

Guaranteed Parameter Estimation in Process Industry – Relation of Lab Experiments and Process Modelling

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Motivation

Model-based optimization and control are becoming more and more important in the process industries. Typical models consist of ordinary or partial differential equations (ODE/PDE) of the following form

$$\frac{dy}{dt} = f(y, u, \vec{p}, y(t_0)) \text{ (ODE)}$$

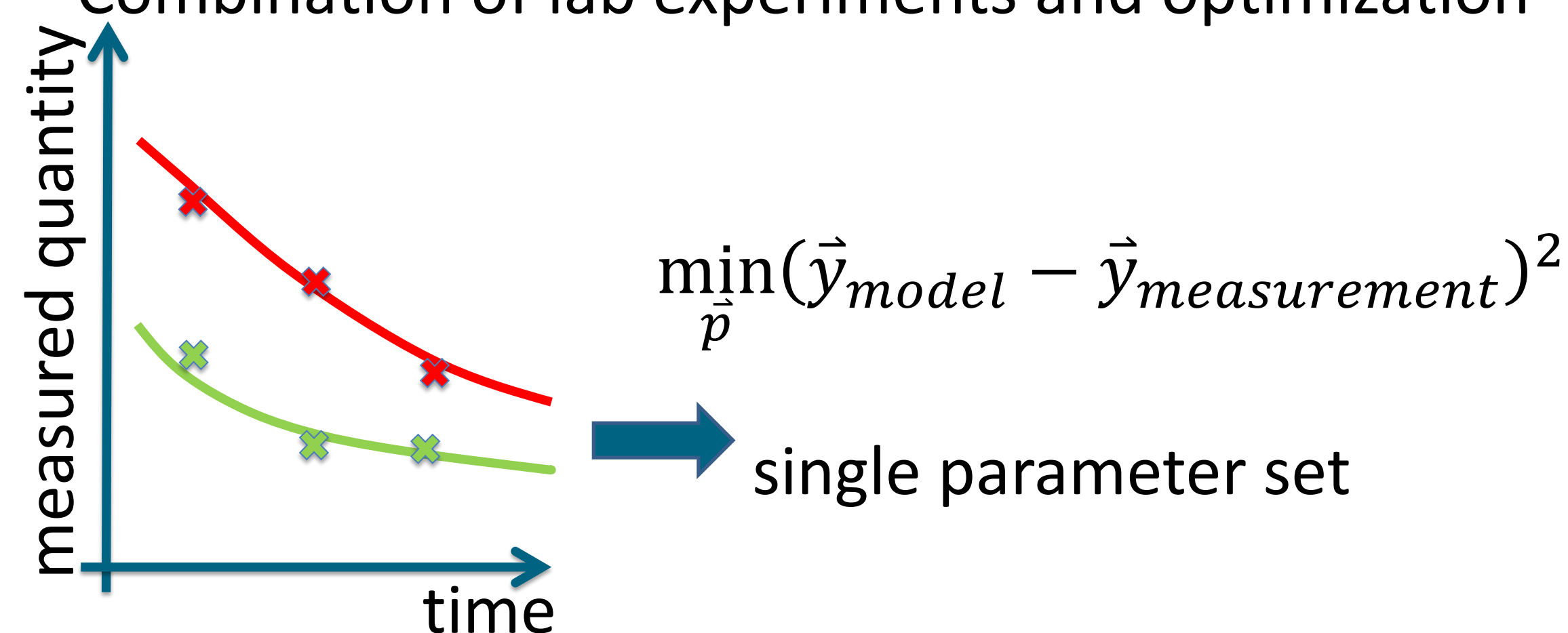
$$\frac{dy}{dt} = f\left(y, \frac{dy}{dz}, u, \vec{p}, y(t_0), y(z_{boundary})\right) \text{ (PDE)}$$

y: process variable; t: time; u: manipulated variable; p: parameter; z: spatial coordinate

The applicability of these models for optimization and control is strongly related to the accuracy of the model parameters.

What is the typical way to determine parameters?

- Combination of lab experiments and optimization

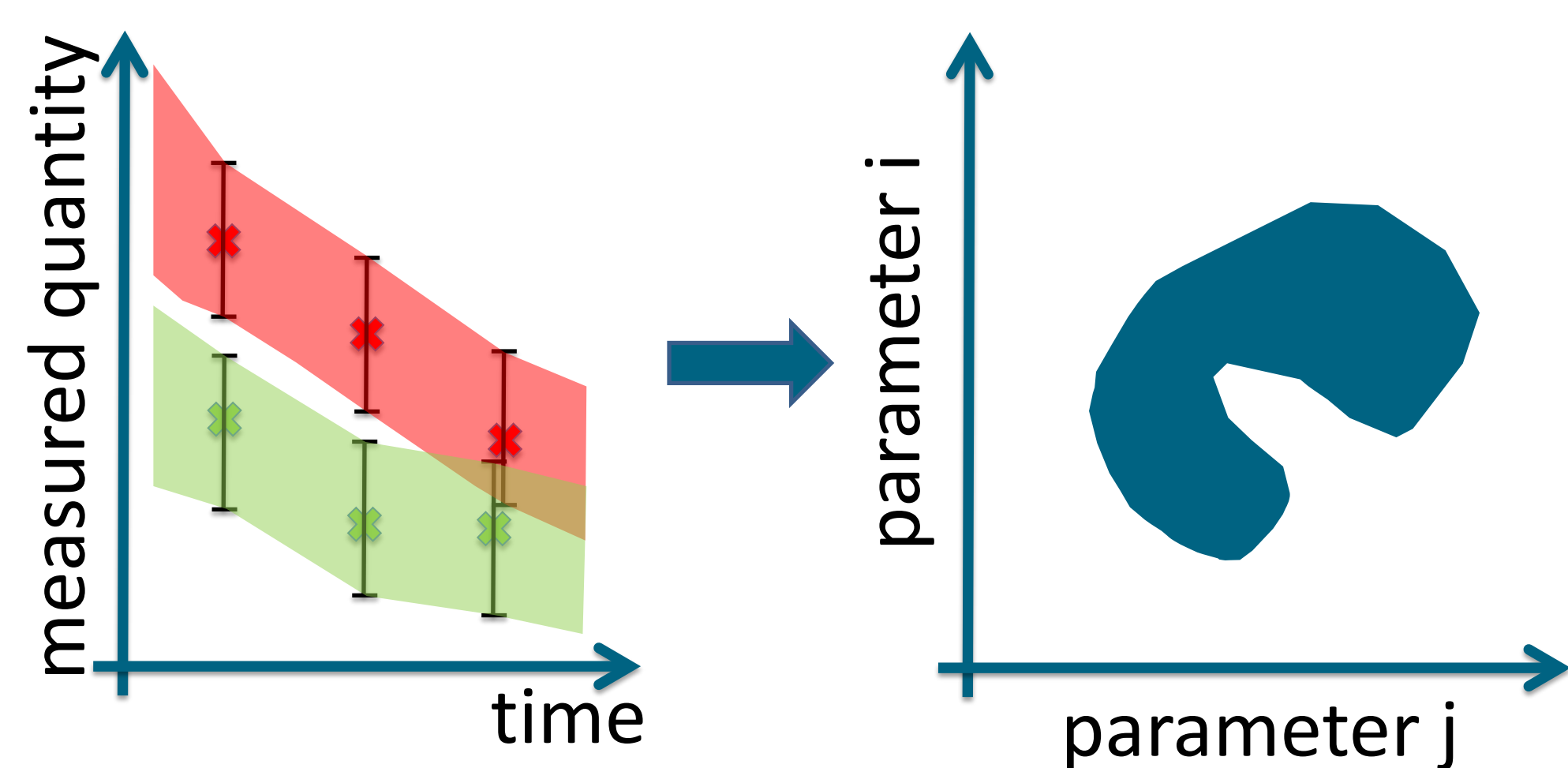


Challenge 1: How to deal with measurement uncertainty?

Challenge 2: Is the set of experimental data sufficient to fit the model parameters? Are additional experiments needed?

Guaranteed Parameter Estimation

Approach: Determination of every parameter set that fits to the measured data including measurement uncertainty.

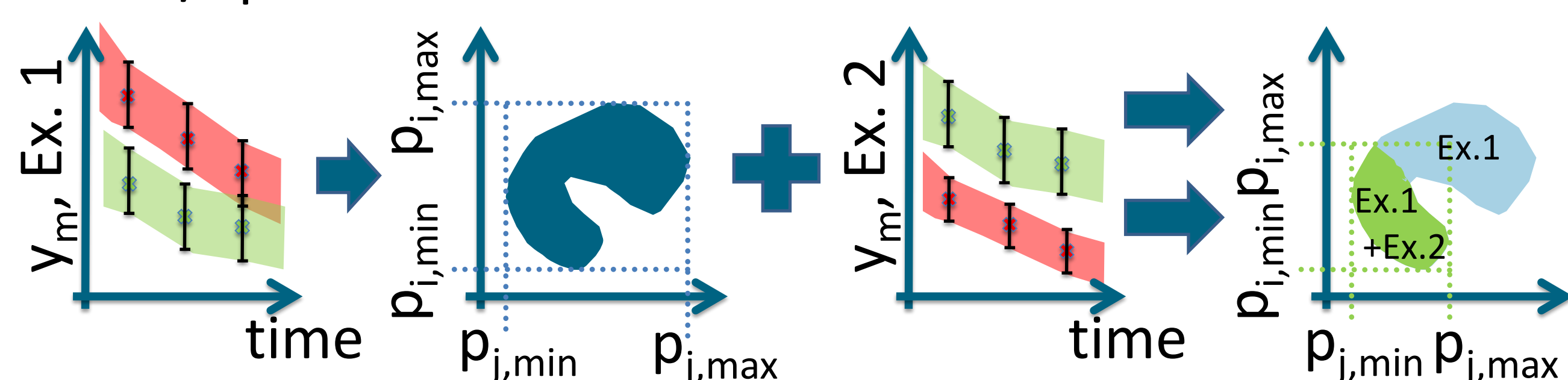


Population based algorithm for the optimization problem: Maximization of the distance towards the feasible solutions within the parameter space

$$\max_{\vec{p}_e} \sum_{a=1}^{N_{feas}} \frac{|\vec{p}_a - \vec{p}_e|}{N_{feas}}$$

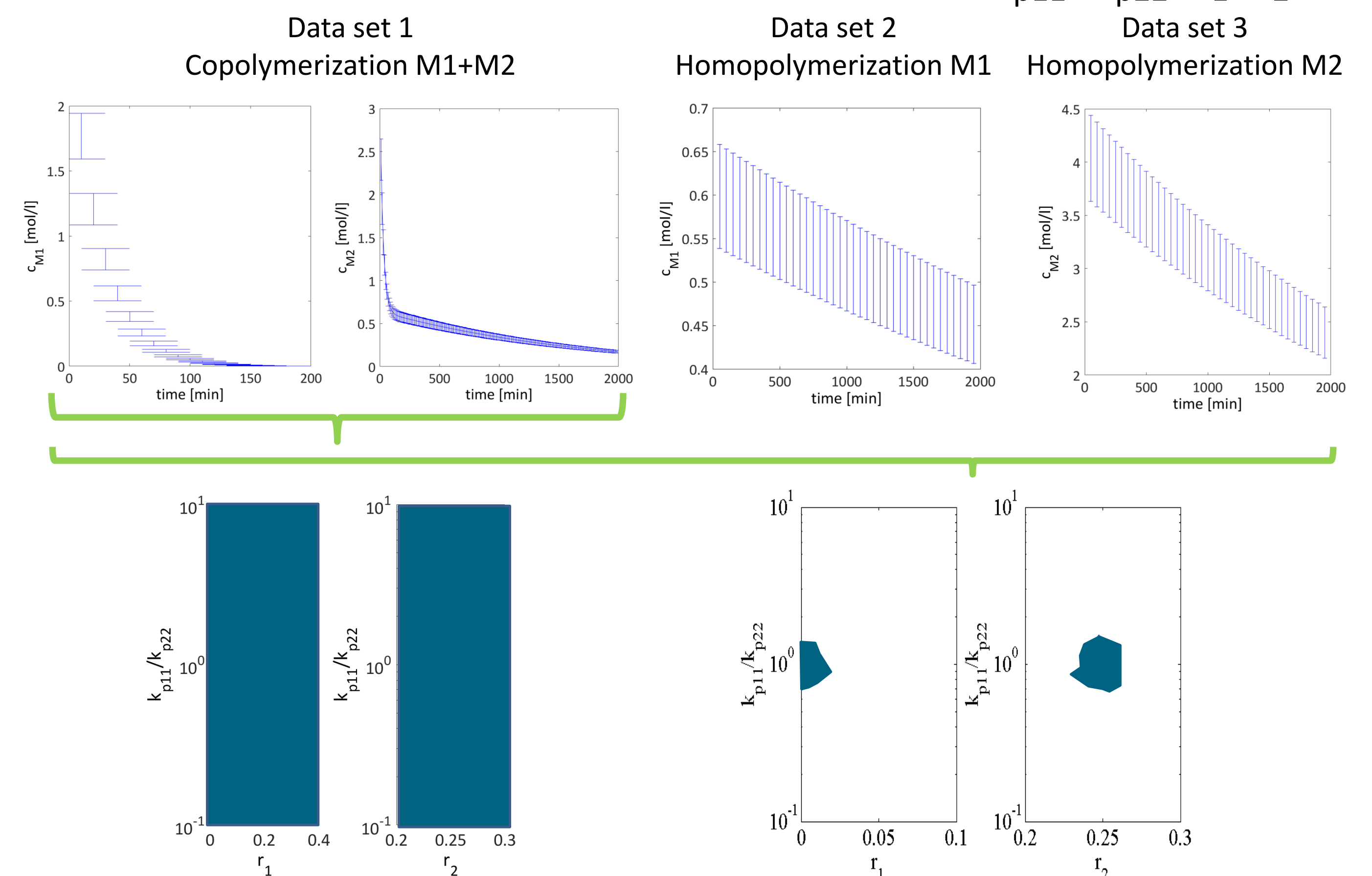
s.t. $(y_m(t_i) - \delta_m) < f(y, y_0, u, \vec{p}_e, t_i) < (y_m(t_i) + \delta_m) \forall t_i$

Analysis of the resulting parameter ranges enables the prediction whether further experiments are needed to achieve the requirements for model-based control/optimization.



Case Study

- Copolymerization process including monomers M1 + M2
- Three experimental data sets available
- Determination of four kinetic parameters: k_{p11} , k_{p22} , r_1 , r_2



After analysis of the results from the copolymerization data new experiments have to be designed to reduce the parameter ranges. Due to the consideration of data from additional homopolymerization experiments the parameter uncertainties are reduced.

Thus the reliability of the estimated parameters is increased.

Exploitation & Impact Assessment

- The analysis based on the available data helps to decide if the available experimental data is sufficient for model-based applications.
- Economical analysis possible, as the experimental effort and the resulting effect on the parameter estimation can be calculated in advance
- Problem formulation is not limited to specific sensor rates and is also applicable to multi rate applications
- The models in this approach are used as black-boxes, thus the algorithm is not limited to any specific model structure and offers the option for a wide application in the process industry.
- The space exploring character of the optimization problem is also applicable to various problems in the process industry. E.g. flexibility analysis of existing/planned plants, safety analysis, experimental design, test of control concepts, economical evaluations.

References and Acknowledgements

[1] Goerke, T., Engell, S.; 2016; Application of Evolutionary Algorithms in Guaranteed Parameter Estimation; IEEE Congress of Evolutionary Computation (CEC); ISBN: 978-1-5090-0622-9; pp. 5100-5105



This project has received funding from the European Union's Horizon 2020 research and innovation programme under the grant agreement N° 636942.

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