SYSTEM ANALYSIS, PROGNOSIS AND CONTROLE

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ANALYSIS, PROGNOSIS AND CONTROL OF COMPLEX SYSTEM AND PROCESS BEHAVIOR

The complex dynamic systems we consider arise from the application fields of energy systems, plant and machine control as well as biology and medicine. The complexity of the systems results from the combination of different subsystems and structures. The systems are each equipped with specific sensor and actuator configurations. In doing so, we often have to consider measurement data superimposed on disturbances if we want to obtain information about current and future system behavior from data streams. In addition, system and structure descriptions are often incomplete.

Typical tasks we deal with in biology are, for example, sensor signal analysis or in medicine the identification of constant and dynamic model parameters in the active substance analysis of drugs. In addition to the control of systems and machines, we also develop innovative methods for predictive maintenance of components. In the field of energy, we develop monitoring systems for power suppliers as well as predictive control strategies for power grids. We support our customers from method development to hardware integration and validation of electronic control units with hardware-in-the-loop.

We use methods from the areas of system and control theory and machine learning to deal with problems in the various fields of application. We have special competencies in the areas of differential algebraic equations and switched systems, in the application of sequential Monte Carlo approaches for the simulation and state estimation of stochastic processes, in statistical learning theory and in the area of machine learning, even with deep architectures (deep learning).

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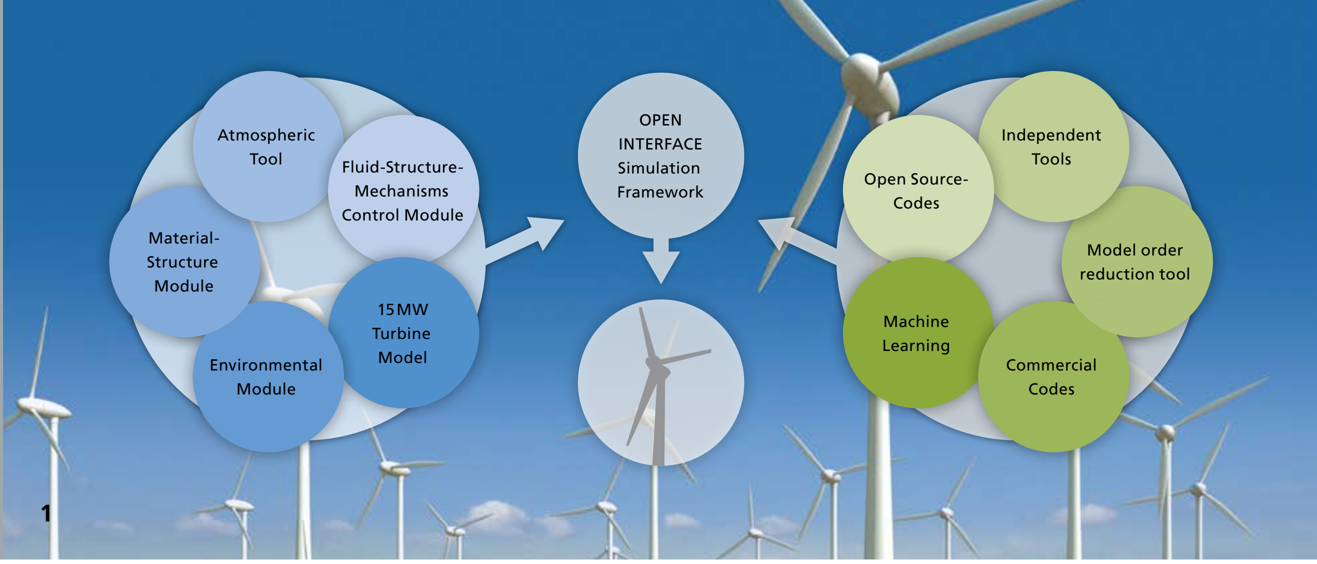
MAIN TOPICS

- Power generation and distribution
- Maschine monitoring and control
- Bio-sensors and medical devices



1 *Overall simulation of a wind farm*

UPWARDS – SIMULATION OF THE PHYSICS OF WIND TURBINES AND ROTOR DYNAMICS

The EU project »UPWARDS - Understanding of the Physics of Wind Turbine and Rotor Dynamics through an Integrated Simulation Framework« was launched in April 2018 with the aim of enabling the development of bigger and better designed wind turbines and thus increasing wind energy capacities throughout Europe and the rest of the world.

This goal will be pursued through the development of the next generation of multiphysical simulations specializing in wind flow, turbine mechanics and their interactions. These simulation tools enable a more cost-effective and faster development of prototypes for wind turbines.

UPWARDS is of strategic importance for the future of sustainable development in Europe and is implemented by a consortium of eleven partners (companies, research institutions and universities) from eight countries and two continents.

Road to more efficient wind turbines

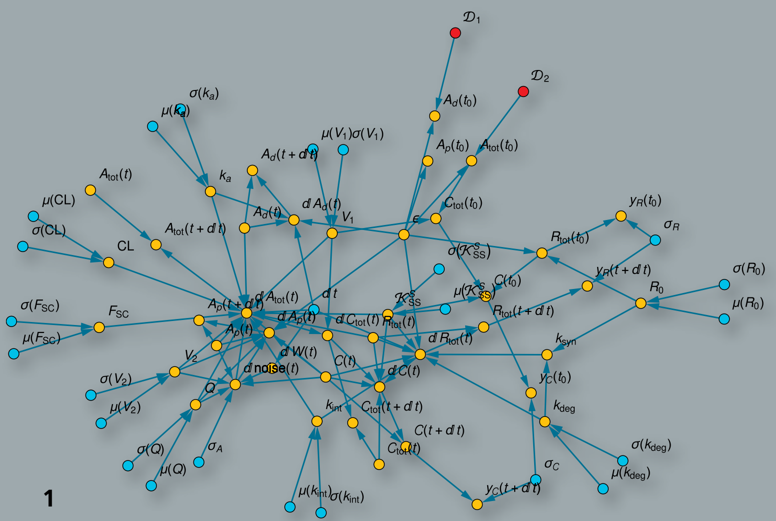
The most important challenges for the development of larger and more efficient wind turbines are:

- Turbulence originating from atmospheric conditions, terrain or wind turbine wake that causes significant fatigue on the rotors
- As rotors become larger the tip speeds increase, resulting in more noise that potentially prohibit use in many onshore locations
- Longer and more slender blades will experience more bending that results in complex, dynamic stresses that need to be accounted for in structural design and material qualification.

Added value through mathematical and computer science methods

Fraunhofer ITWM is developing an integrated simulation platform for the individual software modules; these simulate wind turbines and wind farms with high precision, including wind flow, fully coupled fluid structure interaction, system fatigue and sound propagation.

Methods of model order reduction and high performance computing generate precise simulation results of the relevant system behavior in a short computing time. Machine learning methods are used to identify correlations between important phenomena such as inflow and turbine wind, rotor noise and failure of the composite materials in order to optimize the performance of the associated wind turbines.



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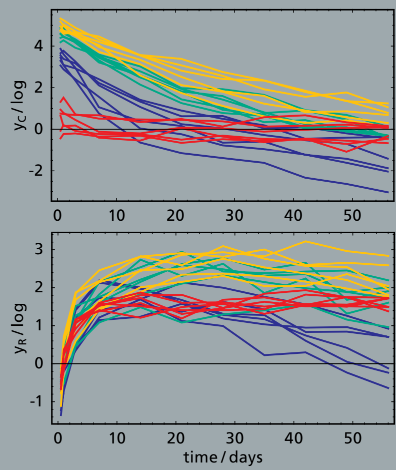

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DOSAGE, EFFECT, RISK: MATHEMATICS FOR NEW DRUG DEVELOPMENT

The development of new active ingredients for pharmaceutical purposes is now supported by mathematical learning methods. This capability relates to an important question: What is the proper dosage? The new remedy should work, but not harm the patient. In cooperation with our partner institute, FCC in Gothenburg, we develop and use mathematical simulation and learning methods to find an answer to the question being tested in clinical trials: What is the distribution of active ingredients throughout the body and what effects occur at the targeted sites of action?

In trial testing, as many patients as possible are given different doses of the new drug and the development of the disease in each individual patient is monitored over a long period of time. Monitoring, in this case, means: evaluation of blood samples and body functions. Unfortunately, not all processes in the body can be measured directly.

Every patient is different

Patients are distinguished by individual characteristics (male/female, age), disease stages, dosages, and method of administration of the active ingredient (infusion, injection, ingestion). Within each of these groups, each person has additional random individual divergences. Here, random means: not everything can happen, just somethings are more probable. This probability can and must be modeled.

The administered drug causes a change in the disease-related condition of each patient over time. These time-dependent changes, in turn, affect the probability that other disease-related events will occur. To truly assess how a drug works, such complex relationships need to be understood.

Mathematical models master complexity

Mathematical models are able to capture the complex interrelationships of our bodies, our individual differences, temporal changes, and the changing risk of illness-related events occurring. Initially, however, these models contain many unknown time-dependent and constant variables. We can determine these unknown variables using measured data and the latest computer-aided mathematical learning methods (state filtering and parameter estimation in nonlinear dynamic models with mixed effects). The results provide information about the best dosage and best mode of action of the new drug.

1 *Complex interdependencies of the variables in a stochastic pharmaco-kinetic/pharmaco-dynamic model*

2 *Temporal development of two substance concentrations (drug and target molecule) in blood plasma of 24 patients (4 dosis groups of 6 patients each; simulated data). Dosis groups are identifiable based on color.*

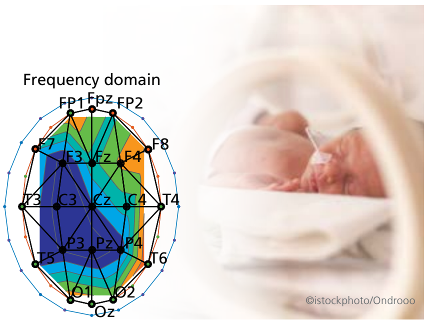
NEWS

BIOCOMP TO CONTINUE AS A MAJOR RESEARCH FOCUS

BioComp is a major research focus of the state of Rhineland-Palatinate. Since 2014, members of various faculties of the Technical University of Kaiserslautern have worked together on interdisciplinary projects using mathematical/computer-aided methods to study biological questions. Our department continues its involvement in several projects and this is expected to last through the 2019 – 2023 project phase. During this time, our goal is to develop a software infrastructure for integrative analysis of biological data. Challenges ranging from the processing and evaluation of raw data to the identification of interconnections and relationships within the data have to be overcome.

THEORY AND PRACTICE: KL-CONTROL SYSTEMS SEMINAR

The department has organized a monthly KL Control Systems Seminar for the past two years. What began as a loose association between our department and several working groups from the faculties at TU Kaiserslautern has developed substantially over the past year with a focus on control systems engineering. The seminar now includes inviting external speakers from industry to speak about ongoing research and development, for example, forecasting strategies for fuel-optimized operation of plug-in hybrid vehicles. In addition, the seminar concept was expanded to include the topic of machine learning (ML) in a control systems environment.



EEG ANALYSIS SOFTWARE FOR PREEMIES

A goal of the recently ended Tenecor project of BMWi was the design of a “diagnostic support system for the health status and brain development of premature babies.” Our department developed the required EEG analysis software for the project, which is a multi-functional monitoring system for babies born prematurely. The innovative approach is based on machine learning methods and enables predictions of the various age-dependent, generic brain states and state change characteristics over time. After monitoring complex brain development, a 3D visualization of the data is prepared and the similarities between patients are easily detected.

Front, left ot right: Dr. Benjamin Adrian, Dr. Alex Sarishvili, Michael Sendhoff, Dr. Andreas Wirsen, Hans Trinkaus, Jens Göbel, Dr. Christian Salzig, Dimitri Morgenstern, Dr. Jan Hauth