Aalto University
School of Chemical
Engineering

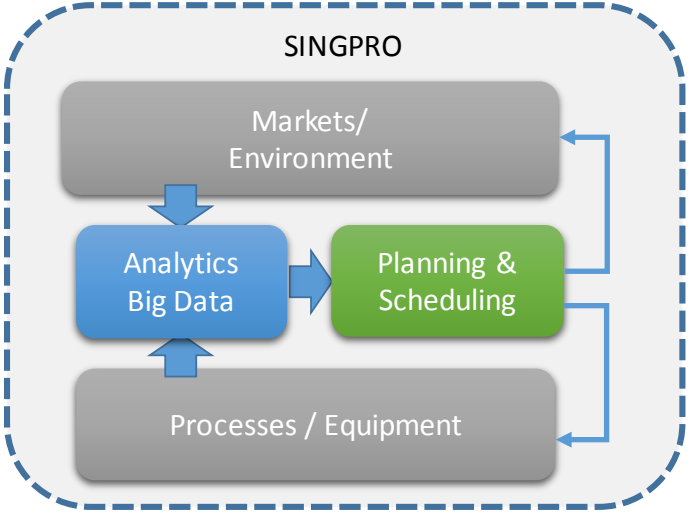
Scheduling and Analytics – Towards Better Planning

Iiro Harjunkoski (Aalto University / ABB Corporate Research Germany)

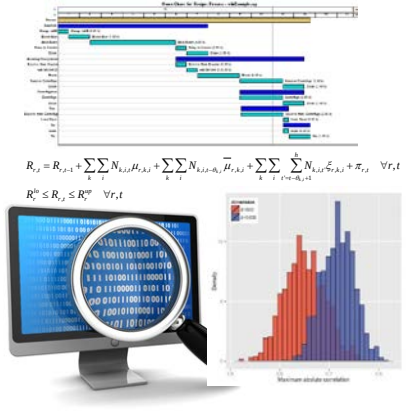
AIChE Annual Meeting 2018, Pittsburgh, 31.10.2018

SINGPRO Project (2018-2019)
Synergistic and intelligent process optimization

Academy of Finland project: Adj. Prof. Harjunkoski (Aalto CHEM) & Assoc. Prof. Heljanko (Aalto SCI)



Robust & agile schedules
Adapted/correlated models



Sustainable & safe operations

- ✓ Energy efficient
- ✓ Optimal throughput
- ✓ Well maintained in time
- ✓ Safe operating conditions
- ✓ On-time production
- ✓ Knowledge-based models
- ✓ Agile and adaptive decisions

SINGPRO Targets
Create and prove novel concepts in real life

- Show that big data technologies can be deployed together with optimization strategies, to close the decision loop in automation
  - The results can help defining future research needs within systems-level integration of process control systems and data-driven decision making
- Collaborate with Finnish industry on piloting the methodology
  - Get access to real data, process information and the opportunity to discuss, test and demonstrate the solution approaches in practice
  - Create concepts that are re-usable across various industries

SINGPRO Project Team

Adj. Prof. Harjunkoski (Aalto CHEM)

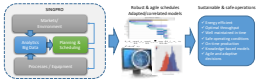
Prof. Heljanko (University of Helsinki)

Dr. Tewodros Deneke

Dr. Teemu Ikonen *(paper 728h on Friday 2.11. at 9:54, room 311)*

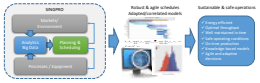
Dr. Hossein Mostafaei

Questions to be Answered (1/2)



- **Often a production plan is already ”old” soon after being rolled out to the plant floor**
  - Could I do better planning by knowing more about the process, i.e. utilizing the real-time data?
- **Schedules are usually based on average durations (tables)**
  - Is it better to dynamically generate accurate statistics on process behaviour every time I want to schedule?
- **Disturbances and breakdowns often come as a surprise**
  - How many incidents can actually be predicted and avoided?

Questions to be Answered (2/2)



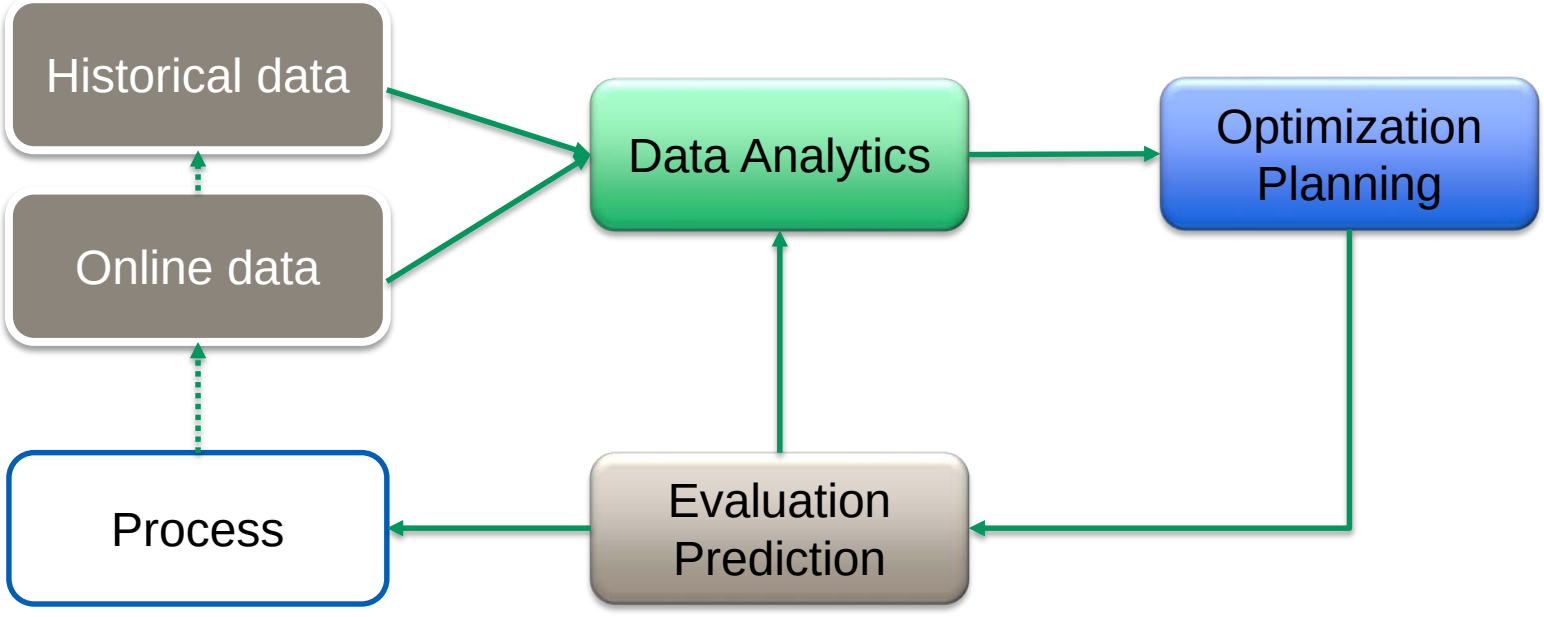
- **Often we focus on the most obvious data assuming simple causality**
  - What information actually is relevant for root-cause analysis? Are there hidden relationships?
- **Many decisions in optimization add to the complexity**
  - Are there decisions that can be excluded from the optimization scope, based on what we know from the data?
- **Data is mostly collected and stored only for troubleshooting**
  - What is the actual value of this data?

SINGPRO Highlights
Combine big data analytics with optimization

Need to develop and focus on:

- Online, reactive and anticipative tools for sustainable and efficient operations
- Collaboration interfaces between scheduling optimization and big data analytics / machine learning resulting in more agile, self-aware and flexible decisions
- Combine first-principle models with machine learning in an efficient way to reduce the modeling complexity and efforts
- Create - in a fully data driven fashion - models of normal process behaviour and predictive models of process disruptions

SINGPRO Methodology
Loop: Process → Analytics → Optimization



SINGPRO Research Activities
Combine big data analytics with optimization

Development steps planned

1. Analyze process data across multiple domains using clustering, pattern matching, identification of causalities
2. Create open and adjustable production scheduling models (discrete and continuous-time) and solution concepts for large-scale problems
3. Run selected pilot case studies using industrial data on both production and supply chain level
4. Build a cloud-based demonstrator built on an industrial platform following generic standards validated on multiple test cases

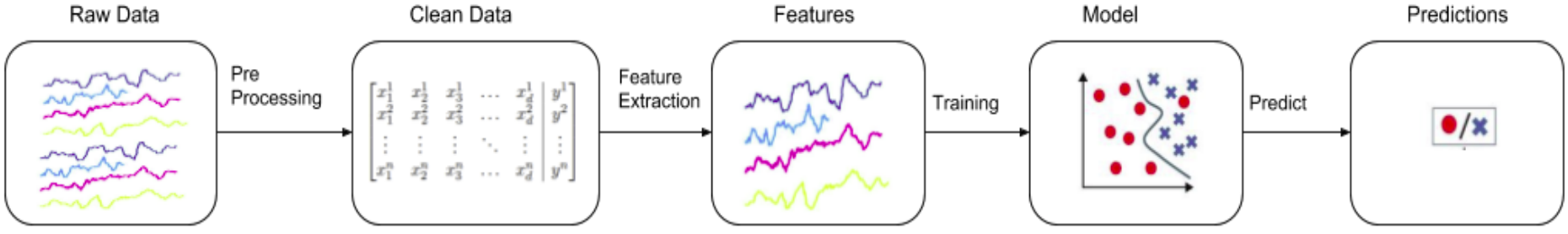
Summary of Ongoing Research

Machine Learning
Dr. Tewodros Deneke

- Starts with a raw data
- Data preprocessing
- Feature extraction
- Model training
- Prediction

Potential applications:

- Predictive maintenance
- Anomaly detection
- Parameter prediction
- AI planning
- Etc ...



Parameter Predictions in Scheduling
Dr. Teemu Ikonen

Research aims

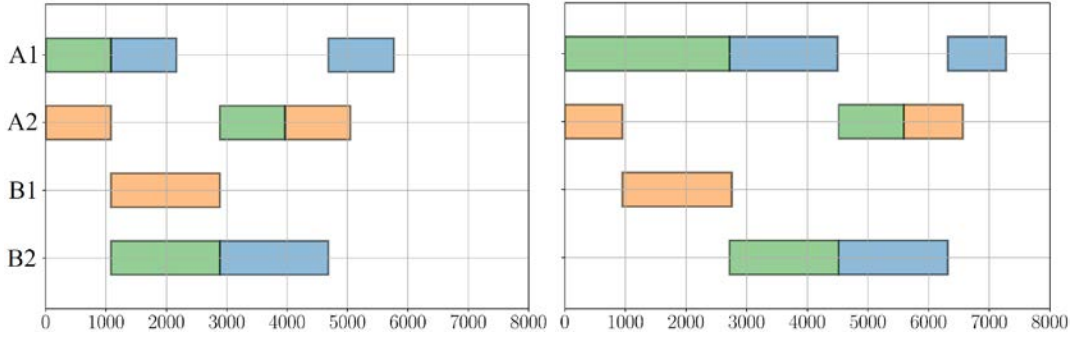
- Improve the quality of scheduling solutions via machine learning based (scheduling) parameter predictions
- Investigate the relationship between scheduled and realized schedules on real datasets

Primary machine learning methods

- Gaussian process regression
- Random forest regression

Scheduling models

- Mainly continuous-time representations



Planning and Scheduling Optimization

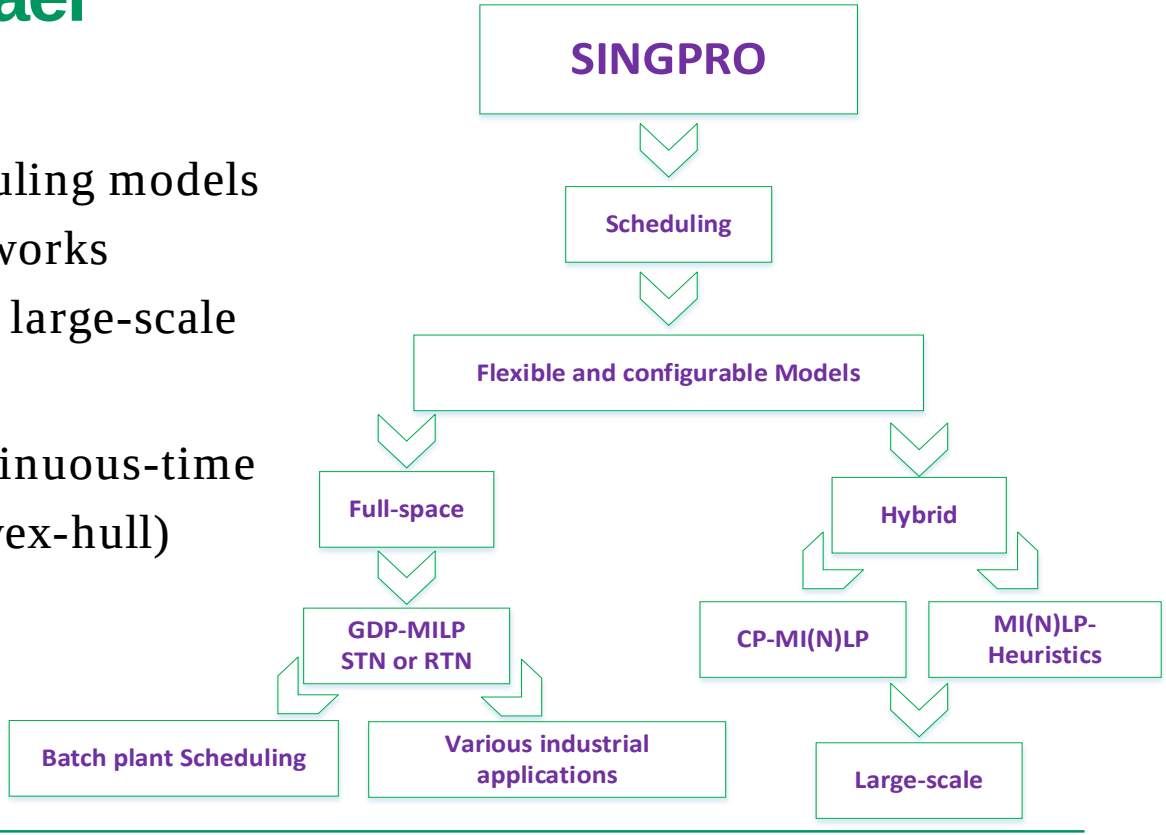
Dr. Hossein Mostafaei

Aims and targets

- Modular and flexible scheduling models
- Hybrid optimization frameworks
- Decomposition schemes for large-scale

Scheduling models

- Based on discrete- and continuous-time
- Based on GDP (mainly convex-hull)
- Based on STN and RTN



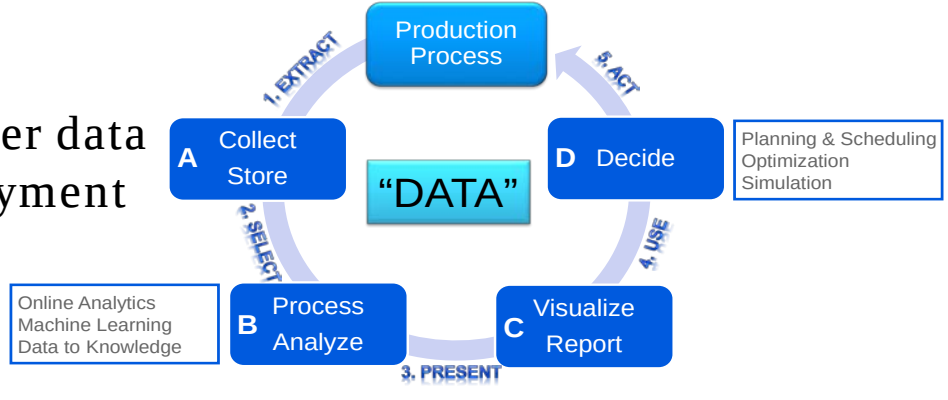
SINGPRO Collaboration

Scientific collaboration with world-leading academics: Carnegie Mellon University, University of Texas at Austin, University of Lisbon and Aalto University.

- Combine cross-domains already in the research phase boosting out-of-the-box thinking and enabling a larger pool of methodologies and synergies of the existing research.

Industrial collaboration

- Identify partners that can provide larger data pools but also support technical deployment e.g. through platforms
- Define joint metrics for improvement



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