From unit control to optimal management of plants, sites, and chemical parks

Sebastian Engell, TU Dortmund, Coordinator

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www.spire2030.eu/copro

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Individual units often are already automated and operated efficiently.

Inefficiencies result from lack of coordination.

Better coordination of production means improved energy and resource efficiency.
## Innovations

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Solution</th>
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<tr>
<td>Plant and site operation efficiency determined by discrete</td>
<td>CoPro includes discrete decisions in plant-wide optimisation</td>
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<td>events and decisions</td>
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<td>Plant managers and operators have a crucial role in the</td>
<td>CoPro develops model- and optimisation-based advanced decision support</td>
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<td>operation of processing plants</td>
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<td>The effort for modelling is a major bottleneck</td>
<td>CoPro develops techniques and software for hybrid and data-based modelling</td>
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<td>Advanced solutions must be embedded into the IT-landscape of</td>
<td>CoPro develops software for easy integration</td>
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<td>the plant</td>
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<td>Operation of plants of different companies in industrial parks</td>
<td>CoPro develops technology for balancing and optimising networks, and for</td>
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<td>that are connected by energy &amp; material streams are not</td>
<td>distributing the joint benefit in industrial parks</td>
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<td>coordinated</td>
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Consortium

Industry with 5 applications covering the complete value chain

Technology providing SMEs

Universities

Dissemination and exploitation support

Research institutes
(Petro-)chemical production: Coupled processes incl. an on-site power plant and the procurement of electricity, unit switch on/off, logistics, detection of anomalies

Coordination of production and distribution of gases: Production and procurement of basic chemical gases in an integrated site

Cellulose fibre production plant: Spinbath recovery network with redundant equipment, selection and switching of equipment, planning of cleaning

Production, formulation and packaging of detergents: Production planning and scheduling, increase of throughput, investigation of new plant layouts

Sterilisation and packaging of food (fish): Batch production steps with continuous production lines, reduction of energy use in sterilization, reduction of changeover times
INEOS in Köln use case – NH$_3$ network optimisation

- Discrete decisions (on/off, ramp-up)
- Described by generic model elements that are connected to build large-scale models
- Connection to the IT-landscape via LeiKon’s Intexc-suite
INEOS in Köln use case – BDP modelling

- BDP = Most efficient observed operation
- Innovative approach for the calculation of baselines based on statistical analysis and surrogate modelling[1]
- Implemented in resource monitoring dashboards of INEOS in Köln

INEOS in Köln use case – Optimal power plant scheduling

- Power plant of INEOS
  - Incinerates the waste gas of the production plants
  - Produces steam for the production plants
  - Electricity is produced as a by-product of producing steam
    - Less than site demand, electricity is also purchased from the grid
- Challenge: Uncertainty of the steam demand
- Scheduling of power plant operation under demand uncertainty
  - Two-stage optimization on a rolling horizon
Covestro use case – CO and H₂ network optimisation

Balancing the networks by coordinating

- Internal production
  - Considering fluctuating electricity prices
- Internal consumption
- External consumers
- Purchases from external producers
  - Minimum purchasing quantities
  - Coupled contracts with different tariffs
- Transfer of gases between sites

Improving economics and resource efficiency by reducing waste streams and demand side response
Lenzing viscose fiber production process

From the pulp to the fibers

CoPro Presentation Final Symposium April 2, 2020
Decision support tool for load allocation

• Fully implemented and already running in the control room.
• Reduced operator workload.
• Faster reaction against production changes.
• Up to 1.9% more efficient operation:
  ≈ 40 t/d steam savings
  ≈ 250,000 €/y savings

Workflow:

matlab → PI HMI → DCS

PI Process data

Results: yes/no

Feasibility Check

Setpoints

BONMIN gets an optimal solution in a few seconds

≈ 40 t/d steam savings
≈ 250,000 €/y savings
The key to an efficient cleaning scheduling is the ability to monitor and predict fouling

Proposed approach summarized:

1. **Data pre-processing stage.** Remove shut downs, unsteady operation, out-of-range points, measurement errors, corrupted data, apply data reconciliation, etc.
2. **Clean plant model building.** Select clean operating data after cleanings and generate a plant model.
3. **Fouling monitoring.** *Fouling state := Difference between current data w.r.t clean model prediction.*
4. **Fouling model regression.** Fit models for the fouling state w.r.t. operation time, type of spinbath, etc.
P&G use case – Optimal planning and scheduling

**Challenges**
- Demand-driven production
- Great variety of products, sequence-dependent changeovers
- Plant-wide manual scheduling not possible for longer time horizons

**Benefits**
- Reduction of waste due to changeovers
- Optimised schedule translates into increased energy and resource efficiency
- Improved production capacity and flexibility
- Less work on weekends
FRINSA use case – Canning, sterilization, and packaging of fish

- **General characteristics**
  - Large order-driven production with high production flexibility
  - **Sterilisation:** Most critical element
    - Ensures food safety & product quality
    - Energy intensive process
    - Production bottleneck

- **Main achievements**
  - Optimisation-based reactive scheduling for better plant utilisation
  - Optimisation of the sterilisation process ➔ **significant energy savings** by better control and coordination with scheduling
Ease of use and reduced engineering efforts to integrate Model-based applications into heterogeneous IT- and OT-system environments
PSE Hybrid modelling tool

- **Hybrid models**
  - Models with a “data-driven” component and a “first-principles component

- **Components**
  - Data-driven model estimation based on ALAMO and PLS (Partial Least Squares)
  - Prediction and quality monitoring of data-driven components in gPROMS
  - Flowsheeting library with hybrid unit operation models
  - User interface elements for surrogate modelling
  - Integrated with PSE’s gPROMS Process Modelling platform
Site-wide optimisation without sharing of sensitive data

**Problem:**
- Increasing the efficiency of the whole site without sharing internal data of business units or companies

**Solution:**
- Market-like distributed optimisation
- Each plant is optimised individually
- Adaptation of the prices by the coordinator (central function)
- Mimics a micro-market

**Enabler of Industrial Symbiosis**
Summary

- CoPro developed and demonstrated
  - Data-based and hybrid modelling for decision support
    - Best is combination of knowledge-based and data-based models
  - Plant-wide optimisation with discrete decisions
    - Feasible with adequate modelling depth and tailored algorithms
  - Tools for hybrid modelling and IT-integration

- Technologies were demonstrated in real environments
- Several solutions will be put into productive operation
- Commercial software tools
Contacts

- Project Coordinator: Prof. Sebastian Engell, TU Dortmund
  sebastian.engell@tu-dortmund.de

- Project website:
  www.copro-project.eu

- LinkedIn:
  https://www.linkedin.com/in/copro-2a5938138/

- ResearchGate:
  https://www.researchgate.net/project/CoPro-Coordinated-Production-for-Better-Resource-Efficiency