  + It leads to more efficient plant utilization with respect to the defined objective
  + Finding good solutions requires a lot of effort
  + The plant operations are inherently uncertain
  + Schedule might become obsolete due to uncertainties
* Significance
  + Scheduling has a great potential for the process industry
  + The adaptation of scheduling depends of the translation of the decisions to the real plant and the flexibility of the solution or approach

1. **Research problem**

* Research Gap
  + Find a method that fits the needs of industrial applications
  + Fast solutions
  + Automation of the scheduling process
  + Adaptation of the approach
  + Unknow which criteria are needed for industrial applications? -> Industry 4.0
  + Unknown if an approach exist that matches all criteria that are needed for industrial applications
    - Fast solution
    - Good solution
    - Dynamic approach
    - Uncertainties
    - Adaptability of the solution
    - Usability
    - Flexibility
    - Adaptability of the solution