Application and Development of Advanced Process Control Schemes in Novozymes Fermentation Pilot Plant

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1/29/2012

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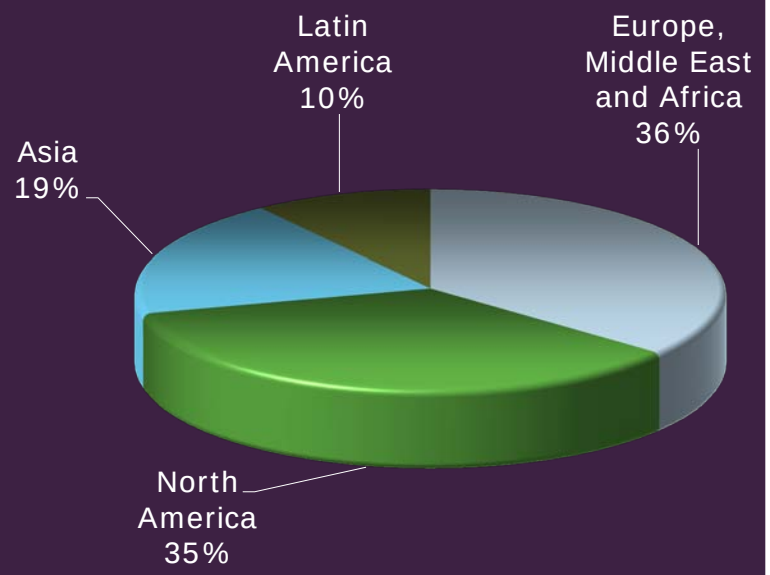
AGENDA

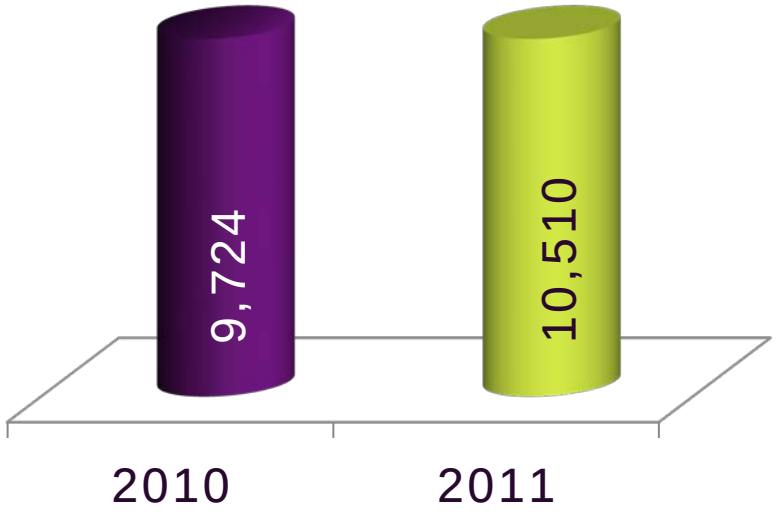
1. Novozymes at a Glance
2. Fermentation Pilot Plant
3. Structure of Academic Projects
4. Projects
5. Concluding Remarks

Novozymes at a Glance

Geographical distribution of 2011 sales



Sales development in DKK million



More than 700 products used in 130 countries

Largest bio product portfolio in the world

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Novozymes at a Glance

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Fermentation Pilot Plant

Scale-up and transfer of strains from R&D to production

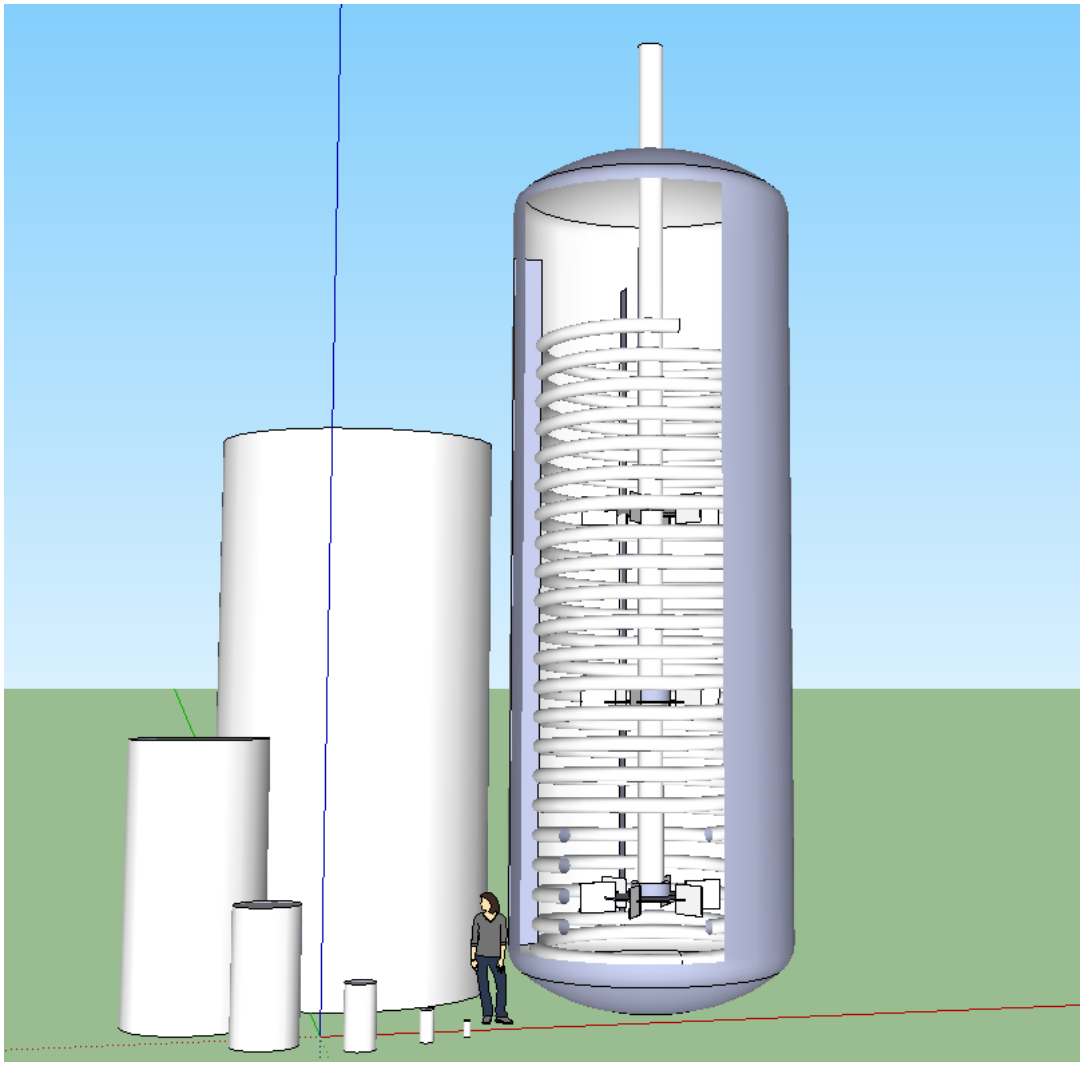
Sample production

Production of material for toxicology characterization

Process optimization

Development and testing of new technology

Fermentation Pilot Plant



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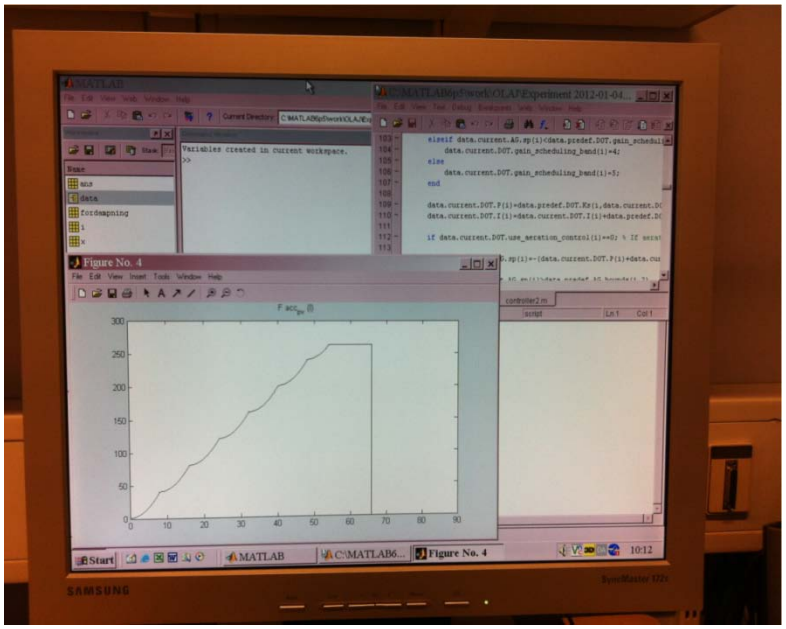
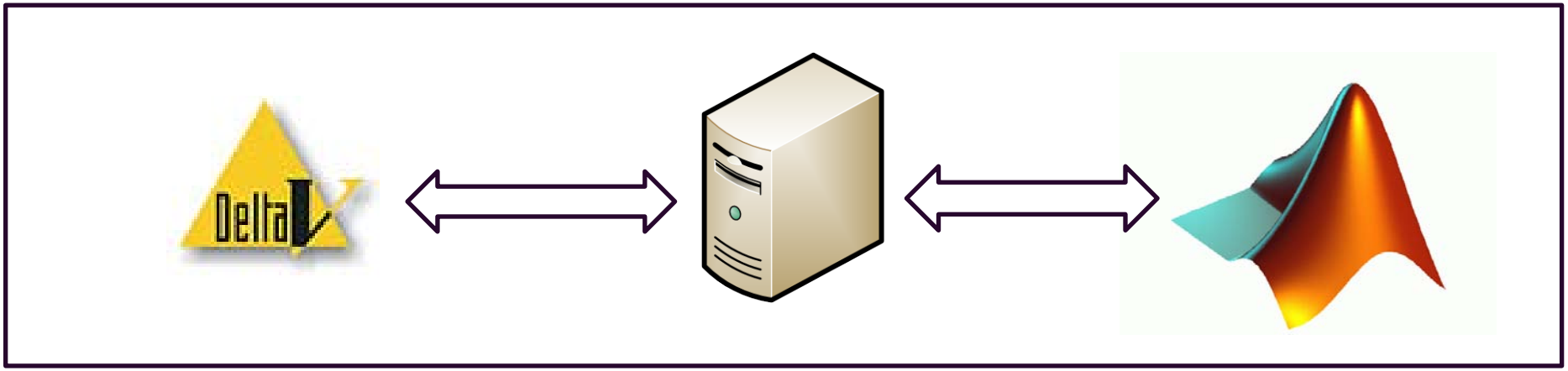
Fermentation Pilot Plant





Structure of Recent Academic Projects

Year	Student	Project Type
2005	D. Bonné	PhD
2006	N. Petersen	M. Sc
2007	N. Faria	Post Doc
2007	M. Villanueva	M. Sc
2007	J. Rasmussen	PhD
2009	O. Johnsson	M.Sc , PhD

Projects

Optimal and Reproducible Operation of Batch Processes (D.Bonné)

Objective

1. Provide theoretical framework for data driven batch modeling

2. The methodology will be used to achieve optimal and reproducible chemical batch processes

3. Extend the methodology to include design of model-based tools such as the Kalman filter, MPC and iterative learning control

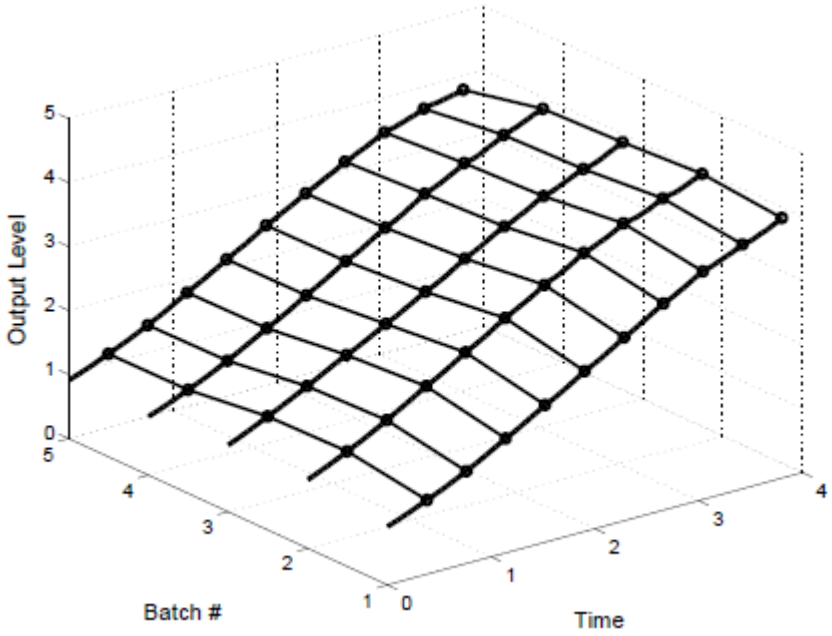
Projects

Optimal and Reproducible Operation of Batch Processes (D.Bonné)

Data preparation

1. Visual inspection to remove outlier batches
2. Data filtered and re-sampled using a Kernel smoother
3. Missing data is reconstructed based on appropriate reference data

Modeling



Projects

Multivariable Modeling for Control of Industrial Fed-batch Cultivations (N. Petersen)

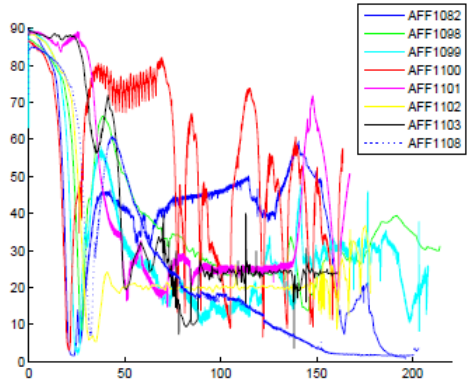
Objective

1. Expand the previous work to industrial fed-batch fermentation process producing an *α-amylase* from *A.oryzea*

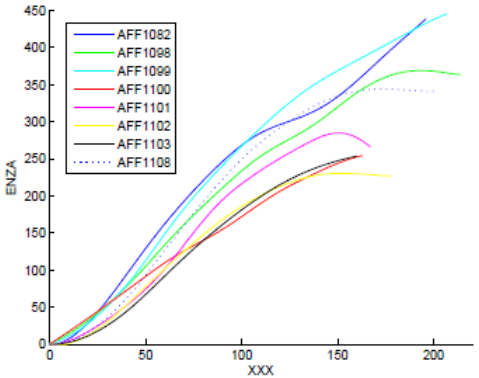
2. Evaluate MPC control using the GoLM framework

Projects

Multivariable Modeling for Control of Industrial Fed-batch Cultivations (N. Petersen)

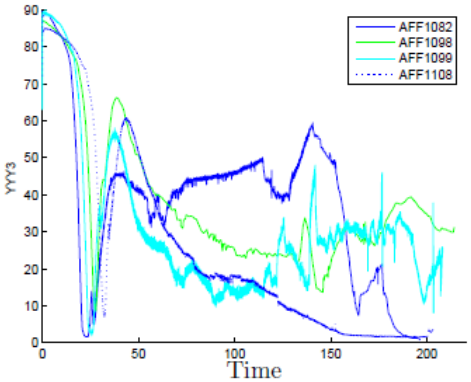


(b) DOT

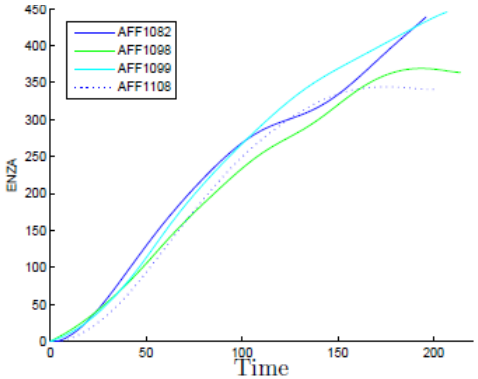


(d) Enzymes activity

Data preparation



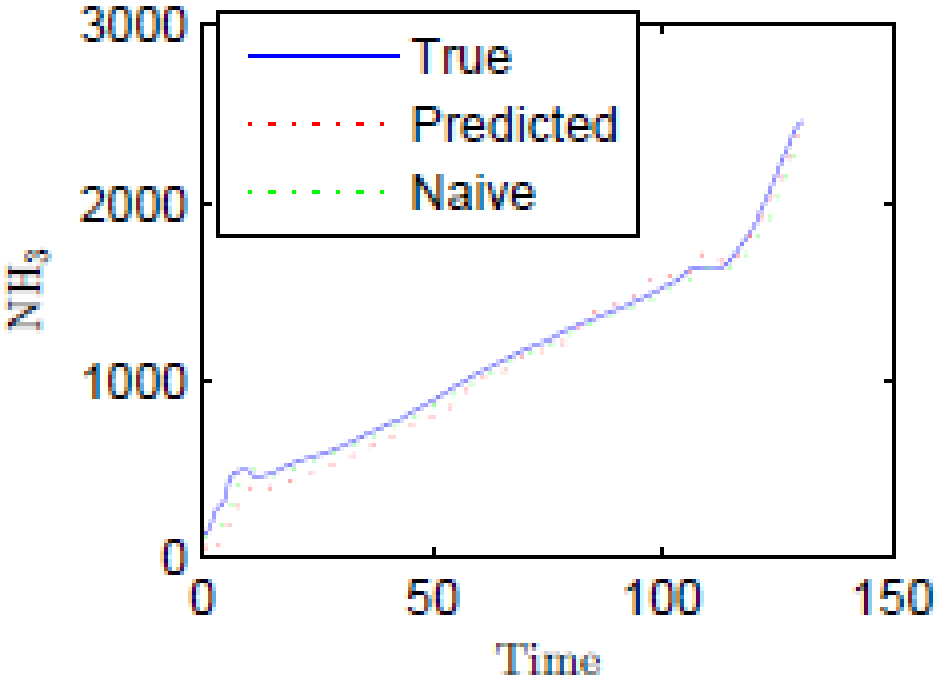
(b) DOT

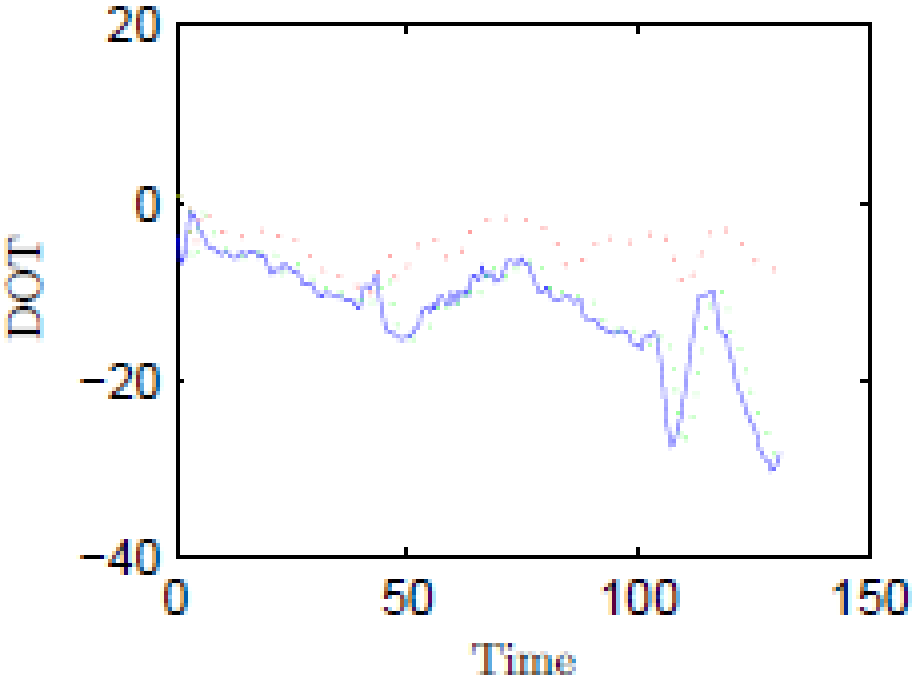


(d) Enzymes activity

Projects

Multivariable Modeling for Control of Industrial Fed-batch Cultivations (N. Petersen)





Projects

Multivariable Modeling for Control of Industrial Fed-batch Cultivations (N. Petersen)

1. Limitations in the number of batches reduces model quality
2. Too big batch to batch variation explain some of the variation
3. Hence the dataset was not optimal for the purpose
4. Although some variation is needed in the data!

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Projects

Fed-batch Process Modeling Using GoLM for Monitoring and Optimizing Control (M. Villanueva)

Objective

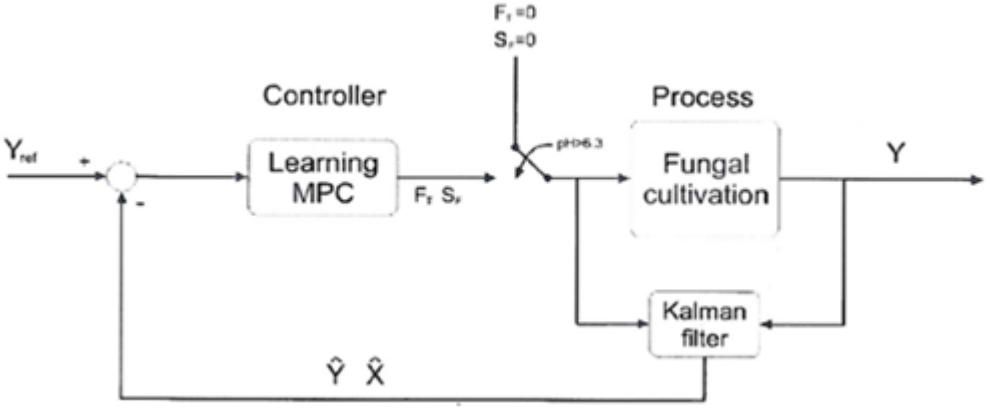
1. Generate dataset that can be used to estimate a model using the GoLM methodology

2. Pertubations in the input variables were used to provide additional information in the output data (identification experiment)

3. Implement an MPC scheme and run a batch with the objective to follow a reference batch

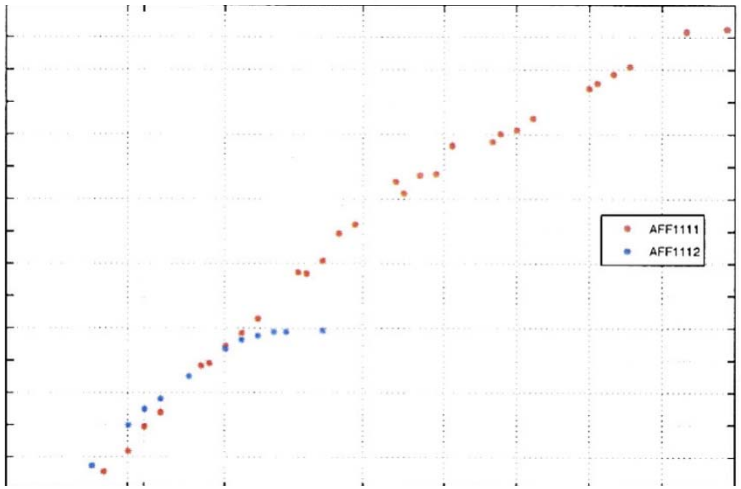
Projects

Fed-batch Process Modeling Using GoLM for Monitoring and Optimizing Control (M. Villanueva)



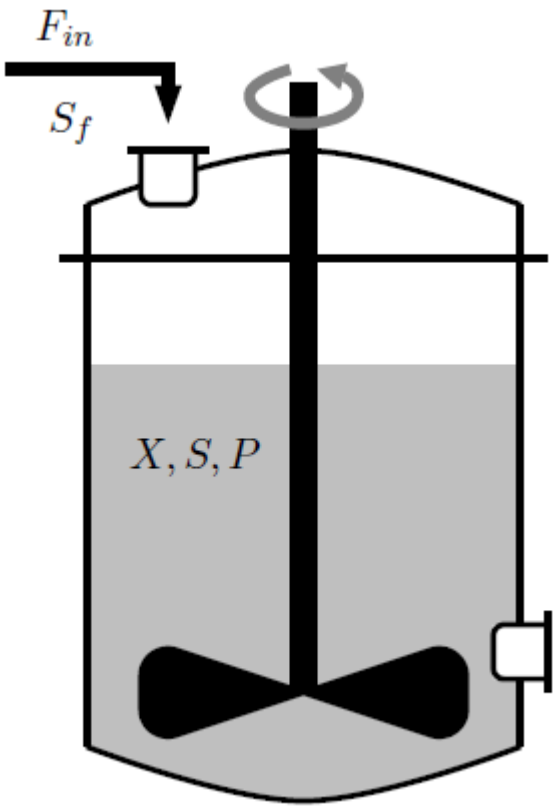
1. Tracking error is based on difference between batch and reference

2. A Kalman filter is used for state estimation



Projects

Oxygen Control for an Industrial Pilot-scale Fed-batch Filamentous Fungal Fermentation (N. Faria)



Objective

Develop high performance oxygen control strategy with optimized setpoint

Evaluate the strategy on an *α-amylase A.oryzea* process

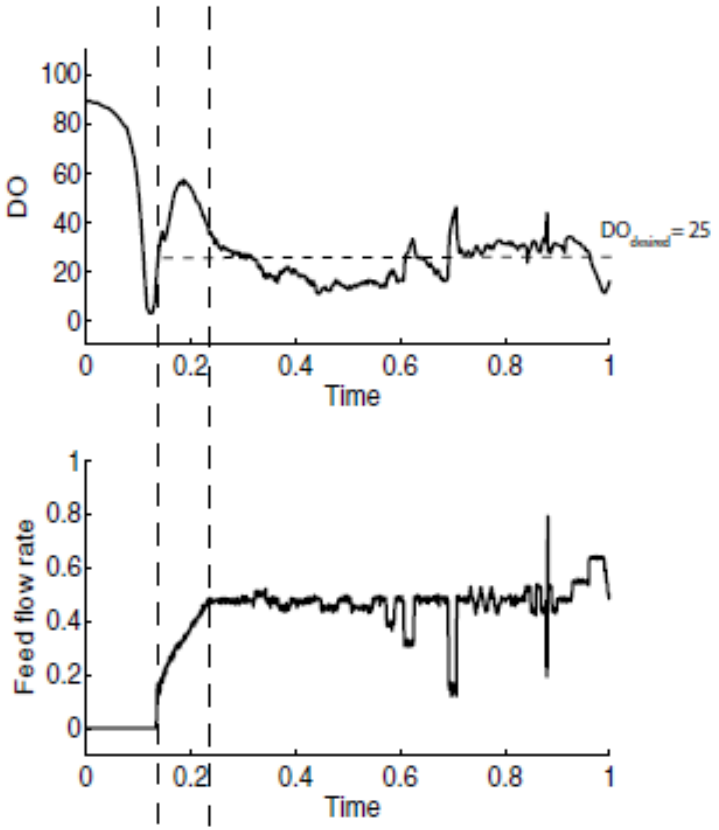
Projects

Oxygen Control for an Industrial Pilot-scale Fed-batch Filamentous Fungal Fermentation (N. Faria)

Poor performance using a standard controller

Biomass and viscosity vary throughout the process

Additional information is available in auxiliary variables like CER and OUR



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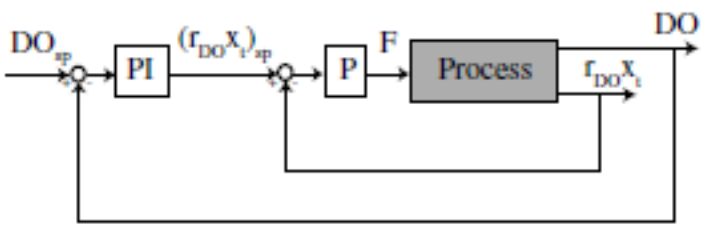
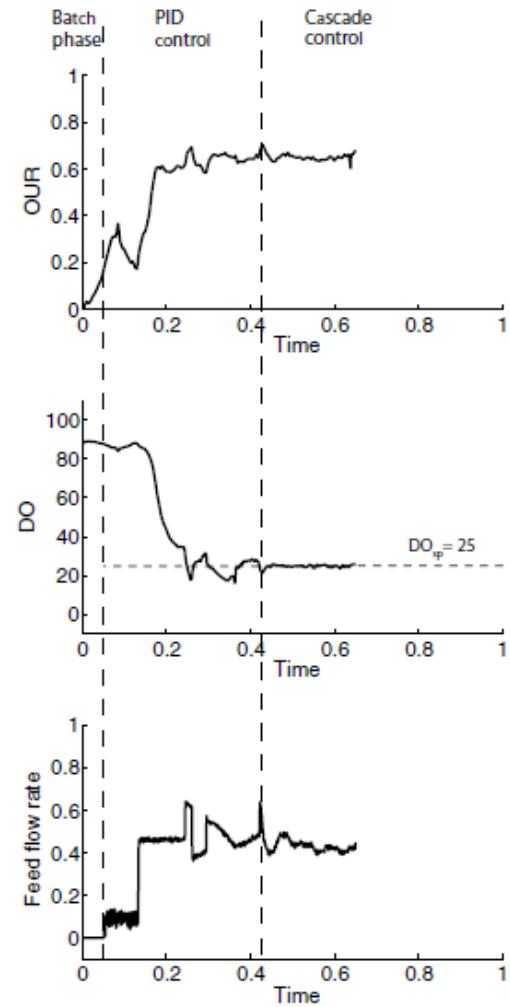




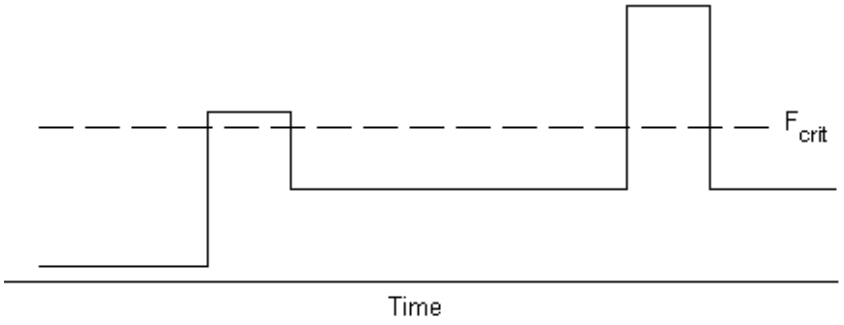
Inner loop regulates oxygen consumption based on CER and OUR measurements

Outer loop provides set-point for consumption

Projects

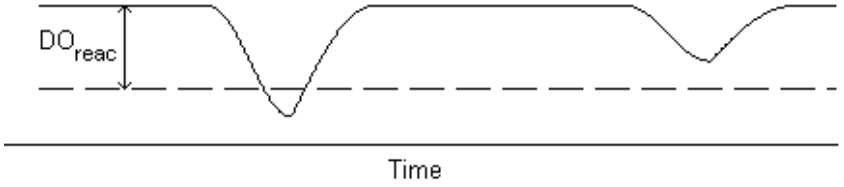
Probing control applied to B.licheniformis fermentations (O. Johnsson)

Decision tree type control scheme



A gain factor is used to scale the pulses so that stability is ensured

The strategy is well known but has here been extended to a Novozymes process and strain



Projects

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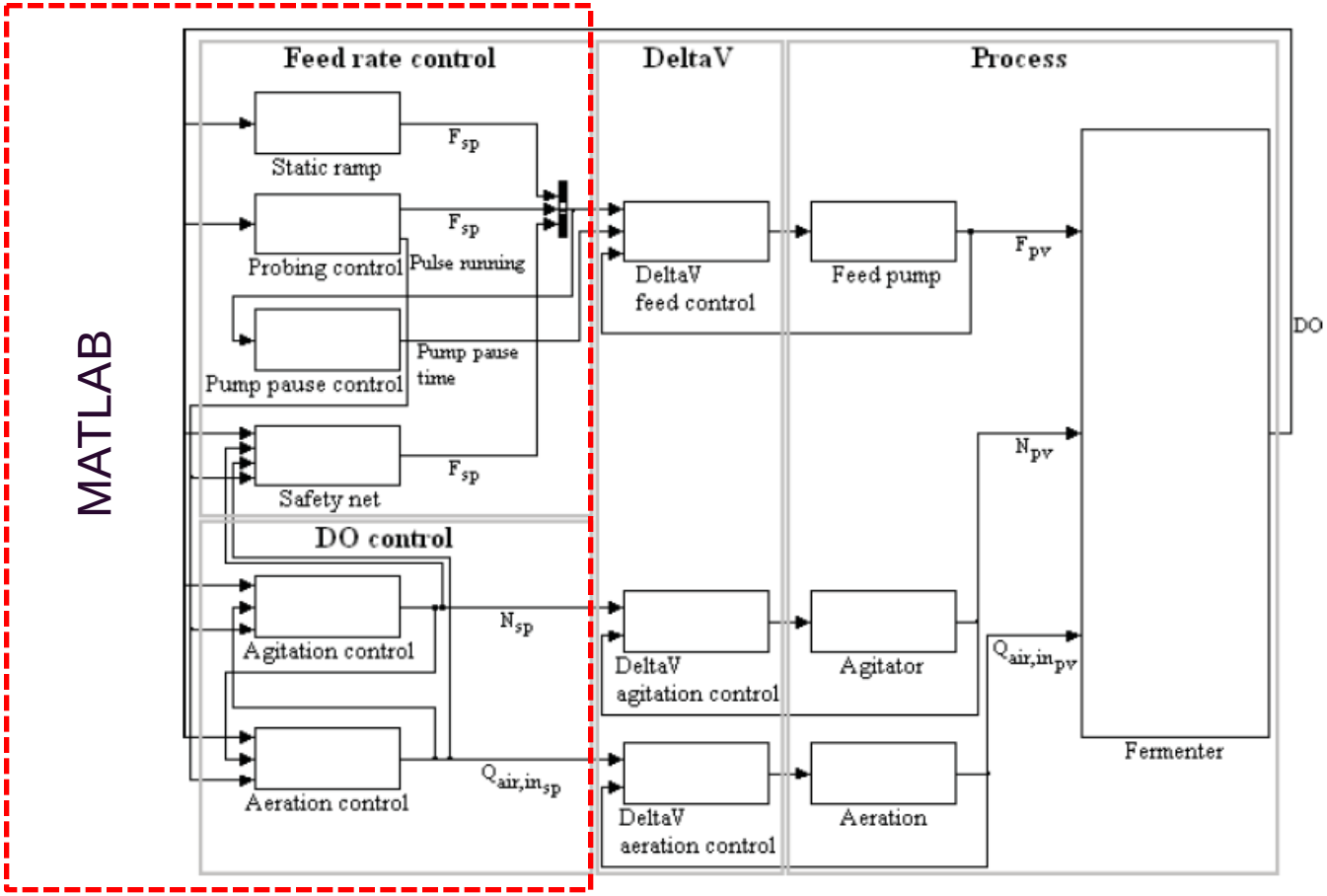

Projects

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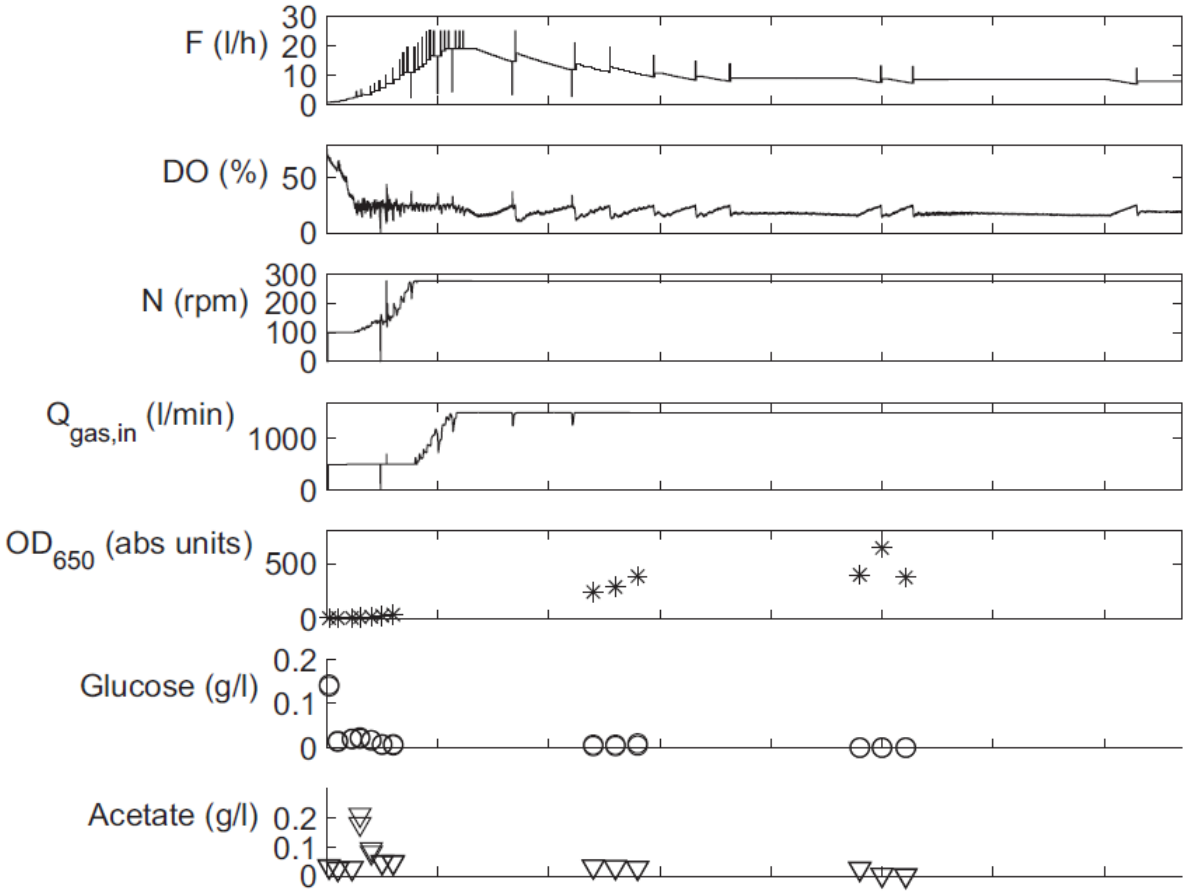

Concluding Remarks

- The Novozymes fermentation pilot plant has the hardware and software set up to facilitate these types of projects
- Novozymes and the fermentation pilot plant is very open towards academic collaboration
- So far, advanced model based strategies have not been so applicable for our types of processes

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Thank you for listening!

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