SYSTEM ANALYSIS, PROGNOSIS AND CONTROL

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In the department's lab, plant and machine models are coupled with controls in a real-time capable hardware-in-the-loop simulation. Control algorithms can be implemented on the department's own control units or integrated with the original client system. A comprehensively equipped HIL platform enables the data capture and generation of many different signal types in addition to error simulations.

The complexity of the dynamic behavior of many technical or biological systems is often the result of a combination of various sub-systems and structures, each equipped with specific sensors and actuator configurations. In many cases, it must be assumed that the information acquired from measurements of the system or structural behavior is distorted by interference from overlapping sensor data. Usually, this situation is additionally compounded by incomplete system and structural descriptions.

The System Analysis, Prognosis and Control department typically works on the issue of identifying dynamic system parameters as well as providing real-time capable simulation models. This is the foundation for development of the forecasting systems needed to monitor, control, or validate the behavior of electronic control devices with "hardware-in-the-loop" methods. The department draws on its core competencies in the field of systems and control theory – with special skills at model reduction for solving differential algebraic equations of switched systems. Sequential Monte-Carlo approaches (particle filter methods) are used for the simulation and state estimation of stochastic processes. Furthermore, the department uses machine learning methods such as deep learning, probabilistic graphic models, and clustering algorithms in high dimensional data spaces.

MAIN TOPICS

- Plant and machine controls
- Energy generation and distribution
- Biosignal processing
- Machine learning in medicine and technology
- Software tools for process and innovation management

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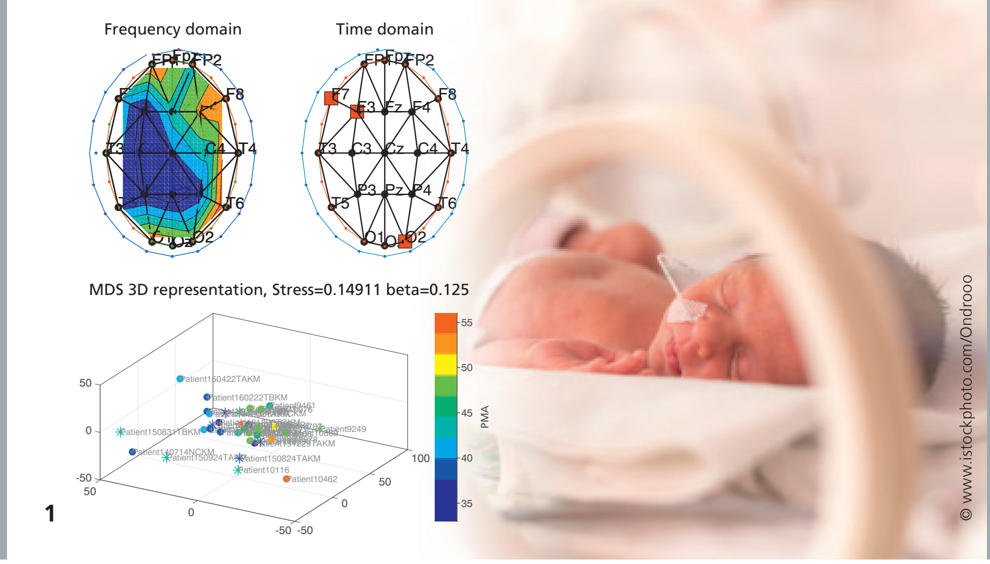

1 *EEG analysis tool: Analyses in frequency and time range (top)*

Positioning of the premature baby with regard to the similarity to the findings and the age of the patient from the database of the hospital information system (bottom)

DIAGNOSTIC SUPPORT SYSTEMS FOR THE BRAIN MATURATION PROCESS IN PREMATURE INFANTS

The aim of neonatal intensive therapy is to support the functioning of the immature organs of extremely premature infants in a way that the development may proceed as if taking place in the mother's womb. The regular development of the brain, especially of the cerebral cortex, is of primary importance. Possible threats to the development process can arise if the oxygen supply of the brain is compromised. Monitoring systems are available, that can detect any restriction in the oxygen supply throughout the entire organism. However, the relevance of a single event for the cortical oxygen supply is, in many cases, vague. During the cortical maturation process neurons are connecting with each other. This process can be disturbed by harmful incidents like oxygen deficiency on the one hand. On the other hand, it is conceivable that the normal cortical development can be effected solely by non-physiological conditions outside of the mother's womb. The cortical maturation process can be studied using the electric discharges of the cortical nerve cells, which are recorded via an EEG.

The System Analysis, Prognosis and Control department is developing an analytical software tool as an integral component of a multifunctional monitoring system for premature infants brains in the sub-project "Diagnostic support system for the maturation process of the brain in premature infants," as part of the Federal Ministry of Education and Research´s Tenecor project. In the final version, this system should be able to help doctors facilitate evaluations of the health status and the maturation process of infantile brains. This is achieved by means of machine learning algorithms through the synergetic examination of five signal sources (NADH, fb-EEG, aEEG, DCEEG, Impedance).

Currently, the diagnostic software disassembles the 12 channels of the neonatal EEGs into time dependent frequency bands; the energies are determined for the separate channels in defined frequency bands, and sorted into an ordinal scale. Next, the paired dependencies between energies in the different channels and frequency bands are determined using mutual information. These are then used to generate a probabilistic network for each patient. The resulting distances between the networks are embedded in a three-dimensional Euclidean space and the formed point clouds are clustered. First tests with EEG's of premature infants have shown that the cluster centers are correlated with pathologies, i.e. preterm infants with similar pathologies are close to each other in Euclidean space. Furthermore, correlations between the distances and the postmenstrual age of the premature infants without serious pathologies were also detected.

1 *Sub-station with wiring and transformers*

CONTROL CONCEPTS FOR THE ENERGY GRIDS OF TOMORROW

The current focus of the energy revolution is mainly on power generation, transportation networks and electric mobility. However, in terms of creating a CO_2-neutral energy supply, perspectives must be broadened because the energy cycle includes generation, conversion, transport, storage, and consumption in electricity, gas, and thermal grids. Regardless of the energy medium, information technology and mathematics encounter a number of basic recurring problems in the modeling, simulation, and control of hierarchical energy grids with stochastic production and consumption. In the project MathEnergy, funded by the Federal Economics Ministry, the solutions to these problems are to be found in the development of new mathematical methods, collected in a software library, and demonstrated in the fields of gas and electricity and even in a coupling of the two. The project is divided in the following segments: overall grid modeling, model order reduction, scenario analysis, state estimation and control, overall system integration, and demonstrators.

In particular, the System Analysis, Prognosis and Control department is working on model-based monitoring and control methods for the synchronous planning and operation of the electricity transport and distribution grid.

The estimation of the current system states of the underlying mathematical model based on the measured data is the starting point for model-based, optimal control of the supply and consumption of electricity or gas. Taking into account the observability of the model and an error analysis of the predicted input to the power grid from alternative energy sources, methods will be developed for the optimal positioning of additional sensors required for the dynamic state estimation. The technical (sampling rates, signal propagation times, errors, etc.) and economic limiting conditions must also be considered. Extended Kalman filters and particle filter methods developed in the department are used for dynamic state estimation. The latter approach can be used for state estimation of systems with stochastic behavior, with physical limitations, and at the same time, non-equidistant sampled measurements. The real-time tools developed for estimating the state and the scenario analysis methods are then used in a control approach for multi-grid coordination by means of model predictive control (MPC). Hierarchical or distributed MPC methods with reduced dynamic models are required to enable the data exchange among the different controller.