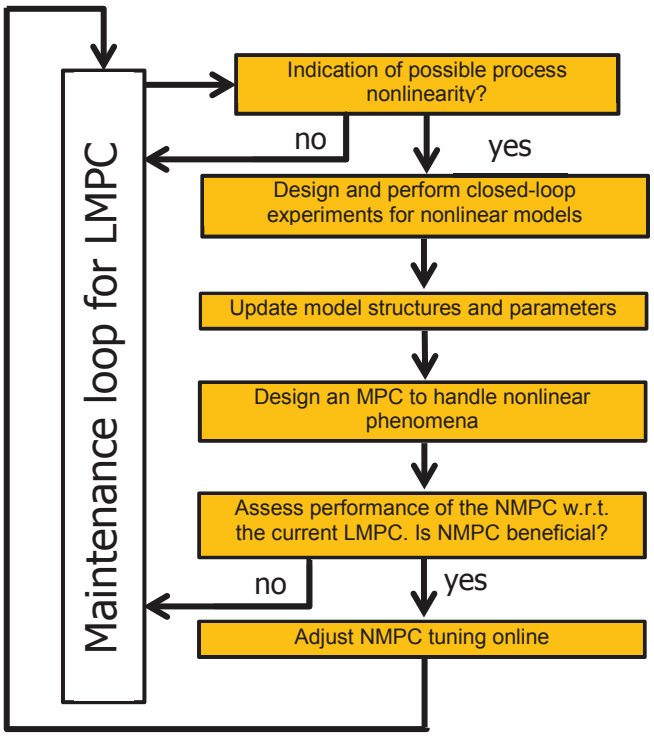
"The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 257059. The 'Autoprofit' project (www.fp7-autoprofit.eu)"

WP2 – MODELS IN MODEL-BASED SYSTEMS

WORK PACKAGE OBJECTIVES

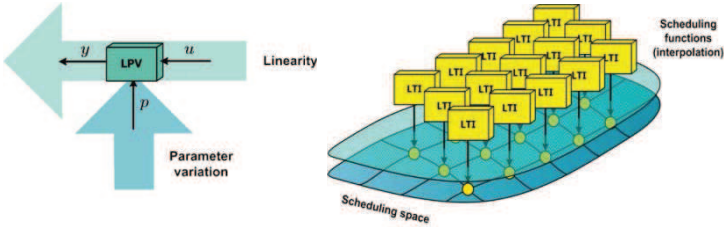
The aim of WP2 is to extend the linear maintenance loop such that situations, where an appropriate nonlinear MPC is likely to improve control performance are detected. After detection, the current linear model of the controller is gradually adapted to describe the nonlinear and time-varying process behavior. The strategy follows the least-costly philosophy of the project and allows an autonomous, smooth transition between linear and nonlinear MPC.

NONLINEAR MAINTENANCE LOOP



INCREMENTAL MODELS (BEYOND LTI)

The LPV concept



Benefits in using LPV models:

- Representing between multiple operating points and transient them in an efficient manner.
- Outer and inner approximation concept of the dynamic behavior: global vs local approaches of LPV modeling
- Preserving linearity between input and output signals (this allows to extend the stealth excitation approach).
- For frozen values of the scheduling parameters, LPV systems become LTI (this provides the possibility for an efficient gain-scheduled MPC design).

DATA-DRIVEN MODELING OF LPV SYSTEMS

The developed identification approaches are able to:

- Efficiently handle general conditions on the noise affecting the output signal observations.
- Efficiently handle the correlation (due to the closed-loop) between the noise corrupting the output measurements and the input of the system.
- Directly estimate the LPV model structure (order, dependencies) from the data.

MPC FOR LPV SYSTEMS

Gain-scheduled MPC: Underlying control strategy:

1. Measure the scheduling parameter p at time k.
2. Keep the scheduling parameter constant (and equal to $\mathrm{p}(\mathrm{k})$) during prediction (LPV → LTI)
3. Compute an LMPC for the frozen LTI model.
4. $k \leftarrow \mathrm{k}+1$. and go back to Step 1.

WORK PACKAGE PARTICIPANTS

Dr. Dario Piga
Dr. ir. Roland Tóth
Eindhoven University of Technology
Department of Electrical Engineering
Control Systems

Dipl.-Math. techn. David Kauven
Prof. Dr.-Ing. Wolfgang Marquardt
RWTH Aachen University
AVT – Aachener Verfahrenstechnik
Process Systems Engineering

Coordinator Contact: Prof. dr. ir. Paul Van den Hof, Delft University of Technology, P.M.J.vandenhof@tue.nl

"The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 257059. The 'Autoprofit' project (www.fp7-autoprofit.eu)"

WP2 – MODELS IN MODEL-BASED SYSTEMS

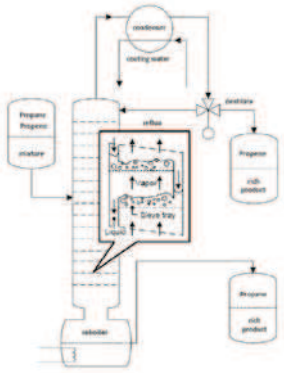
SUMMARY

The main idea of the WP2 is to detect when model/plant mismatch due to appearing nonlinearities deteriorate the MPC performance and correcting that by re-tuning the controller and/or updating (extending) the model. Simulation models are used to evaluate the developed solutions in a Matlab based benchmarking environment.

The data-driven incremental modeling methods, developed in WP2, have been applied for modeling of a high-purity distillation column and of a continuous pulp digester. The obtained models have been used in the gain-scheduled MPC design and applied on the pulp digester benchmark. Studies have been conducted to ensure data-driven detection of plant nonlinearities.

DISTILLATION COLUMN

Process description



Manipulated variables:
- Vapor and liquid flows

Measured variables:
- Top & Bottom purity

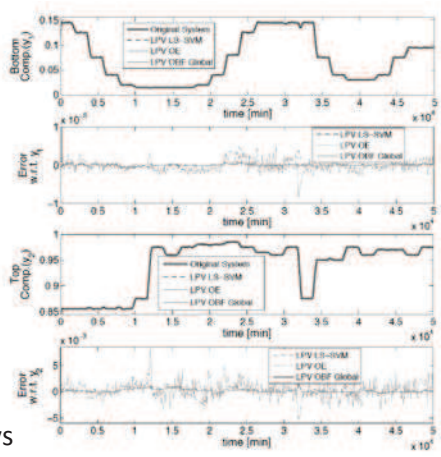
Scheduling variables:
- Top & Bottom purity

Sampling time: 2.5 min

Feautures:
- Directionality
- Locally changing order
- Large OP region
  Top: 99.5% - 85%
  Bottom: 1% - 15%

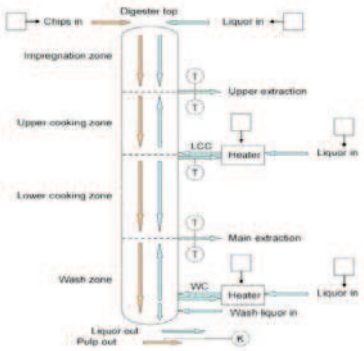
Data-driven Modeling:

- Comparing several LPV methods
- Fully data driven selection of the model structure
- SNR: 25 dB
- Data: 26 days



PULP DIGESTER

Process description



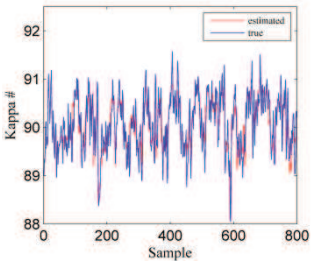
Manipulated variables:
- 3 liquor flows
- 2 temperature set points

Process variables:
- 5 temperatures

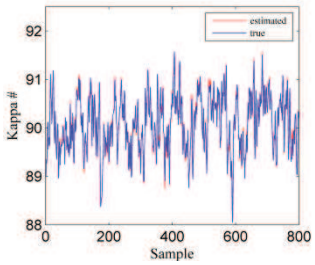
Controlled variable:
- Kappa number

Scheduling variable:
- Chip feed rate

Data-driven modeling



LTI model

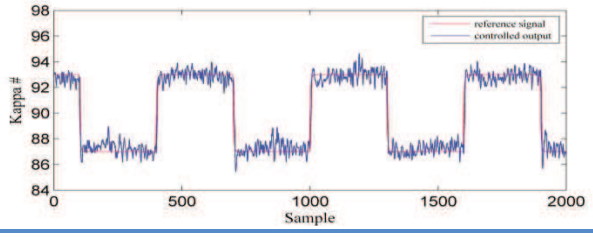


LPV model

Generating data

- Closed-loop simulation (LMPC designed based on a linearized model of the pulp digester)
- Sampling time: 10 minutes
- Measurements of the Kappa number corrupted by noise (SNR=15 dB)
- Number of measurements used for estimation: N=1200

Gain-scheduled MPC



WORK PACKAGE PARTICIPANTS

Dr. Dario Piga
Dr. ir. Roland Tóth
Eindhoven University of Technology
Department of Electrical Engineering
Control Systems

Dipl.-Math. techn. David Kauven
Prof. Dr.-Ing. Wolfgang Marquardt
RWTH Aachen University
AVT – Aachener Verfahrenstechnik
Process Systems Engineering

Coordinator Contact: Prof. dr. ir. Paul Van den Hof, Delft University of Technology, P.M.J.vandenhof@tue.nl