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NISSPI –
Nature Inspired Self healing Soft Sensors
for
Process Industry

**Final Task Force Report
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1. Introduction

The task force NISSPI - Nature Inspired Self healing Soft Sensors for Process Industry – started with the presentation of its aims given in October 2005 in Albufeira at the European Symposium on Nature-Inspired Smart Information Systems (NiSIS). NISSPI was founded in the focus group NiDT (Nature inspired Data Technology) of NiSIS.

In three workshops the task force developed a first concept for a new type of self-healing, self-adaptive soft sensor solution, with a working title called Herman (Healing Evolutionary Robust Models with Algorithms from Nature).

In addition the task force was closely connected to the **NiSIS 2006 Competition**.

2. Roadmap of the Task Force

In April 2006 there was a first workshop on “Nature Inspired Self healing soft Sensors in Process Industry” with multidisciplinary participants in Marl, Germany.

In December 2006 a second NISSPI workshop took place at the 2nd European Symposium on Nature-inspired Smart Information Systems in Puerto de la Cruz, Tenerife, Spain

The last workshop in November 2007 collected experts from biology and other disciplines to exchange about genetic theory.



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3. Project Details

3.1. 1st NISSPI Workshop

Participants of the 1st NISSPI Workshop

Prof. Dr. Bogdan Gabrys, University Bournemouth
Prof. Dr. Rüdiger Brause, University Frankfurt
Reinhard Dudda, Degussa.
Dr. Peter Kaßler, Degussa.
Prof. Dr. Kauko Leiviskä, University Oulu
Michael Kawohl, University Berlin
Prof. Dr. Joseph Lengeler, University Osnabrück
Dr. Robert Mühlhaus Degussa.
Dario Sterpi, University Genua
Prof. Dr. Jens Strackeljan, University Magdeburg
Dr. Uwe Tanger, Degussa.
Dr. Lars von Wedel, AixCape
Monika Berendsen, Degussa.

Agenda of the 1st NISSPI Workshop

2006-04-21

Welcome to participants
Introduction Degussa and its challenges of process control
Dr. Uwe Tanger
Visit of a plant in Marl
Sustainable SoftSensors, experiences, traps and challenges
Dr. Robert Mühlhaus
Discussion

2006-04-22

Biological Sensors
Prof. Dr. Lengeler
Catalyst Monitoring of a Multi-Tube Reactor
Dr. Peter Kaßler
Discussion / Brainstorming of ideas for nature inspired solutions

Report of the 1st NISSPI workshop

Summary

In many areas of industries soft sensors are applied. By the use of software based sensors recent information of plant measurements, quality measurements or analysis can be presented nearly in real time to control processes or even to improve operation mode of a plant. Although for speciality chemistry with its many processes that often change, the development of Soft Sensors is very expensive. Best solution would be self creating Soft Sensors, but in some sense self healing Soft Sensors would be a big step forward, too.

On the one hand the workshop gave an idea of what are the actual problems dealing with soft sensors in chemical process industry.

On the other hand the workshop participants got ideas how to adopt principles derived from nature or especially biology to develop soft sensors which need less human effort in development and maintenance.

By getting a suggestion how the biological sensors work, the workshop participants discussed ideas for a smart adaptive system that develops its structure and functionality in a continuous, self-organized, adaptive and interactive way.

In this way, the Workshop brought together researchers and several experts from university and industry.

Introduction

First Dr. Uwe Tanger, Degussa, introduced Degussa and its challenges of process control. He described the state of the art of process control, which are already integrated in the IT-systems. Missing applications are statistical process control, smart alarm management / monitoring, balances, statements, asset management and adaptive soft sensors. There is still a tremendous need for development in data filtering and reconciliation – like distinction of stationary and transient process states, regular and irregular operation, detection of shut downs, missing values, transformation of time scales in case of batch operations. The industry needs self adapting, self maintaining models for drifting readings, shift of process regimes and hybrid models as a combination of data-driven models and fuzzy rules or similar.



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Plant Visit

The participants visited the OXO-plant at the Degussa site in Marl. We saw the control room of the plant and got a demonstration of all implemented process control including soft sensors. All participants discussed how to improve the monitoring of the process control by nature inspired ideas. The main questions were on the information which enable people to drive the plant. Not all information is measured, the combination of measured and observed data flows together to form a picture of the state of the plant. Operators are doing a kind of pattern recognition for these combination problems.

Experiences and Challenges

Dr. Robert Mühlhaus, Degussa, gave a presentation about sustainable soft sensors including the experiences, traps and challenges concerning soft sensors nowadays. He described actual problems in developing and maintaining soft sensors in chemical process industry. One problem is that multi-purpose-plants have a bundle of different products for each plant, another problem is that continuous or even batch processes are improving, and therefore production conditions are changing which are important for the soft sensors. The products often have short product-life cycles and many processes are small or medium size. So modeling must be cheap, quick and reliable and that needs self-adaptive models. Dr. Robert Mühlhaus showed examples of soft sensors and common approaches for adaptive models. Traps and challenges for future adaptive systems are e.g.

- not every error calls for model correction,
- dealing with short-term contra long-term changes, choosing the appropriate adaptation rate,
- the ability to distinguish between process changes and faults,
- robustness against noise,

- fast reaction to adapt to important changes at the same time,
- intelligent selection of adaptation speed and
- maintain of the ability to generalize.

The chemical industry needs the transferability of process models.

Biological Sensors

Prof. Dr. Lengeler gave an overview of natural biosensors for non-biologists. He showed the general structure of a signal transduction system. He introduced the cellular functionality, details see in the presentation attached.

A few differences between and new aspects comparing soft sensors and biology sensors are

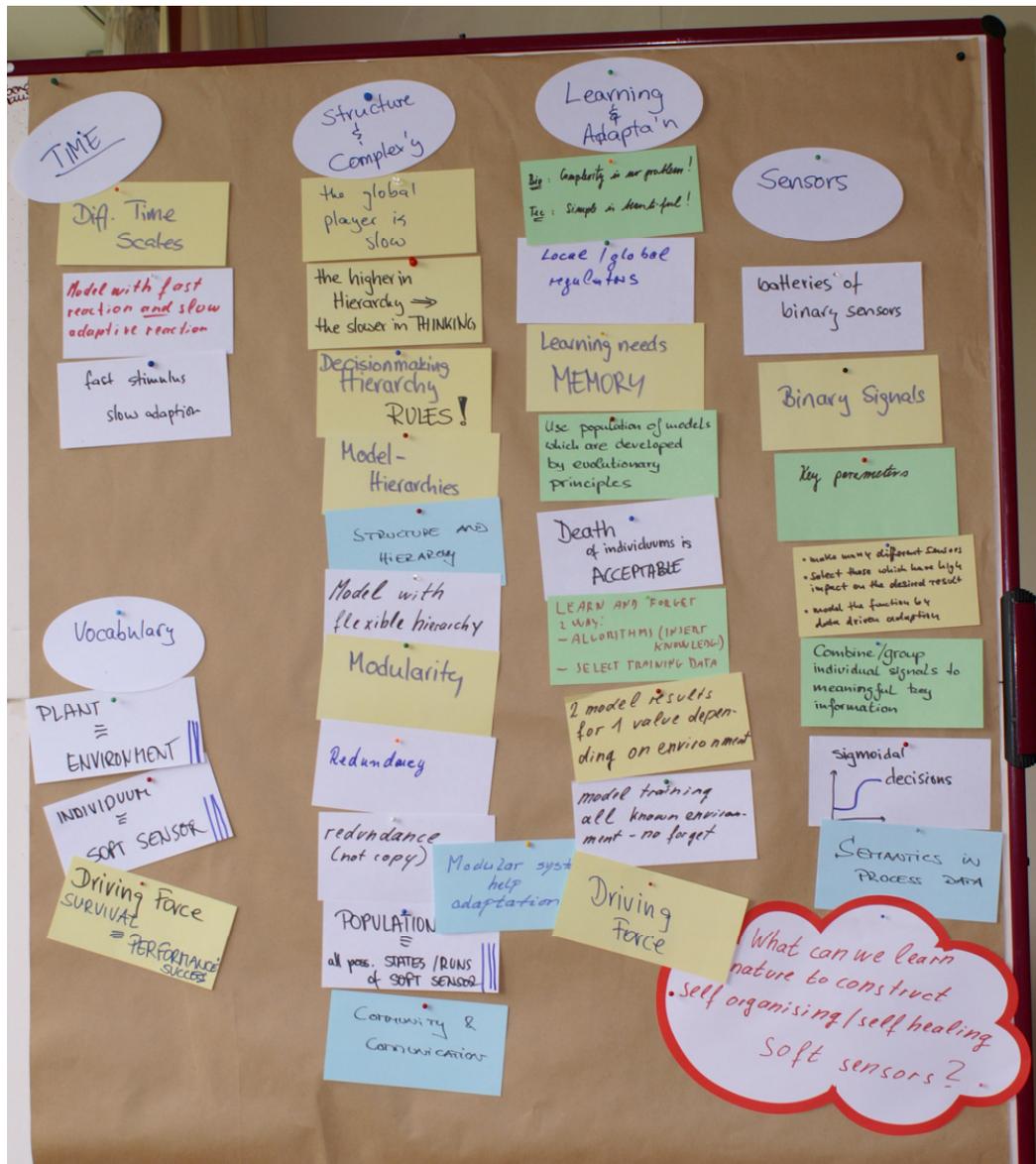
- biological sensors do rapid learning / forgetting,
- they have a high turn over,
- biological sensors have a battery of same receptors,
- cells act on a stimulus threshold,
- cells use flexible hierarchy,
- memory effect fast sensor kinetic ,
- slow adaptive kinetic,
- sensor response is transient,
- many receptors to one transmitter,
- cell-networking,
- one signal controls the actual behaviour fast and the adaptation is slow,
- one signal is connected to 2 or more sensors in different starting positions which react differently,
- optimization happens under all condition the cell ever knows,
- there is no forgetting,
- Sensor reacts only to changes of e.g. temperature, not the absolute value,
- biological systems concentrate on key components,
- there is a difference between local and global control,
- the response time varies, short and delayed reactions are reversible, later it is irreversible,
- neurons transform information.

Catalyst Monitoring

Dr. Peter Kaßler, Degussa, explained the catalyst monitoring of a multi-tube reactor. This model of a problem in the Degussa plants is taken as the NiSIS competition of NiSIS.

Brainstorming of ideas for nature inspired Solutions

The results of the brainstorming are grouped in the picture below.



3.2. 2nd NISSPI-Workshop

Participants of the 2nd NISSPI Workshop

Davide Anguita, University Genova
Monika Berendsen, Degussa.
Andreu Catala, University Catalonia
Emilio Corchado, University Burgos
Reinhard Dudda, Degussa.
Marc Eastwood, University Bournemouth
Anthony Evans, University Lancaster
Bogdan Gabrys, University Bournemouth
Nils Goerke, University Bonn
Christian Igel, University Bochum
Aleksandar Jovanovic, STC
Snezana Jovanovic, STC
Peter Kaßler, Degussa.
Przemyslaw Kazienko, Wroclaw University of Technology
Jose Antonio Larco, Erasmus University Rotterdam
Kauko Leiviskä, University Oulu
Joseph Lengeler, University Osnabrück
Stefano Pizzuti, E.N.E.A.
Ricardo Sanz, University Madrid
Jens Strackeljan, University Magdeburg

Agenda of the 2nd NISSPI Workshop

Summary of the first brainstorming workshop

Challenges of sustainable soft sensors to provide support of process control

Advancing the self-healing properties of polymer-coated surfaces by applying thrombosis-inspired modelling

Suggestion of a concept for further development steps

Discussion

Report of the 2nd NISSPI Workshop

Summary of the first Brainstorming Workshop

The first NISSPI-Workshop took place in 2006 on April 21st and 22nd in Marl, Germany. As an introduction Monika Berendsen, Degussa, summed up the results of the first workshop.

On the one hand the workshop gave an idea of what are the actual problems dealing with soft sensors in chemical process industry. On the other side the workshop participants got ideas of how to adopt biological or nature derived principles to develop soft sensors which need less human effort in development and maintenance. After being able to imagine how the biological sensors work, the workshop participants discussed ideas for a smart adaptive system that develops its structure and functionality in a continuous, self-organized, adaptive and interactive way. In this way, the workshop assembled researchers and several experts from university and industry. (Further information see the report of the first workshop)

Challenges of sustainable Soft Sensors to provide Support of Process Control

Based on the fact that the process industry still has a challenge in optimization of the plant control Monika Berendsen, Degussa, presented challenges of sustainable soft sensors.

The motivation of the process industry is to keep competitiveness. Process industry works with a lot of data and information. This information is necessary to predict the performance of a plant (process monitoring). Models (Patterns, Neural Network,..) are used to predict the plant status, but these models are nowadays static, reality is not static, the plant environment is constantly changing (e.g. feedstock, product change, wear out). Due to the underlying physical-chemical phenomena process data show distinct and characteristic patterns, which can be represented by data-driven models. In order to make use of model predictive plant monitoring and control - being a very powerful tool in principle - the modelling techniques have to be self-adapting, self-healing, self-maintaining.



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Advancing the self-healing Properties of polymer-coated Surfaces by applying thrombosis-inspired Modelling

Aleksandar Jovanovic, Steinbeis Transfer Center, presented an exemplary application, which works with an innovative modeling technique (Dissipative Particle Dynamics - DPD) as a possible tool for multi-scale modeling of the behavior of advanced engineering materials (e.g. coated materials and/or multi-materials). The multi-scale modeling of the behavior of advanced engineering materials is primarily related to the development of new techniques and methods needed to bridge the gap between the atomistic scale and macro applications. The presented example of examination of the applicability of the DPD to damage assessment dealing with the problem of interaction of particles, polymers and surfaces, is an issue concerning many applications in the colloid science. It has confirmed the applicability of the DPD as a method for linking the macro and atomistic scales. The imminent application of the method and the example are in the area of "self-healing" advanced engineering materials.

Suggestion of a Concept for further Development Steps

Starting at the motivation and requirements Reinhard Dudda, Degussa, classified the future task into detection of the current state, prediction with feedback and prediction without feedback. The expected profits of self- ? soft sensors are less amount of analysis, robust process control, enhanced process capability, reduction of quality variation and on-line-monitoring of product quality. The requirements for adaptive soft sensor models are manifold. Reinhard Dudda highlighted the relation between biological and soft sensors by life is fit in a changing world or life has true redundancy. As an imitation of nature the decisions are an important point as they assume erroneous data, they are never sharp, hierarchical and scaled speed. Decisions are always true in their context. Intelligent solutions need memory and the loss of it.

Discussion

On inquiry Prof. Dr. Lengeler approved the presented first concept as reflecting important biological principles. Prof. Dr. Jens Strackeljan, NiSIS-steering committee, emphasised the good results of the task force. After answering some questions a lively discussion of all participants took place.

3.3. NiSIS 2006 Competition

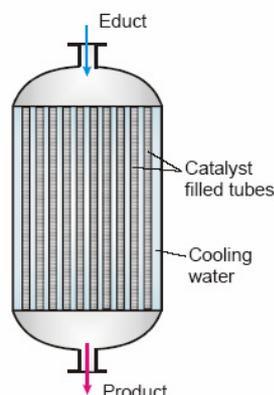
There is a close connection from the task force NISSPI to the NiSIS 2006 Competition. The described industrial problem is built up by Degussa. The decreasing catalyst activity is an example for a prediction task.

Description of the Problem:

The reactor to be modelled consists of some 1000 tubes filled with catalyst, used to oxidize a gaseous feed (ethane is taken as example). It is cooled with a coolant supposed to be at constant temperature. The description of the reaction speed is taken from literature and depends strongly non-linearly from temperature. Its exothermal reaction is counteracted by the cooling and leads to a temperature maximum somewhere along the length of the tube. As the catalyst decays, this becomes less pronounced and moves further downstream. The catalyst activity usually decays within some time to zero, a year is taken as example here. The process to be modelled takes input from other, larger processes, so that the feed will vary over the days. The operating personal reacts to this by choosing appropriate operating conditions. The catalyst decay is however much slower than these effects. The process is equipped with measurements to log all the variations of the feed and the operating conditions. In addition, there are measurements showing some concentrations, flows and a lot of temperatures along the length of a characteristic

tube to identify the processes state. All measurable influences are considered as input variables for a mathematical multi-input-single-output-model describing relevant process variables (model outputs)

All inputs and the output vary dynamically, and there might occur large time-delays.





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3.4. 3rd NISSPI-Workshop

Participants of the 3rd NISSPI Workshop

Monika Berendsen, Degussa.
Reinhard Dudda, Degussa.
Bogdan Gabrys, University Bournemouth
Christian Igel, University Bochum
Peter Kaßler, Degussa.
Joseph Lengeler, University Osnabrück

Agenda of the 3rd NISSPI Workshop

Introduction

Efficient Evolution Strategies for single- and multi-objective Optimization

How Nature is improving the next Generation

What mechanism can be learned from nature to improve Genetic Algorithms?

Introduction

Monika Berendsen visualised the motivation for the process industry to learn from nature. **Particularly** adaptation is a problem in industry nowadays. Existing application examples are soft sensor for artificial rubber, kinetic parameter estimation, estimation of time series, production planning optimization or optimizing of sieving.

Efficient Evolution Strategies for single- and multi-objective Optimization

Christian Igel gave an overview to the members of the workshop about the actual state of the art how information systems work as a copy of biological genetics.

How Nature is improving the next Generation

Prof. Dr. Lengeler presented the mechanisms of natural genetic for non-biologists. He showed how genetic is structured in a modular way. All essential elements are redundant. Redundant elements are not simply doubled, but they have deviating structures and properties. Biological systems are structured in a hierarchical way. Epigenetic non-inherited factors control which genes are expressed under specific conditions.

Epigenetic factors thus define the actual (real) physiological state of a cell. In clonal populations and in multicellular organisms they cause the appearance of cells with varying but stable physiological states. Biological systems are dynamic. Nature optimizes an entire cyclic process, not only one step. Material is short-lived, permanently renewed and has a long-lasting Variability. The natural systems response is “Gaußian”, dictated by physiological needs.

What mechanisms can be learned from nature to improve Genetic Algorithms?

In a brainstorming part of the workshop the participants tried to discover natural genetic mechanisms which are not yet used in information systems.





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4. Conclusions

A first concept to create software to mimic nature phenomenon does now exist. This concept called HERMAN (Healing Evolutionary Robust Models with Algorithms from Nature) is accepted and checked by the participants of NISSPI. In addition a group of the task force participants submitted a proposal to FP7.

It is very likely that this approach for building self-healing soft sensors can not only be applied for process industry, but also for other industrial areas like e.g. telecommunication, paper or steel industry.

In the workshops the task force assembled researchers from university and several experts from industry resulting into a prolific collaboration.