Systems simulation and optimisation at VTT

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SYSTEMS RESEARCH 2006-2013

Models, analyses, simulation and software for better control, safety and productivity of complex systems

Computer Simulation Models and Technology
- Large scale dynamic simulation models
- Integration of simulation and design with semantic information models
- Simulation based automation testing and training

Systems Control
- System dynamic simulation in operations management
- Large scale optimisation in logistics and production control
- Automation architectures, design processes and requirements management

Systems Analysis
- Probabilistic risk assessment (PRA) and decision support
- Assessment of safety critical automation (I&C)
- Complex stochastic systems

Human Factors Engineering (HFE) and Systems Usability
- Human activity and Human-Technology Interaction (HTI) in control centres
- Development and evaluation of control room operations and technology
- Competence development and training
Optimisation of systems
- Multiple objectives
- Optimisation in practise

Operative systems optimisation
- Production control
- Operational optimisation - future prospects

Predictive process control
- Predictive simulation
- Dynamic optimisation

Process simulation
- Integration of simulation and process design
- Vision for industrial information management
Optimisation example

If you liked to have the maximum number of apples and pears, which of the four alternatives would you choose?

Pareto optimal solutions
Optimisation of systems

- There are always several goals for optimal action
- The goals can be formulated as objective functions, soft constraints or hard constraints
- Mathematically and by the use of computational methods a possible Pareto optimal solution can be found among the set of feasible solutions
- The choice of the solution depends on the preferences of the decision maker
- The preferences may be different in different situations
- In practice, operational processes are optimised by using mathematical optimisation, simulation, continuous improvement, trial and error …
Operative optimisation

Production planning in a sawmill

- Create an **optimal plan for sorting of logs** into batches for sawing
- The model covers the production process from incoming logs to individual timber product deliveries
- **Maximise customer order fulfilment and profits**, minimise unsalable production

KnownPap v10.0 (2009)
Operative optimisation

Production planning in a sawmill

- Profit is theoretically maximised when violation of order fulfilment is not penalised
- Fulfilment of all orders substantially decreases profit
- How much is a customer order worth?
- The production plans can be adjusted to market conditions

- Customers are classified to different groups
- Weights for violation of orders may be different
- Optimisation gives better fulfilment of orders than human planning

![Graph showing comparison between optimised and human planning results.](image)
Future prospects of operational optimisation

- A **detailed optimisation model** typically improves even an established way of action by a few per cent.
- The **input data needed for optimisation** is obtained from enterprise information systems.
- **Parallel computing with multicore processors** makes it possible to solve bigger and bigger problems in decent time.
- The **participation of operational management** in specification and testing is essential.
- **Large scale planning problems** are very difficult for humans especially in changing environment.
PREDICTIVE PLANNING AND CONTROL OF BATCH TYPE PROCESSES

Predictive operator support
- A simulation model describes the production line
- The initial state is obtained from the plant automation and information systems
- The operator gives the operational schedule
- An optimal schedule is found by what-if-analysis or computational optimisation for, e.g., 1-7 days
- OPERCOP development environment

Benefits
- Steady operation of the plant, better quality
- Efficient use of the existing capacity, increase in yield
- Management of disturbances and unexpected situations
- Planning of the product changes and service intervals
- Systematic optimisation over the shifts

References
- Production of TiO2 (Kemira Pigments, daily use in 2005)
- Enzyme production, granulation (Genencor International)
Suunniteltu tasainen tuotanto saostimilla

Hyväältä näyttää
Kapasiteetti pienenee ajalla 24-120 h

Syöttö katkeaa
Lasketaan kalsinointiunin syöttötavoitetta

Ei syöttökatkoja
Käyttökokemuksia

"Pystyvän hyödyntämään tehtaan
kapasiteetin kaikissa tilanteissa
optimaalisesti ja toteuttamaan lasketut
tuotantotavoitteet luotettavasti."
-tuotantopäällikkö Ilpo Harju

- Tasaisempi tuotanto – tasaisempi laatu
- Työvuorojen yli ulottuva objektiivinen
  ennuste
- ”Riittävän tarkka ja yksinkertainen”
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Simulation and process design integration

Process simulation

Design Engineers

Process design

Automation design

3D design

Plant design systems:
SmartPlant Foundation, Comos, ...

Simantics

Common user interface environment

Apros Process Simulation

Other simulators:
Balas, DEVS, sd, Fluent, Modelica, company specific

Engineering Information Management

Simulation Information Management
Apros - Hierarchical Modelling

Application modelling without the need to write equations: draw the PI diagrams and input the parameter values.

New instances of process components can be composed with the new Modeller Interface.
Dynamic process simulation with Apros

Control system model

Automation can be included in the model ...

Control circuits
Logic circuits
Sequences
Change-over automation

Measurements

Device controls
Actuators

Set points

... or real/virtual automation application can be connected to the process model.

Conservation equations for mass, momentum and energy
District Energy Planning

Integration of new energy production or regeneration concepts, network concepts, energy storage concepts, behaviour patterns, peak handling, control concepts, testing of local market concepts…

VTT District Energy Planning

Detailed smart city & district energy planning, integrating
- Building types, new & retrofit
- Behaviour patterns
- Generation units:
  - Heat, Power, Combined (CHP), Heat Pumps
  - Building or Process Integrated - e.g. Solarthermal, Photovoltaics
- Energy Storages:
  - Various Thermal, Gas, Electric
  - Electric car integration
- Grids:
  - Electrical, Gas, Steam, Heating and Water networks

Based on APROS and Simantics platform
APROS has users in 26 countries: Power plants, Paper mill engineering, Engineering offices, Safety authorities, Research organisations, Universities, Plant manufacturers: Andritz, Daewoo, Doosan, Foster Wheeler, Metso, Alstom, ..
Vision for information management

Knowledge management

Information management

Document management

Information legacy

Generation 5: ‘Simulation as Part of Semantic Product Model’

Generation 4: ‘Semantic Product Model’

Generation 3: ‘DocHotel’

Generation 2: Filing cabinet

Generation 1: Camp fire stories

Path of evolution

Information value

f(completeness, correctness, accessibility)
VTT - 70 years of technology for business and society