

TKP4550/TKP4551 PROSESS-SYSTEMTEKNIKK (PROCESS SYSTEMS ENGINEERING)

Coordinator: Sigurd Skogestad

Project proposal from Professor Sigurd Skogestad, sigurd.skogestad@ntnu.no

70 Robust implementation of optimal operation of LNG refrigeration cycles.

Co-advisor: Adriana Reyes Lua

71 Optimization of the synthesis-gas loop as example for integrated processes.

Co-advisor: Julian Straus

72 Subsea processing. Co-advisor or main advisor: Johannes Jäschke

- a. Subsea separation of oil and water;
- b. Subsea water treatment.
- c. Subsea separation of gas and liquid (oil)
- d. Subsea boosting

The projects nr .. to ... will include the following:

- part 1. Industrial use (survey, first month)
- part 2. Dynamic and steady state models (survey, second month)
- part 3. Control strategies (survey, third month)
- part 4. Research challenges and proposed research (may include a proposal for Master thesis work.)

73 Industrial use of condition monitoring of process and equipment variables, a survey with emphasis on the oil and gas industries,

Co supervisor: Johannes Jäschke

74 Case study at Perstorp Co. Advisor: Prof. Krister Forsman

Project proposals from associate professor Johannes Jäschke: jaschke@ntnu.no

Category 1: General topics

75 Chance-constrained optimization. A survey and small examples highlighting potential and challenges for use in model predictive control.

When optimizing process plants under uncertainty, it is sometimes desired that certain variables satisfy operational constraints for “most of the time”. This can be translated into the mathematical requirement that the constraint is satisfied with a given probability, e.g. 95%. Such optimization problems, where the constraints are required to be satisfied with a given probability are called “Chance-constrained optimization problems”

The goal of this project is to gain an initial overview over chance constrained optimization and solution approaches for such problems.

This challenging project requires ability to work independently, good knowledge in numerical optimization (e.g. TTK4135 Optimization and Control), and keen interest in learning more about optimization.

Tasks:

1. Survey: basics and solution methods for chance-constrained optimization problems
2. Toy examples for demonstration purposes
3. Survey: Application to model predictive control
4. Research challenges and proposed research (may include a proposal for Master thesis work.)

Category 2: Modelling and monitoring compact separation equipment

The task of these projects is to develop simple models of compact gas-liquid separators that are suitable for optimization and control.

In order to be able to produce hydrocarbons economically from reservoirs under difficult circumstances, such as ultra-deepwater conditions or low reservoir pressure, is necessary to separate oil, gas, and water at the sea floor. This subsea separation enables efficient and economic transport over long distances, and also reduces the back pressure on the reservoir, which leads to increased production.

For economic reasons, the separators used subsea are built very compactly, and this comes with unique operational challenges. These compact processes are often very coupled, and due to the relatively small dimensions, they exhibit fast dynamics, which are challenging when controlling the processes.

Moreover, these models can be used to monitor the process and the equipment of equipment that is difficult to access.

We are looking for someone who likes to program in matlab or a similar language, with good mathematical skills the ability to work independently.

76 Modelling of compact gas-liquid separators

Tasks:

1. Industrial use (survey, first month)
2. Dynamic and steady state models (survey, second month)
3. Control strategies (survey, third month)
4. Research challenges and proposed research (may include a proposal for Master thesis work.)

Supervisor: Associate Professor Johannes Jäschke and Professor Skogestad

77 Modelling of compact liquid-liquid separators

Tasks:

5. Industrial use (survey, first month)
6. Dynamic and steady state models (survey, second month)
7. Control strategies (survey, third month)
8. Research challenges and proposed research (may include a proposal for Master thesis work.)

Supervisor: Associate Professor Johannes Jäschke and Professor Skogestad

78 Industrial use of condition monitoring of process and equipment variables, a survey with emphasis on the oil and gas industries

Tasks:

1. Industrial use (survey, first month)
2. Dynamic and steady state models (survey, second month)
3. Control strategies (survey, third month)
4. Research challenges and proposed research (may include a proposal for Master thesis work.)

Supervisor: Associate Professor Johannes Jäschke and Professor Skogestad

Category 3: Projects in collaboration with DNV GL in Høvik

Note that there may be summer jobs possible. Please mail the contact at DNV GL below.

79 Modelling of multiphase flows in subsea separators

Background

The subsea sector has a great improvement potential with regards to employing new technology. However, the sector is conservative because of the risk related to the uncertainties that relies in the difficult access for doing repair and maintenance subsea. The present work focuses on methods for qualification of subsea processes and seeks to give guidance to the subsea sector for applying new technology with the required confidence for subsea use. The main motivation is to create improved and more cost-efficient methods for subsea process technology qualification.

Objective

Investigate for gas-liquid separation processes relevant for “subsea factories” the potential coupling between fundamental physical and chemical processes at micro scales and failure modes at the macro level.

- **Scope of work**
 1. Literature review of multiphase flows and subsea separation processes, including modelling in general and state-of-the art in multi-scale modelling in particular.
 2. Identify, select and describe a relevant subsea separator case study
 3. Identify and discuss potential failure modes (risks) that is related to the coupling between fundamental physical and chemical processes and the equipment in multiphase separator flow
 4. Review and discuss relevant models to model and simulate the identified failure modes of concern. Discuss pros and cons of the various models and use this to conclude and select model.
 5. Develop model for one or more selected process-equipment failure mode.
 6. Develop a multi-scale model for one or more failure mode and compare with other model identified in pt. 4 above. Compare results with experimental data from case study in pt. 2 above.
- **Deliverable** Project report
- **Summer job**

There might be a possibility for summer job financed by DNV GL. Contact Frank Børre Pedersen, Program Director, Oil & Gas and Energy Systems in DNV GL Strategic Research and Innovation, for more information. Email: Frank.Borre.Pedersen@dnvgl.com.
Work place: Høvik.

Advisors:

Supervisor: Johannes Jäschke, Associate Professor, NTNU
Co-advisor: Tore Myhrvold, DNV GL
Co-advisor: Andreas Hafver, DNV GL

80 Condition and performance monitoring of subsea systems

Background

Subsea installations are remote by nature and intervention is much more difficult and costly. This makes it important to design robust and failure tolerant components and systems, and to develop solutions and strategies for on-line condition and process monitoring and for robust control.

Condition and performance monitoring (CPM) becomes increasingly challenging for complete subsea production and processing systems because of the increasing amount of generated data, especially if rotating equipment is installed.

Bayesian Networks (BN) have previously demonstrated favourable capabilities for online process monitoring in chemical processes, but it seems not so far to have been in use for subsea systems.

Objective

Investigate the applicability of Bayesian Networks for condition and performance monitoring of subsea process systems.

Scope of work

1. Literature review of
 - a. Subsea process systems and subsea process monitoring and control, including “All subsea systems” such as Statoil’s subsea factory concept.
 - b. Previous work (state-of-the-art) in application of Bayesian Networks as a tool for process monitoring
 - c. Investigate knowledge transfer potential for CPM from other industries (such as in maritime and aviation) to the subsea industry
2. Review and discuss pros and cons of using BN compared to other methods for process monitoring and control to conclude on the applicability of BN.
3. Investigate applicability and discuss pros and cons of coupling of BN solvers with process modelling and simulation tools
4. Demonstrate by a case study the use of BN for process monitoring

Deliverable Project report

Summer job There might be a possibility for summer job financed by DNV GL. Contact Frank Børre Pedersen, Program Director, Oil & Gas and Energy Systems in DNV GL Strategic Research and Innovation, for more information.

Email: Frank.Borre.Pedersen@dnvgl.com. Work place: Høvik.

Advisors:

Supervisor: Johannes Jäschke, Associate Professor, NTNU

Co-advisor: Tore Myhrvold, DNV GL

81 Subsea Integrated Operations

Background

Over the past 15 years, subsea technology has moved from subsea wells, manifolds, flowlines, and templates, to include subsea boosting, separation and now compression. Some oil companies and subsea suppliers are targeting moving ever-larger sections of the topside subsea. Without direct access to the subsea installation the operator must rely on sensor data, management and analyses of large amounts of data.

Integrated Operations (IO) is the integration of people, organizations, work processes and information technology to make smarter decisions. IO is enabled by global access to real-time information, collaborative technology and integration of multiple expertises across disciplines, organizations and geographical locations.

Objective

Harvest knowledge from research done at the Center for Integrated Operations (<http://www.iocenter.no>) and how this can be applied for a subsea process system.

Scope of work

1. Literature review of:

- Subsea processing systems, for instance consisting of multiphase pumps, separators, and compressors with specific focus on the operational phase.
 - Integrated Operations, both research done at NTNU IO Center and others.
 - Describe in more detail what research done at NTNU IO center is relevant for a subsea processing station.
 - Identify and discuss main drivers/barriers for Integrated Operations.
2. Select one of the relevant research areas and describe how this can be implemented for a subsea system.
 3. Identify, select and describe a relevant subsea process case study:
 - a. Set up a process model for the system (Hysys).
 - b. Identify what sensor/controls that is needed as a minimum
 - c. Describe how IO will affect the design and infrastructure of the process system.
 - d. How will the implementation of IO affect the people/organization and decision making for an operator

Deliverable

Project report

Summer job

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Work place: Høvik.

Advisors

Supervisor: Johannes Jäschke, Associate Professor, NTNU

Co-advisor: Øystein Grande, DNV GL

82 Subsea process system qualification

Background

For subsea process systems, there is a need to develop and qualify the necessary technology elements, processes, and sub systems enabling the entire system to function as intended over its lifetime. System qualification is a collaborative task, including process, power & control. Current process technology qualification approaches have equipment focus. Subsea process qualification need more focus on the physical and chemical processes and integration with interfaces to equipment, power and control (system qualification).

Objective

Develop knowledge and methods in subsea process technology qualification and subsea system qualification.

Scope of work

4. Literature review of:
 - Subsea processing systems, for instance consisting of multiphase pumps, separators, etc. with specific focus on the control systems and interfaces to process and power
 - Technology qualification in general, for instance DNV-RP-A203, API-RP-17n or similar

- Subsea industry's state-of-the-art methods for qualification of subsea control systems and qualification of interfaces between control and process and power in a subsea processing system
5. Identify and discuss one or more system failure modes related to process-control interfaces
 6. Identify and discuss pros and cons of potential methods for qualifying the identified failure mode(s), e.g. mathematical model, experiment, etc. to conclude on the applicability of the various methods
 7. Develop a model for one or more of the identified system failure mode(s), carry out simulation of potential scenarios and report uncertainty in the results in order to demonstrate qualification.

Deliverable

Project report

Summer job

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Work place: Høvik.

Advisors:

Supervisor: Johannes Jäschke, Associate Professor, NTNU

Co-advisor: Tore Myhrvold, DNV GL

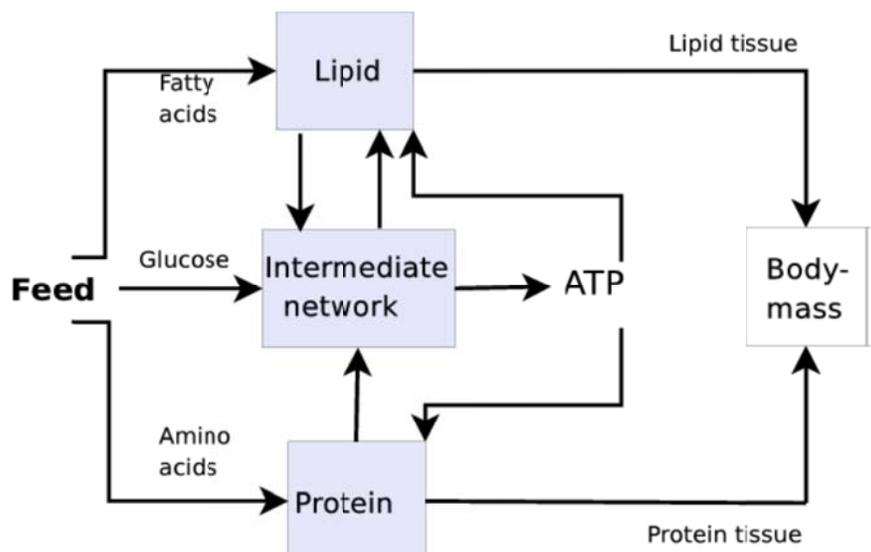
Project proposals from Associate Professor Nadav S. Bar, nadi.bar@ntnu.no

83 Simulation and numerical optimization of a dynamic model of growth (System biology: applied modeling)

A novel model that predicts the growth of fish, given the feed type and environmental conditions, has been developed during 2003-2009. The model traces the nutrients, proteins and fat, through the metabolic processes of the body, and basically it is a set of ordinary differential equations. It was implemented in Matlab code, using a constant time step, first order Euler integration method to solve the differential equations.

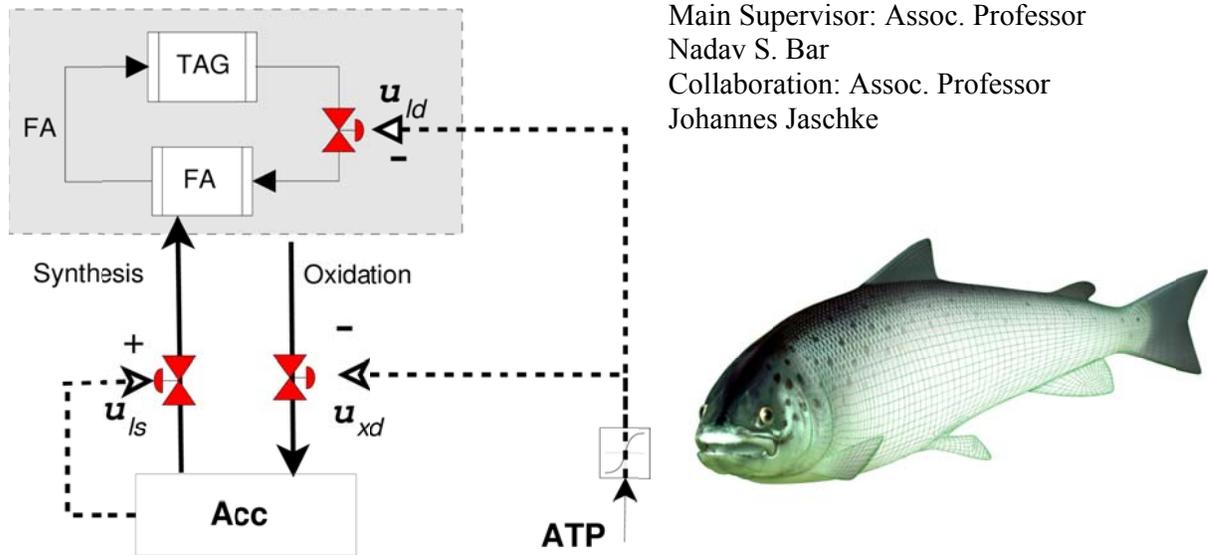
However, this method for solving the differential equations is very inefficient, and a more practical implementation is needed.

The main goal of this project is to optimize the integration method of the model, using a combination between a constant time-step and Matlab's ODE time variable solvers (ode45, ode15s). The project is interesting since it



attempts to give a practical, industrial, applied solution to a theoretical model. If the program (the implementation of the model) could be optimized and made efficient, it will have a great value to the aquaculture field, both in study fish development and design more healthy fish feed.

The candidate will gain many useful skills, that are very important in the research and development in industry, such as how to make model solvers more efficient, how to simulate and solve models using ordinary differential equations, a very important aspect of any applied modeling.



Main Supervisor: Assoc. Professor
Nadav S. Bar
Collaboration: Assoc. Professor
Johannes Jaschke

84 Modeling and simulations of bat flight and sonar in 3 dimensions (Systems biology: Neuroscience).

It was found in 2010 (Science Magazine, Yovel et al. 2010) that Egyptian fruit bats apply a sonar measurement strategy that is similar to the strategy used by certain GPS. One of the explanations was that the bat tries to reduce the sonar measurement noise during its flight to the target (which can be fruit or insect).

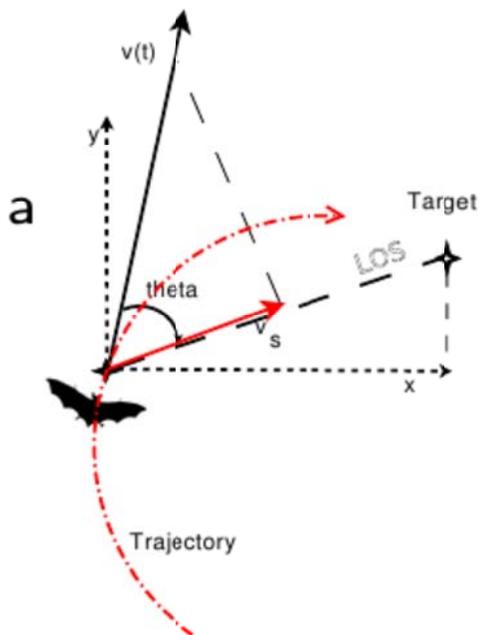
In our lab (in cooperation with Univ. of Maryland, Weizmann Institute of Science, and the U.S. defence), we developed a dynamic model that estimates the x-y trajectories of the bat's flight as it converges to its target, and explored the strategies it applies to reduce the noise that is reflected from the surroundings (trees, leaves, and other objects around the target). We found that the bat's brain processes the sonar information and filter the noise in a very interesting manner, stems from the fact that the bats has to apply a specific flight control system due to its non-linear flight maneuvers.

The main goal of the project is understand the sensory system of the bat, understand the strategies it uses for navigation, both long distance and short. We would like to analyse the data about the navigation using earth's magnetic field we collected from Mexico.

The project can be later integrated in Master thesis, studying the sonar effect and the flight convergence strategies.

See Schrödinger's Katt, NRK, 19.mars 2015.

Main Supervisor: Associate Professor Nadav S. Bar



Project proposals from Professor Heinz Preisig, heinz.preisig@ntnu.no

The projects are in no specific order. Projects are offered both as "fordypningsprosjekter" and master projects. Level changes accordingly. If you have a pet project not listed - we can discuss it.

87 Overseas cooperation: Nonlinear frequency analysis

Literature is scarce in this domain as frequency analysis is often thought to be limited to linear systems. There are however techniques and classes of models for which nonlinear frequency analysis is applicable.

This project is of joint interest with Andreas Linninger professor in the Bioengineering department at University of Illinois at Chicago, Chicago, IL. So this could imply that one organises a stay at Chicago.

Supervisor and daily contact: Heinz A Preisig

88 Overseas cooperation: Model of a rat

Medical technology has come a long way in terms of the ability to measure blood flow, vessel distribution and the physical properties of living tissue. In collaboration with Andreas Linninger professor in the Bioengineering department at University of Illinois at Chicago, Chicago, IL, we want to map a well-documented species into a network description that describes the blood flow in the body, including all organs, which we then plan to extend with simple models for the metabolisms in the different organs.

This project is of joint interest with Andreas Linninger professor in the Bioengineering department at University of Illinois at Chicago, Chicago, IL. So this could imply that one organises a stay at Chicago.

Supervisor and daily contact: Heinz A Preisig

89 CFD: Temperature distribution in milli-reactor, CFD-simulations

FluiTec is a small, hi-tech company located in Switzerland who is the innovator of a new reactor concept called ContiPlant. It is a Lego-like idea in which milli-reactors are the building blocks. These reactor types are currently tested by the large polymer industries to construct small-scale productions that can be placed into containers and thus are mobile. Production range is in the 10 k tons per year.

An expert group has constructed a rig and we have had a master project joint with BASF doing CFD calculations towards the simulation of these reactors for polymer systems. This was done with the main research division of BASF that looks into new production technologies.

So we have now one of a four university installations of the reactor, which was provided by the producer FluiTec. Our installation is equipped with a cutting edge temperature sensor which is based on an optical laser-inferential meter to measure temperatures along the axis of the reactor on 8 positions with only one fibre. The fibre is less than in the order of 0.2 mm and the reactor inside approx 6 mm. So we are talking very highly sophisticated reactor equipment with highly sophisticated measurement equipment. We shall aim at constructing a dynamic residence-time distribution experiment for research and felles lab and using CFD to simulate the behaviour of the plant on a large computer, possibly NTNU's supercomputer.

Supervisor and daily contact: Heinz A Preisig

90 CFD: Residence-time distribution in various mixed systems, CFD simulations

As part of the renewal of the felles lab, I am extending the scope of reactor-engineering related projects. In particular the concept of residence-time distribution is being one of the targets. We have built two flexible bench-scale experiment, which demonstrates the hydraulic behaviour of various different physical systems. We constructed new conductivity sensors which we are implementing and testing. We would now like to model the sensor - injection manifold using OpenFoam CFD simulation with the objective to better understand their behaviour and check and if necessary improve the design of the injector and the sensor.
Supervisor and daily contact: Heinz A Preisig

91 Multi-scale modelling: Design of input patterns for computational experiments

Multi-scale modelling is a key to integrate nano-models into macroscopic descriptions. On a given scale, models of the lower scale are integrated by making time-scale and length-scale assumptions. If the scale difference goes over the limit particular processes / continuous processes, this involves a population averaging whilst retaining conservation of the fundamental physical quantities. On the upper scale, the behaviour of the lower scale is captured in a surrogate model, thus a model that replaces the detailed lower-scale model. This surrogate model is based on the length and time scale assumptions. Its key feature is simplicity in the sense of low computational complexity. As it is integrated to represent the lower scale these surrogate models are often in the most inner loop of the computation and thus very frequently evaluated making the need for low computational complexity evident. We would choose a particular toy problem from the EC project MoDeNa, which is on multi-scale modelling of polyurethane foams from quantum to mechanical properties. The lower scale is then the experiment and we inject conditions for the lower scale such that we optimise the information contents of the input/output signals in the context of the surrogate model. Common criterion is thus the Fisher information matrix, which gives a measure of the minimal variance bound of the estimate. This is then minimised by changing the conditions. The mathematical problem finds more than one formulation. The common one is to use a linearised approach but in many cases the problem is strongly nonlinear and should be handled using nonlinear optimisation. Constraint is then the surrogate model and in some cases also hard constraints on the conditions due to validity limitations of the involved models.

MoDeNa link: <http://modenaproject.eu/>

Supervisor : Heinz A Preisig, MoDeNa team.

92 Modelling fundamentals: Ontology for material models

Models representation overt the scales and link to experiments. This work is also associated with the EC project, but aims at a wider objective to define standards for models and associated data.

The material communities are more and more able to predict the behaviour of materials. Multi-scale modelling is a key to integrate nano-models into macroscopic descriptions. On each scale assumptions are being made about the lower scale and thus a hierarchical system of models is constructed that eventually provides a description of the material or process on the production scale. On all levels, models are being generated and all models are an integrated part of the overall description. If one wants to use these models for the manipulation of the quality of the product, then one could talk of control. If one uses the

models for getting alternative products, then one would talk about product design, if one uses them for design, then it is plant design and if it is for operations than it is mostly control. In all cases the "control" aspect is important.

Currently models and software are intimately linked together, well in most cases they form a monolith on the respective scale and it is re-implemented for each and every application of the model. This is what we should change: models should be in a library in a generic form, such that we can take them out, compile and integrate them with the solver code and generate stand-alone, special purpose computational tasks. In order to be able to do so, the models have to be made available in a generic form. This form must be suitable to capture essentially any of our models and be stored in a form that makes it easy to translate them into any kind of target code. Software factories come to mind, but also model reduction and simplification procedures.

MoDeNa link: <http://modenaproject.eu/>

Supervisor Heinz A Preisig, MoDeNa team.

93 Green chemistry, SINTEF cooperation: SINTEF Bio-Refinery

Humans have to integrate better into the earth's biotope. Mining of carbon in the form of oil, gas and coal, is not sustainable and has many undesired effects on the earth's climate. Future generations will have to be more conscientious about the environment on a global basis

Supervisor: Heinz A Preisig and possibly SINTEF

94 Felles lab: Continuous distillation

We have now four working distillation columns in the felles lab. All of them use an industrial configuration.

What we like to do is to improve all by adding workable pressure measurements in the boiler so as to measure the level. Two columns should be extended to continuous columns. This implies that we refurbish two columns with additional pumps to enable them running in continuous mode. we have now the ability to build the pumps ourself so as to have superior performance over commercial pumps. We combine an advanced pump head with an advanced motor, both from different companies.

Effort focus can vary from control, software to more engineering-type activities.

Supervisor and daily contact: Heinz A Preisig

95 Modelling-fundamentals & tooling: Computer-aided modelling

We are building on a new tool expanding on three previous generations of modelling tools. The objective of this project is to provide a high-level modelling tool generating code for existing software tools, such as gProms or other simulation environments. The software implements a step-wise approach to modelling as it is being taught in the Control Course and the Systems Engineering Course. It builds on a graph representation of the processes, adds the "chemistry". A "theory" module provides the basic descriptions, like the balance equations and, where appropriate alternative transfer descriptions and kinetic laws, material descriptions and the like. The "theory" module is designed using a special tool, which implements a simple, tailored language. The project aims at enhancing and partially substituting the current chemical engineering simulator software.

We are currently implementing a new ontology-based approach. An ontology is a basic framework, in our case it is the mother model of chemical processes

Recent publication: <http://dx.doi.org/10.1016/j.compchemeng.2010.02.023> being noted as one of the most cited papers of Comp & Chem Eng in the period 2010-2013
An excellent opportunity to learn more about modelling and if so desired, programming.
Supervisor and daily contact: Heinz A Preisig

96 Felles-lab: Control and Felles lab rejuvenation

We have now completed the main effort of re-building the felles lab, but would like to extend further so as to make it more versatile and more flexible. There is also an ongoing discussion of extending the scope of the lab to other courses. Also the control lab shall be updated and augmented with a couple of experiments. Initial plans have been developed. We invite to help thinking about possible, interesting processes and their realisation.

An excellent opportunity to learn about real-time programming, control and making experiments fool proof.

Supervisor and daily contact: Heinz A Preisig

97 Process design: Automatic Safety and Hazard Analysis

Safety and hazard analysis are done mostly in a systematic way, but based on mental models of the process. We would like to change this and use a model-based approach. Starting from a model of a continuous process, we have software that computes the possible things that may happen if the environment changes or faults occur.

Since we can do this computation, this method could be used to study if indeed something could possibly happen, which is precisely what a safety and hazard analysis does.

This type of analysis would give a systematic way of exploring the possible faults in a system, a subject of great interest to industry. Possible co-operation with SINTEF on hydrogen gas fuel stations or the like.

Supervisor and daily contact: Heinz A Preisig

98 Modelling - tooling: Simple Thermo Server

The Process Systems Engineering group is heavily involved in process modelling particularly distillation. Distillation models and associated material models are used at a high frequency.

The project is aiming at implementing a server that provides:

- Interface requesting material information over the net
- Generic distillation simulation, freely configurable running on the server

The material model software is running and we are using it in a variety of ways. We thought it would be fun and very useful to build a little user interface that enables the interactive use of what the core can generate. This could then be put on-line in the form of a web page, for example. We have a rather generic distillation column model that is quite generally parameterised, which could be augmented with an appropriate interface to make it usable on the web.

Such a system has been realised for Yara. A prototype sever exists and is currently operable for ammonia, nitric acid and urea production. The Matlab interface is already working and we are working on an interface to other computer languages such as Python.

Supervisors: Heinz A Preisig, Tore Haug-Warberg

99 Modelling fundamentals: On time scaling in chemical processes

The Process Systems Engineering group is heavily involved in process modelling. The objective is to generate a very general framework in which models for the process industry can be generated quickly and rapidly.

Making time-scale assumptions is done very frequently in the modelling process. Mostly it is not really done explicitly, but just kind of happens. Examples are decision on how to model a heat transfer, for example using an overall heat transfer model is making a time-scale assumption about the distributed transfer system to be of negligible capacity. Similar assumptions appear all over the place and we would like to put this problem into a more systematic framework.

The problem of getting measures for the relative dynamic of parallel fundamental transfer process is a common problem in chemical engineering. Probably best known are the “modules” such as the Thiele modules and dimensionless numbers. The derivation of such modules is very frequently based on “pseudo steady-state” assumptions, which in mathematical terms is a standard singular perturbation.

The project should look into the literature and analyse the mechanism behind the derivation of the different modules and the like with the aim of deriving a generic understanding behind these measures. In the next stage we want to know if such measures are useful in deciding if or if not the underlying pseudo steady-state assumption can be made or not and if possible on how wrong one is if one does make the assumption dependent on the dynamics.

100 Process & experiment: Process Identification using Wavelets

Wavelets are mostly used in signal processing as a data reduction processing. A common application is image processing. We are using the same technology for process identification. Essentially we can use wavelets to get derivatives to relatively high order on different level of resolution. This enables us to do identification on a multi-scale a technique matching the current development of multi-scale processes reaching from nano to industrial size equipment. I have also the vision that these technologies will enter the control field heavily in the future as these processes must be controlled across the scales. Thus some kind of plant-wide multi-scale process control.

Will introduce the student to multi-scale process modelling and wavelet methodologies.

Supervisor and daily contact: Heinz A Preisig